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P. L. Gorchakovsky

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HORIZONTAL AND ALTITUDINAL DIFFERENTIATION OF THE VEGETATIONAL COVER OF THE URAL MOUNTAINS[1]

P. L. GORCHAKOVSKY*

ABSTRACT.—The chain of the Ural mountains stretching from north to south for the space of more than 2000 Km. and crossing several phytogeographical zones (from tundra to steppe) offers a handy model in revealing the regularities of horizontal and altitudinal differentiation of the vegetational cover. Zonality as well as belt structure (the belts are: steppe, forest - steppe, mountain forests, subgoltsy, mountain tundra and cold goltsy desert) manifest themselves in this region very clearly; the nature of the belt structure of vegetation in individual sections of the Ural mountain chain depends on their disposition in the system of horizontal phytogeographical zonality.

RESUMÉ.—Différentiation horizontale et verticale du tapis végétal des montagnes ouraliennes. *La chaine des montagnes ouraliennes, qui s'etend du nord au sud sur plus que 2000 Km. et qui traverse plusieurs zones phytogéographiques, présente un très commode modèl pour l'éclaircissement des régularités de la différentiation horizontale et verticale du tapis végétal. La zonalité, de mème que la différentiation altitudinale de la végétation, se manifeste ici très clairement, tandis que l'assemblage des étages altitudinals dans une certaine section des montagnes ouraliennes dépend de sa situation dans le système de la zonalité phytogéographique horizontale.*

RESUMEN.—Diferenciación horizontal y vertical de la cubierta vegetal de los Urales. *La cadena de los Urales se extiende de Norte a Sur a lo largo de más de 2000 Km. y atraviesa varias zonas fitogeográficas (desde la tundra a la estepa), proporcionando un modelo que revela las regularidades de la diferenciación horizontal y altitudinal de la cubierta vegetal. La zonalidad, estructurada en cinturones (estepa, bosque-estepa, bosques montanos, subgoltsy, tundra montana y desierto frío), se manifiesta muy claramente en esta región; la naturaleza de la estructura de los cinturones de vegetación en secciones individuales depende de su disposición en el sistema de zonalidad fitogeográfica horizontal.*

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* Institute of Plant and Animal Ecology, Ural division of the USSR Academy of Sciences, Sverdlovsk, USSR.

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In the course of research on the distribution of ecosystems and vegetational cover in mountain areas, scientists sometimes compare the elements of altitudinal differentiation with the elements of horizontal zonality in the plains. If in the past these elements have been simply identified, lately explorers prefer to speak only about a certain analogy between them (KALESNIK, 1955). Nevertheless, even nowadays certain authors continue to apply the name of "zones" (GVOZDETZKY, 1963) to the basic structural elements of altitudinal differentiation of ecosystems and vegetation, the latter being their important component.

A certain similarity between altitudinal belts in mountain areas, on one hand, and zones and subzones of vegetational cover in the plains on from the other hand is generally known. For instance, judging from communities' physiognomy and dominating species composition, mountain tundras look like plain ones, and mountain dark coniferous forests resemble plain taiga. However, the indentification of altitudinal belts with the zonal subdivisions of their plain analogues is not justified in principle. When ascending towards the peaks of mountains temperature and moistening regimes change considerably faster than when crossing plains from south to north, and a number of specific pecularities might be observed in these changes. Furthermore, hydrothermic conditions in the mountains are more diverse because of differences in height above sea level and in orientation of slopes to the four cardinal points as well as irregular distribution of precipitation caused by the barrier role of ranges. Therefore, altitudinal belts are considerably narrower than analogous zones and subzones, and often their assortment is very diverse even within a restricted area. In the mountains, several altitudinal belts might be found at the same level. Certain components enumerated in the columns of altitudinal subdivisions have no analogues in the plains at all. Altitudinal belts differ sharply from analogous zones and subzones by relief and edaphic conditions, moistening regime, composition and the history of formation of contemporary flora, by composition, spatial correlation between plant communities, tendencies in their dynamics, hydrological role and biomass resources. On thenhole, these differences are so great that they determine (as with the economic situation) different approaches to exploitation of vegetational resources. If zones in the plains may be considered as basic units of physico-geographical and phytogeographical subdivision of territory, altitudinal belts, on the contrary, may not be usually used for this purpose because in the mountains it is possible to

find several belts even in restricted areas (PROKAEV, 1962). Thus, TUMADZHANOV (1963) emphasizes in his work concerning the phytogeographical subdivision of the Big Caucasus that borderlines between large units may not be established on the basis of delimination of adjacent belts. Hence, it is clear that altitudinal belts, not only may not be identified with corresponding zones and subzones but also they even may not be interpreted as versions of the latter; they are independent categories which may and should be compared but should not be united one with other. Therefore it is not expedient to apply the name "zones" to basic elements of altitudinal differentiation of vegetation in the mountains, even though with the epithet "vertical", the name "belts" which had already came into phytogeographical literature (N. A. BUSH, 1917, was the first who used the term in this sense in Russian literature) is more appropriate. In the same way as zones are subdivided into subzones, belts may be subdivided into altitudinal horizons of vegetation which may have their analogues in the form of corresponding subzones in the plains.

The Urals stretching southwards for a distance of more than 2200 Km. crosses a number of phytogeographical zones beginning with the tundra zone in the north and finishing with dry steppe in the south. The mountain system brings a certain disturbance in the "normal" framework of zonality typical for plain territories; therefore in its limits the altitudinal differentiation of vegetation manifests itself more or less clearly. Since the Ural mountains are not very nigh (the summit Mt Narodnaya 1894 m above sea level), especially in certain sections (for example, in the Middle Urals) and the slopes are gentle, there is no sharp transition between plain vegetation and the vegetation of the lowest levels of the mountains, so it is possible to retrace how vegetational zones and subzones typical for the plains, fusing almost imperceptibly on the foot-hills with their mountain analogues, are prolongated within the limits of the Urals as such.

However, specificity of mountain vegetation (compared with those of the plains) manifests itself more clearly within higher sections, and here the similarity of elements of horizontal and altitudinal differentiation of vegetation is expressed to a lesser degree. Nevertheless, such analogy, in its general form, may be retraced in the full length of the Urals.

Zonality caused by the unequal reception of solar radiation is the most general regularity of the distribution of ecosystems and vegetation on the surface of the Earth. Altitudinal differentiation of the vegetational cover may be considered as a form of manifestation of horizontal zonality in regions with well-developed mountainous relief, and it is submitted to this general regularity. The character of altitudinal belt

structure in a mountain massif or in a certain part depends primarily on the disposition of this massif in the system of zonal subdivision of vegetational cover and on the types of vegetation of adjacent plains (STANYUCKOVICH, 1975; GORCHAKOVSKY, 1975).

When a certain mountain range (for instance, the Urals) crosses several zones or subzones it is possible to distingish a few columns (spectres) of altitudinal belts of vegetation peculiar to each subdivision, in the mountains.

1. Zonal subdivision of vegetational cover in the plains adjacent to the Urals

The following phytogeographical zones manifests themselves in the plains adjacent to the Urals: tundra, forest-tundra, boreal coniferous forests, broad-leaved forests, forest-steppe and steppe. The distribution of these zones is illustrated by the map (fig. 1). For the purpose of a more convenient comparison of general regularities of vegetation distribution in the Urals and in the plain territories contiguous to them, the phytogeographical zones and subzones typical for the plains have been prolonged (fig. 1) in the mountain areas and have been joined by corresponding altitudinal belts of vegetation. It is not difficult to notice that as soon as a certain zonal unit enters the mountain part (in the form of its analogue) its limits are displaced southwards; the higher the range in a certain section, the more pronounced is this displacement. Thus, the vegetation of tundra type (mountain tundra) extends southwards quite far along the highest part of the range. Mountain forests penetrate southwards along the range deeply into the forest-steppe zone of the plains.

Tundra zone occupies the northern extremity of the territories adjacent to the Urals (to the west and to the east); it is a typically woodless area. The vegetational cover is composed here basically of different types of tundra in combination with mires. Mosses and lichens predominate in tundra communities; there occur also herbaceous plants, dwarf=shrubs, and, further to south, shrubs.

Forest-tundra zone. The combination of forest and non forest (tundra) elements is typical of this zone. Isolated small patches of light forests (hypoarctic open woodlands) alternate here with open woodless areas covered by tundra (mainly with *Betula nana)* and mire communities. Such woodlands are found not only in river valleys but also on watersheds. Plant communities of tundra type occupy watersheds.

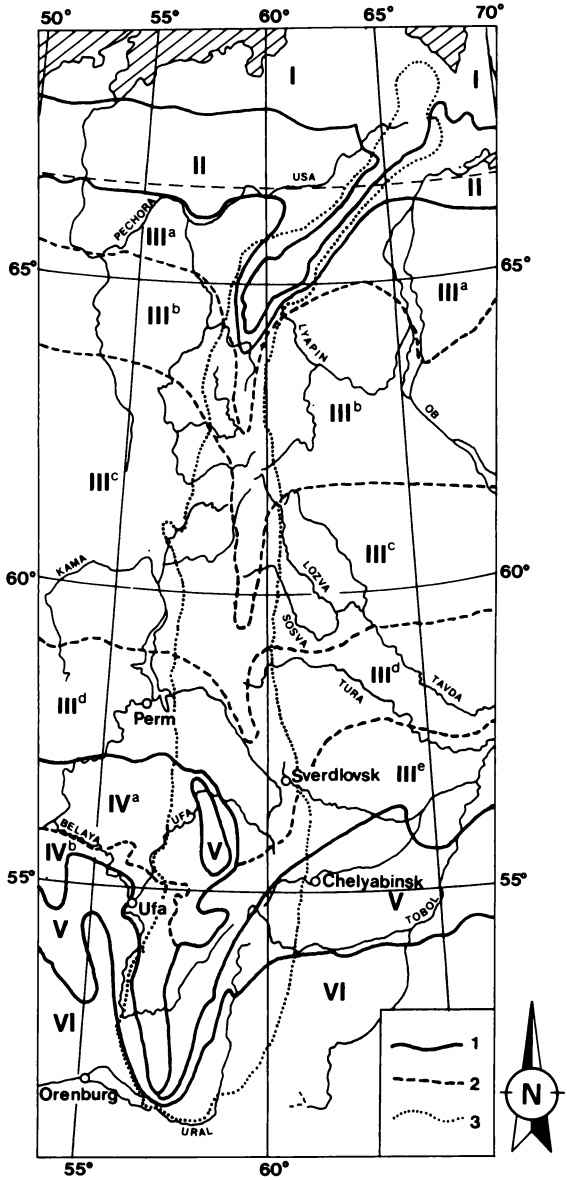

Fig. 1. The main zonal subdivisions of vegetational cover on the plains adjacent to the Urals, and their mountain analogues. 1: borderlines between zones; 2: borderlines between subzones; 3: borderline of the Ural mountain system; I: tundra zone; II: forest-tundra zone; III: boreal coniferous forest zone with subzones: a: pre-forest-tundra open woodlands; b: northern taiga; c: middle taiga, d: southern taiga; e: pre-forest-steppe pine and birch forests; IV: broad-leaved forest zone with subzones: a: mixed broad-leaved- coniferous forests, b: broad-leaved forests; V: forest-steppe zone; VI: steppe zone.

Boreal coniferous forest (taiga) zone is the widest one on the plains adjacent to the Urals (approximately in latitude 54-56º to 66º North). Judging from the character of the vegetation, it is not perfectly homogenous, and it may be subdivided into several subzones. Certain subzones are manifested both in territories to the west and to the east of the Urals; other subzones are typical but for one of the plains adjacent to the Urals. Asymmetry of differentiation of vegetational cover within a certain zone accounts for the fact that the chain of Ural mountains, serving as a peculiar barrier, influenced and influences the distribution of plants from Europe and Siberia as well as the distribution of aerial masses; the climates of the adjacent plains are dissimilar (milder, warmer and more humid in the west; more continental, with smaller precipitation, hotter summers and colder winters in the east).

The main dominant and subdominant tree species in taiga in the montane Urals are *Picea obovata, Pinus sylvestris, Abies sibirica, Larix sibirica* and (in the northern part) *Pinus sibirica.*

Boreal coniferous forest zone is subdivided into five subzones: 1) preforest-tundra open woodlands; 2) northern taiga; 3) middle taiga; 4) southern taiga; 5) preforest-stèppe pine and birch forests.

Broad-leaved forest (nemoral) zone is characterized by predominance of broad-leaved or mixed broad-leaved-coniferous forests of European type. In the form of a gradually tapering tongue it spreads eastwards right up to the foot-hills of the Southern Urals; it is subdivided into two subzones: 1) mixed coniferous-broad-leaved forests; 2) broad-leaved forests.

The main forest forming tree species in this zone are *Quercus robur, Tilia cordata, Acer platanoides, Ulmus scabra, U. laevis,* in its northern part they coexist with coniferous tree species: *Picea obovata, Abies sibirica* and *Pinus sylvestris.*

Forest-steppe zone. During the preagricultural period, meadow steppe communities alternated with patches and small insular groves of hardwood forests (so called "kolki") constituting the basis of vegetational cover of this zone. In the forest-steppe zone groves are found on watersheds as well as in river valleys. Nowadays meadow steppe has been transformed almost everywhere into arable land. Groves have suffered badly from cutting and fires; many of them have been destroyed completely, the area of the others has been decreased considerably.

Steppe zone. This zone is almost completely woodless except for narrow tracts of forest vegetation that may be found in habitats with better moistening —on ravine slopes and in river flood-plains.

Eastwards of the Urals, composition of forest building tree species is extremely poor: *Betula verrucosa, B. pubescens, Populus tremula* and, rarely, *Pinus sylvestris;* there are *Populus nigra* and *Salix alba* in river valleys; westwards of the Urals, broadleaved *(Quercus robur, Acer platanoides, Ulmus laevis)* join them. In general, the percentage of wooded areas is insignificant.

Steppe vegetation, as such, connected with fertil chernozem soils and —to the south— with chestnut soils have been destroyed almost completely as a result of the agricultural development of the territory during a long period. Small patches of virgin steppe (more or less transformed by grazing) remained only here and there.

2. Altitudinal differentiation of vegetational cover in the Ural mountains

In the Urals, the following vegetational belts manifest themselves substituting each other while ascending: a) mountain steppe; b) mountain forest-steppe; c) mountain forests; d) subgoltsy; e) mountain tundra; f) cold goltsy deserts.

However, the complete assortment of these belts is visible only in an abstract, "ideal" scheme of altitudinal belt structure (fig. 2) characterizing probable altitudinal differentiation of vegetation that would have existed if the mountains in the southern section of the range had been significantly higher than they are in fact. As far as the Ural mountains have a considerable extent from north to south, and their heights are rather moderate (in comparison, for example, with the Alps), a more reduced assortment of altitudinal belts (two to four) is revealed in individual sections of the range. This assortment is determined, to a large extent, by the disposition of one or another section of the range in the general system of phytogeographical zonality observed in the plains.

Mountain-steppe belt, analogous to steppe zone of plains, may be observed only in the south-eastern spurs of the Urals (the southern part and lower levels of the middle part of the Irendyck range).

Next in order, *mountain forest-steppe belt,* an analogue of forest-steppe zone, is represented in the middle part as well as on low levels of the northern part of the Irendyk range, in the upper part of the basin of Sackmara river, on the right bank of the river Bolshoy Ik (the tributary of Sackmara river), on Mesyagutovsko-Krasnoufimsky forest-steppe island and, in the form of fragments, in some areas of the eastern slope of the Southern Urals (northwards right up to the lime-stone mountains Egozinskaya and Sugomak).

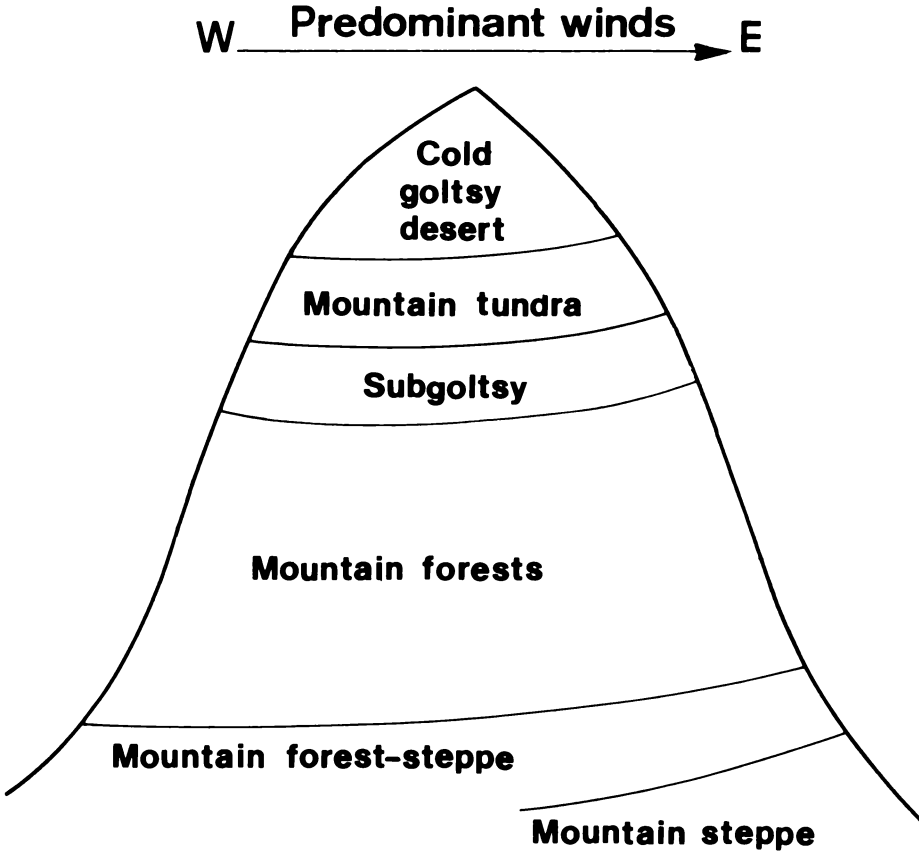

Fig. 2. The abstract "ideal" scheme of altitudinal differentiation of vegetation in the Ural mountains.

The Urals is the region where forests (mainly taiga) prevail; *mountain forest belt* analogous to boreal coniferous forest zone covers the slopes of the mountain system for almost its full length (in latitudes 52º to 60º Norh). As regards the highmountain belts (subgoltsy, mountain tundra and cold goltsy desert), they may be observed in those sections of the mountain system, where relatively big mountain crests rising above the upper forest limit are present.

The position of the upper forest limit in the mountains of the Urals varies greatly depending on the geographical latitude of the locality, steepnes and orientation of slopes, mountains' massivity and on other conditions. When moving southwards, the upper forest limit (including subgoltsy open woodlands too) heightens markedly. For instance, the upper forest limit lies on Sablya range (the Prepolar Urals) upon an average at the height of 500 m above sea level, on Denezhkin Kamen (the Northern Urals) —at 900 m and on the Yaman-Tau mountain— at 1250 m respectively. The height gradient for the upper forest limit is the greatest in the northern part of the Urals (upon the average, it is 100 m, but here and there it reaches up to 150 m per 1º of latitude); however, southwards of Kosvinsky Kamen this heightening slackens up, and on individual plots it even stops completely because many mountain crests further south do not reach the line of possible forest limit caused by the climate.

The upper forest limit lies lower in small isolated mountains compared with big mountain massives, where there are deeply cut river valleys protected from winds; along them tongues of forests reach up quite high. The western part of the mountain system is more exposed to wind effects and it is more rich in precipitation; here snow accumulates, and its slow melting reduces the growing season. That is why the forest limit on the western macroslope of the Urals is lower than on the eastern one. The upper forest limit is considerably lower on very steep slopes which have been eroded intensively.

For subgoltsy belt intensive snow accumulation is typical at the expense both of abundant precipitation and snow blown by the wind. The deep snow mantle accumulated here melts slowly, reducing the growing season. Abundant moistening by melted snow and rains, additional influx of water from more elevated highmountain belts coupled with a reduced growing season weaken the position of the forest in this belt and favour the development of mesophilous meadow vegetation successively competing with forest one.

When moving southwards along the Ural mountain, subgoltsy belt, with undersized open woodlands and crook-stem forests (krummholz) in combination with mesophilous meadows as the base of vegetation,

appears first in the southern part of the Polar Urals and is traced right up to the Southern Urals. In the southern half of the Polar Urals, in the Prepolar Urals and in the greater part of the Northern Urals this belt is well pronounced; it edges every sufficiently high mountain crest on appropriate levels. In the Middle and Southern Urals it reveals itself in the form of fragments only in highest mountains.

Subgoltsy belt may be regarded only as a very remote analogue of plain forest-tundra. Open woodlands, dwarfish trees, sometimes with crooked stems as well as unity of some typical life-forms of plants bring to this belt some features of similarity with forest-tundra.

However, a certain similarity between subgoltsy and forest-tundra open woodlands in tree species composition is observed only in the northern section of the Urals, where subgoltsy open woodlands and krummholz communities are composed of *Betula tortuosa, Larix sibirica* and *Picea obovata.* Southwards the tree species richness is higher than in forest-tundra of the plains adjacent to the Urals. Subsequently *Laris sibirica, Pinus sibirica* and *Betula tortuosa* disappear from forest stands; only *Picea obovata* remains with the admixture of *Abies sibirica* near the upper forest limit. More southwards, on the western slope of the southernmost section of the Ural mountain system, *Quercus robur* whose ecology is incompatible with the conception of forest-tundra becomes the dominating tree species in subgoltsy woodlands.

Judging from composition of non-forest elements of vegetational cover, the subgoltsy belt is still more different from plain forest-tundra. In this belt there are no or almost no mires which are typical of forest-tundra of plains. The tundra element of vegetation is not as a matter of fact represented in it. Only in the northernmost regions in subgoltsy open woodlands and krummholz communities is the role of mosses and lichens forming the pronounced layer still great, and in herbaceous-dwarf shrubs layer hypoarctic and arctomontane species admix to boreal-forest plants. Slightly southwards, hypoarctic and arctoalpine elements disappear completely from the floristic composition of subgoltsy forests. Moving southwards it is possible to recognize that the role of meadow-forest and meadow plants gradually increases at the expense of pressing back taiga dwarf shrubs and herbs as well as mosses and lichens. When advancing further south, it may be observed how the pronounced layer of mosses and lichens gradually is destroyed and finally disappears and the reconstitution of herbaceous-dwarf shrubs layer takes place in subgoltsy forests. At first, taiga herbs and dwarf shrubs, together with scraps of moss cover accompanying them, still hold their position in communities under protection of tree clumps and isolated trees, but then they are compeltely pressed back by

meadow-forest herbs, which comprise many tall plants forming so called tall herbaceous vegetation. In this belt, the mesophilous-meadow element of vegetation competes successfully with the forest one; it explains the fact that meadow glades are found within the majority of types of open subgoltsy forests. Southwards, the percentage of cryophytes gradually decreases and the mesophytization of vegetation of the subgoltsy belt increases. The final link of this chain of spatial replacement in vegetation is represented by open oak (with *Quercus robur)* groves in combination with mesophilous meadows.

Mountain tundra belt at first appears on the northernmost extremity of the Ural mountain system, its lower limit ascending southwards regulary. In the Polar and the Prepolar Urals it extends as a continuous stripe, but still in the Northern Urals it disintegrates into a number of islets connected with larger mountain crests. In the Middle urals —the lowest section of the mountain system— only insignificant fragments of this belt are found. In the Southern Urals it is pronounced slightly better but in the form of fragments too; here there is no prevailing predominance of lichen, moss-dwarf shrub and shrub (with *Betula nana)* tundras which are distinctive of northern regions but herb-moss tundra do prevail.

Above the belt of mountain tundra there extends *the belt of cold goltsy deserts.* It embodies vast stone fields and rocky remainders with scarce open vegetational cover. Here climatic conditions are the most rigorous, the growing season is extremely limited, the moistening regime fluctuates. In winter, snow cover is blown by the wind from the rocky mountain crests to descending belts, especially to the subgoltsy, excluding negative forms of relief in wind-protected places where snow patches are formed. There is no developed soil in this belt, but some quantity of fine earth accumulates between boulders and, here and there, in rifts of cliffs. On the surface of boulders, lichens form a mixed pattern-including crustaceous species belonging to genera *Rhizocarpon, Lecidea, Pertusaria, Lecanora, Haematomma* etc., foliose species of genera *Umbilicaria, Gyrophora, Parmelia, Nephroma, Peltigera* etc. and sometimes fruticose species of genera *Stereocaulon, Alectotia, Bryopogon, Cetraria, Sphaerophorus* etc. as well. Certain moss species, specially *Rhacomitrium lanuginosum, R. microcarpum,* and species of genus *Grimmia* are found here too.

In clefts between boulders a few fern species *(Cystopteris fragilis, Dryopteris fragilis* etc.) and flowering plants *(Gypsophila uralensis, Calamagrostis lapponica, Cardamine bellidifolia* etc.) huddle. Lichen and moss synusiae are unsteady; they replace each other rather quickly immediately after destruction of some parts of the boulders and the

removal of superficial layer of weathering rock. As for vascular plants, the localities in which they can thrive are very restricted and separated one from other; aboveground as well as undergronnd density is insignificant, stratification does not manifest itself. Vascular plants inhabit, under these conditions, solitary or by very small groups; that is why there are no stable, developed plant communities here. Competitive interrelations between vascular come to minimum whose, struggle for life manifests itself generally in the form of surmounting unfavourable environmental conditions, ocuppy only "ecological niches" arising in the course of destruction of large-boulder material. The effect of plant communities upon the environments is only trifling.

The belt of cold goltsy desert is analogous to the zone of arctic deserts occupying the areas of insular land in the Arctic Ocean (ALEKSANDROVA, 1950). The belt of cold goltsy desert is the most clearly pronounced in the Polar and the Prepolar Urals, where it stretches in the form of an almost continuous stripe along the most elevated section of the range. In the Northern Urals this belt disintegrates into a number of isles connected with higher mountain crests, separated one from other by wooded valleys. In the Southern Urals it is possible to discover only a remote similarity to cold goltsy deserts in the upper part of the mountains with pointed or pectinale summits.

The vegation of the Ural mountains in their individual sections bears a certain zonal impress. Zonal correlations are traced particulary clearly, as mentioned above, on the foothills and at the lower levels of mountains; their vegetation is similar in many respects to that of adjacent plains. At the same time, the Urals in their relatively elevated parts are characterized by a more rigorous and more humid climate, which causes a considerable advacement southwards along the mountain crest and slopes of such elements of vegetational cover that the analogues of which are on adjacent plains only in the far distance (200 to 500 km) to the south. In addition, the Urals plays the part of a peculiar climatic barrier in the way of Atlantic aezial masses coming from the west. Therefore their western slope is notable for a more humid and mild climate in comparison with the eastern one, which is relatively dry and continental. It determines the differences between the vegetation of the western and the eastern slopes traced more or less sharply in all their zonal sections.

In order to reveal the main regularities of altitudinal differentiation of vegetational cover in the Ural, two longitudinal profiles characterizing the distribution of vegetational belts on the western and the eastern macroslopes (fig. 3) are presented, as well as schemes demonstrating the peculiarities of belt structure in individual sections of the mountain system, different in zonal position (see fig. 4).

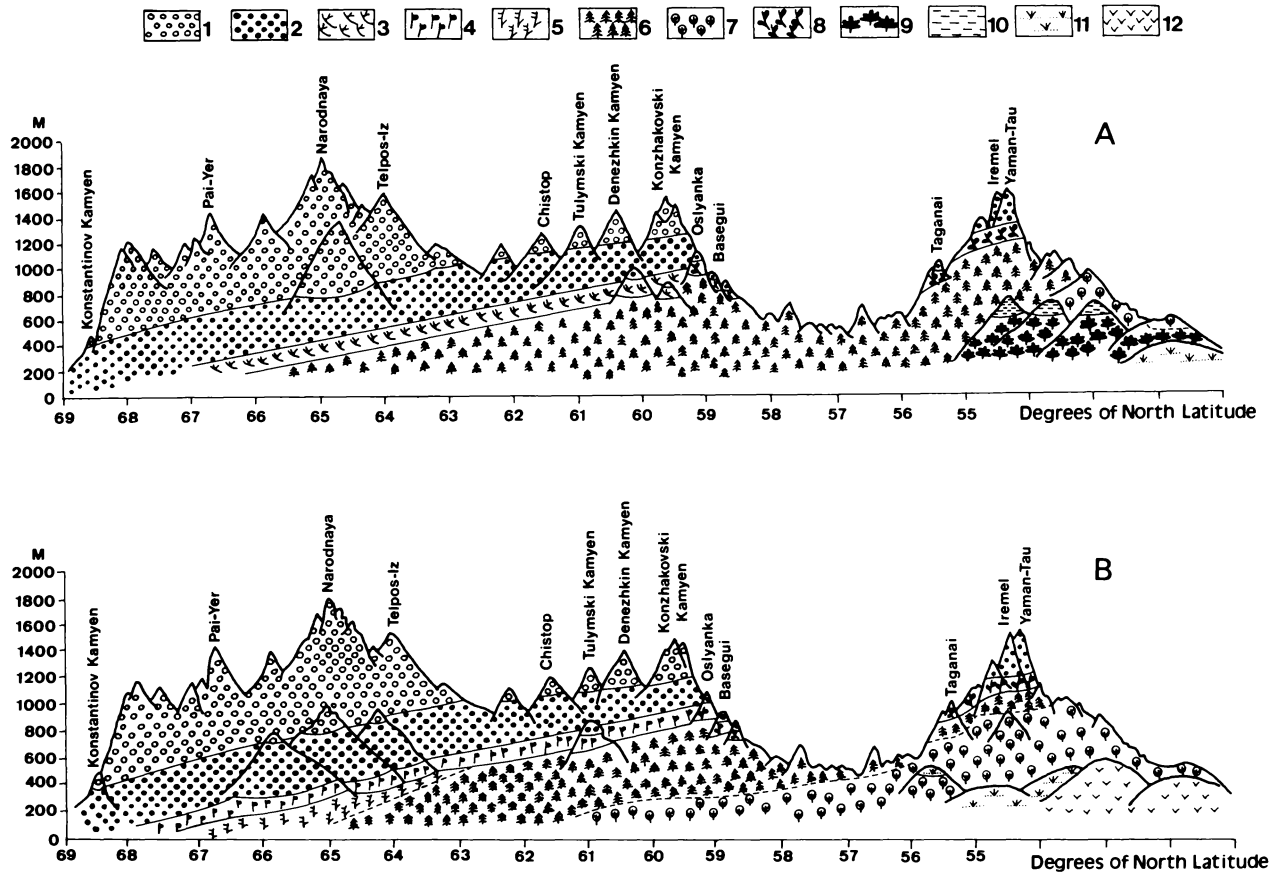

Fig. 3. Distribution of vegetation on the slopes of the Ural mountains. A: western slope, B: eastern slope. 1: cold goltsy deserts; 2: mountain tundras; 3: crook-stem birch forests in complex with meadow glades; 4: subgoltsy larch open woodlands; 5: mountain larch forests of pre-forest-tundra type; 6: mountain spruce forests; 7: mountain pine forests; 8: subgoltsy park fir-spruce forests in complex with meadow glades; 9: mountain broad-leaved (oak, lime maple), forests; 10: subgoltsy oak croocked forests in complex with meadow glades; 11: mountain forest-steppe; 12: mountain steppe.

2.1. *Altitudinal differentiation of vegetation in tundra zone (the northern part of the Polar Urals)*

The Polar Urals in their northern parte have been divided, by erosion, into a number of ranges and mountain massives. Average mountain height is 600-800 m above sea level, but individual crests are significantly higher (Ochenyrd 1373 m and so on). Here the signs of ancient glaciation are visible, and there exist numerous small contemporary glaciers.

The western slope of this section of the Ural mountains, bogged up to greater degree and having more developed permafrost, is absolutely woodless. The eastern slope, drier and more stony, where permafrost is represented to a lesser degree, is almost woodless too, however in the lower part of the mountains small plots of undersized open wooldlands composed of *Larix sibirica* are found here and there.

The vegetation of the lower levels of mountains (up to 400-500 m above sea level) is represented mainly by mountain tundra contacting at the foot of mountain with tundra of the adjacent plains. In the mountain tundra belt the complex of stony, lichen, spotted and shrub-moss tundras is widespread.

Tundras with developed moss cover (spotted shrub-moss) prevail on the western slope of the mountain system while on the eastern slope lichen tundras predominate. Higher than 400-500 m above sea level the belt of cold subgoltsy deserts in situated; withim the mountain tundra belt, the complex of stony, lichen, spotted and shurb-moss tundras is widespread.

Higher than 600-800 m above sea level the belt of cold goltsy deserts is situated; it contains widely-distributed stone fields and eroded cliffs covered by scarce vegetation mainly consisting of mosses and lichens.

2.2. *Altitudinal differentiation of vegetation in forest-tundra zone and in subzone of pre-tundra open woodlands (the Prepolar Urals and the southern part of the Polar Urals)*

The Polar Urals in their southern section are comparatively narrowed, their slopes have been cut by ancient glaciation and river erosion; the crests of ranges are acute, cliffy. So called "kars" containing lakes within them are found frequently. In this section the mountain Pay-Yer (1499 m) rises above. Southwards, where the Prepolar Urals begins, the mountain chan widens significantly. The

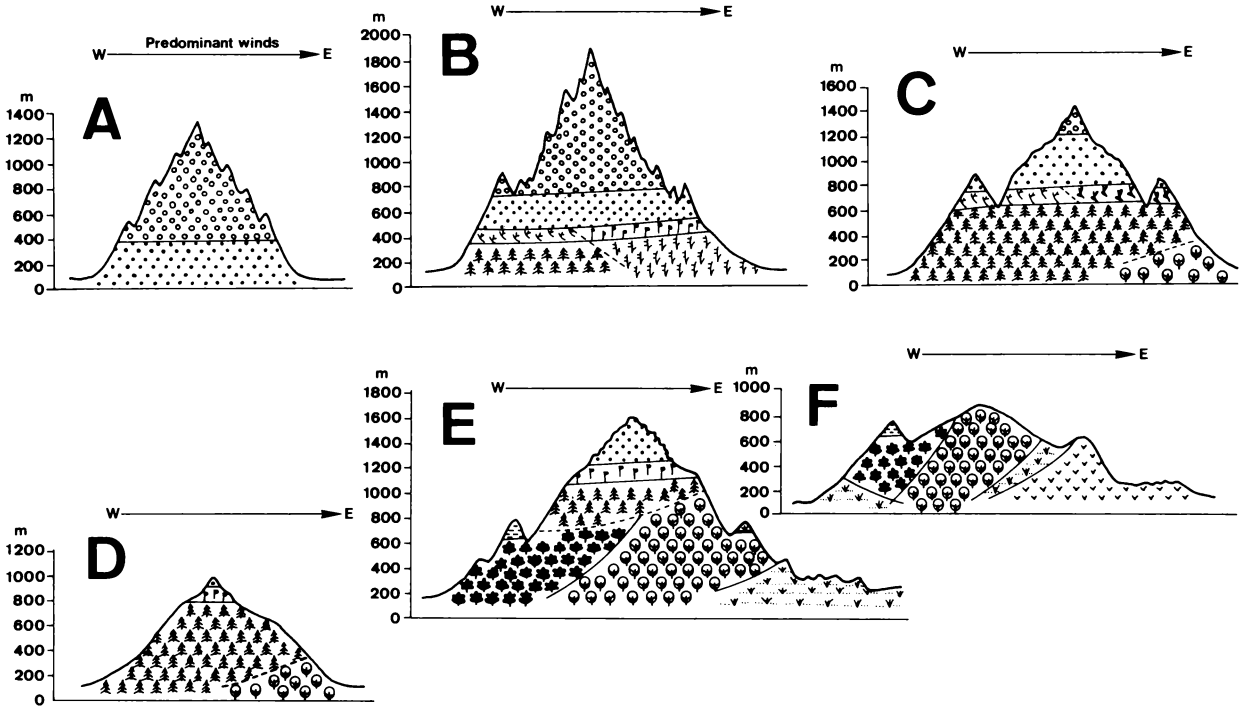

Fig. 4. Altitudinal differentiation of vegetation a: in tundra zone, B: in forest-tundra zone and in subzone of preforest tundra open woodlands, C: in subzones of northern and middle taiga, D: in subzones of southern taiga, pre-forest-steppe birch-pine and mixed broad-leaved-coniferous forests, E: in subzone of broad-leaved forests and in forest-steppe zone, F: in steppe zone. The conventional signs are the same as in fig. 3.

Prepolar Urals are the most elevated part in the northern section of the Urals. Here the biggest mountains of the Urals are concentrated: Narodnaya (1894 m), Manaraga (1820 m); there are many other comparatively high mountains reaching 1000-1400 m above sea level as well. Highmountain relief is sharply dissected; the mountains are crowned by acute combs, the slopes are steep, the valleys are deeply cut up. Fresh signs of glacier activity are distinctly visible. Contemporary miniature glaciers are present too.

In the lower part of slopes the mountain-forest belt stretches in the form of narrow stripe. Westwards of the watershed there prevail fairly light coniferous forests composed of *Picea obotava,* in the regions further south *Abies sibirica* admixes to them somewhere, and eastwards larch forests (composed of *Larix sibirica)* begin to predominate. These forests are analogous to open pre-forest-tundra forest of the plains.

Upwards the subgoltsy belt, in which open larch *(Larix sibirica)* woodlands, open crook-stem birch *(Betula tortuosa)* forest and more rarely open fir-spruce *(Abies sibirica* + *Picea obovata)* forests are distributed, is located. For the western macroslope with its milder climate, open crook-stem birch forests are typical, while for the earstern, more continental climate, open larch woodlands predominate. Close to the upper limit of subgoltsy forests, on steep slopes of deeply cut river valleys (mainly in the northern regions) the thickets of *Alnus fruticosa* are found. The upper limit of subgoltsy belt almost coincides with that of open woodlands and crook-stem communities. In the southern section of the Polar Urals the limit of the open woodlands ascends from 100-200 m in the north to 300-400 m in the south; the forests climb higher on the eastern slope of the mountain system. In the Prepolar Urals averaged line of the upper forest limit extends from 400 m near their northern extremity to 600 m in the southern part. Along deep valleys the upper limit ascends rather highly, but it descends sharply along steep slopes with stone fields. The forest reaches its climatically conditioned level only in few places - in deep valleys enriched with fine earth.

In the subgoltsy belt, mainly westwards of the chief watershed, mesophilous meadows alternating with undersized open woodlands are distributed widely enough.

The greater part of the territory of the Prepolar Urals and of the southern section of the Polar Urals adjacent to it is completely woodless and is attributed to goltsy. Mountain tundra belt bordering upon subgoltsy belt from above stretches up to 600-700 m above sea level in the southern half of the Polar Urals and up to 800-900 m in the

Prepolar Urals. Mountain tundras are represented mainly by stony, more rarely by lichen and in more flat places by moss communities. A great deal of snow patches keeping safe even in summer, to say nothing of glaciers, stipulate the thriving of subnival cryophilous communities situated not far from the edge of melting snow along the banks of streamlets having their sources in snow patches. Cold goltsy deserts spread above the belt of mountain tundra.

2.3. *Altitudinal differentiation of vegetation in subzones of northern and middle taiga (the Northern Urals)*

This section of the mountain system is rather elevated: in their central stripe and on the chines in the foothill area mountains' heights are approximatly 800-1.000 m. above sea level. However the individual mountains are considerably higher, among them the highest are Tel pos-Iz (1617 m.), Denezhkin Kamen (1492 m.), Konzhakovski Kamen (1569 m.). Comparatively smoother and more even relief, as the result of frost weathering and solifluction, is typical for this high mountain areas. There is a clearly pronounced stepped relief in the goltsy part of the mountains: the mountains' saddles as well as some crests have rather flat surfaces. However the crests of the biggest mountains composed of resistant rocks usually look like cliffy residuals, acute peaks or combs.

The greatest part of the mountain territory in this section is wooded. For the mountain forest belt, dark coniferous taiga with *Picea abovata* as the chief dominant, *Abies sibirica* and *Pinus sibirica* prevailing more rarely, is the most typical. Birch forests (mainly composed of *Betula pubescens)* succeeding the dark coniferous taiga after cuttings and fires, are ordinary. Although the forests both of the northern taiga and of middle taiga types are distributed in the plains adjacent to this section of the Urals, in the mountains, in the full range of the Northern Urals right up to the region of Konzhakovsky Kamen in the south, the mountain taiga conserves its northern appearance.

In the Northern Urals undersized open woodlands and crook-stem-forests of subgoltsy belt are diverse in tree species composition. The prevailing formations are open larch *(Larix sibirica)* woodlands, which are especially typical for the eastern macroslope, and birch *(Betula tortuosa)* open crook-stem forest which are found more frequently westwards of the watershed stripe. Here and there, especially westwards of the watershed line, fir-spruce *(Abies sibirica + Picea excelsa)* park forests, fir forests and, on large stony slopes, *Pinus*

sibirica forests reach the upper limit. The line of the upper forest limit ascends in this section of the mountain system from 600 m. above sea level near its northern extremity up to 900 m. in its southern part.

Westwards of the watershed (Tugulymski Kamen, Chyuvalski Kamen, Kvarkush, etc.), mesophilous meadows in combination with open woodlands and crook-stem forests occupy quite a significant area in the subgoltsy belt.

In the northern part of this section of the Ural mountains, woodless goltsy stretch in the form of continuons stripe along the watershed part and on the western (Kvarkush) and on the eastern (Denezhkin Kamen, Konzhakovski Kamen) foothills' ridges; the tops of the lowest mountains are wooded.

The mountain tundra belt extends right up to 1100-1200 m. above sea level; stony, moss spotted and herb-moss tundras prevail there; cryophylous subnival communities close to melting snow patches occur also. Crests exceeding this level belong already to the belt of cold goltsy deserts.

2.4. *Vertical differentiation of vegetation in subzones of southern taiga, birch-pine forests and mixed coniferous-broad-leaved forests* (the Middle Urals)

This section of the mountain system is comparatively lower. The mountains are not high here, 500-600 m. on average, usually wooded up to the summit, but the highest of them (Oslyanka-1122 m., Basegui-993 m. etc.) exceed the upper forest limit. In the mountain forest belt the middle taiga forests prevail, but in the southern regions and on lower levels of the southern taiga dark coniferous forests are more usual. The latter is represented by fir-spruce and more rarely spruce-fir forests (sometimes with the admixture of *Tilia cordata* and certain herbaceous plants of nemoral complex). Here and there, birch forests, secondary with respect to dark coniferous taiga, are found.

Eastwards of the watershed, more or less large massives of mountain pine forests of the southern taiga type intermingle with dark coniferous taiga.

The subgoltsy belt manifests itself only in the upper part of the bigger mountains. The forests at their upper limit, close to cliffy crests, are open, of park type, mainly dominated by spruce, more rarely by spruce and fir. Here there are neither larch open woodlands nor birch Crook-stem forests so typical in further southern regions. Subgoltsy *Pinus sibirica* forests are absent too, although single individuals of *Larix*

sibirica, Betula tortuosa and *Pinus sibirica* are found somewhere in this belt.

The upper forest limit on the majority of relatively high mountains is not climatic, but edaphic; it is lowered significantly (usually not higher than 800-850 m. above sea level) because of lack of fine earth on cliffy mountain crests.

In park subgoltsy forests the herbaceous layer, consisting of tall herbs, is well-developed. More or less large meadow glades are included here and there in such open woodlands. The general surface of goltsy is here insignificant. Goltsy are represented by cliffy residuals and stone fields with fragments of mountain tundra vegetation; the belt of cold goltsy deserts is absent here.

2.5. *Altitudinal differentiation of vegetation in subzone of broad-leaved forests and in forest-steppe zone (the northern and central parts of the Southern Urals)*

The mountains here reach considerable dimensions again. In the northern and especially in central part of the Southern Urals, the heights of many mountains exceed 1000 m. However, the geographical position of this section of the Urals determines a more heightened level of the upper forest limit here, which is why goltsy manifest themselves only on the crests of the biggest mountains and ranges, for instance, on Yaman-Tau (1638 m.) and Iremel (1586 m.).

Broad-leaved *(Quercus robur + Tilia cordata)* forests grow on the lower levels of the western slope of the mountain system (up to 600-700 m.) replaced on the higher levels by mountain dark coniferous *(Pica obovata + Abies sibirica)* taiga with the admixture of broad-leaved trees and their herbaceous companions. In the most elevated part of the Southern Urals, the upper limit of mountain forest belt is situated on a level of 1000-1100 m. The foothills of the eastern slope are occupied by forest-steppe replaced in more elevated areas by mountain pine *(Pinus sylvestris)* forests with the admixture of *Larix sibirica* forests and by birch *(Betula pubescens, B. verrucosa)* forests, secondary with respect to them. The flora of these pine and birch forests contain an admixture of steppe species. The narrow stripe of mountain dark coniferous taiga stretches southwards and eastwards in the most elevated part of the mountains on the eastern macroslope wedging in above the stripe of mountain pine forests.

The upper forest limit in the central, most elevated part of the Southern Urals, is formed mainly by spruce and fir-spruce open

woodlands of park type, with well-developed herbaceous layer. Crookstem birch forests occur in the form of small islets on the slopes of the highest mountains, where they occupy the places more exposed to winds. In the subgoltsy belt, *Larix sibirica* is found very rarely only as single individuals; *Pinus sibirica* is absent. A more favorable thermal regime, abundant precipitation and increased air humidity in subgoltsy belt as well as in the upper part of the mountain forest belt adjacent to it stimulats the luxuriant development of herbaceous vegetation here. The herbaceous layer in highmountain forests is highly developed, and forests alternate with more or less large meadow glades. The line of the upper forest limit ascends from 1000 m. in the northern extremity of the Southern Urals in the region of Taganai range, to 1250 m. in the region of Yaman-Tau. However, in certain less high mountains the forest limit is lower either because of the absence of developed soils on cliffy crests or at the cost of intense snow accumulation on the crests resulting in the reduction of the growing season. In comby-hilly stripes of the western macroslope, where broad-leaved forests prevail, on some mountains' crests exceeding 650-750 m. above sea level the subgoltsy belt manifests itself; its vegetation is represented here by crook-stem oak *(Quercus robur)* forests in complex with glades of tall herbaceous mesophilous meadows.

Goltsy landscape is concentrated mainly in the central part of the Southern Urals. Many big mountains (Iremel, Yaman-Tau) have mesa tops with small cliffy residuals which rise above the flat surface. Narrow ranges badly destroyed by erosion (for example, Zigalga, Nary) are crowned with acute cliffy combs. Herb-moss tundras are the most typical for mountain tundra belt in this section of the Urals.

2.6. *Altitudinal differentiation of vegetation in steppe zone (the southern part of the Southern Urals)*

The mountains in this area are significantly lowered, crests have smoother outlines. In the watershed part (the range Ural-Tau) the individual crests reach 650-1000 m. above sea level, the tops of the spurs lying westwards or eastwards of the watershed yield to them only a little in respect of height.

The western macroslope, receiving more precipitation, is covered near the foothills by mountain forest-steppe. Mountain broad-leaved forests *(Quercus robur, Tilia cordata, Acer platanoides* more rarely *Ulmus scabra)* stretch upwards to the height of 600-700 m. above sea level. Undersized crook-stem oak forests in complex with the glades of

mesophilous meadows occur on the individual crests of the western macroslope exceeding this level. In some places on limestone where soils are thin and rocky, *Quercus robur* takes the shape of prostrate shrub. On the eastern drier macroslope the borderline between the belts with vegetation of xerophytic type (steppe and forest-steppe) is significantly heightened in comparison with the western one. Mountain steppe (for example, as it is well visible in the southern part of the range Irendyk) rises to an average height of 600 m. above sea level. Above this, mountain steppe stretches in the form of a narrow strip; here and there, because of inversion conditioned by irregular moisture distribution, it descends along small valleys into the mountain steppe belt. The central watershed part of the Southern Urals in this zonal section is covered by pine *(Pinus sylvestris)* forests with the admixture of *Larix sibirica* and by birch *(Betula verrucosa, B. pubescens)* forests with stepificated herbaceous layer, secondary with respect to the above mentioned forest type.

3. Conclusions

Altitudinal differentiation of vegetation may be interpreted as the manifestation of horizontal differentiation (zonality) of vegetational cover in mountain areas where zonality is complicated and changed under the impact of mountain raisings on distribution of aerial masses and on local climates.

A certain analogy between the altitudinal belts of vegetation and horizontal zones (or subzones) exists. For instance, mountain tundras are similar to zonal plain tundras in a number of features; mountain dark coniferous taiga - to plain dark coniferous taiga respectively. However, judging from the complex of other features (spatial manifestation of certain types of plant communities and correlation between them, their structure and productivity, reserves and conditions of exploitation of plant resources), significant differences are revealed between these units. On the whole, these differences are so great that, in the course of dividing the territories into phytogeographical districts, the units of vertical differentiation of vegetational cover should not only be excluded from the assortment of appropriate zonal subdivisions on the plains but also they should not be considered as variants of them.

The main types of vertical differentiation of vegetational cover in different parts of the Urals generally coincide with the most significant subdivisions of horizontal phytogeographical zonality which may be traced in the plains adjacent westwards and eastwards to the Urals.

There is no perfect accordance in the columns of vertical differentiation of vegetation to each zonal subdivision because of asymmetry of zonal differentiation of vegetational cover on the plains adjacent to the Urals.

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