ISSN 0031-0301, Paleontological Journal, 2009, Vol. 43, No. 10, pp. 1217–1229. © Pleiades Publishing, Ltd., 2009.

The Coal-Forming Plants of Rhabdopissites in the Lipovtsy Coal Field (Lower Cretaceous of Southern Primorye)

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Received December 17, 2008

Abstract—The plants that produced unique resinous coals (rhabdopissites) of the Lipovtsy coal field are revealed. They belong mainly to the group Miroviaceae (*Oswaldheeria*). *Pseudotorellia* (Ginkgoales) played an important role in the formation of humic coals of this Early Cretaceous coal field. The coal-forming plants comprise also cyatheaceous and gleicheniaceous ferns. A leafy shoot of *Pseudotorellia* has been found in this locality for the first time. It is assigned to the new species *Pseudotorellia krassilovii* Bugdaeva sp. nov.

Key words: coal-forming plants, *Pseudotorellia*, Miroviaceae, Lower Cretaceous, Lipovtsy coal field, Primorye.

DOI: 10.1134/S0031030109100049

INTRODUCTION

The Razdol'noye Coal Basin is situated in the southwestern Primorye region. This includes sediments of the Ussuriysk (Barremian), Lipovtsy (Aptian), and Galenki (Early–Middle Albian) formations and the Korkino Group (Albian–Cenomanian). Only the Aptian beds contain coal (Krassilov, 1967). The Lipovtsy coal field, which is situated in the northwest part of the basin, 120 km north of the city of Vladivostok, includes three workable coal seams. The lowermost seam, Rabochii, varies in thickness from 0 to 17 m or even more and is overlain by the Srednii (0.07–7.7 m thick) and Verkhnii (0–2.5 m thick) seams (Sharudo, 1972). The coals of this field, as well as coals of the Il'ichevka and Konstantinovka coal fields, contain a large quantity of the lipoid components (resin, sporomorphs, and cuticles) and are assigned to so-called liptobioliths based on this parameter.

At the beginning of the 20th century, the Lipovtsy coal field was studied by Kryshtofovich, who described in detail the composition of the workable coal seam and paid a special attention to the "… coal that was compact, hard, brownish-black, opaque, heavy, overfilled, or rather mostly consisting of thin resin needles, transpiercing the coal in all directions and shining in split…" (Kryshtofovich, 1928, p. 19). This author described a peculiar kind of coal that consists of rod-shaped resin bodies as rhabdopissite (from Greece ράβδοζ – rod, and πίσσα – resin). He hypothesized that these bodies "… are simply resin filling or gum of resin ducts of trees, conifers or rather cycadophytes, i.e., probably bennettites…" (Kryshtofovich, 1928, p. 21).

Later, special studies were devoted to the unique coals of the Razdol'noye Coal Basin, which are valuable primary product for chemical industries (Verbitskaya et al., 1965; Sharudo, 1972; *Geology* …, 1973). It was revealed that petrographically the Rabochii seam is mainly composed of alternating interbeds of rhabdopissites and humic coals, and the firsts are represented by two kinds: rhabdopissite proper (pitch liptobiolith) and rhabdopissite with humic bulk. Rhabdopissite is opaque, hard, massive, tough, with conchoidal fracture, and with thin needles of pitch. They are brownish-red, 2–5 mm long and 0.5–1 mm thick. Resin bodies of different sizes may account for 62–91% of the total mass. The parent matter for resin bodies of rhabdopissites might be tannal or resinol resins differing from coniferous resins in composition (*Geology* …, 1973). Therefore, this group of plants could not have produced the liptobiolith of the Lipovtsy coal field.

Based on palynological data it was supposed that the main components of swamp vegetation, or of vegetation which grew in close proximity to swamps, were ferns, some members of the Cupressaceae and Taxodiaceae, and *Sphagnum* (Verbitskaya et al., 1965). Shtempel' believed that "…leaves, stem remains, and shoots of conifers, ferns, horsetails, lycopods, cycads, ginkgos, bennettites, and mosses were the initial material for the Suifun coals (out-of-date name of the Razdol'noye Coal Basin)…" (Verbitskaya et al., 1965, pp. 111, 112). Paleobotanists held the viewpoint of Kryshtofoivch concerning the coal-forming plants of rhabdopissite.

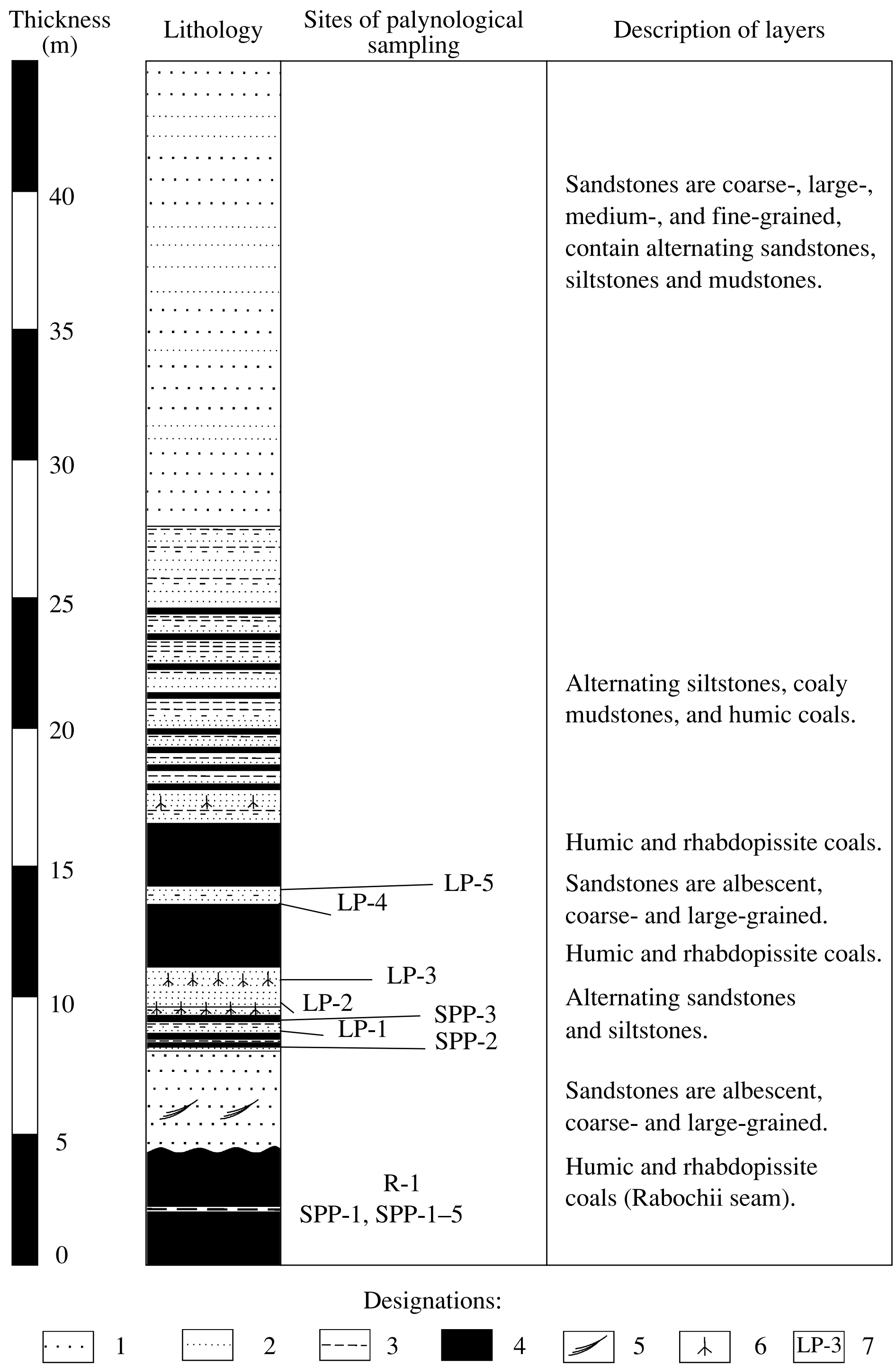

Fig. 1. Geological section of the wall of the Lipovtsy open-pit coal mine. Explanation: (1) coarse sandstone; (2) medium- and fine-grained sandstone; (3) siltstone; (4) coal; (5) cross-bedded layers; (6) roots; (7) numbers of palynological samples.

MATERIAL AND METHODS

In 2006 we studied and Golozubov described in detail the section of the Lipovtsy open-pit coal mine (Fig. 1). The southern wall of the open pit exhibits the uppermost coal-bearing part of the Lipovtsy Formation with three productive coal seams: Rabochii, Srednii, and Verkhnii.

The fossil plants were collected and the palynological samples were sampled from coal seams and interlayers. The general attention was focused on the rhabdopissites of the Rabochii seam, in particular, on siltstones about 20 cm thick within this seam, which divide the seam into the Rabochii-1 and Rabochii-2 seams as well as on the interlayers of humic coals. The aim was to compare plant associations which produced coals of different genesis. Among 42 palynological samples only 10 contained sporomorphs. The collection of fossil plants includes more than a hundred specimens.

Palynological samples were macerated using the standard method proposed by Lüber and Waltz for highly metamorphosed rocks and coals (*Paleopalynology*, 1966). To obtain cuticles, the coals were exposed to oxidation by full-strength nitric acid, washed with distilled water, and then treated with 10% alkali (KOH) and also washed. The cuticular membranes were mounted in constant slides. Photographs were made using a Zeiss Axioplan 2 imaging light microscope, a Zeiss EVO-50XVP scanning electron microscope (Far East Geological Institute, Far East Division of the Russian Academy of Sciences), and an SEM EVO 40 (Institute of Biology and Soil Science, Far East Division, Russian Academy of Sciences).

MATERIAL

The material is kept in the Institute of Biology and Soil Science, Far East Division, Russian Academy of Sciences, collection no. PL.

RESULTS AND DISCUSSION

The section studied starts from a thick coal seam, Rabochii seam, which varies in thickness from 0 to 17 m or even more in the Lipovtsy coal field area. A siltstone interlayer, about 20 cm thick, is well distinguished approximately 2.5 m below the roof. It divides the seam into the Rabochii-1 and Rabochii-2 seams (Fig. 1).

Dissolution of the rhabdopissites of this seam showed that plant material that forms them is represented mainly (nearly 100%) by cuticle remains of leaves of *Oswaldheeria orientalis* Nosova of the Miroviaceae (Pl. 10, figs. 1–7). It should be noted that the organic residue from the Rabochii seam contains resin rods and agglomerations of extremely small cuticle fragments, whereas organic residue from thin coal interlayers contains larger leaf fragments and rare resin rods.

The plant found in the Rabochii coal seam is identical to *Oswaldheeria orientalis* Nosova, particularly in characters visible under a scanning electron microscope. Nosova (2001) transferred *Sciadopitys* sp. described by Samylina (1961) from the Razdol'noye Depression in Southern Primorye to the genus *Oswaldheeria* and noted that this is the southernmost locality with the Miroviaceae. However, the situation is complicated by the fact that the same features are typical of the conifer *Podocarpus* (*Stachycarpus*) *harrisii* Krassil. from Lipovtsy coal field (Krassilov, 1967). For example, the diagnosis of this species mentioned a wide stomatal zone and two narrow marginal nonstomatal zones on the lower epidermis; in some areas, the stomatal zone is divided into two or three parts by narrow nonstomatal zones. We can see this feature in our material (Pl. 10, Fig. 2). The diagnosis of *Oswaldheeria orientalis* describes a central stomatal zone on the lower epidermis (Nosova, 2001). In our opinion, the matter is that the stomatal band may be divided in three bands in the middle part of a leaf, but it remains entire in the lower and apical parts (apical part of a leaf is shown in Pl. 10, fig. 3); it appears that the interpretation of the epidermal structure depends on whether the middle or the lower and upper parts of a leaf were examined. Thus, a rather complicated situation appeared: one plant was described under two different names: *Oswaldheeria orientalis* and *Podocarpus harrisii.* Gordenko (2004, 2007) revealed that *Tritaenia* and *Oswaldheeria* have much in common with the Podocarpaceae in epidermal structure. She also believes that numerous finds of trunks *Podocarpoxylon* sp. associating with *Oswaldheeria eximia* in the Mikhailovskii rudnik locality supports this hypothesis. In addition to leaf remains, a particular attention should be paid to fossil wood in the course of future field-trips. The problem of the Miroviaceae position within the gymnosperm system needs a detailed special study. We can contribute to the clarification of this problem by search of reproductive structures of this plant. Bose and Manum (1990) proposed the family *Miroviaceae* for the Mesozoic conifers only on the basis of the leaf morphology and epidermal micromorphology; no reproductive organs were found. Following Gordenko (2004, 2007), we consider the Miroviaceae as a group rather than a family. According to the rule of priority we should have applied the name *Podocarpus (Stachycarpus) harrisii* Krassil. for the leaves extracted from the rhabdopissite, but the plant from Lipovtsy demonstrates the characteristics of the genus *Oswaldheeria*; therefore, we preliminary decided to use this generic name.

Krassilov (1967) collected numerous plant remains (31 taxa) from the roof of the Rabochii seam. There were ferns *Nathorstia pectinata* (Goepp.) Krassil. and *Cladophlebis frigida* (Heer) Sew., cycadophytes *Nilssoniopteris rithidorachis* Krassil., *Pterophyllum sutschanense* Pryn., *Ctenis yokoyamae* Krysht., and *C. latiloba* Krysht. et Pryn., and conifers *Podocarpus harrisii* Krassil. among the most frequently encountered plants.

The palynological spectrum from rhabdopissite (sample R-1) is dominated by bisaccate pollen of plants allied to the Pinaceae and Podocarpaceae (*Alisporites similis* (Balme) Dett., *A. aequalis* (Bolch.) Chlon., *Rugubivesiculites rugosus* Pierce, *Podocarpidites multesimus* (Bolch.) Poc., and *P. ellipticus* Cook.), constituting in total 26.7%. Pollen grains of *Ginkgocycadophytus* spp. (5.3%) and *Eucommiidites troedsonii* Erdm. (4.3%) are present. Pollen grains

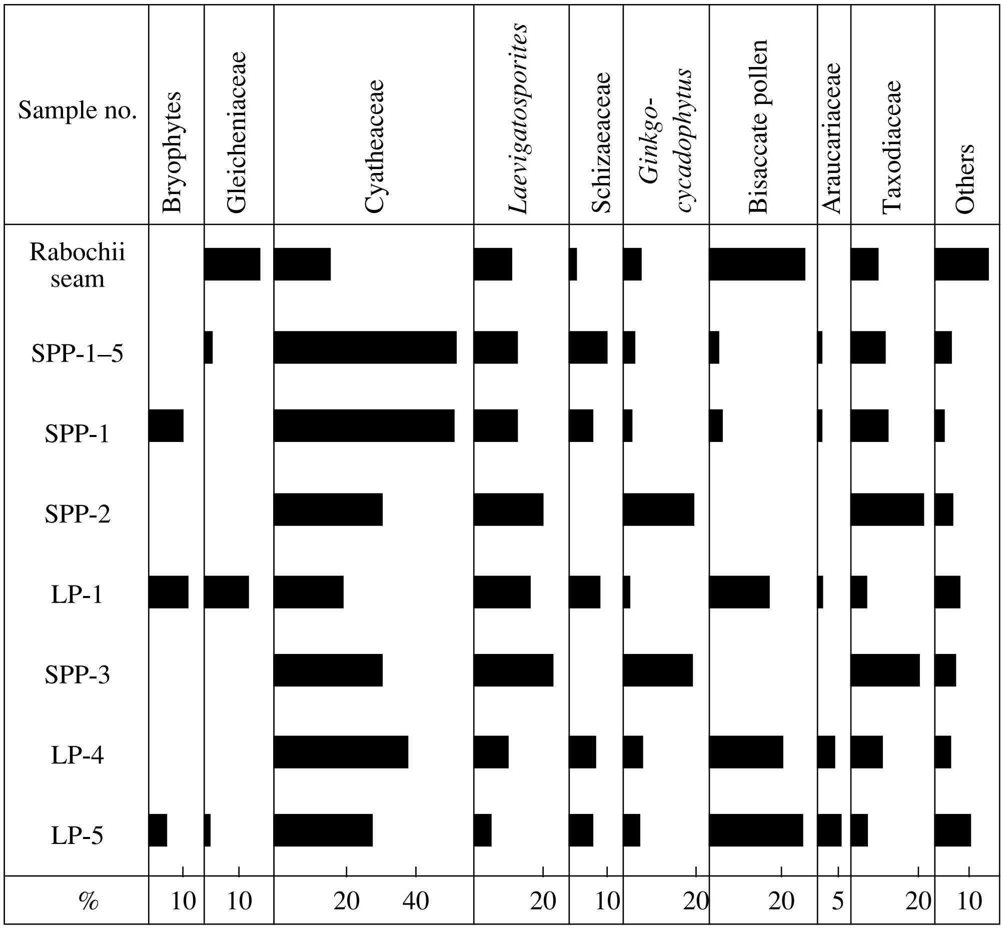

Fig. 2. Proportions of dominant spore and pollen groups in palynological spectra from coal seams and interlayers of the Lipovtsy coal field.

supposedly related to the Taxodiaceae *Taxodiaceaepollenites hiatus* (Pot.) Kremp and *Taxodiaceaepollenites* sp.) account for 7.7% of the assemblage.

The taxonomic diversity of pteridophytes is low. They are represented by spores of ferns allied to the Cyatheoideae and Dicksonioideae (*Cyathidites minor* Coup., *C. australis* Coup., and *Leiotriletes* spp.), in total up to 21%. Spores of gleicheniaceous ferns are represented by *Gleicheniidites laetus* (Bolch.) Bolch., *G. senonicus* Ross, *G. circiniidites* (Swarz.) Nokav., and *Plicifera delicata* Bolch., in total 20%. Members of the Schizaeaceae include *Cicatricosisporites multicostatus* (Boch.) Poc. and *C. dorogensis* Pot. et Gell., in total about 3%. Members of the Osmundaceae (*Osmundacidites nicanicus* (Verb.) Schug.) account for about 3%. Members of the Athyrioideaceae (*Laevigatosporites ovatus* Wils. et Webst.) account for more than 10% (Fig. 2).

In the siltstones, we found a few narrow leaves bearing a dark median stripe (probably, a stomatal band), which probably belong to *Oswaldheeria*, and beddings of bennettitalean leaves *Nilssoniopteris rithidorachis* Krassil.

The palynological spectrum from this interlayer (samples SPP-1 and SPP 1-5) is dominated by taxonomically diverse cryptogams, constituting 77% (Fig. 2). The fern spores related to the Cyatheoideae and Dicksonioideae (more than 52%) forms a substantial proportion of the cryptogams. They were accompanied by spores of ferns allied to the Athyrioideaceae (12.3%)

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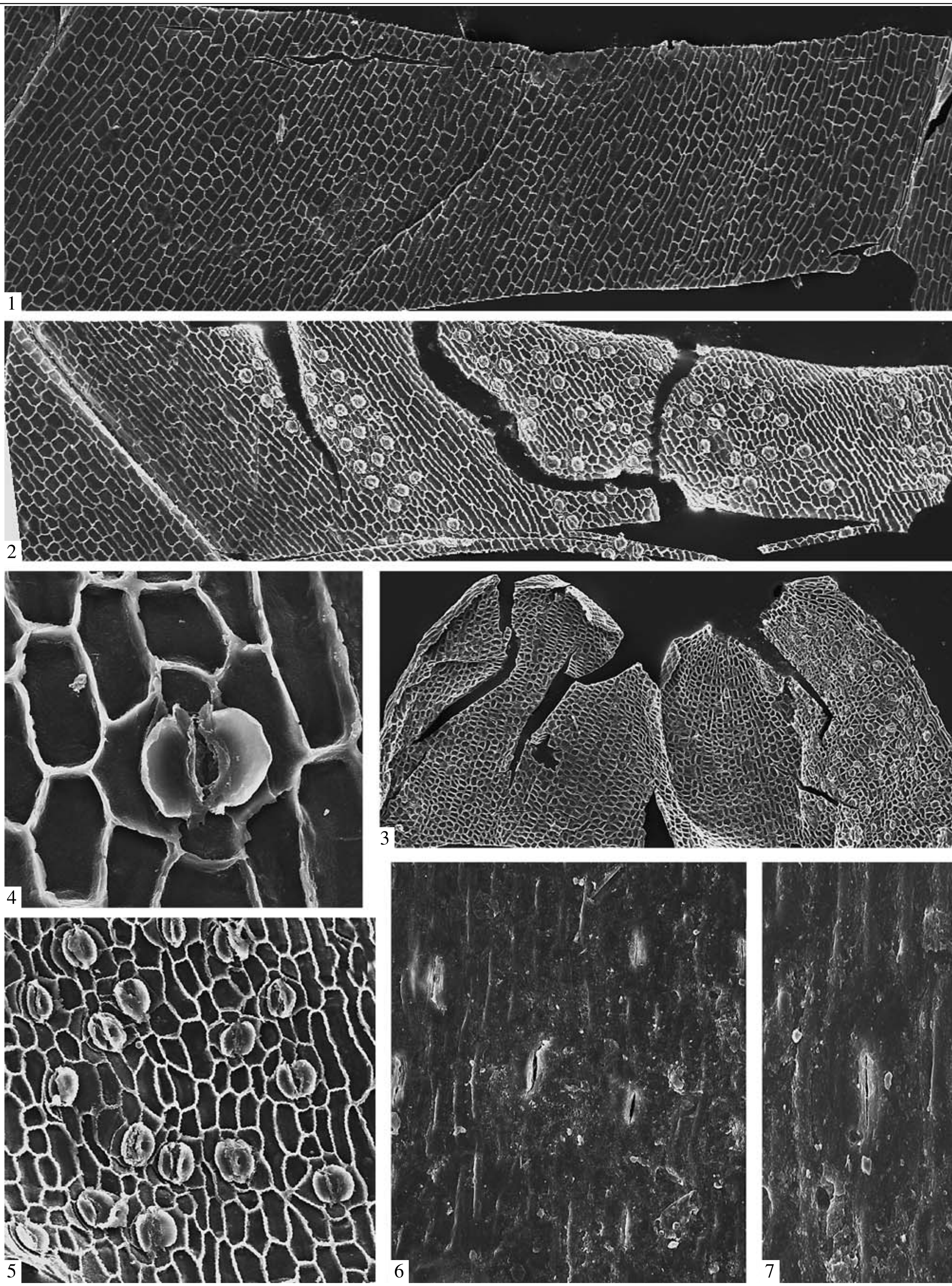
Explanation of Plate 10

Figs. 1–7. *Oswaldheeria orientalis* Nosova, IBSS, no. PL/2, SEM: (1) upper epidermis of a leaf from the Rabochii coal seam, ×50; (2) lower epidermis of a leaf with three stomatal bands, and a portion of the upper epidermis, ×55; (3) apical part of a leaf, upper surface to the left and lower surface to the right, ×35; (4) a stoma, ×460; (5) distribution of stomata within a stomatal band, ×110; (6) outer surface of the lower side of a leaf, ×180; (7) stomatal pit, ×470. All specimens came from the Rabochii coal seam of the Lipovtsy coal field, Primorye region; Lower Cretaceous (Aptian), Lipovtsy Formation.

Plate 10



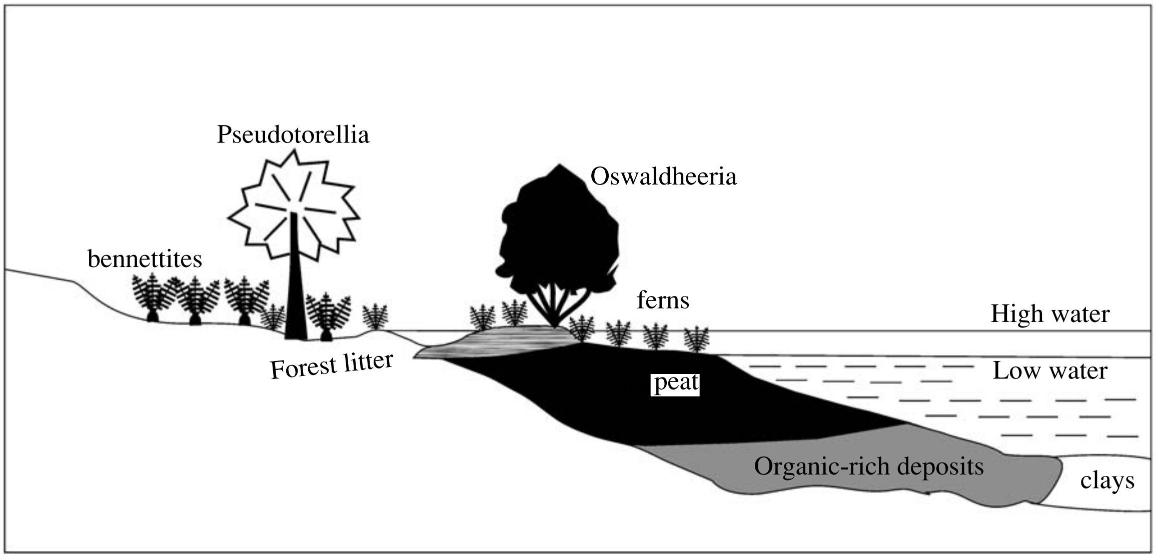


Fig. 3. Plant communities which provided coal-forming material for the Lipovtsy coal field.

and Schizaeaceae (*Cicatricosisporites dorogensis* Pot. et Gell., *C. multicostatus* (Boch.) Poc., *Concavissimisporites asper* Poc., and *Pilosisporites echinaceus* (Bolch.) Singh), in total 6.2%. Less frequent are spores of ferns supposedly related to the Gleicheniaceae and Osmundaceae. Spores of sphagnums and liverworts (*Stereisporites stereoides* (Pot. et Venitz.) Pfl. and *Rouseisporites reticulatus* Poc.) and lycopods (*Ceratosporites aequalis* Cook. et Dett., *Leptolepidites verrucatus* Coup., and *Retitriletes subrotundus* (K.-M.) E. Sem.) are sporadic.

In the composition of gymnosperms (23%) prevail taxodiaceous plants (*Taxodiaceaepollenites hiatus* and *Inaperturopollenites dubius* (Pot. et Gell.) Thoms. et Pfl.), in total more than 10%. Bisaccate pollen, supposedly related to the Pinaceae, amounts only 3%. Pollen of *Ginkgocycadophytus* spp. (2.5%) and pollen related to the Araucariaceae (1.8%) are also uncommon. Pollen grains of the Hirmerellales, *Podozamites* sp., and *Eucommiidites troedsonii* are sporadic.

Leaf cuticle fragments of *Oswaldheeria orientalis* and *Pseudotorellia krassilovii* sp. nov. were extracted during dissolution of a rhabdopissite-humic coal from the thin interlayer (SPP-2), lying approximately 3.5 m above the roof of the Rabochii seam.

The palynological spectrum (SPP-2) is characterized by insufficient (53%) dominance of spores over gymnospermous pollen (47%). Ferns assignable to the Cyatheoideae and Dicksonioideae (32% in aggregate) dominate among cryptogams; they are accompanied by ferns assignable to the Athyrioideaceae (20%). Spores of gleicheniaceous ferns account for 1%.

Among gymnosperms, pollen of taxodiaceous plants (22%) and *Ginkgocycadophytus* spp. (19.5%) are abundant. *Classopollis classoides* (3%) and *Eucommiidites troedsonii* (2.5%) are rare. Bisaccate pollen is absolutely absent.

Cuticle remains of leaves *Oswaldheeria orientalis* and *Pseudotorellia krassilovii* sp. nov. were extracted during maceration of the rhabdopissite-humic coal from the thin interlayer (SPP-3) located approximately 4.5 m above the roof of the Rabochii seam (Fig. 1).

The palynological spectrum of sample SPP-3 is nearly identical to that of sample SPP-2, a fact suggesting that these thin coal seams were formed under similar conditions.

The taxonomic compositions of palynospectra (samples LP-1, LP-4, LP-5) from the clastic interlayer are quite similar to each other. Usually, spores of pteridophytes (48–77%), mainly assignable to the Cyatheoideae and the Dicksonioideae, dominate (Fig. 2). There are no distinct dominants among the gymnosperms: it may be the pollen of the Pinaceae, Taxodiaceae, or *Ginkgocycadophytus* spp. In general, the content of the last two decreases (Fig. 2).

We collected abundant plant remains from interlayers. It should be noted that previous researchers had pointed to the high diversity of fossil flora and sharp distinctions in the taxonomic composition between taphocenoses in the same layer along the strike. Shtempel' noted that this difference "… is so significant that there are no two holes, even nearby, where the species composition would be more or less the same, although layers of the section are the same. Therefore, this is no mere coincidence, but evidence of the nature of the vegetation itself" (Verbitskaya et al., 1965, p. 20).

We found buried in situ matoniaceous ferns *Nathorstia pectinata* (Goepp.) Krassil. and cyatheoideaceous *Alsophilites nipponensis* (Oishi) Krassil., which produced numerous spores *Leiotriletes* and *Cyathid-*

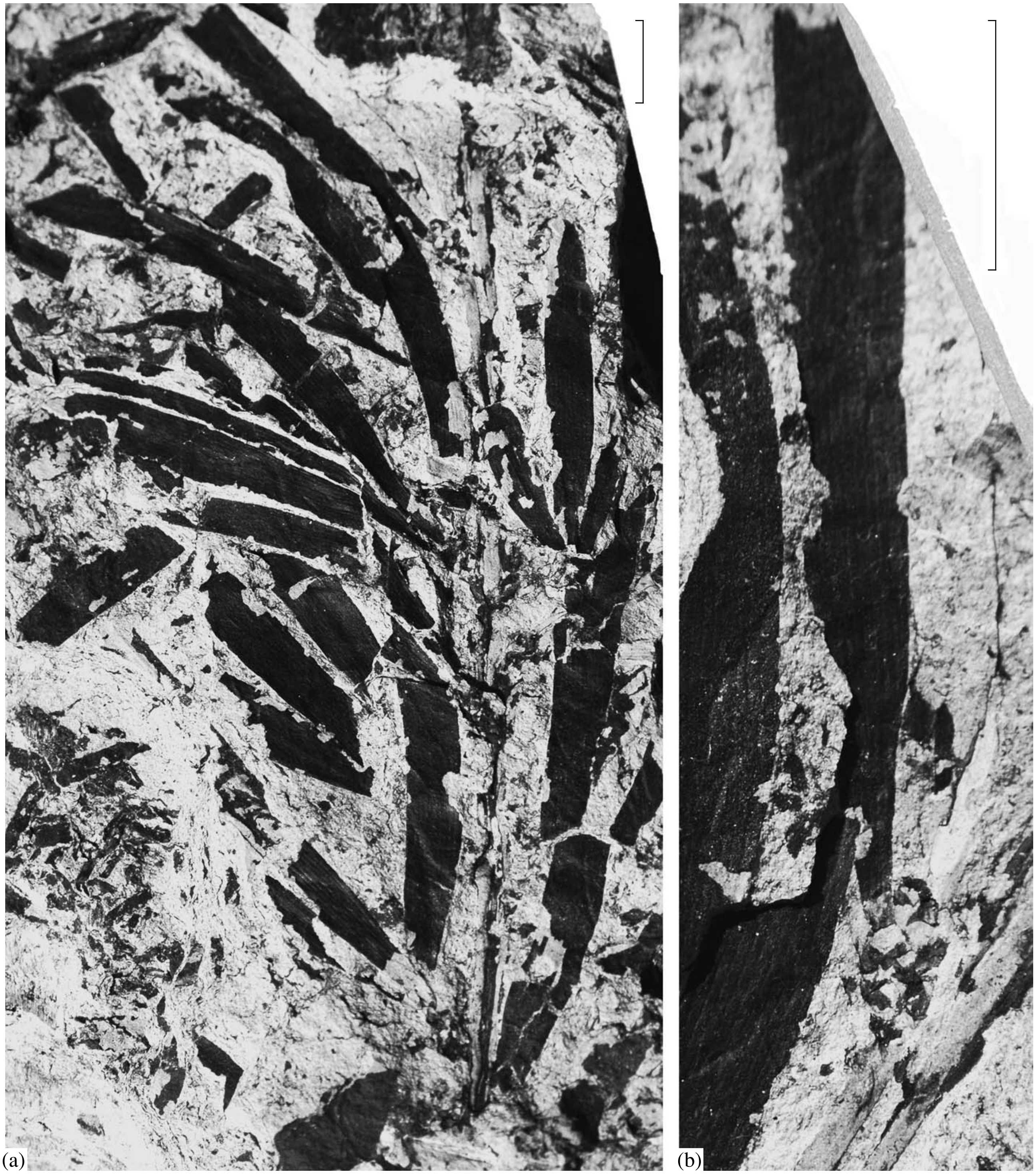


Fig. 4. Leafy shoot of *Pseudotorellia krassilovii* Bugdaeva, sp. nov., holotype IBSS, no. PL/1, Lipovtsy Formation, Southern Primorye: (a) shoot; (b) uppermost short shoot with one attached leaf. Scale bar 1cm.

ites, respectively, and prevail in palynospectra (Krassilov, 1967).

Lithological-facial analysis shows that coals of the Rabochii seam were formed during a period of the maximal planation of relief on a vast alluvial valley with lakes, riverbeds, and flood-plain spaces under conditions of hot and humid climate (Sharudo, 1972). The rhabdopissites of the Lipovtsy coal field were accumulated in the coastal zone of a lake, in the opinion of this author.

The high proportion of light resin bodies in these coals and extreme degree of leaf cuticle fragmentation

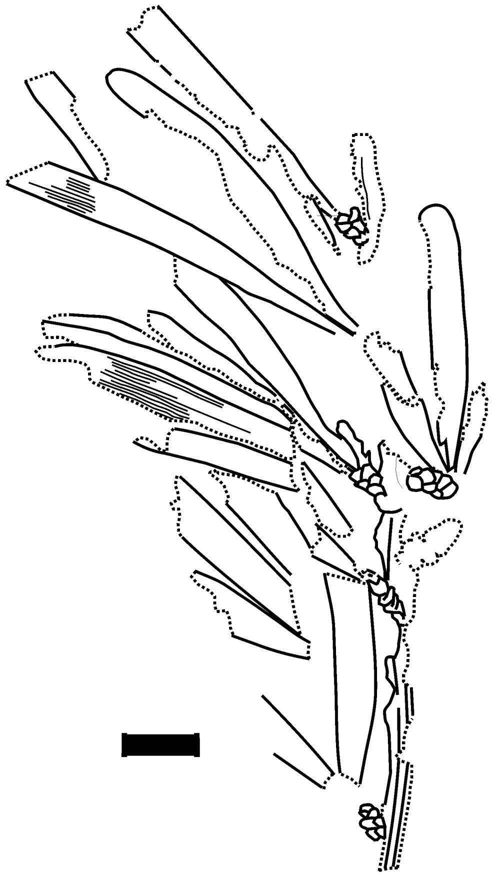


Fig. 5. Leafy shoot of *Pseudotorellia* (The Lipovtsy Formation, Southern Primorye). Scale bar 1 cm.

suggest fairly long-distance or long-term (fungal damages on miroviaceous leaves are evidence of the latter) transportation from the place of growth to the place of burial.

The monodominant taphocenosis of *Oswaldheeria* in the rhabdopissites contradicts with taphocenoses of the coal seam roofs and interlayers with their diverse flora. It is possible that the high bioproductivity of the Miroviaceae played a considerable role in this phenomenon, because their deciduous leaves supplied material for formation of the peat that later was transformed into coal.

Some works (*Phytostratigraphy* …, 1985; Manum et al., 2000; Gordenko, 2004, 2007; etc.) noted that the taphocenoses with miroviaceous leaves were nearly monodominant, which suggests that the coastal vegetation was dominated by these plants. It seems that previously an edificator role of this group was underestimated. Also, their importance for the formation of liptobiolith still is not completely understood, but of no doubt is the fact that they have made a significant contribution to the peach-coals formation.

Resin ducts are equally characteristic of the leaves of the Miroviaceae (Bose and Manum, 1990; Gordenko, 2007) and pseudotorellias. In the Bureya Basin, the latter indubitably dominated in paludal plant communities. In deposits of the Talynzha and Urgal Formations, their leaves dominate and completely cover the rock surface in some areas (Krassilov, 1972). However, coals of these stratigraphic units are not liptobioliths. Organic residue composition of rhabdopissite, as stated above, almost entirely consists of the remains of *Oswaldheeria* leaves. Most probably, the plant was a source of resin bodies.

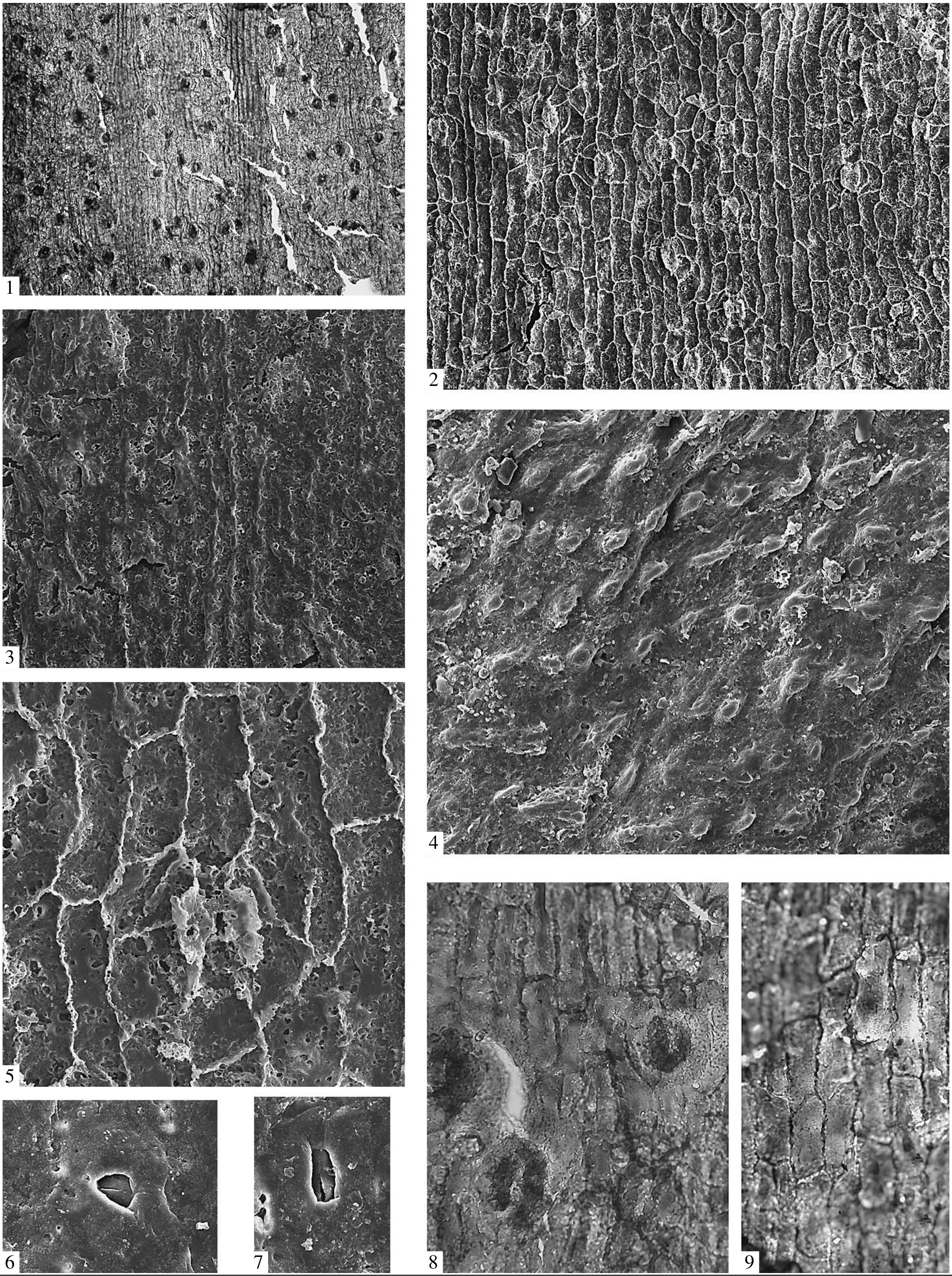
Gordenko (2007) for the first time reconstituted the leaf anatomy of *Oswaldheeria eximia* Gordenko from the Bathonian deposits of the Kursk region. A unique preservation of the material revealed two parallel non adverse vascular bundles and three thick intercostal resin ducts. The latter, being characteristic of miroviaceous leaves, probably played a significant role in a resin-coal formation. According to Gordenko's personal communication, in lignite of the same locality she found both dispersed resin ducts of *Oswaldheeria eximia* and leaves of varied preservation rates, from which virtually remained only resin ducts. It is evident that resin bodies, which constitute the most chemically resistant component of plants, were best preserved and could have been accumulated under favorable conditions, as it was in the Lipovtsy coal field.

Spores of gleicheniaceous and cyatheaceous ferns dominate in spectra from the Rabochii seam, as well as bisaccate pollen. Thin fern cuticles dissolve and are absent in the organic residue, being not resistant to maceration of coals. However, we can assume their active participation in the peat-forming process on the shores of Lake Lipovtsy on the basis of the spore domination in the palynospectra and finds of whole rosettes and leaves of *Nathorstia pectinata* (Goepp.) Krassil. (Matoniaceae) and *Alsophilites nipponensis* (Oishi) Krassil. (Cyatheaceae) in the coal seam roof. According to our data, members of the Cyatheaceae were the prevalent component of the palynospectra in both the Late Jurassic and Early Cretaceous coals of the Bureya Basin; from the Berriasian onward, the Gleicheniaceae began penetrating into the coal-forming plants association (Bugdaeva and Markevich, 2007). The Ginkgoales (particularly *Pseudotorellia*) and Czekanowskiales also supplied coal-forming material (Krassilov, 1972). As previ-

Explanation of Plate 11

Figs. 1–9. *Pseudotorellia krassilovii* Bugdaeva, sp. nov., holotype IBSS, no. PL/1, Russia, Primorye region, Lipovtsy coal field, Lower Cretaceous (Aptian), Lipovtsy Formation: (1) lower epidermis of a leaf with stomatal and non-stomatal zones, ×50; (2) lower epidermis, SEM, ×160; (3) outer surface of the lower epidermis, SEM, ×250; (4) outer sculpture of the lower epidermis, SEM, ×550; (5) a stoma, SEM, ×550; (6, 7) a stomatal pit, SEM, ×250, 300; (8) stomata, ×250; (9) upper epidermis, ×320.

Plate 11



ously stated, *Pseudotorellia* was a dominant plant of the paludal plant communities in Eurasia during the Mesozoic (Bugdaeva, 1999). Evidently, *Pseudotorellia*, cyatheaceous, and gleicheniaceous ferns remained coal-forming plants in the Aptian of the Razdol'noye Basin, but the Miroviaceae already played the main role.

Thus, the miroviaceous plants undoubtedly formed the liptobioliths of the Lipovtsy coal field. Nevertheless, the siltstone sublayer in the rhabdopissite contains taphocenoses with bennettites *Nilssoniopteris rithidorachis* Krassil., remains of which are missing in the coals. The cuticle of this plant is thick, very maceration-resistant, and well-marked among other cuticles. Therefore, its absence in the rhabdopissite is not a result of a chemical treatment, but reflects a real situation—this bennettite was not a member of paludal plant communities. Probably, the stands of *Oswaldheeria* and mainly cyatheaceous ferns surrounded the lake shore; farther inland, bennettites grew on a marshy plain (Fig. 3). The relief was extremely smooth in that time and terrigenous sedimentation was virtually absent. During periods of heavy precipitation and floodings, bennettitalean leaves were broken off and carried away in a basin. Their remains rarely got to taphocenoses under normal, not extreme, conditions. Krassilov (1967) noted that coal seam roofs frequently consist of bennettitalean leaves. Probably, in a replacement of biogenic sedimentation by terrigenous, when basin begins being filled with clastic material, massive infusion of remains of plants occurs, which grew in a certain distance from the shoreline and previously rarely reached the place of burial.

Based on the above, we can conclude that in the Aptian time the main components of the paludal plant communities were miroviaceous conifers (*Oswaldheeria orientalis*) and Ginkgoales (*Pseudotorellia krassilovii* sp. nov.), as well as various ferns. The rhabdopissite and rhabdopissite-humic coals on the territory of the modern Lipovtsy coal field in Southern Primorye were formed through the accumulation of the above-listed plant remains.

Family Pseudotorelliaceae Krassilov, 1972

Genus *Pseudotorellia* Florin, 1936

***Pseudotorellia krassilovii* Bugdaeva, sp. nov.**

Plate 11, figs. 1–9

E t y m o l o g y. In honor of the paleobotanist V.A. Krassilov.

H o l o t y p e. IBSS, no. PL/1; leafy shoot, Lipovtsy coal field, Southern Primorye; Lower Cretaceous, Lipovtsy Formation; Fig. 4, a.

D i a g n o s i s. Leafy shoot bears shortened cylindrical and barrel-shaped branches with bunches of two to five leaves. Leaves elongated, oblanceolate, up to 7 cm long, and about 7 mm wide. Leaf apex rounded. Usually, ten veins situated in widest area of leaf. Epidermis hypostomous. Lower cuticle thicker than upper cuticle. Lower epidermis includes costal zones about 200 μm wide without stomata and intercostal zones about 600 μm wide with stomata. In lower epidermis, anticlinal walls in shape of wide uneven and slightly sinuous ribs. Cutin thickenings on periclinal walls on external surface form beaded row of slightly longitudinally elongated papillae. Stomata numerous, orientated along leaf length, in short longitudinal rows, four or five in each stomatal zone, with five or six subsidiary cells, two of which polar. Papillae on stomata lacking.

D e s c r i p t i o n (Figs. 4, 5). The collection contains one piece of ore with a leafy shoot, the visible length of which is 10 cm and width is 0.5 cm. Five short shoots, from cylindrical to dolioform, 5–10 mm long, 4–5 mm wide, are distinctly visible. The distance between them is about 2 cm. They bear clusters of *Pseudotorellia* leaves; there are five leaves in the most completely preserved cluster and from one to three leaves in poorer preserved clusters. Probably, the quantity of leaves in a cluster depends on preservation. The shape and size of leaf scars, vascular bundles, and resin ducts are unknown because of a rate of preservation.

The leaves are oblong, oblanceolate, with rounded apices, gradually narrowing towards their bases, 4–7 cm long and 7–9 mm wide in the widest part. There are up to ten veins in an upper third of the leaf.

The leaves are hypostomous. A cuticle of the lower leaf surface is thicker than the upper cuticle. The cuticle is poorly preserved and relatively strongly corroded. In the coal organic residue, *Pseudotorellia* is easily distinguishable among cuticle fragments of *Oswaldheeria* because of its light tone and corroded cuticle. The lower epidermis is distinctly divided in coastal non-stomatal zones, about 200 μm wide, and stomatal intercostal zones, 600 μm wide (Pl. 11, figs. 1, 2). The firsts are composed of irregularly-quadrangular longitudinally elongated cells measure 15–30 × 120–250 μm. The anticlinal walls are in a form of wide, irregular, slightly sinuous ridges (Pl. 11, fig. 3). Cells in stomatal zones measure 15–80 × 80–200 μm, more variable in their form and size; they may be elongate, quadrangular, trapezoid, irregularly-polygonal, curved, or roundly-triangular. Under a light microscope, longitudinal cutin thickenings are distinctly visible (Pl. 11, fig. 8). A scanning electron microscope shows that the thickenings on the outer surface of lower epidermis correspond to a row of slightly longitudinally elongated papillae (Pl. 11, fig. 4). Papillae measure 5–7 × 15–23 μm.

Stomata are numerous, situated longitudinally in four or five short rows in each stomatal zone. They are orientated longitudinally and rarely slightly obliquely. The structure is characteristic of *Pseudotorellia.* The stomata are usually surrounded by five or six subsidiary cells, of which two are polar, papillae lacking (Pl. 11, figs. 5, 8). Stomata are measure about 22–32 × 32–43 μm. The outer walls of the guard cells are substantially cutinized and form something like a swelling (Pl. 11, figs. 6, 7).

The upper epidermis is formed of longitudinally orientated irregularly-rectangular cells. Cutin ridges on periclinal walls are absent, or weakly expressed (Pl. 11, fig. 9).

Probably, the preservation type of the material did not allow revealing resin ducts, but it is possible that they are rare.

C o m p a r i s o n. From the Bureya flora, Krassilov (1972) described a unique short shoot with normally developed leaves of *Pseudotorellia angustifolia* Dolud. in attachment. The preservation type of the specimen has allowed him to reveal the shape and size of leaf scars, to recognize two large cicatricles of vascular bundles and three or four small depressions below them at the outlet of secretory canals, to show an apical bud protected by bud scales, and to study the epidermal structure of reduced scale leaves, pressed to the shoot axis. These shoots are characteristic of the Ginkgoales in their general morphology and in two vascular bundles entering a leaf base. The specimen from the Lipovtsy coal field have been preserved in a sandstone, and it is often difficult to distinguish fine details of the plant structure because of a granular rock, but the shape, size, and attachment of *Pseudotorellia* leaves are quite distinguishable. Unlike the short shoots of *Pseudotorellia* from the Bureya, which are cylindrical and rather long (16–60 mm), the shape of the brachyblast in the plants from the Lipovtsy varies from barrel-shaped to cylindrical and their shoots are considerably shorter, 5–10 mm. No reduced scale leaves such as in *P. angustifolia* have been observed on the shoots of the new species; however, this is possibly related to the preservation type of the material.

Krassilov (1972) noted a wide range of shape and size variability in leaves of *Pseudotorellia angustifolia*, linking it with the habitat of the plants. Relatively wide leaves measuring on average 50×6 mm and having ten veins prevail in the Talynzha Formation; narrow linear leaves, 3–4 mm wide, about 70 mm long, with four to six veins, prevail in the Asanovskii section; leaves with a width of no more than 2 mm and three veins prevail in the basal layers of the Urgal Formation. Epidermal structures in all these modifications are identical. Also the shape of the leaf apex varies from rounded to strongly tapering to the end, obtuse, or mucronate. The leaves of *Pseudotorellia* from the Lipovtsy are similar to those from Talynzha Formation in their size. The epidermal structure of the new species differs markedly from that of *Pseudotorellia angustifolia*, in which stomata are arranged in groups of two to four connivent apparatuses with adjacent or even common subsidiary cells; the stomatal furrow is framed by a thick cutin ridge, which usually bears more or less developed papillae. Thickened longitudinal and transverse walls of epidermal cells and the absence of cuticular thickenings such as bands, papillae, or nodes were noted in the description of the species from the Bureya (Vachrameev and Doludenko, 1961), although according to Krassilov (1972) periclinal walls of cells of the lower epidermis are striated, occasionally with a discontinuous central thickening (in his opinion an undeveloped anticlinal wall). The structure of the upper epidermis in *P. angustifolia* is very peculiar: cells are arranged in straight or curved rows, which are interrupted by groups of randomly orientated broader cells. The cells vary in shape from rectangular (prevailing) to triangular, wedge-shaped, transversely elongated, compressed in the central part and roundly-ovate. Often there are alternations of light and thickened dark-colored cells. Resin ducts in *Pseudotorellia angustifolia* are 45–100 μm wide, extend continuously from the leaf base to the apex. Their number corresponds to the number of veins. The presence and number of resin ducts in remains of the new plant species are unknown.

Stomata in *Pseudotorellia* from the Lipovtsy have no papillae, which is also true for *Pseudotorellia nordenskioldii* (Nath.) Florin from the Wealden of Spitsbergen and the Jurassic of Kazakhstan, *P. grojecensis* Reyman. from the Jurassic of Poland, *P. paradoxa* Dolud. from the Early–Middle Jurassic of Irkutsk Basin, *P. longifolia* Dolud. from the Lower Cretaceous of the Soloni Subformation of the Urgal Formation in the Bureya Basin and the Early–Middle Jurassic of Irkutsk Basin, *P. longilancifolia* Li from the Lower–Middle Jurassic deposits of the Tsaydam Depression in China, *P. emarginata* Vassilevsk. from the Aptian deposits of the Silap Formation, Indigirka River, and *P. kharanorica* Bugd. and *P. transbaikalica* Bugd. from the Lower Cretaceous of Eastern Transbaikalia.

However, in *P. nordenskioldii* the anticlinal walls of epidermal cells are sinuous and stomata have another shape (Florin, 1936; Orlovskaya, 1962). *P. grojecensis* has shorter cells, which are flattened in some areas, the venation is not expressed on the upper epidermis; in addition, this species demonstrates a waviness on the outer surface of the periclinal walls of the upper epidermis (Reymanówna, 1963). In *P. paradoxa*, the leaf plate is narrower, 4–5 mm, the anticlinal walls of cells are sinuous, and cutin ridges and protuberances on periclinal walls are lacking (Doludenko and Rasskasova, 1972). Leaves of *P. longifolia* are narrow and long, linear-lanceolate, with less numerous veins, no more than five to eight, unlike the new species. In the Bureya species, stomata within stomatal bands are situated randomly; the epidermal cells wider and shorter. Illustrations published in Vachrameev and Doludenko (1961) and Doludenko and Rasskasova (1972) show that “the central ridge” is poorly developed. Leaves of *P. longilancifolia* are narrow, long, lanceolate, veins are more numerous than in leaves of *Pseudotorellia* from the Lipovtsy: there are 15–18 veins in the widest part of a leaf plate. The epidermis in *P. longilancifolia* is very similar to the epidermis in *P. longifolia* and differs from the latter only in the clearer and wider stomatal bands (Li et al., 1988). Leaves of *P. emarginata*, unlike the new species, are obovate or nearly ovate with a widely rounded apex and a tapered base; trichome bases on the ordinary epidermal cells are absent (Samylina, 1993). The anticlinal walls of ordinary epidermal cells on the lower epidermis are straight or slightly sinuous; on upper epidermis they are sinuous. *P. kharanorica* Bugd. from the Lower Cretaceous of the Turga-Haranor Depression in the Eastern Transbaikalia differs in the narrower leaves with a longitudinal keel and an acute and often curved apex. The venation is not distinguishable, stomata are situated randomly. The stomata are with T-shaped polar cutin thickenings (Bugdaeva, 1995). *P. transbaikalica* from the Bukachacha Depression in Eastern Transbaikalia differs in the shorter leaves with denser venation (14 in the upper part of a leaf); the stomata are more rounded and larger than stomata of *Pseudotorellia* from Lipovtsy. In addition, certain transverse cells are thickened in *P. transbaikalica*; papillae or several cuticular nodes merging in a rough band are visible on the periclinal walls (Bugdaeva, 1999).

R e m a r k s. In recent years, discussions about the classification of parallel-nerved leaves with resin ducts became quite acute, particularly since the family Miroviaceae was erected (Bose and Manum, 1990, 1991; Hvalj, 1997; Manum et al., 2000; Nosova, 2001; Gordenko, 2004). The latter author discussed the problems of distinguishing between the genera *Tritaenia* and *Pseudotorellia*, which are attributed to different orders of gymnospermous plants (Miroviaceae and Ginkgoales, respectively), but their leaves frequently are morphologically similar. She believed that the main differences concern the venation, position of resin ducts (this is a very important character, since resin ducts in *Tritaenia* are not situated below the veins, as in *Pseudotorellia*, but are intercostal, which indicates, for example, an error made by Watson and Harrison (1998)), twisting of petiole, stomatal distribution, structure of stomatal apparatuses, and cutinization of guard cells (Gordenko, 2004).

Watson and Harrison (1998) united leaves described as *Abietites linkii, Tritaenia linkii*, and *T. crassa* under the name *Pseudotorellia linkii* and related to them shoots *Sulcatocladus* with spirally situated leaf scars. *Pseudotorellia* was assigned to conifers on these grounds. The finds in the Bureya and Razdol'noye Basins of pseudotorellian shoots of ginkgoalean type in organic connection with leaves nevertheless unequivocally testify to belonging of these plants to the Ginkgoales. The cooccurrence of leaves and reproductive organs also confirm the affinity to this group (Krassilov, 1972).

M a t e r i a l. A leafy shoot and cuticle fragments, macerated from humic-rhabdopissite coal.

ACKNOWLEDGMENTS

The authors are grateful to V.A. Krassilov, N.V. Gordenko, and N.P. Maslova (Paleontological Institute, Russian Academy of Sciences), to T.M. Kodrul (Geological Institute, Russian Academy of Sciences), to N.P. Domra (Institute of Biology and Soil Science, Far East Division, Russian Academy of Sciences), to V.V. Golozubov (Far East Geological Institute, Far East Division, Russian Academy of Sciences), and to V.I. Podolyan, V.A. Chelpanov, and A.N. Tretyakov (Dal'vostokuglerasvedka Trust). L.F. Simanenko and P.P. Safronov (Far East Geological Institute, Far East Division, Russian Academy of Sciences) are thanked for their assistance with light microscope and scanning electron microscope, respectively. N.N. Naryshkina (Institute of Biology and Soil Science, Far East Division, Russian Academy of Sciences) is thanked for her help with a scanning electron microscope.

The study was supported by the Far East Division of the Russian Academy of Sciences, grant nos. 06-III-A-06-141, 06-I-P11-022, and 06-I-P18-081.

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