

Chasmophytic vegetation of silicate rocks on the southern outcrops of the Alps in Slovenia

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Summary: Applying the standard central-European method we studied the chasmophytic vegetation of the silicate rocks on the southern outcrops of the Alps in the territory of Slovenia, in the Kamnik-Savinja Alps, the eastern Karavanke mountains, on Mt. Kozjak and the Pohorje mountains. Three communities of the order *Androsacetalia vandellii* (*Asplenietea trichomanis*) were recognized: *Campanulo cochleariifoliae-Primuletum villosae* ass. nova (*Androsacion vandellii*), *Woodsia ilvensis-Asplenietum septentrionalis* (*Asplenion septentrionalis*) and *Hypno-Polypodietum* (*Hypno-Polypodium vulgaris*). The communities are distinguished by altitude, light intensity, temperature and the number of endemic species, south-European orophytes or cosmopolite species. Altitude is a significant factor affecting the floristic composition of the studied vegetation.

Keywords: chasmophytic vegetation, silicate rocks, ecology, Southern Limestone Alps, Slovenia

Chasmophytic vegetation of the order *Androsacetalia vandellii* occurs on non-calcareous bedrock of magmatic and metamorphic origin, mainly in central- and south-European mountain ranges (MUCINA 1993: 260).

In some parts of Europe chasmophytic vegetation of silicate rocks has already been very well studied, e.g., in Austria (EGGLER 1955; WENDELBERGER 1967; GRABHERR & POLATSCHKE 1986; ZIMMERMANN 1987; BRANDES 1979, 1992; Grabherr unpublished, quoted from MUCINA 1993; MUCINA 1993), Germany (OBERDORFER 1934, 1938, 1998; KORNECK 1974; HILBIG & REICHHOFF 1977; POTT 1995), Switzerland (BRAUN-BLANQUET & JENNY 1926; MEIER & BRAUN-BLANQUET 1934; BRAUN-BLANQUET 1948), Slovakia (JURKO & PECIAR 1963; VALACHOVIČ 1994, 1995), the Czech Republic (MORAVEC 1967; KOLBEK 1978, 2000; BÖSWARTOVÁ 1983; GRULICH & CHYTRÝ 1993; CHYTRÝ 2009), Poland (NOWAK et al. 2008), Hungary (SIMON 2006), Romania (SCHNEIDER-BINDER 1968, 1975; SCHNEIDER-BINDER & VOIK 1976; BURESCU & PĂȘCUȚ 2010) and in the Balkans (HORVAT 1936, 1960; LAKUŠIĆ & KARADŽIĆ 2010).

Chasmophytic vegetation of silicate rocks of the order *Androsacetalia vandellii* is classified within the class *Asplenietea trichomanis*. The communities of this order have a fewer species number than those on calcareous bedrock (order *Potentilletalia*) and are also rarer (MUCINA 1993: 260).

Plants growing on bare rocks are mainly oligotrophic and exposed to extreme temperature oscillations as well as to the big oscillations of water content in the soil, high radiation, frost and wind (OBERDORFER 1998: 23). Chasmophytes (different fern species, frutescent and pulvinate chamaephytes, hemicryptophytes and numerous mosses) are very well adapted to such extreme edaphic and microclimatic conditions (BRAUN-BLANQUET 1948: 35; MUCINA 1993: 242).

These habitats are characterized by numerous endemic species and communities (SUTTER 1969: 349; MUCINA 1993: 242; OBERDORFER 1998: 23). Endemism in Slovenia is a result of a special

geographical position of the country's territory (Slovenia is situated at the junction of the Alps, the Dinaric-Karst region, the Pannonian Plain and the Adriatic Sea) which, except for the higher belts and Alpine valleys, remained ice-free during the Pleistocene. For this reason, the remains of Tertiary Alpine flora could be preserved until the present day (MAYER 1960: 43). In addition to endemic species, rock crevices host a number of rare and endangered species.

The primary objective was to sample the silicate rocks in the Southern Limestone Alps in the Slovenian territory where silicate rocks occur only locally. We wanted to determine which chasmophytic communities of silicate rocks occur in this region and what the differences between these communities are regarding topographical and environmental factors. This is a first detailed study of chasmophytic vegetation of silicate rocks in Slovenia. Most of the data in the article were obtained from the Graduation Thesis made by N. JUVAN (2008).

Methods

Chasmophytic vegetation of silicate rocks was studied in the region of Slovenia in plots scattered in the Kamnik-Savinja Alps, eastern Karavanke mountains, on Mt. Kozjak and on the Pohorje mountains (Fig. 1). Most of the rocks are in the forest and are therefore in the shadow for most of the day. Only a few isolated rocks are exposed to the sun throughout the day.

The vegetation was recorded using the standard central-European method (BRAUN-BLANQUET 1964) on sample plots of 1 to 10 m². We measured the topographical factors (altitude, aspect and slope) and used Ellenberg's indicator values of plants to estimate the environmental factors of plots (light, temperature, continentality, moisture, soil reaction and nutrients) (ELLENBERG et al. 1991).

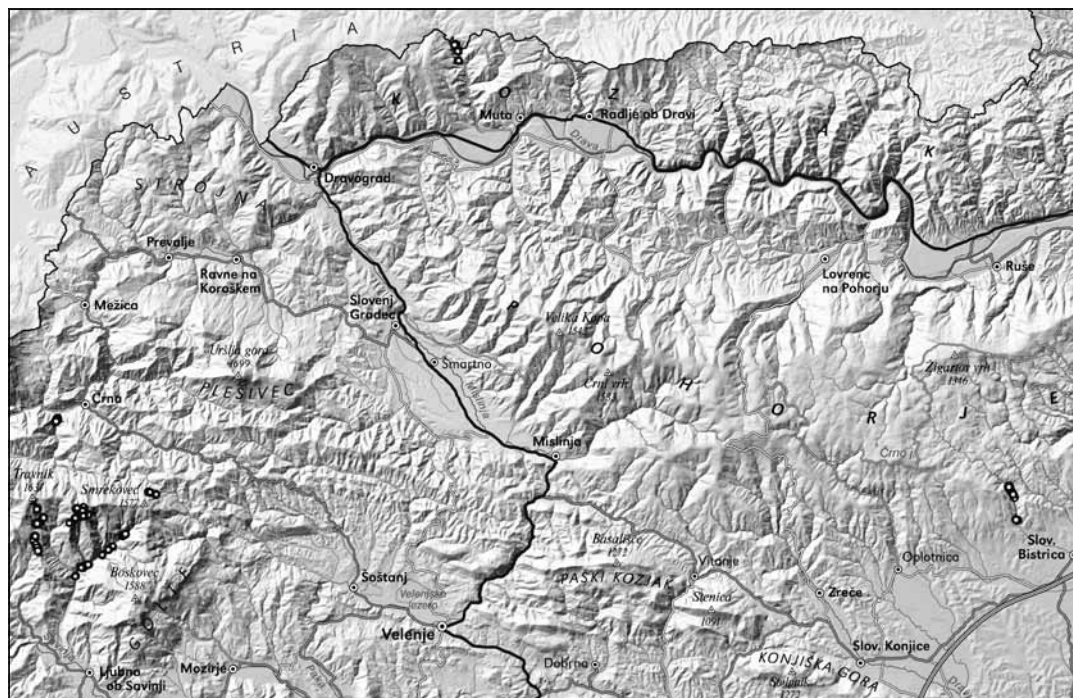


Figure 1. Distribution of relevés in research area.

Chasmophytic vegetation of silicate rocks in Slovenia

The collected relevés were entered into the TURBOVEG database (HENNEKENS & SCHAMINÉE 2001). Numerical analyses were made with Modified TWINSpan Classification (ROLEČEK et al. 2009) in JUICE 6. 5. 6 program (TICHÝ 2002).

The diagnostic species were determined in JUICE program by calculating the fidelity of each species, using the phi coefficient as a fidelity measure. With Fisher's exact test we calculated zero fidelity for the species with $p < 0.05$. As diagnostic we selected the species which fidelity value is more than 25, as constant the species which percentage frequency is more than 25 and as dominant those species which coverage in any relevé exceeds or is equal to 2 (according to the Braun-Blanquet scale).

The calculation of Ellenberg's indicator values and Shannon-Wiener index were made with JUICE program. In CANOCO 4.5 program package (TER BRAAK & ŠMILAUER 2002) we used the indirect gradient analysis (passive projection of Ellenberg's indicator values) to determine the correlation between vegetation relevés, species composition or geoelements (PIGNATTI et al. 2005) and topographical and environmental factors; with direct gradient analysis (Monte Carlo permutation test) we determined the statistical significance of the influence of individual topographical factors on the floristic composition.

STATISTICA 8 (STATSOFT 2007) program was used to determine how altitude correlates with Ellenberg's indicator values (Pearson's correlation coefficient) and the variables through which the communities differ from each other. To determine the normal distribution we used the Kolmogorov-Smirnov, Lilliefors and Shapiro-Wilk's W test. For further analyses from here on we used, depending on the distribution, Tukey HSD or Kruskal-Wallis and F test.

Results

TWINSpan clusters and their interpretation

TWINSpan classification divided the relevés into three clusters. The first cluster comprises 16 relevés, the second 46 and the third 44 relevés. Five of the relevés in the third cluster formed a separate group (67–71, Tab. 2). Three of these relevés comprise the species *Asplenium adiantum-nigrum* and could be classified into a special group. However, as the number of relevés was too small for the result to be reliable, we classified them into the third group. The diagnostic species were determined by calculating the fidelity and presented by percentage and fidelity values (Tab. 1). They are presented also in the vegetation table (Tab. 2). The division of relevés into three clusters is indicated also in the ordination diagram (Fig. 2).

Cluster 1. Diagnostic species, such as *Primula villosa*, *Festuca varia*, *Festuca ovina*, *Paederota lutea*, *Campanula cochleariifolia*, *Grimmia ovalis*, *Racomitrium sudeticum*, demonstrate the occurrence of the community on warmer, drier, sunnier and nutrient-poor regions. Low coverage of plant species is another indicator of such conditions. The average herb coverage is 16%, average moss coverage 7% and average total coverage 19%. On average there are 8 species on a sample plot.

Cluster 2. The diagnostic species *Calamagrostis arundinacea* is a semi-heliophilic plant and an indicator of a moderately warm, fresh and moderately nutrient-rich site, while *Hieracium murorum*, *Athyrium filix-femina*, *Phegopteris connectilis* are already more sciophilous and indicate more wet and more nutrient-rich environment. The average herb coverage is 19%, average moss coverage 22% and average total coverage 33%. On average there are 8 species on a sample plot.

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Table 1. Partially combined synoptic table of the TWINSPAN classification with the percentage frequency and the fidelity index (phi coefficient). Legend: 1 – *Campanulo cochleariifoliae-Primuletum villosae*, 2 – *Woodsia ilvensis-Asplenietum septentrionalis*, 3 – *Hypno-Polypodietum*.

Group number	1	2	3
Number of relevés	16	46	44
Cluster 1			
<i>Primula villosa</i>	75 ^{81.6}	. ---	. ---
<i>Festuca varia</i>	56 ^{67.9}	. ---	. ---
<i>Grimmia ovalis</i>	56 ^{63.5}	4 ---	. ---
<i>Thymus praecox</i> ssp. <i>polytrichus</i>	50 ^{63.2}	. ---	. ---
<i>Festuca ovina</i> agg.	81 ^{62.9}	24 ---	9 ---
<i>Campanula cochleariifolia</i>	56 ^{61.4}	7 ---	. ---
<i>Paederota lutea</i>	38 ^{53.5}	. ---	. ---
<i>Silene saxifraga</i>	31 ^{48.2}	. ---	. ---
<i>Saxifraga paniculata</i>	25 ^{42.6}	. ---	. ---
<i>Calluna vulgaris</i>	25 ^{42.6}	. ---	. ---
<i>Orthotrichum anomalum</i>	19 ^{36.5}	. ---	. ---
<i>Erica carnea</i>	19 ^{36.5}	. ---	. ---
<i>Cardamine resedifolia</i>	25 ^{36.2}	4 ---	. ---
<i>Racomitrium sudeticum</i>	38 ^{35.0}	15 ---	2 ---
<i>Polytrichum</i> sp.	19 ^{32.7}	2 ---	. ---
<i>Primula minima</i>	12 ^{29.5}	. ---	. ---
<i>Pulsatilla alba</i>	12 ^{29.5}	. ---	. ---
<i>Cephalozia catenulata</i>	12 ^{29.5}	. ---	. ---
<i>Euphrasia salisburgensis</i>	12 ^{29.5}	. ---	. ---
Cluster 2			
<i>Calamagrostis arundinacea</i>	. ---	52 ^{49.8}	16 ---
<i>Hieracium murorum</i>	. ---	43 ^{48.3}	9 ---
<i>Phegopteris connectilis</i>	. ---	30 ^{41.4}	5 ---
<i>Epilobium collinum</i>	. ---	20 ^{33.4}	2 ---
<i>Athyrium filix-femina</i>	. ---	30 ^{29.3}	16 ---
<i>Saxifraga hostii</i>	. ---	15 ^{28.3}	2 ---
<i>Picea abies</i>	. ---	13 ^{25.5}	2 ---
Cluster 3			
<i>Polypodium vulgare</i>	. ---	26 ---	84 ^{69.5}
<i>Asplenium trichomanes</i>	6 ---	17 ---	73 ^{61.5}
<i>Hypnum cupressiforme</i>	6 ---	17 ---	64 ^{53.8}
<i>Salvia glutinosa</i>	. ---	2 ---	30 ^{43.6}
<i>Hieracium rotundatum</i>	. ---	. ---	23 ^{40.5}
<i>Dryopteris filix-mas</i> s.str.	. ---	4 ---	23 ^{33.8}
<i>Geranium robertianum</i>	. ---	7 ---	25 ^{33.4}
<i>Cardaminopsis arenosa</i>	. ---	4 ---	18 ^{28.6}
<i>Hedera helix</i>	. ---	. ---	11 ^{28.1}
<i>Galeobdolon flavidum</i>	. ---	2 ---	14 ^{26.5}
<i>Plagiothecium laetum</i>	. ---	2 ---	14 ^{26.5}
<i>Plagiothecium sylvaticum</i>	. ---	2 ---	14 ^{26.5}
<i>Cystopteris fragilis</i>	6 ---	24 ---	39 ^{26.4}
<i>Dryopteris filix-mas</i> agg.	. ---	11 ---	23 ^{25.8}
<i>Melica nutans</i>	. ---	. ---	9 ^{25.0}
Some other species			
<i>Tussilago farfara</i>	. ---	9 ^{24.4}	. ---
<i>Hypericum perforatum</i>	. ---	9 ^{24.4}	. ---
<i>Asplenium septentrionale</i>	19 ---	17 ^{11.6}	. ---
<i>Amphidium mougeottii</i>	38 ---	41 ---	23 ---
<i>Poa nemoralis</i>	12 ---	13 ---	11 ---
<i>Viola biflora</i>	12 ---	9 ---	. ---
<i>Cruciata glabra</i>	12 ---	7 ---	. ---
<i>Veronica urticifolia</i>	6 ---	37 ---	45 ---
<i>Luzula luzuloides</i>	6 ---	17 ---	23 ---
<i>Campanula rotundifolia</i>	6 ---	13 ---	11 ---
<i>Festuca altissima</i>	6 ---	9 ---	14 ---

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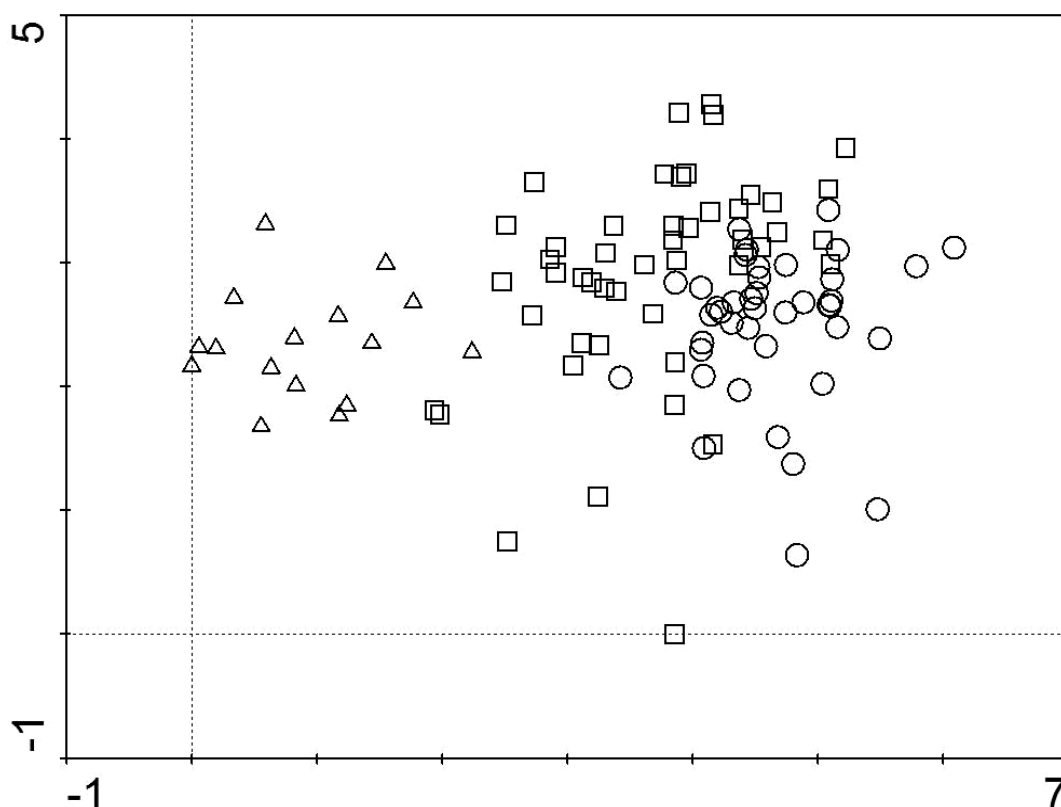


Figure 2. DCA ordination of all relevés. Legend: Δ – *Campanulo cochleariifoliae-Primuletum villosae* (relevés 1–16 in Tab. 2) $\square$ – *Woodsiopsis ilvensis-Asplenietum septentrionalis* (relevés 17–62 in Tab. 2) $\circ$ – *Hypno-Polypodietum* (relevés 63–106 in Tab. 2).

Cluster 3. The diagnostic species *Polypodium vulgare*, *Hypnum cupressiforme*, *Asplenium trichomanes* and *Cystopteris fragilis* indicate a shady, cold to moderately warm, fresh and nutrient-rich site. The large coverage of mosses, which averages 41%, is also indicative of soil moisture. The average herb layer is 18%, total coverage is 46%. The average number of species per sample plot is 9.

Ecological conditions

The ordination diagram (DCA) (Fig. 3) shows the distribution of geoelements along the topographical and the environmental gradients. For better transparency, relevés are not presented in this figure but they can be seen in Fig. 2. The relevés that were made at a higher altitude, where the light intensity and continentality are higher, are grouped on the left side of the diagram and the relevés made at lower altitudes, where the soil is more moist and more nutrient-rich and the temperature higher, are grouped on the right. More south-European orophytes and endemics are found at higher altitudes, whereas there are more cosmopolite, Mediterranean-montane, and Euri-Mediterranean, as well as several Eurasian, boreal and Atlantic species occurring at lower altitudes. The occurrence of geoelements in individual groups is presented also in Fig. 4.

Correlation between altitude, aspect, slope and environmental factors was determined with Pearson's correlation coefficient which demonstrated that altitude correlates with light, temperature, continentality, soil reaction and nutrients. At higher altitudes there is more light

[illegible][illegible]

[illegible]

Hypno-Polypodietum

Hypno-Polypodium vulgare

[illegible]

Androsacetalia vandellii

Asplenieta trichomanis

6	+	+1++..1+.+.+.1.....1+2.1111223122+....+...+++11.++.+1+12.++.++.	41
Asplenium trichomanes			
6	.	+.1+.+.1.....+.....+.....	5
Valeriana tripteris			
6	.	1.....+.....2.....	3
Sedum album			
6	.	1.....+.....11.+.....	3
Asplenium adiantum-nigrum			
Euphrasia salisburgensis			
6	.	++.....	2

Querco-Fagetea

[illegible]

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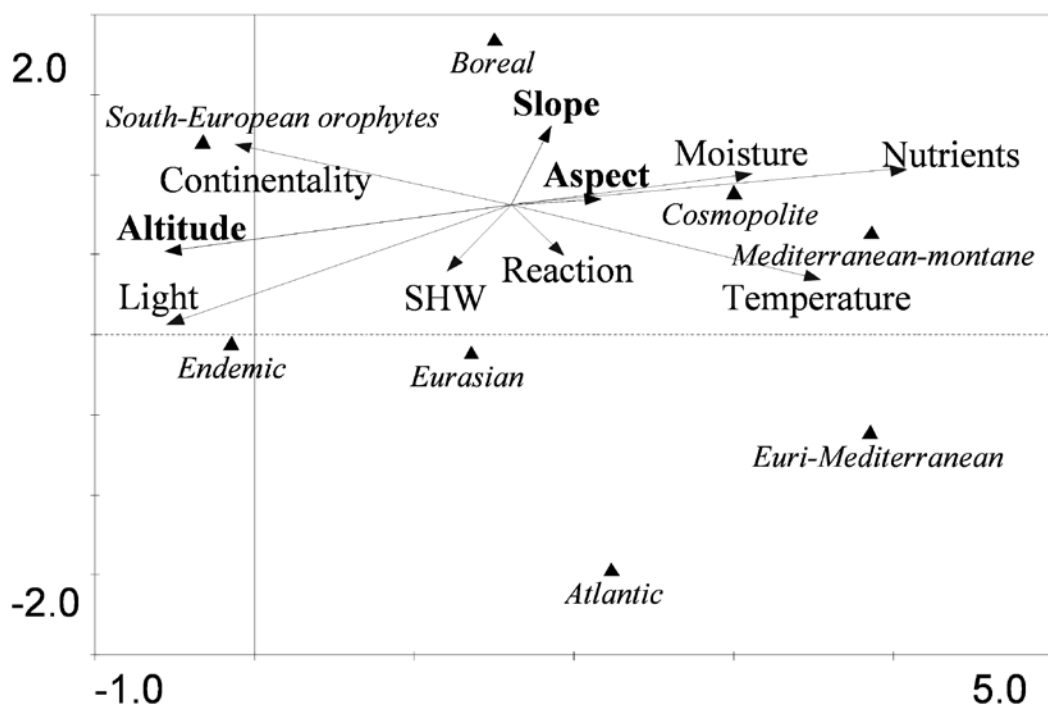


Figure 3. DCA ordination with different geoelements distributed along the topographical and environmental gradients (passive projection of Ellenberg's indicator values).

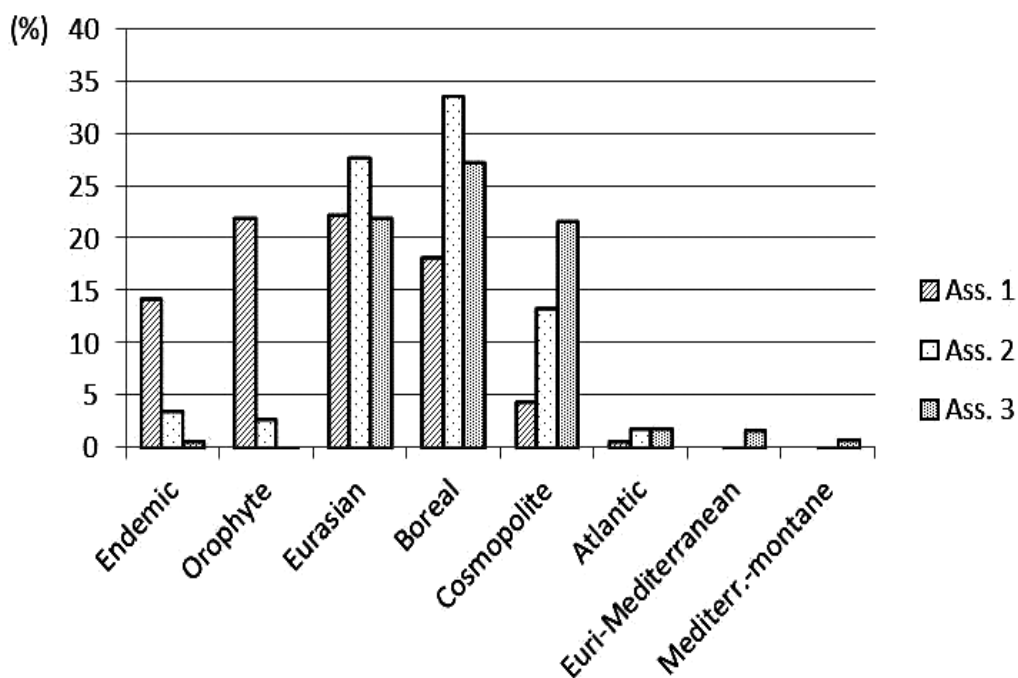


Figure 4. Geoelemental composition of clusters.

Table 3. Correlation between altitude, aspect, slope, and environmental factors. The values shown are Pearson's correlation coefficients.

	Altitude	Aspect	Slope	Light	Temperature	Continentality	Moisture	Soil reaction	Nutrients	SHW
Altitude	1									
Aspect	- 0.2325	1								
Slope	- 0.0822	- 0.1031	1							
Light	0.4872	- 0.1729	- 0.137	1						
Temperature	- 0.5301	0.0201	- 0.0633	- 0.2778	1					
Continentality	0.3551	- 0.0419	- 0.1947	0.2248	- 0.4537	1				
Moisture	- 0.3145	0.0327	0.1638	- 0.5053	0.0656	- 0.2197	1			
Soil reaction	- 0.3899	0.0843	0.1730	- 0.1253	0.1271	- 0.0196	0.1623	1		
Nutrients	- 0.5311	0.1926	0.0778	- 0.5636	0.3895	- 0.2385	0.6357	0.2971	1	
SHW	- 0.1641	0.0461	0.0304	0.1134	- 0.0447	0.1670	0.0449	0.2846	0.1166	1

and continentality is more pronounced, but the temperature is lower, soil reaction is lower and there are fewer nutrients. Light correlates with moisture and nutrients. Moisture and the nutrient content decrease with higher light intensity. Temperature correlates with continentality and nutrients. Higher temperatures mean lower continentality and more nutrients. Moisture correlates with nutrients; the nutrient content increases with the degree of moisture (Tab. 3).

Table 4 shows the impacts on the site conditions or the significance of the effect of altitude, aspect and slope on the floristic composition of the vegetation. Only altitude significantly affects the floristic composition of the studied vegetation, while slope and aspect have no influence.

DCA analysis already showed that the groups are distinguished from one another by altitude, which was further confirmed by Kruskal-Wallis and F test (Fig. 5). On average, the first community occurs at the altitude of about 1600 m, the second at around 1000 m and the third at the altitude of about 750 m.

Topographical and environmental factors and geoelements that distinguish the groups from one another are presented in Tab. 5. All three are distinguished by altitude, light intensity, temperature and the species classified as endemic, south-European orophytes or cosmopolite species. The correlation between the number of south-European orophytes, cosmopolite or endemic species and altitude is presented in Fig. 6. The number of south-European orophytes

Table 4. Marginal (lambda 1) and conditional (lambda A) effect of altitude, aspect and slope on the floristic composition and their statistical significance.

Variable	Variable N	Lambda 1	Lambda A	p-value
Altitude	1	0.53	0.21	0.002
Slope	3	0.18	0.16	0.166
Aspect	2	0.16	0.11	0.550

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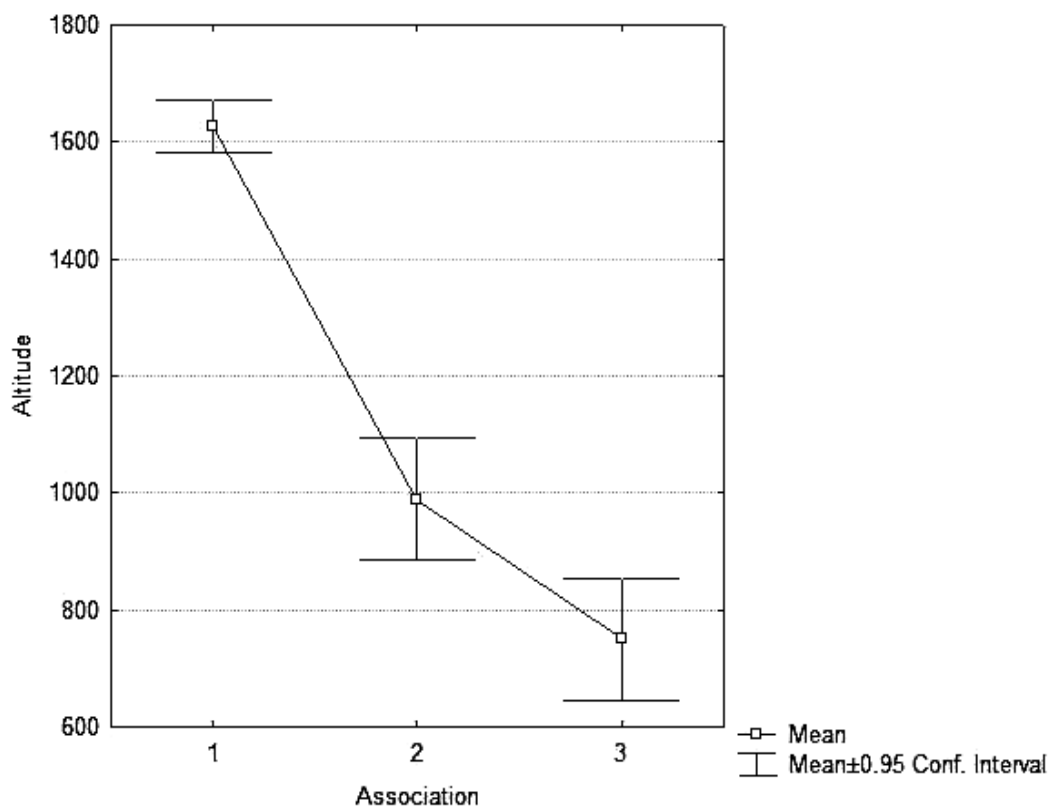


Figure 5. Significant differences between the communities with regard to the altitude and the mean values for each community. Legend: 1 – *Campanulo cochleariifoliae-Primuletum villosae*, 2 – *Woodsia ilvensis-Asplenietum septentrionalis*, 3 – *Hypno-Polypodietum*.

increases with altitude, as well as the number of endemic species. The number of cosmopolite species on the other hand is higher at lower altitudes and decreases with increasing altitudes.

The first and the second group differ also in moisture levels, nutrients and boreal species, and the first and third also in aspect and continentality. The groups are not distinguished from one another by slope, soil reaction, Shannon-Wiener index and by Euri-Mediterranean, Mediterranean-montane, Eurasian and Atlantic species.

Discussion

Based on numerical analyses, calculation of diagnostic species, environmental factors and their correlations and comparative tables we classified the groups obtained into three communities of three different alliances that differ significantly in terms of altitude. Even though altitude does not directly affect the vegetation, it has an indirect influence through environmental factors, such as light, temperature, moisture, soil nutrients content, which is reflected in diagnostic species of all three communities.

Plants at higher altitudes are exposed to higher light intensity as there is more radiation than in the valleys. This happens due to thinner, cleaner and drier air (REISIGL & KELLER 1994: 18). However, light intensity differs also within the same altitude. Individual sample plots are located

Table 5. Topographical and environmental factors and geoelements that differentiate the communities (same letters in the line e.g., AAA, AA, BB, CC – communities do not differ from one another; different letters in the line e.g., ABC, AB, AC – the communities are significantly different from one another). Legend: * – Kruskal-Wallis and F test were used (for others Tukey HSD test was used), 1 – *Campanulo cochleariifoliae-Primuletum villosae*, 2 – *Woodsoia ilvensis-Asplenietum septentrionalis*, 3 – *Hypno-Polypodietum*.

	Association 1	Association 2	Association 3
Altitude*	A	B	C
Light	A	B	C
Temperature	A	B	C
Endemic species*	A	B	C
South-European orophytes*	A	B	C
Cosmopolite species*	A	B	C
Moisture	A	B	B
Nutrients	A	B	B
Boreal species	A	B	AB
Aspect*	A	AC	C
Continentality	A	AC	C
Slope	A	A	A
Soil reaction	A	A	A
Shannon-Wiener index	A	A	A
Euri-Mediterranean species*	A	A	A
Mediterranean-montane species*	A	A	A
Eurasian species*	A	A	A
Atlantic species*	A	A	A

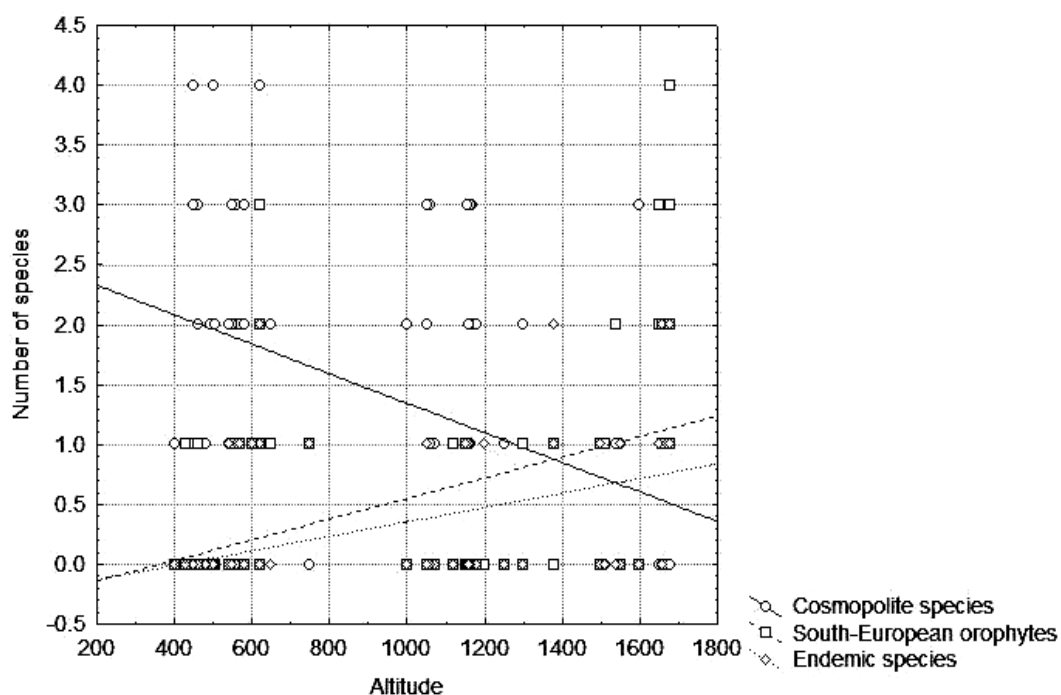


Figure 6. Correlation between the number of south-European orophytes and cosmopolite species or endemics and altitude.

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on sites with a different degree of illumination, e.g., on forest margins, on clearings, dense or sparse parts of the forests, in the shadow of another rock etc.

The communities do not differ in aspect and slope of the rock faces. The aspect may have a considerable influence on the differences in the vegetation, as the northern sites are usually more favourable than the southern, which are exposed to more radiation and in turn to greater temperature oscillations; however, the difference between northern and southern sites increases with higher altitudes. Considering that most of the studied rock faces are either in the forest or are shaded by another hill and are therefore more protected from radiation it is not surprising that aspect has no significant influence on the vegetation. Average slope of the sample plots is 87°; only in 13% of the relevés the slope exceeds 90° and only in 20% the slope is less than 85°. The differences in slopes are not large enough to significantly affect the vegetation.

The area of occurrence of an individual community is indicated also by its geoelemental structure. The influence of higher, colder, open aspects is demonstrated in a higher degree of occurrence of south-European orophytes. In the forests, on lower altitudes, there are more boreal, Eurasian and cosmopolite species. There are also more endemic species at higher altitudes.

Syntaxonomical scheme

Asplenietea trichomanis (Br.-Bl. in Meier et Br.-Bl. 1934) Oberd. 1977

Androsacetalia vandellii Br.-Bl. in Meier et Br.-Bl. 1934

Androsacion vandellii Br.-Bl. in Br.-Bl. et Jenny 1926 corr. Br.-Bl. 1948

Campanulo cochleariifoliae-Primuletum villosae ass. nova

Asplenion septentrionalis Oberd. 1938

Woodsio ilvensis-Asplenietum septentrionalis R. Tx. 1937

Hypno-Polypodion vulgaris Mucina 1993

Hypno-Polypodietum Jurko et Peciar 1963

Description of the syntaxa

Campanulo cochleariifoliae-Primuletum villosae ass. nova (Tab. 2, Relevés 1–16)

Holotypus: Tab. 2, Relevé 9 – holotypus hoc loco

Diagnostic species: *Calluna vulgaris*, *Campanula cochleariifolia*, *Cardamine resedifolia*, *Erica carnea*, *Euphrasia salisburgensis*, *Festuca ovina* agg., *Festuca varia*, *Paederota lutea*, *Primula minima*, *Primula villosa*, *Pulsatilla alba*, *Saxifraga paniculata*, *Silene saxifraga*, *Thymus praecox* ssp. *polytrichus*; *Cephalozia catenulata*, *Grimmia ovalis*, *Orthotrichum anomalum*, *Polytrichum* sp., *Racomitrium sudeticum*.

Constant species: *Amphidium mougeottii*.

Dominant species: *Calluna vulgaris*, *Festuca ovina* agg., *Festuca varia*, *Silene saxifraga*, *Thymus praecox* ssp. *polytrichus*; *Orthotrichum anomalum*, *Racomitrium sudeticum*.

The community *Campanulo cochleariifoliae-Primuletum villosae* was classified into the alliance *Androsacion vandellii* (= *Androsacion multiflorae* Br.-Bl. and Br.-Bl. et Jenny 1926), which includes

chasmophytic communities in the subalpine and alpine belts that extend also downwards into moist ravines. This alliance can be found mainly in the central Alps, but are known also from the Pyrenees (BRAUN-BLANQUET 1948: 36), the Southern Carpathians and the Balkans. In the latter they are classified into an independent alliance *Silenion lerchenfeldianae* (SCHNEIDER-BINDER & VOIK 1976; HORVAT 1936, 1960; VALACHOVIČ 1995; MUCINA 1993).

In terms of environmental conditions, the community *Campanulo cochleariifoliae-Primuletum villosae* resembles the community *Asplenio-Primuletum hirsutae*, which has so far only been known in Switzerland (MEIER & BRAUN-BLANQUET 1934: 37; MUCINA 1993: 262) and Austria (GRABHERR & POLATSCHKE 1986; HERMANN 1990; MUCINA 1993: 262). They differ in character and differential species. *Primula hirsuta* does not grow in Slovenia; it is replaced by *Primula villosa*, an endemic species of the Noric Alps, found in Slovenia only in the Savinja Alps on Mt. Komen near Ljubno (HEGI 1975: 1772). It was detected in 75% of the sample plots. Otherwise, the species grows on non-calcareous rocks in the subalpine and alpine belts, from 1500 to 2200 m. It occurs scattered in Styria (Štajerska) and Carinthia (Koroška): in the Niedere Tauern (Saukogel, Seckauerzinken, Marangerkogel, Hochreichert, Ringkogel), the Mur Alps, Eisenhut, on Turracherhöhe, in the Gurktal Alps (Rosennock, Reichenauergarten [13°54'15" E, 46°50'37" N], Falkert), Ameringkogel, the Stub Alps (Rappelkogel), the Glein Alps, Rennfeld bei Bruck an der Mur and in the Cottian Alps (described as *Primula villosa* f. *cottia* by Widmer) (HEGI 1975: 1771–1772). In these regions we could also expect the occurrence of the community *Campanulo cochleariifoliae-Primuletum villosae*.

In Slovenia, this community occurs in the high montane (from 1380 m) and subalpine belts (up to 1680 m) on andesite, where it is exposed to lower temperatures and higher light intensity. The sites are drought and nutrient poor.

Most of the species are south-European orophytes (e.g., *Festuca varia*, *Campanula cochleariifolia*, *Silene saxifraga*) and Eurasian species (e.g., *Festuca ovina* agg., *Thymus praecox* ssp. *polytrichus*, *Cardamine resedifolia*), there are fewer boreal species (e.g., *Calluna vulgaris*, *Saxifraga paniculata*, *Asplenium septentrionale*) and endemics (*Primula villosa*, *Paederota lutea*, *Campanula barbata*, *Jovibarba arenaria*). There are very few cosmopolite (*Avenella flexuosa*, *Cystopteris fragilis*, *Asplenium trichomanes*) and Atlantic (*Festuca altissima*) species. There are no species classified among Euri-Mediterranean and Mediterranean-montane geoelements. In addition to endemic species, there are many of those that are included in the 'Red Data List of Threatened Vascular Plants' (WRABER & SKOBERNE 1989; ANON. 2002a) (*Primula villosa*, *Festuca varia*, *Cardamine resedifolia*, *Primula minima*, *Pulsatilla alba*, *Woodsia alpina*, *Campanula barbata*) and the 'Red Data List of Mosses' (ANON. 2002b) (*Racomitrium sudeticum*). *Pulsatilla alba*, *Jovibarba arenaria* and *Huperzia selago* are protected in Slovenia (SKOBERNE 2007).

***Woodsia ilvensis-Asplenietum septentrionalis* (Tab. 2, Relevés 17–62)**

The community *Woodsia ilvensis-Asplenietum septentrionalis* was classified into the alliance *Asplenion septentrionalis* which comprises thermophilous and xerophilous chasmophytic communities that are distributed on sunny sites on non-calcareous silicate rocks from the colline to the montane belt (MUCINA 1993: 263). Its characteristic species are drought adapted (drought resistance, poikilohydry, protection against excessive transpiration, etc.) (POTT 1995: 140).

The community was named after the dominant and character fern species *Asplenium septentrionale* and *Woodsia ilvensis* (VALACHOVIČ 1995: 36). This is a pioneer community found in both rock

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crevices (MUCINA 1993: 263; KOLBEK 1978: 214) and screes (Grabherr unpublished, Mucina & Valachovič unpublished, quoted from MUCINA 1993: 264) rich in silicate. Its localities are found on sunny aspects of the montane belt (MUCINA 1993: 264).

In Slovenia this community can be found from lowlands (400 m) to the subalpine (1660 m) belt on different silicate rocks. It is exposed to slightly higher temperatures, lower light intensity and higher moisture content than the community *Campanulo cochleariifoliae-Primuletum villosae*. The higher species coverage indicates that the community thrives in habitats with more favourable conditions.

The character species of the community is *Woodsia ilvensis* which, however, occurs on only two sample plots in the Bistra valley near Črna na Koroškem, where the only site of this species known so far in Slovenia is. *Woodsia ilvensis* is rare also elsewhere in central Europe (HILBIG & REICHHOFF 1977; OBERDORFER 1998). In OBERDORFER et al. (1967) the denomination *Hieracio pallidi-Asplenietum septentrionalis* was proposed.

Most of the species belong to the boreal (e.g., *Hieracium murorum*, *Polypodium vulgare*, *Aruncus dioicus*) and Eurasian (e.g., *Calamagrostis arundinacea*, *Veronica urticifolia*, *Epilobium collinum*) geoelement. In addition, there are some cosmopolites (e.g., *Athyrium filix-femina*, *Cystopteris fragilis*, *Asplenium trichomanes*), endemics (*Saxifraga hostii*, *Campanula barbata* and *Jovibarba arenaria*) and species that fall within the south-European orophytes (*Dryopteris affinis*, *Valeriana tripteris*, *Campanula cochleariifolia*), Atlantic (*Festuca altissima*, *Galium pumilum*, *Allium carinatum*), Mediterranean-montane (*Cardamine trifolia*) and Euri-Mediterranean (*Galium mollugo*, *Sedum album*) species. 'The Red Data List of Threatened Vascular Plants' (WRABER & SKOBERNE 1989; ANON. 2002a) includes *Woodsia ilvensis*, *Cardamine resedifolia*, *Campanula barbata* and *Jovibarba arenaria* as protected in Slovenia (SKOBERNE 2007), and *Racomitrium sudeticum* is included in the 'Red Data List of Mosses' (ANON. 2002b).

Hypno-Polypodietum (Tab. 2, Relevés 63–106)

The community *Hypno-Polypodietum* was classified into the alliance *Hypno-Polypodion vulgaris*, which includes lichen-rich, (sub)sciophilous chasmophytic communities on different silicate rocks. The soil is initial, aerated and rich in raw humus. The high proportion of musci, liverworts and ferns indicates a moist and stable microclimate, which is one of the prerequisites for the growth of these communities. The richest communities occur on lower altitudes (submontane to montane belt) in deep brook ravines composed of silicate rocks (MUCINA 1993: 267).

The community *Hypno-Polypodietum* occurs mainly on granite and quartzite, as well as on other acid to neutral bedrocks (e.g., on Tertiary volcanic rocks). Rock composition determines also the floristic composition of the community. The community is adapted to a reduced light absorption. The character species *Polypodium vulgare* does not thrive on direct sunlight. Its leaves are always positioned perpendicularly to the incoming light. The typical community occurs on relatively dry but shaded sites (JURKO & PECIAR 1963: 203, 205). The community is rich in species, especially acidophilous. More than a third of the mosses are obligate silicicolous plants, while about a tenth prefers alkaline bedrock. In comparison with other communities within the alliance, this community is poor in lichens (JURKO & PECIAR 1963: 205, 207).

The community *Hypno-Polypodietum* occurs in Slovenia from the lowland (430 m) to the high montane (1600 m) belt on moist, nutrient-rich bedrock. The species are adapted to warmer sites

and lower light intensity than those in the communities *Campanulo cochleariifoliae-Primuletum villosae* and *Woodsio ilvensis-Asplenietum septentrionalis*. In comparison with the latter two, this community is the most species-rich, which is the consequence of more fresh and more nutrient-rich sites.

The species occurring here are mainly boreal (e.g., *Polypodium vulgare*, *Oxalis acetosella*, *Polytrichum formosum*), Eurasian (e.g., *Veronica urticifolia*, *Salvia glutinosa*, *Luzula luzuloides*) and cosmopolite (e.g., *Asplenium trichomanes*, *Cystopteris fragilis*, *Geranium robertianum*); few are Atlantic (*Festuca altissima*, *Allium carinatum*), Euri-Mediterranean (*Hedera helix*, *Sedum album*), Mediterranean-montane (*Cardamine trifolia*) species, endemics (*Campanula barbata* and *Saxifraga hostii*) and south-European orophytes (*Dryopteris affinis*, *Valeriana tripteris*, *Moehringia muscosa*).

Conclusions

Chasmophytic vegetation of silicate rocks in Slovenia has not been studied in detail so far, so this paper represents the first account and a base for further research.

For the region of Slovenia we recognized three communities of the order *Androsacetalia vandellii*: *Campanulo cochleariifoliae-Primuletum villosae*, *Woodsio ilvensis-Asplenietum septentrionalis* and *Hypno-Polypodietum*.

All three communities occur in the Kamnik-Savinja Alps. And it is only here where the community *Campanulo cochleariifoliae-Primuletum villosae* had been found, as Mt. Komen remains the only locality of *Primula villosa* in Slovenia. Both, *Woodsio ilvensis-Asplenietum septentrionalis* and *Hypno-Polypodietum* thrive on Pohorje, while only the community *Hypno-Polypodietum* can be found on Mt. Kozjak and only the community *Woodsio ilvensis-Asplenietum septentrionalis* in the eastern Karavanke mountains.

In our case, the floristic composition of the studied vegetation is significantly affected only by altitude, but remains unaffected by slope and aspect. Altitude correlates with light, temperature, continentality, soil reaction and nutrients. Plants at higher altitudes are exposed to higher light intensity and lower temperatures. At lower altitudes on the other hand, the temperature and moisture are higher and the soil is more nutrient-rich.

The plant species growing on the sample plots belong to eight geoelements: most of the species are boreal, followed by Eurasian, cosmopolite, south-European orophytes, endemics, Atlantic, Euri-Mediterranean and Mediterranean-montane species. The number of south-European orophytes and endemics increases with the altitude, while the number of cosmopolite species decreases.

The community *Campanulo cochleariifoliae-Primuletum villosae* occurs in the high montane and subalpine belts and the community *Woodsio ilvensis-Asplenietum septentrionalis* is found from the lowland to the subalpine belt; the community *Hypno-Polypodietum* is distributed from the lowland to the high montane belt.

All three communities differ from one another by altitude, light intensity, temperature, and the species classified as endemics, south-European orophytes or cosmopolite species. The first and the second community differ also in moisture, nutrients and boreal species; and the first and the third community also in aspect and continentality. The communities are not distinguished by slope, soil reaction, Shannon-Wiener index and Euri-Mediterranean, Mediterranean-montane, Eurasian and Atlantic species.

Acknowledgements

We are grateful to Prof. Dr Andrej Martinčič and Dr Petra Košir for help in moss determination. The map was produced by Iztok Sajko. Andreja Šalamon Verbič translated the article into English. Sincere thanks to them. The preparation of this article was supported financially from the Slovenian Research Agency (Projects No. L1-9737 and P1-0236) and the European Union (the European Social Fund).

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Abbreviations

SHW Shannon-Wiener index

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Appendices

Appendix 1. Other species with low frequency (Table 2: – cont.).

Festuca picturata [6] 27: +, 104: +; *Scapania aequiloba* [9] 28: +, 44: +; *Silene nutans* [6] 23: +, 104: 1; *Allium carinatum* [6] 48: +, 49: +; *Brachythecium rutabulum* [9] 44: +, 99: +; *Stellaria media* [6] 1: +, 51: +; *Polystichum braunii* [6] 1: +, 70: +; *Scapania nemorea* [9] 99: 1, 98: +; *Diplophyllum albicans* [9] 99: +, 51: 1; *Prenanthes purpurea* [6] 98: +, 70: +; *Rubus hirtus* [6] 40: +, 38: +; *Atrichum undulatum* [9] 50: +, 51: +; *Conocephalum conicum* [9] 51: 1, 67: +; *Sedum maximum* [6] 55: +, 53: +; *Campanula trachelium* [6] 55: +, 53: r; *Solidago virgaurea* [6] 55: +, 73: +; *Hepatica nobilis* [6] 55: r, 53: +; *Verbascum thapsus* [6] 57: 1, 14: 1; *Mnium stellare* [9] 66: +, 67: +; *Vaccinium vitis-idaea* [6] 27: +; *Antennaria dioica* [6] 30: 1; *Galium pumilum* [6] 23: +; *Euphorbia cyparissias* [6] 23: +; *Verbascum austriacum* [6] 104: +; *Arabis hirsuta* [6] 104: +; *Galium mollugo* [6] 89: 1; *Festuca* sp. [6] 89: +; *Vicia cracca* [6] 89: +; *Stachys alpina* [6] 89: +; *Agrostis capillaris* [6] 89: +; *Lotus corniculatus* ssp. *hirsutus* [6] 48: 2; *Sedum sexangulare* [6] 48: 1; *Pimpinella saxifraga* [6] 48: +; *Scabiosa triandra* [6] 48: +; *Dactylis glomerata* [6] 48: +; *Erigeron acris* [6] 97: +; *Eurhynchium schleicheri* [9] 7: +; *Gentiana asclepiadea* [6] 10: +; *Phyteuma* sp. [6] 21: +; *Plagiothecium* sp. [9] 2: 1; *Cirsium palustre* [6] 87: +; *Veronica officinalis* [6] 87: +; *Athyrium filix-femina* agg. [6] 11: +; *Asplenium ruta-muraria* [6] 5: +; *Asarum europaeum* ssp. *europaeum* [6] 81: 1; *Brachythecium starkei* [9] 99: +; *Bryum* sp. [9] 99: +; *Digitalis grandiflora* [6] 95: +; *Linaria vulgaris* [6] 93: +; *Fagus sylvatica* [6] 50: r; *Jungermannia* sp. [9] 51: +; *Artemisia vulgaris* [6] 51: r; *Vincetoxicum hirundinaria* [6] 49: 1; *Galium* sp. [6] 49: +; *Knautia drymeia* ssp. *intermedia* [6] 49: +; *Arabis turrata* [6] 49: +; *Racomitrium* sp. [9] 55: +; *Veronica chamaedrys* [6] 41: +; *Fraxinus ornus* [6] 38: +; *Placidiopsis* sp. [9] 45: +; *Chrysosplenium alternifolium* [6] 45: +; *Bartramia* sp. [9] 78: 1; *Dentaria trifolia* [6] 68: +; *Mercurialis perennis* [6] 69: +; *Plagiochila porelloides* [9] 67: +; *Pogonatum* sp. [9] 67: +; *Campanula persicifolia* [6] 73: +.

Appendix 2. Localities and description of the relevés (relevé number – corresponds to the number in Table 2; date; relevé surface; altitude; aspect; slope; coverage of the herb layer; coverage of the moss layer; localities of the relevé).

Campanulo cochleariifoliae-Primuletum villosae

1: 6.8.2006; 2 m²; 1550 m; E; 85°; 30%; 50%; rocks below the Mt. Komen, the first rock on the path, in the forest. — **2:** 15.7.2006; 2 m²; 1380 m; SSW; 84°; 40%; 10%; Telečje peči, a large rock to the east of the scree. — **3:** 8.8.2006; 9 m²; 1670 m; SSW; 87°; 15%; 2%; on the top of Mt. Komen, small rock on the eastern side slopes. — **4:** 8.8.2006; 4 m²; 1680 m; SW; 92°; 5%; 2%; on the top of Mt. Komen. — **5:** 8.8.2006; 4 m²; 1680 m; S; 85°; 10%; 2%; on the top of Mt. Komen. — **6:** 8.8.2006; 2 m²; 1680 m; SWW; 92°; 10%; 2%; on the top of Mt. Komen. — **7:** 8.8.2006; 4 m²; 1680 m; SW; 90°; 10%; 3%; on the top of Mt. Komen. — **8:** 6.8.2006; 4 m²; 1540 m; S; 85°; 15%; 2%; rocks below the Mt. Komen, exposed to sun. — **9:** 6.8.2006; 6 m²; 1540 m; S; 80°; 25%; 10%; rocks below the Mt. Komen, the road beside the creek, exposed to sun. — **10:** 8.8.2006; 9 m²; 1670 m; NNE; 92°; 15%; 3%; few meters below the summit Mt. Komen, isolated rock. — **11:** 8.8.2006; 3 m²; 1680 m; SW; 90°; 10%; 2%; on the top of Mt. Komen. — **12:** 8.8.2006; 1 m²; 1680 m; SW; 88°; 10%; 3%; on the top of Mt. Komen. — **13:** 8.8.2006; 4 m²; 1660 m; E; 85°; 20%; 10%; on the top of Mt. Komen, the rock below the chapel. — **14:** 9.7.2006; 4 m²; 1650 m; NNE; 75°; 15%; 3%; on the top of Mt. Komen. — **15:** 9.7.2006; 4 m²; 1650 m;

E; 84°; 10%; 5%; on the top of Mt. Komen, east side slopes. — **16**: 8.8.2006; 4.5 m²; 1660 m; SW; 85°; 20%; 2%; on the top of Mt. Komen.

Woodsia ilvensis-Asplenietum septentrionalis

17: 21.7.2006; 2 m²; 620 m; ESE; 91°; 5%; 10%; Črna na Koroškem, by the road. — **18**: 6.8.2006; 4 m²; 1510 m; SSW; 88°; 20%; 20%; rocks below the Mt. Komen. — **19**: 6.8.2006; 5 m²; 1550 m; S; 89°; 10%; 2%; rocks below the Mt. Komen. — **20**: 1.8.2006; 4 m²; 750 m; SE; 80°; 25%; 10%; on the way from Ljubenske Rastke to the Mt. Smrekovec. — **21**: 19.6.2006; 4 m²; 1150 m; W; 75°; 25%; 35%; Kolarica, on the way to the partisan hospital. — **22**: 19.6.2006; 4 m²; 1150 m; SW; 78°; 15%; 40%; Kolarica, on the way to the partisan hospital. — **23**: 19.6.2006; 9 m²; 1160 m; SW; 90°; 20%; 35%; Kolarica, big rock above the road to the partisan hospital. — **24**: 27.5.2006; 5 m²; 600 m; S; 80°; 25%; 70%; Ljubenske Rastke, northwest of the bridge and the Pečnik farm. — **25**: 19.6.2006; 6 m²; 1160 m; SW; 90°; 20%; 30%; Kolarica, in the forest. — **26**: 22.7.2006; 6 m²; 540 m; E; 80°; 35%; 50%; Ljubenske Rastke, right bank of the Ljubnica river; 50 m before Rastke. — **27**: 21.7.2006; 9 m²; 1150 m; S; 87°; 15%; 10%; on the path from Ljubenske Rastke to the Mt. Smrekovec. — **28**: 21.7.2006; 4 m²; 620 m; W; 86°; 30%; 40%; Črna na Koroškem, right bank of the Bistra river. — **29**: 21.7.2006; 3 m²; 620 m; W; 80°; 25%; 45%; Črna na Koroškem, right bank of the Bistra river. — **30**: 14.6.2006; 2 m²; 570 m; N; 90°; 40%; 50%; Ljubenske Rastke, next to the Robanšek stream. — **31**: 14.6.2006; 6 m²; 560 m; N; 90°; 10%; 20%; Ljubenske Rastke, next to the Krumpah stream. — **32**: 21.7.2006; 9 m²; 620 m; SWW; 90°; 20%; 3%; Črna na Koroškem. — **33**: 6.8.2006; 4 m²; 1500 m; SW; 90°; 10%; 40%; on the top of Mt. Komen, east side slopes. — **34**: 6.8.2006; 6 m²; 1500 m; SW; 88°; 10%; 70%; rocks below the Mt. Komen. — **35**: 6.8.2006; 2 m²; 1510 m; S; 85°; 20%; 35%; rocks below the Mt. Komen. — **36**: 21.7.2006; 3 m²; 620 m; E; 89°; 10%; 5%; Črna na Koroškem, west side of the road, in the forest. — **37**: 21.7.2006; 4 m²; 620 m; W; 82°; 15%; 10%; Črna na Koroškem, right bank of the Bistra river. — **38**: 23.5.2006; 7 m²; 620 m; ESE; 10°; 10%; 10%; Črna na Koroškem, next to the pasture. — **39**: 21.7.2006; 6 m²; 1120 m; W; 85°; 20%; 1%; on the way from Ljubenske Rastke to the Mt. Smrekovec. — **40**: 15.6.2006; 9 m²; 1300 m; E; 85°; 40%; 40%; Počka planina, above the hunting lodge. — **41**: 8.8.2006; 4 m²; 1200 m; NE; 87°; 15%; 10%; Grezica. — **42**: 6.8.2006; 3 m²; 1500 m; SSW; 86°; 10%; 45%; rocks below the Mt. Komen. — **43**: 17.6.2006; 6 m²; 1155 m; SSW; 87°; 15%; 3%; Kolarica, on the path to the partisan hospital. — **44**: 15.7.2006; 5 m²; 1380 m; SW; 85°; 15%; 5%; Telečje peči. — **45**: 19.7.2006; 3 m²; 1164 m; W; 80°; 15%; 30%; last rock of the Oltarna peč, above the road to the Murc farm. — **46**: 21.7.2006; 2 m²; 620 m; E; 88°; 50%; 10%; Črna na Koroškem, west side of the road, under the overhanging rock. — **47**: 19.6.2006; 6 m²; 1160 m; E; 80°; 15%; 40%; Počka planina, by the road from hunting lodge to Oltarna peč. — **48**: 8.8.2006; 4.5 m²; 1660 m; N; 93°; 15%; 5%; on the top of Mt. Komen, east side slopes. — **49**: 21.7.2006; 3 m²; 620 m; W; 95°; 10%; 10%; Črna na Koroškem, right bank of the Bistra river. — **50**: 21.7.2006; 6 m²; 620 m; S; 13°; 15%; 5%; Črna na Koroškem, right bank of the Bistra river, under the overhanging rock, across from the pasture. — **51**: 19.8.2006; 3 m²; 430 m; ENE; 80°; 10%; 50%; Pohorje, on the path to the Bistriški Šum waterfall, right side of the path from the direction of Zgornja Bistrica. — **52**: 19.8.2006; 3 m²; 400 m; NNW; 85°; 5%; 30%; Pohorje, on the path to the Bistriški Šum waterfall, left bank, above the path. — **53**: 21.7.2006; 6 m²; 620 m; SWW; 80°; 15%; 5%; Črna na Koroškem, right bank of the Bistra river. — **54**: 21.7.2006; 5 m²; 1060 m; NNW; 88°; 15%; 5%; Mt. Smrekovec, under the hill Brezovci. — **55**: 21.7.2006; 4 m²; 1070 m; NNW; 80°; 20%; 15%; Mt. Smrekovec, north from the Javorski potok stream, by the road. — **56**: 21.7.2006; 5 m²; 1120 m; SW; 80°; 25%; 2%; on the path from Ljubenske Rastke to the Mt. Smrekovec. — **57**: 19.6.2006; 9 m²; 1155 m; SSW; 88°; 25%; 5%; Kolarica, big rock by the road to the partisan hospital, across from the stream. — **58**: 21.7.2006; 2 m²; 1070 m; N;

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85°; 5%; 10%; on the path from the Mt. Smrekovec to Črna na Koroškem, next to the Javorski potok stream. — **59**: 21.7.2006; 3 m²; 1060 m; NW; 85°; 10%; 5%; Mt. Smrekovec, under the hill Brezovci. — **60**: 8.8.2006; 4 m²; 1250 m; E; 90°; 30%; 10%; Grezica. — **61**: 21.7.2006; 4 m²; 1060 m; NNW; 85°; 25%; 20%; Mt. Smrekovec, under the hill Brezovci. — **62**: 21.7.2006; 6 m²; 1050 m; NNW; 80°; 35%; 25%; Mt. Smrekovec, under the hill Brezovci.

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63: 23.5.2006; 5 m²; 560 m; SE; 90°; 50%; 60%; Ljubenske Rastke, right bank of the Krumpah stream, under the bridge. — **64**: 19.7.2007; 8 m²; 460 m; SWW; 90°; 15%; 5%; last rock in the Mučka Bistrica, the sharp bend, the road from Muta to the Austrian border. — **65**: 8.7.2006; 4 m²; 580 m; NE; 85°; 20%; 40%; Ljubenske Rastke, right bank of the Kozlov graben stream. — **66**: 19.7.2007; 2 m²; 460 m; SWW; 90°; 20%; 20%; Mučka Bistrica, the road from Muta to the Austrian border. — **67**: 22.7.2006; 4 m²; 540 m; NEE; 90°; 20%; 35%; The Ljubnica river right bank, 50 m before the village on the road from Ljubenske Rastke to Ljubno. — **68**: 19.7.2007; 8 m²; 460 m; NW; 85°; 15%; 20%; Mučka Bistrica, left bank of the Bistrica river, opposite the house. — **69**: 19.7.2007; 4 m²; 460 m; E; 85°; 15%; 5%; Mučka Bistrica, opposite the green bridge, right bank of the Bistrica river. — **70**: 19.7.2007; 4 m²; 460 m; W; 85°; 10%; 50%; Mučka Bistrica, left bank of the Bistrica river, towards the blue bridge. — **71**: 19.7.2007; 3 m²; 460 m; W; 80°; 35%; 70%; Mučka Bistrica, left bank of the Bistrica river, opposite the house. — **72**: 19.8.2006; 4 m²; 430 m; NE; 90°; 25%; 50%; Pohorje, on the path to the Bistriški Šum waterfall, eastern side of the road. — **73**: 23.5.2006; 7 m²; 560 m; SE; 90°; 25%; 40%; Ljubenske Rastke, northwest of small power, 25 m from the main road, at the stream. — **74**: 23.5.2006; 10 m²; 650 m; NW; 90°; 20%; 20%; Ljubenske Rastke, Krumpah stream left bank, the power. — **75**: 23.5.2006; 7 m²; 560 m; SE; 90°; 25%; 25%; Ljubenske Rastke, at the stream, northwest of the small power, 20 m from the main road. — **76**: 8.7.2006; 5 m²; 550 m; SE; 87°; 30%; 50%; Ljubenske Rastke, the road on the northwestern side, 5 m from the exit for Praprotnica. — **77**: 19.7.2006; 6 m²; 1166 m; SW; 85°; 20%; 5%; Oltarna peč, exposed to sun. — **78**: 15.7.2006; 9 m²; 1300 m; SW; 120°; 5%; 5%; Hlipovc, north of the road, overhanging rock, in front of forest. — **79**: 19.7.2006; 4 m²; 1179 m; SW; 87°; 15%; 30%; Oltarna peč. — **80**: 17.6.2006; 7 m²; 1050 m; W; 90°; 20%; 40%; Kolarica, by the road to the partisan hospital, in the forest. — **81**: 15.6.2006; 9 m²; 1250 m; S; 87°; 10%; 40%; Pritašce. — **82**: 19.7.2006; 5 m²; 1167 m; SW; 92°; 10%; 20%; Oltarna peč, exposed to sun. — **83**: 20.7.2006; 6 m²; 1164 m; E; 90°; 10%; 50%; east side of Oltarna peč. — **84**: 8.7.2006; 2 m²; 580 m; NE; 92°; 10%; 20%; Ljubenske Rastke, right bank of the Kozlov graben stream, first rock. — **85**: 20.7.2006; 3 m²; 1159 m; NE; 87°; 5%; 40%; Oltarna peč. — **86**: 19.7.2006; 5 m²; 1169 m; SWW; 87°; 15%; 35%; Oltarna peč. — **87**: 19.7.2006; 2 m²; 1174 m; SWW; 88°; 15%; 65%; Oltarna peč. — **88**: 20.7.2006; 5 m²; 1164 m; NEE; 89°; 10%; 35%; Oltarna peč. — **89**: 20.7.2006; 3 m²; 1156 m; NEE; 88°; 20%; 45%; Oltarna peč. — **90**: 19.8.2006; 4 m²; 430 m; ENE; 89°; 50%; 80%; Pohorje, on the path to the Bistriški Šum waterfall, right side of the path from the direction of Zgornja Bistrica. — **91**: 19.8.2006; 2 m²; 450 m; E; 90°; 10%; 30%; Pohorje, on the path to the Bistriški Šum waterfall, west side. — **92**: 19.8.2006; 2 m²; 450 m; NE; 92°; 10%; 15%; Pohorje, on the path to the Bistriški Šum waterfall, west side. — **93**: 19.8.2006; 6 m²; 460 m; ENE; 10°; 3%; 5%; Pohorje, Bistriški Šum waterfall, right bank, overhanging rock. — **94**: 6.8.2006; 6 m²; 1600 m; NEE; 87°; 10%; 45%; rocks below the Mt. Komen, large rock in the forest. — **95**: 17.6.2006; 6 m²; 1000 m; W; 87°; 15%; 60%; Kolarica, rock with the 'Partisan hospital' sign. — **96**: 19.8.2006; 5 m²; 495 m; N; 75°; 20%; 80%; Pohorje, right bank of the Bistrica river at Bistriški Šum waterfall. — **97**: 19.8.2006; 6 m²; 505 m; NW; 90°; 10%; 50%; Pohorje, Bistriški Šum waterfall, along the path, east side, above Bistrica river. — **98**: 19.8.2006; 2 m²; 500 m; SSE; 85°; 45%; 60%; Pohorje, Bistriški Šum waterfall, west of the waterfall, next to the path. — **99**: 20.7.2006;

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3 m²; 1157 m; NEE; 85°; 5%; 75%; Oltarna peč. — **100**: 19.8.2006; 4.5 m²; 450 m; NNE; 92°; 10%; 15%; Pohorje, Bistriški Šum waterfall, west of the Roman quarry. — **101**: 19.8.2006; 3 m²; 550 m; ENE; 75°; 10%; 70%; Pohorje, west of the Bistriški Šum waterfall. — **102**: 17.6.2006; 5 m²; 1050 m; W; 85°; 15%; 75%; Kolarica, east of the path to the partisan hospital, across the brook in the forest, 10 m above the path. — **103**: 19.8.2006; 4 m²; 505 m; NE; 85°; 20%; 75%; Pohorje, Bistriški Šum waterfall, along the path to the parking. — **104**: 19.8.2006; 2 m²; 550 m; N; 80°; 10%; 35%; Pohorje, above Bistriški Šum waterfall. — **105**: 19.8.2006; 5 m²; 500 m; ENE; 87°; 20%; 50%; Pohorje, on the path to the Bistriški Šum waterfall, from the direction of Zgornja Bistrica. — **106**: 19.8.2006; 5 m²; 480 m; ENE; 85°; 25%; 65%; Pohorje, on the path to the Bistriški Šum waterfall, from the direction of Zgornja Bistrica.

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Jahr/Year: 2011

Band/Volume: [18](#)

Autor(en)/Author(s): Juvan Nina, Carni [ÄŒarni] Andraz [AndraÅ¾], Jogan Nejc

Artikel/Article: [Chasmophytic vegetation of silicate rocks on the southern outcrops of the Alps in Slovenia. 133-156](#)