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INTERNATIONAL SYMPOSIUM ON HIGH-MOUNTAIN GEOECOLOGY

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The Commission on High-Mountain Geoecology of the International Geographic Union, organized in 1968 on the initiative of Karl Trolle (FRG), considers its basic task to be the advancement of comprehensive study of the high-mountain regions of the world from ecological points of view. As materials are accumulated the results obtained are discussed at special symposia. At the end of July 1976 the periodic Symposium on High-Mountain Geoecology was held in the Elbrus Region within the framework of the field program of 23rd International Geographic Congress.

The field program included scientific sessions and excursions. Participating in the work of the symposium were 56 people from 10 countries, including the USSR, USA, Canada, Japan, France, the FRG, Switzerland, Austria, Brazil, and the Czechoslovak SSR. J. Ives (USA) was supervisor of the scientific program, and the local organizers were R. P. Zimina and G. N. Golubev.

The sessions were held in the conference hall of the high-mountain station of Moscow University (Azau settlement, Kabardino–Balkar ASSR). A total of 27 reports were heard.

Considerable attention at the symposium was given to the vegetational zonation in mountains and the upper forest boundary. Reports on the results of investigations conducted in Japan, Central America, and the Canary Islands, North America, the Carpathians, Caucasus and in the mountains of the boreal zone of the USSR were devoted to these questions.

The altitudinal vegetational belt of Japan in relation to the species of climatic conditions were characterized by M. Yoshino (Japan). He distinguishes four belts: foothill, mountain, subalpine, and alpine. Especially characteristic of the foothill belt (from sea level to 500-600 m) are evergreen forests forming in conditions of a warm winter under the influence of the warm sea currents along the coast. Forests of *Shiia sieboldii* and *Machilus thunbergi* predominate in the shore zone of the Sea of Japan; in the inland part of Japan until 300 m above sea level there dominate forests of *Quercus stenophylla* with participation of *Aucuba japonica*, and, higher, forests of *Fagus crenata*. Broadleaf deciduous forests characteristic of temperate–cold climate are widespread in the mountain belt. On the slope facing the Sea of Japan, where the thickness of the snow cover reaches 1-2 m and more, there predominate forests of *F. crenata* with participation of *Sasa paniculata* or *S. kurilensis*, and on the Pacific slope, communities of *F. crenata* + *Pseudosasa purpurascens*. The subarctic belt is in Central Japan situated at an elevation of 1500-2500 m, while in the north of the country it is considerably lower. A thick snow cover and the strong winter monsoon winds cause retarded growth of the coniferous trees in this belt and the deformation of their crowns. These altitudinal levels are most characterized by low forests of *Abies veitchii*, *A. mariesii*, *Tsuga diversifolia*, and *Larix leptolepis*. Higher there is situated the alpine belt, where the climax community are stands of *Pinus pumila*, against the background of which are scattered sections of high-mountain waste land, grass communities, and deserts. The speaker gave particular attention to the distribution of various species of bamboo in connection with elevation above sea level, slope orientation, and thickness of the snow cover.

Some results of an investigation of the upper forest boundary on volcanos in Central Mexico were presented by V. Lauer (FRG). The timberline here runs at approximately the level of 4000 m, where communities of *Pinus hartwegii* with sod grasses are replaced by single trees or groups of trees. There were demonstrated the climatic parameters determining the upper

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level of distribution of relatively closed forest communities. The contemporary timberline was formed in considerable degree under the influence of fires, both natural and caused by shepherds. Natural and anthropogenic fires differ according to frequency, intensity, and season of occurrence and exert differing influence on the timberline. Under the influence of the exploitation of high-mountain meadow and annual burning of shrubs, the timberline on the volcanos of Central Mexico has in recent time been lowered.

The zonation of vegetation and the character of the timberline in the subtropics were examined with the example of the Canary Islands in P. Hellerman's (FRG) report. Here on Tenerife Mt. the following belts are distinguished: lower (up to 400 m) with semiarid shrubs and "succulent steppe," mid (up to 2000 m) with subhumid forests and sparse forests (evergreen laurel forests and sparse-forest heath communities in the lower belt and forests of Canary pine in the upper), and upper (above timberline) with semiarid cushion shrubs, and later with single pioneer plants. There are no tree species at timberline (2000 m) besides the Canary pine (*Pinus canariensis)*. The reasons for the relatively low (as compared with other massifs of subtropical latitudes) position of the timberline on Mt. Tenerife are still insufficiently clear. The contemporary timberline was suppressed here by recent volcanic activity; the earlier prevalent juniper belt (*Juniperus oxycedrus)* has almost disappeared.

The results of investigations conducted in the high-mountain regions of the Pacific Northwest of the USA were communicated by L. Price (USA). For comparison three mountain regions in the state of Oregon were selected: the Cascade Mountains and Wallowa and Steens mountains. The timberline in the Cascades varies from 1650 m in the north to 2300 m in the south. Cliff outcrops and subalpine meadows are widespread in the Wallowa Mts., but the trees at places reach the summits (3300 m) and apparently might have gone higher if the mountains were of greater height. In the Steens Mts. the timberline runs at an elevation of 2575 m. In the Cascades and Wallowa Mts. the timberline is formed by coniferous trees (*Tsuga mertensiana, Picea engelmanni, Abies lasiocarpa, Pinus albicaulis*), while in the Steens Mts., by leafy forests (*Populus tremuloides)*. *Tsuga,* emerging in the Cascades as one of the dominants of forests at their upper limit, is almost absent in the Wallowa Mts., where Engelmann spruce is primary. In the Wallowa Mts. there are comparatively many arctic-tundra species above the timberline; in the Cascades they conversely, are few in number, but here there are more species genetically related with deserts. In the flora and fauna of Steens Mts. there predominate more continental elements and elements common with the Great Basin; however, thanks to the isolated position of this massif, a series of endemic species has developed here.

In the report of N. Shumatov (USA) there were presented certain statistical data on the position of the timberline in the Rocky and Cascade mountains and on Mount Olympus in North America in comparison with the Alps. The differences in the position of the timberline in the various mountain regions are for the most part only stated by the authors, but in some instances they are explained by differing thickness of snow cover, differing exposure of slopes, etc.

The influence of man on the timberline in the Western Carpathians was clarified in the report of P. Plesnik (Czechoslovak SSR). The grazing of livestock in the mountains, which was begun in the 13th century and especially intensified in the 15th and 16th centuries, played the greatest role in this respect. The destruction of forest by nomad livestock breeders for expansion of forest pastures as well as livestock grazing have caused a lowering of the timberline in many places in the Western Carpathians. The contemporary climax timberline reaches 1420 m in the Lesser Fatra and 1740 m in the High Tatra. In the most elevated part of Tatra it is composed of spruce (*Picea abies)* with an admixture of larch (*Larix decidua)* and Swiss pine (*Pinus cembra*). Widespread above timberline are communities of procumbent mountain pine (*Pinus mugo* ssp. mugus).

After the destruction of the forests comprising the timberline on acid rocks, as a result of livestock grazing there form communities of whortleberry (*Vaccinium myrtillus*) and then matgrass (*Nardus stricta*). On calcareous substrates (dolomites, limestones) at the site of cut forests there first form meadow communities rich in species composition, but they then slowly degrade under the influence of grazing, finally passing to the matgrass stage. The degree of human impact on the timberline in one or another region in many ways depend on the character of the relief. Livestock-breeder nomads have selected for grazing primarily mountain regions with a soft relief counter and gentle slopes. At such sites the timberline was greatly lowered. In contrast, in the most uplifted parts of the High Tatra, strongly subjected to glaciation and with steep slopes, rock walls, boulders, and other rocky territories, the timberline has in considerably less degree been subjected to lowering and at places corresponds to the potential timberline.

In the past, especially in the 19th century, communities of mountain and Swiss pine at their upper limit were in a number of regions intensely utilized in connection with the production of essential oils. Recreational activity, especially winter ski sports, exerts the greatest influence on the timberline in the 20th century. The destruction of high-mountain forests and the lowering of the timberline lead to the return of wind and water erosion and considerable intensification of mudflows and snow avalanches. The optimal regimes of nature utilization need to be developed in order to eliminate these undesirable phenomena.

In characterizing the timberlines and subalpine belt in the Caucasus, A. G. Dolukhanov (USSR) noted that in the eastern part of the Caucasus, more favorable for nomadic and semi-nomadic animal raising, the timberline has almost everywhere been subjected to strong lowering; natural timberlines are encountered extremely rarely here. More or less preserved natural ecosystems are encountered more frequently in the subalpine belt in the western part of the mountain land. Under the influence of anthropogenic effects the role of herbaceous vegetation in the subalpine belt increased strongly, including that of a number of long-derived meadow and hemixerophilic formations and subalpine tall herbaceous vegetation. The climatic boundary of woody vegetation in different regions of the Caucasus runs at different levels, varying from 2200 to 2750 m. Its high position depends not only on the continental character of the climate and the massiveness of the mountains, but also on the membership of woody plants to one or another florogenetic groups. The upper limits of boreal species (*Pinus sosnovskyi, Betula liwinowii,* and others) and of the flora of semiarid regions (*Quercus macranthera,* certain species of the genus *Juniperus*) rise, when the continental character of the climate is intensified, higher into the mountains almost parallel to the July and August isotherms; in species genetically related with the flora of moist oceanic climate (*Betula medwedewii, Quercus pontica*) the limits, on the contrary, decline in these cases; in species belonging to the floral elements of moderately moistened mountains of mid latitudes (*Picea orientails, Abies nordmanniana, Fagus orientalis*) the limits change little.

The report of P. L. Gorchakovskii and S. G. Shiyatov (USSR) was devoted to the timberline in mountains of the boreal zone of the USSR and its dynamics. It was stressed in the report that the character of altitudinal zonation depends first of all on the position of the given mountain land within the system of horizontal zonation of vegetation. Depending on the principal limiting factors in the boreal zone the following types of timberline should be distinguished: climatic (thermic, wind), edaphic, avalanche, and anthropogenic. Furthermore, based on the composition of the dominating species of trees and the structure of high-mountain forests a number of physiognomic types of timberline may be distinguished: a) principal (*Betula tortuosa,* larch, Erman spruce) and b) (Siberian pine, spruce).

According to the composition of the principal physiognomic types of timberline of the high-mountain region of the boreal zone three sectors are separated: 1) western (Atlantic) moderately continental with dominance of birch crooked forests (mountains of Kola Peninsula, the western part of the Near-Polar and Northern Urals); 2) central (Siberian) sharply continental with dominance of larch sparse forests (eastern part of Near-Polar and Northern Urals, mountains of northeastern Siberia, Baikal and Transbaikal regions, northeastern part of Sayan); 3) eastern (Pacific) monsoon with predominance of forest of Erman birch (mountains of Kamchatka, of the coast of the Sea of Okhotsk, Sikhote-Alin, the mountains of Sakhalin). On the extreme flanks of the boreal zone, in the western (Atlantic) and eastern (Pacific) sectors the timberline is formed by leafy trees (respectively, *Betula tortuosa* and *B. ermani*); only in the south of the eastern sector does a small admixture of conifers appear. In the central sector with its sharply continental climate, there emerge at timberline primarily coniferous trees with foilage that is dropped in the winter (*Larix sibirica, L. sibirica* var. sukaczewii, *L. dahurica*); in certain regions of this sector with a more favorable regime of heat and moisture evergreen conifers (*Picea obovata, Pinus sibirica*) are encountered at timberline, sharing dominance with larch or even predominating over it.

In the north of the Eurasian continent the timberline is situated lower than in more southern regions. The gradient of rise of the timberline in moving from the north to the south is approximately 100 m per 1 degree latitute. In oceanic regions the timberline is situated lower than in continental. The lowest timberline is characteristic of the northern part of the western and eastern sectors of the boreal zone (Khibiny, Kamchatka), and the highest, the southern part of the central sector (Sayan).

On the basis of study of the fluctuations in the tree growth and age structure of tree stands in the Khibiny, the Urals, in northern Siberia, and in Kamchatka there were demonstrated climatic cycles of from 5-6 to 800-900 years in duration. The most appreciable influence on the displacement of the timberline is exerted by cyclic climatic fluctuations of 60-80 and 140-160 years duration. At the present time there is being witnessed a rise of the timberline, which the majority of investigators relate to the warming of the climate in the northern hemisphere during the last several decades. However in many regions the moment of the forest higher into the mountains is hindered by fires and the economic activity of man. The cooling of the climate at the end of the 20th to the beginning of the 21st centuries, predicted by climatologists and heliogeographers, should result in a lowering of the timberline in many mountain regions of the boreal zone.

In the communications of Soviet scientists presented for discussion but not read at the symposium a characterization was given a certain pattern of distribution of high-mountain vegetation in the mountains of Northern Eurasia (K. V. Stanyukovich), the change in the timberline in the Greater Caucasus under the influence of avalanches (M. Ch. Zalikhanov), fluctuations of the timberline in Teberdina Reserve (S. A. Khapaev), the structure of the altitudinal zonation of landscapes of the northern slope of the Greater Caucasus in the Baksan Basin (A. E. Fedina), the structure of the altitudinal zonation of landscapes of the Armanian SSR (G. B. Grigoryan), the patterns of distribution of vegetation in dry high-mountain regions of Pamir (M. B. Stanyukovich), the timberline in Tien Shan (V. A. Bykov), the structure and productivity of high-mountain regions of Tien Shan ecosystems (R. I. Zlotin), characteristics of the high-mountain ecosystems of the Northern Urals (P. L. Gorchakovskii and V. N. Bol'shakov).

The analysis and discussion of the materials presented showed convincingly that the character of the vegetation of the upper levels of one or another mountain land in many ways depend on its position in the system of horizontal zonation, as well as on the height of the mountains. Each landscape zone (boreal, nemoral, subtropical, arid, etc.) is characterized by its own spectrum of altitudinal vegetational belt, its own timberline characteristics. The terms "alpine belt," "subalpine belt," etc. are suitable for characterizing the vegetation and ecosystems of the Alps and certain other mountains with similar ecological conditions (for example, the humid part of the Caucasus), but are completely inapplicable for the vegetation and ecosystems of Africa, South America, and the boreal and arid zone of Eurasia. The nomenclature of plant or landscape belts adopted by certain investigators is "faceless," it does not reflect the geoecological characteristics of individual mountain lands, their position in the system of horizontal zonation. Some belts are named according to geomorphological or even morphometric traits ("mountain," "foothill," "lower," "mid," "upper"). The "alpine cliché" in belt nomenclature ("alpine," "subalpine") is used for mountain lands where, due to their particular zonal position, there are no landscapes of the alpine type. In distinguishing the boundaries of belts greater significance is sometimes given to geomorphological and morphometric traits than to biochorological traits. There is a clear need for development of a special nomenclature of altitudinal belts and ecosystems applicable to high-mountain regions of the boreal, tropical, subtropical, and arid zones.

The timberline in mountains is one of the most important biogeographical boundaries. Originally this boundary was studied by botanists and silviculturists, but in recent time it has attracted the interest of geographers, climatologists, glaciologists, pedologists, zoologists, and the representatives of other branches of knowledge, which was strikingly reflected at the symposium. As a result of discussion of the reports presented the necessity was revealed for further comprehensive geoecological study of timberlines in various landscape zones, of their position, physiognomic, and ecological differentation, as well as dynamics. The concept of the zonal conditioning of the character of timberlines, which was developed in the reports of the Soviet participants of the symposium, was approved. In the course of the discussions there was emphasized the desirability of further comprehensive study of the timberline in various lands, the factors limiting it, and dynamics. It is obviously necessary to protect mountain forests at their upper limit and to restore timberlines where the forest boundary has been articifially lowered (in order to reduce the intensity of soil erosion, the activity of mudflows and snow avalanches, to improve the regimen of mountain rivers).

A number of reports were devoted to the influence of avalanches on the formation of natural-territorial complexes and economic activity in mountains. Here one should note the reports of the colleagues of the Problems Laboratory of Avalanches, Mudflows, and Firn Snows of Moscow University, headed by G. K. Tushinskii. In the report of K. V. Akif'eva, N. A. Volodacheva, E. S. Troshkina, V. I. Turmanina, and G. K. Tushinskii on avalanches in the USSR it was noted that the characteristics of avalanche natural-territorial complexes are in greater degree determined by vertical zonation than by latitudinal zonation. If the effect of avalanches on ecosystems is negligible in the nival belt, then in the subalpine and forest belts they strongly lower the biological potential of habitats. However, with decrease in geographical latitude and in the elevation of habitats above sea level the transforming activity of vegetation increases at the sites of avalanche descent. If in conditions of a continental climate the effect of avalanche on vegetation is primarily positive (moistening of the substrate), then in conditions of an oceanic climate there predominates a negative effect (mechanical injury and destruction of vegetation and soil, reduction of length of vegetative period).

In the report of V. I. Turmanina and E. R. Volodina on the dynamics of vegetation of the Elbrus Region there were summarized station investigation (1968-1974) of the dynamics of vegetation (seasonal, yearly, long-term) near Azau Glade (2250 m) and at Dzhankuat Glacier (2650 m). During cold and moist years incomplete passage and delay of plant phenological phases is observed in the majority of communities. The floristic composition, abundance indicators, viability, and annual production change in years differing according to climatic conditions. The optimal conditions for the development of plant biomass are created in years when a mean seasonal temperature higher than 10° holds for 50 days and longer, while the yearly sum of precipitation comprises 900-1000 mm. The displacement of phytocenose boundaries may reach tens of meters within several decades, and hundreds of meters within centuries. In the last century, in connection with the contraction of glaciers and the warming of the climate, there occurred the energetic development of chazmophytes and the spread of pioneer plants after the retreating glaciers. Alpine and subalpine meadows, *Rhododendron* stands, and birch crooked forests moved upward into the mountains over moistened and shaded slopes; at the same time the mountain-steppe zones increased their areas over south dry slopes. A similar picture of the dynamics of vegetation in the Elbrus Region was observed in the eighth to 12th centuries and in the 13th-16th centuries. The reverse processes occurred during periods when glaciers advanced (12th-19th centuries with a maximum in the 17th century). The reorganization of the plant cover is reflected by the presence in some communities of species with differing ecological properties.

An assessment of the quantitative characteristics of the interactions of forests with snow avalanches was given in the report of V. S. Chuenkov and V. P. Vlasov. An attempt was made to construct a biophysical model of avalanche-protective forests in the high-mountain regions of the north slope of the Greater Caucasus. Different aged and mixed forest gives the most effective protection from avalanches. The avalanche path length has decisive influence in the subalpine zone on the composition and structure of tree stands growing on avalanche-hazardous slope. Three types of conditions of stability of the system "forest—snow avalanches" were distinguished: 1) first stable condition, when the angle of inclination of the slope does not exceed 40° and the path of the avalanche body to the timberline is not more than 300 m (in this instance the forest retards the avalanches on the slope); 2) second stable condition, when the snow avalanches reach the vally bottom, completely destroying the forest; 3) unstable condition, when the forest and nidus of avalanche activity are in a condition of unstable dynamic equilibrium. For characterization of the interaction of the forest and snow avalanches and the comparability of situations there has been suggested the utilization of coefficients of system stability and of the effect of the avalanche-protective function of the forest.

In the report of B. Messerli, K. Pfister, and H. Zumbuhl (Switzerland) on the fluctuations of climate and glaciers and the geoecological significance of these phenomena during recent decades, there was presented a large amount of factual material collected in the northern part of the Swiss Alps. Using the data on the fluctuations of the Lower and Upper Grindenwald glaciers, historical evidence on weather, and the data of instrumental meteorologic observations after 1755, the authors reconstructed the climatic fluctuations and showed how these fluctuations influence certain mountain ecosystems (forest communities at timberline, soil cover, agricultural areas). Cold and moist summer periods lead to the activation of mountain glaciers, while warm spring and autumn periods, to their contraction. Until

1860 the climate was cold and moist. There then occurred the considerable warming of the climate and such a strong contraction of the glaciers as had not been observed in historical time. Short-term (less than 10 years) climatic fluctuations, also exerting influence on mountain ecosystems, can also be rather clearly traced. However, such fluctuations do not lead to appreciable disturbance or disorganization of forest communities growing at timberline. The hypothesis was stated that in the postglacial period the timberline could not have appreciably shifted in altitude, since beginning from approximately 9000 A.D.* the fluctuations in the margin of glaciers were such as those during recent centuries.

Climatic fluctuations exert appreciable influence on the process of soil formation in high-mountain belts. Soils are formed during relatively long periods with favorable climatic conditions. The course of soil formation may be disturbed and interrupted in years catastrophic with respect to climatic conditions. In cold and snowy summer periods there occurs massive destruction of alpine vegetation, which leads to considerable intensification of soil erosion. Cold and moist summer periods in combination with long snowy winters exert a catastrophic influence on agricultural production in high-mountain regions, especially if such a combination is repeated several years in a row. The consequences of unfavorable periods are seen for an extended time.

The geographic characteristics of the high-mountain biota of nontropical Asia were examined in the report of R. P. Zimina and D. V. Panfilov (USSR). It was noted in the report that in spite of the separation and, at times, isolated position of the mountain ecosystems of various regions, the systematic composition of the organisms populating them is often very similar. This is explained not only by the similarity in the conditions of life in high-mountain regions, but also by floristic and faunistic connections between the various mountain systems of Eurasia in the Tertiary Period, and especially during the glacial period. Central Asia is considered as the most important and most ancient primary center of formation of high-mountain biota. The reports of O. S. Grebenshchikov, as well as those of O. E. Agakhanyants and I. K. Lopatin (USSR) were devoted to an analysis of the geographical characteristics and productivity of high-mountain ecosystems. S. A. Harris (Canada) gave a comparative characterization of patterns of the belt distribution of mollusks in Iran and the Rocky Mountains.

Further, at the symposium there were heard reports clarifying a number of other aspects of high-mountain geoecology. The specifics and dynamics of separate elements of high-mountain landscapes (glaciers, relief) were examined in the reports of G. N. Golubev, V. M. Kotlyakov, and V. F. Perov (USSR) and B. Lakman (Canada). A considerable number of reports were devoted to indication, mapping, and prognosis of natural calamities in mountains. There should be noted here the communications of M. Bovas, J. Ives, P. Krebs (USA), and H. Kuholz (Switzerland). A sound showing of color slides illustrating the manifestation various natural calamities in mountain lands (D. Conger USA) produced a great impression on the symposium participants. The reports of R. King, J. Howell, and S. Harris (Canada) were devoted to the characteristics of soil formation in the Rocky Mountains. The influence of human economic activity of mountain ecosystems was the topic in the reports of J. D. Ives and B. K. Bishop (USA). H. Uhlig (FRG) reported on the progress of rice cultivation in high-mountain regions of Southeast Asia and the Himalayas.

The symposium was carefully prepared and went off very successfully. The active discussion of the report and communications presented promoted the coordination and progress of geoecological investigations conducted in various landscape zones of the world.

*As in Russian original; presumably 9000 B.C. though possibly 9000 years ago.