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BASIC PROBLEMS OF GEOCRYOLOGY

CONTEMPORARY PERIGLACIAL ENVIRONMENT AND ITS HUMANITARIAN AND GEOGRAPHIC FEATURES

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The new area of the science, periglacial geography, is described as a study of contemporary periglacial environment. The paper highlights the characteristics of the contemporary periglacial nature which covers high-latitude and high-altitude areas stretching from the cold timberline up to the snowline.

Periglacial environment, high-latitude and high-altitude areas, tundra, global changes

INTRODUCTION

A large number of fundamental reports are dedicated to the global reviews of the glacial regions of the Earth. Yet, the adjacent ice-free and treeless land is generally neglected in the overall planetary context. A large amount of data has been accumulated by the studies of different components of the periglacial nature. However, their discussions have been limited mostly to narrow aspects. The studies of permafrost scientists and geomorphologists [*Tricart, 1969; Troll, 1973; French, 1983; Washborn, 1988*] rarely concern the biological and ecological characteristics of periglacial environments, while their biological studies [*Billings, 1973; Wardle, 1974; Arno and Hammerly, 1990*] do not characterize terrain-forming features. And finally, there are no conceptual studies of the humanitarian, social, and ethnic features of periglacial environments, despite the abundance of such works on individual regions.

V.M. Kotlyakov and *Yu.P. Badenkov* [*1999*], *Yu.P. Seliverstov* [*2002*], and *D.V. Sevastyanov* [*2006*] propose a new scientific discipline, montology, for discussion. It is viewed as a complex and inter-disciplinary science of mountains of a natural and humanitarian profile. Yu.P. Seliverstov considers montology to be not only a natural and humanitarian science with practical orientation but also a certain philosophical category of cognition. D.V. Sevastyanov describes montology as humanitarian geography of mountainous areas, "including a wide variety of issues – from alpine ecology and disasters in the mountains to the specific features of nature use in the mountains, the ethnography and the economy of the peoples living in the montane areas" [*Sevastyanov, 2006, p. 28*].

Studies of the North are characterized in a similar way [*Zaidfudim and Golybchikov, 2003; Agranat, 2007*]. There are also serious grounds for recognizing the study of high-latitude and high-altitude regions, periglacial geography, as a science [*Golubchikov, 1996*]. Periglacial environments are as variable for their natural and cultural features as the high-altitude and high-latitude regions. It is here that a number of global geographic, geological, and biological issues are resolved most completely. The forecast global climate changes seem much more significant here than those occurring at lower latitudes and altitudes. Similarly, the management errors are manifested here faster, vaster, and brighter than elsewhere.

THE MAIN CHARACTERISTICS OF CONTEMPORARY PERIFLACIAL ENVIRONMENTS

The term "periglacial" was proposed by the Polish geologist Valery Łozynski in 1909 to designate the conditions of frost weathering in the Carpathians above the upper timberline. Further on, scientists expanded this notion. In the Russian geology, this term was used only to denote a strip of land directly adjacent to Pleistocene or modern ice sheets [*Glaciological Dictionary, 1984*]. Abroad, the term began to be used for description of geomorphological processes and forms in the regions with a cold climate, irrespective of their proximity to contemporary or ancient glaciers [*Tricart, 1969; French, 1983; Washborn, 1988*].

In our understanding, periglacial environments cover cold treeless extraglacial expanses, whose look is mainly determined by tundra and forest tundra or their alpine counterparts. Thus, they are determined in three coordinates: latitude, longitude, and altitude above sea level. However, periglacial environments include not only processes and forms. They contain life and terrains of their own, i.e., land and people.

It was Alexander Humboldt who noted the correspondence between altitudinal and latitudinal zones. Identifying "terra fria" in the Andes as a zone of cold, he viewed it as a tiny spot and reflection of the great Polar Zone [*Humboldt, 1851*].

The air temperature and the duration of the warm period decrease from each point of the Earth in the directions of both the altitude and the latitude. Beginning with a certain point, the entire environment adjusts itself to the increasingly somber and severe colors. Beyond the cold frontier of the forests, life begins to contract into a thin film. First its thickness is measured by meters, then by centimeters, and finally, by millimeters. At the same time, the area of abiogenic surfaces not covered with vegetation grows. Near the extreme limits of its existence, life exists under conditions of increased cosmic impacts and high activity of natural forces of destruction. It is here that, according to the expression of *L.R. Serebryanny* [*1980*], that inter-penetration and interaction of such contrast layers as biosphere and glaciosphere occur. Beginning with a certain altitude, the natural conditions begin to be favorable for H_2O to exist in the solid phase around the year. If mountains reach this altitude, glaciation takes place even in hot tropics. Part of the troposphere, where, given the suitable terrains, the existence of perennial snow patches and glaciers is possible, is called chionosphere. Its lower frontier has been named the snowline. Below the snowline, up to the cold timberline, modern periglacial environments dominate.

To be true, there are striking contrasts between highlands and polar regions in the world. The specific features of the environment of highlands are determined by reduction of atmospheric pressure as the altitude grows. In high latitudes, the polar day and the polar night reign for a large part of the year, while in lower latitudes, day and night alternate the year round. Yet, are these differences so important beyond the cold limits of the timberline? Or, maybe, it is more important, following Alexander Humboldt, to observe the features common to plains and highlands, to see the regularity of natural phenomena on the Earth, and to compare climbing a mountain to the travel to the North or South Pole?

It is not accidental that the periglacial regions of the world are compared to a certain continuum encompassing the entire globe [*Barry and Ives, 1974*]. In fact, this is the common periglaciosphere, including part of the troposphere within the range of altitudes from the snowline to the cold timberline (from high-latitude plains and lowlands to low-latitude highlands). In the equatorial latitudes, a special periglacial type of the environment is identified – páramo.

Similarly to the chionosphere, the periglaciosphere is developed over each point of the Earth's surface; however, in middle and low latitudes the montane "screen", on which the modern periglacial environments may be seen, does not always exist. In the Southern Hemisphere, large areas of the periglaciosphere are found in the ocean.

It is rather difficult to determine precise spatial limits of the modern periglacial environments. The snowline delineating the zone of perennial snow below demonstrates significant variations. It rises in the warm and arid areas, reaching 6,500 m above sea level in Tibet and the Andes and goes down in cold and moist areas, descending to the sea in the Antarctic level. Generally, the upper and polar timberlines and lines of flowering plants extend in parallel with the snowline. In the perioceanic regions, they retreat down the longitude and altitude, while in the continental regions they reach their maximum values. In some arid highlands, forests completely drop out of the range of altitudinal zonality; yet, there, too, it is possible to find the level corresponding to the upper timberline in the neighboring mountain ranges or to their occurrence limits in the past.

The snowline and the cold timberline, the most complex frontiers of our planet, are bordering on the periglacial environments. As *B.A. Yurtsev* said [*1991*], it is dropping out of trees in all the thermal zones, from the equatorial zone to the taiga zone, that indicates the most significant transformation of the ecosystems, which displays itself in reduction of the vertical capacity of the phytosphere by an order of magnitude, and, more often than not, of the horizontal sizes of biogeocenoses.

In extreme cold environments, many factors characteristic of the terrains of warmer regions become most evident. It becomes easier to discern their peculiar features, and in some respects they can be viewed as a model of terrains of lower latitudes and altitudes.

The following features of the Earth's land are characteristic of the modern periglacial environments:

1. High susceptibility to planetary and cosmic impacts due to reduction in the thickness of the troposphere (16 km at the equator compared to 8 km at the poles) and in the structure of the magnetosphere, extreme manifestation of cosmic and heliogeophysical parameters and phenomena, increase in the fraction of the invisible infrared and short-wave radiation in the Sun's spectrum; exacerbation of all the dormant illnesses in an unadjusted human organism.

2. Low positive values of the annual radiation balance and of the average annual air temperature; significant heat losses due to long-wave radiation of the Earth's surface. When exposed to direct solar heating, emergence of significant different between low air temperature and relatively high temperatures of the Earth's surface.

3. Susceptibility to large fluctuations in the parameters of the environment during frequent and prolonged decrease of temperatures below the limits of vital activity.

4. High activity of the forces of nature; extremely high rates of denudation and thermal denudation, often exceeding 1 cm per year on large areas; increased terrain-forming of snow and its wind transfer, a large amount of meltwater, of undulated water flows, frost weathering, permafrost phenomena, underground ice, and ice-saturated grounds, a high annual yield of water.

5. The young age of terrains, which more often than not escaped from water or ice only in the Holocene; continuing process of capturing the Earth's surface by the living matter, with a slow rate of soil and vegetation development.

6. High spatial concentration of all the natural zones and subzones; manifestation of altitudinal zonality at insignificant altitude alterations, sometimes amounting to only several thousand meters; drastic reduction in the thickness of living formations from many tiers of open forests 10 m high and more up to several millimeters-thick films.

7. Contrast micro-differentiation of environments, with wide distribution of symmetric circles, polygons, grids, steps, and strips of structural grounds, soils, and plant communities; emergence of contrast horizontal mosaic structure of life instead of the loss of horizontal tiers.

8. Increased intensity of horizontal energy and mass transfer, with its certain reduction in the vertical direction; high migration activity of animal and human communities.

9. Scarcity of the species composition of the flora and fauna, with extreme concentrations of certain populations in the periods of outbursts of their activity (masses of gnats and mosquitos, sudden cycles of rapid reproduction of lemmings, ample blooming of water); prevalence of evergreen perennials with a broad environmental range; absence of forests or insular occurrence of crooked and undergrowth timber.

10. Low reserves of phytomass (not more than 200 t/hectare) and its low annual growth rate (not more than 10 t/hectare), with high rates of daily productivity of phytomass (up to 1 t/hectare per day) at the beginning of the vegetation period; total excess of the underground phytomass over the over-the-ground phytomass, with the exception of extremely severe and dynamic locations, like scatterings of boulders.

11. Significantly different from the rest of the land, contemporary periglacial environments have to be special regions of cultures and of ethnicities; low density of population, with a focal character of development, is combined with traditional methods of nature use, social formations, beliefs, and cultures, the histories of which are counted by millennia.

High spatial contrasts of the periglacial environments. Despite the spatial concentration of the periglacial environments, several drastically contrasting terrains alternate here at relatively small distances. Beyond the cold timberlines, at a distance of several hundreds of kilometers from south to north, the vertical thickness of the phytosphere, the layer of the highest concentration of the plant life, decreases by 3–4 orders of magnitude. Accordingly, the vertical structure of the plant communities decreases and becomes simpler, while the horizontal structure of the plant communities becomes more complex. The reserves of phytomass and the biological productivity of the plant communities decrease by several orders of magnitude. If we assume the biomass of a cold desert to be equal to unity, its relation ship with the biomass of a cold semi-desert, tundra, and low-bush tundra will be expressed by the following ratio: 1:50:100:500 [*Alexandrova, 1983*]. As the total productivity of the plant cover decreases, all its main biotic parameters and characteristics seem to decrease drastically, as well. For example, in the most mountainous regions the main reduction in the density of the birds' population occurs during transfer from the sub-goltsy altitudinal belt to the goltsy altitudinal belt, while less significant reduction occurs during transfer from the forest belt to the sub-goltsy altitudinal belt [*Romanov, 2013*].

Significant concentration of the natural borders can be seen in the Southern Hemisphere approaching the Antarctic. Moving from north-east to south-west of Tierra del Fuego, over the extent of only 200–250 km, prairies give way to summer-green woods, which, in their turn, are changed by evergreen red beech forests and subarctic hummocky and mossy forest tundra consisting of crooked copses and bushy vegetation of birch-like red beech. In the south, this vegetation is limited by the ocean.

It seems that the high degree of concentration of the spatial borders of the periglacial nature needs closer attention of geographers. Unfortunately, such contrasts and gradients are not shown on the physical geography schemes of our planet, with their uniform latitudinal belts cut from the equator to the poles. The equatorial, subequatorial, and tropical belts shown on these schemes do not reveal the presence of such gradients as one subpolar belt. This follows from the very notion of the word "climate", which in ancient Greek means the tilt (of sunrays). The degree of this tilt rises on a sphere in the direction towards the poles, if illumination is above the equator.

One can detect even sharper contrasts above the upper timberline in the mountains, where the above mentioned zonal series is sometimes squeezed into a belt several hundred meters wide. The contrasts are most vivid in subtropical and tropical mountains. Nowhere in the world is there such diversity and are there such contrasts of habitats, climatic conditions, and ecological niches as in these regions. Hot arid deserts interchange with sultry moist spots, while brilliant ice neighbors a dark wood abundant with life.

One can say that such differences exist between hot arid deserts and tropical forests. However, if water emerges in a hot desert, life develops the same multi-tier formations in the oases as in the corresponding forests. In periglacial environments, life cannot achieve such abundance and diversity, even where heat is no longer a limiting factor, for example, near the hot springs of Iceland, Chukotka, or the Erebus Volcano in the Antarctic. Organisms cannot struggle for heat as actively as they struggle for water in the hot deserts.

Vividly expressed is the spatial zonality of environments not only at the zonal but also at the local level of observation, the closest one. Life beyond the cold timberline squeezes into thin near-surface film. It loses its vertical extent of tiers but instead acquires extraordinary horizontal variety and contrasts of micro-environments created by symmetric forms of the frozen micro-terrains. Nowhere except in the periglacial environments do they become so ividly expressed. Their sizes reveal a trend for reduction from several dozens of meters in high latitudes to several centimeters in tropical and equatorial highlands [*Golubchikov, 1996*].

The young age of the terrain and the relic character of its components. Of special interest is the high activity of the forces of nature in the periglacial environments, which most often reach the character of disasters here. The high rates of denudation here cover large areas. Snow and its wind transfer, meltwater, undulated water flows, frost weathering, permafrost phenomena, underground ice, and ice-saturated grounds play a major terrain-forming role here.

Modern periglacial environments are some of the youngest environments on our planet. Prevailing are shallow soils at the initial formation stage. The ragged shapes of the terrain and the undeveloped profiles of equilibrium of main plains and forests bear the traces of geological youth. The process of capturing these areas of the planet by the living matter is not yet complete. It can stop at any moment again. At the same time, these young terrains are rich with many relic and archaic elements, which are unstable in the modern environment. They include ancient lichen communities, developmentally imperfect dicotyledonous plants (families Ericaceae Ranunculaceae, Papaveraceae, Rosaceae, Saxifragaceae, Caryophyllaceae, Salicaceae, and Betulaceae, as well as insects [*Chernov, 1980*]. Most species of the animal and plant worlds have been ousted here by more modern forms of life from more favorable environments. Such a law can be traced for the human communities, as well.

Huge deposits of thermodynamically unstable buried ground ice and bodies of freshly frozen representatives of the mammoth megafauna can also be referred to relic and archaic elements. It was the great *Georges Cuvier* [*1840*] who assumed that they had been buried catastrophically fast.

The most ancient, often endangered ethnic groups have survived in the high-latitude and high-altitude environments. The hardly accessible territories hid them from invaders, while the few strangers who penetrated there would become part of the local communities. Now we see the most archaic models of life and the most ancient populations preserved in the mountains and forests and in the Arctic which are difficult to access. This archaism does not mean "backwardness", a mythologeme created in the framework of evolutionary Darwinism. According to the metaphor of Lev Gumilev, these are "not children but old people who have not yet lost all their experience but have too little strength to struggle against the young predator neighbors" [*Gumilev, 1989, p. 43*]. Their distant predecessors would survive on Earth not due to their victories over the others but due to their ability to live where the others could not live.

A CHANGE OF POLAR PARADIGMS

Resulting from the progress in the area of transport and network technologies, the environmentally clean and unpopulated periglacial expanses are becoming more and more attractive for the Man. There have appeared affordable light and warm clothes and chemicals to keep off mosquitos and gnats. Cost-efficient heating systems and heat insulation building materials have become widely spread. The Internet and mobile telecommunications, as well as small aircraft, have severed the insularity of the northern micro groups. Due to all this, cold and poor-access areas are becoming less significant obstacles for living in the severe cold environments.

Tourism is becoming the major factor of human presence in many high-latitude and high-altitude regions. The number of tourist visits to both polar regions is growing from year to year. About 5 million tourists come to Arctic and Subarctic every year. Alaska alone is visited by 2 million people. During the polar day season, 200,000 cruise passengers arrive at Nordcapp (North Cape) in Norway, and nearly 90,000 tourists visited Spitsbergen in 2008 [*Hall and Saarinen, 2010*]. Russia occupies the vastest expanse on the Arctic tourist market; however, there are no precise statistical data on the number of tourists there. There are forecasts predicting that tourism in Spitsbergen or Alaska will become as important as that in the Mediterranean countries or in the Caribbean basin [*Snyder and Stonehouse, 2007*].

Russia is the only country in the world which has extremely attractive periglacial expanses which are suitable for tourism. Practically all our peri-Arctic mountains may serve as unique spiritual retreats for those willing to escape from the burdens of the technological civilization. Nowhere in the world can one find such sunsets and sunrises as on the long polar day. Especially majestic are they under the continen-

tal skies of Russia. In Europe and even in Alaska, the skies at the same latitudes are often overcast by the mist of moist air. Our air is clear, due to the unique combination of Russia's polarity and continentality.

"If we remember the extraordinary clearness of the northern air in any season and the absence of dust and microbes in it, we will realize why living in the north turns out to be so healthy for all those who come there healthy and even for those who arrive with illnesses", – wrote the outstanding adept of the tundra *S.A. Buturlin* [*1929, p. 36*]. "Finally, there is no man or woman who would remain indifferent to the peculiar and rare beauty of the northern nature", – continues S.A. Buturlin. Among the attractions of the Arctic, he named "the feeling of absolute actual freedom which only the North provides, and especially the tundra" as one of the main ones driving people to come there.

– "Freedom of vision, as there are neither buildings nor trees obstructing the horizon not the omnipresent, except for the North, atmospheric dust, which blurs even the unobstructed horizon.

– Freedom of movement, as ways are open in the tundra for moving in any direction, and not only in winter. There are no impassable bogs and marshes, and there are neither quicksands not waterless deserts.

– Freedom to do any work you want, as you sleep, wake up, walk, and work whenever you like, unlimited by the time of the day and night. Only having experienced the never-setting sun of the summer half year, one can really appreciate this treasure. These sun-lit nights not even double our forces and capabilities, they increase them fourfold" [*Buturlin, 1929, p. 43–44*].

The famous polar explorer *Willem Stefanson* [*1933*] wrote that the Spaniards looked for gold in America, not for potatoes. However, the value of the tubers they delivered to Europe far exceeded the value of all the gold ever produced on the Earth. Extreme cold environments are similar to this. It is becoming clear now that they are not the bale but rather the blessing of mankind. Unlike the waterless deserts, inaccessible highlands or stifling rainforest, Arctic and Antarctic are more accessible for living. They are just cold, and that can be coped with. It is easier to avoid cold than sizzling heat. Cold is not a problem for an active man. Finally, one can get accustomed to cold.

Many of our contemporaries agree with the statements of *A.P. Parshev* [*2000*], who wrote that the climate of our country is too bad and bleak for its residents to have a comfortable life and that a good climate is found only in the Mediterranean area, in the subtropics or in South-Eastern Asia. "A good climate" is believed to be the climate good for languid leisure. However, a resting person seeking for relaxation and resting at resorts has never been the ideal for the mankind. At all times, active working men and women deserved appreciation and approval.

A.I. Treivish [*2002*] notes that Parshev's model is suitable only for the resources-dependent third world, whereas the scientific, technological, and cultural progress allows entirely new ways and approaches to nature use in these, yet severe for us, environments to be discerned. It is becoming more and more clear that the presence of cold expanses is not "a pest and curse" but the national treasure of the countries possessing them, their competitive strength.

The opinion is gaining momentum that it is necessary to develop new methodology for exploring the cryosphere as a source of benefits and opportunities for mankind, not as a source of threats [*Melnikov and Gennadinik, 2011; Melnikov et al., 2013*]. Thus, we are witnessing a change of paradigms in relation to the cold regions of the planet.

CONCLUSIONS

Reasons are provided for recognizing a new direction in the science of cryosphere, dedicated to the study of cold treeless iceless expanses, periglacial geography. Its subject is periglaciosphere, an equally important component of cryosphere as glacioshere and chionosphere.

Nowhere in the world is there such diversity and are there such contrasts of habitats, climatic conditions, and ecological niches as in periglacial environments. Many factors significant in the life of warmer belts reach their maximum there.

Tourism is becoming the main factor of human presence in the perioglacioshere. Awareness of periglacial expanses as a national treasure of the countries possessing them necessitates a change of the paradigm of cryology from the categories of risk to the categories of value.

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