

On plant communities of arid regions of Altai-Sayan mountains

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Abstract. 8 basic types of plant communities of arid regions of Altai-Sayan mountains have been revealed, their floristic classification has been carried out. Short description of the basic types has been given, their altitudinal distribution has been characterized.

1. Introduction

The South-East Altai and the South-West Tuva (Fig. 1) form the northern outpost of Central Asian arid area, while the main part of Altai-Sayan mountains belongs to the boreal zone. The South-East Altai center is the largest Altaian depression – the Chuya depression (1800–2100 m); the steep flanks of mountain ranges encircle the depression. Kuraisky ridge (2800–3800 m) forms its northern border, the spurs of North Chuysky ridge (2500–3000 m) – the western, and Chikhachev ridge (3000–4000 m) – the eastern, Ukok plateau and the Sailugem ridge (2900–3200 m), – the southern. Rivers of the South-East Altai originate in nearby ridges and flow into Chuya river [1]. The South-West Tuva includes Mongun-Taiga mountains (3400–3900 m), the southwestern flank of Tsagan-Shibetu ridge (3300–3500 m) and Kargy depression (1800–2100 m). Shallow mountain rivulets flow into Kargy river.

Three main types of climate appear to correspond to three main geomorphological units: (1) the climate of Chuya and Kargy depressions, (2) the climate of the flanks of the mountain ridges encircling depressions and (3) the climate of high-altitude ridges and plateaus. Low winter temperatures are caused by Siberian anticyclone; the cold air flows down from the slopes, fills the intermountain depressions and creates temperature inversions (January temperature in Chuya depression is -32°C). Mountain slopes are noticeably warmer than depressions: the average January temperature is -16°C . The climatic conditions of mountain flat tops are similar to those in a free atmosphere [2]: the average January temperature at altitude of 3000 m is -18°C . In the summer, the Chuya depression is the warmest place in the South-East Altai: the average temperature in July is $+14^{\circ}\text{C}$, while on the surrounding mountains slopes it is $+11^{\circ}\text{C}$. At an altitude of 2500 m, the average July temperature goes down to $+8^{\circ}\text{C}$, and at an altitude of 3000 m – to $+4^{\circ}\text{C}$. Annual rainfall in depressions varies from 100 to 150 mm. The surrounding mountain slopes receive up to 400 mm of precipitation; annual rainfall at the height of the snow line reaches 600 mm on the Chikhacheva ridge and 800–1000 mm on the South Chuysky ridge [2].

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The altitudinal zone series is known to comprise two belts (altitudinal zones): steppe (1800–2400 m) and alpine (2400–2800 m) one. The limits of altitudinal zones correspond to the main relief forms [3].

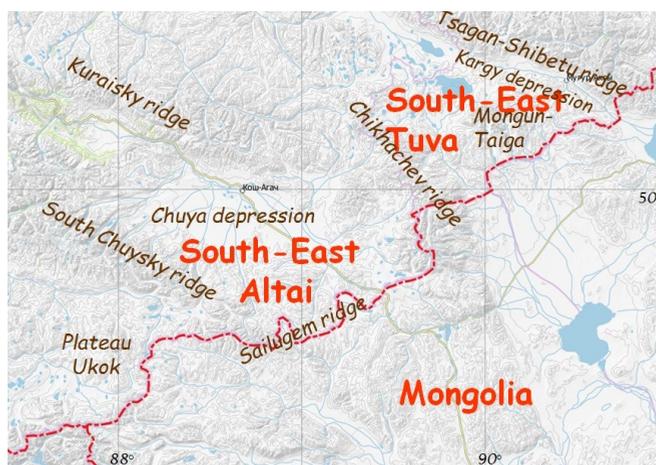


Fig. 1. Geographical position of arid regions of Altai-Sayan mountains.

2 Results

1.1 Biodiversity

In arid regions of Altai-Sayan mountains we revealed 8 basic types of plant communities: i – shrub tundra, ii – cryophytic forest, iii – alpine meadow, iv – Kobresia tundra, v – tundra-steppe, vi – cryophytic steppe, vii – petrophytic steppe, viii – dry steppe (bunch-grass typical and desert steppe).

We carried out floristic classification of plant communities of all basic types: dataset of 858 geobotanical relevés (published information and unpublished materials of the authors) was analyzed. Most of relevés belongs to published syntaxa, some new ones were ascertained on the basis of our unpublished data. The biodiversity of arid region vegetation is 25 associations and communities from 5 classes, 6 orders and 8 alliances (Table 1).

Table 1. Prodrum of basic plant communities of Altai-Sayan arid regions

Class **LOISELEURIO-VACCINIETEA** Egger 1952

Order **BETULETALIA ROTUNDIFOLIAE** Mirkin et al. ex Chytrý, Pešout et Anenchonov 1993

Alliance *Empetro-Betulion rotundifoliae* Zhitlukhina et Onishchenko ex Chytrý, Pešout et Anenchonov 1993

1 Ass. *Flavocetrario nivali-Betuletum rotundifoliae* Telyatnikov 2013

2 Ass. *Hylocomio splendidis-Caricetum sabynensis* Telyatnikov 2013

3 Ass. *Aulacomnio turgidi-Lagotidetum integrifoliae* Telyatnikov 2013

Class **RHYTIDIO RUGOSI-LARICETEA SIBIRICAE** Korotkov et Ermakov 1999

Order **FESTUCO OVINAE-LARICETALIA SIBIRICAE** Korotkov et Ermakov ex Ermakov et al. 2000

Alliance *Pachypleuro alpini-Laricion sibiricae* Ermakov in Ermakov et al. 2000

4 Ass. *Swertio obtusae-Laricetum sibiricae* Makunina 2014

(syn. *Polemonio coerulei-Laricetum sibiricae* ass. prov. Telyatnikov 2013)

5 Ass. *Kobresio myosuroides-Laricetum sibiricae* Ermakov in Ermakov et al. 2000

6 Ass. *Artemisio rupestris-Laricetum sibiricae* Makunina 2014

Class **JUNCETEA TRIFIDI** Hadac in Klika et Hadac 1944
 Order **VIOLATAICA-FESTUCETALIA KRYLOVIANAE** ord. prov. Ermakov et Zibzeev 2012

Alliance *Viola altaicae-Festucion krylovianae* all. prov. Ermakov et Zibzeev 2012

7 Ass. *Antennario dioicae-Pulsatilletum patentis* Telyatnikov 2013

8 Ass. *Seselo condensati-Trollietum asiatici* Telyatnikov 2013

Class **CARICI RUPESTRIS-KOBRESIETEA BELLARDII** Ohba 1974

Order **KOBRESIETALIA MYOSUROIDIS** Mirkin et al. (1983) 1986

Alliance *Kobresion myosuroidis* Mirkin et al. (1983) 1986

9 Ass. *Minuartio verna-Papaveretum pseudocanescentis* Telyatnikov et Mamakhatova 2011

(syn. *Rhytidio rugosi-Oxytropidetum alpinae* Telyatnikov 2013)

10 Ass. *Festuco krylovii-Kobresietum myosuroidis* ass. prov.

Alliance *Potentillo niveae-Caricion pediformis* Telyatnikov et Mamakhatova 2011

11 Ass. *Eritrichio villosi-Helictotrichetum hookeri* Telyatnikov et Mamakhatova 2011

12 Ass. *Oxytropido recognitae-Helictotrichetum altaici* ass. prov.

13 Ass. *Carici rupestris-Festucetum krylovianae* Korolyuk et Namzalov 1994

Class **CLEISTOGENETEA SQUARROSAE** Mirkin et al. 1992

Order **HELICTOTRICHETALIA SHELLIANI** Hilbig 2000

Alliance *Stellario petraeae-Festucion tschuensis* all. prov.

14 Ass. *Artemisio phaeolepidis-Kobresietum myosuroidis* Makunina 2011

15 Ass. *Sileno repentis-Caricetum pediformis* Makunina 2014

16 Ass. *Stellario petraeae-Poetum attenuatae* ass. prov.

17 Ass. *Oxytropido eriocarphae-Poetum attenuatae* Makunina 2014

18 Ass. *Oxytropido macrosemae-Agropyretum cristatae* Makunina 2014

Alliance *Helictotrichion schelliani* Hilbig 2000

19 Ass. *Potentillo sericeae-Agropyretum cristati* Makunina 2014

20 Comm. *Oxytropis tragacantoides* comm. prov.

Order **STIPETALIA KRYLOVII** Mirkin in Gogoleva et al. 1987

Alliance *Stipion krylovii* Kononov, Gogoleva et Mironova 1985

21 Ass. *Artemisio frigidiae-Stipetum krylovii* Korolyuk et Makunina 2009

22 Ass. *Artemisietum obtusilobae-santolinifoliae* Korolyuk in Korolyuk et Makunina 2009

23 Comm. *Stipa krylovii-Caragana bungei* comm. prov.

24 Ass. *Festuco tschuensis-Stipetum glareosae* ass. prov. Korolyuk 2002

25 Ass. *Allio vodopjanovae-Stipetum glareosae* ass. prov. Korolyuk 2002

To find out the significance of differences of floristic classification syntaxa and their accordance with basic types of plant communities, we carried out a cluster analysis of floristic classification syntaxa. The dendrogram was made in Past [4] using Ward method.

Two main groups were revealed (Figure 2): 1) high mountain communities and cryophytic forest (i – v), 2) steppes (vi – viii). Shrub tundra (i) belongs to class **LOISELEURIO-VACCINIETEA**, cryophytic forest (ii) – to class **RHYTIDIOLARICETEA**. Kobresia tundra (iv) and tundra-steppe (v) represent the class **CARICI-KOBRESIETEA**: the first one – alliance *Kobresion myosuroidis*, the second one – alliance *Potentillo niveae-Caricion pediformis*. Alpine meadow (iii), because of the lack of regional higher syntaxonomic units, was pre-assigned to the class **JUNCETEA TRIFIDI**. Kobresia tundra, tundra-steppe and alpine meadow form one common cluster. All steppe communities were ascribed to class **CLEISTOGENETEA SQUARROSAE**. Dry steppe was included in the order **STIPETALIA KRYLOVII**, the others – in the order **HELICTOTRICHETALIA SHELLIANI**: petrophytic steppe belongs to alliance *Helictotrichion schelliani*, cryophytic one – to alliance *Stellario petraeae-Festucion tschuensis*.

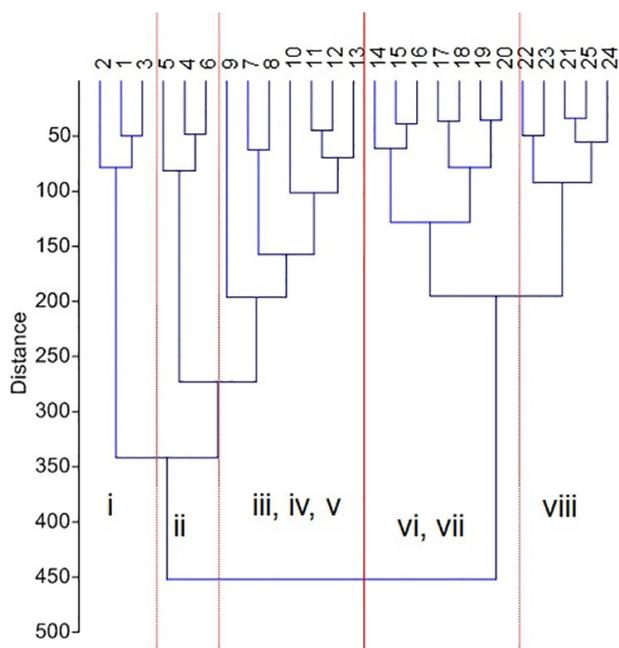


Fig. 2. Dendrogram of syntaxa. Arabic numerals in the dendrogram correspond to those in the prodromus. i – shrub tundra, ii – cryophytic forests, iii – alpine meadows, 4 – Kobresia tundra, 5 – tundra-steppes, 6 – cryophytic steppes, 7 – petrophytic steppes, 8 – bunch-grass steppes.

1.2 Characteristics of basic plant communities

To give short characteristics of basic plant communities we chosen active species, defining community visual appearance. The activity of the species was calculated as the square root of the multiplication of constancy by mean cover [5]. Very active (activity ≥ 40), active ($40 > \text{activity} \geq 20$), and moderately active ($20 > \text{activity} \geq 10$) species form the core of active species (Table 2). Very active species dominate in plant communities, active ones – codominate; moderately active species are constantly present.

Betula rotundifolia, mosses (*Aulacomnium turgidum*, *Hylocomium splendens*, *Rhytidium rugosum*), and lichens (*Cladonia arbuscula*, *C. stellaris*, *C. amaurocrea*) define the appearance of shrub tundra (i). *Larix sibirica* dominates in tree layer of cryophytic forest (ii); *Betula rotundifolia* and *Lonicera altaica* form shrub layer; tolerant to cold species make up the herb layer. Alpine meadow (iii) has no obvious dominants; *Pentaphragma fruticosum*, a wide range of alpine species, and tolerant to cold meadow-steppe species (*Pulsatilla patens*) codominate. Kobresia tundra (iv) has two main dominants: *Kobresia myosuroides* and *Dryas oxyodontha*. Tundra-steppe (v) and cryophytic (vi) steppe occur only in arid high mountains; they possess the numerous group of cryophytic species, the most part of which are inactive ones. Their distinctive feature is the simultaneous presence of species of different altitudinal zone groups. Alpine (*Carex rupestris*, *Festuca kryloviana*), forest-steppe (*Carex pediformis*), and steppe (*Helictotrichon altaicum*) species codominate in tundra-steppes (v); cryophytic species *Eremogone meyeri* and *Saussurea schanginiana* are moderately active. Steppe (*Koeleria cristata*, *Helictotrichon altaicum*) and forest-steppe (*Carex pediformis*) species make the core of cryophytic steppe (vi), alpine species have no significant role; in numerous group of cryophytic species only *Festuca tschujensis* is active. In petrophytic steppe (vii) steppe grasses (*Agropyron cristatum*, *Poa botrioides*) dominate; numerous petrophytic herbs are

present, but not active. Dry steppe (viii) are composed of only steppe species (*Agropyron cristatum*, *Artemisia frigida*, *Poa botryoides*).

Table 2. Active species of basic plants communities in Altai-Sayan arid regions

Basic vegetation types	i	ii	iii	iv	v	vi	vii	viii	Basic vegetation types	i	ii	lii	iv	v	vi	vii	viii
Most of plant communities									Cryophytic forests, alpine meadows and Kobresia tundra								
<i>Aster alpinus</i>		x	xx	x	x	x	x		<i>Bupleurum multinerve</i>		x	X	x	.	.	.	.
<i>Carex pediformis</i>	.	x	x	x	xx	xx	x		<i>Kobresia myosuroides</i>	.	x	X	xxx	.	.	.	.
<i>Helictotrichon altaicum</i>		.	x	.	xx	xx	xx		<i>Pachypleurum alpinum</i>	.	x	X	x	.	.	.	.
<i>Poa botryoides</i> + <i>P. attenuata</i>	.	x	x	x	xx	xx	xx	x	<i>Potentilla nivea</i>		x	X	x	.	.	.	.
Highmountain and cryophytic forest communities									Alpine meadows, Kobresia tundra and tundra-steppes								
<i>Betula rotundifolia</i>	xx	xx	x	x					<i>Carex rupestris</i>	.		X	x	xx			
<i>Bistorta major</i>	x	.	xx	xx	x	.	.		<i>Festuca kryloviana</i>	.		Xx	xx	xx			
<i>Bistorta vivipara</i>	x	x	x	xx	.	.	.		Alpine meadows and Kobresia tundra								
<i>Carex stenocarpa</i>	x	.	x	xx	.	.	.		<i>Dracocephalum grandiflorum</i>	.	.	Xx	x	.	.	.	.
<i>Cetraria islandica</i>	xx	.	x	x	.	.	.		<i>Eritrichium villosum</i>	.	.	X	x	.	.	.	.
<i>Cladonia arbuscula</i>	xx	.	.	x					<i>Helictotrichon hookeri</i>	.	.	X	x	.	.	.	.
<i>Festuca altaica</i>	x	x	xx	x	.	.	.		<i>Minuartia verna</i>	.	.	X	x	.	.	.	.
<i>Flavocetraria cucullata</i>	x	.	.	xx	.	.	.		<i>Potentilla gelida</i>	.	.	X	x	.	.	.	.
<i>Hedysarum austrosibiricum</i>	x	x	xx	x	.	.	.		<i>Schulzia crinita</i>	.	.	X	x	.	.	.	.
<i>Rhytidium rugosum</i>	xx	xx	.	xx	.	.	.		<i>Thalictrum alpinum</i>	.	.	X	x	.	.	.	.
<i>Spiraea alpina</i>	x	.	x	x	.	.	.		Kobresia tundra								
Shrub tundra									<i>Dryas oxyodonta</i>	.	.	.	xxx	.	.	.	.
<i>Aulacomnium turgidum</i>	xx	.	.	.					<i>Flavocetraria nivalis</i>	.	.	.	xx	.	.	.	.
<i>Cladonia stellaris</i>	xx		.	.					<i>Oxytropis alpina</i>	.	.	.	xx	.	.	.	.
<i>Dicranum species</i>	xx	.	.	.					<i>Carex ledebouriana</i>	.	.	.	x	.	.	.	.
<i>Hylocomium splendens</i>	xx	.	.	.					<i>Claytonia joanneana</i>	.	.	.	x	.	.	.	.
<i>Cladonia amaurocraea</i>	x	.	.	.					<i>Crepis chrysantha</i>	.	.	.	x	.	.	.	.
<i>Cladonia rangiferina</i>	x	.	.	.					<i>Gentiana algida</i>	.	.	.	x	.	.	.	.
<i>Peltigera species</i>	x	.	.	.					<i>Gentiana grandiflora</i>	.	.	.	x	.	.	.	.
<i>Polytrichum strictum</i>	x	.	.	.					<i>Lagotis integrifolia</i>	.	.	.	x	.	.	.	.
<i>Pyrola incarnata</i>	x	.	.	.					<i>Papaver pseudocanescens</i>	.	.	.	x	.	.	.	.
<i>Salix glauca</i>	x	.	.	.					<i>Patrinia sibirica</i>	.	.	.	x	.	.	.	.
<i>Sanionia uncinata</i>	x								<i>Pedicularis oederi</i>	.	.	.	x	.	.	.	.
Cryophytic forests									<i>Ptilagrostis mongholica</i>	.	.	.	x	.	.	.	.
<i>Larix sibirica</i>	.	xxx	.	.					<i>Thamnia vermicularis</i>	.	.	.	x	.	.	.	.
<i>Festuca ovina</i> + <i>F. Abietinella abietina</i>	x	xx							Kobresia tundra and tundra-steppe								
<i>Aconitum baicalense</i>	.	x							<i>Eremogone meyeri</i>	.	.	.	x	x			
<i>Aconitum barbatum</i>	.	x							<i>Saussurea schanginiana</i>	.	.	.	x	x	.		
<i>Atragene sibirica</i>	.	x							Tundra-steppes								
<i>Bromopsis pumpelliana</i>	.	x							<i>Agrostis tuvinica</i>	.	.	.	.	x	.	.	.
<i>Carex amgunensis</i>	.	x							<i>Artemisia phaeolepis</i>	.	.	.	.	x	.	.	.
<i>Lonicera altaica</i>	.	x							Steppes								
<i>Polemonium</i>	.	x							<i>Artemisia frigida</i>	.	.	.	.	x	xx	xx	
									<i>Koeleria cristata</i>	.	.	.	.	.	xx	x	x
									Cryophytic and petrophytic steppes								

CARICI-KOBRESIETEA; steppes were ascribed to class **CLEISTOGENETEA SQUARROSAE**.

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