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Alpine vegetation of the Altai

(Preliminary overview of the higher syntaxa)

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Abstract

A preliminary concept of the Altai alpine vegetation classification using the Braun-Blanquet approach has been developed on the basis of a geographically wide ranging set of original data and available published data. Five main phytosociological types of alpine vegetation (classes) were distinguished: alpine tundra (class *Loiseleurio-Vaccinietea* Eggler ex Schubert 1960, *Schulzio crinitae-Betuletalia rotundifoliae* ord. nova prov., *Pleurozio-Betulion rotundifoliae* all. nova prov., *Thamnolio-Betulion rotundifoliae* all. nova prov.), alpine meadows (class *Juncetea trifidi* Hadač in Klika et Hadač 1944, *Violo altaicae-Festucetalia krylovianae* ord. nova prov., *Violo altaicae-Festucion krylovianae* all. nova prov.), subnival chionophytic meadows (*Salicetea herbaceae* Br.-Bl. 1948, *Sibbaldio-Ranunculetalia altaici* ord. nova prov., *Salicion turczaninowii* Ishbirdin 1996), alpine dry meadows (*Carici rupestris-Kobresietea bellardii* Ohba 1974, *Kobresietalia myosuroidis* Mirkin ex Hilbig 2000, *Kobresion myosuroidis* Mirkin ex Hilbig 2000), and subnival screes (*Rhodioletea quadrifidae* Hilbig 2000, *Rhodioletalia quadrifidae* Hilbig 2000, *Rhodiolion quadrifidae* Hilbig 2000). Important diagnostic species groups of 30 associations and informal units (communities) are given in the synoptic table. Phytosociological and ecological peculiarities of the higher units are briefly described. The geographical concept of the high mountain vegetation class is discussed.

1. Introduction

The Altai is the mountainous region placed in the central part of Eurasia between latitudes 48º40' – 56º06' and longitudes 83º51' – 93º30'. It is characterized by a system of high mountain ridges (up to 4500 m) and a well-developed alpine belt occupying about 16% of the area. High altitudes, changes of regional climate from ultra-humid to arid together with a long history of the intensive orographical processes result in a high diversity of alpine vegetation and unique alpine flora of this mountain system. Until now, extensive areas of the Altai high mountains (as well as of Siberia in general) are inaccessible and vegetation is poorly studied.

Most existing papers on Siberian alpine communities have been written following the traditional Russian approach, when vegetation types were distinguished on the basis of main dominants and subdominants (GLUZDAKOV 1956, KUMINOVA 1956, 1960, GUDOSSHNIKOV 1965, KRASNOBOROV 1961, 1964, 1971, SEDELNIKOV, 1979, 1988). There are a few contributions devoted to syntaxonomy of alpine and subalpine vegetation carried out according to the Braun-Blanquet method only in certain restricted areas in Siberia and Mongolia (ZHITLUKHINA & ONIŠ ENKO, 1987, ERMAKOV et al. 2000, ZIBZEEV, 2009, 2010, 2012, TELYATNIKOV & MAMAKHATOVA 2011, MIRKIN et al., 1983, 1986; HILBIG, 1990, 2000, CHYTRÝ et al. 1993, DANIHELKA & CHYTRÝ, 1995). An integrated classification system of the alpine vegetation has not been developed yet and there is no consensus between the authors on the syntaxonomical position of alpine communities among the existing higher units.

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In the present paper, the results of preliminary study of the Altai alpine plant communities classification based on original data and available literature are represented.

2. Area under Study

The alpine vegetation is confined to the highest central and southern regions of the Altai mountain system (Fig.1) located in the transcontinental steppe zone near the center of Eurasia. The highest mountainous area of the Altai at altitudes of 1700-2900 m is dominated by ancient table-lands. The highest ridges (altitudes 2500-4500 m) have a rugged topography with steep slopes on metamorphic rocks, mainly base-rich chloride slates, with igneous rocks and limestones occupying small areas. Due to its location in the centre of Eurasia, the macroclimate of the Altai is strongly continental. Local climate, however, is considerably modified by its mountainous topography. The high-frontal ranges (up to altitudes of 2400–3010 m) of the Northern Altai intercept the westerly (Atlantic) humid air masses, which weaken the continental climatic features (POLIKARPOV et al. 1986). This area thus becomes warmer and more humid than elsewhere in Southern Siberia. The temperature of the coldest month (January) ranges from -14ºC to - 16ºC, while the temperature of the warmest month (July) is from +11ºC to +14ºC and annual precipitation varies from 1100 mm to 1900 mm (GIDROMETEOIZDAT 1966–1970). The abundant winter precipitation forms snow cover of up to 1.5 m, protecting soil and ground vegetation from frost. In contrast, south-eastern part of the Altai is in an area of rain shadow. Its climate is arid and continental, with annual precipitation below

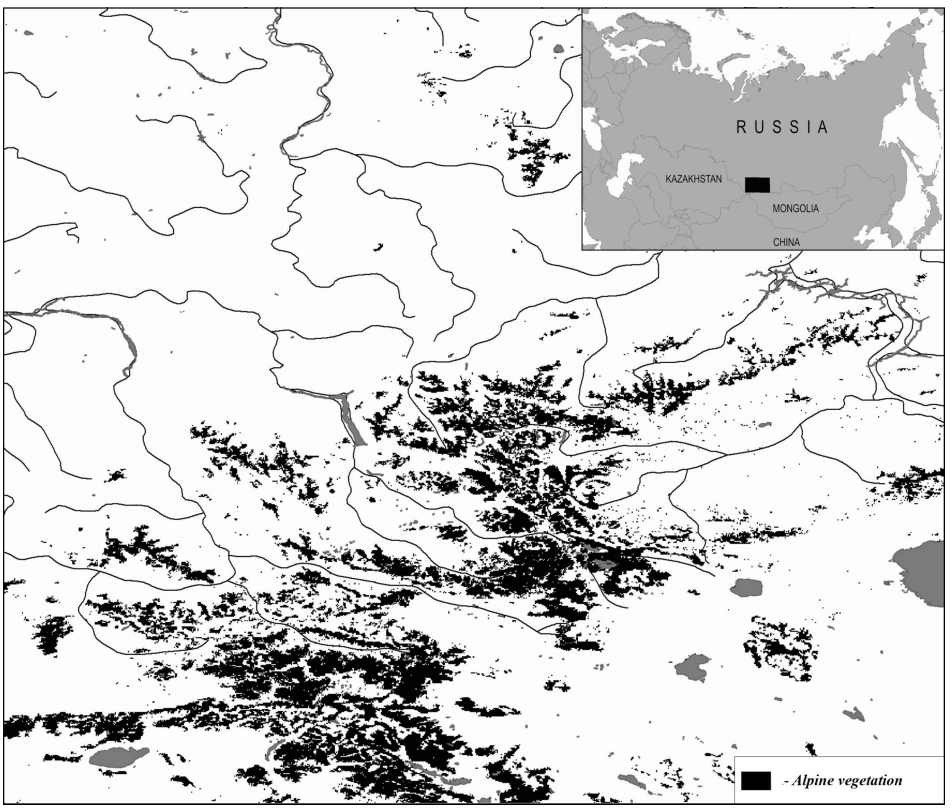

Fig. 1: Alpine vegetation range in the Altai.

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400 mm, of which 88–95% falls during a short period from late July to September. January temperatures range from - 27ºC to - 33ºC and July temperatures from +13ºC to +16ºC (GIDROMETEOIZDAT 1966–1970). In winter the weather is affected by the northern Asian anticyclone, leading to cooling, the formation of stagnant cold air masses and the absence of stable snow cover.

3. Materials and Methods

The basis for the analysis was comprised of 391 relevés of alpine, chionophytic, dry meadows, dwarf-shrub tundra and alpine screes. Most of the relevés were collected by authors. Additional information was included into the study from different publications (KRASNOBOROV 1961, KOROLYUK 2001, TELYATNIKOV & MAMAKHATOVA 2011). Species names follow the list of vascular plants of the former USSR (CHERREPANOV 1995) and the check-list of mosses of the former USSR (IGNATOV & AFONINA 1992).

Classification was carried out using the Braun-Blanquet approach according to WESTHOFF & VAN DER MAAREL 1973, supplemented by the use of the programs TWINSPAN and MegaTab (HILL 1979, HENNEKENS 1996). At the first stage, relevés from the region were classified separately to yield small informal groups at a fine ecological scale. 30 groups were identified at this level. At the second stage, the formal groups were analysed together and the recognition of the units was carried out using available syntaxonomic literature. At this stage synoptic tables from regional literature sources were added. TWINSPAN and MegaTab were applied again for the floristic integrity of the higher level syntaxa (alliances to classes) elucidation and for more precise definition of diagnostic taxa. As a consequence, a unified system of classification was developed which combined existing regional systems and particular syntaxa. While researching, it became clear that there is a need to reconsider diagnostic features of some units singled out earlier, as well as relevés of new provisional syntaxa.

For the syntax description, diagnostic species (D.S.) were used according to WESTHOFF & VAN DER MAAREL (1973): characteristic species, differential species and constant companions. We avoided separating the characteristic species into a discrete group because there are still very little data on the ecology, distribution and phytocoenotic position of the species from the vast territory of Northern Asia.

Syntaxonomical interpretations have been carried out using the available phytosociological literature (OHBA 1974, KIELLAND-LUND 1981, ELLENBERG 1986, MIRKIN et al. 1989, KOROTOV et al. 1991, OBERDORFER 1983, MUCINA 1997).

Data on distribution of species were taken from different Floras: FLORA OF THE USSR 1934-1960, FLORA OF SIBERIA 1988-1998 as well as from MEUSEL et al. 1964, 1978.

For characterization of the syntaxa the constancy scale: I (1-20 %), II (21-40 %), III (41-60 %), IV (61-80 %), V (81-100 %) is used.

4. Results

Using the Braun-Blanquet approach and TWINSPAN software, 30 units of alpine vegetation were distinguished, each with a distinct floristic composition and clear ecological and geographical interpretation. After comparing these groups with the phytosociological literature, we suggest their syntaxonomic interpretation at level of 5 classes, Alpine tundra (*Loiseleurio-Vaccinietea*), Alpine dry meadows (*Carici rupestris-Kobresitea bellardii*), Alpine meadows (*Juncetea trifidii*), Snow-bed chionophilous vegetation (*Salicetea herbaceae*), and

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Subnival screes (*Rhodioletea quadrifidae*). The main floristic peculiarities of these syntaxa are given in Tab. 1.

Table 1: Diagnostic species group of the Altai alpine vegetation higher syntax

Syntaxa nr.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Mean total number of releves	12	5	10	25	25	16	20	16	22	15	25	5	6	8	16	10	10	11	8	12	5	7	10	7	20	6	7	10	7	15
Diagnostic combination of the Loiseleurio-Vaccinietea																														
Betula rotundifolia	.	.	III	V	.	IV	V	V	V	V	V	.	II	.	.	.	III	.	.	.	II	II	III	III	II	.	IV	II	.	III
Vaccinium vitis-idaea	V	V	IV	V	III	V	IV	V	V	V	IV	IV	.	III	.	.	II	.	.	.	.	.	.	.	IV	.	.	.	.	.
Vaccinium uliginosum	V	IV	III	.	III	V	IV	V	V	V	.	IV	.	.	.	.	.	.	.	.	.	.	.	.	II	.	.	.	.	.
Vaccinium myrtillus	III	.	V	IV	II	.	V	.	V	.	III	.	.	.	.	III	III	II	.	.	III	III	IV	IV	.	.	.	.	.	.
Empetrum nigrum	IV	V	III	V	III	V	III	IV	IV	IV	II	.	.	.	.	.	.	.	.	.	.	.	.	.	IV	II	III	.	.	.
Alectoria ochroleuca	IV	V	.	.	III	V	.	IV	.	IV	III	.	.	V	II	.	.	.	.	.	.	.	.	.	V	.	.	.	.	.
Carex ensifolia	IV	V	IV	IV	IV	.	.	.	IV	.	.	.	.	.	II	.	.	.	.	.	.	.	.	.	V	.	.	.	.	.
Cladonia stellaris	V	V	IV	II	IV	IV	IV	V	II	V	V	.	.	IV	.	.	IV	II	.	.	.	.	II	.	IV	.	.	.	.	.
Cladonia rangiferina	IV	V	IV	II	IV	IV	V	V	II	V	V	.	.	IV	.	.	V	IV	.	.	.	II	II	III	IV	.	.	.	.	.
Cladonia amaurocraea	.	.	.	.	III	IV	III	IV	.	IV	II	.	.	III	IV	.	.	.	.	.	.	.	.	.	IV	.	.	II	.	.
Cladonia arbuscula	.	.	III	.	V	V	V	IV	II	IV	V	.	V	V	V	II	III	IV	.	.	II	II	IV	IV	IV	.	.	.	.	.
Thamnolia vermicularis	.	.	.	.	IV	V	II	IV	.	IV	III	.	V	V	V	.	IV	.	.	.	.	.	III	.	IV	V	IV	II	IV	.
Cetraria islandica	IV	V	III	II	III	IV	V	V	III	V	IV	.	V	V	V	III	IV	V	II	II	V	II	V	V	IV	III	III	III	IV	.
Flavocetraria cucullata	IV	V	.	.	III	V	III	V	.	V	IV	.	V	IV	V	III	III	II	.	.	.	.	IV	.	IV	IV	IV	IV	IV	.
Regional Asian species group of the alpine tundra																														
Rhododendron aureum	V	V	V	IV	IV	V	IV	V	V	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Salix glauca	V	.	III	V	.	III	IV	IV	V	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II	.	.	IV		
Carex iljinii	IV	.	IV	.	.	.	V	V	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Campanula dasyantha	.	III	.	III	V	V	II	III	V	III	III	.	.	.	.	.	.	.	.	.	.	.	.	.	III	.	.	.	.	.
Gentiana algida	IV	V	III	III	V	V	III	IV	V	IV	V	.	IV	V	IV	III	IV	.	.	.	.	.	III	.	IV	III	IV	III	IV	.
Diagnostic combination of the Juncetea trifidi																														
Anthoxanthum alpinum	.	.	V	II	V	.	V	.	V	.	IV	.	.	III	II	V	V	V	III	III	V	V	V	V	II	.	.	.	.	III
Hierochloe alpina	III	IV	.	.	V	V	.	IV	V	IV	IV	.	V	V	II	.	II	III	.	.	.	III	.	.	V	II	.	II	.	.
Minuartia biflora	.	.	III	.	.	.	.	.	.	.	.	.	.	.	IV	V	III	V	II	III	IV	IV	IV	II	.	.	.	II	II	.
Minuartia arctica	.	.	.	IV	V	IV	.	.	.	.	IV	.	IV	V	III	IV	IV	.	.	.	.	.	II	.	V	.	.	.	.	.
Antennaria dioica	.	.	.	.	.	.	.	.	.	.	II	.	.	.	IV	IV	.	II	.	.	II	IV	II	.	.	.	.	.	.	.
Festuca kryloviana	.	.	.	.	.	.	.	.	.	.	.	.	V	IV	V	V	V	V	III	V	V	IV	IV	.	.	.	.	.	.	IV
Lloydia serotina	.	.	.	.	IV	III	.	.	III	.	II	V	V	V	IV	III	IV	II	.	.	.	II	.	.	III	.	IV	.	.	III
Polytrichum piliferum	.	.	III	.	.	.	.	.	V	.	.	V	V	IV	V	V	IV	IV	II	II	V	V	V	V	.	.	.	.	.	.
Polytrichum commune	IV	.	IV	III	.	.	.	.	V	.	.	IV	IV	.	IV	IV	II	.	.	.	.	.	II	.	.	.	.	.	.	.
Polytrichum juniperinum	.	.	.	II	.	.	.	.	IV	.	.	V	V	IV	V	V	V	V	II	III	V	V	V	V	.	.	.	.	.	.
Rhytidium rugosum	.	.	.	.	.	.	.	.	.	.	.	.	IV	V	IV	IV	V	III	.	.	.	.	III	.	.	II	II	II	II	.
Regional Asian species group of alpine meadows																														
Swertia obtusa	.	.	.	V	.	.	.	.	.	.	V	.	III	III	IV	IV	IV	III	II	.	.	II	IV	.	III	.	.	.	.	.
Carex ledebouriana	III	.	.	IV	.	IV	III	III	.	III	IV	V	V	V	V	V	III	II	.	.	.	.	III	.	V	II	.	IV	.	.
Patrinia sibirica	.	.	.	II	V	IV	.	.	.	.	IV	.	V	V	V	V	IV	.	.	.	.	.	.	.	IV	II	.	V	II	.
Anemonastrum narcissiflorum	.	.	.	III	V	.	.	.	.	.	V	V	IV	.	IV	V	.	II	.	.	.	.	.	.	III	.	.	.	.	.
Silene chamarensis	.	IV	.	II	IV	.	.	.	.	.	.	.	V	IV	IV	IV	IV	.	.	.	.	.	.	.	II	.	.	.	.	.
Oxytropis sulphurea	.	.	.	.	.	.	.	.	.	.	.	.	IV	.	IV	IV	.	.	III	.	.	.	.	.	.	.	.	.	.	.
Hedysarum austrosibiricum	.	.	.	.	.	.	.	.	.	.	.	IV	.	II	V	.	IV	IV	.	.	IV	IV	III	.	II	.	.	.	.	.
Tephroseris turczaninovii	.	.	.	IV	.	.	.	.	.	.	III	.	IV	II	IV	II	.	.	.	.	.	.	.	.	III	.	.	.	.	III
Helictotrichon hookeri	.	.	.	.	.	II	II	II	.	II	.	V	.	.	IV	III	IV	II	.	.	.	.	.	.	II	III	.	IV	IV	.
Dracocephalum grandiflorium	.	.	III	II	.	.	.	.	.	.	IV	.	V	III	V	IV	IV	V	II	.	IV	III	III	.	III	.	.	IV	III	.
Trisetum altaicum	.	.	III	.	.	.	.	.	.	.	.	.	II	V	.	II	IV	V	.	.	V	IV	V	.	.	.	.	II	.	IV
Asian alpine species with high constancy in several higher units																														
Viola altaica	III	IV	V	III	.	.	IV	III	.	III	IV	IV	V	V	IV	V	IV	V	III	.	IV	IV	V	V	II	.	.	.	.	.
Gentiana grandiflora	.	.	V	IV	IV	IV	IV	III	IV	III	V	V	V	IV	V	V	V	IV	IV	III	.	.	V	V	III	.	II	II	II	.
Schulzia crinita	IV	IV	V	III	V	V	IV	III	III	III	IV	III	V	V	V	IV	V	V	III	III	IV	IV	V	V	III	II	III	IV	III	.
Dryas oxyodonta	.	.	.	IV	V	V	.	II	III	II	V	V	V	V	III	.	II	.	.	.	.	.	.	.	V	V	IV	V	.	.
Diagnostic combination of the Salicetea herbaceae																														

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Sibbaldia procumbens	.	.	III	.	.	.	.	.	.	.	IV	.	.	.	.	II	II	IV	IV	V	IV	IV	V	V	II	.	.	.	.	.
Polytrichum sexangulare	.	.	III	.	.	.	.	.	III	.	.	IV	.	.	.	.	II	.	V	V	.	II	IV	III	.	.	.	.	.	.
Ranunculus altaicus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	V	V	IV	IV	II	.	.	.	.	.	.	.
Omalotheca norvegica	.	.	III	.	.	.	.	.	.	.	.	.	.	.	.	.	II	IV	II	II	V	III	IV	IV	.	.	.	.	.	.
Deschampsia cespitosa	.	.	III	.	.	.	.	.	.	.	II	.	.	.	.	II	III	V	.	V	V	III	V	IV	.	.	.	.	.	.
Dichodon cerastoides	.	.	III	.	.	.	.	.	.	.	.	.	.	.	.	.	III	V	IV	IV	IV	IV	.	II	.	.	.	.	.	III
Salix turczaninowii	.	.	.	.	.	.	.	.	.	.	II	.	V	III	.	.	.	.	II	.	.	V	V	III	II	II	IV	II	.	.
Carex aterrima	III	.	IV	IV	.	.	IV	.	.	.	II	.	.	.	.	.	II	V	III	II	V	V	IV	III	.	.	.	.	.	III
Veronica densiflora	.	.	.	II	.	.	.	.	.	.	II	.	.	II	.	.	.	IV	II	.	IV	IV	III	.	.	.	.	.	.	.
Carex altaica	.	.	.	.	.	.	III	II	.	II	.	.	.	.	II	.	.	.	IV	IV	.	.	III	III	.	II	IV	.	.	.
Lescuraea saxicola	.	.	.	.	.	.	.	.	.	.	.	III	.	.	.	.	.	.	.	.	.	IV	III	IV	.	.	.	.	.	.
Diagnostic combination of the Carici rupestris-Kobresietea bellardii																														
Kobresia myosuroides	.	.	.	.	.	.	.	.	.	.	.	.	.	III	.	.	III	.	.	.	.	.	.	.	III	V	V	V	III	.
Kobresia sibirica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II	IV	.	V	.
Carex rupestris	.	.	.	.	.	.	.	.	.	.	.	IV	V	V	.	.	II	.	.	.	.	.	.	.	.	IV	II	II	IV	.
Festuca sphagnicola	.	.	.	V	IV	V	V	IV	V	IV	IV	V	.	.	.	.	.	.	.	.	.	.	.	II	V	III	IV	IV	V	.
Potentilla nivea	.	.	.	.	.	.	.	.	.	.	III	.	.	IV	II	II	V	II	.	.	.	.	II	.	IV	IV	.	IV	IV	.
Potentilla gelida	.	IV	.	III	.	.	II	.	.	.	III	III	.	.	III	II	.	.	.	.	.	II	.	.	II	II	IV	IV	III	IV
Pedicularis oederi	.	.	.	V	V	II	.	III	III	III	IV	.	.	.	IV	III	.	.	III	.	.	III	III	.	IV	IV	IV	III	II	.
Pachypleurum alpinum	.	.	.	IV	.	.	.	.	.	.	II	.	.	II	.	II	II	.	.	.	III	II	II	.	II	III	.	IV	V	IV
Minuartia verna	.	.	.	.	.	.	.	.	.	.	III	.	II	III	.	.	II	III	.	.	IV	III	.	.	IV	V	II	IV	IV	IV
Flavocetraria nivalis	.	.	.	.	.	II	.	III	.	III	.	.	.	.	III	.	.	.	.	.	.	.	.	.	III	V	IV	V	IV	.
Vulpicidia tilesii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV	III	IV	II	.
Regional Asian species group of the Carici-Kobresietea																														
Oxytropis alpina	.	.	.	.	.	.	.	.	.	.	.	.	II	II	.	.	III	.	.	IV	II	.	.	.	III	V	IV	IV	IV	III
Sajanella monstrosa	.	.	.	IV	.	.	.	.	.	.	II	.	.	III	II	.	IV	III	.	.	.	.	IV	.	III	.	IV	IV	.	.
Lagotis integrifolia	.	.	.	IV	.	.	.	.	.	.	II	.	II	III	.	.	III	II	III	II	.	.	III	.	II	IV	IV	III	III	III
Festuca altaica	III	.	III	.	.	.	.	.	.	.	.	.	.	III	.	.	II	II	.	.	.	.	III	.	.	IV	IV	V	III	.
Thalictrum alpinum	.	.	.	.	.	.	.	.	.	.	II	.	.	III	.	.	IV	.	.	.	.	.	.	.	III	IV	II	IV	IV	.
Eritrichium villosum	.	.	.	V	.	.	.	.	.	.	III	.	.	.	.	.	.	.	.	.	.	.	.	.	III	III	.	IV	IV	.
Papaver pseudocanescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	V	II	V	V	IV
Crepis chrysantha	.	.	.	.	.	.	.	.	.	.	II	.	.	IV	.	.	IV	.	.	.	.	.	.	.	IV	IV	.	IV	IV	III
Saussurea schanginiana	.	.	.	.	.	.	.	.	.	.	IV	.	.	III	.	.	III	.	.	.	.	.	.	.	III	IV	.	IV	IV	.
Diagnostic combination of the Rhodioletea quadrifidae																														
Rhodiola rosea	.	.	.	IV	.	.	.	.	.	.	III	.	II	II	.	.	III	II	II	.	.	.	.	.	II	.	.	.	II	IV
Rhodiola algida	.	.	.	.	.	.	.	.	.	.	.	.	II	II	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III
Rhodiola coccinea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV
Gastrolychnis apetala	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III	II	III	V
Saxifraga nelsoniana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II	III	.	.	.	.	.	.	V
Saxifraga sibirica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II	.	III	.	.	.	.	.	.	II	V
Saxifraga macrocalyx	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV
Saxifraga cernua	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II	IV
Cerastium lithospermifolium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV
Poa alpigena	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV
Chamaenerion latifolium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV
Trisetum mongolicum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II	II	III	.	IV
Saxifraga oppositifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II	.	.	.	III
Primula nivalis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV
Oxyria digyna	.	.	.	.	.	.	.	.	.	.	.	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III

List of syntaxa (Syntraxa nr.)

1. Community Vaccinium uligonosum-Rhododendron aureum. Eastern Sayan ridge (Krasnoborov 1961).
2. Community Empetrum nigrum-Vaccinium vitis-idaea. Eastern Sayan ridge (Krasnoborov 1961).
3. Community Rhododendron aureum-Vaccinium myrtillus. Eastern Sayan ridge (Krasnoborov 1961).
4. Community Betula rotundifolia-Empetrum nigrum. Western Sayan ridge (Zibzeev 2012).
5. Community Dryas oxyodonta-Rhododendron aureum. Western Sayan ridge (Zibzeev 2010).
6. Community Rhododendron aureum-Vaccinium vitis-idaea-Alectoria ochroleuca Western Sayan ridge (Zibzeev 2010).

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7. Community Betula rotundifolia- Anthoxanthum alpinum. Western Sayan ridge (Zibzeev 2010).
8. Community Betula rotundifolia-Carex iljinii-Vaccinium vitis-idaea. Western Sayan ridge (Zibzeev 2010).
9. Community Rhododendron aureum-Vaccinium uliginosum-Hierochloe alpina. Western Sayan ridge (Zibzeev 2012).
10. Community Rhododendron aureum-Carex iljinii. Eastern Sayan ridge (Zibzeev 2009).
11. Community Dryas oxyodonta-Gentiana algida. Western Sayan ridge (Zibzeev 2010).
12. Community Dryas oxyodonta-Arctous alpina-Callianthemum sajanense-Paraquilegia microphylla. Eastern Sayan ridge (Zibzeev 2009).
13. Ass. Carici sempervirentis-Dryadetum oxyodontae Zibzeev, Basargin 2012. Western and Central Altai.
14. Ass. Carici sempervirentis-Dryadetum oxyodontae Western Sayan ridge, Central Altai (Zibzeev 2012).
15. Ass. Festuco krylovianae - Schulzietum crinitae Zibzeev 2012. Western Altai.
16. Ass. Carici sempervirentis-Dryadetum oxyodontae Zibzeev 2012, subass. asteretosum alpini Zibzeev 2012. West Altai.
17. Ass. Festuco krylovianae-Schulzietum crinitae Zibzeev 2012. Central Altai.
18. Ass. Aquilegio glandulosae-Festucetum krylovianae Korolyuk 2001. Western and Central Altai (Zibzeev. 2012)
19. Ass. Polytricho sexangularis-Ranunculetum altaicae Korolyuk 2001. Western and Central Altai.
20. Ass. Polytricho sexangularis-Ranunculetum altaicae Korolyuk 2001. Western Altai.
21. Ass. Aquilegio glandulosae-Festucetum krylovianae Korolyuk 2001. Central and Western Altai.
22. Ass. Salici turczaninowii-Sibbaldietum procumbentis Danihelka et Chytry 1995. Central Altai, Western and Eastern Sayan ridges (unpublished).
23. Ass. Salici turczaninowii-Sibbaldietum procumbentis Korolyuk 2001. Central Altai.
24. Community Sibbaldia procumbens-Schulzia crinita. Eastern Sayan ridge (unpublished).
25. Community Festuca sphagnicola-Dryas oxyodonta. Western Sayan (unpublished).
26. Ass. Minuartio vernae-Papaveretum pseudocanescentis Telyatnikov et Mamakhatova 2011. South-Eastern Altai.
27. Ass. Hedysaro consanguinei-Kobresietum myosuroidis Telyatnikovet Mamakhatova 2011. South-Eastern Altai.
28. Ass. Minuartio vernae-Papaveretum pseudocanescentis subass. patrinietosum sibiricae Telyatnikov et Mamakhatova 2011. South-Eastern Altai.
29. Ass. Minuartio vernae-Papaveretum pseudocanescentis subass. kobresietosum sibiricae Telyatnikov et Mamakhatova 2011. South-Eastern Altai.
30. Community Festuca sphagnicola-Rhodiola coccinea. Central Altai (Korolyuk 2001).

Alpine tundra - Loiseleurio-Vaccinietea Eggler ex Schubert 1960 (Tab. 1, col. 1-11)

Synonyms: Betuletea rotundifoliae Mirkin 1983 nom nud., Betuletea rotundifoliae Mirkin ex Chytrý 1993 nom. ambig., Betuletea rotundifoliae Mirkin (Hilbig 2000) nom nud.

Shrub (*Betula rotundifolia*) – dwarf shrub – lichen – moss tundra represents a prevalent type of alpine vegetation in the humid and moderately humid bioclimatic sectors of the Altai. It occupies extensive areas on slopes of different expositions and inclinations in the higher parts of mountain ridges at altitudes of 1800-3000 m. The Altai alpine tundra is characterized by predominance of ericoid dwarf-shrubs (*Vaccinium vitis-idaea* s.l., *V. myrtillus*, *V. uliginosum* s.l., *Ledum palustre* s.l., *Empetrum nigrum*), well-developed shrub layer of *Betula rotundifolia* (*B. nana* ssp. *rotundifolia*), *Salix glauca* and some *Rhododendron* species (*R. aureum, R. parviflorum, R. adamsii*) and well-developed layer of lichens (*Cladonia stellaris, C. rangiferina, C. arbuscula, Cetraria islandica, Alectoria ochroleuca*) and bryophytes (*Pleurozium schreberi, Polytrichum juniperinum, Dicranum scoparium*). Along with widespread ericoid dwarf shrubs the floristic composition also includes a group of arctic-alpine species of Eurasian and Holarctic chorological groups (*Hierochloe alpina, Anthoxanthum alpinum, Pedicularis oederi, Minuartia arctica, Gentiana algida, Bistorta vivipara*). Regional peculiarity of the Altai alpine tundra is indicated by a distinct Asian regional group of species related to the mountains of Southern Siberia, Mongolia and Middle Asia (*Viola altaica, Gentiana grandiflora, Schulzia crinita, Patrinia sibirica, Campanula dasyantha*). These species are not strongly related to the Loiseleurio-Vaccinietea. However they play an important role in geographical differentiation of communities from this class and they may be used in the determination of the new provisional order Schulzio crinitae-Betuletalia rotundifoliae ord. nova prov. uniting alpine tundra of mountain systems in Southern Siberia and Northern Mongolia.

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The *Schulzio crinitae-Betuletalia rotundifoliae* includes two distinct ecological types of alpine tundra which may be considered as two alliances.

Communities of the alliance *Pleurozio-Betulion rotundifoliae* all. nova prov. (Tab. 1, col. 1-4) are widespread in humid climate of northern part of the Altai, where they occur at lower altitudes near timberline where the snow cover form a thick layer (up to 1.5 m). They are characterized by a distinct layer of boreal mosses and participation of some shrub and herb species typical of the Vaccinio-Piceetea forests and open woodlands (*Pleurozium schreberi, Hylocomium splendens, Aulacomnium turgidum, Lonicera altaica, Carex globularis, C. ensifolia*).

Communities of the alliance *Thamnolio-Betulion rotundifoliae* all. nova prov. (Tab. 1, col. 5-11) predominate in moderately arid climate of central and south-eastern parts of the Altai, where they occur at higher altitudes on the tops of mountain ridges with thinner snow cover (30-40 cm, up to 50 cm). They are characterized by a distinct layer of numerous lichens (*Cladonia amaurocraea, C. sulphurina, C. uncialis, Cetraria laevigata, Thamnolia vermicularis, Flavocetraria cucullata*) and participation of true alpine and arctic-alpine species (*Dryas oxyodonta, Festuca sphagnicola, Pedicularis oederi, Lloydia serotina,* fig. 2).

Fig. 2: *Dryas oxyodonta* community.

Alpine meadows - Juncetea trifidi Hadač in Klika et Hadač 1944 (Tab. 1 col. 12-18)

Typical alpine meadows occur dominantly in the western part of the Altai characterized by high humidity and low continentality of local climate. They occupy flat summits and gentle slopes of mountain ridges with short-frozen soils (alpine meadows avoid long-frozen soils and permafrost). In the eastern part of the Altai with more continental and cold climate, alpine meadows occur in local habitats related to river valleys and well-drained small depressions on slopes with moderately humid soils. Class *Juncetea trifidi* was not mentioned for Southern Siberia in previous papers. Only one association *Alectorio ochroleucae-Patrinietum sibiricae* described by CHYTRÝ et al. 1993 within the class *Betuletea rotundifoliae* may be attributed

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to the *Juncetea trifidi.* Our opinion about accessory character of the Altai alpine meadows to the *Juncetea trifidi* is explained by their clear floristic relations with European and Caucasian alpine meadows. Altai communities contain a combination of geographically widespread species which can be considered characteristic for this class: *Anthoxanthum alpinum, Hierochloe alpina, Minuartia arctica, M. biflora, Bistorta vivipara, Lloydia serotina, Antennaria dioica, Juncus trifidus, Polytrichum commune, P. juniperinum, Rhytidium rugosum, Carex aterrima, C. stenocarpa, Pedicularis verticillata*. Besides there is a group of European and Asian vicarious species indicating the similarity between European and North Asian alpine meadows: *Carex tristis – Carex sempervires, Helictotrichon hookeri – H. versicolor, Festuca kryloviana – F. ovina*. The Altai and European alpine meadows show a very similar phytocoenotic structure (physiognomy) and ecology. Typical combination of alpine higher vascular plants with mosses (*Polytrichum commune, P. juniperinum, Rhytidium rugosum, Abietinella abietina, Dicranum scoparium*) and lichens (*Cladonia arbuscula, C. uncialis, Cetraria islandica, Flavocetraria cucullata, Thamnolia vermicularis*) is a characteristic feature for both geographical types of alpine meadows.

Strong regional floristic peculiarities of the Altai alpine meadows are confirmed by a group of species of Asian chorological group (*Dracocephalum grandiflorum, Dryas oxyodonta, Festuca kryloviana, Hedysarum austrosibiricum, Carex ledebouriana, Gentiana grandiflora, Oxytropis sulphurea, Patrinia sibirica, Swertia obtusa, Silene chamarensis, Tripleurospermum ambiguum, Tephroseris turczaninovii, Trisetum altaicum, Viola altaica*). These species can be considered as regional characteristic species of South Siberian alpine meadows and should be used for special new provisional order *Violo altaicae-Festucetalia krylovianae* ord. nova prov. including communities from the Southern Siberia and Northern mountain systems of Middle Asia (Saur, Tarbagatay and Tyan-Shan). Currently the new provisional order includes one alliance *Violo altaicae-Festucion krylovianae* all. nova prov.

Subnival chionophytic meadows - Salicetea herbaceae Br.-Bl. 1948 (Tab. 1, col. 19-24)

Subnival vegetation occurs along the whole Altai mountain system and is weakly related to a certain bioclimatic type. It occupies long-lasting snow-beds and slopes irrigated by melt waters. Like in Europe, these communities are characterized by predominance of *Sibbaldia procumbens* and other species of the *Salicetea herbaceae* (*Omalotheca norvegica, Anthoxantum alpinum, Carex aterrima, Ranunculus glacialis, R. nivalis, R. sulphureus, Dichotodon cerastoides, Polytrichum sexangulare*). A characteristic feature of the Altai subnival chionophytic meadows is an essential phytocoenotic role of small prostrate species of Salix (*Salix turczaninowii, S. recjulis, S. berberifolia*) as well as a similar role of a group including vicarious chionophilous species: *Ranunculus altaicus – R. sulphureus, Deschampsia altaica – D. caespitosa, Salix turczaninowii – S. herbacea*, fig. 3*).*

The Altai chionophilous communities contain a group of regional Asian alpine species (*Dracocephalum grandiflorum, Festuca kryloviana, Hedysarum austrosibiricum, Carex altaica, Gentiana grandiflora, Aquilegia glandulosa, Luzula sibirica, Solidago dahurica, Tripleurospermum ambiguum, Veronica densiflora, Viola altaica*). These species do not represent a characteristic element of the *Salicetea herbaceae* because most of them show higher constancy values in the *Juncetea trifidi* alpine meadows. However they can be considered as an important geographical differential species group for the special regional order *Sibbaldio – Ranunculetalia altaici* ord. nova prov. uniting snow-bed vegetation of the South-Siberian Mountains. At present this order includes one alliance *Salicion turczaninowii* Ishbirdin 1996.

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Fig. 3: *Ranunculus altaicus* subnival meadow.

Alpine dry meadows - Carici rupestris-Kobresietea bellardii Ohba 1974 (Tab.1, col. 25-29)

Communities of the class are widespread in the south-eastern part of the Altai with semi-arid and arid climates. They occupy dry convex parts of mountain slopes and well-drained flat summits. These sites are characterized by the lack of a stable snow cover resulting in a high variation of soil temperature regime. As a rule, dry alpine meadows are replaced by cryophytic Central Asian steppes of the *Cleistogenetea squarrosae* Mirkin et al ex Korotkov et al. 1991 on south-facing slopes and by dwarf-shrub communities with *Betula rotundifolia* (*Loiseleurio-Vaccinietea* class) in depressions on north-facing slopes in the same landscapes. Communities of the *Carici-Kobresietea* are characterized by a well-developed layer of cryophilous drought-resistant alpine species (*Kobresia myosuroides, Kobresia sibirica, Carex rupestris Festuca altaica Lagotis integrifolia Minuartia verna Pedicularis oederi Potentilla gelida P. nivea Sajanella monstrosa Thalictrum alpinum*) as well as by a distinct lichen layer (*Cetraria islandica, C. loevigata, Flavocetraria cucullata, F. nivalis, Thamnolia vermicularis, Vulpicidia tilesii*). Bryophytes do not play an essential role there. Floristic geographic peculiarity of the Altai class communities is indicated by the South-Siberian – Middle Asian species group (*Crepis chrysantha, Dryas oxyodonta, Eritrichium villosum, Carex pediformis, Festuca sphagnicola, Oxytropis alpine, Papaver pseudocanescens, Sajanella monstrosa, Saussurea schanginiana*). These species are typical for the alliance *Kobresion myosuroidis* Mirkin ex Hilbig 2000 and the order *Kobresietalia myosuroidis* Mirkin ex Hilbig 2000.

Subnival screes - Rhodioletea quadrifidae Hilbig 2000 (Tab. 1, col. 30)

This class was described in Mongolia by HILBIG (2000). Subnival scree communities are widespread on talus slopes of mountain ridges at the higher altitudes (2300-3700 m). However at present only one community *Festuca sphagnicola-Rhodiola coccinea* of this class

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(alliance *Rhodiolion quadrifidae* Hilbig 2000) was described in the Altai (KOROLYUK 2001) from the Katunsky ridge. It is characterized by a very peculiar floristic composition comprised of many Asian petrophytic cold-tolerant plants (*Rhodiola algida, R. coccinea, R. quadrifida, R. rosea, Chamaenerion latifolium, Gastrolychnis apetala, Poa alpigena, Saxifraga nelsoniana, S. sibirica, S. macrocalyx, S. cernua, S. oppositifolia, Cerastium lithospermifolium, Primula nivalis, Trisetum mongolicum*). Further study of these communities and their comparison with geographically widespread class *Thlaspietea rotundifoliae* is needed.

5. Discussion

The Altai mountain system represents one of the centers of alpine flora and vegetation diversity in Eurasia. Complicated history of orogenesis and paleoclimate of this system was accompanied by geographical isolation of Alpine flora in some periods and by intensive floristic migrations (especially during the Pleistocene). As a result, the modern alpine flora is characterized by various plant geographical relations with mountain systems placed in Europe, Middle Asia, North-Eastern Asia as well as with flora of the Arctic zone. The Altai also contains a lot of endemic elements. That is why the classification of high mountain vegetation should be based on the detailed analysis of horologic elements, vicarious species groups, regional endemics distributions and ecology of plant communities. Phytosociologists started the classification of the alpine vegetation in Southern Siberia and Mongolia (MIRKIN et al. 1983, 1986; ZHITLUKHINA & ONIŠČENKO 1987, HILBIG 1990, 2000, CHYTRÝ et al. 1993), described several new regional classes (e.g. *Betuletea rotundifoliae, Kobresietea myosuroidis, Aconito-Geranietea, Juniperetea pseudosabinae*). This approach emphasized distinct floristic differences of Siberian-Mongolian and European alpine higher syntaxa. However, a very important plant geographical unity of physiognomy, ecology and series of systematically close vicarious species in the North Eurasian alpine communities was ignored. Actually there are two ways of the alpine vegetation classification development at the scale of continents. One of them is a description of series of "small" ecologically vicarious local classes based on only formal floristic differences. Another approach is an application of the above mentioned criteria to accept a broad geographical concept of classes. The latter one was proposed by DANIËLS (1994), PIGNATTI (1995), PIGNATTI et al. (1995). Using this concept we included the diversity of the Altai alpine vegetation into traditional Eurasian classes *Carici-Kobresietea, Loiseleurio-Vaccinietea, Salicetea herbaceae* and *Juncetea trifidi*. However the high regional floristic peculiarities observed in the alpine communities may be demonstrated at the level of orders. In the current paper we propose a preliminary concept of orders and their diagnostics because additional data on geography of new provisional units as well as ecology and distribution of diagnostic species are needed.

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