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LIVERWORTS OF THE MUS-KHAYA MOUNTAIN (YAKUTIA, ASIATIC RUSSIA)

ПЕЧЕНОЧНИКИ ГОРЫ МУС-ХАЯ (ЯКУТИЯ, АЗИАТСКАЯ РОССИЯ)

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Abstract

Mus-Khaya Mountain ("Ice mountain" in Yakutian), 2959 m alt., is the main summit of Suntar-Khayata Range situated in the southern part of the Verkhoyansk Range. It is the second highest peak of Yakutia and the largest glaciated area in the North-East Siberia. The article characterizes in details this area as a center of liverwort diversity in Verkhoyansk Range and the compiles chiefly unpublished results of first bryological expedition to Mus-Khaya Mt. in 2011. The liverwort flora of Mus-Khaya Mt. is very different in species composition and species activity from the rest Verkhoyansk Range. In total 78 species and 2 varieties were recorded in the study area and listed. Among them 4 species found for the first time for Yakutia in Mus-Khaya Mt. Area, 12 found for the first time for Verkhoyansk Range and 11 species for Suntar-Khayata Range. The list of liverworts of tundra belt of Suntar-Khayata Range is expanded in 40 species. Three endemics of Russia *Frullania ignatovii, Scapania rufidula* and *Scapania sphaerifera* were recorded in Mus-Khaya Mt. Area. Data on frequency, altitude range, recorded localities, habitats, substrates, growth pattern, structures associated with reproduction, representative specimens are listed for every species. Annotations of selected species are accomplished by data on associated species and additional notes on distribution, ecology, morphology, *etc.* Most remarkable are records of rare in Russia and Yakutia *Bucegia romanica, Gymnocolea* cf. *fascinifera, Herbertus* cf. *aduncus, Isopaches alboviridis, Gymnomitrion commutatum, Prasanthus suecicus, Scapania sphaerifera*. Among them *Bucegia romanica, Gymnomitrion commutatum, Scapania sphaerifera* are included in the Red Data Book of Russian Federation.

Резюме

Гора Мус-Хая (Ледовая гора Якутии), 2959 м над ур. м., является главной вершиной хребта Сантар-Хаята, расположенного в южной части Верхоянского хребта. Это второй по высоте пик Якутии и крупнейшая порытая поверхностным оледенением территория в Северо-Восточной Сибири. В статье приводятся описание горы Мус-Хая как центра разнообразия печеночников Верхоянского хребта и обобщение преимущественно раннее неопубликованных данных по видовому составу, распространению и экологии печеночников, выявленных в ходе первой бриологической экспедиции на гору Мус-Хая в 2011 г. Флора печеночников г. Мус-Хая отличается от флоры печеночников всего Верхоянского хребта по видовому составу и активности видов. В целом выявлено 78 видов и 2 разновидности, включая 4 вида, отмеченные в Якутии только в районе исследования, 12 видов являются новыми для Верхоянской горной цепи, 11 видов – для хребта Сунтар-Хаята, 40 видов – для тундрового пояса хребта Сунтар-Хаята. Три вида (*Frullania ignatovii, Scapania rufidula, Scapania sphaerifera*) – эндемики России. В списке для каждого вида указаны встречаемость, высотный диапазон распространения в районе исследования, выявленные местнахождения, местообитания, субстрат, наличие структур связанных с размножением, характер произрастания и репрезентативные образцы. Для ряда видов приводятся сопутствующие виды, а также комментарии по распространению, экологии, морфологии и т.д. Особого внимания заслуживают находки таких редких для флоры печеночников России видов, как *Bucegia romanica, Gymnocolea* cf. *fascinifera, Herbertus* cf. *aduncus, Gymnomitrion commutatum, Isopaches alboviridis, Lophozia pellucida, Prasanthus suecicus, Scapania sphaerifera*, из которых *Bucegia romanica, Gymnomitrion commutatum, Scapania sphaerifera* включены в Красную книгу Российской Федерации.

KEYWORDS: liverworts, flora, Mus-Khaya Mountain, Suntar-Khayata Range, Verkhoyansk Range, Oymyakon, Pole of Cold, Yakutia.

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Introduction

Mus-Khaya Mountain ("Ice mountain" in Yakutian), 2959 m alt., is the main summit of Suntar-Khayata Range, that is situated in the southern part of the Verkhoyansk Range, its length is 550 km. Mus-Khaya Mt. is the second highest peak of Yakutia and the largest glaciated area in the North-East Siberia. It is located in the central part of the Suntar-Khayata Range on the southern border of the republic with the Khabarovsk Territory. This area is close to the Pole of Cold in the Northern Hemisphere, Oymyakon, where –71.2°C has been recorded. Southern districts of Mus-Khaya Mt. have been bryologically investigated in July 12–17, 2011, in the upper reaches of the Knory River (the Agayakan River Basin) in the area of mountain pass to the Yudoma River (62°31'–36'N, 140°56'–141°07'E). The study area was described and illustrated by Ignatova *et al*. (2011). Additional physiographic facts that may cause liverwort diversity and an annotated list of liverworts of the area are listed below.

Study area: Geology, Climate, Vegetation

Suntar-Khayata Range is a gigantic horst basing on more ancient Mesozoic folding with absolute altitudes 2089 to 2959 m in the study area and valley height 1470 to 1600 m. From a lithological point of view the composition of the Suntar-Khayata Range is characterized by dominance of non-carbonate underlying rock comprising shales, argillites, aleuropelites and sandstones (aged from Permian to Lower Cretaceous). They have chalky granitoid intrusions and blankets of acid effusives. Wide distribution of granodiorite-porphyritic rocks is typical for the study area. Sometimes rock outcrops are rich in manganous sulfide (MnS) and other rare and heavy metals (Pb, Sn, Zn, Ag, *etc.*, usually sulfides). Permafrost of study area lies in the zone of perennially frozen soils. The permafrost exceeds 700 m thick. Permafrost is a basic factor greatly influencing the distribution and functioning of ecosystems, and vegetation in particular. Soils start thawing right after the snow cover has melted, and they freeze in autumn as soon as the average daily air temperature comes below 0°C. The freezing process proceeds simultaneously in a top-down and a bottom-top direction, and in January both frozen layers meet. Thawing depth values are not constant and depend on the meteorological features of a year. Firmly frozen, ice-bound strata represent waterproof horizons for precipitation and facilitate to some extent soil wetting by oozing out ground moisture during seasonal periods of thawing. Glacial and cryogenic relief is common in the study area. Traces of the ancient glaciations in mountains and valleys of rivers are combined with traces of retreat of modern glaciers. The range is characterized by alpine relief with sharp summits and peaks. Mountains are separated from each other by deep canyons with brooks inflowing in rivers with trough valleys, steep slopes and fragments of ancient moraine relief. Because of recent climate warming in the region in question, the area of glaciers of Mus-Khaya Mt. is diminished much in comparison with that in the middle of XX century. In the course of our study young moraines have been observed on slopes of Mus-Khaya Mt. They are represented by rocky conglomerates moving from mountain slopes by moving glaciers. Late snow area were mentioned on north-faced slopes in places sheltered from the winds. The permafrost soils cause much formation of the relief and moisture of liverwort habitats. Among cryogenic processes the frost soil heaving, frost cracking, formation of vein ice and polygonal surfaces, solifluction and thermokarst are most common. From floristic point of view the study area is interesting in combination of modern mountain glaciation, very hot and light summer, when day longevity exceeds 20 hours. The hydrographic system is dense; the rivers are fed with snow, rain and glacier waters (Baranova & Biske, 1964; Yurtsev, 1964; Mozolevskaya, 1973; Korzhuev, 1974; Nekrasov, 1984; Leshkevich, 2008; Troeva *et al.*, 2010; Ignatova *et al.*, 2011; Sofronov *et al.*, 2013).

The climate is humid, the average annual precipitation varies from 450 to 729 mm. About 80% of the precipitation falls during the warm season. In winters the region is subjected to the winter continental anticyclone with heavy frosts and minor precipitation. Extremely low temperatures (-71.2°C) have been recorded in Oymyakon Settlement located in the Oymyakon depression (Table 1). Yakutia has no analogues both in minimal temperature values and the duration of the period with extremely low temperatures in the Northern Hemisphere. A distinct feature of the warm period is the quick rise of the average daily temperatures in spring and their quick drop in autumn, July is the warmest month. Differences between temperatures of the warmest and coldest months and differences between absolute minimum and maximum values in the interior Yakutia are greatest in the world and attain 104°C in Oymyakon (Table 1).

Relatively stable temperature regime at the beginning of winter, that accompanied by increasing of heat irradiation, is gradually broken by mountain temperature inversions. During anticyclone type of weather in winter temperature on the convex relief areas is always higher than in adjacent valleys. Thus average January temperature and absolute minimal temperature in high moun-

Table 1. Meteorological data from the nearest to Mus-Khaya Mt. meteorological stations (according to monthly meteorological data for period since 1935 till 1961).

Meteorological stations with distance from Mus-Khaya Mt. and altitude	annual t°C	January t°C	min t°C	July t°C	max t°C	annual precipitation, mm
Oymyakon (135 km to NE, 726 m alt.)	–16.6	–50.0	–71	14.5	33	175
Agayakan (70 km to N, ca. 775 m alt.)	–16.1	–48.4	–67	13,9	33	220
Suntar-Khayata (20 km to N, 2068 m alt.	–13.8	–28.9	–51	6.6	21	555

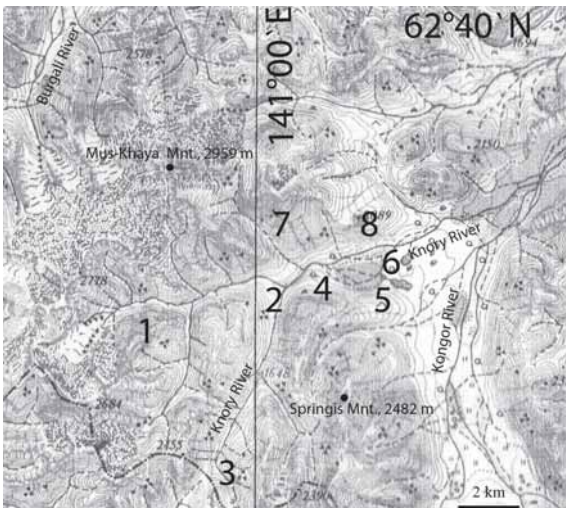

Fig. 1. Collecting sites:

1. Upper course of unnamed left tributary of the Knory River, 62°33'N – 140°56'E, tundra belt, 1700-1800 m alt.
2. Upper course of the Knory River, 62°33'N – 141°01'E, tundra belt, 1585-1669 m alt.
3. Upper course of the Knory River near the mountain pass to Yudoma River, 62°30'N – 140°58'E, tundra belt, 1880 m alt.
4. Foot of Springis Mt., 62°33'-62°34'N –141°02'-141°03'E, tundra and forest belts, 1550-1591 m alt.
5. Northern slope of Springis Mt., 62°33'N – 141°03'-141°04'E, tundra belt, 1640-2027 m alt.
6. Surroundings on nameless lakes in the Knory and Kongor rivers interfluve, 62°34'N – 141°03'-141°06'E, forest belt, 1480-1550 m alt.
7. Southern slope of Mus-Khaya Mt., 62°34'N – 141°01'E, tundra, 1580-1910 m alt.
8. Spurs of Mus-Khaya Mt., southern slopes, 62°35'N – 141°05'-141°06'E, tundra and forest belts, 1600-1745 m alt.

tain meteorological station Suntar-Khayata are –29°C and –51°C whereas in valley meteorological station Oymyakon they are –50°C and –71°C respectively. In Mus-Khaya Mountain area the stable transition of the average daily air temperature above +5°C (the beginning of the vegetation period) falls at the end of June. The average frost-free period is 42 days. However, during the summer months sporadic frosts and snowfalls happen. The average temperature of July is +6.6°C and the maximal temperature of July is +21°C. In high mountains the summer is not so hot as in neighbour Oimyakon depression. According to data of Suntar-Khayata meteorological station the annual temperature fluctuation (72°C) is somewhat less than in neighbour Oymyakon depression (Tab. 1). However, the study area is located not so high as the meteorological station that should cause considerable variability of annual temperature. (Izyumenko, 1966, 1968; Troeva *et al*., 2010; Ignatova *et al*., 2011).

In study area the forests are formed of larch only (*Larix cajanderi* Mayr) with *Vaccinium vitis-idaea* L., *Vaccinium uliginosum* L., *Ledum palustre* L. subsp. *decumbens* (Aiton) Hult., *Aulacomnium turgidum* (Wahlenb.) Schwägr., *Pleurozium schreberi* (Brid.) Mitt., *Cetraria* ssp., *Stereocaulon* sp. At the Knory River Valley they attain a height to a maximum of 1530 m alt., and on the northern slopes of the mountains 1643 m alt. This appears to be a result of temperature inversion. In warm season the warm air from Mus-Khaya glaciers flows down in the river trough valley and forms such a belt height discrepancy. Besides forests, in forest belt occur bushland, wetlands, steppes and rock-fields. Shrubs of *Betula divaricata* Ledeb., *B. fruticosa* Pall., *B. nana* L., *Salix glauca* L., *S. pulchra* Cham. Mires can be classified here in two main types: bogs of *Sphagnum* (*S. fuscum* (Schimp.) H. Klinggr., *S. lenense* H. Lindb. ex L.I. Savicz *et al.*) and mires of *Carex aquatilis* Wahlenb. subsp. *stans* (Drej.) Hult. and *Eriophorum* ssp. with *Sphagnum* ssp., *Gymnocolea inflata, etc.* Steppe communities are characterized by the dominance of *Kobresia myosuroides* (Vill.) Fiori with significant participation *Dryas punctata* Juz., *Rhytidium rugosum* (Hedw.) Kindb. Shrubs belt are usually situated above the forest, in the sites studied absent. Small patches of cedar elfin wood (*Pinus pumila* (Pall.) Regel), not more than a few square meters, recorded only on the southern slopes of the mountains. The tundra belt is located above the forest belt and occupies about 80% of the study area. There are common lichen (*Alectoria ochroleuca* (Hoffm.) A. Massal., *Cetraria islandica* (L.) Ach., *C. laevigata* Rassad., *Flavocetraria cucullata* (Bellardi) Kärnefelt et Thell, *Thamnolia vermicularis* (Sw.) Schaer.), mosses (*Sanionia uncinata* (Hedw.) Loeske, *Hylocomium splendens* (Hedw.) Bruch et al. var. *obtusifolium* (Geh.) Paris, *Dicranum elongatum* Schleich. ex Schwägr., *Racomitrium lanuginosum* (Hedw.) Brid., *Tomentypnum nitens* (Hedw.) Loeske), shrub tundra (*Dryas punctata, Cassiope tetragona* (L.) D. Don, *C. ericoides* (Pall.) D. Don, *Rhododendron lapponicum* (L.) Wahlenb. subsp. *parvifolium* (Adams) Malysch., *Rh. redowskianum* Maxim., *Salix tschuktschorum* A. Skvorts.) and rock-fields. At 1900-2100 m alt. slopes are very steep and covered with moving stone fields (Yurtsev, 1964; Timofeev, 2003; Troeva *et al*., 2010; Ignatova *et al*., 2011; Isaev, 2011; Sofronov *et al*., 2013).

MATERIAL AND METHODS

Until present data of liverworts of Mus-Khaya Mt. were scant. Sofronova (2012) published record of *Prasanthus suecicus* – for Verkhoyansk Range. Sofronov, Sofronova and Ivanova (2013) listed 30 liverwort species of 24 genera found if dwarf shrub, lichen, moss and *Kobresia* mountain tundras in four localities.

The paper is based on detailed study of 208 specimens collected by E.V. Sofronova, M.S. Ignatov, O.V. Ivanov and E.I. Ivanova, and identified by the authors. The specimens collected by M.S. Ignatov are marked as "I". We sampled the all biotopes from the Knory River Valley level to an altitude of 2030 m in study area (see Fig. 1). All specimens are deposited in Herbarium of Institute for Biological Problems of Cryolithozone SB RAS, Yakutsk (SASY), some duplicates are in Herbarium of Komarov Botanical Institute (LE). The list below includes liverworts, nomenclature follows Potemkin & Sofronova (2009, 2013); Cailliau *et al.* (2013); Vilnet *et al.* (2007).

Results

In total 78 species and 2 varieties of liverworts were recorded in Mus-Khaya Mt. and its surroundings. This represents ca. 60% of liverwort species number known for the whole Verkhoyansk Range and 40% of the liverwort flora of Yakutia. Four species were recorded for the first time for Yakutia, 12 species – for the Verkhoyansk Range and 11 species – for Suntar-Khayata Range. The list of liverworts of tundra belt of Suntar-Khayata Range is expanded in 40 species. Three endemics of Russia *Frullania ignatovii, Scapania rufidula* and *Scapania sphaerifera* were recorded in Mus-Khaya Mt. Area.

Species are presented alphabetically. The list is annotated in the following order: species name, abbreviations of structures connected with reproduction, if present, in parentheses: gyn. – unfertilized gynoecia, andr. – androecia; per. – perianthia, pseudoperianthia or other protective structures of gynoecia/sporophytes, spor. – mature sporophytes, gem. – gemmae; frequency: unique – 1 collection, rare – 2-3 collections, sporadic – 4-7 collections, frequent – 8 and more collections; elevation range in square brackets; collecting sites (1–8) (Fig. 1); vegetation belt (forest – F, tundra – T); substrate, habitats and growth pattern. The following scale was used for determination of growth pattern: few plants (FP), minute continuous cover (M) – up to 1 sq. cm, small continuous cover (S) – up to 100 sq. cm, large (L) – up to 1 sq. m and extensive continuous cover (E) – more than 1 sq. m. Substrates, habitats and growth patterns in the list are provided in descending frequency. Every species is annotated by representative specimens. Annotations of selected species are accomplished by data on associated species and additional notes on distribution, ecology, morphology, *etc.* First records for Yakutia are marked with a triple asterisk (***), and first records for Verkhoyansk Range are marked with a double asterisk (**), first records for Suntar-Khayata Range are marked with an asterisk (*) before species name.

Most specimens collected by E.V. Sofronova have numbering started with MX.

Annotated list of species

Anthelia juratzkana (Limpr.) Trevis. (spor.) – Common. [1569-2027 m alt.]. 1, 2, 4, 5, 7, 8: F, T. On soil, stones with soil: tundra, stone fields, banks of creeks, mire. FP, M, S. # MX 3. Extremely sporadic in Verkhoyansk Range. Usually grows along banks of brooks, much rarer in stone field or tundra belt.

Barbilophozia barbata (Schmidel ex Schreb.) Loeske – [1488-1900 m alt.]. 5, 6, 8: F, T. On soil: forest, stone field in forest, tundra. FP, M, S. # MX 160.

Blepharostoma trichophyllum (L.) Dumort. (per.) – Sporadic. [1569-1823 m alt.]. 1, 4, 5, 7: F, T. On soil: banks of creeks, tundra, stone field. M, S. # MX 25.

Bucegia romanica Radian – Unique. [1880 m alt.]. 3: T. On soil: bank of creek, associated with *Orthocaulis quadrilobus, Scapania cuspiduligera*. FP. # MX 116-I. Included in Red Data Book of Russian Federation (Bardunov, 2008). In Verkhoyansk Range and in vicinities of Mus-Khaya Mt. *B. romanica* occurs in calciferous loamy wet soils in solifluction flows along steep rocky slopes in tundra belts above 1200 m. alt. Similar habitats of this species were described for its Svalbard populations (Konstantinova *et al.*, 2014).

Calycularia laxa Lindb. et Arnell (spor.) – Sporadic. [1700-1770 m alt.]. 1, 8: T. On soil: stone fields, tundra, associated with *Cephalozia bicuspidata, Blepharostoma trichophyllum, Scapania scandica, Schistochilopsis incisa* and other. FP, S, L. # MX 183-I.

Calypogeia integristipula Steph. – Unique. [1481 m alt.]. 6: F. On *Sphagnum*: mire. FP. # MX 189.

C. muelleriana (Schiffn.) Müll. Frib. – Sporadic. [1540-1550 m alt.]. 4, 6: F. On soil, *Sphagnum*: waterlogged forests. FP. # MX 168.

C. sphagnicola (Arnell et J. Perss.) Warnst. et Loeske – Rare. [1481-1495 m alt.]. 6: F. On *Sphagnum*: mires. FP. # MX 188.

***Cephalozia albescens* (Hook.) Dumort. – Unique. [1690 m alt.]. 5: T. On soil: tundra, associated with *Blepharostoma trichophyllum, Orthocaulis binsteadii, Scapania cuspiduligera, S. mucronata*. FP. # MX 84. Distribution of this arctic-alpine species is apparently associates with territories having subоceanic or moderately continental climate. Until present *C. albescens* has never been recorded in Verkhoyansk Range having strongly continental climate.

C. bicuspidata (L.) Dumort. (spor.) – Common. [1481-1909 m alt.]. 1, 2, 4-8: F, T. On soil, once on the *Sphagnum*: tundra, stone fields, mires, waterlogged forest, cracks in rock, bank of creek. FP, M, S. # MX 123.

C. pleniceps (Austin) Lindb. (spor.) – Sporadic. [1495-1700 m alt.]. 1, 4-6: F, T. On soil, *Sphagnum*: bank of creeks, mire, tundra. FP, M, S. ## MX 178, MX 191-I.

**Cephaloziella elachista* (J.B. Jack ex Gottsche & Rabenh.) Schiffn. – Unique. [1481 m alt.]. 6: F. On *Sphagnum*: mire, associated with *Mylia anomala, Calypogeia integristipula, Lophozia ventricosa* var. *longiflora, Orthocaulis binsteadii, Sphenolobus minutus*. M. # MX 189.

C. rubella (Nees) Warnst. (spor.) – Rare. [1494-1899 m alt.]. 2, 5, 6: F, T. On soil: tundra, dwarf birch community. FP, M. # MX 170.

C. varians (Gottsche) Steph. (gem.) – Sporadic. [1532-1738 m alt.]. 4, 5, 7, 8: F, T. On soil: stone fields, tundra, banks of creeks, shrub community on the pebbles of the river. M, FP. ## MX 13, MX 93.

Diplophyllum obtusifolium (Hook.) Dumort. (spor.) – Common. [1578-1833 m alt.]. 1, 2, 5, 7: T. On soil: stone fields, tundra, cracks in rock, associated with *Schistochilopsis incisa, Cephalozia bicuspidata, Gymnomitrion* ssp., *Odontoschisma macounii, Prasanthus suecicus* and other. FP, M. # MX 32.

D. taxifolium (Wahlenb.) Dumort. (gem.) – Rare. [1736-1745 m alt.]. 8: T. On soil: stone field, tundra, associated with *Isopaches bicrenatus, Lophozia sudetica, Scapania scandica*. M. ## MX 128, MX 150. Plants from MX 128 represent mod. *parvifolia-acutiloba* of the species and resemble much *D. taxifolium* var. *mucronatum* R.M. Schust. known from North Carolina, USA (Schuster, 1974). Despite much similarity of studied plants in leaf shape and coarsely papillose cuticle (Fig. 2) with the latter variety we avoid to attribute them to it because plants look impoverished and correlation of size reduction and formation of acuminate lobes appears to be possible for this species.

****Frullania ignatovii* Sofronova, Mamontov & Potemkin – Unique. [1800 m alt.]. 1: T. On soil: rocky outcrops, associated with *Frullania subarctica, Herbertus* cf. *aduncus*. M. #

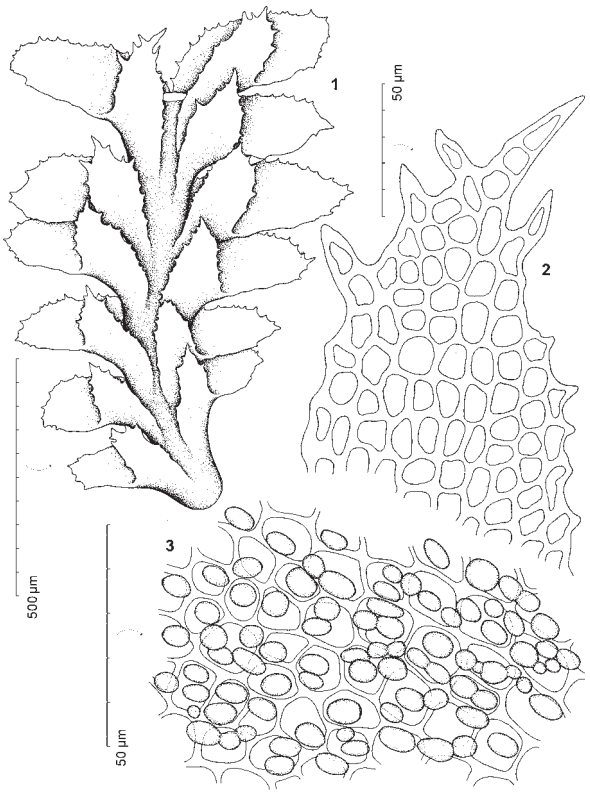

Fig. 2. *Diplophyllum taxifolium*: 1 – habit, dorsal aspect; 2 – an enlarged dorsal leaf lobe; 3 – cells in the middle of the ventral leaf lobe with coarse papillose cuticle indicated. All from Russia, Yakutia, Suntar-Khayata Range, *E.V. Sofronova # MX 128*(LE).

MX 199-I. Found on rocks in alpine type highlands of Siberia (Sofronova *et al.*, 2013), in forest, forest-tundra and tundra belts. Rather rare but locally abundant species. Occurs together with calciphilous bryophytes in regions with carbonate rocks.

F. subarctica Vilnet, Borovich. & Bakalin (= *F. nisquallensis* auct. non Sull. p. p. see: Vilnet *et al.*, 2014) – Unique. [1800 m alt.]. 1: T. On soil: rocky outcrops, associated with *Frullania ignatovii, Herbertus* cf. *aduncus*. L. # MX 199-I. Infrequent but locally abundant species in alpine type highlands of non-arctic Siberia. Growth on wet rocks in forest-tundra belt or on wet peaty soil near water courses in tundras in highland plateaux. This species was listed for the study area as *F. nisquallensis* (Sofronova *et al.*, 2013).

****Gymnocolea* cf. *fascinifera* Potemkin – Unique. [1495 m alt.]. 6: F. On *Sphagnum*: mire, associated with *Lophozia polaris, Scapania paludicola*. FP. # MX 175. Sterile plants with poorly developed rhizoids. Until present this species is known from Bolshezemelskaya tundra (Potemkin, 2008) and Yamal Peninsula in Russia and from Seward Peninsula, Alaska, in the USA (Potemkin, 1993).

***G. inflata* (Huds.) Dumort. (spor.) – Common. [1591-1669 m alt.]. 2, 4: T. On soil: mire, bank of creek, tundra, rocky outcrops. S, L, E. ## MX 69, MX 81. Despite rather broad distribution in North Holarctic *G. inflata* have never been found during long-term studies in Verkhoyansk Range until present.

****Gymnomitrion commutatum* (Limpr.) Schiffn. – Rare. [1585 m alt.]. 2: T. On soil: tundra, associated with *Gymnomitrion corallioides, Diplophyllum obtusifolium, Prasanthus suecicus, Marsupella sprucei, Isopaches alboviridis*. M. ## MX 76, MX 79. Included in Red Data Book of Russian Federation (Bardunov, 2008). Widespread in more southern highlands of Siberia and the Far East (Konstantinova *et al.*, 2002; Konstantinova *et al.*, 2009; Afonina *et al.*, 2012, 2013), occurs there in forest-tundra and tundra belts on wet fine-earth mostly near watercourses or water bodies, at foot of moist rocks or on soil and boulders in late snow areas. Infrequent but locally abundant species.

**G. concinnatum* (Lightf.) Corda (andr.) – Sporadic. [1698-1833 m alt.]. 7, 8: T. On soil: stone fields, tundra. FP, M, S. ## MX 15, MX 144.

G. corallioides Nees (spor.) – Common. [1578-1833 m alt.]. 2, 7: T. On soil: stone fields, tundra, rocky outcrops. MM, S, L. ## MX 67, MX 73.

***Herbertus* cf. *aduncus* (Dicks.) Gray – Unique. [1800 m alt.]. 1: T. On soil: rocky outcrops, associated with *Frullania ignatovii, Frullania subarctica*. FP. # MX 199-I. The plants resemble recently described *H. buchii* Juslén which differentiation remains uncertain. This species was listed for the study area as *H. buchii* (Sofronova *et al.*, 2013).

****Isopaches alboviridis* (R.M. Schust.) Schljakov (andr., gem.) – Rare. [1585-1615 m alt.]. 2: T. On soil: tundra, associated with *Cephalozia bicuspidata, Marsupella* ssp., *Gymnomitrion corallioides* and other. FP. # MX 63. These Mus-Khaya records of *I. alboviridis* is the second Siberian find outside the Arctic. The first Siberian non-arctic record was from Stanovoye Upland (Bakalin, 2004). Because of minute size of plants and their frequent occurrence among the other liverworts it may be under recorded.

I. bicrenatus (Schmidel ex Hoffm.) H. Buch (per., gem.) – Sporadic. [1578-1833 m alt.]. 7, 8: T. On soil: tundra, stone field. M, FP. ## MX 16, MX 129.

**Jungermannia polaris* Lindb. (spor.) – Unique. [1823 m alt.]. 7: T. On soil: bank of creek. M. # MX 24.

Lophozia excisa (Dicks.) Dumort. (spor., gem.) – Sporadic. [1532-1899 m alt.]. 5, 6, 8: F, T. On soil: stone fields, tundra, bank of creek, shrub community on the pebbles of the river. FP, M. # MX 127.

L. jurensis Meyl. ex Müll. Frib. – Rare. [1494-1690 m alt.]. 5, 6: F, T. On soil: tundra, dwarf birch community. FP. # MX 78.

L. longidens (Lindb.) Macoun (gem.) – Unique. [1603 m alt.]. 8: F. On soil: stone field. M. # MX 159.

***L. pellucida* R.M. Schust. (gem.) – Rare. [1823 m alt.]. 7: T. On soil: bank of creek, associated with *Blepharostoma trichophyllum, Scapania cuspiduligera*, *Ptilidium ciliare*. M. ## MX 19, MX 21. They were collected along the same creek. In MX 21 leaves 2(3)-lobed with acute lobes and deep acute leaf sinuses, ca. 0.3–0.5 leaf length. The specimen MX 19 is represented by plants of mod. *densifolia-fulva-succulenta-gemmipara* and mod. *densifolia-purpurea-succulenta-gemmipara*. They resemble arctic plants of *L. excisa* with fleshy stems, but distinct in scant mycorrhyza, often extensively vinaceous postical leaf bases, nearly colorless large gemmae. Leaves in these plants with obtuse to acute lobes and rather shallow sinuses.

**L. polaris* (R.M. Schust.) R.M. Schust. et Damsh. (gem.) – Sporadic. [1495-1902 m alt.]. 5, 6: F, T. On soil, *Sphagnum*, stones with soil: tundra, mire, bank of creek. FP, M. ## MX 99, MX 175.

***L. savicziae* Schljakov – Rare. [1615 m alt.]. 2: T. On soil: tundra, associated with *Cephalozia bicuspidata, Gymnocolea inflata*. M. ## MX 56, MX 60.

****L. sudetica** (Nees ex Huebener) Grolle (gem.) – Common. [1669-2027 m alt.]. 1, 2, 5, 7, 8: T. On soil: stone fields, tundra, rocky outcrops. S, FP. ## MX 42, MX 68. Uneven distribution of acidophilous *L. sudetica* within Verkhoyansk Range formed of acid rocks still remains unclear. It is rather common in Mus-Khaya Area but extremely rare and known from single collection only from Suntar-Khayata Range (Sofronova, 2000).

L. ventricosa (Dicks.) Dumort. var. *ventricosa* (gem.) – Rare. [1495-1540 m alt.]. 6: F. On *Sphagnum*: mires. FP. ## MX 167, MX 177.

var. *longiflora* (Nees) Macoun sensu Schuster 1969 (per.) – Rare. [1481-1550 m alt.]. 6: F. On *Sphagnum*: mire, forest. M. ## MX 165, MX 187.

****L. wenzelii** (Nees) Steph. cf. var. *lapponica* H. Buch et S.W. Arnell (gem.) – Unique. [1578 m alt.]. 7: T. On soil: stone field. FP. # MX 9.

****** *Marsupella apiculata* Schiffn. – Common. [1669-2027 m alt.]. 2, 5, 7: T. On soil: stone fields, tundra, rocky outcrops, associated with *Anthelia juratzkana, Lophozia sudetica, Isopaches bicrenatus, Cephalozia bicuspidata* and other. FP, S, M, E. ## MX 70, MX 111.

M. emarginata (Ehrh.) Dumort. s. l. – Sporadic. [1698-1770 m alt.]. 1, 8: T. On soil: stone fields, associated with *Scapania crassiretis, S. spitsbergensis, Lophozia sudetica, Tritomaria quinquedentata* and other. FP, S, L. ## MX 143, MX 196-I.

****M. sprucei** (Limpr.) Bernet (per.: paroicous) – Sporadic. [1902 m alt.]. 2, 5: T. On stones with soil: bank of creek, usually forms pure minute continuous cover, sometimes associates with *Lophozia polaris, Scapania obcordata*. M. # MX 27. It is rare in more southern regions of Siberia (Konstantinova *et al.*, 2009; Afonina *et al.*, 2012). It was collected there in tundra belt only, mostly on moist soil of cryogenic spots usually with *Prasanthus suecicus*.

Mesoptychia gillmanii (Austin) L. Söderstr. et Váňa (per.: paroicous) – Unique. [1690-1823 m alt.]. 5, 7: T. On soil: bank of creek, tundra, associated with *Aneura pinguis, Blepharostoma trichophyllum, Ptilidium ciliare.* FP, M. # MX 22.

M. heterocolpos (Thed. ex Hartm.) L. Söderstr. et Váňa – Sporadic. [1569-1770 m alt.]. 1, 4, 5: F, T. On soil: banks of creeks, tundra. FP, S. # MX 87.

Mylia anomala (Hook.) Gray (gem.) – Sporadic. [1481-1800 m alt.]. 1, 6: F, T. On *Sphagnum*, soil: mire, rocky outcrops. FP, M. ## MX 189, MX 201.

Odontoschisma macounii (Austin) Underw. (gem.) – Sporadic. [1770-1823 m alt.]. 1, 5: T. On soil: tundra, rocky outcrops, bank of creek. M, S. ## MX 104, MX 197-I.

Orthocaulis binsteadii (Kaal.) H. Buch (per., gem.) – Common. [1481-1690 m alt.]. 5, 6: F, T. On *Sphagnum*, soil: mires, forest, tundra. FP, S, M. ## MX 166, MX 190.

O. kunzeanus (Huebener) H. Buch – Rare. [1550-1640 m alt.]. 5, 6: F, T. On *Sphagnum*, soil: forest, bank of creek. FP, M. ## MX 92, MX 165.

***O. quadrilobus** (Lindb.) H. Buch – Rare. [1669-1880 m alt.]. 2, 3: T. On soil: rocky outcrops, bank of creek. FP. ## MX 66, MX 116-I.

*****Plagiochila arctica* Bryhn et Kaal. – Unique. [1640 m alt.]. 5: T. On stones with soil: bank of creek. FP. # MX 92.

P. porelloides (Torrey ex Nees) Lindenb. – Rare. [1692-1700 m alt.]. 1, 5: T. On soil: tundra, stone field. FP. ## MX 96, MX 182-I.

****Prasanthus suecicus** (Gottsche) Lindb. (spor.) – Common. [1585-1850 m alt.]. 2, 5, 7: T. On soil: tundra, stone field, associated with *Gymnomitrion* ssp., *Cephalozia bicuspidata, Anthelia juratzkana, Sphenolobus minutus* and other. M, FP, S. ## MX 33, MX 110. Rare species in East Siberia and avoids territories with strongly continental climate, occurs in alpine highlands on bare soil, southwards on bare soils of cryogenic spots usually with *Marsupella sprucei*.

Ptilidium ciliare (L.) Hampe – Common. [1488-1823 m alt.]. 1, 4-8: F, T. On soil, *Sphagnum*: tundra, forest, stone field, mires, banks of creeks, dwarf birch community. FP, S. # MX 85.

Radula prolifera Arnell – Sporadic. [1700-1800 m alt.]. 1: T. On soil: tundra, rocky outcrops, associated with *Odontoschisma macounii, Blepharostoma trichophyllum, Ptilidium ciliare, Scapania simmonsii* and other. S, FP. ## MX 192-I, MX 198-I. Occurs in alpine type highlands of Siberia in regions with carbonate and basalt rocks. Infrequent, grows on wet rocks, in niches between rocks or on wet peaty soil near watercourses in mountains.

Riccardia cf. *chamedryfolia* (With.) Grolle – Sporadic. [1481-1700 m alt.]. 1, 4, 6: F, T. On *Sphagnum*, soil: mires, tundra. FP. # MX 50.

Scapania brevicaulis Taylor [*S. brevicaulis* phenotype] (gem.) – Unique. [1700 m alt.]. 1: T. On soil: stone fields, associated with *Marsupella emarginata, Plagiochila porelloides, Sphenolobus minutus, Tritomaria quinquedentata*. FP. # MX 182-I.

S. crassiretis Bryhn (gem.) – Common. [1481-1771 m alt.]. 1, 5-8: F, T. On soil, *Sphagnum*, stones with soil: stone fields, banks of creeks, tundra, mires. FP, S, M. ## MX 1, MX 135. Most coenotically active species of *Scapania* in mountains of Siberia. Usually abundant along watercourses through the whole elevation range.

****S. curta** (Mart.) Dumort. (gem.) – Unique. [1833 m alt.]. 7: T. On soil: stone field, associated with *Anthelia juratzkana, Cephalozia bicuspidata, Diplophyllum obtusifolium, Marsupella apiculata, Solenostoma obovatum*. FP. # MX 32.

****S. cuspiduligera** (Nees) Müll. Frib. (gem.) – Rare. [1823-1880 m alt.]. 3, 7: T. On soil: banks of creeks, associated with *Blepharostoma trichophyllum, Bucegia romanica, Lophozia pellucida, Orthocaulis quadrilobus, Tritomaria quinquedentata*. FP, M. # MX 21.

***S. hyperborea** Jørg. (gem.) – Rare. [1690-1738 m alt.]. 5, 8: T. On soil: tundra, stone field, associated with *Tritomaria* ssp., *Scapania cuspiduligera, S. simmonsii, Sphenolobus minutus, Tritomaria heterophylla* and other. FP, M. ## MX 78, MX 137.

***S. kaurinii** Ryan – Unique. [1736 m alt.]. 8: T. On soil: stone fields, associated with *Lophozia sudetica, Tetralophozia setiformis*. M. # MX 155.

S. microdonta (Mitt.) Müll. Frib. – Unique. [1738 m alt.]. 8: T. On soil: stone field. S. # MX 138.

S. mucronata H. Buch (per.) – Rare. [1615-1690 m alt.]. 2, 5: T. On soil: tundra. FP, M. ## MX 55, MX 84.

***S. obcordata** (Berggr.) S.W. Arnell (gem.) – Sporadic. [1902-1909 m alt.]. 5, 7: T. On soil, stones with soil: tundra, bank of creek, associated with *Solenostoma confertissimum, Cephalozia bicuspidata, Lophozia polaris, Marsupella sprucei*. FP, S. ## MX 40, MX 115.

S. paludicola Loeske et Müll. Frib. – Rare. [1481-1495 m alt.]. 6: F. On *Sphagnum*: mires. S, FP. # MX 172.

S. praetervisa Meyl. (gem.) – Unique. [1603 m alt.]. 8: F. On soil: stone field. S. # MX 157.

S. rufidula Warnst. – Unique. [1569 m alt.]. 4: F. On soil: bank of creek, associated with *Anthelia juratzkana, Blepharostoma trichophyllum, Cephalozia pleniceps, Cephaloziella varians*. FP. # MX 90.

S. scandica (Arnell & H.Buch) Macvicar (per., gem.) – Common. [1578-1770 m alt.]. 1, 2, 4, 5, 7, 8: T. On soil: tundra, stone fields, mire. M, FP, S. ## MX 8, MX 12.

**S. simmonsii* Bryhn et Kaal. – Rare. [1690-1770 m alt.]. 1, 5: T. On soil: tundra, associated with *Mesoptychia heterocolpos, Blepharostoma trichophyllum, Radula prolifera, Scapania cuspiduligera, Tritomaria heterophylla* and other. FP. ## MX 78, MX 192-I.

S. sphaerifera H. Buch et Tuom. (gem.) – Sporadic. [1603-1738 m alt.]. 1, 8: F, T. On soil: stone fields, associated with *Tritomaria quinquedentata, Lophozia excisa, Scapania spitsbergensis*. S, FP. ## MX 162, MX 185-I. Included in Red Data Book of Russian Federation (Bardunov, 2008). Rather frequently occurs at Verkhoyansk Range. It grows there in niches between rocks of stone fields usually scattered among *Tetralophozia setiformis, Scapania microdonta, Sphenolobus saxicola, Tritomaria quinquedentata* on soil or fine earth over subjacent rocks, more rare on rotten wood or soil there (Sofronova *et al.*, 2014). In general in Baikal Siberia appears to be rather common (Konstantinova, Potemkin, 1994; Kazanovsky, Potemkin, 1995; Mamontov *et al.*, 2011; *etc.*). Usually it needs to be specially searched in stone fields from forest to tundra belt. In Trans-Baikal Territory its populations with high abundance were found. On shaded rocks in forest belt there it may form continuous cover up to 100 sq. cm.

**S. spitsbergensis* Müll. Frib. (per.: paroicous, gem.) – Common. [1698-2027 m alt.]. 1, 5, 7, 8: T. On soil: stone fields, tundra. FP, S, M. ## MX 112, MX 132.

Schistochilopsis grandiretis (Lindb. ex Kaal.) Konstant. (gem.) – Rare. [1640-1770 m alt.]. 5: T. On soil: bank of creek, tundra. S. ## MX 92, MX 104.

S. incisa (Schrad.) Konstant. (spor., gem.) – Sporadic. [1578-1833 m alt.]. 1, 4, 7: T. On soil: stone fields, tundra, mire. FP, M, S. ## MX 4, MX 181-I.

S. opacifolia (Culm. ex Meyl.) Konstant. – Unique. [1640 m alt.]. 5: T. On soil: bank of creek, associated with *Aneura pinguis, Anthelia juratzkana, Blepharostoma trichophyllum, Cephalozia pleniceps, Solenostoma obovatum, Tritomaria heterophylla*. FP. # MX 91.

Solenostoma confertissimum (Nees) Schljakov (spor.) – Sporadic. [1823-1909 m alt.]. 7: T. On soil: bank of creek, tundra. FP, S. ## MX 25, MX 41.

S. cf. *hyalinum* (Lyell) Mitt. – Unique. [1591 m alt.]. 4: T. On soil: mire, associated with *Cephalozia bicuspidata, Gymnocolea inflata, Lophozia ventricosa* var. *longiflora, Schistochilopsis incisa*. FP. # MX 49. Few sterile plants.

S. obovatum (Nees) R.M. Schust. (spor.) – Sporadic. [1569-1850 m alt.]. 4, 5, 7: F, T. On soil, stones with soil: banks of creeks, stone field. FP, M, S. ## MX 20, MX 46.

Sphenolobus minutus (Schreb.) Berggr. (per., andr.) – Common. [1481-1770 m alt.]. 1, 2, 5-8: F, T. On soil, *Sphagnum*: tundra, stone fields, mires, forest, dwarf birch community. FP, M, S. ## MX 7, MX 189.

S. saxicola (Schrad.) Steph. – Rare. [1578-1738 m alt.]. 7, 8: T. On soil: stone fields. S. ## MX 14, MX 130.

Tetralophozia setiformis (Ehrh.) Schljakov – Common. [1578-1738 m alt.]. 7, 8: F, T. On soil: stone fields. L, S, M, FP. # MX 2.

Tritomaria heterophylla R.M. Schust. (gem.) – Common. [1640-1771 m alt.]. 5, 7: T. On soil, stones with soil: banks of creeks, tundra. M, FP, S. # MX 83. In mountains of Siberia rare but occurs through the whole elevation range.

T. quinquedentata (Huds.) H. Buch (per., andr.) – Common. [1540-2027 m alt.]. 1, 4-8: F, T. On soil, *Sphagnum*: stone fields, mire, forest, tundra, bank of creek. S, FP, M. ## MX 86, MX 147.

LIVERWORTS IN LANDSCAPE AND PLANT COMMUNITIES OF MUS-KHAYA MT. AREA

The role of liverworts in plant cover formation of Mus-Khaya Mt. is often different from the other regions of Verkhoyansk Range and often Yakutia as a whole.

The liverworts take part in overgrowing of glacial and cryogenic shapes of relief together with vascular plants, mosses and lichens. In the study area they were found in solifluction flows, young morains, frost cracks near snowfields.

Cryogenic solifluction in the study area develops on grounds subjected to shallow fire-setting and over wetted by water from melted snow and rain, that can not percolate through frozen ground. As a result the over wetted melted ground masses flow along the frozen and fixed by ice slope surfaces. On gentle slope (5°-20°) of the first terrace above the flood plain of the Knory River (h ~ 1639 м) over the solifluction weakly fixed layer of broken stones the lichen-dwarf shrub tundra with *Ledum palustre* subsp. *decumbens* (40%), *Vaccinium vitis-idaea* (15%), *Cassiope ericoides* (10%) and abundant development of lichens in depressions (*Cetraria* sp. up to 30%) has been found. There on wet soil under the dense cover of dwarf shrubs *Gymnocolea inflata* covers up to 15 % of depressions surface. This rather widespread in Siberia species is infrequent in Yakutia and has been found for the first time for the whole Verkhoyansk Range. *Gymnocolea inflata* is apparently avoids regions with strongly continental climate characteristic of Yakutia. New for liverwort flora of Yakutia *Isopaches alboviridis* was also found in this community. It was associated with *Cephalozia bicuspidata* (Sofronov *et al.*, 2013).

A number of liverworts in the study area is often associated with frost soil heaving. When amount of soil water is considerable, increasing of its amount resulted in rupture of ground surface, extrusion of unfrozen ground through it and formation of such cryogenic clayey spots that often are overgrown by liverworts. In the study area the liverworts were found chiefly on such spots. They form there small patches (1-3 sq. cm) of common for Verkhoyansk Range species (*Cephaloziella varians, Isopaches bicrenatus, Odontoschisma macounii, Scapania scandica, Schistochilopsis grandiretis, Sphenolobus minutus*, *etc.*) and new and rare for the Range (*Anthelia juratzkana, Gymnomitrion corallioides, Lophozia savicziae, Prasanthus suecicus*). The latter species are ± common in the Arctic and mountain regions located southward but apparently avoid regions with continental climate and rare in Verkhoyansk Range or new for it.

Frost cracking in comparison with more northern regions of Yakutia are rather rare in the study area. In frost cracks in vicinities of Mus-Khaya Mt. the following common for Verkhoyansk Range species were mentioned: *Calycularia laxa, Cephalozia bicuspidata, Lophozia excisa, Scapania scandica, Sphenolobus minutus.*

Moraine deposits on slopes of Mus-Khaya Mt. are covered by dwarf shrub tundras with dominance of *Cassiope ericoides*, *Salix sphenophylla, Ledum palustre* subsp. *decumbens*, *Rhododendron lapponicum* subsp. *parvifolium, R. redowskianum* mostly. Depressions between

morains are occupied by moss tundras. Despite moss cover is very weak and consists of spots of *Polytrichum hyperboreum* R. Br., *P. piliferum, Racomitrium lanuginosum* et al. (Ignatova *et al.*, 2011; Sofronov *et al.*, 2013) the role of liverworts in this community is significant. *Gymnomitrion corallioides* and *Marsupella emarginata* form large continuous cover on bare soils and on rocks covered by soil respectively. Minute and small continuous cover on soil is charactristic of *Gymnomitrion commutatum* recorded for the first time for Yakutia, and of *Gymnomitrion concinnatum, Marsupella emarginata, Scapania spitsbergensis* which are rare in Verkhoyansk Range. Few plants of rare in Verkhoyansk Range *Anthelia juratzkana, Diplophyllum obtusifolium, Isopaches alboviridis, Lophozia sudetica, Prasanthus suecicus* and *Marsupella sprucei* were found there. These species apparently avoid regions with strongly continental dry climate also. Their neighbour records are known from mountains of South Siberia and Far East (Potemkin, Sofronova, 2009). Among common for Verkhoyansk Range species *Cephalozia bicuspidata, Scapania crassiretis, Tetralophozia setiformis, Tritomaria quinquedentata* were found.

In depression between morains in places with hampered groundwater run-off the moss tundras with *Bryum* ssp., *Cynodontium strumiferum* (Hedw.) Lindb., *Dicranum* ssp., *Niphotrichum panschii* (Müll. Hal.) Bednarek-Ochyra & Ochyra, *Pohlia* ssp., *etc.* (Ignatova *et al.*, 2011) are developed. Liverworts there are represented by new or rare for Verkhoyansk Range species, *i.e.*, *Anthelia juratzkana, Marsupella apiculata, Prasanthus suecicus, Scapania obcordata, Solenostoma confertissimum* that form minute or small continuous cover. A few plants of three common in Verkhoyansk Range species (*Cephalozia bicuspidata, Isopaches bicrenatus, Schistochilopsis incisa*) were collected in moss tundras.

In places of distribution of permafrost that regularly thaws out on North- and East-faced often steep (up to 40°) slopes the hummock larch forests with extensive *Sphagnum* cover forming hummocks are common. Common for Verkhoyansk Range liverwort species were recorded in this community. They are *Calypogeia muelleriana, Lophozia ventricosa* var. *longiflora, Orthocaulis binsteadii, O. kunzeanus, Ptilidium ciliare, Sphenolobus minutus, Tritomaria quinquedentata*.

In the valley of the Knory River on well-matted south-faced slopes *Kobresia* and *Kobresia-Dryas* steppes with a high diversity of herbs are developed. Liverworts are nearly totally absent in these communities. Only *Cephaloziella varians* was recorded in microdepression.

Like in the rest Verkhoyansk Range the late snow areas in vicinities of Mus-Khaya Mt. are poorly developed. They located on the North-faced slopes and most of them melt away at the end of summer. Near investigated late snow areas in vicinities of Mus-Khaya Mt. liverworts mostly absent. It may be explained by exceeding mobility of soil around late snow areas. Only near one large late snow area that probably does not melt away five liverwort species were found. They are *Anthelia juratzkana, Marsupella apiculata, Scapania spitsbergensis*, that formed small continuous cover and few plants of *Lophozia sudetica* and *Tritomaria quinquedentata*. Below the late snow area along the brook streaming down from it the moss tundra with dominance of S*anionia uncinata* (50%), *Hylocomium splendens* var. *obtusifolium* and *Tomentypnum nitens* (20% each) is developed in conditions of excessive moistening. Despite only *Ptilidium ciliare* took place there in soil cover formation several hepatics were collected in niches under stones. They are *Blepharostoma trichophyllum*, *Lophozia polaris*, *Orthocaulis binsteadii*, *Tritomaria heterophylla*, *Scapania crassiretis*, *S. hyperborea*, *S. scandica*, *S. cuspiduligera*, *Cephalozia albescens*. The latter two species are listed for the first time for the whole Verkhoyansk Range.

In Verkhoyansk Range in the regions of traces of ancient glaciation of mountains and river valleys the lateral trough brooks valleys are usually are less deep in comparison with main trough. This results in formation of waterfalls in such places up to 30-50 m high. Several very interesting for the liverwort flora of Yakutia species were collected there. Only in such place *Herbertus* cf. *aduncus, Frullania ignatovii and F. subarctica* were collected.

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