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METHODOLOGICAL BASES OF COMPARISON OF LARGE-SCALE PHYTOCENOCHORE MAPS OF BOREAL HIGH-MOUNTAIN REGIONS

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On the basis of the experience of the mapping of one of the mountain massifs of the Central Urals with application of distant (aerial photography) and terrestrial study of the vegetation, a method is presented for comparing large-scale maps of topologic subdivisions of the plant cover (phytocenochores) of boreal high-mountain regions.

High-mountain regions have in recent time been attracting the increasing attention of scientists working in various branches of knowledge. For ecologists and botanists high-mountain regions are interesting primarily as the arena of adaptation of plants to extremely peculiar and severe environmental conditions, as the site of existence of a series of rare plant species (including endemics and relics), as a convenient object for the elucidation of the connection between the distribution of plant communities and the environment. Furthermore, high-mountain regions represent a reserve of plant resources and a potential fund of natural reservations (reserves, sanctuaries, etc.).

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The geobotanical map is an important step in the study of the plant world of high-mountain regions. It may be considered as the synthetic expression of the accumulated data on the structure and patterns of distribution of the plant cover and at the same time as the starting point for new generalizations and more profound investigations.

Investigators are confronted by a number of difficulties in the geobotanical mapping of high-mountain regions. These difficulties result from the diversity of the plant cover and biotopes, which is conditioned by the dissectedness of the relief, differences in the steepness and orientation of the slopes, the large range in elevations. Application of the usual method of terrestrial geobotanical survey to elucidate the boundaries between altitudinal belts and the configuration of the subdivisions of the plant cover is insufficiently effective in high-mountain regions. However, judging from the published data, in the boreal zone of the USSR there has not yet been attempted the geobotanical mapping of high-mountain regions using distant methods. Typological subdivisions of the plant cover as the principal mapping units are unsuitable for high-mountain regions.

In this article on the basis of the experience of large-scale (1:25,000) mapping of vegetation using both distant (aerial photography) and terrestrial study, a number of considerations are advanced concerning the techniques of elucidating and means of demonstrating on a geobotanical map the structure and patterns of distribution of the plant cover in boreal high-mountain regions (as exemplified by Kos'vinskii Kamen' Mountain in the southern part of the Northern Urals).

MATERIAL OF INVESTIGATION AND REGION OF STUDY

Kos'vinskii Kamen' (1519 m absolute elevation) is a comparatively small isolated mountain with vegetation of the high-mountain type on the upper levels (high-mountain region is 4.5 × 5 km). It is located in the watershed belt of the southern part of the Northern Urals and is a part of the Tylaisko—Konzhakovsko—Serebryanskii mountain massif. The mountain is primarily made up of olivinic pyroxenites, while dunites are exposed on its eastern slope ("shoulder," a terrace-like bench rising above the timberline).

According to its position in the system of botanical-geographic zonation Kos'vinskii Kamen' is assigned to the subzone of northern taiga of the boreal-forest zone. In moving from below upwards the alternation of the following vegetational belts can be traced on its slopes: mountain-taiga, sub-bald-mountain, and mountain-tundra belts and a belt of cold bald-mountain deserts, which is expressed only fragmentarily (Gorchakovskii, 1975). In the mountain-taiga belt there predominate coniferous forests of the taiga type, and in the sub-bald-mountain, low forests combined with mesophilic meadows and sometimes small sections of mountain tundras; in the mountain-tundra, various types of mountain tundras; while in the belt of cold bald-mountain deserts, craggy monadnocks with an extremely scanty plant cover primarily of lichens and mosses.

Terrestrial study of the vegetation was conducted on two transects (one of them passed from west to east, the other from north to south), crossing the whole mountain massif, including its most elevated part. The distant survey was carried out in a scale of 1:25,000.

HIGH-MOUNTAIN PHYTOCENOCHORES AS THE PRINCIPAL SUBDIVISIONS MAPPABLE IN LARGE SCALE

As pointed out by V. B. Sochava (1972, 1976) the plant cover combines within itself two tendencies: towards homogenization and towards diversification of structure. The tendency towards homogenization finds its reflection in a hierarchical series of phytocenochores arranged according to the criteria of a gradually decreasing homogeneity (elementary homogeneous distribution range, association, association group, association class, formation, etc.). The tendency towards diversity of structure is reflected in a hierarchical series of phytocenochores (in abbreviated form, cenochore), which are subdivisions of the territorial integration of the plant cover (elementary diverse distribution range, microcenochore, mesocenochore, topocenochore, macrocenochore). Depending on the structure of the plant cover and the scale of mapping, there can be composed maps both of phytocenomeres and of phytocenochores.

In the boreal high-mountain regions, especially in the mountain-tundra belt, the plant communities are fragmentary, sections of associations are usually expressed on a small area and, combining with one another, form a variegated mosaic. Such a structure of the plant cover cannot be depicted on a large-scale (1:25,000) geobotanical map on the basis of a system of typologic subdivisions of the plant cover or phytocenomeres. For these purposes it is necessary to resort to phytocenochores (Sochava, 1972, 1976), i.e., topologic territorial subdivisions (units) of the plant cover (Vinogradov, 1976). By topologic subdivisions of the plant cover we, following B. V. Vinogradov (1976), mean the territorial unifications of plant communities connected in a single topoecological series which are characterized by a specific pattern of distribution and are regularly repeated in a definite combination of components. The expediency of utilizing topologic subdivisions in the mapping of territories with a variegated (complex) plant cover has been noted by a number of geobotanists for various botanical-geographic zones (Dokhman, 1936; Karamysheva and Rachkovskaya, 1962; Golgofskaya, 1964; Gribova and Isachenko, 1972). However, none of these investigators worked in boreal high-mountain regions.

The hierarchical system of topologic subdivisions of the plant cover and their nomenclature are still insufficiently developed. The concepts of micro-, meso-, macro-, and megachores were originally advanced by Neef (1963) for application to landscape categories. V. B. Sochava (1972, 1976) utilized a similar terminology in developing a system of subdivision of the territorial integration of plant communities (microcenochores, mesocenochores, etc.). Still earlier G. I. Dokhman (1940) proposed distinguishing such categories of the territorial integration of plant communities as micro-, meso-, macro-, and megacomplexes.

Recently B. V. Vinogradov (1976), in applying Neef's terminology with respect to topologic subdivisions of the plant cover, attempted to improve the hierarchical system of taxa proposed by this author by adding to it a number of subdivisions at the highest (gigachores, terachores) and lowest (femtochores, picochores, nanochores) levels of the hierarchy. He proposed that to femtochores and picochores there be assigned combinations of sections or fragments of associations on the order of 0.01 and 0.1 ha, respectively, in area, which makes it possible to map them in scales of 1:3000-1:10,000, and to nanochores, combinations of associations (or their groups) on the order of 1 ha in area, which allows mapping in a scale of 1:30,000.

PRINCIPAL PHYTOCENOCHORES OF HIGH-MOUNTAIN REGIONS OF NORTHERN URALS, THEIR STRUCTURE, AND FEASIBILITY OF RECOGNITION ON AERIAL PHOTOGRAPHS

During the investigation combinations of sections of associations, elementary phytocenochores (EPCCs) were revealed, the composition of the communities (components) within them was established, and the ratio of components was determined. Then the EPCCs were joined at three levels of integration:

The first level (PCC') is combinations of plant communities at the rank of associations, the result of the integration of EPCCs according to the principle of similarity and of the ratio of components;

The second level (PCC") is the combinations of plant communities at the rank of association groups, the result of integration of PPC's according to the principle of the membership of homologous components to a single association group with consideration of the ratio between components;

The third level (PCC''') is the combinations of plant communities at the rank of formations and groups of formations (altitudinal vegetational belts), the result of integration of PCC"s with consideration of the patterns of their altitudinal distribution.

The description of the EPCCs was carried out on sample plots 100 m² in size. The boundaries of PCC's and PCC"s were noted on transects.

The deciphering of aerial photographs was by means of comparing the distribution of discernable contours with the distribution of PCC's and PCC"s on transects. Criteria were found permitting the deciphering of separate phytocenomeres and phytocenochores. It was determined that there are quite readily recognized on photographs 1:25,000 in scale not only PCC' and PCC" boundaries, but also the boundaries of their respective components. However recognition of the taxonomic rank of the components (phytocenomeres) on aerial photographs is possible only at the level of association groups, and not of separate associations (for example, the membership of one or another sections to a group of shrub-tundra associations is easily determined, but it is impossible to establish the membership of these sections to a particular association by the composition of dominant shrubs). Therefore the mapping of the vegetation of high-mountain regions on the basis of aerial photographs with ground correction was done at the PCC" level.

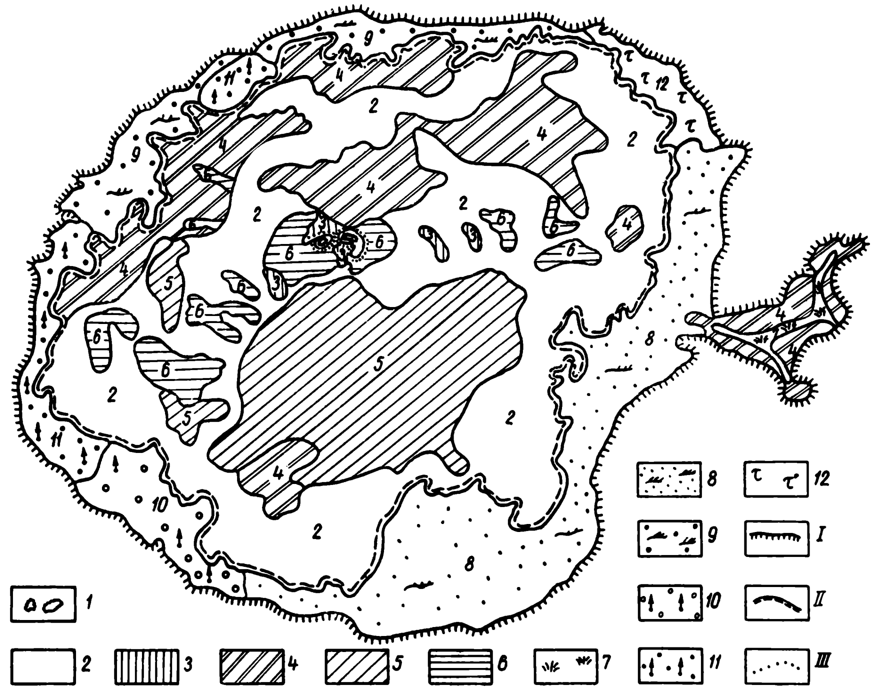

Fig. 1. Schematic map of distribution of principal topological subdivisions of plant cover (phytocenochores) on Kos'vinskii Kamen' Mt. (Northern Urals). 1-12) Combinations of communities at rank of association groups (see designations under corresponding numbers in Table 1). I-III) Boundaries between vegetational belts (combinations of communities at ranks of formations and formation groups) (I is boundary between mountain taiga and sub-bald-mountain; II, between sub-bald-mountain and mountain tundra; III, between mountain-tundra belt and belt of cold bald-mountain deserts).

The boundaries of territorial subdivisions of the plant cover at the PCC''' level (altitudinal vegetational belts) are readily apparent on aerial photographs. The boundary between the mountain-taiga and sub-bald-mountain belts is traced along the transition from a continuous dark background of granular structure (dark coniferous taiga) to an alternation of patches of a gray tone of finely granular structure (low forest) and structureless patches of whitish tone, created by sections of mesophilic meadows and fragments of mountain tundras. The transition from the sub-bald-mountain belt to the mountain tundra coincides with the upper limit of low forests; it is readily recognized by the lighter tonality of mountain tundras as compared with low forests. The belt of cold bald-mountain deserts is readily separated from the mountain tundra by the characteristic pattern of craggy crests and large monadnocks, rising above the level of the mountain tundras.

The composition of subdivisions mappable in large scale of the plant cover of the high-mountain regions of the southern part of the Northern Urals at the second level of integration of elementary phytocenochores (combinations of plant communities at the rank of association groups) is shown in Table 1; here there are presented the deciphering criteria of separate subdivisions. The general patterns of distribution of the vegetation of the high-mountain regions of Kos'vinskii Kamen' at the PCC" and PCC''' levels are illustrated with a schematic map (see Fig. 1).

CONCLUSIONS

1. The combined utilization of distance (aerial photography) and ground study is most effective in boreal high-mountain regions for elucidating the structure and patterns of distribution of the plant cover.

2. Taking cognizance of the fragmentary character of the plant communities and the complex character of the plant cover, the geobotanical mapping of boreal high-mountain regions is expediently carried out not on the basis of a hierarchical system of typologic subdivisions

TABLE 1. Topological Subdivisions of Plant Cover (phytocenochores) of High-Mountain Regions of Southern Part of Northern Urals Mappable in 1:25,000 Scale

Sequence No.	Designation of topological vegetational subdivisions	Edaphic conditions	Deciphering criteria
1	Most impoverished variants of primary labile communities consisting of crustose (Rhizocarpon spp., Lecidea spp., Lecanora spp.) and foliose (Umbilicaria, Gyrophora) lichens and mosses (Rhacomitrium lanuginosum and others), in cracks in blocks are separate individuals of ferns (Cystopteris fragilis), club mosses (Lycopodium selago), and higher plants (Gypsophila uralensis, Saxifraga hieracifolia, Silene acaulis, Luzula nivalis, and others)	Large craggy monadnocks in most elevated parts of massif	Craggy peaks and large rock blocks, clearly apparent stereoscopically on photographs; ground correction necessary
2	Primary labile plant communities consisting of crustose and foliose lichens (Rhizocarpon geographicum, Umbilicaria pennsylvannica, Alectoria ochroleuca, Stereocaulon paschale) and mosses (Rhacomitrium lanuginosum, and others) in combination with shrub–lichen and herb–moss tundras, with stands of shrubs and woody creeping vegetation	Large rock blocks and coarse rubble on steep and moderately steep slopes; no formed soil, small amount of fine earth between blocks	Light-gray tone with dark speckled pattern formed by fragments of various types of tundras
3	Lichen tundras with predominance of foliose and fruticose lichens (Cladonia alpestris, C. rangiferina, Cetraria cucullata, C. islandica, C. nivalis) in combination with primary labile communities	Fine-rubble substrate; horizontal areas or slightly inclined slopes at high levels near summits	Gray tone, banded pattern
4	Shrub–lichen and shrub–moss–lichen tundras (Cladonia alpestris, C. rangiferina, Alectoria ochroleuca, Aulacomnium turgidum, Rhacomitrium lanuginosum, Pleurozium schreberi, Dryas octopetala, Arctous alpina, Vaccinium uliginosum, Empetrum hermaphroditum) in combination with the primary labile communities	Shallow mountain-tundra soil with thin layer of fine earth; lower levels of north and west sloping slopes	Light-gray tone; indirect criteria are slope steepness and orientation
5	Shrub–moss tundras (Hylocomium splendens, Pleurozium schreberi, Polytrichum juniperinum, Salix lanata, S. phylicifolia, Juniperus sibirica) in combination with primary labile communities	Mountain-tundra soil of medium thickness (fine-earth layer to 20 cm); gently sloping and level surfaces of saddles and highland terraces of south slope	Dark-gray tone with diffusely patchy pattern; indirect criteria are slope orientation, position in the relief

6	Herb—moss tundras (Hylocomium splendens, Rhitidium rugosum, Aulacomnium turgidum, Ptilium crista-castrensis, Carex hyperborea, Deschampsia flexuosa, Pachypleurum alpinum, Saussurea alpina) in combination with perinival lichens (Lagotis uralensis, Anemone biarmiensis, Ranunculus borealis, Polygonum bistorta, P. vivparum, Potentilla crantzii, Rhodiola rosea)	Sod—mountain-tundra (with fine-earth layer to 30 cm) soil; level horizontal surfaces of plateaus, saddles, and highland terraces	Gray dense tone and wavy image pattern; indirect criteria are slope orientation, position in relief
7	Weakly steppified groupings on dunite outcrops (Dianthus acicularis, D. repens, Veronica spicata, Gypsophyla uralensis, Festuca supina), lichens (Caloplaca elegans, Cetraria tillesii, Thuidium abietinum)	Terrace-like benches ("shoulder"), dunite outcrop with fine earth in cracks between blocks	White tone, indirect criteria are position in relief
8	Shrub—lichen and shrub—moss—lichen tundras (Cladonia alpestris, C. rangiferina, Alectoria ochroleuca, Aulacomnium turgidum, Rhacomitrium lanuginosum, Pleurozium schreberi, Dryas octopetala, Arctous alpina, Vaccinium uliginosum, Empetrum hermaphroditum) in combination with the primary labile communities	Sloping and weakly sloping east and southeast slopes; soil relatively deep, well moistened, loamy	
9	Crooked forests of B. tortuosa with small admixture of P. obovata, whortleberry (Vaccinium myrtillus) in combination with grass (Deschampsia flexuosa, Calamagrostic arundinacea) meadows	Gently sloping surfaces and terrace-like benches of west and northwest slopes; soil shallow, well moistened	Boundaries of separate contours poorly distinguished on photographs, corrected with ground survey; indirect criteria are slope steepness and orientation, position in relief
10	Herb—moss tundras (Hylocomium splendens, Rhitidium rugosum, Aulacomnium turgidum, Ptilium crista-castrensis, Carex hyperborea, Deschampsia flexuosa, Pachypleurum alpinum, Saussurea alpina) in combination with perinival lichens (Lagotis uralensis, Anemone biarmiensis, Ranunculus borealis, Polygonum bistorta, P. vivparum, Potentilla crantzii, Rhodiola rosea)	Gently sloping and weakly sloping south and southwest slopes; soil loamy, rocky	
11	Fir—spruce low forest of P. obovata and A. sibirica with admixture of B. tortuosa, mixed-herb—grass (Calamagrostis arundinacea, Melica nutans, Deschampsia flexuosa, Rubus saxatilis, Anemone biarmiensis) in combination with fragments of mountain tundras	Strongly sloping west and northwest slopes, soil strongly moistened, loamy	
12	Pine sparse low forests of P. sibirica with small admixture of P. obovata and A. sibirica, shrub—green-moss (Hylocomium splendens, Pleurozium schreberi, Vaccinium myrtillus, V. vitis-idaea) in combination with shrub—lichen mountain tundras	Slightly sloping northeast slopes; soil loamy fresh, rather deep	

or phytomeres (associations, groups of associations, etc.), but on the basis of a hierarchical system of topologic (territorial) subdivisions of the plant cover or phytocenochores.

3. Elementary phytocenochores (EPCCs) distinguishable in the process of investigations are expediently joined at three levels of integration: PCC", are combinations of plant communities at the rank of association; PCC",combinations of plant communities at the rank of association groups; PCC''', combinations of plant communities at the rank of formations and formation groups. The third level of integration corresponds to altitudinal vegetational belts.

4. The boundaries of PCC's and PCC"s and the boundaries of their respective component phytocenoses are quite readily recognized on large-scale aerial photographs, while the typologic membership of phytocenomeres is revealed only at the rank of association groups. Therefore a large-scale geobotanical map of high-mountain regions composed on the basis of aerial photographs (with ground correction) can reflect the structure and distribution of the vegetation at the second level of integration of elementary phytocenochores (combinations of plant communities at rank of association groups).

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