Analysis of the plant cover of the Upper Alpine belt of the northern part of the Central and Eastern Caucasus

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Abstract. The natural conditions of highlands of the northern part of the Central and Eastern Caucasus are described. Three high-rise belts – alpine, subniveal, niveal – were identified within the studied territory. Features of vegetation cover of these belts are emphasized: fragmented vegetation in the form of separate rock-talus groups and microgroups; sparseness and simplification of its structure, participation of mosses and lichens and huge amounts of types of underlying high-rise belts. According to the high-rise distribution in the subniveal belt, the following groups of species were identified: 1) found at 3100 m above sea level, involved in creating fragmentary carpet-like alpine meadows at the bottom of the belt; 2) found mainly at 3000-3300 m above sea level; 3) living mainly in the range from 3000 to 3600-3700 m above sea level. There is a prevalence of petrophytes, high percentage of endemicity in the subniveal belt (Pseudobetckea, Pseudovesicaria, Didymophyssa, Trigonocarium, Eunomia, Vavilovia, etc.). The paper lists the most characteristic families of monocotyledones (Poaceae, Cyperaceae, Juncaceae and Liliaceae), the most characteristic families of dycotyledonae (Asteraceae, Brassicaceae, Caryophyllaceae, Fabaceae, Saxifragaceae, Rosaceae, Scrophulariaceae, Campanulaceae) and species growing on different substrates – taluses of clay shale, moving taluses, rocks, rocky and crushed slopes, moraines, alpine lawns, common and rare species (Galium rugosum, Jurinea filicifolia, Jurinella moschus, Vavilovia formosa), as well as Veronica bogosensis, Cerastium multilorum, Delphinium caucasicum endemic for the eastern part of the studied area – Erysimum subnivale, Ranunculus tebelossicus, Pyretrum aromatucum, Pseudobetckea caucasicqa, Sedum stevenianum, etc.

1. Introduction
There are no special works dedicated to the plant cover of the Upper Alpine belt of the northern part of the Central and Eastern Caucasus in the literature. Therefore, the main features of the vegetation cover within the studied territory is based on the works of A.A. Grossheim [1], E.V. Schiffers [2, 3], V.M. Prima [4, 5], M.A.-M. Astamirova [6–9], etc.

The plant cover of this belt is characterized by a great variety. Different vegetation types are found here ranging from mountain xerophytes to cold-resistant alpine meadows. This diversity is caused by the mountain relief.

The Upper Alpine Belt is characterized by extremely harsh living conditions. The snow line runs here at an altitude of 3,700 m above sea level. Somewhere from under snow and ice there are rocks, on which there are crustaceous lichens, there is specific pioneer vegetation of free-growing groups on rocks and taluses, some species of Cerastium, Minuartia, Primula, Saxifraga, Veronica genera are found, any other vegetation is not present here.
2. Materials and methods
The material was based on floristic and geobotanical data collected by the authors over ten years (2009-2019) during route and semimobile research. As a result, more than a hundred geobotanical descriptions were made, a herbarium was collected, which is stored in the repositories of the Department of Botany of the Chechen State Pedagogical University, Kh. Ibragimov Complex Institute of the RAS, as well as the Caucasus Department of the Komarov Botanical Institute of the Russian Academy of Sciences.

In developing the research methodology, the authors relied on methodological manuals widely used in geobotanical practice. This includes the following: Field Geobotanical Research Methodology [10]; works by A.I. Tolmachev [11]; I.N. Beideman [12]; A. A. Korchagin [13, 14]; V.M. Ponyatovskaya (1964) [15]; A.A. Yunatova [16]. Methodological guidelines specifically devoted for the study of flora and vegetation in mountain regions were also taken into account [17-19], etc.

3. Results and discussion
Moisture and thermal conditions are the leading climatic factors determining the spread of vegetation in mountains, especially in high mountain ecosystems [20]. In general, there are 8 belts in the Caucasus: niveal, subniveal, alpine, subalpine, semi-arid vegetation (mountain xerophilous), forest (forest-meadow) and steppe (forest-steppe) [21]. Within the studied territory, in its highest parts there are 3 first belts, in the lower – only alpine and subalpine.

The niveal belt is located in different parts at the altitudes of 3200-3800 m above sea level, and the more to the east the mountain system, the higher it shifts. It is the area of eternal snow and glaciers where higher vascular plants are absent, the boundary of their distribution is the snow line. It is characterized by year-round negative air temperatures and almost complete lack of soil [3]. But, due to high intensity of solar radiation in summer, the dark surface of rocks is heated more strongly than the air, the temperature difference between the underlying surface and the air can reach 30 ºС, as a result of which snow melts thus forming water necessary for organisms. On stones and rocks facing south, there are crustaceous lichens, and between stones and in rock cracks there are moss-like lichens. Blue-green, diatomic and green algae are found in the surface layer of snow and ice [22].

In the subniveal belt, the distribution nature of plants and microgroups, temperature and water regimes of habitats, and the rhythm of plant development heavily depend on the snow cover. In extreme high mountain conditions there are plants exposed to long-term exposure to low temperatures. In the process of evolution, they have become able to counteract the disruption of the structure and functions of membranes inevitable under such action, and in the process of low-temperature adaptation they have developed the properties of cryostability (Trunova, 2007) [23]. Physiological mechanisms to counteract hypothermia are also explained, namely the synthesis of various stress proteins [24], accumulation of cryoprotectors [25], activation of antioxidant system [26], increase of unsaturated fatty acids in membrane lipids [27].

As G. Walter notes [28], the vegetable kingdom of highlands is divided into two groups depending on the snow cover: chionophiles – plants overwintering under the snow cover, and chionophobes – plants wintering outside the snow cover. The species belonging to the first group are less resistant to temperature, while the members of the second group are characterized by very high cold resistance.

One of the most pronounced features of the high-mountain biomes of various zones of the globe, including the subniveal belt of the Caucasus, is the variety of ecological niches within even a very small territory. Metabolism, plant growth in extreme high mountain conditions are mainly controlled by the microclimate of these niches.

It is known that the common features of ecotope for all the Earth’s highlands are high solar radiation (in polar mountains – long day in summer), sharp daily temperature fluctuations, strong winds, relatively low partial pressure of carbon dioxide and water vapor. Plants growing at high altitudes, except for all the above-mentioned loads, are also affected by ultraviolet (UV) radiation, but as many researchers note, they are quite well adapted to this factor.
In addition to climate features, the species composition of the subniveal belt is strongly affected by the lithological composition of the weathering crust, as well as the degree of separation of high mountains with similar edaphic and climatic conditions. Besides, it was noted that the species closely related to certain rocks in most cases are characterized by endemism, while among the species more or less indifferent to the lithological basis of weathering crust there are considerably fewer endemic species, and the species with a wide distribution prevail.

High-altitude phytocenoses are in extreme environmental conditions determined by high temporal dynamics of climatic factors, when, within 24 hours, plants experience opposite environmental effects – from high temperatures during the day to freezing at night, from drying in the absence of precipitation to watering in the opposite case. Figure 1 shows the scheme of influence and interaction of various environmental factors in high mountain conditions.

The criterion for the survival of plants in high mountain conditions is the ability developed during long-term evolution to tolerate such extreme conditions [29].

In extreme high mountain conditions, life activity is mainly controlled by the surface air temperature.

Besides, the subniveal belt of the Caucasus is characterized by the following:
1. fragmented vegetation distribution as separate rock-and-talus groups and microgroups;
2. sparseness and simplification of its structure with significant participation of mosses and lichens;
3. large participation of underlying belt species.

Figure 1. Scheme of action of environmental factors on plants in extreme conditions of high mountains and their interaction with each other (according to I.V. Volkov and I.I. Volkova [23]. Photo Vavilovia formosa (Stev.) Fed. By A.L. Ivanov from www.plantarium.ru
The diagram also shows that stenotope species (ss) are arranged in the following sequence: lapishistophytes (141) – rupestrophytes (48) – schistophytes (31) – lapidophytes (12) – morenophytes (1). There are no stenotope glareophytes in the studied flora.

Specific plant communities are formed under high mountain conditions. Here they are represented by separate groups (mainly microgroups), the formation of which depends both on the configuration of the terrain or the nature of the substrate (mobility, crushed stone) and on the environment created by some plant. In the latter case, in our opinion, it is more correct to call them ultramicrogroups or nanogroups.

The subniveal belt is characterized by free-growing groups (aggregations) formed by a population of one species. For example, on rocks: Saxifraga ruprechtiana, Jurinea filicifolia, on moderately moving taluses: Cerastium kasbek, Delphinium caucasicum, etc.; on weakly moving taluses: Veronica minuta, Scrophularia minima; on non-moving taluses and crushed stony habitats: Symphyoglocoma glaveolens, Jurinella moschus, etc.

Depending on the altitude above sea level, the species of this belt are divided into 3 groups. The first group includes species occurring at 3100 m above sea level: Corydalis emanuelii, Potentilla crantzii, Senecio taraxacifolius, Tripleurospermum caucasicum, etc. This group includes some alpine plants: Campanula biebersteiniana, Gentiana djimilensis, Primula alpiga, etc., which are involved in the creation of carpet-like alpine meadow found fragmentally in the lower part of the subniveal belt.

The second group includes species found mainly at 3000-3300 m above sea level: Delphinium caucasicum, Draba siliquosa, Jurinella moschus, Scrophularia minima, Viola minuta, etc.

The third group includes species found mainly at 3000 to 3600-3700 m above sea level: Alopecurus glacialis, Erigeron venustus, Potentilla gelida, Saxifraga exarata, S. sibirica, Senecio karjaginii, etc.

Due to the lack of areas with more or less developed soil, almost all of the plants typical for subsurface ecosystems are petrophytes. It is noteworthy that there are many endemic species, including narrow-endemic species, some of which belong to mono- or oligotype genera (Pseudobetskea, Pseudovesicaria, Didymphysa, Trgonocarium, Eunomia, Vavilovia, etc.).

The subniveal belt occupies the heights within 2800-3200 – 3300-3800 m above sea level. The relief is characterized by extreme unevenness with traces of glacial activity – trough valleys (toughs), glacial amphitheatres, cirque glaciers, carats, etc. [3] The upper boundary of the subniveal belt is considered to be the line above which the snow cover is held all year round, the so-called level 365 [30]. The belt is characterized by sparseness and simplification of the vegetation cover, the prevalence of rocky, crushed stony, talus and moraine habitats. There is no free-growing vegetation cover, the plants form single specimen or small groups of rock-and-talus species such as Silene humilis, Ranunculus arachnoideus, Vavilovia formosa, Pseudobetckea caucasica, Alopecurus glacialis, Draba bryooides, etc. Shrubs and subshrubs – Salix kashbekensis, S. apoda, Vaccinium vitis-idaea, Empetrum caucasicum, etc. – prevail on grass-shrub heathlands [1].

Given that the flora and vegetation of this belt is formed on the territory newly freed from the ice, being a product of the grass base transformation, petrophytes – plants of rocky substrates (hasmophytes), taluses and moraines (glareophytes) – dominate here. It is characterized by the absence of ferns, gymnosperms, trees and shrubs [4]. Among monocotyledones there are Poaceae, Cyperaceae, Juncaceae, and Liliaceae families, among dicotyledones – Asteraceae, Brassicaceae, Caryophyllaceae, Fabaceae, Saxifragaceae, Rosaceae, Scrophulariaceae, Campanulaceae are most characteristic.

Oberna lacera, Trigonocarium involucratum, Thymus caucasicus, Saxifraga moschata, Alopecurus glacialis, etc. are found on the taluses of clay shale across all gorges.

On rocks, rocky and crushed stone slopes, less commonly on moraines there are Lloydia serotina, Arenaria lychnidea, Alopecurus dasyanthus, Carum alpinum, etc.

On rocks and rocky places there are Campanula petrophila, Viola caucasia, Draba supranivalis, Saxifraga exarata, S. ruprechtii, S. pontica, S. Adenophora, quite often Potentilla gelida.

On alpine lawns and moraines there are Astragalus alpinus, Taraxacum tenuisectum, Murbeckiella huetti, Campanula bellidifolia, etc.
Cereals found as separate small pieces of turf are presented by *Phleum, Festuca, Colpodium, Poa*.

On shale taluses and moraines, crushed stone places there are *Galium fistulosum, Colpodium versicolor, Poa caucasica, Cerastium kasbek, C. polymorphum, Minuartia inamoena, Scrophularia minima, Veronica minuta, Anthemis iberica, Pyrethrum daghestanicum, Senecio karjaginii, Sedum stevenianum, Pseudobetckea caucasica, Androsace albana, Corydalis alpestris*. There are also louseworts – *Pedicularis nordmanniana, P. caucasica, P. crassirostris, P. balkharica*. Quite rare there are *Galium rugosum, Jurinea filicifolia* and *Jurinella moschus*. There are many catchflies – *Silene caucasica, S. pygmaea*, but prevail *Oberna lacera and S. humilis*. Besides, *Lamium tomentosum, Sedum stevenianum, Dentaria bipinnata, Vavilovia Formosa* – a rare perennial relative of peas, highly promising for selection, as well as *Veronica bogosensis, Cerastium multiflorum, Delphinium caucasicum Erysimum subnivale* and *Ranunculus tebulossicus, Pyrethrum aromaticum, Pseudobetckea caucasica, Sedum stevenianum*, etc. that are endemic for the eastern part of the studied area, are commonly found on taluses.

The typical plants of mobile taluses and moraines are *Pseudovesicaria digitata, Saxifraga mollis, Symphyoloma graevoleos, Corydalis alpestris, Ranunculus arachnoideus*.

Rock vegetation does not form a solid cover, but is found in some sections, fragmentarily, in cracks, on poorly grass-covered rocky terraces. It is spread within all major mountain ranges and their branches. Ledge rocks and petrophilous flora in the middle altitude and highlands are most widely present, especially within the Rocky and Side Ranges. Typical rock species of foothills are *Campanula ossetica, Omphalodes rupestris, Saxifraga columnaris, S. dinnikii, S. ruprechtii, S. juniperifolia* are typical for the Rocky Mountain, while *Saxifraga charadzeae, Jurinea coronopifolia* are typical for the Rocky Range.

In various parts of the Greater Caucasus the alpine belt occupies the heights from 2200 to 3300 m above sea level. Plants here live on rocky substrates with weak soil cover, in harsh cold and relatively dry climate, as well as at high intensity of sunlight [3]. Significant rock ledges are common – ledge rocks, stone fields and taluses, moraines, slide outwash cones, snowfields, glaciers. Vegetation is similar to tundra in terms of some features: low-growing procumbent, cushion-like, rosette biomorphs, dominance of psychrophytes and cryophytes, reduced transpiration of plants and short vegetation period, prevalence of vegetative reproduction compared to seed reproduction, etc. For this reason, a number of researchers call the alpine belt a mountain tundra [30].

Within the alpine belt there are four types of vegetation: rock-talus, carpet, meadow, cryophyte.

Rock-and-talus vegetation in the alpine belt occupies significant areas, forming numerous diverse plant groups rich in endemic species. The endemic species such as *Ranunculus tebulossicus, Viola meyeriana, Erysimum subnivale, Saxifraga dinnikii, Vicia larissae, Bupleurum subnivale, Cruciatella elbrussica, Veronica bogosensis* and many others are concentrated here. *Polygonum panjutinii, Oberna lacera, Lamium tomentosum, Veronica minuta, Nepeta supina* are typical inhabitants of taluses and alluvial deposits [31-33]. Alpine carpets represent low-growing communities, predominantly represented by dycotyledonae. Plants here form dense turf due to the presence of rosette-tap forms of life. Typically, such communities occur in relatively small areas, especially in the central part [30].

Alpine meadows are represented by firm communities involving cereals and/or wasps. The main grass crops are *Carex tristis, C. oligantha, C. huetiana, Festuca brunnescens, Poa glauca*, etc., involving legumes and mixed herbs. Alpine meadows are characterized by dwarfishness (10-20 cm), high projective cover – 95-100% and poor species composition limited mainly to 25-30 species (Razumov et al., [29] Astamirova [7–9]).

The heaths are formed by mosses and lichens with a sparse tier of flowering plants, as well as psychophilic shrubs and subshrubs. Such lichen heaths are found on the upper boundary of the alpine belt on the northern slopes of the Main and Side Ranges. They are characterized by poor species composition, among the shrubs thee are the already mentioned *Empetrum caucasicum, Salix kazbekensis, S. apoda, Vaccinium vitis-idaea*, as well as some species of cereals and dycotyledonous plants [7–9, 30].
4. Conclusion
The plant cover of the upper alpine belt of the northern part of the Central and Eastern Caucasus as a whole is characterized by spareness and sparse nature of plants, unclear tier differentiation. Primary groups represent aggregations that transfer to semiaggregation in case of species composition amplification and further to comytations with phytocenotic bonds between plants at least in the underground tier. The following stages of the seral series are related to the enhancement of the role of inclusions from background phytocenoses, the introduction of dressers and, ultimately, the formation of background-type phytocenoses for certain high-altitude belts.

In case of rock growth in the subniveal belt, the formation of groups does not reach the stage of comytations. In the underlying belts there are 3-4 comytations in each. The intensity of rock growth depends on the nature of ecological niches: more complex groups are formed on the rock caps, then in horizontal cracks and the simplest ones – in vertical cracks of rocks.

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