

LOWER CRETACEOUS MOSSES FROM KHASURTY
(TRANSBAIKALIA)

МХИ ИЗ НИЖНЕМЕЛОВЫХ ОТЛОЖЕНИЙ ХАСУРТЫ
(ЗАБАЙКАЛЬЕ)

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Abstract

A collection of Lower Cretaceous mosses from the Khasurty, Transbaikalia, South Siberia includes numerous compressions of the moss *Bryokhutuliinia obtusifolia* sp. n., and also specimens referred to *Palaeodichelyma sinitzae* and *Tricostium longifolium* sp. n. Preservation allows clear views of leaf areolation in these species. Three more species with strong costae are likely acrocarpous, but due to an unclear view of the cell structure they are described as *Muscites* sp. 1, sp. 2 and sp. 3.

Резюме

В сборах из нижнемеловых отложений с реки Хасурты (Забайкалье, Республика Бурятия), обнаружены многочисленные остатки мха *Bryokhutuliinia obtusifolia* sp. n., а также *Palaeodichelyma sinitzae* и *Tricostium longifolium* sp. n., сохранность которых позволяет изучить их клеточную структуру. Кроме того, еще три вида, в основном имеющие сильную жилку и, вероятно, относящиеся в верхоплодным мхам, представлены материалом, в котором детали строения клеточной сети листа не или плохо сохранились. Они описаны как *Muscites* sp. 1, sp. 2 и sp. 3.

KEYWORDS: mosses, fossil, Lower Cretaceous, Transbaikalia, Khasurty

INTRODUCTION

Upper Jurassic and Lower Cretaceous bryophytes in the southeastern Asiatic Russia and Mongolia were described by Krassilov (1973, 1982), Srebrodolskaya (1980), Ignatov (1992), and Ignatov & Shcherbakov (2007), illustrating their abundance in at least several types of ecosystems. Subsequent collections from Khasurty [=Khasurtyi], described here, and also the Baigul area (see Ignatov et al., present volume) contribute additional information on species composition and diversity, allowing us to expand circumscriptions of previously described taxa.

LOCALITY AND AGE

Western Transbaikalia, Buryatia, Zakamensk District, 10 km S of Tsakir, roadcut at left bank of Khasurty River 0.7 km upstream Dzhidot Creek, 50°21'N – 103°38'E; Gusinoe Ozero Group, Lower Cretaceous. Coll. D.E. Shcherbakov et al., Borissiak Paleontological Institute RAS, 2004.

The locality was discovered in 2003 by Olga R. Minina, Geological Institute SB RAS, Ulan-Ude. Over 3000 fossil insect specimens were collected in this locality in 2004 and 2009 by field parties of the Borissiak Paleontological Institute RAS (see Sinitshenkova, 2011). This material is

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characterized by a unique diversity of insects, which belong to 21 orders and more than 80 families. Aquatic insects are numerically dominant, although their diversity is markedly lower than that of terrestrial insects. Among aquatic insects, the dominants are chaoborid midges; numerous mayfly nymphs were also found. The abundance of stoneflies, caddisflies, dragonflies, mecopterans, water beetles, and water bugs is somewhat smaller. The fossiliferous beds are assigned to the Lower Cretaceous Gusinoe Ozero Group. Composition of the fossil insect fauna agrees with its earliest Cretaceous age.

MATERIAL AND METHODS

Plant material is attached to the surface of aleurolites and argillites, and well-preserved, allowing observation of the leaf cell structure in most specimens. Stem material was more strongly coalified and does not display details of surface cells. Similarly, mosses with strong single costae had only imperfect (if any) leaf cell structure, so they are illustrated and only briefly discussed under formal names (*Muscites* sp. 1, sp. 2 and sp. 3).

Less fine-grained rocks usually had larger plant fragments with poorer preservation, thus the longest shoot (Fig. 1) has leaves outlined just by MnO₂ deposits.

Mosses were photographed mostly using Leica M 165 and Olympus SZX16 stereomicroscopes, mostly in the dry condition, and sometimes under ethanol (for contrasting cell structure) and a few pictures were taken also using Zeiss Axioplan compound microscope with 4× and 10× magnification, in these cases always under alcohol.

When the surface of rock was not flat enough, the captured images were assembled with Helicon Focus 4.50 software (Kozub et al., 2008: <http://www.heliconsoft.com>).

TAXONOMY

Genus **Bryokhutuliinia** Ignatov, J. Hattori Bot. Lab. 92: 379. 1992.

Description: Plants robust. Stem pinnately branched at an angle of (25-)50-70°. Leaves patent to reflexed, ovate to ovate-lanceolate, acute to broadly rounded at apex; margin entire, bordered; costa absent; laminal cells rectangular, with transversal cell walls more or less perpendicular to leaf length, alar cells more short and

broad than central basal cells.

Type species: *Bryokhutuliinia jurassica* Ignatov, Upper Jurassic, Mongolia.

The genus includes three species from the Upper Jurassic to Lower Cretaceous of South Siberia and Mongolia.

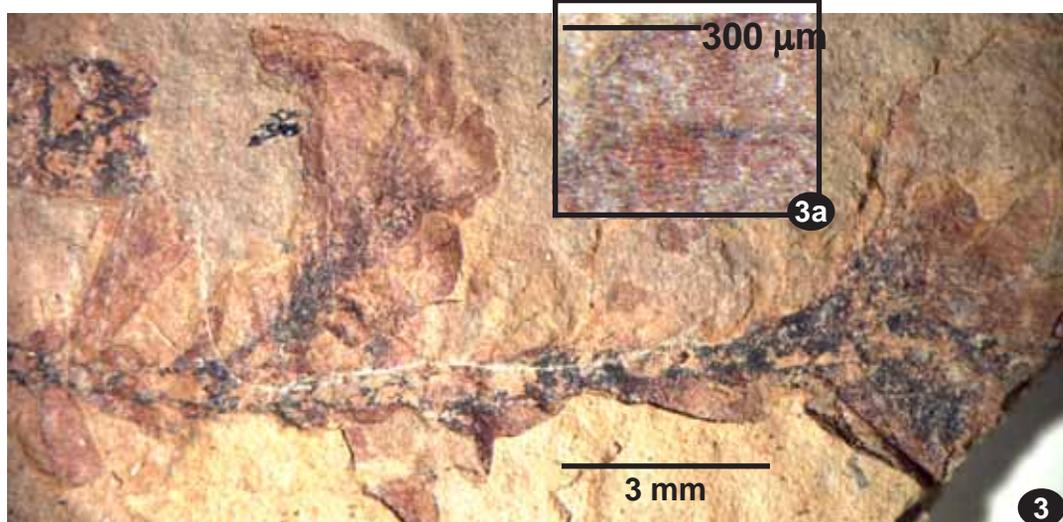
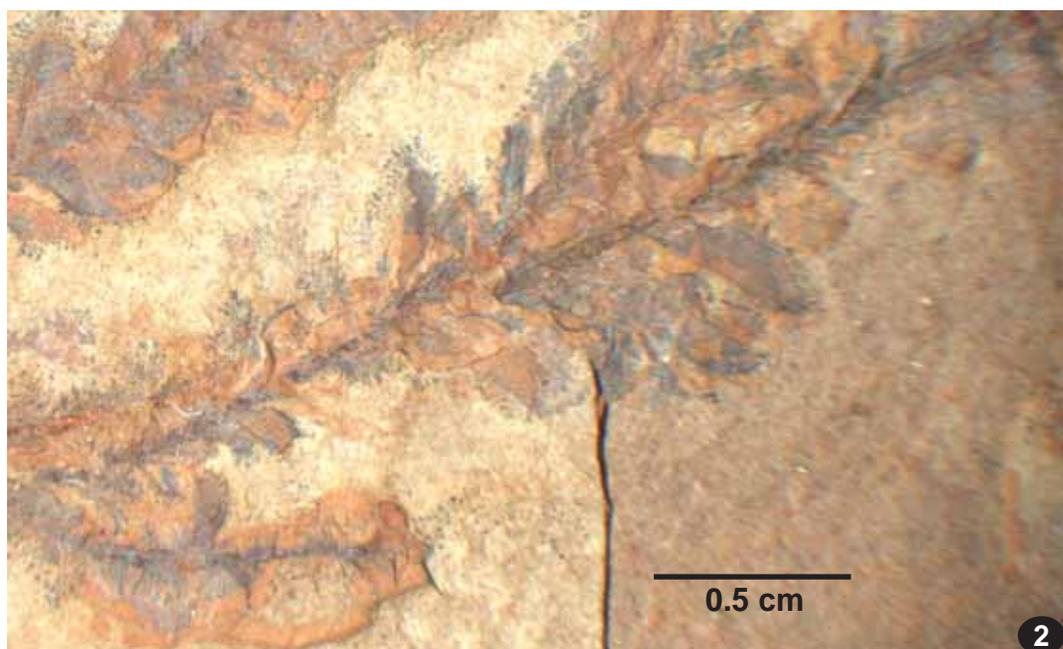
Bryokhutuliinia obtusifolia sp. nov.

Figs. 1-45

Holotype: Khasurty River, PIN 5438/76. Lower Cretaceous. Figs. 11-12.

Description: Plants in loose wefts. Stem creeping or floating to ascending and almost erect, >14 cm long, 0.35-0.45 mm wide, terminated at least sometimes by a leaf rosette formed by 7-15 leaves, foliage terete and variable from loose to dense in subapical part or occasionally all along stem; irregularly pinnately branched, branches deviating from stem at (25-)50-75°(-100°), straight, to 2 cm long, often poorly differentiated from stem in width and foliage, or leaves are more densely arranged, subcomplanate and having more acute angle with branch axis compared with nearby stem leaves. Proximal branch leaves smaller and sometimes remote, without apparent group of crowded leaves at branch base.

Stem leaves deviating from stem at broad angle (55-80°), patent to gradually reflexed and sometimes abruptly reflexed, up to 150°(-180°) with stem or sometimes reflexed from their bases, to 3.0-4.0(-4.3)×1.5-2.1 mm, ovate-elongate to lingulate, broadly rounded at apex or occasionally apiculate (the latter usually takes place in parts of stems with smaller and more remote leaves), rounded below and at base somewhat clasping, plane or only weakly concave; margin entire, bordered throughout, border dark, ca. 50 μm wide, formed by darker cells only slightly narrower than laminal cells. Cells rectangular, 60-90×13-20 μm, shorter and slightly broader towards apex (up to 2:1, and to 25-30 μm wide), and also broader to alar region of leaf base, to 30-42 μm wide. Branch leaves smaller, to 3.3×1.2 mm, relatively narrower and less reflexed, otherwise similar to stem leaves. Ends of shoots sometimes with a zone with leaves abruptly much smaller, to 0.5 mm long, ovate-lanceolate, acute; in some cases nearby part of stem is leafless due to deciduous leaves, likely those smaller ones.



Figs. 1-3. *Bryokhutuliinia obtusifolia* sp.n. 1-2: PIN 5438/27; 3: PIN 5438/4. Shoots showing irregular branching. Preservation in aleurolite is moderate, with numerous MnO_2 deposits around plant material, but at the same time representing the longest shoot (fogs. 1-2) of 14 cm long. Areolation is seen at places, confirming the species identity.



Figs. 4-5. *Bryokhutiinia obtusifolia* sp.n. 4 – PIN 5438/11; 5 – PIN 5438/30. Shoots, illustrating variation in growth, probably erect (fig. 4) and floating (fig. 5), by analogy with habit of contemporary mosses. The specimen in fig. #4 at picture bottom is “submerged” in MnO_2 deposits. See cells from shoot in fig. 5

Material: *Bryokhutiinia obtusifolia* is found as compressions on ca. 34 rock slabs, 10 of them having counterparts. The longest shoot is 14 cm (Figs. 1-2), while most specimens represent short shoot fragments or isolated leaves. Shoots are very variable in the leaf density and overall appearance, so their placement in one species is not at once apparent. Some stems have remote leaves, 5-7 leaves per 5 mm (Fig. 5), other have foliage quite even and more or less dense, about 15 leaves per 5 mm (Figs. 1-2, 6), while in many shoots leaves are more or less crowded at shoot tips (Figs. 3, 4, 7) and in some cases the leaf rosettes occur at shoot ends (Figs. 13-17, 23). The presence of a coalified mass in the centre of a leaf rosette (Fig. 13) and the occasional presence of small leaves (Figs. 16, 23) indicate that these rosettes were probably groups of leaves around gametangia, and most likely perigonia (that are usually more sharply delimited and often have minute leaves near peri-





Figs. 6-8. *Bryokhutuliinia obtusifolia* sp.n. 6 – PIN 5438/9; 7 – PIN 5438/10; 8 – PIN 5438/22. Shoots, showing variants of a relatively dense foliage for the species.

gonia centres). Collection includes a number of rosettes (Figs 13-17) that are probably isolated shoots tips, like that in Fig. 4.

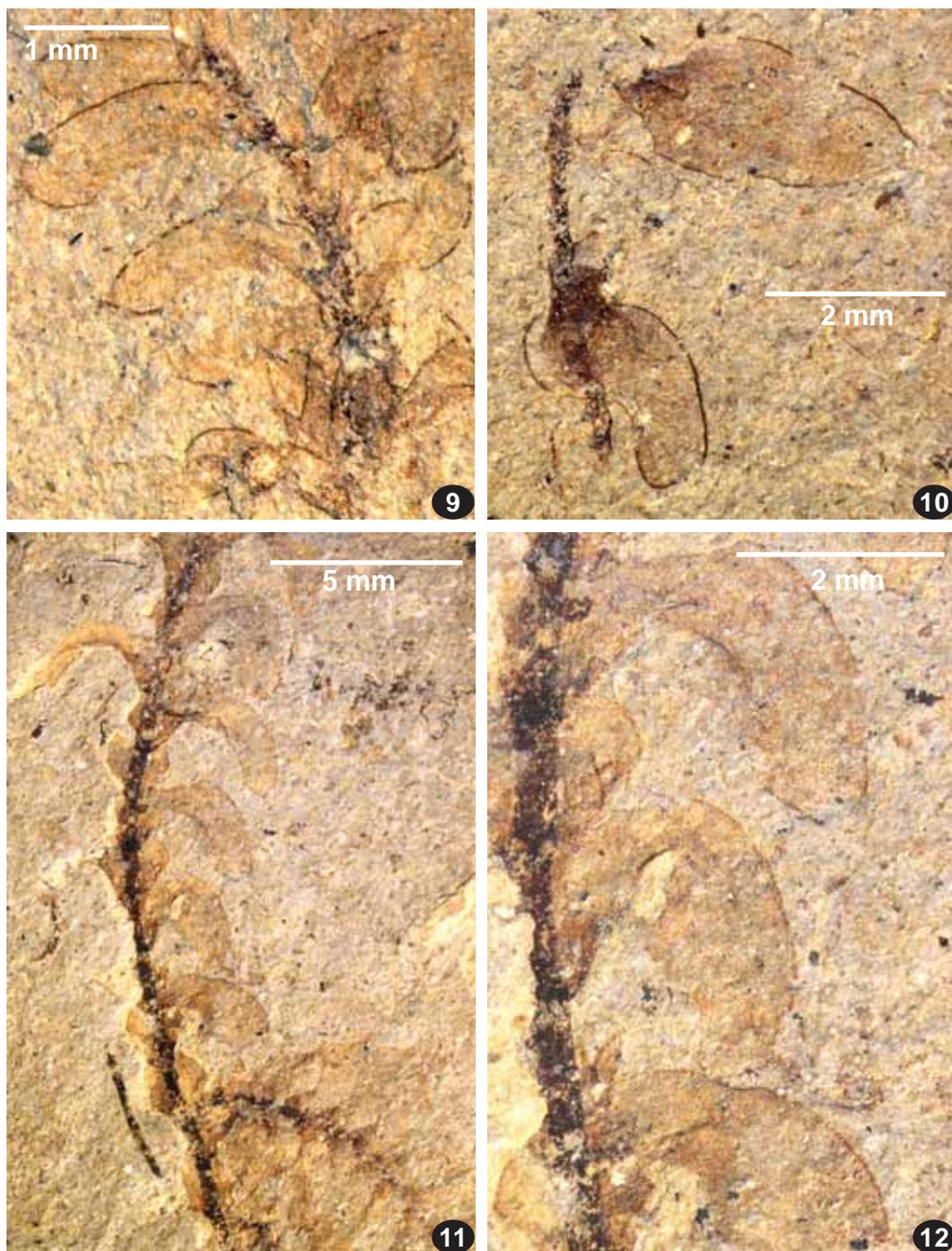
Taking into consideration the variation here in comparison with the variation in modern mosses in swampy habitats, we think that all these specimens can be attributed to one species, which is supported by the specific and easily observable leaf structure, i.e., the combination of (1) no costa; (2) dark even border all around the leaf; (3) rectangular leaf cells.

Leaf variation includes mostly the pattern of the apical part: obtuse (Figs. 8-12, 14, 17) or apiculate (Figs. 19, 28, 36, 39). Unfortunately

many leaves lack this part (Figs. 26-27, 30, 32). A similar variation however is known in modern mosses within a single species (e.g., in aquatic groups of *Rhynchostegium*, cf. Huttunen & Ignatov, 2010), and in some rock pieces where leaves likely represent the same plant the variation includes both types.

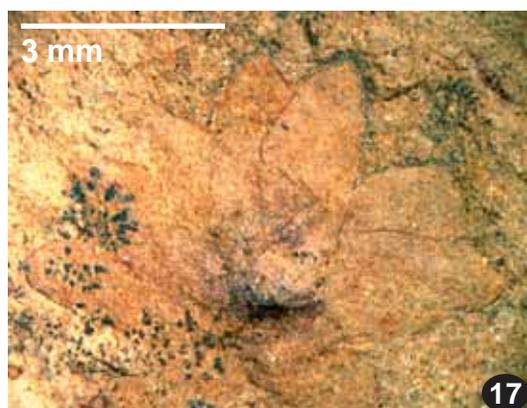
Areolation is well-preserved in many specimens, allowing its comprehensive overview. Note that the alar region in *Bryokhutuliinia* is only moderately differentiated (Figs. 33, 42-43), compared to another nearly synchronous genus *Palaeodichelyma*.

(continued on page 29)



Figs. 9-12. *Bryokhutuliinia obtusifolia* sp.n. 9 – PIN 5438/54; 10 – PIN 5438/18a; 11-12 (holotype) – PIN 5438/76. Shoots, showing variants of a relatively loose foliage for the species, correlated with reflexed stem leaves. Fig. 11 also represents branch with more dense and subcomplanate foliage.

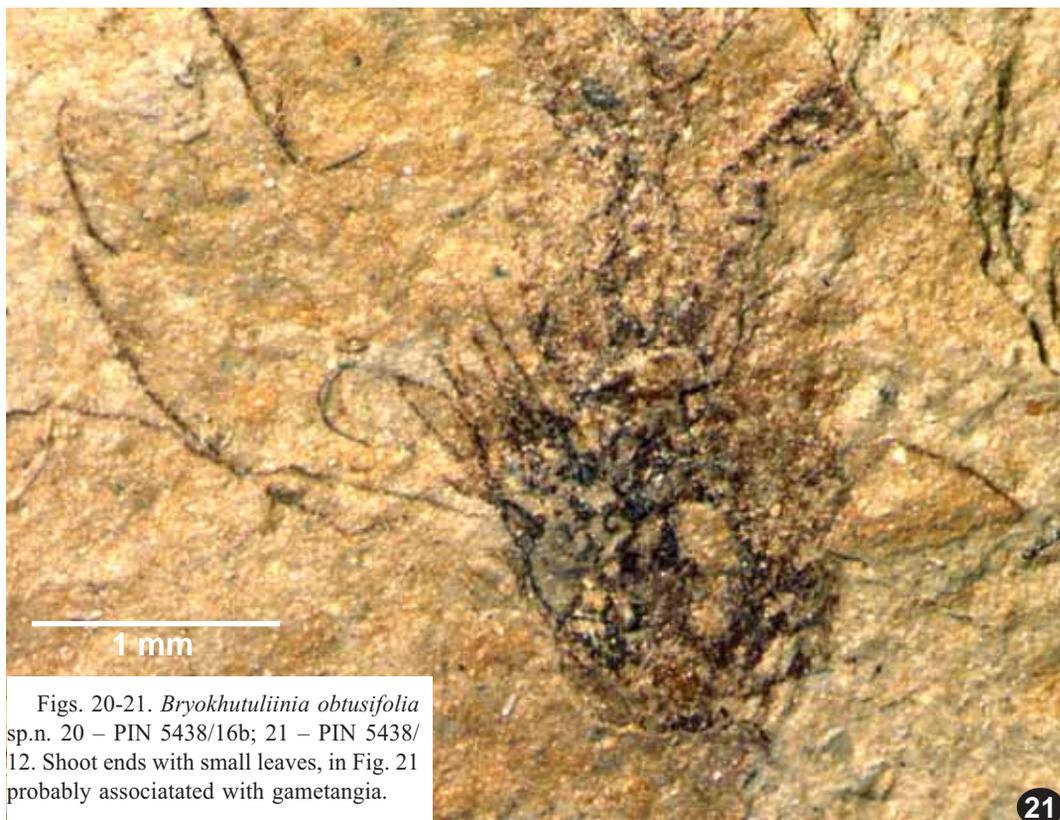
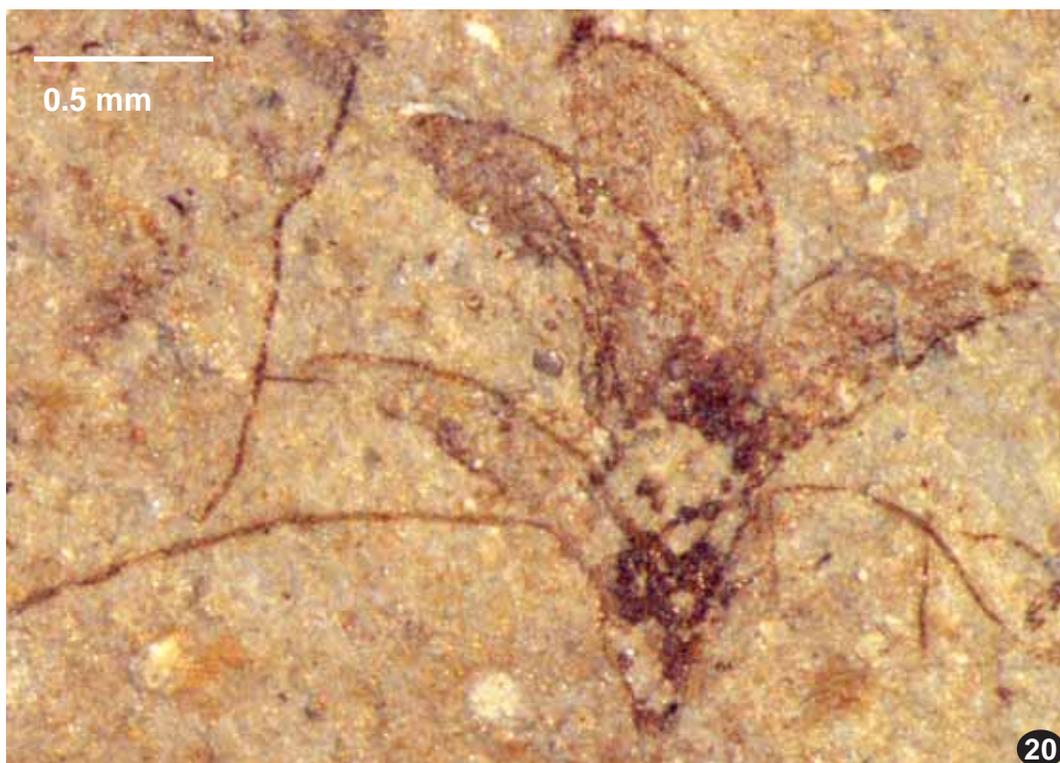
Figs. 13-17 (opposite page). *Bryokhutuliinia obtusifolia* sp.n. 13 – PIN 5438/43; 14 – PIN 5438/43 counterpart; 15 – PIN 5438/20; 16 – PIN5438/57; 17 – PIN 5438/1. Leaf rosettes, view from its upper side (figs. 13-14, 16) and view from below (figs. 15, 17). Small leaf ca. 0.5 mm long is clearly seen in Fig. 16 (less clearly seen another one in fig. 16 and in fig. 13).



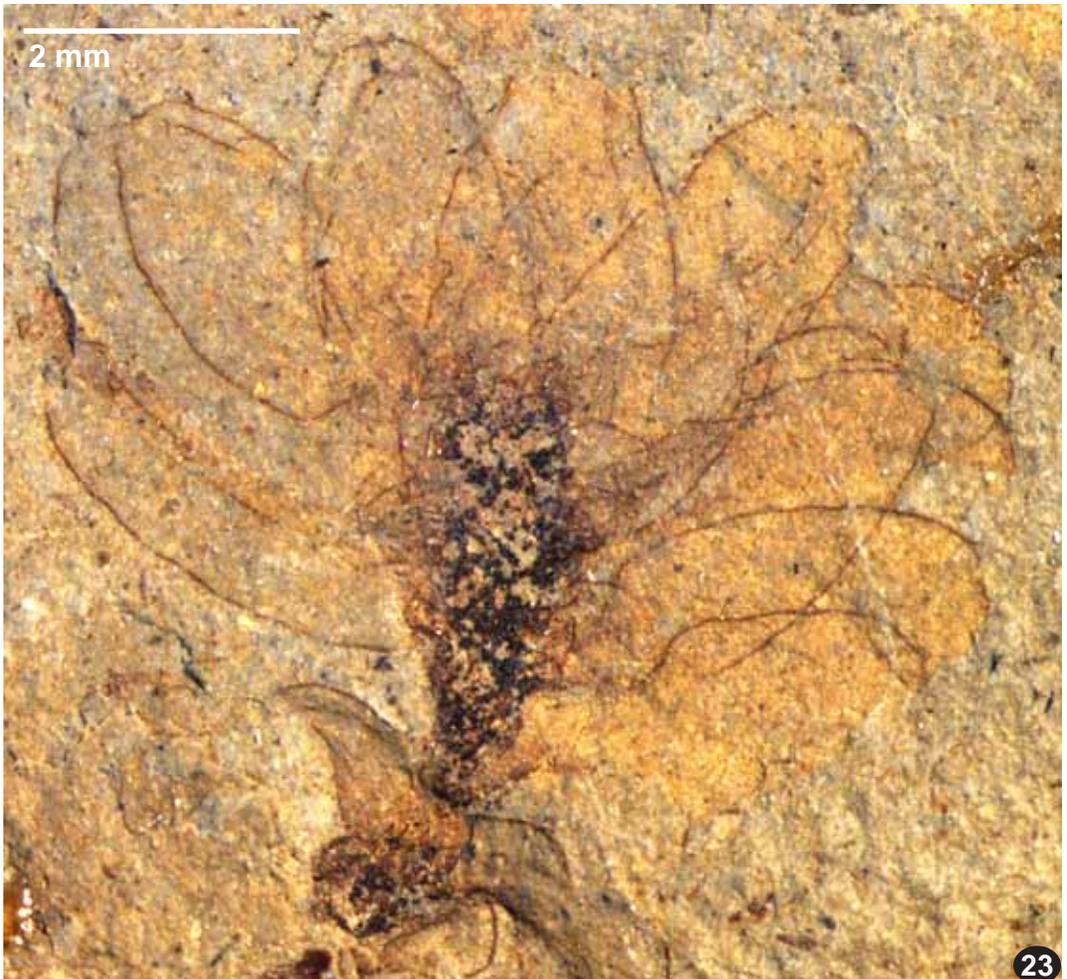
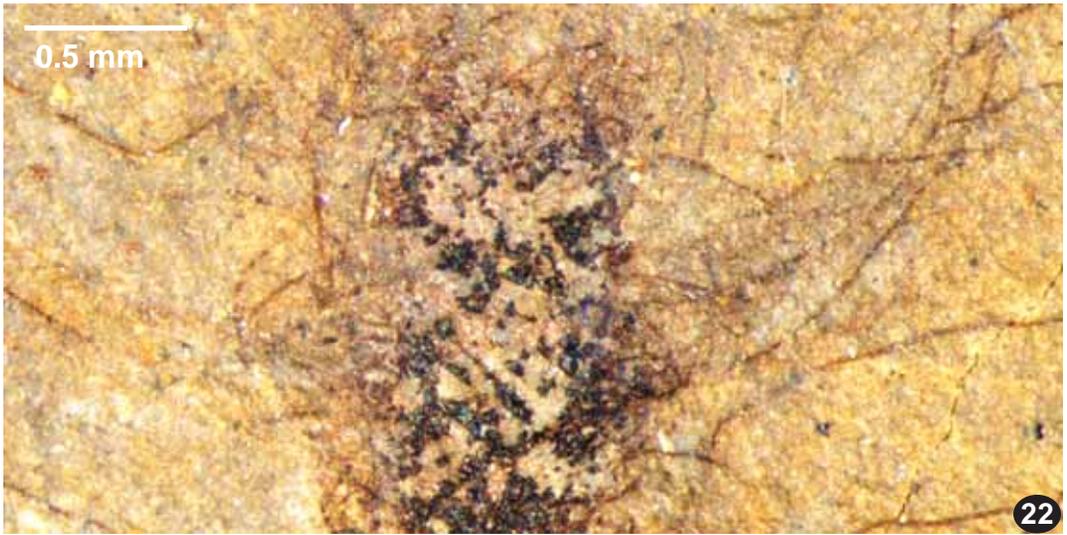


Figs. 18-19. *Bryokhultulinia obtusifolia* sp.n. PIN 5438/14. 18 – part of shoot with a relatively small apiculate leaves. Stem continues above and two bigger leaves occur above (not shown); 19 – magnified upper parts of apiculate leaves.

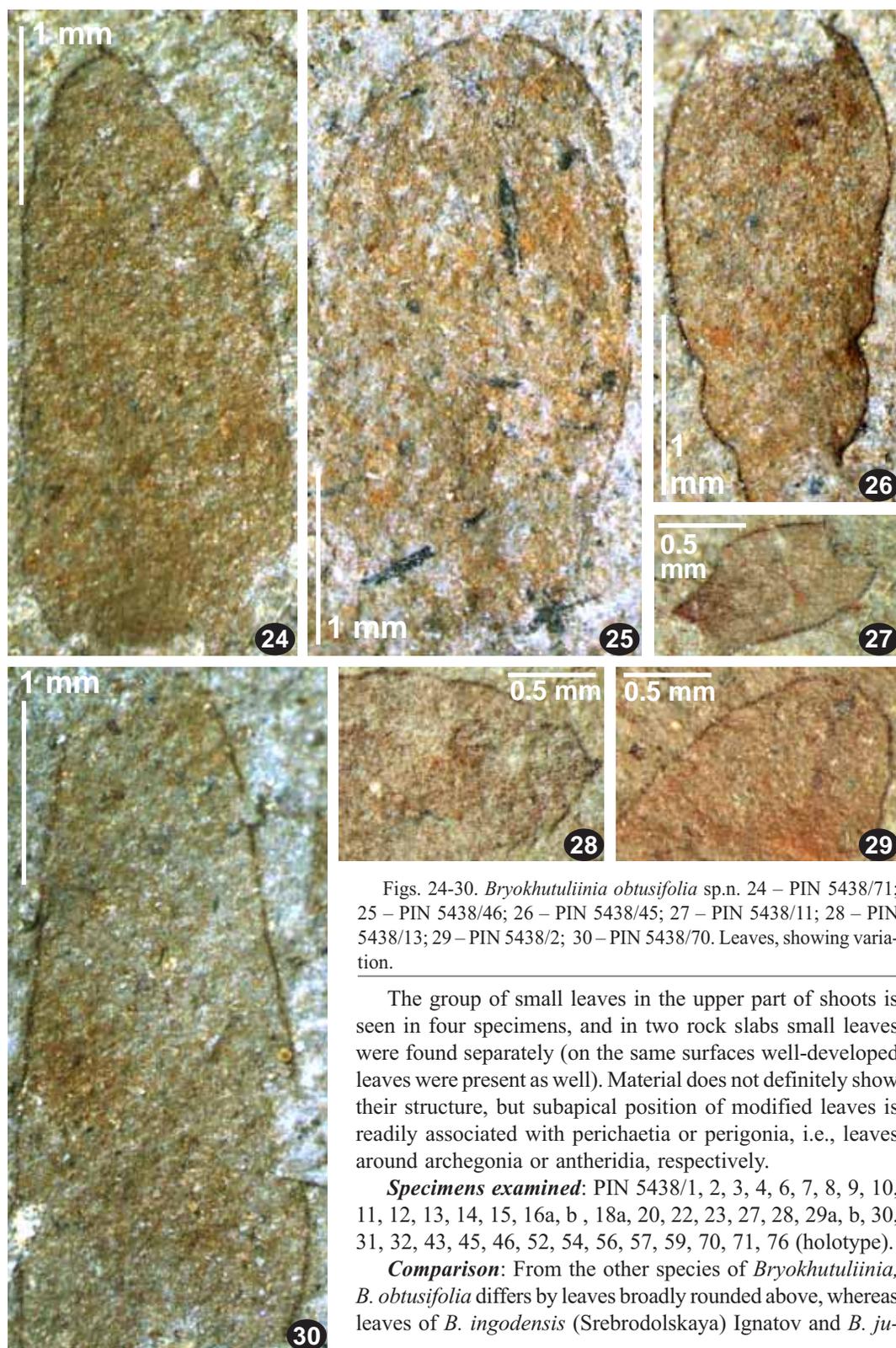




Figs. 20-21. *Bryokhutuliinia obtusifolia* sp.n. 20 – PIN 5438/16b; 21 – PIN 5438/12. Shoot ends with small leaves, in Fig. 21 probably associated with gametangia.



Figs. 22-23. *Bryokhutuliinia obtusifolia* sp.n. PIN 5438/32. Upper part of shoot, with crowded rosette leaves and some smaller leaves (poorly seen), probably surrounding gametangia.

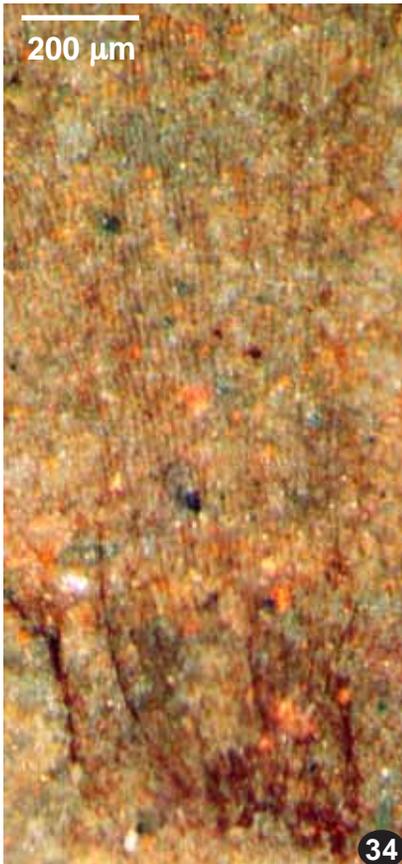
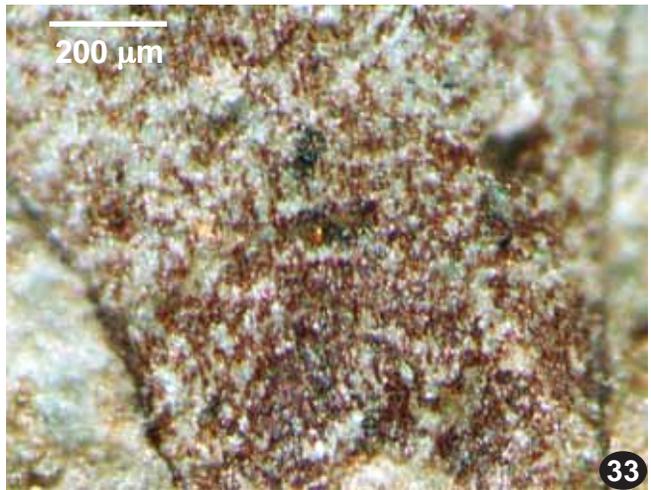
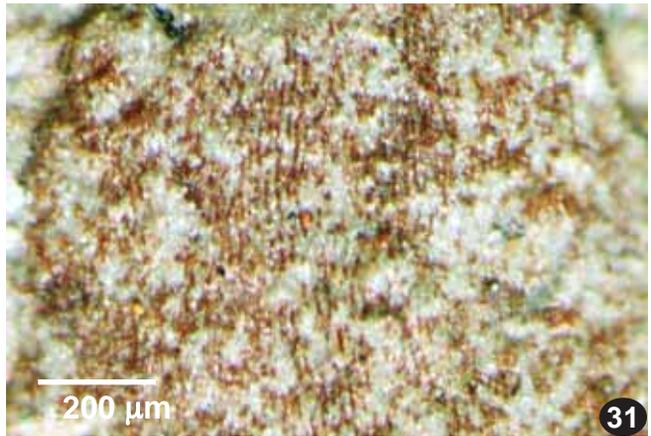


Figs. 24-30. *Bryokhutuliinia obtusifolia* sp.n. 24 – PIN 5438/71; 25 – PIN 5438/46; 26 – PIN 5438/45; 27 – PIN 5438/11; 28 – PIN 5438/13; 29 – PIN 5438/2; 30 – PIN 5438/70. Leaves, showing variation.

The group of small leaves in the upper part of shoots is seen in four specimens, and in two rock slabs small leaves were found separately (on the same surfaces well-developed leaves were present as well). Material does not definitely show their structure, but subapical position of modified leaves is readily associated with perichaetia or perigonia, i.e., leaves around archegonia or antheridia, respectively.

Specimens examined: PIN 5438/1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16a, b, 18a, 20, 22, 23, 27, 28, 29a, b, 30, 31, 32, 43, 45, 46, 52, 54, 56, 57, 59, 70, 71, 76 (holotype).

Comparison: From the other species of *Bryokhutuliinia*, *B. obtusifolia* differs by leaves broadly rounded above, whereas leaves of *B. ingodensis* (Srebrodolskaya) Ignatov and *B. ju-*



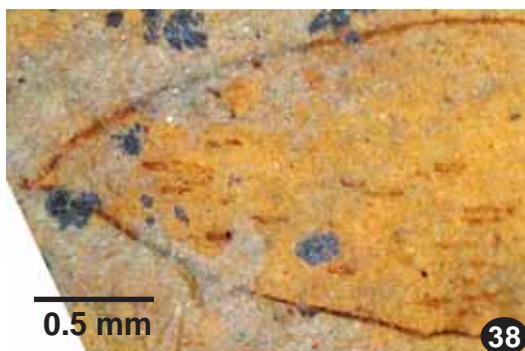
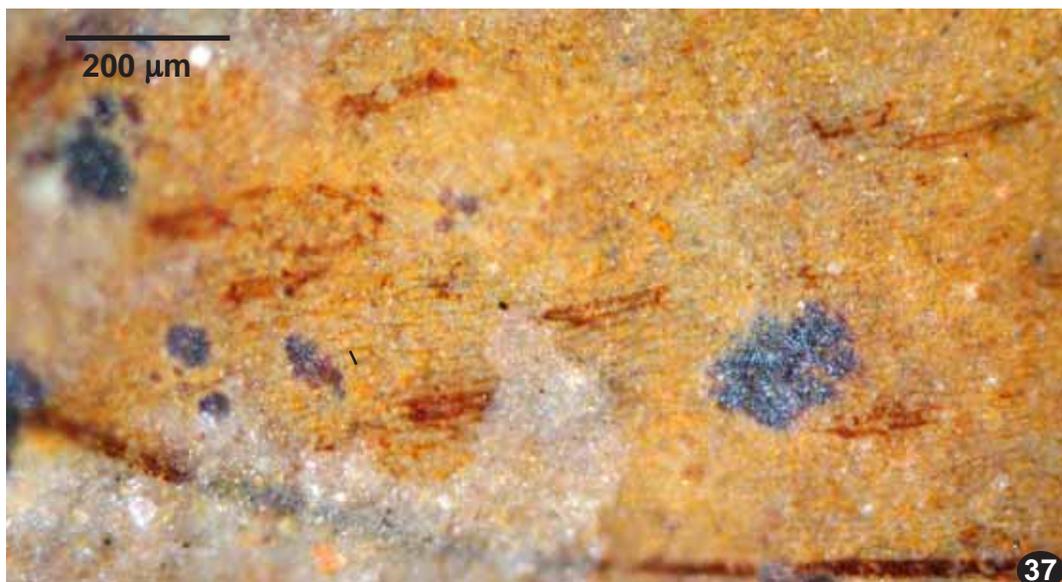
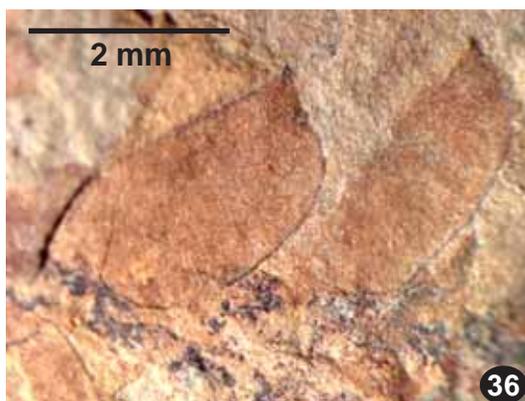
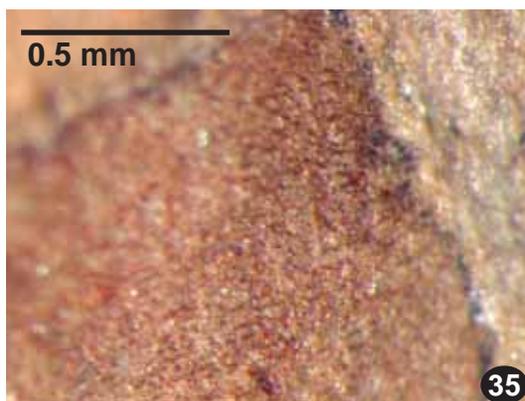
Figs. 31-34. *Bryokhutuliinia obtusifolia* sp.n. 31-33 – PIN 5438/16a; 34 – PIN 5438/31 (under alcohol). Areolation of leaf in its middle and basal parts.

rassica are gradually acute, and leaf rosettes also were never observed in these two latter species.

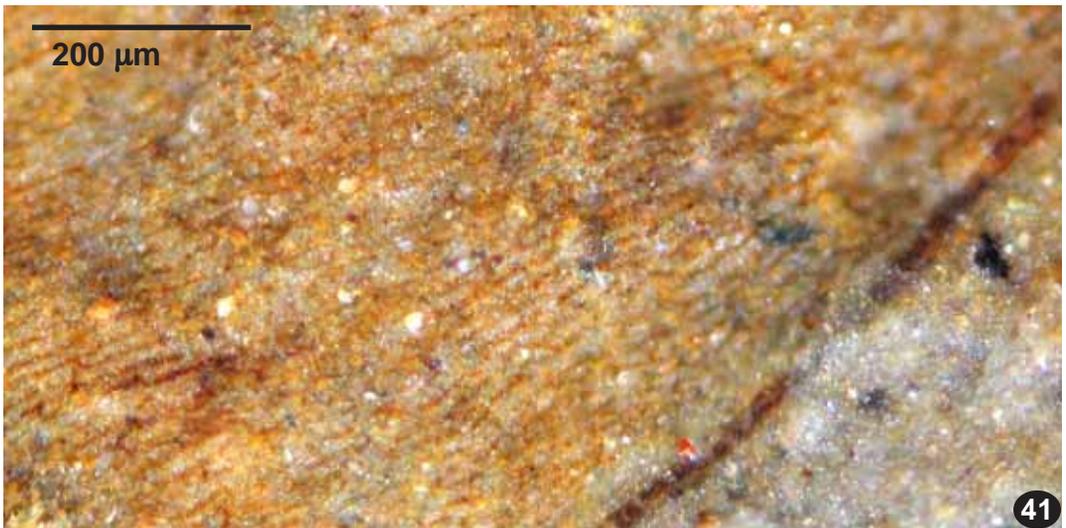
The original description of *Bryokhutuliinia* (Ignatov, 1992) left the genus without any definite familial placement. The present additional data, and especially the discovery of leaf rosettes make this problem even more difficult.

The branching pattern, especially that which was found in *B. ingodensis* (cf. Ignatov et al., 2011, present volume), with rather regular pinnate branching is very similar to pleurocarpous mosses.

At the same time, the leaf rosettes themselves (and moreover if the idea of the apical/subapical position of gametangia is correct) are characteristic of modern acrocarpous mosses and only extremely rarely occur in pleurocarps, for example in *Pseudocryphaea* (Newton, 2007).



Figs. 35-39 (37-39 under alcohol). *Bryokhutuliinia obtusifolia* sp.n. 35-36 – PIN 5438/3; 37-38 – PIN 5438/29b; 39 – PIN 5438/29a; upper and middle leaf areolation, showing variation.



Figs. 40-41 (under alcohol). *Bryokhutuliinia obtusifolia* sp.n. – PIN 5438/28. Leaf areolation, showing variation.

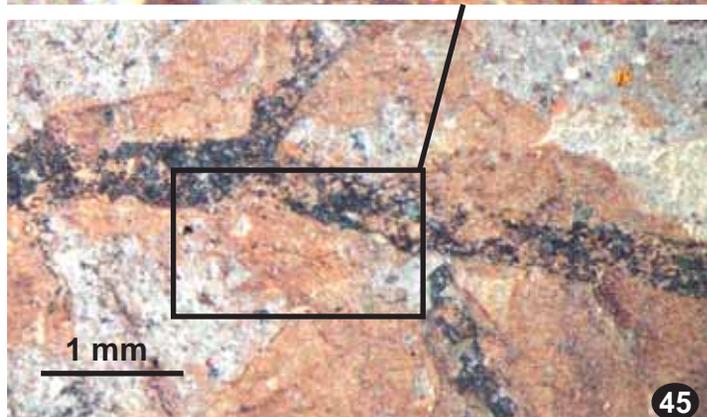
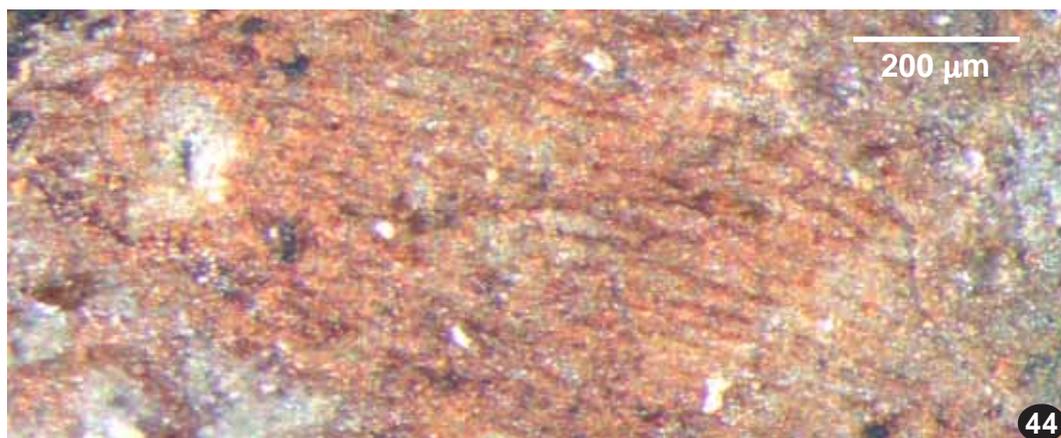
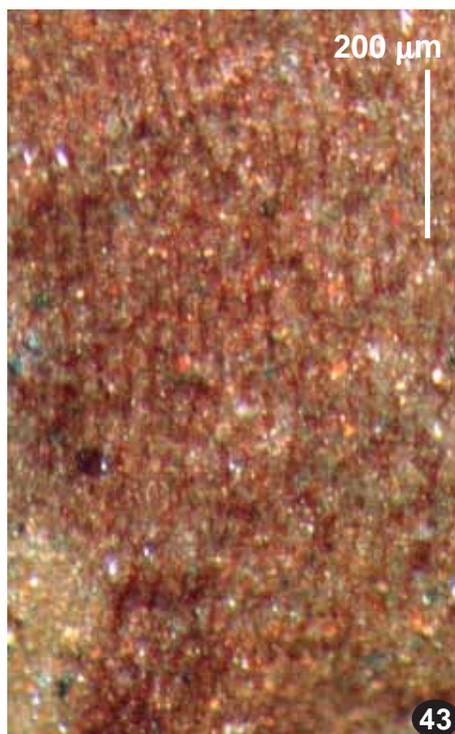
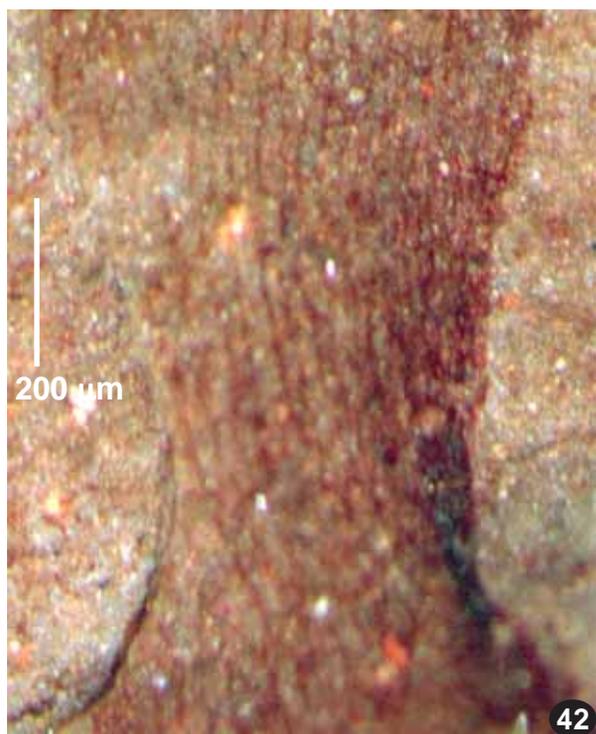
This genus however has long single costa and very distinct habit, so it is not a good subject for further comparison.

An ecostate acrocarpous mosses are rare, but in, e.g., Dicnemonaceae some species have leaf shape quite similar to that of *Bryokhutuliinia obtusifolia*. However, these plants have non-bordered leaves and stems are densely foliate and not pinnate branched.

The rectangular laminal cells are an odd character state in pleurocapous mosses where cells

usually have oblique ‘transversal’ walls, which depends on the pattern of leaf ontogenesis (Frey, 1971). The perpendicular cell walls almost throughout the lamina excepting the apical part are known in Hypnales only in groups with very short, almost isodiametric cells, like Thuidiaceae, but there are no exceptional species with long cells.

The Hookeriales include genera that have most of diagnostic characters of *Bryokhutuli-*



Figs. 42-45. *Bryokhutuliinia obtusifolia* sp.n. 42-43 – PIN 5438/30 (shoot is also shown in Fig. 5); 44-45 – PIN 5438/6. Basal leaf areolation, showing variation.

nia, but 'scattered' among different genera: *Hookeria* has ecostate leaves (but no border, and cells have oblique ends), *Daltonia*, *Cyclodictyon*, and *Calyptrochaeta* have border, and cells with transverse walls perpendicular to their lengths, however all these genera have distinct costa. Pinnate branching is not common in Hookeriales, although it is well-performed in, e.g., *Hypopterygium*, which also has bordered leaf margin, differs considerably in lamina areolation and plant habit.

Leaf rosettes are not rare in Mniaceae, but pinnate branching and lack of costa is difficult to associate with members of this family.

Genus **Palaeodichelyma** Ignatov & Shcherbakov, Syst. Assoc. Spec. Vol. 71: 327. 2007.

Description: Plants rather robust. Stem creeping, loosely foliate, irregularly pinnately branched. Leaves erectopatent to reflexed, ovate to lanceolate, acute; margin unbordered, plane, entire to subentire; costa single, reaching leaf apex or disappearing shortly below it; laminal cells rectangular, in alar region laxer and larger.

The genus includes one species.

Palaeodichelyma sinitzae Ignatov & Shcherbakov, Syst. Assoc. Spec. Vol. 71: 327. 2007.

Figs. 46-48.

Description (based on Khasurty material): Stem >5 mm long, 0.35 mm wide, remotely foliate. Leaves to >3.5×1.5 mm. Costa ca. 50 µm. Basal cells ca. 30 µm wide.

Material: This moss, described from two localities (Unda and Daya, Upper Jurassic or, possibly, Lower Cretaceous) in Transbaikalia is represented in Khasurty by a single shoot, which however, completely falls within the variation of *P. sinitzae* (original description was based on numerous plant fragments). Leaves mostly have only basal part, where leaf width is readily available and only in one place can leaf length be measured. Cell width can be observed at the base of a few leaves (Figs. 47-48), and their short rectangular shape is also apparent.

Specimens examined: PIN 5438/48 (Figs. 46-48).

Comparison: In Late Jurassic – Early Cretaceous of Transbaikalia, *Palaeodichelyma* is one of two pleurocarpous mosses with leaves having

long single costa. *Muscites ostracodiferus* Krassilov (Krassilov, 1982) from the Cretaceous of Mongolia also has a long single costa, lanceolate leaves, and its foliage is similar to that of terminal shoots of *Palaeodichelyma*. However, in that species the cell structure is unknown, and there are also some differences in leaf size: (1.7-)2.5-3.5(-4.2)×(0.7-)0.8-1.5 mm in *Palaeodichelyma* vs. 5-6×0.5-0.6 mm in *Muscites ostracodiferus*.

Genus **Tricostium** Krassilov, Palaeontographica, Abt. B, 143: 100, figs. 75-86. 1973.

Description: Plants growing as individual shoots. Stem erect, >1 cm long, 0.3 mm wide, remotely spirally foliate. Leaves erect to widely spreading, straight to gently reflexed, ovate to oblong-lanceolate, shortly acute; margin plane, denticulate in upper part, entire below; middle costa rather thin, ending shortly below apex; two submarginal costae present, reaching above 0.9 leaf length. Laminal cells quadrate-polygonal to short rectangular, towards leaf base slightly longer, rectangular.

Type species: *T. papillosum* Krassilov.

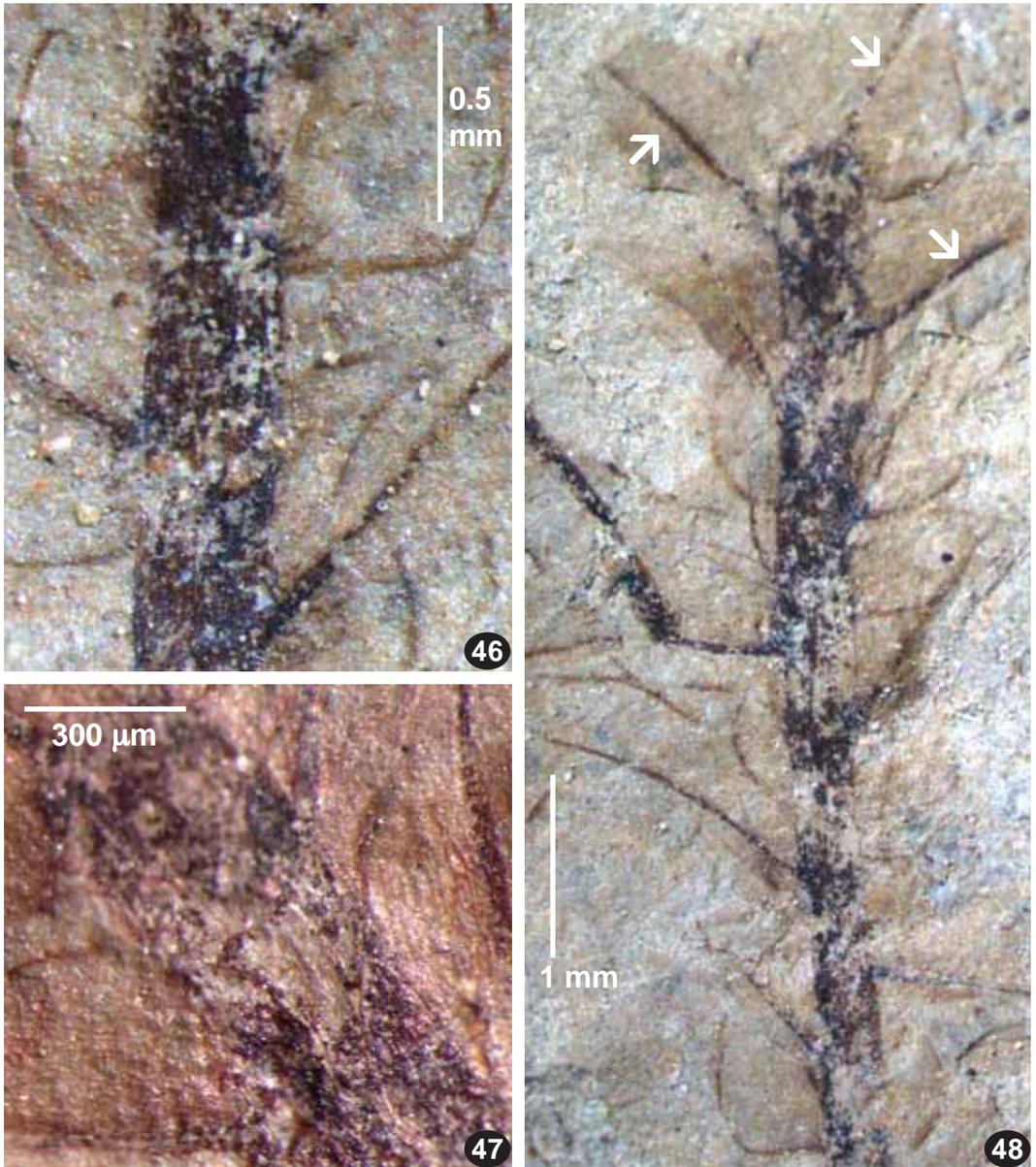
The genus definitely includes two species: *T. papillosum* from Umalta River (Bureya River tributary), Late Jurassic, and one described below from the Lower Cretaceous, *T. longifolium*. Less definite material from the Early Triassic of Yaman Us, Mongolia (see Ignatov & Shcherbakov, 2011, present volume) is also referred to this genus.

Tricostium longifolium sp. nov. Figs. 49-57.

Holotype: Khasurty River, # PIN 5438/33. Lower Cretaceous. Figs. 50-52.

Description: Stem erect, >1 cm long, 0.3 mm wide. Leaves widely spreading, straight to gently reflexed, 4-6 mm long, 1.3-1.5 mm wide, elongate, shortly acute, middle costa 60-80 µm wide, submarginal costae slightly thinner; laminal cells isodiametric, 13-17 µm.

Material: Plant is represented by 5 rock slabs with shoots, all having rather remote foliage, and 8-9 dispersed leaves that can be more or less definitely attributed to this species. Most specimens are preserved on a more coarse rock matrix compared to *Bryokhutuliinia*, and probably because of this fact, and likely also because of smaller laminal cells, the leaf areolation is



Figs. 46-48. *Palaeodichelyma sinitzae* Ignatov & Shcherbakov. PIN 5438/48. Same shoot at different magnification, and lower leaf areolation (Fig. 47). Note leaves with prominent single costa (Fig. 48, arrowed).

seen in less than half of leaves. Most leaves however can be identified due to their peculiar tricostrate leaves.

Specimens examined: PIN 5438/16c, 17, 18b, 21, 33, 34?, 40, 41, 44, 49, 58, 73, 74, 75.

Comparison: The unusual presence of three costae in leaf indicates a close relationship between our species and *Tricostium papillosum* from the Bureya River (now ca. 2000 km to the east

from Khasurty). In addition, the laminal cell shape and size are also almost identical.

The differences include mostly the size and shape of leaves.

Krassilov (1973) had material from bulk maceration that usually results in somewhat more fragmented material due to decomposition during acid treatment. The smaller leaves that usually occur in lower and subapical parts of stems



Figs. 49. *Tricostium longifolium* sp. nov. PIN 5438/21. Part of shoot with three leaves (lower and upper part of shoot not presented).

in mosses have obviously a higher probability to be found as whole leaves in bulks.

Krassilov (1973) described leaves as 1.2 mm long and 0.5 mm wide, noting however that some fragments are 1 mm wide. These values do not completely agree with illustrations, where the holotype, almost a whole leaf, is 1.8×0.8 mm (Krassilov, 1973, fig. 79) and one leaf fragment (in Fig. 82) has half-leaf width 0.7 mm. So the leaf width of *T. papillosum* was the same as in *T. longifolium*. However in the former species numerous leaves show invariable ovate-elongate shape, hardly exceeding 2-2.5:1. At the same time numerous specimens from Khasurty have leaves 3.5-5:1, being sufficiently longer than in *T. papillosum*.

Imprint collections have the advantage against bulks (at least in most cases) in showing plant appearance, but at the same time do not allow the observation of fine characters, so we fail to make any conclusion about papillosity of laminal cells in *T. longifolium*. Even an entire or denticulate mar-

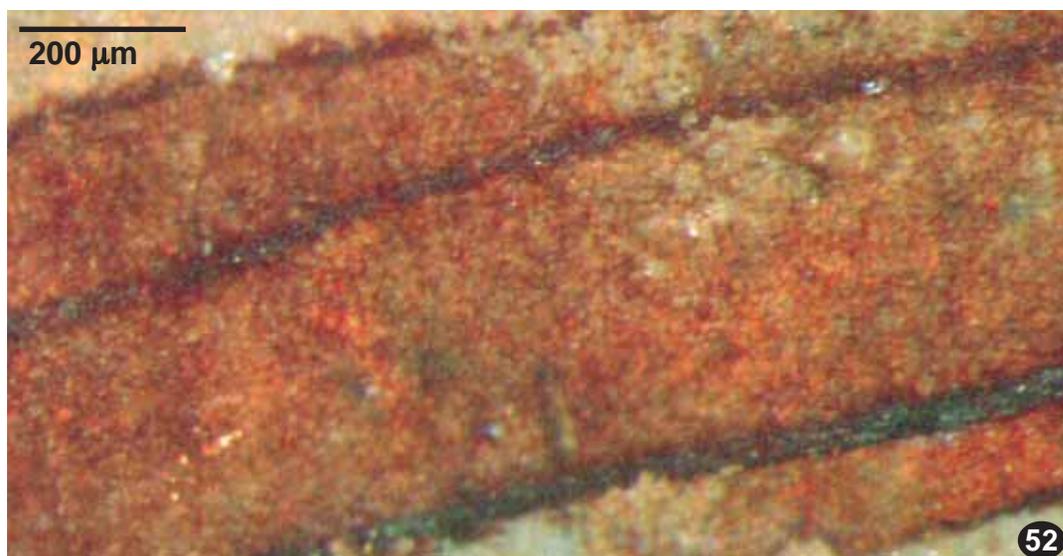
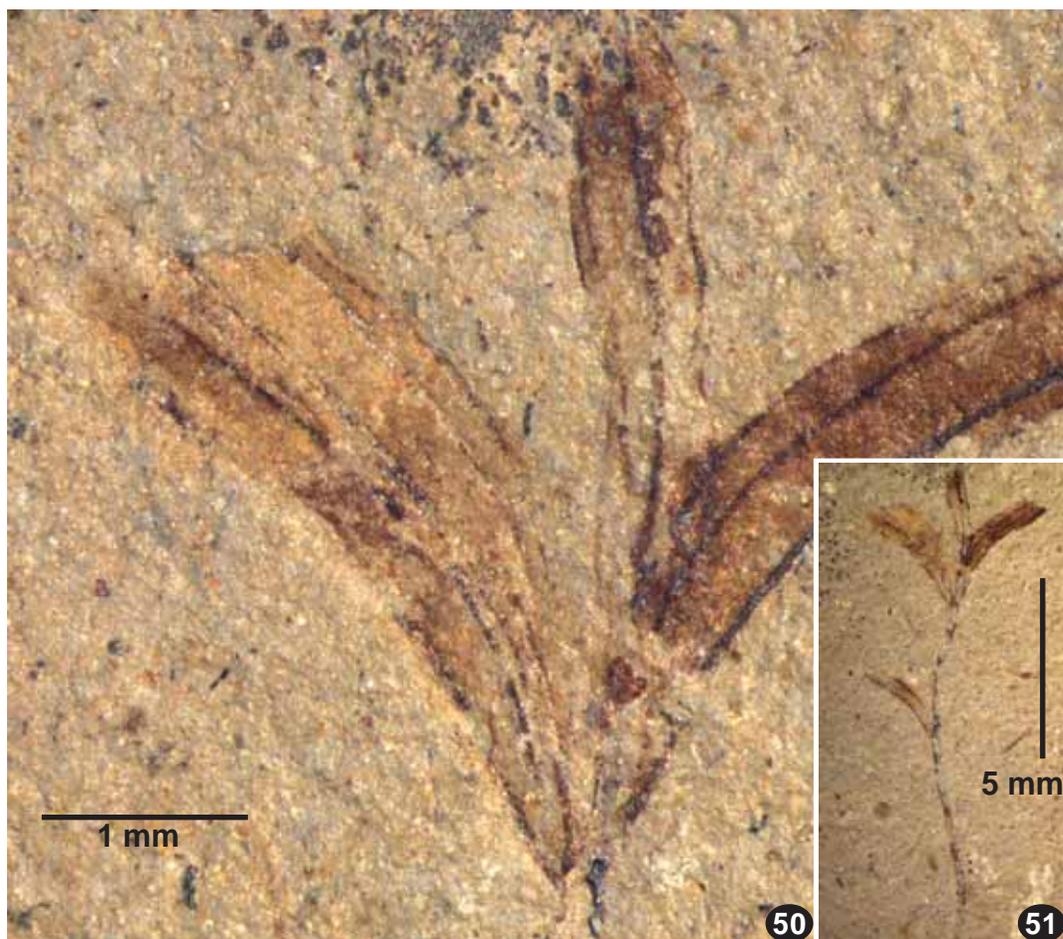
gin cannot be certainly understood from our material, moreover the uppermost parts of most leaves were often damaged.

Foliage pattern in *T. papillosum* was much denser and leaf bases were invariably erect. Although it is totally unknown how the species looks, it is quite likely that it was not very similar to the present collections of *T. longifolium*.

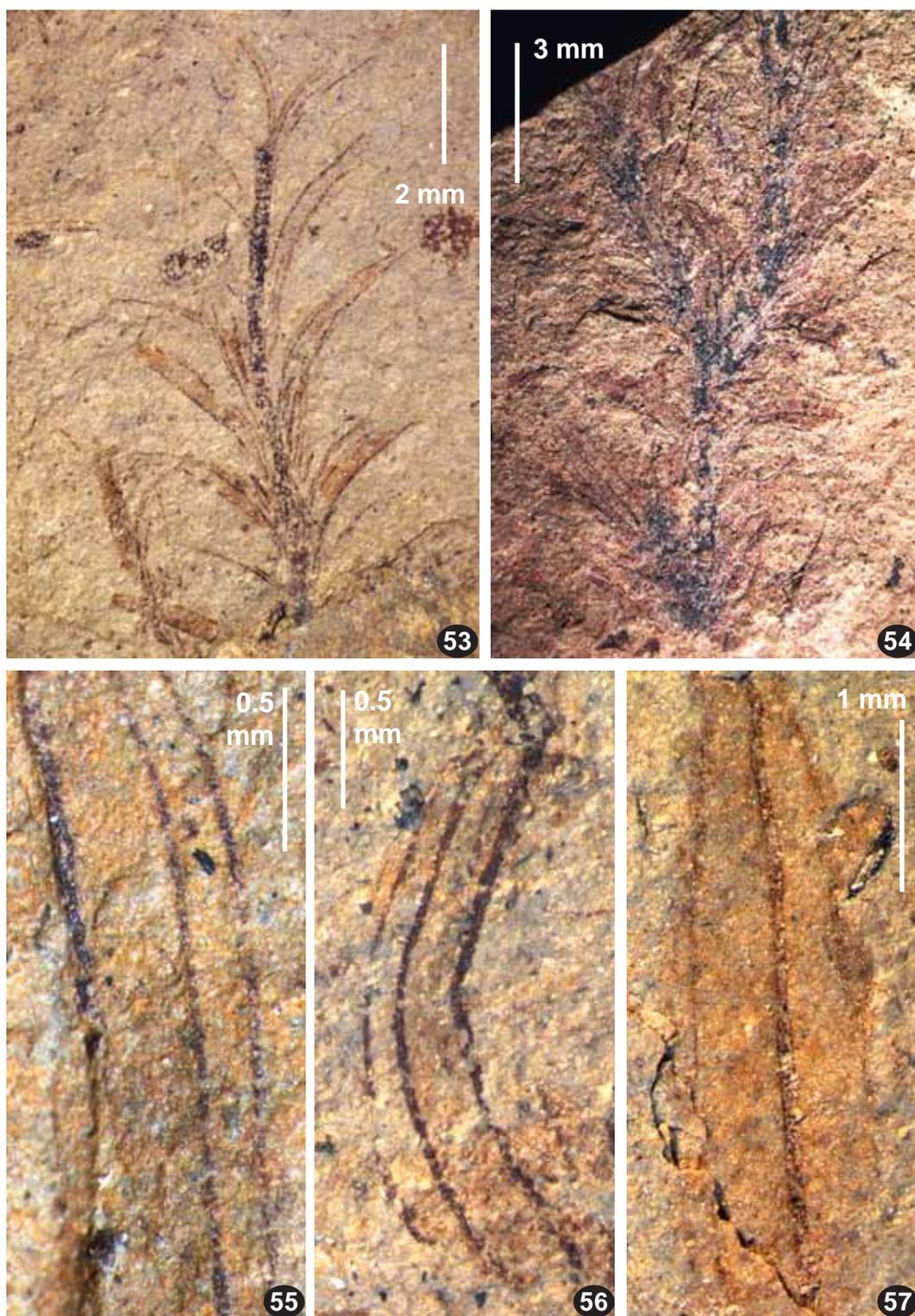
The familial placement of *Tricostium* cannot be decided basing on available characters. Very clear submarginal 'costae' occur in, e.g., *Scouleria marginata*, a large aquatic moss growing in Pacific North America. Traditionally it was placed in the Grimmiaceae, but molecular phylogenetic analyses indicate that this is more ancient separate lineage of acrocarpous mosses. However marginal 'costae' are known in other quite unrelated groups too (cf. Ochyra, 1990).

* * *

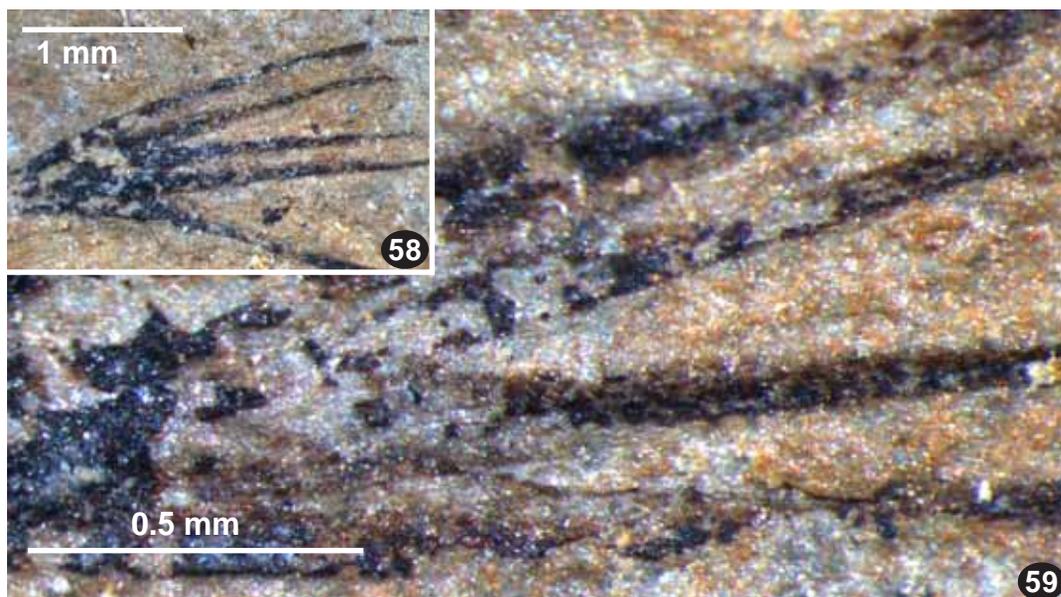
Mosses with indiscernible or obscure laminal areolation are described here without formal



Figs. 50-52. *Tricostium longifolium* sp.n. PIN 5438/33 (holotype). Figs. 50-51 – shoots; Fig. 52 (under alcohol) – mid-leaf areolation.



Figs. 53-57. *Tricostium longifolium* sp.n. (Fig. 53 – PIN 5438/49; Fig. 54 – PIN 5438/17; 55 – PIN 5438/73; 56 – PIN 5438/16c; 57 – PIN 5438/58). Shoots (Figs.53-54) and leaves (Figs. 55-57), showing variation.



Figs. 58-59. *Muscites* sp. 1, PIN 5438/47, shoot tip with five leaves with stout costa.

name, as their comparison cannot be complete enough.

***Muscites* sp. 1.** Figs. 58-59.

Fragment represents shoot apex with five leaves. Leaves erect, $2.5 \times > 0.4$ mm, from ovate sheathing base linear-lanceolate, gradually long-acuminate; margin apparently entire; costa filling more than half of leaf width; unistratose lamina is seen in lower half of leaf; laminal cells elongate, ca. 12-15 μm wide.

Specimen examined: PIN 5438/47.

Specimen has appearance that is characteristic of many Dicranaceae s.l., also mosses from the Ditrichaceae and Bartramiaceae may have a similar appearance. Cell characters are poorly represented, but elongate, not isodiametric cell shape is more or less apparent.

***Muscites* sp. 2.** Figs. 60-62.

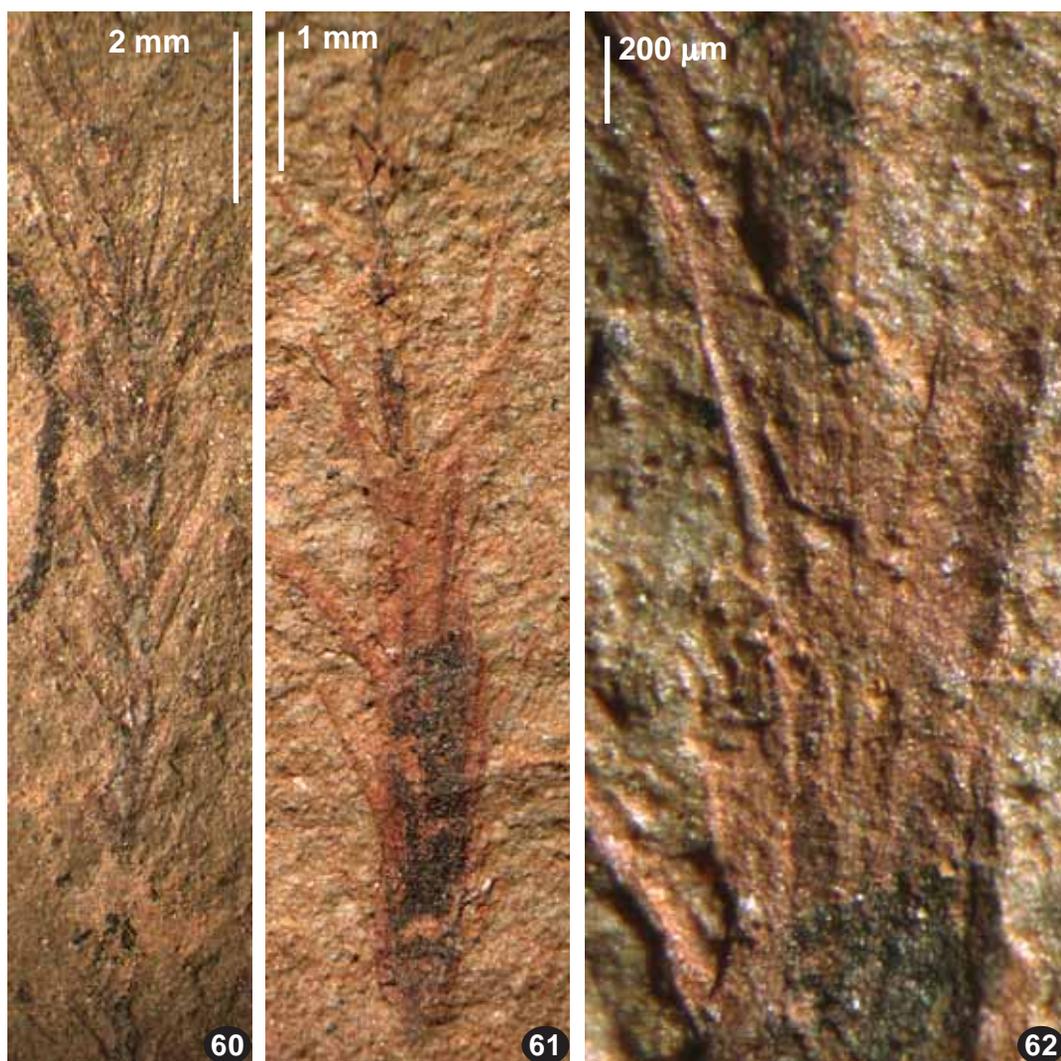
Represented by two fragments of unbranched shoots, one being ca. 15 mm (Fig. 60) and another 5 mm long (Figs. 61-62). Foliage rather dense, no less than 10 leaves per 5 mm. Leaves erect, 3-3.5 mm long and ca. 0.5 mm wide. Costa percurrent, constituting no more than 1/6 of leaf width; laminal cells elongate, ca. 10-12 μm wide.

Specimens examined: PIN 5438/72, /53 and with question mark PIN 5438/42, /53, /72.

As material is poorly preserved, the dimensional characteristics, including leaf width are rather approximate. Cell width could only be measured in striolate areas near the costa in the shorter fragment (Fig. 62).

This is an acrocarpous moss with possible affinities to the families discussed in the previous moss, and also the Catascopiaceae and Pottiaceae. Poor preservation of laminal areolation and only two shoots are the main reasons why these specimens are not described in a standard way.

Two Upper Jurassic-Lower Cretaceous mosses, *Muscites ostracodiferus* and *Palaeodichelyma sinitzae* also have long single costa, but leaves are erecto-patent, only at places erect, whereas in *Muscites* sp. 2 they are invariably erect-appressed. In addition, two former mosses have branched stems and branches forming broad angles with the stem. The leaves of *Stachybryolites zhoui* (Wu et al., 2000) are erect, but the fully developed leaves are rather crowded distally, while the proximal part of shoot looks leafless, although more likely leaves are present, but small and inconspicuous. Description of the species is however confusing, as leaves are described being 0.5 mm wide, while laminal cells being 80-100 \times 100-120 μm .



Figs. 60-62. *Muscites* sp. 2 (Fig. 60 – PIN 5438/72; Figs. 61-62 – PIN 5438/53). Shoot with dense foliage of narrow leaves.

***Muscites* sp. 3.** Figs. 63-64.

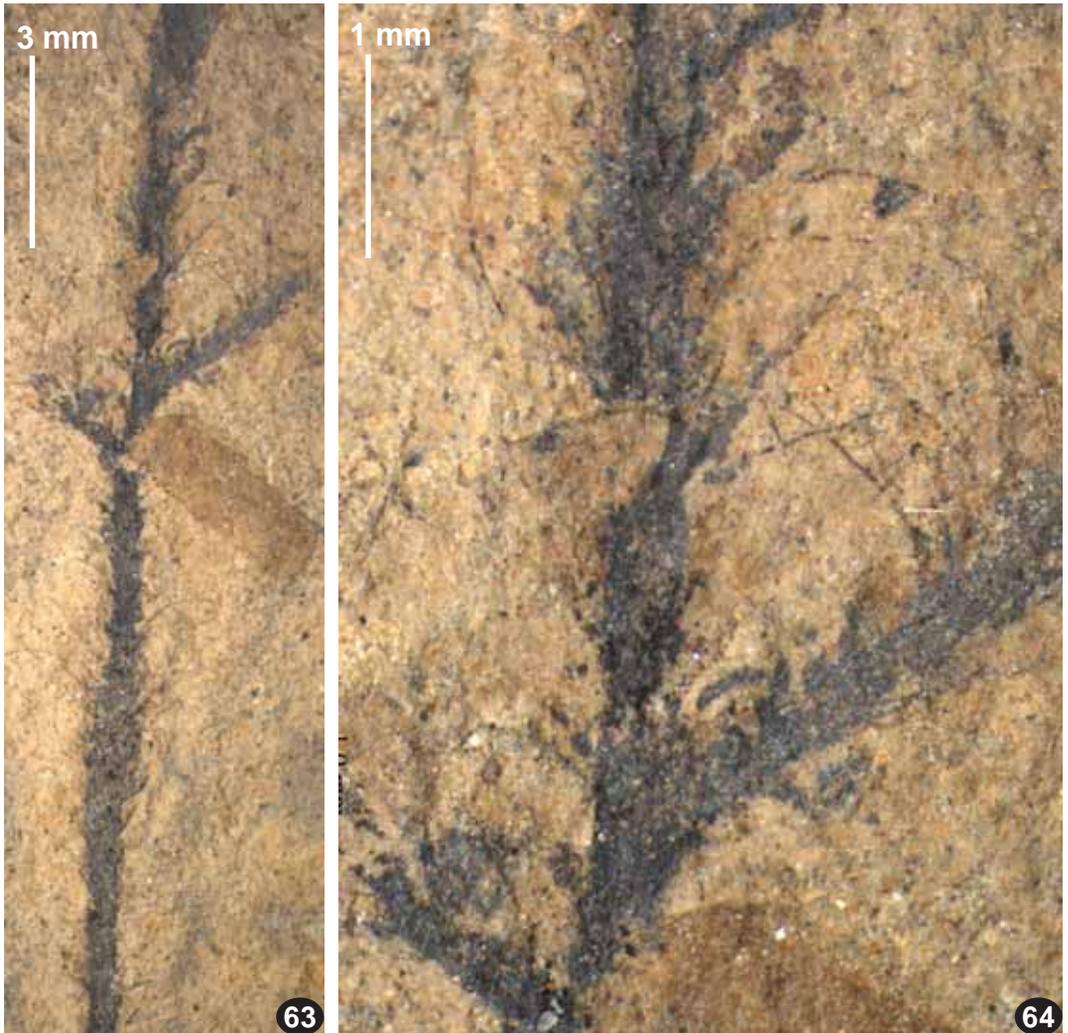
Stem > 1.5 cm, very densely spirally foliate, with two branches sitting nearby and deviated at ca. 60° from stem; branch foliage similar to that of stem. Leaf bases apparently erect or appressed, upper parts of leaf to 1.5 mm, very narrow, reflexed.

An acrocarpous affinity is most likely. The rock surface of this piece is especially sandy, so the expanded comparison is not relevant – the lamina may be simply decomposed, and only costae remain.

Being poorly preserved, the mosses mentioned here as *Muscites* sp. indicate a quite diverse eco-

system. Association with contemporary ecosystems allows one to imply that *Palaeodichelyma* was floating, *Bryokhutuliinia* was also floating, as well as growing in shallow and temporarily inundated banks, *Tricostium* (judging from the delicate stature) and maybe *Muscites* sp. 3 also likely occurred in shallow water, and *Muscites* sp. 1 and sp. 2 may have occurred on banks, although subaquatic habitats cannot be excluded as well.

It is interesting to note that rocks with mosses in most cases lack any other plants, thus corroborating the observations made by Neuburg (1960) for Permian mosses.



Figs. 63-64. *Muscites* sp. 3, PIN 5438/51. Shoot with remnants of leaves (mostly costae?)

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LITERATURE CITED

- FREY, W. 1970 [1971]. Blattentwicklung bei Laubmoosen. – *Nova Hedwigia* **20**: 463-556.
- HUTTUNEN, S. & M.S. IGNATOV 2010. Evolution and taxonomy of aquatic species in the genus *Rhynchostegium* (Brachytheciaceae, Bryophyta). – *Taxon* **59**: 791-808.
- IGNATOV, M.S. 1992. *Bryokhutuliinia jurassica*, gen. et spec. nova, a remarkable fossil moss from Mongolia. – *J. Hattori Bot. Lab.* **71**: 377-388.
- IGNATOV, M.S., E.V. KARASEV & S.M. SINITZA 2011. Upper Jurassic mosses from Baigul (Transbaikalia, South Siberia). – *Arctoa* **20**: 43-64.
- IGNATOV, M.S. & D.E. SHCHERBAKOV 2007. Did pleurocarpous mosses originate before the Cretaceous? – In: Newton, A.E. & R. Tangney (eds.) *Pleurocarpous mosses: systematics and evolution. [Syst. Ass. Special Vol. 71]* CRC Press, Boca Raton–London–New York: 321-336.
- IGNATOV, M.S. & D.E. SHCHERBAKOV 2007. Lower Triassic mosses from Yaman Us (Mongolia). – *Arctoa* **20**: 65-80.
- KOZUB, D., V. KHMELIK, YU. SHAPOVAL, V. CHENTSOV, S. YATSENKO, B. LITOVCHENKO & V. STARYKH 2008. Heicon Focus Software. <http://www.heliconsoft.com>
- KRASSILOV, V.A. 1973. Mesozoic bryophytes from the Bureja Basin, Far East of the USSR. – *Palaeontographica, Abt. B*, **143**: 95-105 + Pl. 41-51.
- KRASSILOV, V.A. 1982. Early Cretaceous flora of Mongolia. – *Palaeontographica, Abt. B*, **181**: 1-43.
- NEWTON, A.E. 2007. Branching architecture in pleurocarpous

- mosses. – In: Newton, A.E. & R. Tangney (eds.) *Pleurocarpous mosses: systematics and evolution*. [Syst. Ass. Special Vol. 71] CRC Press, Boca Raton–London–New York: 287-307.
- [NEUBURG, M.F.] НЕЙБУРГ М.Ф. 1960. Листостебельные мхи из пермских отложений Ангариды. – [Mosses from the Permian of Angaraland] *Trudy Geol. Inst. Akad. Nauk SSSR* **19**: 1-104 + 78 pl.
- OCHYRA, R. 1990. On the relationships of *Thamnobryum negrosense* (Bartr.) Iwats. & Tan (Musci: Thamnobryaceae). – *J. Hattori Bot. Lab.* **68**: 293-302.
- SINITSHENKOVA, N.D. 2011 New stoneflies (Insecta: Perlida = Plecoptera) from the late Mesozoic locality Khasurty, Transbaikalia. – *Paleontological Journal* **45**: 552-558.
- [SREBRODOLSKAYA, I.N.] СРЕБРОДОЛЬСКАЯ И.Н. 1980. Новые позднемезозойские листостебельные мхи из Забайкалья. – [New Late Mesozoic mosses from Transbaikalia] *Труды ВСЕГЕИ [Trudy Vsesoyuznogo Nauchno-Issledovatel'skogo Geol. Inst.]* **204**: 27-28.
- WU, X.-W., X.-Y. WU & Y.-D. WANG 2000. Two new forms of Bryiidae (Musci) from the Jurassic of Junggar Basin in Xinjiang, China. – *Acta Palaeontol. Sinica* **39**, **Suppl**: 167-175.