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Syntaxonomy and geography of light-coniferous and mixed (*Pinus sibirica*, *Larix sibirica*) forests of the Bolshoy Agul River basin (Eastern Sayan, Southern Siberia)

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Summary. The classification of forests in the Bolshoy Agul river basin (Eastern Sayan) was developed using the Brawn-Blanquet method and cluster analysis. Two zonal forests categories in North Asia – boreal forests of the *Vaccinio–Piceetea* Br.-Bl. in Br.-Bl. et al. 1939 and hemiboreal forests of the *Rhytidio–Laricetea* Korotkov et Ermakov 1999 were revealed. Boreal coniferous forests are represented dominantly by two orders of the East Siberian-Mongolian type – *Ledo–Laricetalia* Ermakov et Alsynbayev 2004 and *Lathyro–Laricetalia* Ermakov et al. 2002. The first order includes alliance *Pino sibiricae–Laricion* Ermakov et Alsynbayev 2004 and two associations – *Carici globularis–Pinetum sibiricae* ass. nov. and *Linnaeo–Pinetum sibiricae* ass. nov. occurring on long-term frozen soils with different moisture regimes. The second order of the East Siberian-Mongolian type is represented by community *Senecio nemorensis – Larix sibirica* (*Rhododendro–Laricion* Ermakov in Krestov et al. 2009). The third order of boreal forests – *Piceo obovatae–Pinetalia sibiricae* Ermakov 2013 represents extra-zonal communities of the Ural-Siberian geographical type occurring in the moderately warm habitats. Hemiboreal light-coniferous forests of the East Siberian-Mongolian type (class *Rhytidio–Laricetea* Korotkov et Ermakov 1999, alliance *Festuco–Laricion* Korotkov et Ermakov ex Ermakov et al. 2000, *Campanulo turczaninovii–Laricetum sibiricae* ass. nov.) are locally found in the driest sites. The results of the classification and comparative plant-geographical analysis make it possible to correct the border between the East Siberian and Euro-Siberian geobotanical subregions as well as the boundaries of districts, provinces and regions in the forest zonation system of Southern Siberia.

Географические и синтаксономические особенности светлохвойных и смешанных (*Pinus sibirica*, *Larix sibirica*) лесов бассейна р. Большой Агул (Восточный Саян, Южная Сибирь)

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Ключевые слова: Браун-Бланке, география растительности, классификация растительности, лиственничные, Сибирь, сосновые леса, *Vaccinio–Piceetea*.

Аннотация. Разработана классификация лесов бассейна реки Большой Агул (Восточный Саян) с использованием метода Браун-Бланке и кластерного анализа. Разнообразие сообществ включено в состав двух классов, относящихся к двум зональным категориям лесов Северной Азии – таежным лесам класса *Vaccinio–Piceetea* Br.-Bl. in Br.-Bl. et al. 1939 и гемибореальным лесам класса *Rhytidio–Laricetea* Korotkov et Ermakov 1999. Таежные смешанные хвойные (*Pinus sibirica, Larix sibirica*) леса представлены преимущественно двумя порядками восточносибирско-монгольского типа – *Ledo palustris–Laricetalia gmelinii* Ermakov et Alsynbayev 2004 и *Lathyro–Laricetalia* Ermakovet al. 2002. Первый порядок включает один союз *Pino sibiricae–Laricion* Ermakov et Alsynbayev 2004 и две ассоциации – *Carici globularis–Pinetum sibiricae* ass. nov. и *Linnaeo–Pinetum sibiricae* ass. nov., распространенные на длительно-мерзлотных почвах с разным режимом увлажнения. Второй порядок восточносибирско-монгольского типа, включающий сообщества «сухой континентальной тайги», представлен одним сообществом – *Senecio nemorensis–Larix sibirica* (союз *Rhododendro–Laricion* Ermakov in Krestov et al. 2009). Третий порядок таежных лесов – *Piceo obovatae–Pinetalia sibiricae* Ermakov 2013 – представляет экстразональные сообщества урало-сибирского географического типа. В бассейне р. Большой Агул они локально встречаются в умеренно теплых местообитаниях. Гемибореальные светлохвойные (*Larix sibirica*) леса восточносибирско-монгольского типа (класс *Rhytidio–Laricetea* Korotkov et Ermakov 1999, порядок *Festuco–Laricetalia* Korotkov et Ermakov ex Ermakov et al. 2000, союз *Festuco–Laricion* Korotkov et Ermakov ex Ermakov et al. 2000, ассоциация *Campanulo turczaninovii–Laricetum sibiricae* ass. nov.) локально встречаются на территории исследований по самым сухим местообитаниям. Результаты классификации и сравнительного ботанико-географического анализа позволяют уточнить границу между Восточносибирской и Евросибирской геоботаническими подобластями, а также границы округов, провинций и областей в системе лесорастительного районирования Южной Сибири.

Introduction

The boreal forest classification of the Altai-Sayan Mountain Region using the Braun-Blanquet approach has been actively developing in the last 20 years (Ermakov, 2003; Ermakov, Alsynbaev, 2004; Ermakov, 2013, 2014; Telyatnikov, 2015; Makunina, 2020). However, the forest vegetation of the Eastern Sayan Mts. has still been studied extremely poorly, despite the fact that the forest belt predominates in the mountain system and a high diversity of natural forests habitats is observed there. Information about only one larch forest association from the southeastern part of the Eastern Sayan was published by M. Telyatnikov (2015).

The forest communities diversity in the Bolshoy Agul river basin (the right tributary of the Agul River) (Fig. 1) was studied in 2012. The study area is located on the territory of the Tofalarskiy Nature Reserve in the remote part of the Eastern Sayan, where pine-larch (*Pinus sibirica, Larix sibirica*) taiga, high-mountain tundra and alpine meadows predominate in the landscapes. It is placed close to the watershed of the Eastern Sayan Mts., within the Agulskie Belki mountain ridge bordering with the Kanskoe Belogorie Ridge in the west and with the Dzhuglymsky Ridge in the east. This territory composed of metamorphosed limestones, dolomites and slates is stretching about 80 km long and is characterized by altitudes ranging from 780 m to 2652 m. The forest belt is placed within the mid-mountainous relief with deep valleys and altitudes of less than 2000 m. The accumulative relief of the intermountain basins is formed by fluvio-glacial and lacustrine deposits. Discontinuous permafrost is observed on the north-oriented mountain slopes (Voskresenskiy, 1968). The main studies were carried out in the Bolshoi Agul River basin from the place of its confluence with the Malyi Agul River to Lake Agul located at an altitude of 920 m. The lake (of 11 km long, up to 1.2 km wide) stretches along the Bolshoy Agul river valley and is surrounded by steep mountain slopes. The local climate is ultra-continental with long (from mid-October to March) very cold winters. The depth of soil freezing reaches 2 meters. Spring is characterized by sharp temperature fluctuations, strong winds and clear weather. The final melting of snow occurs in early June. The cool summer with mostly cloudy weather lasts from mid-June to mid-August. In contrast to the first dry half, the

second half of summer is full of rain. Average annual precipitation varies from 300 to 600 mm. The average January temperature at altitudes of 900–1300 m is −17…−25 °C, the average July temperature is of +12…+14 °C (Mikhailov, 1961). Poor, weakly podzolic stony soils are formed on the material of the weathering of crystalline rocks on the mountain slopes. Seasonally frozen bogged soils develop on the northern mountain slopes under the canopy of coniferous forests (Gorbachev, 1978).

The aim of the study is to develop the forest vegetation classification using the Braun-Blanquet method and to present the results of comparative plant-geographical and syntaxonomic analyses.

Materials and methods

The field research was carried out in July 2012. We sampled 42 relevés of 100 m^2 in key area placed in the Bolshoy Agul river basin (Eastern Sayan) (Fig. 1). Within each relevé, the percentage cover of the tree, shrub, herb and moss layers was estimated and the cover of particular species in each layer was assessed. Percentage data of each species were converted in the seven-degree Braun-Blanquet (old) cover-abundance scale in final classification table. Geographical coordinates (WGS 84) and the altitude of relevés were recorded using a portable GPS device GPS map 60CSx. All relevés were input in database using the software TURBOVEG (Hennekens, Schaminée, 2001). The quantitative classification of the entire set of relevés was carried out using cluster analysis (Ward's method, Euclidian distance) implemented in Statistica 6.0. The finalization of the classification table was done in the software Juice 7.0 (Tichy, 2002). The forest classification was carried out based on the Braun-Blanquet method (Westhoff, van der Maarel, 1973). The syntaxa names were given in accordance with the Code of Phytosociological Nomenclature (Theurillat et al., 2020). Taxonomy: S. K. Czerepanov (1995), M. S. Ignatov et al. (2006).

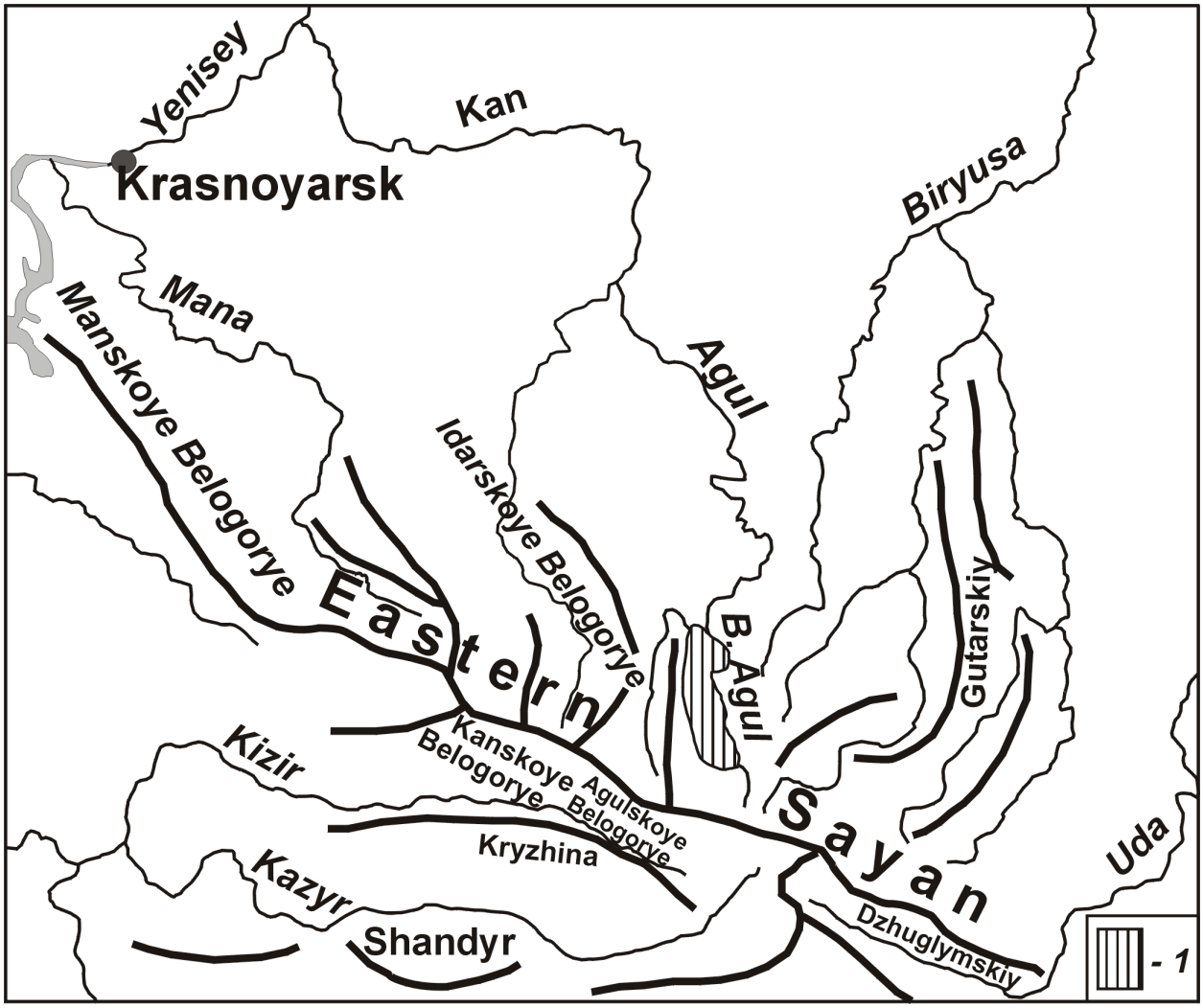

Fig. 1. Study area (1) and position of the main mountain ridges in the Eastern Sayan.

Results and discussion

The results of quantitative classification (cluster analysis, Ward method, Euclidian distance) demonstrated on the dendrogram (Fig. 2) a clear division of the entire set of relevés into 5 basic groups interpreted as associations. These groups of relevés (associations) were united into clusters of different hierarchical levels identified after syntaxonomic analysis as the higher rank categories – classes–alliances. At the highest hierarchical level of the classification, all communities were divided into two classes representing two subzonal vegetation types – Central Asian hemiboreal forests (class *Rhytidio–Laricetea* Korotkov et Ermakov 1999) and Eurasian taiga forests (class *Vaccinio–Piceetea* Br.-Bl. in Br.-Bl. et al. 1939). The division into units of orders and alliances ranks is also clearly observed at the lower hierarchical levels of the dendrogram (Fig. 2). The final forest classification including two classes, four orders, four alliances and five associations was developed for the upper part of the Bolshoy Agul river basin after a comparative syntaxonomic analysis of described units with the existing boreal forests categories in Northern Asia.

Syntaxonomic prodromus:
Cl. *Vaccinio–Piceetea* Br.-Bl. in Br.-Bl.et al. 1939
Ord. *Ledo palustris–Laricetalia gmelinii* Ermakov in Ermakov et Alsynbayev 2004
All. *Pino sibiricae–Laricion sibiricae* Ermakov in Ermakov et Alsynbayev 2004
Ass. *Carici globularis–Pinetum sibiricae* ass. nov.
Ass. *Linnaeo borealis–Pinetum sibiricae* ass. nov.
Ord. *Piceo obovatae–Pinetalia sibiricae* Ermakov 2013
All. *Aconito rubicundi–Abietion sibiricae* Anenkhonov et Chytry 1998
Ass. *Gymnocarpio dryopteridis–Pinetum sibiricae* ass. nov.
Ord. *Lathyro humilis–Laricetalia cajanderi* Ermakov, Cherosov et Gogoleva 2002
All. *Rhododendro daurici–Laricion gmelinii* Ermakov in Krestov et al. 2009
Community *Senecio nemorensis–Larix sibirica*
Cl. *Rhytidio–Laricetea sibiricae* Korotkov et Ermakov 1999
Ord. *Festuco ovinae–Laricetalia sibiricae* Korotkov et Ermakov ex Ermakov et al. 2000
All. *Festuco altaicae–Laricion sibiricae* Korotkov et Ermakov ex Ermakov et al. 2000
Suball. *Festuco altaicae–Laricenion sibiricae* Ermakov 2000
Ass. *Campanulo turczaninovii–Laricetum sibiricae* ass. nov.

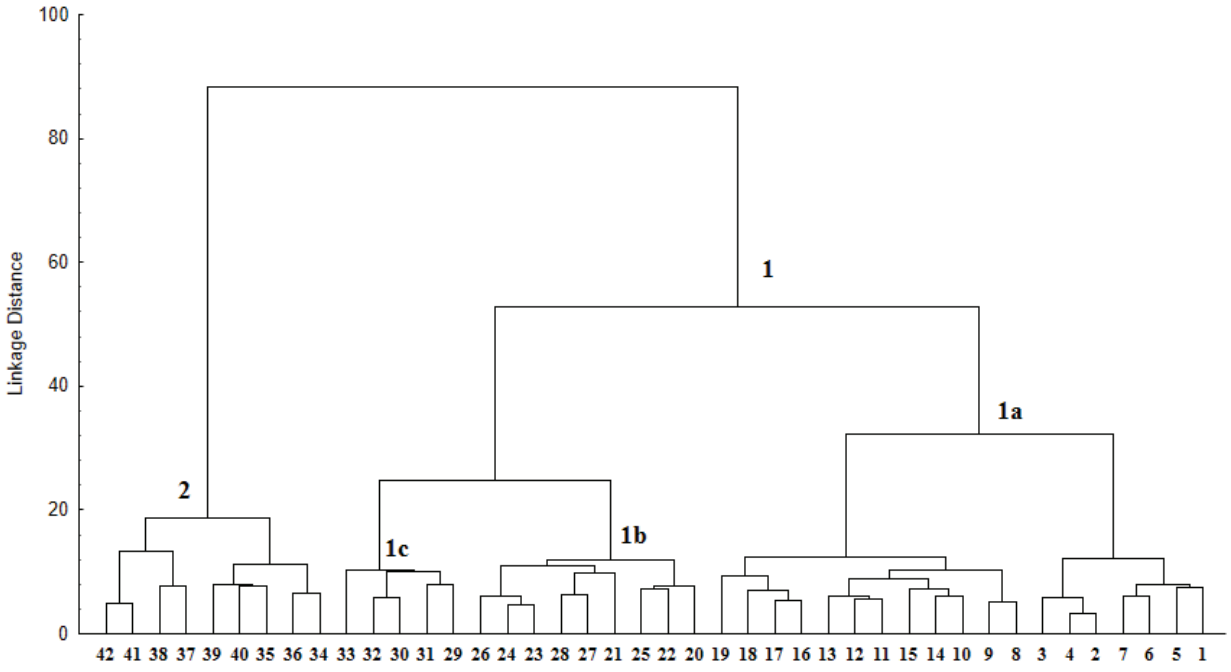

Fig. 2. The results of quantitative classification (cluster analysis, Ward method, Euclidian distance) of 42 relevés: 1 – class *Vaccinio–Piceetea*; 1a – order *Ledo palustris–Laricetalia*, alliance *Pino sibiricae–Laricion sibiricae*; 1b – order *Piceo obovatae–Pinetalia sibiricae*, alliance *Aconito rubicundi–Abietion sibiricae*; 1c – order *Lathyro humilis–Laricetalia*, alliance *Rhododendro daurici–Laricion*; 2 – class *Rhytidio–Laricetea sibiricae*, alliance *Festuco altaicae–Laricion*.

Table 1

Larch and pine-larch forests syntaxa of the Bolshoy Agul river basin

Relevé No.		1	2	3	4	5	6	9	12	11	19	20	24	25	23	38	34	48	39	27	40	26	28	29	23	18	31	37	47	13	10	15	17	16	35	36	41	22	21
Species of tree layer																																								
Larix sibirica VP, RL	t1	3	2	3	3	2	2	2	3	3	2	2	2	2	2	2	3	3	3	2	2	2	2	2	2	2	1	3	2	4	2	3	2	2	3	4	3	3	3	3	3	3	3
Pinus sibirica VP	t1	2	2	2	2	3	3	3	2	2	3	4	3	3	3	2	2	2	2	2	3	3	3	3	3	3	4	3	3	2	3	3	3	3	2	2	.	.	1	2	2	2	2
Picea obovata VP	t1	.	.	.	.	+	.	.	.	2	.	.	.	.	1	+	1	2	2	2	2	1	+	2	2	+	1	1	1	1	2	+	2	+	.	.	.	.	2	.	1	.	.
Betula pendula	t1	.	.	+	.	.	1	1	2	2	2	1	+	+	1	1	1	1	2	1	+	1	1	1	2	2	2	+	1	2	2	2	2	2	2	.	2	2	2	2	2	.	+
Ass. *Carici globularis–Pinetum sibiricae*																																									
Carex globularis LL	hl	2	2	2	2	2	2	2	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cladonia arbuscula	ml	.	2	.	1	2	1	1	.	+	.	.	.	.	.	+	+	+	.	+	.	.	.	.	.	.	.	.	.	.	+	1	+	2	+	+	+	.	.	+	.	.	.
Polytrichum juniperinum LL	ml	2	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cetraria islandica	ml	.	1	2	2	2	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Cladonia stellaris	ml	.	2	2	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cladonia rangiferina	ml	.	1	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Polytrichum strictum LL	ml	.	+	1	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Oxycoccus microcarpus	hl	.	+	r	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ass. *Linnaeo borealis–Pinetum sibiricae*, all. *Pino sibiricae–Laricion sibiricae*, ord. *Ledo palustris–Laricetalia*																																									
Calamagrostis obtusata	hl	.	.	.	.	.	+	.	2	2	1	+	1	1	2	1	1	2	2	1	2	1	2	2	2	1	1	1	.	1	.	.	1	.	.	.	.	.	.	.	.	.
Ledum palustre	hl	3	3	3	3	3	3	2	2	2	2	2	2	2	2	.	3	2	2	2	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex iljinii	hl	1	+	.	+	.	.	1	1	.	1	.	2	+	2	2	1	2	2	2	+	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Aulacomnium turgidum	ml	1	2	2	2	.	2	1	2	2	.	2	2	2	.	2	1	1	.	2	1	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Aulacomnium palustre	ml	.	.	.	1	.	1	.	.	.	1	2	1	.	2	1	2	1	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Vaccinium uliginosum	hl	.	.	2	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ptilidium ciliare	ml	.	.	.	.	.	+	1	1	+	2	1	1	1	1	2	1	+	2	+	1	1	.	.	.	.	.	+	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Polytrichum commune	ml	2	2	1	2	+	.	2	2	2	+	.	.	.	.	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sphagnum girgensohnii	ml	+	1	2	2	.	2	1	.	1	1	2	2	1	.	1	+	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sphagnum capillifolium	ml	.	1	+	+	.	.	1	+	.	+	.	.	+	2	+	+	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sphagnum angustifolium	ml	.	.	+	.	.	+	+	+	.	.	.	+	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sphagnum warnstorfii	ml	+	+	+	+	.	.	.	.	.	+	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Table 1 (continued)

Sphagnum wulfianum	ml	.	.	.	.	.	.	+	+	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sphagnum russowii	ml	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sphagnum squarrosum	ml	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ass. *Gymnocarpio dryopteridis–Pinetum sibiricae*																																											
Calamagrostis langsdorffii	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	1	2	.	1	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rubus matsumuranus	s1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	+	1	1	.	.	.	.	.	.	.	.	+	.	.	.	.	.
Calamagrostis pavlovii	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	+	2	.	.	.	+	1	1	1	2	2	2	2	1	2	1	2	2	2	1	1	2	2
Com. *Senecio nemorensis–Larix sibirica*, all. *Rhododendro daurici–Laricion*, ord. *Lathyro humilis–Laricetalia*																																											
Spiraea chamaedrifolia	s1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	2	2	.	1	1	1	2	2	1	2	.	2	1	.	2	2	1	2	2	1
Rhytidium rugosum RL	ml	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	2	2	2	.	3	4	3	4	2	2	3	3	3	4
Galium boreale	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	+	.	.	.	.	1	1	1	1	.	2	1	1	2	2	2	2	1	1
Thalictrum minus	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	+	.	1	1	.	1	.	2	1	1	2	2	2	.	1	2
Atragene sibirica	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	1	1	+	1	.	1	1	1	1	1	+	1	+	1
Chamaenerion angustifolium FL	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	+	.	+	+	+	.	+	.	.
Saussurea parviflora	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	1	+	.	+	.	.	.	.	.	+	1	+	.	+	1	+	.	.	.	.	.	.
Ass. *Campanulo turczaninovii–Laricetum sibiricae*																																											
Saussurea controversa	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	+	.	1	2	2	1	2	2	2	2	1
Hedysarum neglectum	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	.	1	1	+	1
Cimicifuga foetida	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.	+	.	.	.	+	.	2	1	+	.	1	1
Astragalus frigidus	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	2	1	2	.	.	+	1	.	.
Rhododendron dauricum	s1	.	.	.	.	.	.	.	.	.	.	1	.	2	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	1	.	.	.	1	1	2	2
Oxytropis strobilacea	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	+	1	.	.
Phlojodicarpus villosus	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	.	.	1	+	.	.
Cypripedium guttatum	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	+	+	.	+	.	+	.	.
Pedicularis resupinata	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	1	.	+	.	.
Angelica tenuifolia	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	+	.	.	+	+
Astragalus alpinus	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	+	+	+
Patrinia rupestris	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	+
Viola uniflora	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	+	+	.	.	.	+

Table 1 (continued)

Festuca sibirica	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	2	1	.	.
Cotoneaster melanocarpus	s1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	+	.	.	+	.
Cypripedium macranthon	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	+	+	.	.
Aquilegia sibirica	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1	.	.	.	.	.	+	.	+	.	+	+
Poa urssulensis	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	+	.	.
Caragana jubata	s1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	2	1	.	.
All. *Aconito rubicundi–Abietion sibiricae*, ord. *Piceo obovatae–Pinetalia sibiricae*																																											
Aconitum septentrionale	hl	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	1	1	1	1	1	+	1	1	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.
Senecio nemorensis	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	+	.	.	1	+	+	+	+	+	.	.	.	.	+	+	.	.	.	.
Cacalia hastata	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	.	.	+	.	.	+	.	.	.	+	+	+	+	+	.	.	.	.
Stellaria bungeana	hl	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	.	.	.	1	.	+	1	+	.	1	1	1	.	+	.	1	.	.	.	.	.	.	.	.	.	.
Aegopodium alpestre	hl	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	+	.	+	1	.	+	.	.	+	1	+	1	.	+	1	+	+
Sorbus sibirica	s1	.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	1	2	+	1	2	2	2	+	2	.	+	.	+	.	+	.	.	+	1	.	+	+	.
Rhytidiadelphus triquetrus	ml	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	+	2	2	+	+	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gymnocarpium dryopteris	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	+	2	2	1	2	2	2	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Rhodobryum roseum	ml	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	1	+	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Circaea alpina	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	+	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Diplazium sibiricum	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	+	2	2	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Maianthemum bifolium	hl	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	1	.	.	+	.	.	.	+	+	2	+	1	+	.	.	.	+	+	.	.	.	+
Padus avium	s1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
All. *Festuco altaicae–Laricion sibiricae*, ord. *Festuco ovinae–Laricetalia sibiricae*																																											
Campanula turczaninovii	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	1	1	1	.	+	1	1	1	1
Anemonastrum crinitum	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	+	1	1	1	1	1
Dendranthema zawadskii	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	2	2	2	1	1	2	2	2	2
Bromopsis pumpelliana	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	1	.	.	1	2	.	.
Lathyrus humilis	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1	2	.	.	.	.
Vicia cracca	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	2	2	+	1	.	.
Valeriana alternifolia	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	.	+	.	+
Cl. *Vaccinio–Piceetea*																																											

Table 1 (continued)

Vaccinium vitis-idaea	hl	2	2	2	2	2	2	3	3	3	3	3	3	3	2	3	3	3	3	2	3	2	3	3	2	4	2	2	2	3	3	3	3	3	.	.	.	.	.	.	.	.	.
Pleurozium schreberi	ml	3	4	4	4	4	3	2	2	2	.	2	3	3	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	1	.	.	.	.	1	.	.	.	.
Ptilium crista-castrensis	ml	2	1	+	+	2	2	2	2	2	2	2	2	.	2	2	2	2	2	1	1	.	1	2	2	2	2	2	2	.	.	2	.	.	.	.	.	.	.	.	.	.	.
Hylocomium splendens	ml	.	.	.	.	2	2	3	3	3	3	3	2	2	3	3	3	3	3	3	3	3	3	3	3	4	3	3	3	3	2	1	3	2	2	.	1	.	.	.	.	.	1
Dicranum scoparium	ml	.	.	.	.	2	.	+	2	2	2	2	.	1	1	+	2	2	2	.	2	2	.	.	+	.	2	2	2	2	2	2	2	2	1	.	.	.	1	.	.	.	.
Lonicera altaica	s1	.	.	.	.	+	1	1	1	1	1	1	+	1	2	1	1	1	1	+	1	1	2	2	2	1	2	1	1	1	2	1	1	1	.	+	.	.	.	.	.	.	.
Linnaea borealis	hl	.	.	.	.	.	.	1	2	1	2	1	1	2	2	1	+	1	.	+	2	2	2	2	2	1	2	2	2	.	1	1	2	1	.	.	.	.	.	.	.	.	.
Trientalis europaea	hl	.	.	.	.	.	.	.	+	+	.	.	.	+	.	+	+	+	1	+	+	+	+	+	+	+	+	+	+	+	1	1	+	.	+	.	+	.	+	.	+	.	.
Pyrola incarnata	hl	.	.	.	.	.	.	.	1	+	.	.	.	.	.	.	1	1	.	1	2	1	2	2	2	1	2	2	2	2	.	1	1	.	.	.	.	.	.	.	.	.	.
Peltigera aphthosa	ml	.	.	.	.	.	1	+	1	.	.	.	.	.	+	+	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	1	.	2	.	.	.	.	.	.	+	.	.
Equisetum scirpoides	hl	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pyrola rotundifolia	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	2	1	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Orthilia obtusata	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	+	.	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Goodyera repens	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cl. *Rhytidio–Laricetea*																																											
Carex pediformis	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	1	1	1	1	1	2	2	1	1
Aster alpinus	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	2	.	.	2	1	+	1
Thalictrum foetidum	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	1	2	1	1	+
Aconitum barbatum	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	+	+	+	+
Abietinella abietina	ml	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	2	.	.	2	2	.	.
Other species																																											
Equisetum pratense	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	1	1	1	+	1	1	1	1	.	1	+	1	.	+	.	.	+	.	.	+	.	.	.	1	.	.
Rosa acicularis	s1	.	.	.	.	.	.	+	+	+	1	.	.	.	1	1	1	1	1	1	+	.	+	.	.	.	+	1	.	.	1	+	1	+	1	1	1	.	.	.	1	.	.
Duschekia fruticosa	s1	.	.	.	.	.	.	.	.	.	.	+	.	+	.	+	.	2	+	.	.	+	.	.	.	.	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ribes hispidulum	s1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	+	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dicranum species	ml	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	+	+	.	+	.	.	.	.	.	.	.	+	.	.	.	+	.	.	+	.	.	.	.	.	+	.
Bistorta major	hl	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Poa sibirica	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	+	+	.
Lilium pilosiusculum	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	+	+	.	+	.	.

Table 1 (end)

Allium microdictyon	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	.	.	.	.	.	1	+	.	.	.	.
Viola biflora	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	+	.
Pentaphylloides fruticosa	s1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	1	+	.	.
Gentiana macrophylla	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	+	.	.
Kobresia filifolia	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	1	.	.
Euphorbia discolor	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	+

Rare species: *Aconitum anthoroideum* (hl) – 42(+), *Aconogonon alpinum* (hl) – 35(+), *Allium strictum* (hl) – 41(+), 43(+), *Artemisia integrifolia* (hl) – 22(+), *Astragalus adsurgens* (hl) – 41(+), *A. species* (hl) – 15(+), *Athyrium filix-femina* (hl) – 40(+), *Bistorta vivipara* (hl) – 17(+), 42(+), *Campanula glomerata* (hl) – 7(+), 36(+), *Cardamine macrophylla* (hl) – 18(+), 27(+), 29(+), *Carex amgunensis* (hl) – 7(2), 37(1), *C. aterrima* (hl) – 41(1), 43(+), *C. caryophyllea* (hl) – 41(+), *C. species* (hl) – 39(+), *Cerastium pauciflorum* (hl) – 26(+), *Cinna latifolia* (hl) – 29(+), *Cirsium serratuloides* (hl) – 35(+), 36(1), *Cladonia sp.* (ml) – 4(+), *Cystopteris fragilis* (hl) – 26(+), *Delphinium sp.* (hl) – 16(+), *Dicranum fuscescens* (ml) – 34(+), 39(+), *D. majus* (ml) – 25(+), 30(+), *Elymus mutabilis* (hl) – 17(+), 39(+), *Ephedra monosperma* (hl) – 17(+), *Gypsophila patrinii* (hl) – 39(+), *Hedysarum gmelinii* (hl) – 17(+), *Heracleum dissectum* (hl) – 26(+), 29(+), *Hieracium korshinskyi* (hl) – 13(+), *Angelica tenuifolia* (hl) – 41(+), 42(+), *Luzula rufescens* (hl) – 7(+), *Lycopodium annotinum* (hl) – 26(+), *Malaxis monophyllos* (hl) – 36(+), *Moehringia lateriflora* (hl) – 7(+), 37(+), *Paeonia anomala* (hl) – 35(1), 36(+), 37(+), *Polytrichum sp.* (ml) – 15(+), 16(+), *Populus tremula* (t1) – 35(2), 36(+), *Ribes nigrum* (s1) – 26(1), 29(+), *Rubus arcticus* (hl) – 7(+), 8(+), *Salix caprea* (s1) – 34(+), *Saussurea alpina* (hl) – 39(1), *Schizachne callosa* (hl) – 26(+), *Trollius asiaticus* (hl) – 17(+), *Valeriana officinalis* (hl) – 30(+), *Veratrum lobelianum* (hl) – 31(+), *Viola dactyloides* (hl) – 36(1), *V. dissecta* (hl) – 35(+).

Description of associations

Carici globularis–Pinetum sibiricae ass. nov. hoc loco (Table 1, 1a)

Diagnostic species: *Carex globularis, Cetraria islandica, Cladonia arbuscula, C. stellaris, C. rangiferina, Oxycoccus microcarpus, Polytrichum juniperinum, P. strictum.*

Holotypus: Relevé no. 2 (Table 1, 1a).

Boreal forests occurring in lower parts of northern slopes at altitudes of 800–950 m. Their habitats are characterized by excessive waterlogging due to slow thawing of long-term frozen soils during the growth season. The nano-relief is hilly as a result of seasonal solifluction processes. *Larix sibirica* and *Pinus sibirica* predominate in the tree layer with a height of 14–16 m and cover of 30–45 % while *Picea obovata* and *Betula pendula* are found occasionally. The shrub layer is not developed. The herb-dwarf-shrub layer is characterized by a cover of 55–70 % and height of 20 cm. Its characteristic feature is a very poor species composition and absolute predominance of dwarf-shrubs *Vaccinium vitis-idaea* and *Ledum palustre*. The latter species and *Carex globularis* indicate the increasing stagnant moisterning as a result of the gradual thawing of long-term frozen soils. A well-developed ground layer (a cover of 100 %) is formed by the typical boreal moss – *Pleurozium schreberi* and the less abundant species – *Ptilium crista-castrensis* and *Hylocomium splendens*. The participation of some hygrophilous moss species – *Polytrichum commune, P. juniperinum, Sphagnum girgensohnii, S. capillifolium, S. warnstorfii, S. angustifolium, Aulacomnium turgidum* – is significant. A group of lichens – *Cetraria islandica, Cladonia stellaris, C. rangiferina, C. arbuscula* – is also found in the ground layer.

Linnaeo borealis–Pinetum sibiricae ass. nov. hoc loco

Diagnostic species are the same as for the alliance *Pino sibiricae–Laricion sibiricae* and order *Ledo palustris–Laricetalia*.

Holotypus: Relevé no. 19 (Table 1, 1a).

Community occupies the shaded northern, north-western and north-eastern parts of the mountain slopes at altitudes of 850–1000 m. In contrast to the previous association, it is confined to more drained soils on steep rocky slopes.

The tree layer (a cover of 45–60 %, a height of 18–24 m) is dominated by *Pinus sibirica*, *Larix sibirica* with an admixture of *Betula pendula* and *Picea obovata*. Shrubs (*Lonicera altaica, Rosa acicularis*

Table 1a

Header data of relevés from table 1

1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	2012.07.07	859	300	7	30	5	55	100	15	0	0	54°32'21.6"	96°13'53.5"
2	2012.07.07	895	N	7	35	4	60	100	16	0	20	54°34'07.1"	96°14'04.4"
3	2012.07.07	925	350	5	30	4	60	100	16	0	20	54°33'02.6"	96°14'03.6"
4	2012.07.07	908	280	12	35	5	70	100	16	0	25	54°32'06.1"	96°14'15.7"
5	2012.07.07	885	W	20	40	2	65	90	16	0	20	54°32'14.3"	96°14'08.9"
6	2012.07.07	847	W	25	45	4	65	90	17	0	20	54°32'20.1"	96°14'92.9"
7	2012.07.07	819	190	25	50	5	65	45	18	0	12	54°31'33.7"	96°13'07.0"
8	2012.07.07	838	S	5	55	4	70	60	20	0.5	18	54°31'52.9"	96°13'12.4"
9	2012.07.07	840	210	5	60	4	60	70	19	0.5	18	54°31'61.2"	96°13'40.2"
10	2012.07.08	852	240	40	45	3	45	60	21	0.5	8	54°31'33.8"	96°12'56.3"
11	2012.07.08	858	240	15	50	4	65	90	23	0.5	15	54°31'21.0"	96°13'08.5"
12	2012.07.08	814	W	12	50	4	65	90	24	0.5	15	54°31'40.7"	96°12'54.6"
13	2012.07.09	973	S	5	60	7	60	90	23	1.1	8	54°17'26.8"	96°14'06.0"
14	2012.07.09	964	170	4	60	15	60	70	24	1.2	10	54°17'24.9"	96°14'06.6"
15	2012.07.09	932	S	3	50	5	55	80	22	0.5	15	54°17'23.9"	96°14'09.5"
16	2012.07.09	915	170	3	40	3	50	80	20	0.5	10	54°17'23.7"	96°14'07.4"
17	2012.07.09	941	190	3	50	5	55	70	24	0.7	15	54°17'22.6"	96°14'04.6"
18	2012.07.10	940	330	3	60	7	65	70	24	1.4	15	54°17'00.1"	96°14'30.8"
19	2012.07.10	930	350	5	60	3	75	80	24	0.5	17	54°16'57.7"	96°14'36.4"
20	2012.07.10	966	300	25	55	4	60	85	23	1.6	11	54°16'57.4"	96°14'38.7"
21	2012.07.10	999	240	45	50	25	35	70	19	2	20	54°16'54.1"	96°14'41.0"
22	2012.07.10	1015	230	45	40	15	40	40	23	1.3	20	54°16'52.9"	96°14'42.7"
23	2012.07.10	948	300	45	60	20	65	90	22	1.6	8	54°16'58.1"	96°14'40.5"
24	2012.07.10	940	310	15	60	3	65	90	23	0.6	17	54°16'57.7"	96°14'39.0"
25	20120710	942	290	17	50	5	60	90	20	1.3	12	54°16'59.9"	96°14'41.5"
26	2012.07.10	964	W	3	50	8	70	80	23	0.9	14	54°17'00.7"	96°14'40.3"
27	2012.07.10	959	280	3	55	5	65	80	24	1.1	10	54°16'58.2"	96°14'33.1"
28	2012.07.10	929	W	3	60	12	70	60	24	1.2	15	54°16'58.8"	96°14'29.7"
29	2012.07.10	923	280	3	50	12	70	60	24	1.1	17	54°16'57.4"	96°14'28.0"
30	2012.07.12	917	260	5	65	12	65	70	24	1.5	12	54°15'58.7"	96°13'04.1"
31	2012.07.12	934	300	5	50	15	65	75	24	1.6	15	54°15'58.8"	96°13'08.4"
32	2012.07.12	920	E	7	60	8	60	85	22	0.8	8	54°17'28.5"	96°14'10.7"
33	2012.07.12	925	60	8	45	4	65	90	20	0.8	10	54°17'30.0"	96°14'09.1"
34	2012.07.13	925	SSE	3	60	12	65	85	17	1.7	12	54°15'16.9"	96°11'15.4"
35	2012.07.13	1012	170	15	60	12	65	10	16	1.2	37	54°15'20.7"	96°11'09.3"
36	2012.07.13	1008	150	40	55	10	65	15	18	1.2	27	54°15'24.6"	96°11'12.1"
37	2012.07.13	1018	200	12	60	15	65	70	24	1.2	12	54°15'21.9"	96°11'05.4"
38	2012.07.13	925	350	3	60	5	60	90	23	0.6	10	54°15'17.5"	96°11'15.2"
39	2012.07.14	937	N	1	40	4	55	90	18	0.6	8	54°12'08.0"	96°10'05.1"
40	2012.07.14	952	W	25	60	5	65	70	18	1.4	14	54°12'54.7"	96°10'59.5"
41	2012.07.14	927	100	5	40	15	60	40	18	1.4	15	54°16'34.4"	96°12'59.3"
42	2012.07.15	928	100	3	40	10	65	70	19	1.1	18	54°17'25.1"	96°14'12.1"

Headings: 1 – Relevé No., 2 – Date (year/month/day), 3 – Altitude (m), 4 – Aspect (degrees), 5 – Slope (degrees), 6 – Cover tree layer (%), 7 – Cover shrub layer (%), 8 – Cover herb layer (%), 9 – Cover moss layer (%), 10 – Height (highest) trees (m), 11 – Height (highest) shrubs (m), 12 – Aver. height (high) herbs (cm), 13 – Latitude, 14 – Longitude.

and *Duschekia fruticosa*) form a sparse layer with a cover of 3–8 % and height of 0.5–1.7 m). The grass layer has a cover of 60–75 %, height of 11–18 cm and species richness of 17–35 species per 100^2. The main dominants and subdominants are typical boreal plants: *Vaccinium vitis-idaea, Linnaea borealis, Trientalis europaea, Calamagrostis obtusata*. Shallow position of seasonally frozen ground is indicated by *Ledum palustre*. The well-developed moss layer (a cover of 60–90 %) is formed by a combination of mesophilous species (*Pleurozium schreberi, Ptilium crista-castrensis, Hylocomium splendens, Dicranum scoparium*) and hygrophytes (*Aulacomnium turgidum, A. palustre, Sphagnum girgensohnii, S. capillifolium, S. warnstorfii, S. angustifolium*).

Gymnocarpio dryopteridis–Pinetum sibiricae ass nov. hoc loco.

Diagnostic species: *Calamagrostis langsdorffii, C. pavlovii, Rubus matsumuranus*.

Holotypus: Relevé no. 40 (Table 1, 1a).

The community was found only on the higher terraces of Lake Agulskoye and in the Agul River valley, where it occupies sites with well-drained and moist non-frozen soils. The tree layer (a height of 23–24 m and cover of 50–65 %) is dominated by *Pinus sibirica*. The shrub layer (a cover of 5–15 % and height of 0.9–1.6 m) includes *Sorbus sibirica, Lonicera altaica, Rubus matsumuranus, Spiraea chamaedryfolia*. The main peculiarity of the well-developed grass layer is a high abundance and constancy of moderately cold-tolerant boreal mesophytes *Gymnocarpium dryopteris, Diplazium sibiricum, Circaea alpina*, as well as tall-forb species – *Senecio nemorensis, Aconitum septentrionale, Cacalia hastata*. Moss layer is dominated by typical boreal species – *Hylocomium splendens, Pleurozium schreberi, Ptilium crista-castrensis, Dicranum scoparium*.

Community ***Senecio nemorensis–Larix sibirica***

At present we have only five relevés of this vegetation type. The community represents moderately dry boreal forest occurring both on steep and gentle (4–25°) well-warmed slopes of the southern, south-eastern and south-western aspects, on stony non-frozen soils.

The tree layer with a cover of 40–60 % and height of 18–24 m is dominated by *Larix sibirica* and *Pinus sibirica*. The floristic composition of the herb-dwarf-shrub layer (a cover of 45–60 % and height of 12–24 cm) is characterized by a combination of typical boreal plants (*Vaccinium vitis-idaea, Linnaea borealis, Pyrola incarnata, Trientalis europaea*) and species of more thermophilous hemiboreal forests and meadow (*Calamagrostis pavlovii, Galium boreale, Thalictrum minus, Atragene sibirica, Saussurea parviflora*). The well-developed lichen-moss layer is dominated by boreal mesophytes – *Hylocomium splendens, Pleurozium schreberi, Dicranum scoparium* – with admixture of petrophytic xerophylous species – *Rhytidium rugosum*.

Campanulo turczaninovii–Laricetum sibiricae ass. nov. hoc loco

Diagnostic species: *Angelica tenuifolia, Aquilegia sibirica, Astragalus alpinus, A. frigidus, Caragana jubata, Cimicifuga foetida, Cotoneaster melanocarpus, Cypripedium guttatum, C. macranthon, Festuca sibirica, Hedysarum neglectum, Oxytropis strobilacea, Patrinia rupestris, Pedicularis resupinata, Phlojodicarpus species, Poa urssulensis, Rhododendron dauricum, Saussurea controversa, Viola uniflora.*

Holotypus: Relevé no. 17 (Table 1, 1a).

The association includes unique relict hemiboreal cryo-xerophilous larch forests of Central Asian geographical type. Their main range is associated with the ultra-continental high-mountainous regions of Northern Mongolia, Tuva and Eastern Siberia. In the Bolshoy Agul River basin, the small isolated areas of these forests were met along steep (40–45) southern, south-eastern and south-western mountain slopes with outcrops of carbonate rocks. Occasionally they occur on gentle south-oriented parts of terraces near Lake Agulskoye at altitudes of 915–1050 m.

The tree layer (a cover of 40–60 %, height of 19–24 m) is formed dominantly by *Larix sibirica* with an admixture of *Pinus sibirica*. The shrub layer (a cover of 5–25 % and height of 0.5–2 m) is dominated by *Spiraea chamaedrifolia*, *Rhododendron dauricum*, *Rosa acicularis* and alpine species – *Caragana jubata*. The floristic peculiarity of the communities is determined by the combination of ecologically different plants in the well-developed grass layer: drought-resistant steppe species (*Carex pediformis, Saussurea controversa, Aster alpinus, Dendranthema zawadskii, Thalictrum foetidum, Aconitum barbatum, Vicia cracca, Oxytropis strobilacea, Phlojodicarpus species, Festuca sibirica, Patrinia rupestris*), alpine cryophytes (*Campanula turczaninovii, Anemonastrum crinitum, Hedysarum neglectum, Astragalus alpinus, Kobresia filifolia*) and hemiboreal mesophytes (*Calamagrostis pavlovii, Cimicifuga foetida, Cypripedium guttatum, Cypripedium macranthon, Bromopsis pumpelliana, Viola uniflora, Pedicularis resupinata, Lilium pilo-*

siusculum, Thalictrum minus). The well-developed moss layer (a cover of 70–80 %) is absolutely dominated by xerophilous species – *Rhytidium rugosum* and *Aietinella abietina*.

The obtained results of forests classification in the Bolshoy Agul river basin demonstrate important patterns of ecology and geography of the highest forests categories in the mountains of Southern Siberia. Most of the described associations belong to the East Siberian-Mongolian geographical type of light coniferous forests being formed in an ultracontinental dry climate. This is a rather unexpected result, because the northern macro-slope of the Altai-Sayan Mountain System (where the studied area is placed) as a whole demonstrates lower indices of the climate continentality and higher humidity in general. Therefore, dark coniferous forests of the Ural-Siberian geographical type should predominate here. However, the Bolshoy Agul river basin is characterized by special meso-climatic features closely related to the position of the main ridges in the western part of the Eastern Sayan. The high mountain ridges – Manskoe Belogorye, Kanskoe Belogorye and Idarskoe Belogorye – adjacent to the study area from the west play the role of regional barriers to the movement of western moist air masses. As a result, the effect of "rain shadow" leading to the predominance of the anticyclone during most of the year is observed in the Bolshoy Agul river basin. Ultimately, it leads to the formation of a cold ultra-continental regional climate with low precipitation what favors a deep soil freezing in winter and moisture deficit on well-warmed southern slopes in summer. Therefore, the cold-resistant hygro-mesophilous light-coniferous and mixed boreal forests of the order *Ledo–Laricetalia* (ass. *Linnaeo borealis–Pinetum sibiricae* and *Carici globularis–Pinetum sibiricae*) prevail here in the colder shaded parts of the mountain slopes with long-term frozen soils, while the communities of the "dry taiga" – of the order *Lathyro–Laricetalia* (ass. *Senecio nemorensis–Laricetum sibiricae*) occur on the warmer parts of exposed slopes. Both of these higher categories of boreal forests belong to Eastern Siberian-Mongolian geographical type. Floristic compositions of hemiboreal grass forests of the association *Campanulo turczaninovii–Laricetum sibiricae* occurring locally in the extra-zonal xeric sites of the Bolshoy Agul river basin demonstrate their remarkable ecological and plant-geographical relations with the drought-resistant *Rhytidio–Laricetea* forests widespread in ultra-continental Mongolian forest-steppe. They are characterized by a combination of plant species with contrasting ecological properties – alpine cryophytes and steppe xerophytes (mentioned above when characterizing the association), as well as the presence of such unique South Siberian-Mongolian cryo-xerophytes as *Caragana jubata*.

One association – *Gymnocarpio dryopteridis–Pinetum sibiricae* represents an example of another extra-zonal geographical type of Urals-Siberian dark-coniferous boreal forests (the order *Piceo obovatae –Pinetalia sibiricae*) widespread in the adjacent north-western part of the Eastern Sayan Mts. with more humid and cyclonic climate. The community penetrates into the studied area along well-drained parts of river valleys and terraces of Lake Agulskoe, where long-frozen soils are absent. The warmer and humid ecological properties of these sites are indicated by a group of mesophilous, moderately cold-resistant plant species – *Sorbus sibirica, Padus avium, Gymnocarpium dryopteris, Diplazium sibiricum, Circaea alpina, Rhodobryum roseum, Rhytidiadelphus triquetrus*.

The obtained results may be used for correction of forest zonation system in the mountains of Southern Siberia proposed by Smagin et al. (1980). In accordance with it, the Bolshoy Agul river basin belongs to the Agul-Tumanshetsky district of the East Sayanian forest province, the Altai-Sayanian mountain forest region. Smagin et al. (1980) characterized the Agul-Tumanshetsky district as an area of Urals-Siberian subnemoral dark-coniferous and boreal pine (*Pinus sibirica*) forests. However, the results of classification obtained showed absolute predominance of larch and pine-larch mixed forests of East-Siberian-Mongolian type widespread in the neighboring East-Tuvinian-South Zabaikalskiy mountain forest region. Therefore, the forests of the Bolshoy Agul river basin must be included in the latter and in the East-Tuvinian forests province. It is also obvious that in the scheme of geobotanical zonation of Northern Eurasia (Vasiliev et al., 1947), this region should be included in the East Siberian geobotanical subregion but not in the Euro-Siberian one.

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