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Biogeography of the Byrranga Mountains, Taymyr Peninsula, Russian Arctic

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ABSTRACT. The Byrranga Mountains (Gory Byrranga) are the most northern mountainous massif of the Taymyr Peninsula (Poluostrov Taymyr) in the Russian Arctic. Although studies of them began in 1736, they are one of the least studied areas of the Arctic. The region has no population, is remote, and has difficult access. As a result, the mountainous tundra ecosystems are preserved practically in a pristine state. The mountains are composed of siltstones and intrusive rocks of neutral composition; vast areas along all the mountain chain are occupied by exposed limestone. Rivers flow in deep intermontane depressions while lakes are found mainly in faults. The climate is an extremely severe continental type. Microclimatic areas provide some relief and support a rich and diverse flora. There have been 391 species and subspecies of vascular plants recorded, but no reliable data on the number of species of mosses and lichens are available. Relict thickets of tall willows are found in protected valleys of piedmont brooks, whereas relict alder-tree thickets occur on warm slopes. The mountain fauna includes nine mammal and 56 bird species. Intermontane depressions serve as corridors for seasonal migrations of wild reindeer that usually spend summers in the southern piedmont areas. Northern piedmonts and wide intermontane depressions are places where herds of musk-ox, introduced in the 1970s, concentrate. The bird fauna of relict willow thickets is highly specific and the fish fauna is quite diverse (16 species), but some species in Taymyr Lake (Ozero Taymyr) have been overexploited. This paper provides the first detailed biogeographical description of the Byrranga Mountains in English.

Contents

Introduction

The Byrranga Mountains (Gory Byrranga) remain one of the least accessible and least studied areas of the continental Arctic in Russia. The lack of access to the area during the former USSR, together with its remoteness, are obstacles that still exist today for researchers. Only small groups of scientists have managed to work in the Byrranga Mountains. The majority of their results either remain unpublished or have been published in short form in the Russian scientific press. In order to make this information available to the international scientific community, the authors have synthesized the biogeographical information on this region from a diversity of Russian sources, including their own research.

Taymyr Peninsula (Poluostrov Taymyr) is the only place on Earth where an entire ecotone, from northern taiga to polar deserts, is present and where a forestless ecosystem extends along a meridian for 900 km. This is also a place where formation of a tundra biome is the result of specific radiation and heat balances, and is why the peninsula could serve as a model of the entire Arctic (Matveyeva 2000). At the same time, the Byrranga Mountains occupy the central part of the peninsula and modify the distribution of heat and water, making the Byrranga biogeography unique. The diversity of ecological niches existing in the mountains, due to altitudinal zonation, the mixed character of the rocks, the presence of wide intermountain depressions, and slopes that protect against Arctic air masses, is important in determining the biological diversity.

The Byrranga Mountains were a powerful factor in the modern distribution of vegetation on the Taymyr Peninsula. It seems likely that they played the role of a 'protective shield' during the last Quaternary glaciation. As a result, reserves were formed in the mountains in which biotopes characteristic of a warmer pre-glaciation period were preserved. At the same time, during warmer periods when forest-tundra vegetation stretched up to piedmonts, the mountains hindered their northward distribution. As a result, the conditions that formed were favorable for the appearance (on the northern seaside depression and in low mountains) of a typical tundra flora and vegetation lacking southern boreal and hypo-Arctic plants.

History of discovery and exploration

The Byrranga Mountains occupy the northern part of the Taymyr Peninsula, which is the most northern continental part of the Arctic. They stretch 1100 km from west by southwest to east by northeast, from Yenisey Bay (Yeniseyskiy Zaliv) to the Laptev Sea, between latitudes 73°N and 77°N and longitudes 80°E and 114°E, making them the most northern continental mountains in the world (Fig. 1). The total area of the Byrranga Mountains is 170,000 km^2, with a maximum altitude of 1146 m. The area is one of the most pristine regions of the continental Arctic.

During seasonal nomadic movements, the indigenous Taymyr people (Nganasans, Nenets, Entsy, Evenkis, and later Dolgans) usually only went as far as the southern foothills of the Byrranga Mountains (Anderson 1998). However, a great number of mosquitoes appear on the North Siberian Lowland (Severo-Sibirskaya Nizmennost; Fig. 1) in early to middle June, which causes the reindeer to migrate to the seaside in July to escape them. Only rarely did local hunters follow these herds through the Byrranga Mountains, as local folklore made them a forbidden place.

The first Russian arrived on the Taymyr Peninsula at the end of the fifteenth century (Anuchin 1890, 1903; Bakhrushin 1927; Verbov 1943; Berg 1946; Lebedev and Yesakov 1971; Robarts and others 1999). The first information about the Byrranga Mountains dates back to the early seventeenth century. At that time a group of Russian manufacturers guided by A. Muromets and I. Muromets left their wrecked ship and presumably crossed the Byrranga Mountains from Fadey Bay (Zaliv Faddeya) to Taymyr Lake (Ozero Taymyr) (Magidovich 1957; Magidovich and Magidovich 1983).

In 1736 a group of the Great Northern Expedition (1733–43) headed by V.V. Pronchischev drifted along the eastern coast of the Taymyr Peninsula and caught sight of the eastern outskirts of the Byrranga Mountains. From 1740 to 1742, groups of the Great Northern Expedition headed by Lieutenant Khariton Laptev crossed the mountains several times through the Nizhnyaya Taymyra River valley (Laptev 1851), mapping parts of them. In 1743 the Academy of Sciences of the Russian Empire published the second edition of *Atlas of the Russian Empire*, with maps that were based on results of the Great Northern Expedition (Arseniev and Petrushevsky 1898). However, the Byrranga Mountains were not included. In 1759 the Academy of Sciences decided to publish a new (third) edition of the Atlas and sent a special list of 30 questions to all areas of the Empire. In 1766 'Topographic news for complete geographic description of the Russian Empire' was published (Arseniev and Petrushevsky 1898). But again, it contained no known information about the Byrranga Mountains.

In 1843 Professor Middendorf's expedition traveled along the Nizhnyaya Taymyra River valley. The expedition collected preliminary materials on the environment of central Taymyr and adjacent areas, including information on climate, hydrology, orography, ethnography, vegetation, and fauna (Kastren 1860; Middendorf 1869; Pasetsky 1974; Robarts and others 1999). Middendorf finally proved that the Taymyr Peninsula is a plain and that the Byrranga Mountains truly exist. In 1843 Middendorf proposed the name 'Taymyr Peninsula' (Troitsky 1980); when translated from Nganasan it means 'lush, rich, and abundant.' It is considered that Middendorf was the first to put the Nganasan name of the mountains, Byrranga, into common usage. Byrranga is translated as 'country of the dead.'

After the Turukhan expedition of I.A. Lopatin was completed in 1866 (the diary of the expedition was published only in 1897 after N. Miklukho-Maklay worked on it – see Lopatin 1897), preparation for an expedition to the north of Taymyr began but did not take place.

In the late 1880s and early 1890s, a group headed by Captain Michail Krasavin collected geographical and statistical materials in the region under an assignment of the Military Headquarters of the Russian Empire (Siberian Battalion of Engineering Troops). The works were performed under the guidance of the Nikolayevskaya Military Engineering Academy as well as the Empire Russian Geographical Society, and the St Petersburg Academy of Sciences. The group consisted of three officers and five civilians (casual workers). Among the participants was Captain Alexander Kurochkin, under whose leadership the mapping of 'Obdorsky North' (now Salekhard) was performed in 1893. Also among them was Iliya Miettinen, who in 1891 made a report on the expedition's scientific results at the St Petersburg Academy of Sciences and the Empire Russian Geographical Society (Zhulidov, unpublished data). As far as can be judged, interest in Taymyr and the adjoining southern territories

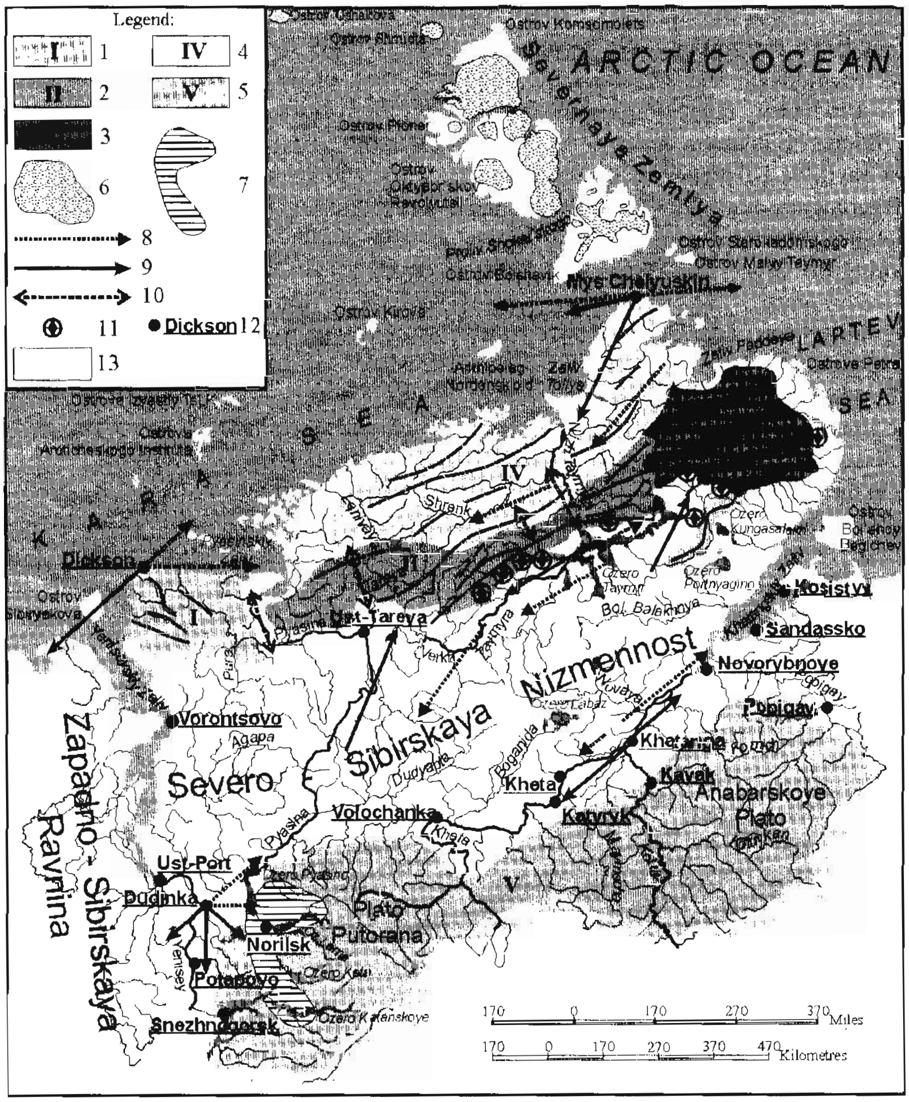

Fig. 1. Scheme of air-mass circulation in the Byrranga Mountains and adjacent areas prepared using data of the *Atlas Arktiki* (Anonymous 1985) and the *Klimaticheskii atlas SSSR* (Anonymous 1967) with amendments. Legend: 1–4. Regions in the Byrranga Mountains; 5. Sredne-Sibirskoe Ploskogor'ye (Middle Siberian Plateaus); 6. Glaciers; 7. Forest area damaged by emissions from the Norilsk ore mining and processing plant; 8. Summer prevailing wind directions; 9. Winter prevailing wind directions; 10. Areas of intensive summer exchange between Arctic and temperate air masses (the largest meridional intermontane depressions of the Byrranga mountains); 11. Areas where the authors worked; 12. Settlements (village and town names underlined); and 13. Taymyr area border. The length of the summer and winter wind arrows indicates the relative occurrence of seasonal wind direction in each region. Severo-Sibirskaya Nizmennost is the North Siberian Lowland and Zapadno-Sibirskaya Ravnina is the West Siberian Plain.

developed in connection with plans to build the Siberian railway (construction began in 1891).

By the early 1890s the average area of Taymyr Lake, the largest lake on the peninsula, was given as 2183 km^2 (Arseniev and Petrushevsky 1898; Robarts and others 1999). However, by the end of the nineteenth century the Byrranga Mountains remained unmapped. In fact, at the time no maps for Taymyr or any of Siberia existed with the exception of those of the Arctic Ocean coastline, narrow strips along the main rivers, and small territories near mines.

The next period of study of northern Taymyr began in 1921. A temporary Marine Scientific Institute, or Plavmornin, was organized to study the Northern Sea Route (Zhulidov, unpublished data). In 1928 a USSR Academy of Sciences expedition headed by botanist A. Tolmachev worked in the Taymyr Lake area and the southern foothills of the Byrranga Mountains (Tolmachev 1932a, 1932b). A project to measure the area of Taymyr Lake was commenced, and in 1929 geologist N.N. Urvantsev completed the measurements. Until the late 1990s, it was accepted that the area of Taymyr Lake was

4560 km^2 (Muranov 1973; Treshnikov 1986; Yegorov and Khomutova 1995; Magidovich and Magidovich 1983). Meanwhile, N.N. Urvantsev traveled from the upper reaches of the Verkhnyaya Taymyra River to the mouth of the Nizhnyaya Taymyra River, becoming the first to prepare a detailed geological description of the mountains and to set up a hypothesis about repeated glaciations of the Byrranga area during the Quaternary period (Urvantsev 1931; 1978).

However, a significant part of the Byrranga Mountains remained a blank spot until the late 1940s, when a detailed topographic survey was carried out. From the late 1930s to the mid-1940s the altitude of the Byrranga Mountains was considered to be 500 to 600 m (Filatov 1945), the same as that of the ridges in the central part of the region (Zernov and Kuznetsov 1937; Berg 1938). The mountains and the northern bank of Taymyr Lake were finally mapped between 1947 and 1952 but the northeastern part of the mountains was not included in the *Large physical geography world atlas* (Anonymous 1947). Also, the pattern of the coastline of Taymyr Lake and location of the rivers in the northeastern mountains remained unknown. When in 1928 A.I. Tolmachev climbed to the peak of the Titkounetti foothill massif, the visibility in the northeast was poor and prevented a view of local physical geographic features. For the next 20 years it was assumed that the main tributary of the Bikada River was a small river, the Kholide-Tari, which flows from the south and that there were no large tributaries originating in the mountains (that is, the rivers Malakhay-Tari, Nyunkaraku-Tari, Muruptuma-Tari).

In the 1930s ichthyological studies were carried out on the Pyasina River (Ostroumov 1937; Adamenko and Yegorov 1985; Pavlov and others 1999).

After the start of construction of the Norilsk mining-metallurgy plant and Dudinka post in 1935 and the railway from Norilsk to Dudinka in 1942, geological prospecting began in the Byrranga Mountains. However, the majority of the range was not investigated for ore deposits. During the development period of the Soviet nuclear programme, the mountains were searched for uranium ore, particularly near Lake Surovoye (Lake Bleak). There was also an attempt to mine uranium ore in the mouth region of the Pyasina River. The distribution of ore in the central and western parts of the mountains appeared to be widespread, but its content of uranium was so low that industrial mining was unprofitable (Pospelov, unpublished data). In the 1980s a number of goldfields were prospected, predominantly in the northeastern part of the range, and some of them began to be mined (such as Barkova River in the Leningradskaya River basin, Chelyuskin Peninsula). Some fields of copper and nickel were found, but most were unprofitable because of the small water volume of local rivers. The largest fields were prospected in the central part of the mountains between the Pyasina River and Verkhnyaya Taymyra River (Pospelov, unpublished data). A characteristic feature is that these fields are connected with limestone massifs.

In 1946 and 1947 mammoth remains were found at Mamont (Mammoth) River. An integrated expedition of the USSR Academy of Sciences working in the northern lowlands intermontane depression resulted in the preparation of the first floristic lists of vascular plants by Tikhomirov (1948, 1966) and studies of the perennially frozen ground by A.I. Popov. In 1968 an expedition journeyed to the most northern area of continental glaciation in the world, the glacial knot, Neozhidanny, to collect data (Govorukha 1971, 1973).

Intensive investigations of the Byrranga Mountains started in the late 1970s. Descriptions of the flora were produced for the Malakhay-Tari River and Bolshaya Bootankaga River (Kozhevnikov 1982, 1992), Aya-Turku Lake and Shaitan River (Sokolova 1982), and the Chernye Yary River basin (Safronova and Sokolova 1989). A biogeochemical survey of certain areas and an aerial inventory of reindeer were also conducted.

After the Taymyr Reserve — which, including the Bikada protected area, is 2,719,688 ha — was created in 1979 an integrated scientific working group began activities in the Byrranga Mountains and adjacent areas. Studies of the ecosystem, flora, vegetation, ornithofauna and teriofauna (mammals) have been made (Pospelova 1994, 1999; Anisimov and Pospelov 1999; Pospelova and Pospelov 2000, 2001, 2002; Pospelov and Voronin 2000). Specialists have also worked in areas of the North Siberian Lowland adjacent to the mountains (Matveyeva 1979; Chernov and Matveyeva 1979; Safronova and Sokolova 1989).

Experts of the Institute of Lake Research conducted long-term studies on Taymyr Lake (Adamenko and Yegorov 1985). Since 1989 the Arctic Expedition of the Institute of Evolutionary Morphology and Animal Ecology, under Professor E.E. Syroechkovsky's supervision, undertook annual studies of the Taymyr Lake area. Specialists from a wide variety of institutes took part in the Arctic Expeditions (Rogacheva 1994a, 1994b). The 'Large Arctic Reserve' — an area of 4.2 million ha (Syroechkovsky and Rogacheva 1994) — was established in May 1993, becoming one of the key achievements of the Arctic Expedition. In parallel, a group of specialists worked in the Byrranga Mountains and the Taymyr Lake area in the late 1980s and early 1990s (Zhulidov and others 1997a, 1997b, 1999; Robarts and others 1999). From 1993 to 1996 an integrated Russian–German expedition worked in the Levinson-Lessing Lake basin (Siegert and Bolshiyanov 1995; Bolshiyanov and Huberten 1996; Melles and others 1997).

Geology and relief

The Byrranga Mountains are folded block mountains of the Hercinian Age. In the north the geological structure borders upon more ancient Caledonian massifs of the Chelyuskin Peninsula (this name is not officially designated on a map, but it is widely used in the Russian Arctic and means the northern extremity of the Taymyr Peninsula separated by the 'Toll Bay–Faddey

Fig. 2. The main range of the Byrranga Mountains in the central reaches of the Fadyukuda River.

Bay line'). In the south the structure is limited by downwarping of the North Siberian Lowland, which is the continuation of the Western Siberian plateau. The most widespread rocks in the Byrranga Mountains are siltstones, intrusive dolerites, gabbro-dolerites, diabases, and granites (Fig. 2). Late Paleozoic limestone can be found almost everywhere in the mountains. In some places limestone forms mountains (Belaya Ridge, northeastern Byrranga). Jurassic and Cretaceous rocks (sandstone and sand) are scattered mainly in the foothill area. Quaternary deposits are represented largely by modern cryological regoliths (ranging from coarse boulder to detritus-loamy regoliths). Mountains composed of alluvial coarse pebbles and boulders are common in the intermontane depressions (Fig. 3). Sand-gravel deposits of ancient marine transgressions (Farmdale Interstadial and Holocene) are found almost everywhere in the foothills (Fig. 4) and in the peripheral areas of these depressions, as are lacustrine and bog deposits. They form fragmented terraces with heights of 50–250 m above sea level (Fig. 5). Diluvium loam deposits are well developed in the lower parts of the mountains. The existing peat bogs are no more than 0.5 m thick.

In terms of relief, the Byrranga Mountains can be divided into five regions (Fig. 1):

1. An isolated western massif, separated by the Pyasina River. It is a system of parallel ridges with altitudes of up to 426 m asl.
2. A central part of the Glavny Ridge, stretching between the Pyasina River in the west and the

Fig. 3. Nyunkaraku-Tari River valley situated between the mountains, eastern Byrranga.

Fig. 4. Southern foothills of the Byrranga Mountains and the lower reaches of the Oleniya River.

Severny River in the east. The region is a system of parallel table ridges (5–15) with altitudes of up to 697 m asl (average 400–600 m) divided by meridional tectonic intermontane depressions.

3. An eastern highland occupies almost the entire northeast of the Taymyr Peninsula. The highland is a system of chaotic alpine ridges with absolute heights of up to 1146 m asl (average 600–800 m). The ridges are divided by tectonic and glacial-exaration intermontane depressions.
4. Northern lowlands are a system of widely spaced parallel table ridges with altitudes of up to 420 m asl (average 250–300 m). They are located in the Shrenk, Trautfetter, and Leningradskaya river basins to the north of the Glavny Ridge.
5. Sredne-Sibirskoe Ploskogor'ye (Middle Siberian Plateaus): solitary enclaves are located to the southeast of the Byrranga Mountains. These enclaves are isolated ridges and the Kiryaka-Tas, Titkounetti, and Lambeshinetti massives with heights up to 617 m asl.

Geocryological conditions

The Byrranga Mountains are located in an area with an average permafrost depth of 1100 m and an air temperature of −18°C (Ershov 1989). The seasonal thawing of soils is 0.2 m in peat bogs on river terraces and 1.4 m on crushed-rock and detritus-sandy soils.

Almost all cryological processes and phenomena are well developed in the area (Anisimov and Pospelov 1999).

Fig. 5. The relief form of relict stony *baydjarakhs* developed on *ostanets'* (weathered ancient marine terraces), typical of the frontier zone of Byrranga intermontane depressions indicated in Fig. 1.

The most developed process is cryogenic weathering resulting in the formation of block breakdowns of stable rocks (dolerites, gabbro, etc). Eventually this process, together with cryogenic sorting, leads to the formation of nanostructural relief — different types of stone rings, honeycomb rocks, stone polygons (according to Washburn 1979). Nanostructural relief is more typical for the apical plateau.

Development of patterned nanorelief is closely associated with cryological processes. The patterned nanorelief brings about formation of bare ground areas banded by a border and divided by inter-area cracks. The patches are divided into three types (Pospelov 2001):

- Denudation — corrosive patches occur on low peaks and on ancient terrace surfaces in conditions of cryogenic sorting and weathering at sites the surfaces of which are covered with coarse detritus and pebbles. There is no vegetation on the borders of these patches due to strong winds blowing off the snow.
- Cryoturbative patches are common on loams with small amounts of detritus. The pattern of spots is formed under ice wedges during periods of freezing and melting. There is no vegetation on such patches because of intensive cryoturbation and the development of surface needle ice (similar to the thixotropic state) on bare soils in autumn.
- Solifluction patches originate on gentle slopes and are associated with sod breaches and effusions of thixotropic soil under conditions of solifluction.

Congelifluction (according to Washburn 1967, 1979) is well-developed. The predominating process is slow mass wasting along low steep slopes, resulting in the formation of the above-mentioned patches and breaches. On more gentle slopes another microrelief is formed: a system of low banks stretching across the slope (washboard). Rapid solifluction (thermodenudation) is rare and can be observed only on slopes washed away by rivers and brooks and located in lowlands and intermontane depressions composed of permafrost.

Ice wedges (vein ice) and related polygonal relief of different stages are found on river terraces in intermontane depressions. The thickness of these modern ice wedges is up to 1.5 m and they can extend down to a depth of 15 m. Thermokarst is well-developed, in some cases leading to the formation of cemetery mounds (or *baydjarakhs*). Besides the linear thermokarst on slopes, so called 'dell' complexes can often be found in the Byrranga Mountains. It is one of the most widespread cryogenic forms in terms of the area occupied, second only to patchy tundra.

Icings are occasionally found, with the largest, having an area that exceeded 0.5 km^2, being discovered in the junction of the Fadyukuda and Ostantsovaya rivers.

Modern glaciation

Modern glaciation is found only in the northeastern part of the Byrranga Mountains (regions III and IV, Fig. 1) and is represented by six large and small glaciers. The largest is the Nezhdanny glacier with an area of 4 km^2. There are 96 glaciers with a total area of 30.5 km^2 (Dolgushin and Osipova 1989). Alimentation of the glaciers occurs mainly from northwestern winds. The average annual precipitation in glacier zones is 400–500 mm with a melting rate of 100–120 g cm^{-2}, which exceeds snow accumulation on glacial surfaces, the latter being 40–70 g cm^{-2}. Thus, the Byrranga glaciers are decreasing in size. From 1960 to 1977 more than a dozen glaciers disappeared and some of the glaciers split into smaller ones (Govorukha 1971, 1973; Dolgushin and Osipova 1989).

Climate

There are no fixed meteorological sites in the Byrranga Mountains, and reliable climatic data, especially for winter, are extremely limited. The following description is based on archived data from the 'Dikson' Meteorological Station on Taymyr Peninsula (Fig. 1). Part of the archive is now kept in the Taymyr Reserve. The archive contains information from temporary checkpoints of geological expeditions between 1944 and the 1970s and from other expeditions and visits by specialists to the region.

The mountains are located in the Arctic temperate continental climatic zone (in the western part, the climate is less continental). In summer the prevailing Arctic air masses intensively move to the south with moderate air masses moving to the north through meridional 'corridors' — intermontane depressions/glacial troughs (Fig. 1).

Winter lasts for 8.5–9 months (from October to May). Average January temperatures are –35 to –40°C. The lowest temperature (–63°C) was registered on 27 January 1958. However, there have been verbal reports that the absolute minimum recorded was –71°C. The polar night continues for 85–100 days. The snow cover is 34–75 cm deep on flat surfaces not exposed to wind. But on convex mountain summits there is no evidence of snow cover. On the leeward slopes and in canyons, snowfields of up to 15 m high are formed, thawing only by the end of the summer, or not melting at all (Pospelov, unpublished data).

The average temperature in July is +7 to +10°C with an absolute maximum of 25°C, which occurs not more than 2–3 times per summer. July is the warmest month of the year. In August the average temperature can be +4 to +5°C, and short-term maxima up to +12°C, with snowfalls possible and night frosts recorded. According to the sparse information available, the annual average air temperature in the central part of the range is –19.4°C. The vegetative period is estimated (with $T \geq +5°C$) at 30–50 days. In these conditions annual flowering for some vascular plants is impossible. Some perennial herbaceous species are unable to develop epigeal organs every year. However, photosynthesis in the Arctic can proceed under temperatures well below +5°C (Gerasimenko and others 1980).

Annual precipitation varies from 250 mm in the east to 450 mm in the west. Maximum precipitation occurs in summer (Anonymous 1985). According to the available

Fig. 6. Oleniya River canyon, central Byrranga.

scanty information, the average annual amount of precipitation in the mountains is 324 mm. For comparison, in the Taymyr Lake area the average precipitation level for the 1881–1980 period of instrumental observations was 241 mm with a maximum of 380 mm in 1968 and a minimum of 137 mm in 1903 (Adamenko and Yegorov 1985).

The available data show that despite their moderate altitude the Byrranga Mountains become a significant barrier for high Arctic cold air masses on their way to the south in summer. Due to this, the southern foothills contain a zone with a microclimate warmer than in the more southern middle part of the North Siberian Lowland (Fig. 1). In this zone vegetation is more specific for the southern belt of typical tundra rather than for the northern tundra of the Taymyr Peninsula (Pospelov 2000).

The Norilsk mine and concentrating plant poses the only impact on the western sector of the mountains (see Fig. 1). This is due to the peculiarities of the wind pattern in the Norilsk area. During winter southern winds prevail while in summer western and southwestern winds dominate, and are partially detained by the Putorana Plateau offshoots. Summer winds are less intensive than winter ones. During the year eastern winds prevail in the central and eastern parts of the foothills and the mountains. The area impacted by the Norilsk ore mining and concentrating plant coincides with the forest damage zone located in the vicinity (Fig. 1).

Hydrology

Rivers

The Byrranga Mountains are crossed by two large rivers, the Pyasina (818 km long; basin area of 182,000 km^2 and average flow of 2,600 m^3 s^{-1} (Domanitsky and others 1971; Treshnikov 1986) and the Nizhnyaya Taymyra (187 km long; basin area of 124,000 km^2 and average flow of 900–1,200 m^3 s^{-1}; Robarts and others 1999). All rivers located in the mountains are shallow (<1.5 m) with intensively meandering river-beds. Most of the river-beds occupy wide (3–10 km and more) intermontane depressions (Fig. 3). However, in some sections rivers in the northern parts of the lowlands (Shrenk and Trautfetter rivers) have deeply incised river-beds. Often canyon-like valleys of 20 to 200 m in height (Fig. 6), some with waterfalls, are characteristic of the rivers crossing the main ridge of the mountains.

High water periods and ice drifts on the large rivers start in late June to early July. Floods occur by mid-June in the mountains. At this time, small rivers often experience water and snow flows. Mountain rivers flood after heavy summer rains when water can rise up to 1.5 m above the low-water level for short periods. The rivers freeze by the end of September; this extends to the bottom, with even large rivers completely freezing by the end of winter.

Lakes

Taymyr Lake is the largest Arctic lake in the world. It is wholly located within the Byrranga Mountains except for three of its bays (Nestora Kulika, Ledyanaya, and Yamu-Baikura) that border the mountains in the south. Significant annual fluctuations of water levels — up to 9 m according to the archive data of the polar station 'Ozhidaniya Bay' — are typical. The maximal water levels are recorded in early or mid-July, the only period when the actual shoreline corresponds to that mapped. The central part of the lake dries up almost completely in winter, when the inflow of rivers essentially ceases (Robarts and others 1999).

As a rule the lakes of the region are located in tectonic faults. The largest are Levinson-Lessing, Gornoye, Schel, Surovoye, Entusiastov, Aya-Turku, and Naduda-Turku.

Fig. 7. Surovoye (Bleak) Lake, central Byrranga.

These have an elongated form (except for Aya-Turku and Naduda-Turku) and steep basin slopes without beaches (Gornoye and Surovoye lakes) (Fig. 7). The lake areas vary from 3 to 20 km^2. Their depth is considerable; for example, Levinson-Lessing Lake is 108 m deep (Bolshiyanov and Hubberten 1996), and Schel Lake 65 m. In both cases, lake bottoms lie below sea level (the surface of Levinson-Lessing Lake is 47 m below sea level (Bolshiyanov and Hubberten 1996). The period when a lake is ice-free depends on its size, but it rarely exceeds two months (from mid-July to September). By the end of winter the ice on the lakes is 2–2.4 m thick. Water temperature in the hypolimnia of such lakes is 1–2°C (Melles and others 1997). There is only a short period when, in the coastal shoals, the water warms up to 10°C.

There are notable variations in pH values (6.5 to 7.5) only in the upper water layers (up to 10 m deep). At great depths they are constant at 7.5 throughout the year (Melles and others 1997). However, depending on the mineral composition of the rock in the basin, pH values can vary, as in, for example, some small lakes in which the pH at the surface (0–0.5 m) is 6.12–6.32.

Sedimentation rates (as dry weight) in such lakes are highest in the rainy summer period and can reach 3.5 g m^{-2} during spring floods. In summer these range from 0.05 to 0.2 g m^{-2} (Melles and others 1997).

Large intermontane depressions enclose ox-bow (bayou) and thermokarst lakes no more than 2 m deep.

Flora and vegetation

Routine methods of field landscape descriptions were used for the studies in the Byrranga Mountains. These included detailed vegetation descriptions and collecting plants for the herbarium. Botanical descriptions were carried out on test areas of 100 m^2. At least five such areas were described for each location. Botanical descriptions for these were accompanied by brief botanical observations on study walks. Dominant and co-dominant species, belonging to different life forms (mosses, dwarf shrubs, shrubs, grasses, lichens) were registered. The title (formula) of plant associations was given according to rules adopted in the Moscow phytocenology (botanical) schools, that is, based upon dominants of each layer, which as a rule is presented by a single biomorph. Dominant species or group of species is given last; for example, in the moss-dryad tundra, the dryad is dominant, while in the dryad-moss tundra the moss is dominant. Besides the title, a formula consisting of scientific names of dominant and co-dominant species is given. First place in a title is allocated for the species of the dominant biomorph, the second place is for the first order co-dominants, and the third is for the second order co-dominants, irrespective of their height. If several dominants (or co-dominants) of a single biomorph are present they are united by a plus (+) while those of different biomorphs are linked by a minus (–).

Plant species were identified according to Anonymous (1960–87); the vascular plants according to Cherepanov (1995); and the mosses according to Ignatov and Afonina (1992). To confirm identifications, the authors' herbarium materials were compared with those of the herbaria at Moscow University and the Botanical Institute of the Russian Academy of Sciences, St Petersburg.

Flora overview

According to available herbarium data, there are 391 taxa of vascular plants (species and sub-species) in the

Byrranga Mountains, belonging to 118 species and 40 families. Of all the species discovered in the mountains and foothills, 63 (or 18%) inhabit only this area without spreading to the plain. Most of the plants are evenly distributed in the Byrranga area and are found from the far northwestern foothills to the northeastern part of the mountains. However, some have specific distributions. In the Byrranga flora there are plant populations, the main habitats of which are located in remote eastward areas, indicating that in the Megaberingiya epoch there was an intensive floristic exchange between Taymyr, the northeastern extremity of Asia, and Alaska (Petrovsky 1997). There are also relict isolated plant populations the principal habitats of which are 400–500 km to the south, which is evidence that in the early Holocene period vegetation similar to the modern forest tundra was widely developed in the southern foothills of the Byrranga Mountains (Pospelova 1999; Pospelova and Pospelov 2000). The peculiarity of the mountainous flora is emphasized by a high percentage of endemic and sub-endemic Western Siberian species (19% compared to 10% on the plain). In general, the Byrranga flora can be characterized as mountainous moderately Arctic continental (Pospelova and Pospelov 2002).

Vegetation overview

Byrranga vegetation is diverse — mainly due to the variety of substratum and hydrothermal conditions — and changes from the southwest to the northeast with the climatic gradient. The diversity of phytocenosis and vegetation composition are higher than in the western part of the central Byrranga (Fadyukuda River basin, Aya-Turku Lake). In the middle part of the mountains (Levinson-Lessing Lake, Nizhnyaya Taymyra River basin) community diversity is lower, and in the far northeast, where the mountains border the flat Arctic tundra, the vegetation is poor and unvarying.

The peculiar features of the vegetation are associated both with the relief and microrelief (for example, patterned grounds, stone rings, block-strips, mountain dells) formed under the impact of cryogenic processes (Anisimov and Pospelov 1999). Spot (frost-boil) tundra is widely spread. On unsteady taluses, isolated patches of vegetation replace tundra. Main characteristic species in these patches are dwarf shrubs such as *Dryas punctata*, *Cassiope tetragona*, and *Salix polaris*, creeping stem and sod grasses. Lichens are epilithic, and rarely epigenous, in the areas with altitudes >600 m, and only in the river valleys and lowland depressions are mosses characteristic. These patchy communities differ from plain tundra vegetation, where in most communities dominant species are mosses. In conditions of micropolygonal soil cracking, mosses are concentrated in polygon cracks and moss sod is penetrated by rhizomes of *Carex*, forb-grass (motley-grass), *Salix polaris*, and *Cassiope tetragona* strips. On elevated borders of polygons with patterned ground in the middle, *Dryas punctata* cushions and trellises, patches of forbs, turfs of grasses, and woodrushes are developed.

Vegetation of different relief elements and altitude zones

Altitude zoning is typical for the Byrranga Mountains, with borders of the zones fluctuating, depending mostly on slope exposure, steepness, and substratum density. There are two altitude zones, lower and upper.

The lower zone is represented on southern slopes by dwarf shrub-sedge-moss tundra (*Hylocomium splendens* + *Tomentypnum nitens* – *Carex arctisibirica* – *Dryas punctata* + *Cassiope tetragona*) with inclusion of willows (*Salix reptans*, *S. pulchra*). In the lower sections of the eastern part of the mountains the amount of *Cassiope tetragona* increases. The lower western parts of the mountains are covered by birch-sedge-moss tundra (*Tomentypnum nitens* + *Aulacomnium turgidum* – *Betula nana* – *Eriophorum polystachion* – *Carex arctisibirica*) more typical for the southern plain Taymyr tundra. From an altitude of 50–100 m, as the surface becomes covered by crushed rocks, the birch-grass-moss tundra is replaced by forb-moss-dryad tundra and dryad-moss tundra with predomination of *Dryas punctata*, *Cassiope tetragona*, and various forbs (*Minuartia arctica*, *Luzula* sp., *Papaver polare*, *Eritrichium villosum*, *Potentilla hyparctica*, *Saxifraga* sp.), sedges (*Carex rupestris*, *C. misandra*), and grasses (*Poa arctica*, *Festuca brachyphylla*, *Alopecurus alpinus*). The area of forbs-moss-dryad tundra and dryad-moss tundra steadily increases with altitude. The coverage of the vegetation is reduced from 50–60% in the lower part of the mountains to 20–30% in the upper part. Also, the vegetation cover becomes less variable and more xerophytic (*Novosieversia glacialis*, *Draba subcapitata*, *Oxytropis nigrescens*, *Poa pseudoabbreviata* are more abundant). In drained areas *Dryas punctata* is partially or fully replaced by ground willow (*Salix polaris*), and the number of *Luzula nivalis*, *Deschampsia brevifolia*, and *Ranunculus nivalis* increases.

From east to west the upper boundary of the forbs-moss-dryads tundra and dryad-moss tundra zones rises from 250 to 450 m. However, on convex and flat surfaces of crushed rock tops more than 250 m high covered with little snow cover, dryad tundra is replaced by tundra patches. The predominant species are cryoxerophite mosses (*Racomitrium lanuginosum*, *Dicranoweissia crispula*, *Abietinella abietina*, *Rhytidium rugosum*), low grasses and forbs (*Poa pseudoabbreviata*, *Draba* spsp., *Saxifraga* spsp.), and *Papaver polare*, *Potentilla uniflora* and *P. subvahliana*. Not more than 15% of the area is covered with vegetation. If the substratum is loam and low detritus then the dryad tundra is replaced by grass-willow-moss tundra (*Aulacomnium turgidum* + *Tomentypnum nitens* + *Sanionia uncinata* – *Salix polaris* – *Deschampsia brevifolia* – *Luzula nivalis*). Above the dryad tundra zone the prevailing types are willow-moss-*Novosieversia* tundra patches (*Novosieversia glacialis* – *Rhytidium rugosum* + *Abietinella abietina* + *Hypnum* sp. – *Salix polaris*) (the coverage is 15%) or epilithic–lichen mountain deserts with certain vascular plants. In places with weathered substratum *Deschampsia brevifolia*-willow-moss tundra

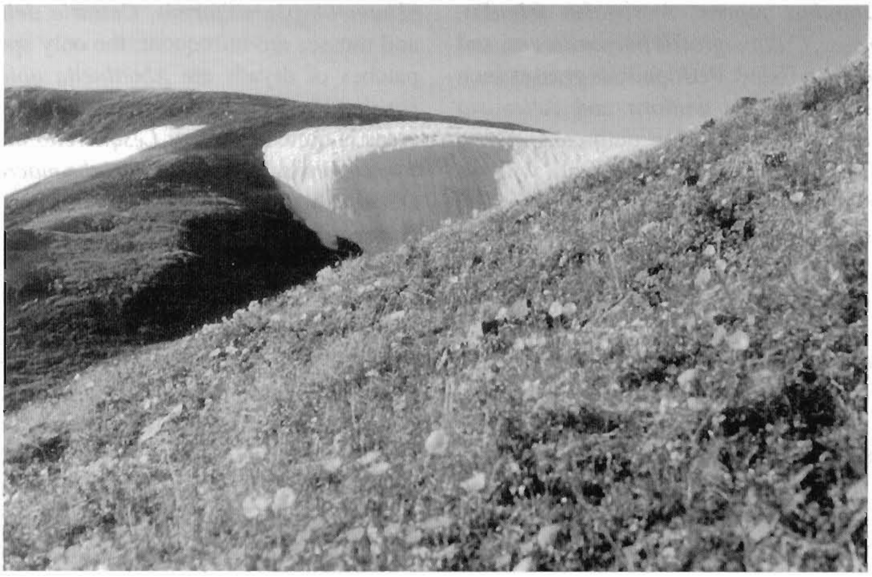

Fig. 8. Alpine meadow in the Byrranga Mountains with rich grass-forbs vegetation.

patches (*Tomentypnum nitens* + *Sanionia uncinata* – *Salix polaris* – *Deschampsia brevifolia*) are found, the coverage being less than 25%.

In the upper zone the vegetation appears at altitudes exceeding 600 m. It is either rarified *Phippsia algida* – mosses wet tundra (*Distichium inclinatum* + *Dicranoweissia crispula* – *Phippsia algida* – *Herbae*) (similar to Arctic deserts) or mostly lifeless rock rubble. Lichen deserts represent vegetation on the highest plateaus. Vegetation disappears at altitudes above 800 m (typical only for the western upland). On the northern gentle slope of the Glavny Ridge all zone borders are shifted 100–150 m downwards and the zones of moss-dryad and dryad-moss tundra (*Dryas punctata*) give way to ground willow (*Salix polaris*).

For slope benches and bases of nival mountainous terraces, small back bogs are typical at all altitudes. The dominant vegetation is eutrophic mosses (*Cinclidium stygium*, *Bryum cryophyllum*) and certain grasses and forbs (in the high zones the usual species are *Carex arctisibirica*, *Saxifraga cernua*, *Cardamine bellidifolia*, *Ranunculus nivalis*; in low zones they are joined by *Dupontia fischeri*, *Carex lachenalii*, *Minuartia stricta*, *Pedicularis albolabiata*). In nival niches on carbonate slopes *Carex redowskiana*, *C. atrofusca* and *Equisetum variegatum* are common.

On intermontane steep slopes with southern exposure, the predominating vegetation is similar to that described above. Here *Carex concolor*, *Eriophorum vaginatum*, *E. polystachion*, and *Salix reptans* with a predomination of mosses (*Tomentypnum nitens*, *Sanionia uncinata*, *Dicranum elongatum*), lichen (*Stereocaulon alpinum*), and some vascular plants (*Carex arctisibirica*, *Dryas punctata*, *Salix polaris*) occur more frequently. At a height of 100 m this vegetation is replaced by complexes of forbs-dryad tundra and forbs-*Cassiope tetragona*-moss tundra with abundant forbs. Occasionally they are replaced by cryophilic steppe meadows. Rocky outbreaks with small underlying nival niches are particularly rich in flora: a single slope can hold up to 80 species of vascular plants, and most of the relict populations of rare species can be found here. Dryad tundra is typical for convex parts of the slopes; *Cassiope tetragona* tundra is typical for mildly concave areas with favorable conditions. Mosses are poorly developed here. In *Cassiope tetragona* tundra such forbs as *Hylocomium splendens*, *Tortula ruralis*, and *Philonotis tomentella* are multifarious. Species typical for this tundra are *Carex quasivaginata*, *C. melanocarpa*, *Draba pilosa*, *D. pseudopilosa*, and *Pyrola grandiflora*.

Abundant forbs of cryophilic steppe meadows (Fig. 8) are relict communities that have survived in the Byrranga Mountains since the Holocene optimum, a period 7000–10,000 years ago when the climate was significantly warmer and tundra-steppe landscapes flourished in the continental Arctic. Most often these relict communities are found in western Byrranga regions, especially on the southern macroslope. They are also quite common in the eastern upland and in the central mountainous part, although covering smaller areas. As a rule, abundant forbs of cryophilic steppe meadows are common for southern slopes in mountain canyons. These meadows can also be found on more open slopes but species diversity is poor. Abundant forbs of cryophilic steppe meadows are closely set grass plant communities with predomination of fine grasses such as *Poa glauca* s.l., *Festuca brachyphylla*, *F. viviparoidea*, *F. auriculata*, sometimes *Elymus vassiljevii*, *Trisetum spicatum*, *Koeleria asiatica* and various forbs such as *Potentilla prostrata*, *P. anachoretica*, *Rumex pseudooxyria*, *Oxytropis middendorffii*, *Astragalus subpolaris*, *Hedysarum arcticum*, *Pedicularis amoena*, *P. oederi*, *Polemonium boreale*, *Delphinium middendorffii*, and *Arnica iljinii*. In certain parts of such meadows species unusual for the Byrranga Mountains, such as *Thymus extremus*, *Carex fuscidula*, *Kobresia* *simpliciuscula, Dianthus repens, Astragalus frigidus, Artemisia arctisibirica, Calamagrostis purpurascens*, and *Eremogone formosa*, are found. Petrophilous grasses such as *Rhodiola rosea, Potentilla uniflora* and *Artemisia sericea* are common on the rocky outbreaks. Ferns (*Dryopteris fragrans, Woodsia glabella*) and willows (*Salix lanata* s.l., *S. hastata, S. arctica*) are usually located in boulder outbreaks, especially in the lower periphery of the slopes. Here, due to snow accumulation in winter and subsequent warming during summer, some dwarf shrubs more typical for southern zones (*Ledum decumbens, Vaccinium uliginosum* subsp. *microphyllum, V. minus, Empetrum subholarcticum*) are found.

Communities of nival small-sized grasses (*Ranunculus pygmaeus, Saxifraga hyperborea, Cochlearia arctica, Phippsia algida, Draba lactaea*) are distributed under rocks and slope edges that accumulate large amounts of slowly melting snow. In peripheral parts of the communities moss cover (*Sanionia uncinata, Campylium stellatum*) is developed. Towards the inner periphery it is gradually replaced by moss-*Cassiope tetragona* tundra similar to that described above.

Relict thickets of alders (*Duschekia fruticosa*) were discovered in the western part of the mountains in the foothills. The brushwood is very thick and 70–80 cm high. Such species as *Betula nana, Ledum decumbens, Vaccinium uliginosum* subsp. *microphyllum, V. minus, Pyrola grandiflora* and mezoxerophilous sedges (*Carex macrogyna, C. rupestris, C. ledebouriana*) are always found near it. Moss cover is comprised of *Hylocomium splendens, Abietinella abietina* and *Rhytidium rugosum*. There is no vegetation, apart from mosses, under the alder bushes.

Waterlogged eutrophic communities with a specific floristic composition (*Carex concolor, Eriophorum callitrix, Juncus biglumis, Cardamine microphylla, Minuartia stricta, Oxytropis mertensiana, Gastrolychnis apetala*) are common in areas with abundant continuous moisture. On stony ground, especially in the west, *Poa paucispicula* is common and *Cinclidium stygium, Campylium stellatum, Orthothecium chryseon, Bryum cryophyllum* and *Sanionia uncinata* form dense moss cover. On taluses the common species are long-rhizome or turf plants that are able to root in the moving material, such as *Artemisia borealis, Poa glauca, Cardaminopsis petraea, Chamaenerion latifolium, Papaver polare* and *Novosieversia glacialis*.

Vegetation cover of mountain areas composed of limestone should be specially mentioned. The most convex tops have almost no vegetation, or at least no densely growing vegetation. The only plants that can be found here are several robust fine grasses such as *Saxifraga oppositifolia, Braya purpurascens*, and *Carex rupestris*, bushes of *Salix arctica* that are often flat and deformed, and oppressed dryads. On more turf-covered flat tops and slopes, forbs-sedge-dryad tundra patches (*Dryas punctata-Carex rupestris + C. misandra-Oxytropis* spsp.) are usual, covering up to 50% of the surface. Lichens (*Thamnolia subuliformis, Cetraria delisei*) are common and mosses are infrequent: the only species found under patches of dryads are *Abietinella abietina* and *Tortula ruralis*. Floristically, the plant community on limestone areas is quite abundant: *Lesquerella arctica, Puccinellia byrrangensis, P. angustata, Draba macrocarpa, D. pohlei, D. alpina, Braya spsp., Taraxacum phymatocarpum, Papaver polare, Thalictrum alpinum*, are found here. In damp sections on limestone slopes *Carex redowskiana, C. atrofusca, Equisetum variegatum, Minuartia stricta, Oxygraphis glacialis* and mosses, such as *Orthothecium chryseon* and *Ditrichum flexicaule*, are common. Very rarely mountain cryophilic-steppe meadow communities with a predomination of *Poa glauca, Festuca viviparoidea, Elymus* sp., and *Koeleria asiatica*; sedges, such as *Kobresia myosuroides, K. simpliciuscula* and *Carex rupestris*; and cryophilic-xerophyte forbs such as *Potentilla prostrata, Oxytropis tolmaczevii, Dianthus repens* and *Eremogone formosa*, are found on dry and protected limestone slopes.

Valley vegetation is developed in intermontane depressions occupied by large rivers and springs. In the upper reaches of rivers located in higher mountain areas, the vegetation cover is sparse and consists of mosses and small-sized grasses. Unstable groups of petrophytes periodically destroyed by floods are found in central parts of the valleys on flooded pebble soils and cobble round stones. Areas flooded only during spring floods have meadow vegetation with a prevalence of *Leymus interior, Chamaenerion latifolium, Oxytropis middendorffii, Astragalus subpolaris* and *A. tolmaczevii*, whereas on damper ground the dominant form is low grass willows. Due to the fact that the floodplains in the Byrranga Mountains are composed solely of pebble and cobble round stones with small amounts of sand detritus, psammophytes that are common on river delta plains are scarce. However, on fragmented sand terraces small sections of *Kobresia myosuroides* communities are often found with the inclusion of sub-shrubs such as *Cassiope tetragona, Dryas punctata* and, occasionally, *Salix polaris*. Most elevated sections of the floodplain are colourfully covered with dryad-forbs tundra with a prevalence of *Festuca richardsonii, Oxytropis middendorffii, Astragalus subpolaris*, and *Dryas punctata*. Its floristic composition is very diverse. As the tundra overgrows, it is replaced by dryad-moss tundra with frequent undersized willows (*Salix reptans, S. lanata* s.l.) and thick moss cover (*Sanionia uncinata* and *Tomentypnum nitens*). Some grassland species recede and the species composition grows scantier. Finally, on river valley terraces, polygonal bogs are found at different stages of development (from sedge bogs to flat hummocky integrated bogs with dry hummocks to *Polytrichum strictum* and wet sedge depressions). Most probably these ecosystems/complexes are relicts.

In valleys of some springs located mainly on southern mountain slopes, willows (*Salix alaxensis, S. lanata* s.l., and occasionally *S. hastata*) are found (Fig. 9). The shrubs

Fig. 9. Tall-tree willow thicket (small forest) in the Dyabaka-Tari intermontane depression.

are tall (up to 2.5 m high) and are apparently relicts. These unique communities are dense thickets, sometimes growing directly on pebble alluvium or on adjacent floodplain areas. Because of the thickness of growth, there is no grass cover directly under the shrubs, but between them there are grass-plots/glades with grasses and mesophyllous forbs such as *Poa alpigena*, *Calamagrostis lapponica*, *C. langsdorffii*, *Bromopsis taimyrensis*, *Ranunculus propinquus*, *Taraxacum ceratophorum*, *Potentilla stipularis* and *Valeriana capitata*.

Soils

In contrast to the soil cover of plain tundra, in the mountains gley processes are weakly developed and may occur only on wide plain terraces and on gentle slopes of the lower mountain belt. Gleysols are found only in relief depressions, in sags between ridges and/or under moss communities of dellies. The following are the most widely spread:

1. Lithosols: a characteristic of stony tundras of the upper belt, and of highly and moderately steep slopes, occupied by fragmentary vegetation.
2. Leptosols are found under dwarf shrubby tundras of medium and lower belts, and under meadow and shrubby vegetation in valleys. Under parts of meadows and grass-dryad tundras on insolated slopes of the lower belt, relatively strong leptosols with high humus content are developed.

Carbonate soil moieties occur widely: from primitive lithosols to well-developed leptosols on carbonates with pH exceeding 7.0. In general, acid soils (pH <6.0) are virtually absent as even bog histosols on terraces have a pH of 6.0–6.5. Under mountain-'hanging' small bogs, peculiar peaty soils are developed. These soils are morphologically similar to histosols but lack gley in their profiles.

Fauna

The animal species occurring in the Byrranga Mountains was determined from visual observations using test routes and the noting of nests in the case of birds. Small vertebrates were studied by catches on test lines.

For fish sampling, the authors used fixed gill nets (mesh size 16–80 mm), dip-nets, and close-meshed 6–20 m-long beach seines for fish fry, as well as 250 m-long beach seines, trap nets, and ledger hook tackle.

Mammals (Mammalia)

Nine species of mammals inhabit the mountains: mountain hare (*Lepus timidus* L.), collared lemming (*Dicroctonyx torquatus* Pallas), brown lemming (*Lemmus sibiricus* Kerr), wolf (*Canis lupus* L.), Arctic fox (*Alopex lagopus* L.), wolverine (*Gulo gulo* L.), stoat (*Mustela erminea* L.), reindeer (*Rangifer tarandus* L.), and musk-ox (*Ovibos moschatus* Zimmermann). Occasionally polar bears (*Ursus maritimus* L.) travel along the Nizhnyaya Taymyra River valley from the seacoast.

The hare inhabits the mountains mainly in summer. It can often be seen on mountain meadows at lower altitudes.

It is known that collared lemmings and brown lemmings experience cyclic peaks and declines. These coincide for both species but the cycles have different timing in the areas of the Taymyr Peninsula and the Byrranga Mountains. For the central and eastern parts of the mountains the greatest lemming numbers were recorded in 1991, 1994, 1997, and 2000, whereas population lows were observed in 1993, 1995, and in 1998–99 (Pospelov, unpublished data). Brown lemmings mainly inhabit the tundra on mountain slopes and in intermontane depressions; collared lemmings populate dry dryad stone tundra, up to the tops of the mountains. New findings suggest that a special combination of predators can drive lemming populations through a four-year boom and bust cycle. Gilg and others (2003) suggested that predators may be solely responsible for the four-year population cycle of collared lemmings in eastern Greenland and, possibly, in other collared lemming populations. In contrast to previous hypotheses, food or space shortages did not appear to be involved.

Wolves and wolverines are not habitual. Wolf burrows have been found in block breakdowns of the lowlands. Stoats occur sporadically, inhabiting lowland stone deposits and river valleys. Arctic foxes are widely spread. In years when lemming numbers are high, Arctic fox numbers are high. As a rule, Arctic foxes make burrows on ancient marine terraces in intermontane depressions.

Wild reindeer are the most numerous large mammals of the Byrranga Mountains. Most reindeer found in the mountains are on summer migration. But in the northern foothills of the Shrenk and Trautfetter river basins there are large wintering sub-populations.

Musk-ox moved to the Taymyr Peninsula in 1974, mainly inhabiting the mountains east of the Nizhnyaya Taymyra River. About 80% of the population roams from the foothills to the mountains throughout the year, while a small sub-population inhabits the Bolshaya Balakhnya River basin outside the mountain region. At present the total number of animals is estimated at approximately 2000.

Birds (Aves)

There are 56 species of birds registered in the Byrranga Mountains, 42 of them constantly or periodically nesting in the area. There are more plovers (*Charadriidae*) than any other species (23). There are 14 species of passerine (Passeriformes). The Lapland bunting (*Calcarius lapponicus* L.) and horned lark (*Eremophila alpestris* L.), which populate the lowlands up to 300 m above sea level, are the most numerous sparrow species. The snow bunting (*Plectrophenax nivalis* L.) is the only specimen nesting at altitudes higher than 400 m above sea level. On rock scarps, white wagtail (*Motacilla alba*) and wheatear (*Oenanthe oenanthe*) are commonly found.

Geese, loons, and ducks mainly inhabit intermontane depressions. The most widely spread species are the Arctic loon (*Gavia arctica* L.), the white-fronted goose (*Anser albifrons* Scop.), and the king-eider (*Somateria spectabilis* L.). Intermontane depressions are an important migration corridor for waterfowl. In spring the following maritime species migrate here: Brent goose (*Branta bernicla* L.), Steller's eider (*Somateria stelleri* Pall.), and the red knot (*Calidris canutus* L.) (Pospelov and Voronin 2000). The most widespread snipes are gray plover (*Pluvialis squatarola* L.), *Pluvialis fulva* Gmelin, dunlin (*Calidris alpina* Brunn), *Calidris ferruginea* L., ring dotterel (*Charadrius hiaticula* L.), and *Calidris minuta* Leisl. The dotterel (*Charadrius morinellus* L.) and the stint (*Calidris ruficollis* Pall.) nest almost exclusively in the Byrranga Mountains and the Taymyr Peninsula. The dotterel nests in dry dryad detritus tundra of the lowlands and the stint near valleys and depressions of the slopes.

Herring gull (*Larus argentatus* Pontopp.) and burgomaster (*Larus hyperboreus* Gunn.) nest along the river and lake shores (a detailed list of the birds at Lake Taymyr can be found in Robarts and others 1999) on the plains and settle in colonies in mountainous areas. There are three species of jaegers, the most numerous being the long-tailed jaeger (*Stercorarius longicaudus* Vieill.). Pomarine jaeger (*S. pomarinus* Temm.) and parasitic jaeger (*S. parasiticus* L.) occur sporadically, although they nest in the region.

The most typical bird of prey is *Buteo lagopus* Pontopp. In favorable years the nesting density of peregrines (*Falco peregrinus* Tunst.) is higher in mountains in comparison with the adjoining flat areas. Moreover, Arctic falcons (*Falco gyrfalco* L.) and merlins (*Falco columbarius* L.) nest here occasionally. Birds of prey nest on rock scarps and in canyons that are difficult to access. Snowy owls (*Nyctea scandiaca* L.) permanently inhabit the mountains but nest only in years when lemming numbers are high.

The only nesting specimen of Galliformes is the rock ptarmigan (*Lagopus mutus* Mont.). Willow grouse (*Lagopus lagopus* L.) can be found in winter migration areas.

The ornithological fauna of high relict willows found in intermontane depressions is highly distinctive. The species nesting here are *Luscinia svecica* L., little bunting (*Emberisa pusilla* Pall.), *Acanthis hornemannii* Holboell, mealy redpoll (*A. flammea* L.), and red-throated pipit (*Anthus cervinus* Pall.). The usual nesting grounds for these species can be found 150–200 km to the south of the mountains.

Fish (Pisces)

Almost the only fish species inhabiting medium-sized intermontane rivers is the Arctic grayling (*Thymallus arcticus pallasi* Valenciennes). Spawning grounds of the Arctic char (*Salvelinus alpinus* L.) and other chars — *S. boganidae* Berg, *S. tolmachoffi* Berg, *S. drjagini* Logaschev, *S. taimyricus* Michin — are located in large rivers in the northern foothills (Shrenk, Trautfetter, and Leningradskaya rivers), and in the Verkhnyaya Taymyra River, Nizhnyaya Taymyra River, Bikada River, and Taymyr Lake. The largest spawning grounds of the Arctic char on the Taymyr Peninsula are on the Shrenk River. Species diversity of the Shrenk, Trautfetter, and Leningradskaya rivers, as well as the Pyasina and Nizhnyaya Taymyra rivers, is the most prominent. Besides char, various species of whitefish, such as *Coregonus nasus* (Pallas), *C. muksun* (Pallas), *C. lavaretus pidschian* (Gmelin), *C. sardinella* Valenciennes and *C. peled* (Gmelin) are common, as well as burbot (*Lota lota* (L), omul (*C. autumnalis* (Pallas)), nine-spined stickleback (*Pungitius pungitius* (L.)) and Siberian sculpin (*Cottus sibiricus* Kessler) (Adamenko and Yegorov 1985; Pavlov and others 1999). The report on fish catches in 1989–92 of the fisheries plant in Khatanga village indicates that perch (*Perca fluviatilis* L.)

was caught by fishermen in small amounts — less than 100 kg — at Taymyr Lake.

In intermontane lakes, the char (*Salvelinus* sp.) is the most typical fish representative. Chars inhabiting Levinson-Lessing and Protochnoye lakes are small (<40 cm for body mass up to 800 g) and have an unusual bright red color. These are very rare on the plains. Stomachs of char caught in Levinson-Lessing Lake contained various crustaceans, whereas char occurring in water bodies located on the plains are predators and feed on fish, including their fry. The available scanty information indicates that the char population in the Byrranga lakes is not large.

Summary and conclusions

The Byrranga Mountains stretch 1100 km from Yenisey Bay to the Laptev Sea. Their mountainous tundra and low-lying tundras in the foothills form one of the most pristine regions of the continental Arctic. This is due to the mountains' poor accessibility, lack of permanent human populations, and lack of significant economic development in the area. For the same reasons, the mountains have been little studied. This paper is the first detailed biogeographical description of the mountains in English.

The Byrranga Mountains are composed of siltstones and intrusive rocks of neutral composition; vast areas along all the mountain chain are occupied by exposed limestone. Deposits of the last sea transgression are widespread in the piedmonts. According to the relief and age of the deposits the Byrranga region can be divided into five regions. Almost all existing Arctic types of cryogenic processes can be observed. The rivers flow in deep intermountain depressions and have a typical mountain character. There are numerous lakes with depths up to 108 m. Lake Taymyr is the largest Arctic lake in the world. Although the climate is an extremely severe continental one, microclimatic areas permit a rich and diverse vegetation to develop. On the summits, where winds remove the snow cover, there is little vegetation, which is mostly Arctic desert species. On convex slopes and low plateaus the most common vegetation is tundra dominated by dwarf shrubs, while vegetation on concave slopes is dominated by sedges and mosses. In valleys and on warm protected slopes floristically rich meadow communities have developed. In some places these communities are steppe-like. Relict thickets of tall willows have been found in several locations in protected valleys of piedmont brooks, while relict alder-tree thickets occur on warm, sun-facing slopes. Little is known about the soils of the region. In general, leptosols are predominant, while histosols and gleysols are well-developed only in valleys. The mountain fauna includes nine mammal and 56 bird species. Intermountain depressions that stretch meridionally serve as corridors for the seasonal migrations of wild reindeer herds, which usually spend summer in the southern piedmont areas. Northern piedmonts and wide intermountain depressions are places where herds of musk-ox that were introduced in the 1970s concentrate. The bird fauna is dominated by plovers and passerines while waterfowl (geese, ducks, and loons) are found only in river valleys and on lakes. The bird fauna of relict willow thickets is highly specific for the Byrranga region. The fish fauna is diverse. Lake Taymyr's fish stocks supported a commercial fishery during the former USSR but today, with the economic troubles being experienced in Russia, this has fallen onto hard times (Robarts and others 1999). In addition, some species have been over-fished and information on their growth rates in these cold waters is required if a sustainable fishery is to be maintained. The forest damage caused by the emissions from the Norilsk mine and concentrating plant and the over-fishing of Taymyr Lake are the only significant anthropogenic impacts the authors have been able to identify.

The authors are not aware of what plans there may be by government authorities or industry for future development of this area. Because of its remoteness there may be none at this time. However, the authors hope that future studies will build upon what is currently known to form a sound scientific basis for integrated resource management plans for the Byrranga Mountains that will be required if the area is to be developed.

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