

## **Vegetation of the Vitoša Mountains (Bulgaria) in relation to an anemo-orographic system**

**Vegetace Vitoše (Bulharsko) ve vztahu k anemo-orografickému systému**

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Convergent funnel-shaped valleys collect the prevailing western winds and create a combined anemo-orographic system causing floristic and ecological peculiarities on the summit plateau and over the lee zone in the N. E. Vitoša Mountains.

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### INTRODUCTION

Dependence of mountain vegetation on relief, microclimate, snow depth and disturbing effects of avalanches was observed by many botanists a long time ago. In the Sudeten Mountains, JENÍK (1959, 1961) described the "anemo-orographic system" (hereafter abbreviated A-O system), a model of integrated geographical and ecological factors explaining the distributional pattern of vegetation in relation to relief, climate, soil and avalanche action. Later on, the same model has been applied in the explanation of various abnormities of the distribution in plant populations and communities of several Central European ranges, such as the Šumava Mountains (SOFRON et ŠTĚPÁN 1971), Vosges and Schwarzwald Mts. (Black Forest) (JENÍK 1961), Western Carpathians (HAJDÚK 1983), and Eastern Alps (JENÍK, HÜBEL, HOLZNER, msc.). All above named mountains are exposed to unilateral action of western winds blowing from the Atlantic Ocean, and causing stabilized local air currents streaming through the valleys stretched in the west-east direction. In S. E. Europe, air circulation is much more complicated due to the interference between oceanic and mediterranean air masses, and, consequently, common occurrence of distinct A-O systems could not be expected.

In May 1983, I managed to identify a well developed A-O system in the S.E. part of the Vitoša Mountains, near Sofia, the capital of Bulgaria. Many features of this system correspond with the original model described from the Krkonoše and Hrubý Jeseník, the two dominant ranges of the Sudeten Mts., however, certain specialities have also been noted. The vernal stage of the growing season did not allow a detailed floristic study of the area, however suitable conditions for comparison of snow accumulation and differential phenological phases of plants made the function of the A-O system quite obvious. Following is a sketch of geobotanical circumstances that might enhance future investigation into the causative factors of the distributional pattern of vegetation in the summit region of the Vitoša Mts.

## GEOLOGICAL CONDITIONS

From the geological viewpoint, the Vitoša Mts. is far from being too complicate. Its core area, called "Vitoša Pluton", is composed mainly of syenites, thus making the region of our observation rather homogeneous. The outcrops of andesites and limestones are restricted mainly to the N. W. part of the mountains. Geomorphologically, the flat summit region of the Vitoša Mts. represents a denuded peneplain with scattered summits protruding above the average level of the plateau; the resemblance with the summit area of the Krkonoše Mts. is quite obvious. Rising abruptly from the foothills, the Vitoša Mts. are most precipitous on the N. E. flanks facing the Sofia Basin (see Figs. 2 and 3).

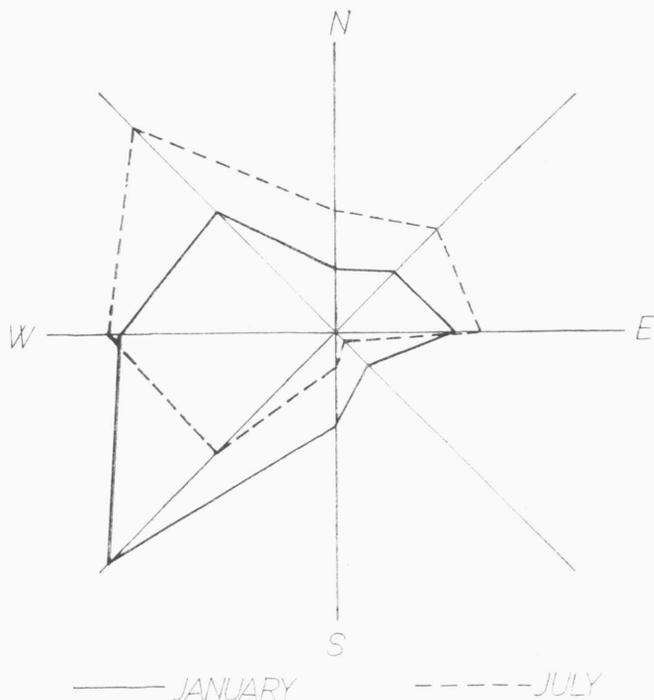


Fig. 1. — Proportional distribution of the individual wind directions in the summit area of the Vitoša—Černi Vrch Mts. (2290 m) in January and July (after GERASIMOV et GALABOV, 1966).

## DESCRIPTION OF THE A—O SYSTEM

In agreement with the model described in the Sudeten Mts., the Vitoša A-O system has developed as a result of stabilized action of orographic winds blowing across a high plateau, and creating a prominent wake in the lee of the massif. Generally, three component parts make a functional A-O system: (1) collecting windward valley, (2) accelerating summit area, and (3) vortex lee zone. The following paragraphs describe these components, respectively:

While in the Sudeten Mts. only one or two "collecting windward valleys" join an exposed summit plateau, in the Vitoša Mts., a fan of radially converging valleys form an air nozzle situated over the central summit region (Fig. 2, 3). According to Geografija Bulgarii (GERASIMOV et GALABOV 1966)

western winds heavily prevail in this range, throughout the year. If calculated separately for individual seasons (Fig. 1), the valleys of the headwaters of Struma, i.e. Kladniška Stream, Matnice and its tributaries, and Rudarščica Stream make an important channel for the prevailing south-

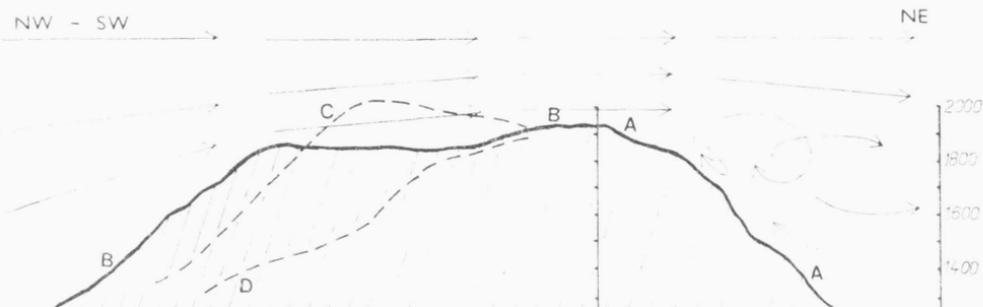


Fig. 2. — Schematic cross-section of the summit region of the Vitoša Mts., cutting the lee valley of the Dragalevska Rivulet (A) and windward Rudarščica valley (B); profile of the windward Matnice valley (c) and windward Bojanská and Vladajská valleys (D). Position of the cross-sections also marked in Fig. 3. The arrows indicate the streamlines of the prevailing western air currents.

westerlies and westerlies in winter, while the valleys of the Vladajská River and its tributaries serve as funnels mainly in summer when the northwesterlies and westerlies prevail. All the above named valley-heads smoothly rise towards the upland plateau, thus creating a fan of funnel-shaped channels collecting the streamlines of air currents and directing them towards the central plateau. The orographical situation of the Vitoša Mts. in a gap between the Stara Planina and Rila Mountains reinforces the frequency and speed of western winds, as clearly reflected in the January means from Černi Vrch (2290 m), illustrated by Beškov (1973, mappa 49).

The "accelerating summit area" of the Vitoša A-O system is represented by a large undulating plateau stretching about 5 to 6 km to the N.W. from the peak of Černi Vrch (2290 m). The average altitude of this undulating plateau varies between 1800 and 2000 m, an elevation reaching well above the natural timberline. Physiognomically, the vegetation cover resembles the alpine tundra, mires and krummholz encountered on the flat crests of the Sudeten Mts. Strong prevailing winds trim *Juniperus sibirica* into flag-shaped scrub in both the Vitoša Mts. (see Plate XII, above) and the Hrubý Jeseník Mts., though only relict stands survive in the latter range.

The third component of the Vitoša A-O system, the "vortex lee zone", is obviously situated in the valley-head of the Dragalevska Rivulet whose upper slopes are divided by a rocky promontory called Vlčata Skala into two branches. Throughout the year, abrupt deceleration of air currents and associated vortices affect the deposition of wind-blown materials, particularly the accumulation of vast snow drifts creating a starting zone of avalanches. Though real Pleistocene glaciers never developed in the Vitoša Mts. (Gerasimov et Galabov 1966), niviation processes around the patches of longlasting-snow resulted in the formation of the present-day concave depressions. These

nivation niches provide a variety of habitats suitable for establishment and survival of abundant populations and communities of alpine, subalpine and forest origin; however, due to the absence of large rock faces and precipitous crags, this diversity of habitats and plant life is smaller than that of comparable vortex lee zones of the Sudeten A-O systems, situated in glacial cirques.

Regular and secular function of the Vitoša A-O system can be described as follows:

Channeled by windward valleys, the wind currents achieve high speeds over the treeless summit plateau. Due to a natural barrier of the highest peaks (Samara, Černi Vrh, Rezen) on the southern margin of the plateau, the accelerated air currents are deflected towards the S.E. direction. Crossing the upper edge of the lee side, the air currents expand over the valley-head of the Dragalevskaia Rivulet, with a variety of climatic and ecological effects described by JENÍK (op.c.) from vortex lee zones in many European mountain ranges. Uneven sedimentation of snow during snow blizzards, and secondary redistribution of snow during the winter are the major effects of the A-O system: while vast treeless summits are disposed of snow, large snow drifts are deposited in the lee, closely below the abrupt break of the terrain. At the beginning of May 1983, remainders of snow cornice and large patches of late snow still were visible in the lee zone of the Vitoša Mts. According to local

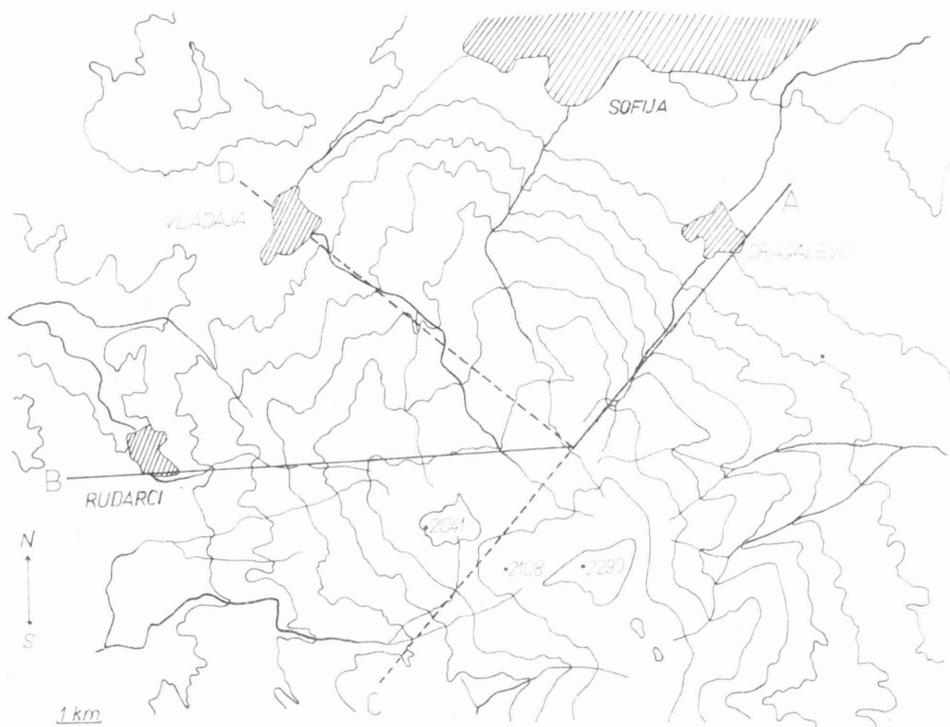


Fig. 3. Sketch-map of the summit region of the Vitoša Mts. showing the position of the cross-sections A, B, C and D in Fig. 2; contour lines at 100 m altitudes.

sources of information, this area preserves snow until June. Remarkably, the lee slopes are a favourite ski area, but the skiing public has been warned by appropriate signs reminding of the avalanche hazard. The avalanche activity is clearly recorded in the wide and long strip of treeless vegetation descending well under the level of the climatic timberline. Even in snow-poor years, the vast summit region provides huge amounts of redistributed snow; consequently, avalanches must be accounted for in the florogenesis and succession of plant communities, possibly throughout the Postglacial Age. Disturbance of continuous growth and severe competition of both woody and graminoid plants, and rejuvenation of nutrient-rich soil on the avalanche track supported the establishment, and secured preservation of plant populations seldom occurring at similar altitude. Diversed microclimate of the sheltered yet variously exposed surface, together with variable moisture around the springs and snow patches reinforced the floristic richness and mosaics of plant communities along the avalanche path. Several altitudinal zones are connected by this effective corridor: down across the alpine/sub-alpine belt and spruce montane belt (according to STOJANOV et GEORGIEV 1934, even a zone with *Pinus peuce* can be accounted for at the timberline) down to the broad-leaved forest dominated by beech.

The summits of the Vitoša A-O system are situated about 300 m higher than those of comparable Sudeten systems; however, the higher level of the timberline in all mountains of the Balkans enhances the similarity of the Sudeten and Vitoša Mts. Though heavily influenced by pasturing, the timberline of the latter range was naturally developed at about 1800 m altitude, on the western and eastern slopes, and between 1600 and 1700 m a.s.l. on the northern slopes (STOJANOV et GEORGIEV 1934). This could be estimated after remaining groups of trees (*Picea excelsa*, *Pinus silvestris* *P. peuce*) preserved in sheltered depressions on the margin of the summit plateau, e.g., in the lee of small crags or around spring heads.

At the present time, the summit region of the Vitoša A-O system is completely treeless, with dominant *Juniperus sibirica* occupying mostly convex parts of the terrain — while concave patches are covered by herbaceous vegetation and by mires. Among the most abundant species, following grasses and forbs prevail: *Deschampsia caespitosa*, *Festuca poaeformis*, *Sesleria dhleoides*, *Ranunculus montanus*, *Noccaea viridisekala* (syn. *Thlaspi praecox*) and *Homogyne alpina*. In the area of snow patches, *Crocus veluchensis* and *Polygonum bistorta* occur. In peaty habitats, namely *Primula farinosa* and *Trichophorum caespitosum* grow besides *Sphagnum* sp. div. The alpine communities of the Vitoša Mts. were described in detail by PENEV (1965) who realized the species-poor vegetation of this region, consisting of 120 species of vascular plants.

A prominent change of vegetation pattern can be observed toward the upper margin of the valley of the Dragalevska Rivulet. Here, stands of *Juniperus sibirica* are obviously loose and sculptured by wind action (see Plate XII., above), and their undergrowth is dominated by ericaceous shrubs, viz. *Arctostaphylos uva-ursi* (exceeding 50 % cover degree), *Bruckenthalia spiculifolia* (about 30 %), and *Vaccinium myrtillus* (about 8 %), with smaller representation of forbs and grasses, such as *Deschampsia flexuosa*, *Calamagrostis villosa* — none of them exceeding 5 % of cover. Lichens are an essential component of this marginal zone, with *Cetraria islandica* covering up to

40 % of the area, though the same species is rarely encountered over other parts of the summit plateau. These communities are characteristic of all wind-swept sites which are devoid of snowpack during the greater part of winter. Similar chionophobic stands can be seen on the windward side of crags protruding above the general level of the summit flats, and even on exposed crags situated in the lee space of the A-O system. According to JENÍK, HÜBEL and HOLZNER (msc.) similar *Ericaceae* and lichen-rich habitats mark the exposed summits of A-O system of the Eastern Alps.

Marked by a snow cornice the upper edge around the lee side of the Vitoša A-O system is much shorter than corresponding edges around the Sudeten cirques, and air vortices are asymmetrically shifted towards the north facing side. Still on the summit plateau the spring head is situated in a shallow depression and its surroundings are covered by vegetation markedly influenced by cattle and Man, both using the same source of drinking water; *Rumex alpinus* is the dominant component of this site. Species-rich moss and herb communities grow along the uppermost reaches of the stream flowing down the leeward slope; *Caltha palustris* s.l., *Primula farinosa* and several short *Epilobium* species thrive amidst the dense carpet of mosses. Apparently, the most luxuriant vegetation develops above a hollow located only several tens of meters below the spring head. In May 1983, this hollow was largely filled up by a thick layer of snow, and the snow patch was still about 20 by 40 m in size. On the margin successive ablation uncovered a species-rich "snow-bed" community represented by *Crocus veluchensis*, *Polygonum bistorta*, *Scilla bifolia*, *Alchemilla vulgaris* s.l. and *Doronicum columnae*. At the lower edge of the snow patch, there was a characteristic stand of willow scrub, between 1 and 2 m in height, dominated by *Salix arbuscula* (see Plate XIII., above). Still partly overlaid by ice derived from snow transported downward and accompanied by flushing herbaceous vegetation, this scrub resembled stands of *Salix lapponum* around the springs in the Krkonoše cirques.

A long avalanche track descends below its starting zone marked in the spring by persistent snow patch. Obviously, this patch represents the most interesting feature of the Vitoša A-O system. The treeless strip is covered by stands of subthermophilous *Calamagrostis arundinacea*, thus resembling similar communities of the Sudeten Mts. Beside the subdominant *Festuca poaeformis* (= *Belardiochloa violacea*), these stands contain *Euphorbia amygdaloides*, *Libanotis montana*, *Carlina vulgaris*, *Astrantia major*, *Hypericum maculatum*, *Orchis pallens*, *Cytisus supinus*, *Silene inflata*; even shrubby *Rosa pendulina* and *Cotoneaster* cf. *integerrima* are present. At its lower portion the avalanche track is dominated by tall-herb communities with *Filipendula ulmaria* and *Geranium macrorrhizum*. The runout zone of avalanches lies between 1550 and 1600 m alt. and is vegetated by dense groves of willows, birches, mountain ash and alder (*Alnus viridis*), again with predominating *Calamagrostis arundinacea* in the undergrowth, and admixture of numerous "forest" species, such as *Daphne mezereum*, *Paris quadrifolia*, *Lilium martagon* and even *Polystichum lonchitis*. Lower down, the avalanche scrub merges the beech forests, leaving the plants of the upper coniferous belt nearly unrepresented on the whole track. No wonder that numerous subalpine species, e.g., *Crocus veluchensis* and *Veratrum lobelianum*, descend down the avalanche track into small clearings within the beech forest. For obvious reasons, e.g.,

lower flexibility of the trunk and absence of vegetative propagation, the stunted spruce accompanied by *Luzula silvatica* and *Vaccinium myrtillus* can be observed in small groups on the emerging crags and convex elevations of the avalanche path.

Along the avalanche track and on small protruding ridges, a marginal mantle of old *Juniperus sibirica* can be observed; these stands differ from communities of the same species on the summit plateau by vigorous growth and different companions. At an altitude of about 1700 m, the mantle consisted of *Corylus avellana* (probably an altitudinal maximum of this species), *Cotoneaster* cf. *integerrima*, birch scrub, *Pinus mugo*, *Rubus idaeus*, abundant *Arctostaphylos uva-ursi*, *Vaccinium myrtillus*, *V. vitis-idaea*, etc.

Large fields of scree cover the lee flanks of the Vitoša A-O system (see Plates XII., below; XIII., below) — a contrast to the lee zone of the Sudeten cirques, where Pleistocene glaciers made the clearance of periglacial debris. The scree harbours merely individual specimens of *Geranium macrorrhizum* and narrow patches of willows and birches. Even Norway spruce cannot survive on the mobile substrate, and the coniferous montane belt is poorly represented by small groups on rocky outcrops. The diversity of the lee zone of the Vitoša A-O system is enhanced by the above mentioned cliffs of Vlčjata Skala, dividing the valley-head into two parallel branches at 1600 m. Beside a few botanical oddities luxurious growth of *Geranium macrorrhizum* at the foot of wet rock faces deserves notification.

#### CONCLUSIONS

It can be concluded that, in the S.E. part of the Vitoša Mts., the valley-head of the Dragalevska Rivulet represents a diversified botanical locality whose origin and development can readily be explained by its appurtenance to the above described A-O system. Natural values of this region deserve further botanical and ecological studies, and, no doubt, represent a priority in nature conservancy. It is very likely that some neighbouring valley-heads on the eastern slopes of the Vitoša Mts., e.g., that of Bistriška River, also gain benefits from the lee position within an A-O system (flag shaped scrub on the upper margin of the valley Bistriška River, snow drifts preserved until July, species-rich communities with *Calamagrostis arundinacea*, maybe in the only glacial cirque in the Vitoša Mt. — STOJANOV 1939). These localities should be examined with regard to adjacent summit areas and windward valleys in order to identify their individual wind and snow regime. Complementary effects with the above described A-O system are to be expected.

Exploration of the Vitoša A-O systems may help in better understanding of the abnormalities in distribution of rare plant populations, and explanation of causative factors in the vegetation mosaics of these mountains. Applying the model of A-O systems, it will be possible to explain certain oddities, e.g. the low floristic diversity of the alpine vegetation of the Vitoša Mt. in comparison with the species richness of the entire mountains, as pointed out by PENEV (1965). Studies of the ancient treeless enclaves maintained within the forest zone by frequent avalanche motion may also contribute towards clarification of the origin of species composing the man-made grasslands (meadows), as already suggested by ELLENBERG (1963).

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## SOUHRN

Z pohoří Vitoša v záp. Bulharsku je popisován dobře vyvinutý anemo-orografický (A-O) systém, představující obdobu A-O systému v Sudetských horách v Českých zemích (JENÍK 1959, 1961). Ve srovnání s nimi tvoří na Vitoše vodící návětrnou část několik údolí, rozbíhajících se hvězdovitě z centra pohoří k Z a SZ. Zrychlující náhorní rovina leží ve výšce 1800–2000 m n. m., již nad horní hranicí lesa. Okraje plošiny porůstají skupiny *Juniperus sibirica*, výrazně formované do větrných forem, dále erikoidní keřky a lišejníky. Závětrný prostor A-O systému představuje karoid závěru údolí Dragalevska rečka s periodickými lavinovými drahami s pestrým bylinným krytem (dominantní *Calamagrostis arundinacea*). Tyto lavinové dráhy sahají od alpského stupně, probíhají stupněm jehličnatého lesa a končí až v horní části bukového stupně. Na lavinových drahách dochází k vzájemnému prolínání rostlinných druhů z různých vegetačních stupňů. Podrobnější sledování A-O systému Vitoše by pomohlo objasnit další kausální závislosti v rozšíření jednotlivých druhů i celých biocenos.

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