Cryopetrophytic communities of the Altai-Sayan mountain system

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Abstract. Floristic classification of the cryopetrophytic alpine communities of the Altai-Sayan mountain system have been performed. The ***Rhodioletea quadrifidae*** Hilbig 2000 class of the Altai-Sayan mountain system includes two order, one alliance and six associations. We were described new order (***Valerianetalia petrophyllae*** order nova prov.) and three associations (***Ranunculo akkemensis–Valerianetum petrophilae*** ass. nova prov., ***Mesostemmo martjanovii–Leiosporetum exscapae*** ass. nova prov., ***Potentillo biflorae–Sibbaldietum tetrandrae*** ass. nova prov.) These associations include communities with a predominance of Asian alpine and arctalpine petrophytes.

1 Introduction

Cryopetrophytic communities of the Altai-Sayan mountain system as those of the Asian highlands exhibit a unique type of vegetation confined to cold rock habitats. In the South-East Altai and central part of the West Sayan, they represent a type of vegetation characterized the belt [1, 2]. Despite their wide distribution, these communities are the infrequently studied.

In terms of the Russian geobotanical school, the communities formed on scree slopes are rarely considered an independent assemblage. Most often they are referred to "scree communities" or "rock and scree vegetation" [3–5]. We do not agree with other researchers [4] that "scree slopes are not distinct in the originality of their flora." Our data demonstrate that these communities are characterized by high heterogeneity in species composition, and this is due to numerous factors: the feature of the underlying rocks, the mobility of the substrate, the nature and structure of scree slopes, chemical composition, the rate of silt accumulation, steepness of slopes, slope exposure, etc. Various combinations of these factors lead to formation of high coenosis diversity. R. V. Kamelin named these cryopetrophytic communities “cryopetrophyton oreoasiaticum” and conside them as different vegetation types [1].

The system of higher units of floristical classification of the cryopetrophytic communities of the Altai-Sayan mountain system was proposed by V. Hilbig [6, 7, 8]. Based on the geobotanical data collected in the highlands of northern Mongolia, he identified the class ***Rhodioletea quadrifidae*** Hilbig 2000 with two associations: ***Saxifrago***

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setigerae-Rhodioletum quadrifidae Hilbig (1987) 1990 and ***Oxygraphio glacialis-Potentilletum biflorae*** Hilbig (1987) 1990. We found these communities on Katun Range of the Central Altai [9] and Sailig-Hem-Taiga Ridge of the Western Sayan [2]. We described new association of ***Saxifrago oppositifoliae-Rhodioletum quadrifidae*** Zibzeev 2013 on the territory of the Western Sayan [2].

An integrated classification system of the ***Rhodioletea quadrifidae*** class does not developed yet and there is no consensus of the authors about higher units of cryopetrophytic alpine communities.

This paper presents ecological characterization of the communities of the class ***Rhodioletea quadrifidae*** the Altai-Sayan mountain system and their coenotic diversity .

2 Study area

The highest mountainous area of the Altai-Sayan mountain system at altitudes of 1700-2900 m is dominated by ancient table-lands. The highest ridges (altitudes 2500-4500 m) havesteep 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-Sayan mountain system is strongly continental. Local climate, however, is considerably modified by its mountainous topography.

3 Material and methods

The materials for this paper were 45 relevés performed using a standard technique when studying the alpine vegetation of the Altai-Sayan mountain system in 2012-2017. The Braun-Blanquet approach was used to classify the plant communities. The relevés were processed with the automatic classification technique using JUICE 7.0 software package. The nomenclature of the syntaxonomical units was done in accordance with the "International code of phytosociological nomenclature" [10]. Latin names of species and nomenclature follow The International Plant Names Index (IPNI) (http://ipni.org/).

4 Results and discussion

The class ***Rhodioletea quadrifidae*** Hilbig 2000 includes alpine petrophytic communities of the mountain systems of Siberia, northern Mongolia and East Kazakhstan, growing on eluvial scree slopes. These communities are characterized by a high heterogeneity in species composition due to factors such as altitude, slope exposure, slope steepness, nature, size and composition of rock screes. Such factors as the rate of silt accumulation and soil formation significantly affect the qualitative composition of these communities. Currently, the class is represented by alliance ***Rhodilion quadrifidae*** Hilbig 2000 and tow order ***Rhodioletalia quadrifidae*** Hilbig 2000 and ***Valerianetalia petrophyllae*** order nov. prov.

Class ***Rhodioletea quadrifidae*** Hilbig 2000
Ord. ***Rhodioletalia quadrifidae*** Hilbig 2000
All. ***Rhodilion quadrifidae*** Hilbig 2000
Ass. ***Saxifrago oppositifoliae–Rhodioletum quadrifidae*** Zibzeev 2013
Ass. ***Saxifrago setigerae–Rhodioletum quadrifidae*** Hilbig (1987) 1990
Ass. ***Oxygraphio glacialis–Potentilletum biflorae*** Hilbig (1987) 1990
Ass. ***Potentillo biflorae–Sibbaldietum tetrandrae*** ass. nova prov.
Ord. ***Valerianetalia petrophyllae*** order nova prov.
All. ?

Ass. ***Ranunculo akkemensis–Valerianetum petrophilae*** ass. nova prov.
Ass. ***Mesostemmo martjanovii–Leiosporetum exscapae*** ass. nova prov.

Based on the analysis of coenoflora of all associations, we propose the following composition of the diagnostic group of the class ***Rhodioletea quadrifidae***: *Cardamine bellidifolia* L., *Carex rupestris* Turcz. ex Ledeb., *Cerastium pusillum* Ser., *Gastrolychnis apetala* (L.) Tolm. et Kozhanch., *Lagotis integrifolia* (Willd.) Schischk., *Lloydia serotine* (L.) Salisb. ex Rchb., *Luzula confuse* Lindeb., *Minuartia arctica* (Steven) Graebn., *M. verna* (L.) Heirn, *Oxygraphis glacialis* (Fisch.) Bunge, *Papaver pseudocanescens* Popov, *Rhodiola quadrifida* Fisch. et C.A. Mey., *Saxifraga cernua* L., *S. oppositifolia* L., *Smelowskia alba* B. Fedtsch., *Smelowskia calycina* (Stephan ex Willd.) C.A. Mey., *Thalictrum alpinum* L. [6].

The order ***Rhodioletalia quadrifidae*** unites the communities developing on stabilized alpine scree. It includes one alliance and four associations.

Ass ***Saxifrago oppositifoliae–Rhodioletum quadrifidae*** Zibzeev 2013.

Diagnostic species: *Campanula dasyantha* M. Bieb., *Carex tristis* M.Bieb. subsp. *stenocarpa* (Turcz. ex V.I.Krecz.) T.V.Egorova, *Cerastium lithospermifolium* Fisch., *Hierochloë alpina* Roem. & Schult., *Paraquilegia microphylla* J.R.Drumm. & Hutch., *Salix berberifolia* Pall., *Saussurea foliosa* Ledeb., *S. schanginiana* (Wydler) Fisch. ex Herder, *Saxifraga bronchialis* L., *S. hirculus* L., *S. melaleuca* Fisch. ex Spreng., and *S. nelsoniana* D. Don.

The association ***Saxifrago oppositifoliae–Rhodioletum quadrifidae*** includes the communities with a predominance of alpine and arctic-alpine petrophytes, most of which are facultative and obligate calcicoles. This association occurs not only in the West Sayan Mts., but also in the west and central parts of the East Sayan [2], and North-West and Central Altai [1, 9]. Typically these cenoses do not occupy large areas. They occur on the eluvial scree slopes of relatively flat tops of ridges and extending slopes (up to 25°) at altitudes of 2300–2570 m above sea level in moderately humid sites.

Ass. ***Saxifrago–Rhodioletum quadrifidae*** Hilbig (1987) 1990

Diagnostic species: *Rhodiola quadrifida* (Pall.) Fisch. & C.A. Mey., *Lagotis integrifolia (Willd.) Schischk., Eremogone meyeri* (Fenzl) Ikonn., *Potentilla sericea* L., *Eritrichium pauciflorum* (Ledeb.) DC., *Saxifraga setigera* Pursh., *S. cernua* L., *S. hirculus* L., *Eutrema edwardsii* R. Br., *Draba fladnizensis* Wulfen.

These communities occur in the upper part of the alpine belt on shallow stony soils and rock debris. They were found in the highlands of the South Tuva, Hangai and the Mongolian Altai at altitudes from 2600 to 3600 m. *Rhodiola quadrifida* (Pall.) Fisch. & C.A. Mey., *Lagotis integrifolia (Willd.) Schischk., Eremogone meyeri* (Fenzl) Ikonn., *Potentilla sericea* L., and *Eritrichium pauciflorum* (Ledeb.) DC. predominate.

Ass. ***Oxygraphio glacialis–Potentilletum biflorae*** Hilbig (1987) 1990

Diagnostic species: *Oxygraphis glacialis* (Fisch.) Bunge, *Potentilla biflora* Willd. ex Schltdl., *Saxifraga oppositifolia* L., *Poa alpine* L., *Cerastium pusillum* Ser.

These high-mountain communities inhabit the alpine belt of Northern Mongolia and the southern mountain ranges of the Altai-Sayan mountain system (2500-3950 m). The vegetation cover is from 30 to 60 %. In a relevé 5-16 species are recorded. In addition to diagnostic species, *Festuca altaica* Trin., *Oxytropis martjanovii* Krylov, *Polygonum viviparum* L., *Potentilla crebridens* Juz., *Saxifraga cernua* L., *Smelowskia alba* (Pall.) Regel, *Stellaria petraea* Bunge have high constancy.

Ass. ***Potentillo biflorae–Sibbaldietum tetrandrae*** ass. nova prov.

Diagnostic species: *Sibbaldia tetrandra* Bunge, *Rhodiola algida* (Ledeb.) Fisch. & C.A. Mey., *Cerastium lithospermifolium* Fisch., *Lloydia serotina* (L.) Rchb..

This association is widely distributed in the South-East Altai (Kuray, South-Chuyskiy, Chikhacheva). Patches of this association occur from 1650 to 2900 m. Soil layer is

extremely shallow or completely lacking. The vegetation cover is 40 to 75 %. *Sibbaldia tetrandra* is the absolute dominant of the community; other species (*Cerastium lithospermifolium* Fisch., *Gastrolychnis apetala* (L.) Tolm. & Kozhanch., *Poa alpina* L., *Potentilla nivea* L., *Rhodiola quadrifida* (Pall.) Fisch. & C.A. Mey., *Smelowskia calycina* (Stephan) C.A. Mey., *Taraxacum glabrum* DC.) have a high occurrence but low cover.

On the territory of South-East Altai (Kuraisky, Chikhachev and South-Chuisky ranges), we described cryopetrophytic communities are formed on unstable alpine scree. Soil layer is completely lacking. We propose to include these communities in the new order ***Valerianetalia petrophyllae*** order nov. prov. The order includes two associations ***Ranunculo akkemensis–Valerianetum petrophilae*** and ***Mesostemmo martjanovii–Leiosporetum exscapae***.

Ass. ***Ranunculo akkemensis–Valerianetum petrophilae*** ass. nova prov.

Diagnostic species: *Valeriana petrophila* Bunge, *Smelowskia calycina* (Stephan) C.A. Mey., *Ranunculus akkemensis* Polozhij & Revjakina.

The association includes communities on unstable alpine scree. Patches of the association are rather poor in species. In a relevé, there are 5-10 species. Cover of ***Ranunculo akkemensis–Valerianetum petrophilae*** is 10-20 %. High constancy species of this community include *Crepis nana* Richardson, *Eremogone formosa* (Fisch. ex Ser.) Fenzl, *Lagotis integrifolia* (Willd.) Schischk., *Minuartia arctica* (Steven ex Ser.) Graebn., *Ranunculus altaicus* Laxm..

Ass. ***Mesostemmo martjanovii–Leiosporetum exscapae*** ass. nova prov.

Diagnostic species: *Leiospora exscapa* (C.A. Mey.) F. Dvorak, *Mesostemma martjanovii* (Krylov) Ikonn.

These are rare communities dominated by *Leiospora exscapa* (C.A. Mey.) F. Dvorak and *Mesostemma martjanovii* (Krylov) Ikonn. These species are listed in the Red Book of Russia. This association is very similar with the community ***Ranunculo akkemensis–Valerianetum petrophilae*** association by structure and ecology. In a relevé, there are 5-12 species. Its vegetation cover varies from 10 to 30 %. Several species have high constancy: *Allium pumilum* Vved., *Dracocephalum bungeanum* Schischk. & Serg., *Papaver pseudocanescens* Popov, *Pulsatilla campanella* (Fisch. ex Regel et Tiling) Krylov., *Thymus narymensis* Serg. etc. are.

Thus, alpine vegetation on the screen and stone debris were ascribed to the class ***Rhodioletea quadrifidae***. The class includes two orders, one alliance and six associations. Cryopetrophytic communities of the Altai-Sayan mountain system possess a group of regional Asian cryopetrophytic alpine species. It is cryo-petrophytes species. The order of ***Rhodioletalia quadrifidae*** and ***Valerianetalia petrophyllae*** differ from each other not only by species composition, but also by habitat features (the presence of soil horizon and substrate mobility).

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