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The flora and vegetation on serpentinites in Serbia – a review

Abstract

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In the western, south-western, and central parts of Serbia, huge serpentinized masses occur, among the largest on the European continent. The combination of geographical, geomorphological, and ecological characteristics with geohistorical factors has led to a peculiar flora and vegetation in that area. Josif Pancić was among the first to point out the unique features of serpentine flora. He noted that the flora thriving on serpentine chiefly consists of endemic, often relict taxa, adapted to the extremely unfavourable conditions of these habitats. Pančić's view was confirmed by subsequent investigations. A large number of rare plant species, mentioned in numerous papers, confirm the uniqueness of Serbian habitats. Their vegetation shows peculiar syntaxonomic, ecological, physiognomic, and floristic features especially manifest in open phytocoenoses on rocky ground, where physical-chemical effects of the parent stone on the plant world are most conspicuous.

Introduction

The rock serpentinite may contain one or a mixture of the four serpentine minerals. These have the same composition, but differ in atomic structure, so that antigorite (laminated structure and deep green), serpentine (more or less fibrous and of a paler green than antigorite), chrysotile (fibrous and yet paler in colour) and serpophyllite (amorphous and of the palest green) are distinguished. The colour of the rocks varies depending on the mineral combination. The parent rock is metamorphized,volcanic, basic peridotite which, over several phases, gradually turns into serpentinite and other alteration stages like chlorite and asbestos, and then into clay and loess. It is subject to atmospheric influences, particularly high temperature, which bring about alterations in the structure (Ilić & Karamata 1963, Huang 1967, Knežević - Djordjević & Djordjević 1976). Thus in a matter of few decades the compact, lustrous, green rock turns into crumbled dull brown, grey-brown, or grey-blue mass. Shiny and beautiful at first, it becomes cheerless and drab (Fig. 1, 2).

Serpentine rocks in Europe are mostly limited to far smaller regions than other geological substrata, and are mostly localized in the Alps and the Balkan region. In Serbia, this ratio is different. Although the serpentinite forms only 15 % of the total area of 88,000 km^2, relative occurrence of serpentinite is greater because it takes part in the formation of moun-

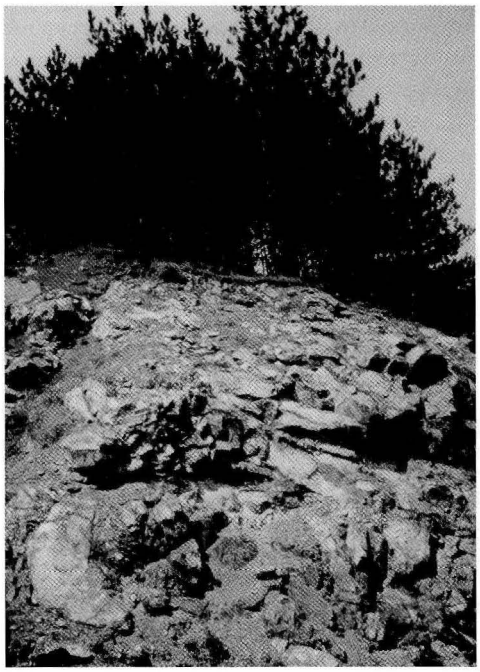

Fig. 1. Zlatibor Mt. - "young" serpentinite (Photo: O. Vasić)

tain massifs, that forms 75 % of Serbia's entire territory. Accordingly it is the core of serpentine mass on the Balkans, and among the largest in Europe.

Serpentinite dominates in south-western Serbia (Fig. 2). Zlatibor Mt. (14,000 km^2), is the central serpentinite massif, rightly regarded as the most powerful. From there, serpentinite masses expand into several directions. The north-western belt reaches Croatia via Bosnia. The southern one follows the Ibar river over a series of mountains, and then bifurcates. One branch, stretching over the western slopes of Kopaonik Mt. and Studena Planina Mt., reaches Albania. Another branch expands over Kosovo and Metohija and passes into Greece through Macedonia. Brdjanska Klisura gorge and several lower mountains lie to the north of Zlatibor, while the northernmost exclave is in the Pannonian Plane, on Fruška Gora, a mountain which had been an island in remote past. As serpentinite retains water, these parts characteristically abound in streams and rivers whose beds are steep as a rule. Between them are numerous strewn, mostly sharply sloping areas.

The devastation and cutting of forests leading to denudation are extremely dangerous in serpentinite regions where the soil unprotected by vegetation is easily worn away, so that it is scarce and often eroded from the parent rock.

The serpentinite is rather unfavourable to the plant growth, even inhospitable in extreme cases. However, plants would not be what they are, if they weren't able to conquer any tolerably suitable substratum by adapting to it. As regards the serpentinite substratum, three basic plant groups are usually distinguished: (1)

Fig. 2. Brdjanska klisura gorge - "old" serpentinite (Photo: B. Ivančević).

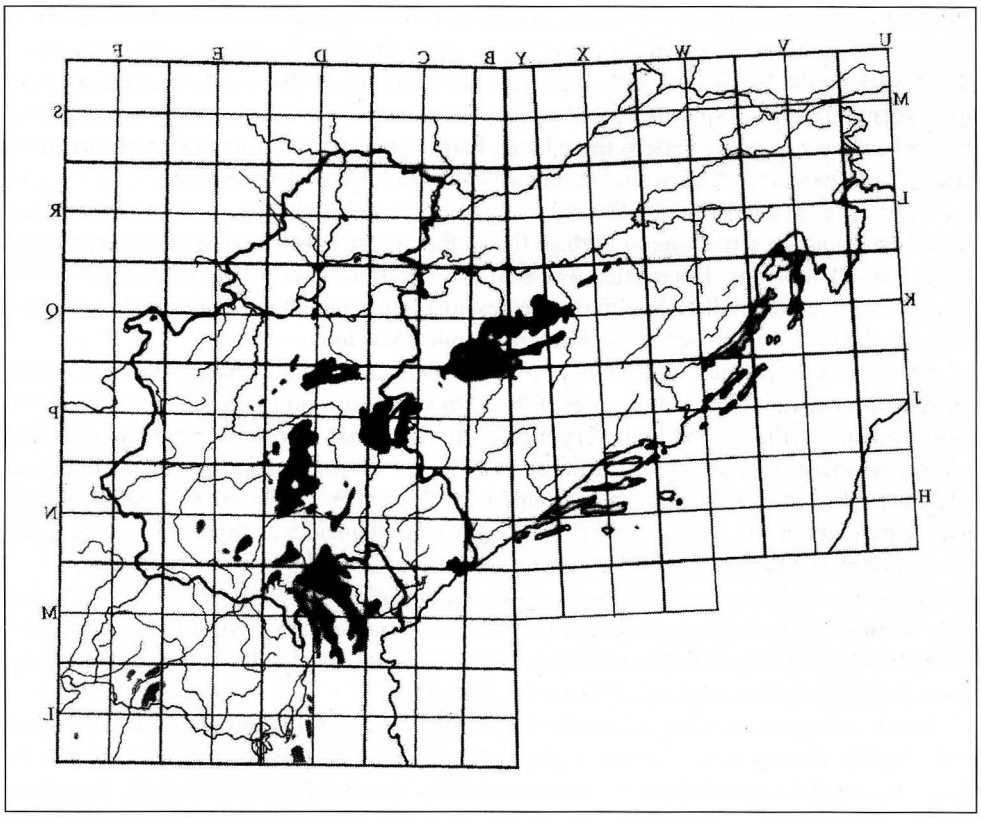

Fig. 3. Distribution of the serpentinite in Yugoslav countries.

serpentinophytes which occur solely on serpentinite, (2) those which mostly occur on serpentinite, and (3) those which may grow on serpentinite. In order to survive in so specific ecological conditions, these plants have developed appropriate morphological and physiological characteristics. Many of them are of Tertiary age and endemic in distribution.

Floristic investigations

When discussing the history of investigations of the Serbian flora even considering specific plant groups, it is impossible to forego Josif Pančić (1814-1888).

Pančić commenced his studies of the plant world of Serbia in 1846, and already in 1859 published a paper the very first work "On Serpentine Flora of Central Serbia".

At the beginning of his investigations, Pančić observed that both plants and animals on serpentinite show special qualities. He also observed that in the past these areas were overgrown with oak, pine, and beech forests, as shown by remaining single trees of *Quercus pubescens*, *Q. cerris*, *Fagus sylvatica*. Besides the absence of woody species strictly related to serpentinite, he pointed out a greater occurrence of *Rhus cotinus, Acer tataricum*, and

Juniperus oxycedrus, which form large shiblak and bush communities on certain sites. Even if abuses on nature were nowhere near as bad as today, Pančić was already aware of the need for preserving the forest fund and emphasized how important the woody communities are for serpentinite areas, especially for stopping and preventing erosion, and for protection of the herbaceous plants. As regards these latter, Pančić stressed their role in humus formation and soil regeneration which would in turn allow the oak forest to form again.

Pančić (1859) cited around 300 species, but only for 39 of them he underlined that they were first found on serpentine in Serbia. To say that he thus described them as serpentinophytes would be wrong. His caution was well in order, since later studies (Adamović 1909, Pavlović 1962) shown that 18 of those species are quite limited to serpentinite substratum, whereas the rest of them occur outside serpentinite areas too.

Pančić (1859) pointed to a series of plants which, calciphilous though they are, occur on serpentinite, and inferred that, even if they can survive on substrata with a minimal calcium content, in these conditions they are far from optimal. For these plants he recorded several distinctive morphological features with respect to other conspecific plants living on adequate substratum, such as a smaller number of flowers and fruits, more slender and less hard, often recumbent stalks, denser and longer hairs. Pančić was obviously speaking of serpentinomorphoses, as they were named later.

Despite some imprecision, the value of Pancić's work lies in his description of the specific features of flora on serpentinite, such as a far smaller presence of terophytes, later confirmed by phytocoenological analyses of living forms, or the disproportionately large roots in comparison with the part above the ground.

Pančić did not later treat independently the serpentinite flora, but his studies enlarged considerably the knowledge of these plants. His special contribution were the species he discovered in the serpentinite areas and described by himself (*Potentilla visianii*, *Eryngium serbicum*, *Potentilla mollis*, *Centaurea melanocephala*) or together with Visiani (*Scabiosa achaeta*, *Scabiosa fumarioides*, *Haplophyllum boissieranum*) or by Visiani (Visiani & Pančić 1866) on the basis of the same Pančić's collections (*Euphorbia glabriflora*). It is remarkable that many of the Pančić's data are still valid; as confirmed by Wraber (1993) and Niketić & Diklić (1990) which recently cleared the taxonomical status of *Centaurea melanocephala* and *Potentilla mollis,* respectively.

After Pančić, at the turn of this century, also Adamović (1909) studied the flora on serpentinite and described the plants related to this substratum in Moesia as: (1) exclusive serpentinophytes, (2) inclined to serpentinite, and (3) possible on serpentinite.

Of the 39 species cited by Pančić he considered only 14 related to serpentinite, at different degrees: *Euphorbia glabriflora*, *Potentilla visianii*, *Scabiosa webbiana*, *Silene paradoxa*, *Genista diffusa*, *Lasiagrostis colorata*, *Dianthus scheuchzeri* were included in the first group, *Daphne blagayana*, *Eryngium serbicum*, *Notholaena marantae*, *Astragalus dasyanthus*, *Erysimum helveticum*, *Milium vernale* and *Thlaspi montanum* in the second one.

Adamović enlarged the knowledge of the diversity of serpentinite flora adding 14 species not cited by Pančić. 7 of them (*Erica carnea*, *Thymus adamovicii*, *Dianthus vaginatus*, *Polygala bosniaca*, *Epimedium alpinum*, *Linaria rubioides*, *Bromus vernalis*) as exclusive serpentinophytes, and the remaining 7 (*Dianthus papillosus*, *Silene parviflora*, *Potentilla cinerea*, *Asplenium serpentini*, *A. brunfelsii*, *Goniolimon collinum*, *Gypsophila spergulifolia*) as inclined to serpentinite. Particularly important were the species until then

unknown. *Thymus adamovicii* was described from Brđanska Klisura gorge by Velenovsk" (1906) who named it after Adamović in recognition of the material received. *Helleborus serbicus* was described by Adamović (1906), but not as serpentinophyte, even if it has so far been found only on such substratum.

Several years later, Košanin (1914) published a comprehensive study on *Forsythia europaea* Deg. & Bald., a Tertiary relict endemic to Balkan, now included in the World Red List of endangered species (Stevanović & al. 1995). Košanin investigated the distribution and ecology of this serpentinophyte, as well as its communities belonging to the specific vegetation of shiblaks in Serbia in the southern parts of Kosovo and Metohija. It is noteworthy that the *Forsythia europaea* communities are classed as a special type of shiblak.

Košanin also discovered *Viola ducadjinica* Becker & Košanin on serpentinite in Albania (Becker 1926). Until 1990, when Stevanović and Niketić found it on Šar-Planina Mt., also on serpentinite substratum, the species was thought not occurring in Serbia.

The serpentine flora of Serbia also attracted the Czech botanist František Novak, who investigated the large plateau of Zlatibor Mt. in the period 1923-26. Unfortunately, Novak (1926, 1928, 1929), following the system of plant classification, analyzed only 196 species ending with the representatives of the *Apiaceae* family. Nevertheless, he greatly contributed to the knowledge of Serbian flora and certain characteristics of serpentine by publishing 42 species until then unknown to Serbia and discovering a new endemic species later described as *Alyssum jancheni* by Nyárády (Novak 1927). This serpentinophyte was found later only in north Albania.

Novak (1928) considered serpentinomorphosis as polymorphous structures more or less worthy of taxonomic interpretation and described a series of infraspecific forms, subspecies, varieties and forms as the adaptive result to serpentinite conditions.

From 1947 to 1962, Zagorka Pavlović, curator at the Natural History Museum in Belgrade, devoted fifteen years to the study of vegetation on serpentinite, paying attention to the areas still not well investigated. She emphasized relationship between phytogeography and geological substratum in W. Serbia. According to Beck von Mannagetta (1901) and Adamović (1909) the eastern part of Illyrian floristic region lies in Serbia in the western, south-western, and partly the central area, i.e. in the core of serpentinite. Pavlović (1953) concluded that the eastern boundaries of Illyrian floristic area mostly coincide with those of the serpentinite area in Serbia and pointed out the importance of geographical position, in addition to geological substratum, in the forming of serpentinite flora. Accordingly, in order to establish precisely to which extent species were related and adapted to serpentinite substratum, it was also necessary to consider the geographical factors.

Pavlovic's investigations were restricted to the species she regarded as typical serpentinophytes. Comparing several mountain massifs, she observed that frequency of typical serpentinophytes differs from mountain to mountain, and reaches its maximum on Zlatibor Mt (Pavlović 1951, 1953, 1955, 1955*a*, 1962). This may be considered as a realistic view as Zlatibor occupies the central position in Serbia's serpentinite mass.

Pavlović's work is essentially an analysis of the structure of serpentinite flora in Serbia in view of the geological age of the species and the degree of their general distribution and endemism. Accepting Pichi - Sermolli's (1948) theoretical explanation of the origin of ser-

pentinophytes, sustained by the results obtained by Krucberg (1951) and Walker (1954), she established the following basic groups (Pavlović 1962).

(1) Relict species restricted to serpentinite. The species which had inhabited other substrata, but survive only on serpentinite. For these species this substratum is a refugium.

(2) Endemic species related to serpentinite. Living on this substratum, populations diverged from the source species both territorially and taxonomically, and formed new taxa at varying rank betwen the form and the independent species, regarded as neoendemic (Pichi - Sermolli 1948).

These two groups differ one from another in the defining criterion. The most important in the former group is the historical element, in the latter the ecological one. Furthermore, the relicts on serpentinite contain no vicarious species on other substrata, while most endemics do.

In nature, however, the distinctions are not so sharp as we choose to see in order to shape our conclusions more smoothly. Clearly enough, the historical approach to the relicts involves the ecological principle. There is the telling fact that some species in the group of relicts on serpentinite are endemic.

In her survey of serpentinite flora, Pavlović (1962) gave special attention to typical serpentinophytes, she analyzed from historical, floristic-geographical, and ecological aspects, as shown in Table 1:

Tertiary relicts	
WIDESPREAD	BALKAN ENDEMICS
Notholaena marantae (L.) Desv.	*Forsythia europaea* Degen
Asplenium adulterinum Milde	*Halacsya sendtneri* (Boiss.) Dörfler
	Potenitilla visianii Pančić
Endemics	
SERBIAN	f. *reichenbachianum* Nyár.
Euphorbia serpentini Novák	**Linum tauricum*
Thymus adamovicii Velen.	var. *serbicum* (Podp.) Hayek
Helleborus serbicus Adamović	SERBIAN AND BOSNIAN
Potentilla mollis Pančić	*Verbascum bosnense* K. Mal″
**Alyssum montanum*	*Silene paradoxa* L.
subsp. *serbicum* Novák	**Scrophularia canina*
**Potentilla hirta* L. var. *zlatiborensis* Novák	subsp. *tristis* (K. Mal″) V. Nikolić
**Armeria canescens* var. *serpentini* Novák	*Rubus zwornikensis* Fritsch
**Genista friwaldszkyi* f. *serpentinicola* Novák	**Thymus jankae* Čel.
**Goniolimon collinum* var. *serbicum*	var *hirsutus* K. Mal″
(Vis. & Pančić) Hayek	**Dianthus croaticus*
**Gypsophila spergulifolia*	var. *longearistatus* K. Mal″
f. *serbica* Vis. & Pančić	**Potentilla australis* Krašan
**Alyssum murale*	subsp. *maliana* (Bor.) Novák
	**Stachys recta* var. *chrysophaea* (Pančić) Hayek

SERBIAN AND MACEDONIAN	*Haplophyllum boissieranum* Vis.
Scabiosa fumarioides Vis. & Pančić	*Alyssum janchenii* Nyár.
	Alyssum markgrafii O. E. Schultz
SERBIAN AND ALBANIAN	*Sedum serpentini* Janchen
Eryngium serbicum Pančić.	*Orobanche nowackiana* Markgr.
*species including the serpentinomorphoses as infraspecific taxa	

In addition to the species limited in distribution, she cited some widespread ones such as *Fumana bonapartei* Maire & Petitm., occurring in Serbia, Bosnia, Albania and Macedonia, and *Asplenium cuneifolium* Viv. with a wider European range (Pavlović 1962).

A very important centre for forming serpentinite endemics also lies in Kosovo and Metohija (Mayer & Greuter 1985, Niketić 1992-1993, Tatić & Krivošej 1993 etc.). The serpentinite areas are frequently interrupted so that each of them has its characteristic species which, in view of the general distribution, belong to the category of very rare plants. Local endemics on serpentinites from Kosovo comprise a larger number of rare plants including *Aristolochia merxmuelleri* Greuter & E. Mayer, *Cerastium neoscardicum* Niketić, *Saponaria intermedia* Simmler, *Bornmuellera dieckii* Degen, *Sanguisorba albanica* Andraszovsky, *Stipa mayeri* Martinovsky, *Sempervivum kosaninii* Praeger, *Tulipa serbica* Tatić & Krivošej. Serbian - Albanian endemites inhabit Albania as well as serpentinized areas in Kosovo. Among these species there are: *Genista hassertiana* (Baldacci) Baldacci, *Polygala doerfleri* Hayek, *Veronica andrasovszkyi* Jàvorka, *Viola ducadjinica* Becker & Košanin, *Aster albanicus* Degen.

Although serpentinite occurs only in isolated patches, in the area of Djerdapska Klisura gorge (NE Serbia) *Veronica scardica* Gris., described as serpentinophyte by Fischer & al. (1984), grows.

Tatić & Veljović (1982, 1992) were most specific in defining serpentinophytes. Seeing that the previous authors neglected the exact knowledge of the chemical composition of the substratum, they gave it the greatest attention. In their opinion, the term serpentinophyte should be limited to the plants whose root system is in direct contact with the serpentinite substratum. They described such species as obligatory serpentinophytes. Applying these severe criteria, they reduced the number of Balkan serpentinophytes to 16, 11 of which occur in Serbia: *Alyssum markgrafii*, *Asplenium adulterinum*, *Bornmuellera dieckii*, *Fumana bonapartei*, *Gypsophila spergulifolia*, *Halacsya sendtneri*, *Haplophylum boissieranum*, *Polygala doerfleri*, *Potentilla visianii*, *Saponaria sicula* and *Sedum serpentini*.

Also interesting, particularly with regard to ecology, are the plants which thrive on other substrata beside serpentinite, but which are chiefly related to serpentinite rock in these areas. These include rare and endemic species of Serbia such as *Stachys recta* L. subsp. *baldaccii* (K. Mal") Hayek, *Stachys scardica* (Gris.) Hayek, *Centaurea kosaninii* Hayek.

Some species, like *Daphne blagyana* Freyer, *Erica carnea* L. and *Selaginella helvetica* (L.) Spring occur on other substrata elsewhere, but are limited to serpentinite in Serbia (Tatić & al. 1987).

Investigations of vegetation

The effect of serpentinite substratum on vegetation is neither so conspicuous nor limiting as on certain plant species, but it determines certain specific qualities. The character of vegetation is affected not only by ecological conditions, but also by the fact that the serpentinite areas in Serbia lie in the eastern part of Illyrian floral region. The specific qualities of vegetation on serpentinite are most striking in chasmophyte communities because the contact between plants and parent rock is the most direct.

Forest vegetation

Generally speaking, the edificators of forest communities on serpentinite are the same species as on other soils (*Quercus pubescens*, *Q. cerris*, *Q. frainetto*, *Q. petraea*, *Fagus sylvatica*, *Carpinus betulus*). However, the presence of *Ostrya carpinifolia* and *Juniperus oxycedris* in a large number of communities on serpentinite, is rather conspicuous.

Since the anthropogenic factor has reduced particularly the oak forests, thus Serbia's climatogenic forest *Quercetum frainetto cerris* Rudski (1940) 1949 occurs on serpentinite 400 m a. s. l. only in scant patches where certain features peculiar to serpentinite can still be observed: far less species on the tree floor, great frequency of *Ostrya carpinifolia* and *Juniperus oxycedrus*; besides *Helleborus serbicus*, one of the most conspicuous serpentinophytes endemic to Serbia, is particularly frequent.

The association *Quercetum sessiliflorae* Pavlović 1951 [*Quercetum montanum* (B. Jov. 1948) Čer. & B. Jov 1953], has developed at altitudes around 1000 m. Its fragments on serpentinite are distinguished by Illyrian and Mediterranean elements, including numerous obligatory serpentinophytes, as *Helleborus serbicus*, *Alyssum markgrafii*, *Asplenium serpentini*, *Daphne blagyana* (Pavlović 1951).

The association *Fagetum abietetosum* Horvat (Tatić 1969) is characterized by a comparatively great number of woody edificators. According to Tatić (1969), only *Pinus nigra* and *Quercus petraea* in addition to *Abies alba* and *Fagus sylvatica* occur on serpentinite. Therefore the presence of herbaceous serpentinophytes is striking.

The most characteristic forest of the serpentinite areas in western Serbia is formed by *Pinus nigra* and *Pinus silvestris*. The centre of its range lies exactly in this part of the Balkans and expands towards south, southeast and southwest. In spite of some peculiarities responding to local ecological conditions, Pavlović (1964) considered this forest as belonging to one unique association, *Pinetum silvestris nigrae* Pavlović 1964, ranging at 800-1350 m a.s.l. within which Pavlović (1964) syntaxonomically defined subass. *ericetosum* with *Erica carnea*, subass. *seslerietosum* with *Sesleria rigida*, and subass. *genistetosum* with *Genista januensis*. It is important, for an analysis of serpentinite vegetation, to take into account that serpentinophytes occur far more frequently in the *Pinetus silvestris nigrae* community, than in oak or beech forests. Open canopy and denuded serpentinite are favourable to *Asplenium serpentini, Euphorbia serpentini, Helleborus serbicus, Verbascum bosnense*. Their presence points to the endemic character and relict age of pine forests in that part of the Balkans. In addition to the *Pinetum sylvestris nigrae*, the *Pinetum nigrae* Pavlović 1951 and the *Potentillo - Pinetum gocensis* Jovanović 1959, have been described (Pavlović 1951, Jovanović 1959).

Ass. *Ptilotricho - Bruckentalio - Pinetum mughi* Janković & Bogojević 1976 has devel-

oped on the massif of Ostrovica Mt. Occurring at heights around 2000 m, it represents the forest serpentinite community at the highest altitude (Janković & Bogojević 1976). Before, the *Pinetum mughi* had been recorded on limestone and silicate substratum.

Important aspects of vegetation on serpentinite, the shiblaks, are natural bushy formations.

A relict species, *Syringa vulgaris* L. is characteristic of the *Syringetum vulgaris serpentinicum* Jovanović & Vukićević 1988. On serpentinite rock blocks, this association represents the primary phytocoenosis which allows the initial stages of pedogenesis.

The associations *Pteridio - Prunetum spinosi* D. Lakušić 1993 and *Junipero oxycedri - Prunetum spinosae* D. Lakušić 1993 developed in the *Quercetum montanum* climatic zone at about 1100 m a.s.l., are likewise important for the forest regeneration (Lakušić 1997).

The shiblak formed by the endemic and relict association *Polygalo - Forsythietum europaeae* Blečić & Krasnići 1971, is regarded as a truly serpentinophyte community which develops at 370-930 m a.s.l. Besides the edificator *Forsythia europaea* Deg. & Bald., also *Polygala doerfleri*, *Sanguisorba albanica*, *Dioscorea balcanica*, *Alyssum markgrafii*, *Asplenium serpentini*, *Euphorbia glabriflora*, *Centaurea kosaninii*, *Potentilla visianii*, *Moltkea doerfleri*, *Veronica anrasovszkyi* etc., all related to serpentinite substratum (Blečić & Krasnići 1971), belong to this community.

Although the shiblak vegetation is by definition formed by deciduous species, the association *Juniperetum oxycedri serpentinicum* Jovanović 1980 was described from the western and central Serbia. The edificator, *Juniperus oxycedrus* L., a coniferous, evergreen Mediterranean species, lies on its northern distribution boundary, forming almost pure populations on huge tracts of land. Serpentinophytes play important role in the ground floor. According to Adamović (1906), in Mediterranean submontane and montane zone, *J. oxycedrus* represents the most frequent element of pseudo-maquis vegetation together with numerous other evergreen plants. In Western Serbia, this species is a unique evergreen element belonging to the *Juniperetum oxycedri serpentinicum* which can be considered as a particular vegetation standing between pseudo-maquis (Mediterranean) and shiblak (continent), which has developed under the influence of the Mediterranean climate.

The devastation of forests, far more dangerous on serpentinite than other substrata, has led to the formation of secondary vegetation such as meadows, pastures, and rocky tracts. Relating to the altitude and vegetation belt they belong to, meadows, pastures, and rocky grounds are determined by the pedological stages. Therefore the most striking effects of serpentinite are shown in the composition and character of rocky and rocky grounds vegetation where the soil is more or less thin or practically absent and the plants are directly in contact with the parent rock. This is the reason for a high frequency of pronounced serpentinophytes, often endemic, in the vegetation on rocks and rocky grounds.

Meadows

Meadow vegetation mostly develops under more or less evolved edaphic conditions, where the parent rock influence is practically absent. Therefore, serpentinophytes are almost lacking in the meadows on serpentinite. Although the associations *Agrostidetum vulgaris* Pavlović 1955 [*Agrostidetum capillaris* Pavlović 1955] and *Molinietum coeruleae* W. Koch 1926 (Tatić 1969), occur at the foot of the mountains on damp places, even in the serpentinite areas, their composition does not differ from that on other sub-

strata. The same hold for the mesophilous association *Molinieto - Deschampsietum* Pavlović 1951, as well as the communities of *Festuca fallax - Dianthus deltoides* Pavlović 1951 and *Polygonum bistorta - Poa trivialis* Pavlović 1951, developed on thicker soil cover and on moister substratum (Pavlović 1951).

In Western Serbia, the associations formed by the Pontic-Mediterranean species *Chrysopogon gryllus* (L.) Trin. frequently occur in the 310-700 m mountain belt. The areas at lower altitudes, with less sharp slopes, and thicker soil layer, are occupied by the *Agrostio - Chrysopogonetum* Kojić 1958, whose mesophilous character is indicated by *Agrostis capillaris* L. This association also comprises no serpentinophytes. However, the composition of the termophilous association *Bromus fibrosus - Chrysopogon gryllus* Tatić1969, thriving at about 700 m altitude, chiefly includes the species related to serpentinite: *Eryngium serbicum*, *Alyssum markgrafii*, *Euphorbia glabriflora*, *Potentilla zlatiborensis*, *Haplophyllum boissieranum*, *Notholaena maranthae* (Tatić 1969). A sharper slope, and thinner and drier soil allow the parent rock to affect the association composition more significantly.

At 1000-1400 m altitude, where soils become scant and rocky, the vegetation of meadows becomes more affected by serpentinite influence. Under these conditions, besides *Danthonia calycina* (Vill.) Rchb., *Koeleria montana* Hausm. and *K. eriostachya* Panč., 80 more species belong to the *Koelerio - Danthonietum calycinae* Pavlović 1974, which occurs in the montane-alpine region of western and central Serbia. The effect of the serpentinite is seen in the presence of a large number of serpentinomorphoses such as: *Potentilla recta* var. *zlatiborensis*, *P. hirta* var. *zlatiborensis*, *Armeria canescens* var. *serpentini*, *Ranunculus montanus* f. *serpentini*, *Hieracium fussianum* var. *serpentinaceum*, *Silene vulgaris* var. *zlatiborensis*, *Genista friwaldszkyi* f. *serpentinicola* (Pavlović 1974).

Pastures

The most frequent pasture vegetation on serpentinites in western Serbia (950-1400 m) belongs to the association *Poeto molinerii - Plantaginetum carinatae* Pavlovuć 1951 [*Poo molineri - Plantaginetum holostei* Pavlović 1951] which occurs in the pine forest zone. Pavlović (1955) considers this association as the final stage of pine forest regression, but recognizes a pioneer role on the entirely degraded serpentinite substratum. Although *Poa molinerii* Lam. & DC and *Plantago holosteum* Scop. are characteristic of rocky and sunny sites in the best part of southern Europe, in Serbia they often occur on serpentinite with *Potentilla australis* subsp. *malyana*, *P. hirta* var. *zlatiborensis*, *Alyssum montanum* subsp. *serbicum*, *Scleranthus dichotomus* var. *serpentini*, *Stachys scardica*, *Verbascum bosnense* etc. which are more or less related to serpentinite.

The *Festuco - Potentilletum zlatiborensis* Pavlović 1951, an association occurring on the plateaux with thicker soil, comprises an important group of serpentinophytes besides the widespread species (Pavlović 1951).

In central Serbia, on the serpentinites of Kopaonik Mt. (750-1590 m) in the climacic forests of *Fagetum montanum* B. Jovanović 1953 and *Abieti - Fagetum* B. Jovanović 1953, the pasture and rock vegetation is represented by the *Artemisio - Achnatherum calamagrostis* R. Jovanović - Dunjić & S. Jovanović 1987, *Carici humilis - Festicetum pancicianae* R. Jov. - Dunj. & S. Jov. 1987 and *Erico - Seslerietum rigidae* R. Jov. - Dunj. & S. Jov. 1987. These associations occur in the areas formerly covered by pine formations

(*Euphorbio glabriflorae - Pinetum nigrae* B. Jov., *Erico - Pinetum nigrae* B. Jov.) they represent the final stage of the regressive succession of these forests.

In the borderland between Serbia and Macedonia (Preševo surrounding) smaller isolated serpentinite areas occur. The pasture association *Festuco - Plantaginetum serpentini* Randj. & Ružić 1982 thrives in the *Quercus pubescens* and *Q. petraea* belt between 600 and 960 m a.s.l. (Randjelović & Ružić 1983). Unlike the pasture vegetation of serpentinite in western Serbia, it comprises terophytes in an unusually high percentage (28%). This feature is a response to the influences of the Mediterranean, borne by the Vardar river valley.

In these communities the basic role is played by many species of the *Poaceae* family, which, according to Pavlović (1962), most readily conquer serpentinite habitats, even without ecotypic differentiation. Edificators of associations, likewise the representatives of the *Poaceae*, are as a rule the plants of wide distribution and a greater ecological valence.

Rocky ground vegetation

The serpentinite rock, often bereft of the thinest soil layer, manifests itself in the vegetation of rocks and rocky grounds as appears in the *Halacsya sendtneri - Potentilla mollis* Pavlović 1955 an association endemic to the western Serbia occurring at about 1000 m altitude (Pavlović 1955). Of the edificators of this association, *Halacsya sendtneri* is a Tertiary relict, and *Potentilla mollis* is endemic to Serbia. Both these species are serpentinophytes, and all other members of the community are more or less related to serpentinite.

On the serpentinite blocks in the Ibar river valley, at the foot of Rogozna Mt., in the zone of sub-Mediterranean forest *Quercus pubescens*, the association *Sedo - Dianthetum serbici* Pavlović 1962-64 occurs. This association comprises over 25% of serpentinophytes, while most other members are chiefly widespread on serpentinite.

Blečić & al. (1969) established three strictly local endemic communities, syntaxonomically well differentiated, on several sites in Kosovo and Metohija.

In the *Cynancho - Saponarietum intermediae* Blečić, Tatić, Krasnići 1969 (820-1280 m a.s.l.) the characteristics of the association are exclusively serpentinophytes such as *Notholaena marantae*, *Asplenium serpentini*, *Silene longiflora*, *Euphorbia glabriflora*, *Centaurea kosaninii*. Most of these plants are endemic to the Balkans.

The dominant species, as well as the other members of both the *Polygalo - Genistetum hassertianae* Blečić, Tatić, Krasniči 1969 and the *Sedo - Bornmuelleretum dieckii* Blečić, Tatić, Krasnići 1969, are serpentinite related. Being of different floristic composition, and differing from other communities on serpentinite, these three associations belong to special alliance *Centaureo - Bromion fibrosii* Blečić & al. 1960.

Discussion

Although serpentinite is not a favourable substratum for plants, however, the plant variation by adapting to specific ecological conditions, and the complex geohistory of Serbia have combined to form an interesting and considerable flora and vegetation.

The flora and vegetation features have been analyzed in the light of their relation to serpentinite, and the effects of Serbia's geographic position, climate, and plant geography

have also been considered. Accordingly, the role of each single element in the formation of the peculiar features of flora and vegetation have been stressed out.

Future investigations, carried out through modern methods in physiology, ecophysiology, and anatomy, and the knowledge of chorology, ought to show a more realistic picture of the composition of flora on Serbia's serpentine areas. However, serpentinite, which is geologically neither simple nor uniform, ought to be defined with respect to the plants.

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