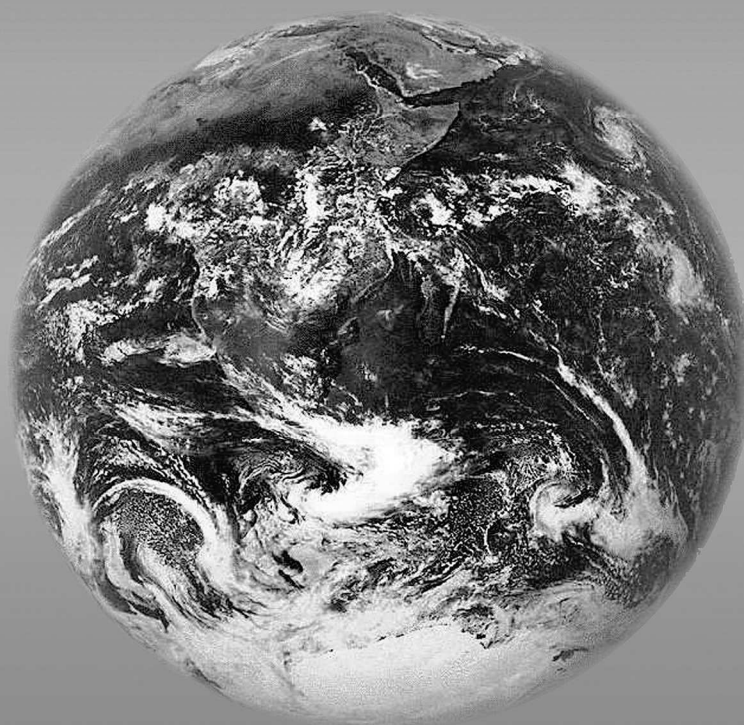


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# Lipovtsy flora of Razdolnaya (Suifun) River Basin, Primorye region, Russia

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**Abstract:** The Lipovtsy flora originates mostly from the synonymous Formation exposed at the coal quarries in the Razdolnaya (Suifun) River Basin in Heilongjiang Province (China) and Primorye Region (Russia). The thorough study of this flora has revealed its high diversity and abundance. One of the most prominent groups in the Lipovtsy flora is the ferns. Next in diversity are conifers (Miroviaceae, Taxodiaceae, Podozamitaceae, Taxaceae, Cephalotaxaceae). It was revealed the remarkable quantity of bennettitalean remains (24 taxa). The main peculiarity of this flora is the appearance of first angiosperms (pollen, dispersed cuticle, leaves). The fine preservation of the cuticles from the coals allows us to research the taxonomical composition of peat-forming plants and clear main components of the swamp plant communities. These plants supplied the material for the accumulation of resinite coals on the territory of Razdolnaya River Basin were conifers Miroviaceae, taxodiaceans, bennettites, as well as gleicheniaceous and cyatheaceous ferns.

**Key words:** fossil plants; spores; pollen; floral assemblages; Lipovtsy Formation; Razdolnaya (Suifun) River Basin; Primorye region

## 1 Introduction

The history of the study of the Early Cretaceous flora of Primorye region has more than a hundred years (Kryshtofovich, 1916). D. L. Ivanov for the first time collected fossil plants in 1888-1893 nearby Konstantinovka and Poltavka villages. This collection was transferred to the Swedish paleobotanist T. Halle, who later noticed similarities of the flora from Primorye region with Wealden flora from Europe (Halle, 1921). The famous Russian paleobotanist A. N. Kryshtofovich named this flora as Nikan flora.

Kryshtofovich first visited the coal-bearing deposits in southwest Primorye region and collected plant

remains in 1917. Later some other paleobotanists also collected fossil plants, in this area, including A. I. Kozlov, V. D. Prynada, etc.

Kryshtofovich (1921, 1923) described in detail sections of Lipovtsy and Konstantinovka coal fields and collected plant remains in 1922. On the Konstantinovka coal field for the first time he found the leaves of monocotyledonous angiosperm and described it as *Pandanophyllum ahnertii* Krysht. Kryshtofovich analyzed the taxonomic composition of Nikan flora in Razdolnaya River Basin and compared it with the Early Cretaceous Potomac flora from North America (Kryshtofovich, 1925).

The flora of the South Primorye attracted also at-

tention of such outstanding paleobotanists as V. D. Prynada, V. A. Vachrameev, V. A. Samylina, and V. A. Krassilov.

Since the early 1960s, detailed research on the Early Cretaceous flora and stratigraphy of the South Primorye was undertaken by Krassilov (1964a, 1964b, 1965a, 1965b). He elaborated the sequence of stratigraphy in the Lower Cretaceous in the Razdolnaya River Basin, which has been relevant until now. Krassilov (1967) divided these deposits based on the paleobotanical and lithological data into Ussuri (Barremian), coal-bearing Lipovtsy (Aptian) and Galenki (Albian) formations.

Every formation has a certain assemblage of fossil plants and palynomorphs (Krassilov, 1967; Markevich, 1994, 1995), but the Lipovtsy flora is the most abundant and diverse. The Lipovtsy flora derives from the homonymous formation.

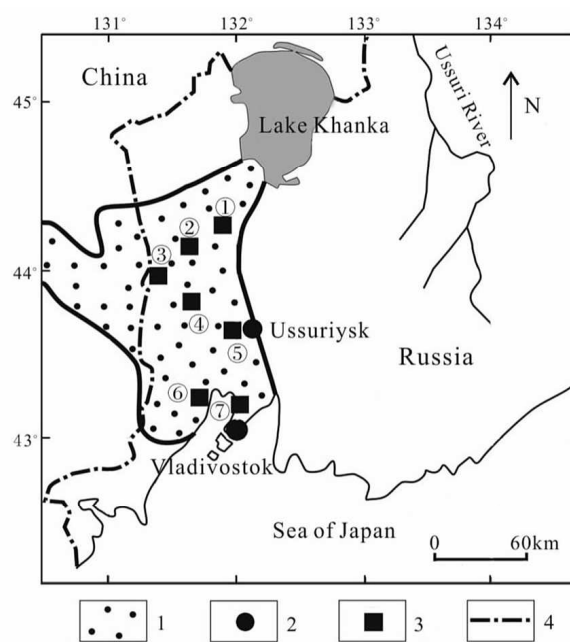
From the mid- 1980s we initiated the research of fossil floras of this basin. Our data on the Lipovtsy flora of the Razdolnaya coal basin give grounds to extend knowledge of taxonomic composition of this flora (Bugdaeva & Markevich, 2009; Bugdaeva *et al.*, 2015; Kovaleva *et al.*, 2012; Kovaleva *et al.*, 2016; Markevich, 1994, 1995; Volynets, 2005, 2006, 2013, 2015), because we collected the fossil plants from new localities and coal mines.

## 2 Material and method

The material for this paper comes from the Lipovtsy Formation which is widespread in Razdolnaya River Basin. This basin extends from the north-west (from the Lake Khanka) to south-west, as far as the Possiet Bay. More than 15000 specimens were collected from the numerous localities (Fig. 1).

The spore-pollen samples were taken from coal seams and interlayers. Samples for the palynological analysis were processed using the standard maceration method of A. A. Lüber and I. E. Waltz for metamorphic rocks and coals (Paleopalynology, 1966).

The fossil plants often have well-preserved cuticle. The phytollems were skimmed from specimens by



1. Razdolnaya River Basin; 2. cities; 3. locality of the Lipovtsy flora: ①Lipovtsy Coal Field, ②Ilyichevka Coal Field, ③Konstantinovka Coal Field, ④Aleksée-Nikolsky Coal Field, ⑤Ussuriysk Coal Field, ⑥Zanadvorovka Coal Field, ⑦Podgorodnenka Coal Field; 4. national boundary between China and Russian Federation.

**Fig. 1** Map showing localities of Early Cretaceous Lipovtsy flora in Razdolnaya River Basin, Primorye region, Russia and Heilongjiang Province, China

a needle, passed through the nitric acid and alkali, washed with distilled water. The leaf cuticle was sometimes processed with Schulze solution and alkali, and then slides for light microscopy and stubs for electron microscopy were prepared. To obtain phytollems from coal, the latter was exposed to complete dissolution a concentrated HF and then 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. All received cuticle preparations then analyzed for light (LM) and scanning electron (SEM) microscopes.

Photographs were taken by the authors using an Axioscop 40 microscope, with a Axiocam HRc camera and by N. N. Naryshkina with the aid of a SEM EVO 40 (Institute of Biology and Soil Science, Far East Branch, Russian Academy of Sciences).

### 3 Results

The Razdolnaya Coal Basin is filled by the Cretaceous clastic continental sediments with industrial coal seams and tuffaceous material in the overlying strata. Coal-bearing sediments of the basin are associated with the Lipovtsy Formation containing abundant phytofossils.

#### Lipovtsy Formation

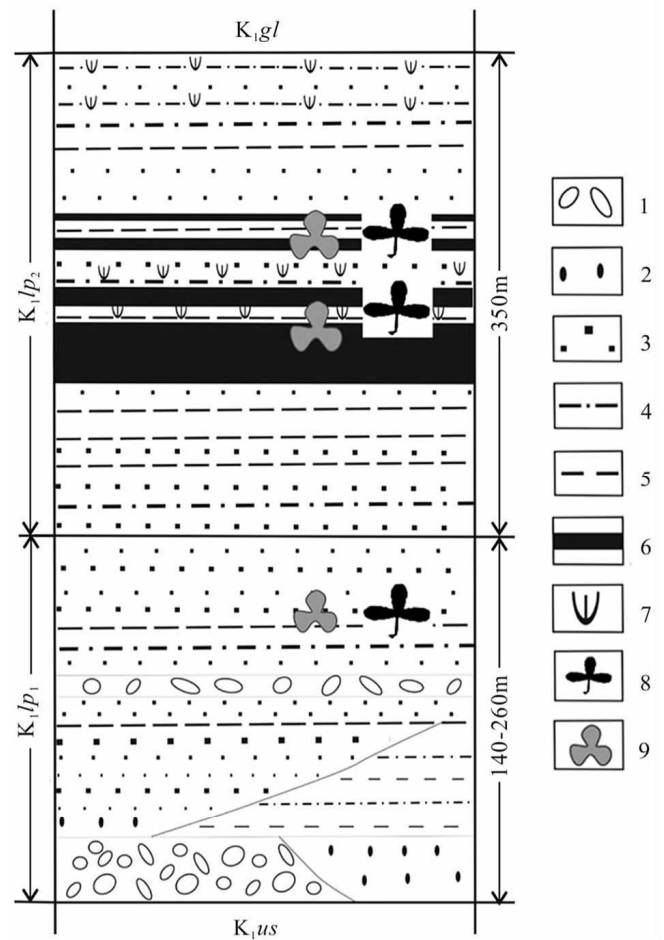
The Lipovtsy Formation ( $K_1lp$ ) conformably overlies the Ussuri Formation. Based on the lithologic composition, the formation is divided into 2 subformations: Lower Lipovtsy ( $K_1lp_1$ ) and Upper Lipovtsy ( $K_1lp_2$ ). The thickness of this formation is nearly 600 m (Fig. 2). The boundary between subformations is indistinct and defined by the base of the first thin coal layer at the Upper Lipovtsy Subformation or, in its absence, by the bottom of coarse-grained rocks.

The Lower Lipovtsy Subformation ( $K_1lp_1$ ) is represented by coarse deposits-conglomerates and coarse-grained gravelly sandstones. Coal seams are absent. The thickness of this stratigraphic unit varies from 140 to 260 m.

The Upper Lipovtsy Subformation ( $K_1lp_2$ ) consists mainly of fine-grained sandstones, siltstones, mudstones, and coals. The lower coal seam "Rabochii" (up to 19 m thick) has industrial significance, while the superposed coal seam "Gryaznyi" (1-2 m thick) does not have commercial values. The coals mined in the northern part of the Razdolnaya coal basin are humic and liptobiolithitic (resinous). The thickness of this subformation is 350 m (Kutubzade, 2010).

#### Fossil plants of Lower Lipovtsy Subformation

The floral assemblage of the Lower Lipovtsy Subformation involves *Thallites* sp., *Lycopodites nicanicus* Krassil., *Isoetites* sp., *Equisetites* ex gr. *burejensis* (Heer) Krysht., *E. ramosus* Samyl., *Coniopteris burejensis* (Zal.) Sew., *Coniopteris* sp., *Alsophilites nipponensis* (Oishi) Krassil., *Onychiopsis psilotoides* (Stokes et Webb) Ward, *Cladophlebis matonioides* Oishi, *C. frigida* (Heer) Sew., *Cladophlebis* sp., *Lo-*



1. conglomerate; 2. gravelstone; 3. coarse- and fine-grained sandstone; 4. sandy mudstone; 5. mudstone; 6. coal; 7. tuff; 8. findings of fossil plants; 9. place of palynological sampling.

**Fig. 2** Generalized section of the Lipovtsy Formation, Razdolnaya River Basin, South Primorye

*bifolia novopokrovskii* (Pryn.) Rasskaz. et E. Leb., *Sphenopteris* ex gr. *fontainei* Sew., *Sagenopteris* sp., *Pterophyllum burejense* Pryn., *P. manchurense* (Oishi) Krassil., *Pterophyllum* sp., *Dictyozamites cordatus* (Krysht.) Pryn., *Nilssoniopteris robusta* (Krysht. et Pryn.) Krassil., *Nilssonia* ex gr. *brongniartii* (Mant.) Dunk., *N. densinervis* (Font.) Berry, *N. nicanica* Pryn., *Nilssonia* sp., *Baiera ahnertii* Krysht., *Podozamites* ex gr. *lanceolatus* (Lindl. et Hutt.) Schimp., *Podozamites* sp., *Pityophyllum* sp., *Elatides* ex gr. *curvifolia* (Dunk.) Nath., *E. asiatica* (Yok.) Krassil., *Athrotaxites berryi* Bell, *Athrotaxopsis expansa* Font. emend. Berry, *Brachyphyllum japonicum* (Yok.) Oishi, *Brachyphyllum* sp.

This assemblage consists of 34 taxa including

those belonging to ferns (9 taxa), cycadophytes (9 taxa), and conifers (9 taxa). The age of this floral assemblage based both on the paleobotanical and palynological data is the Aptian (Krassilov, 1967; Markevich, 1995; Volynets, 2005).

The palynological assemblage of this subformation is dominated by schizaeaceous ferns and gymnosperms. Ferns are represented mainly by *Appendicisporites*, *Cicatricosisporites*, *Concavissimisporites*, *Impardecisporites*, *Tribolobosporites*, and *Pilososporites*. Spores of Gleicheniaceae and Cyatheaceae are accompanying them. The plants produced *Ginkgocycadophytus* dominates among gymnosperms.

#### Fossil plants of Upper Lipovtsy Subformation

Numerous localities of fossil plants in the basin are located mainly in the Lipovtsy, Ilyichevka, Konstantinovka, Alexee-Nikolsk, Ussuriysk, Zanadvorovka and Podgorodnenka coal fields (Fig. 1). We have described in detail all the partial sections and collected from them the abundant phytofossils.

The floral assemblage from the Upper Lipovtsy Subformation consists of 167 taxa. The most significant are ferns (47 taxa), among them *Nathorstia pectinata* (Goepf.) Krassil. *Alsophilites nipponensis* (Oishi) Krassil. *Onychiopsis psilotoides* (Stok. et Webb) Ward, accompanied by *Coniopteris burejensis* (Zal.) Sew., *Polypodites polysorus* Pryn. *Teilhardia tenella* (Pryn.) Krassil., *Cladophlebis frigida* (Heer) Sew. Rarely *Osmunda denticulata* Samyl. *Birisia onychioides* (Vassilevsk. et Kara-Mursa) Samyl. occur.

Among conifers (42 taxa) *Araucariodendron heterophyllum* Krassil., *Podozamites* ex gr. *lanceolatus* (Lindl. et Hutt.) Schimp., *Elatides asiatica* (Yok.) Krassil., *Athrotaxopsis expansa* Font. emend. Berry are most important. They are accompanied by *Pityophyllum* ex gr. *nordenskioldii* Heer, *Sequoia* ex gr. *reichenbachii* (Gein.) Heer, *Torreya nicanica* Krassil. *Mirovia orientalis* (Nosova) Nosova.

The presence of cycadophytes is significant (38 taxa), namely Bennettitales (24 taxa) and Cycadales (14 taxa). Among Bennettitales *Pterophyllum burejense* Pryn. *Zamiophyllum ivanovii* (Krysht. et

Pryn.) Krassil., *Cycadites sulcatus* Krysht. et Pryn. are numerous, they are accompanied by *Pterophyllum sutschanense* Pryn. *Dictyozamites cordatus* (Krysht.) Pryn. *Nilssoniopteris rhitidorachis* (Krysht.) Krassil. Among Cycadales *Ctenis yokayamae* Krysht., *Nilssonia densinervis* (Font.) Berry, *N. ex gr. brongniartii*, (Mant.) Dunk *N. ex gr. orientalis* Heer, *N. nicanica* Krassil. are abundant.

Also there are diverse Lycopodiales (*Lycopodites prynadae* Krassil., *L. nicanicus* Krassil., *L. multifurcatus* Lee, *Lycopodites* sp., *Isoetites* sp.), Caytoniales (*Caytonia orientalis* Krassil., *Sagenopteris variabilis* (Velen.) Velen., *S. mantellii* (Dunk.) Schenk, *Sagenopteris* sp.), and Ginkgoales (*Ginkgo concinna* Heer, *G. pluripartita* (Schimp.) Heer, *G. ex gr. adiantoides* (Ung.) Heer, *Pseudotorellia* sp., *P. krassilovii* Bugdaeva), rather rare Equisetales (*Equisetites* sp., *E. ramosus* Samyl., *E. burejensis* (Heer) Krysht.), Czekanowskiales (single *Czekanowskia* ex gr. *rigida* Heer), Bryales (*Marchantites yabei* Krysht. et Pryn., *Thallites* sp.) and possible Gnetales (Volynets, 2005, 2014; Bugdaeva et al., 2014).

In the upper part of Lipovtsy Formation (Podgorodnenka and Ilyichevka coal fields) extremely rare angiosperms (mega-, mesofossils, and pollen) appear for the first time. They are represented by leaves of *Monocotylophyllum* sp., *Dicotylophyllum* spp., and by dispersed cuticle of indeterminable platanoids.

The characteristic of this floral assemblage is the presence of *Nathorstia pectinata*, *Dictyozamites cordatus*, *Cycadites sulcatus*, *Torreya nicanica*, with the significant role of "young", evolutionary the most advanced taxa - *Osmunda denticulata*, *Birisia onychioides*, *Sequoia* ex gr. *reichenbachii*, *Taxites brevifolius*, as well as the first appearance of flowering plants.

The palynological assemblage of this subformation is dominated by Gleicheniaceae. The Cyatheaceae and Dicksoniaceae are subordinates. The Schizaeaceae, Polypodiaceae and Osmundaceae accompany them. Among spores *Roiseisporites radiatus* Poc., *Lobatia involucrata* (Chlon.) Chlon., *Kuylisporites lunaris* Cook. et Dett., *Lophotriletes babsae* (Brenn.) Singh

are characteristic. Among gymnosperms the plants close to taxodiales and produced the *Ginkgocycadophytus* prevail. The pollen of Pinaceae and Hirmeriaceae is rare. The particular feature of this assemblage is the appearance of the single pollen of angiosperms. This pollen is represented by *Tricolpites* spp., *T. vulgaris* Pierce, *Retitricolpites georgiensis* Brenn., *Clavatipollenites hughesii* (Coup.) Kemp, and *Quercites sparsus* (Mart.) Samoil.

#### Peat-forming plants of Lipovtsy Formation

Processing the coals from Lipovtsy, Ilyichevka, Konstantinovka, and Aleksee-Nikolsky coal fields, we have revealed the cuticles of plants. These data on composition of the peat-forming plants were obtained for the first time. Kryshtofovich as far back as 1928 pointed out the specific character of coals mine in the northern part of the Razdolnaya River Basin. The coals are humic and liptobiolithitic (resinous). Their description is following: "... coal is compact, hard, brownish-black, opaque, heavy, or rather mostly consisting of thin resin needles, transpiercing the coal in all directions and shining in split..." (Kryshtofovich, 1928, p. 19). He recognized a special type of coal composed of small sticks of resin bodies and named this coal as rhabdopissite (from Greek  $\rho\acute{\alpha}\beta\delta\omicron\varsigma$ -small stick and  $\pi\acute{\iota}\zeta\alpha$ -resin).

We revealed that coals in Lipovtsy coal field are composed of leaves of *Mirovia orientalis*, spores of cyatheaceous and gleicheniaceus ferns, bisaccate pollen of conifers having affinity with the Pinaceae and Podocarpaceae, and taxodiaceous pollen (Bugdaeva & Markevich, 2009).

In Ilyichevka open coal mine (Ilyichevka coal field) the peat-forming plants are represented mainly of leaves *Tritaenia* sp. and *Elatides asiatica*.

In Porechye open coal mine (Ilyichevka coal field) the lower thick humic-rhabdopissite seam (thickness is about 7 m) consists of remains of *Araucariodendron heterophyllum*, *A. angustifolium*, *Tomharrisia florinii*, *Nilssoniopteris rhitidorachis*, and *Pterophyllum sutschanense*. In the upper part of this productive seam there are several thin tuffaceous mud-

stone beds having beddings of leaves of *Nilssoniopteris rhitidorachis*, *Cephalotaxus ussuriensis*. According to palynological data the gleicheniaceus, cyatheaceous, and dicksoniaceus ferns, as well as plants produced *Ginkgocycadophytus* took part in the formation of this coal.

Here in the middle humic-rhabdopissite seam (its thickness is 1–2 m) we found remains of leaves of *Araucariodendron heterophyllum* and *Pagiophyllum* sp.. The composition of palynospectra from this seam is close to that from lower seam, but differs by appearance of rare angiosperm pollen *Tricolpites* sp. and *Clavatipollenites hughesii*.

Upper thin coal seams (thickness is about 0.1 – 0.5 m) contain remains of *Nilssoniopteris rhitidorachis*, *N. prynadae* Samyl., *Anomozamites* sp., *Araucariodendron heterophyllum*, and Platanaceae sp. indet.

The coals in the Konstantinovka coal field include the remains of *Nilssoniopteris rhitidorachis*, *Araucariodendron heterophyllum*, *Athrotaxites orientalis* Deng et Chen, *Machairostrobus* cf. *sutschanicus* Krassil.

The rhabdopissites of Aleksee-Nikolsky coal field contain the remains of scales of conifers of unclear systematic position *Machairostrobus* cf. *sutschanicus*, spores of gleicheniaceus, cyatheaceous and dicksoniaceus ferns, pollen of conifers having taxodiaceous affinity, and *Ginkgocycadophytus*.

## 4 Conclusions

The Lipovtsy flora originates mostly from the synonymous Formation exposed at the coal quarries in the Razdolnaya (Suifun) River Basin in Heilongjiang Province (China) and Primorye Region (Russia). The thorough study of this flora has revealed its high diversity and abundance.

In the early 20th century, pioneering studies were carried out on the Early Cretaceous macrofloras of South Primorye (Kryshtofovich, 1910, 1916; Krasser, 1921; Halle, 1921). Later, Krassilov (1967) monographed the macroscopic remains, focussing on the Early Cretaceous floras, paleogeogra-

phy and stratigraphy of this region. Most succeeding papers were dedicated to narrow aspects of the flora (Nosova, 2001; Volynets, 2005, 2006, 2010, Bugdaeva & Markevich, 2009). V. A. Samylina (1961) first has undertaken a detailed study of cuticles from the Lipovtsy plants. More recently, the authors collected well-preserved macrofloral remains from the newly open coal quarries in the northern part of the Razdolnaya River Basin.

The Lipovtsy Formation based on the sedimentological data is divided into two subformations. The lower latter is represented by coarse-grained sediments and does not contain the coal seams, the upper-mainly is represented by fine-grained sediments and contain industrial coal seams. Accordingly, we can distinguish two assemblages in the Lipovtsy flora are characteristic for lower and upper subformations.

One of the most prominent groups in the Lipovtsy flora is the ferns. Next in diversity are conifers (Miroviaceae, Taxodiaceae, Podozamitaceae, Taxaceae, Cephalotaxaceae). It was revealed the remarkable quantity of bennettitalean remains (24 taxa). The main peculiarity of this flora is the appearance of first angiosperms (pollen, dispersed cuticle, leaves). The fine preservation of the cuticles from the coals allows us to research the taxonomical composition of peat-forming plants and clear main components of the swamp plant communities. These plants supplied the material for the accumulation of resinite coals on the territory of Razdolnaya River Basin were conifers Miroviaceae, taxodialeans, bennettites, as well as gleicheniaceus and cyatheaceous ferns (Bugdaeva *et al.*, 2015).

The sedimentary sequence of Lipovtsy Formation recorded such an important biotic event of the Cretaceous period, as the appearance of angiosperms, the most evolutionarily advanced plants. Recently, in the coal quarries of the northern part of the Razdolnaya River Basin (Ilyichevka, Konstantinovka, and Aleksee-Nikolsky coal fields) in the siltstones, overlying the productive coal seams, we found angiosperm pollen of tricolpate and trichotomosulcate morphotypes.

Most likely, the plants produced these palynomorphs inhabited on the slopes, and the pollen was brought to burial by water flows.

According to our observations, in the above-mentioned coal fields of the Razdolnaya River Basin the thick industrial rhabdopissite seam is terminated by alternation of layers of volcanic ash and coal. This is a reflection of such event as the distant volcanic eruptions that caused intense ash falls, bombarded with a vast swamp, and suppressed the biogenic sedimentation. Destruction of the habitats of the swamp plants in result of heavy ash falls was causing stressful conditions for plants and animals. In such crisis situations the plants of the ruderal environmental strategy (e. g., angiosperms) got the advantage in the plant communities.

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## Explanations of plates

### Plate I

- ① *Osmunda denticulata* Samylna, fragment of sterile pinna, Podgorodnenka coal field.
- ② *Alsophilites nipponensis* (Oishi) Krassilov, several fertile pinnae, Lipovtsy coal field.
- ③ *Gleicheniopsis suifunensis* Krassilov, fertile frond, Lipovtsy coal field.
- ④ *Anemia dicksoniana* (Gein.) Krassilov, sterile pinna, Podgorodnenka coal field.
- ⑤ *Nathorstia pectinata* (Goep.) Krassilov, sterile frond, Lipovtsy coal field.
- ⑥ *Polypodites polysorus* Prynada, sterile foliage, Podgorodnenka coal field.
- ⑦ *Gleicheniopsis suifunensis* Krassilov, fragment of sterile frond, Ilyichevka coal field.
- ⑧ *Weichselia reticulata* (Stok. et Webb) Ward, fragment of sterile pinna, Ilyichevka coal field.
- ⑨ *Hausmannia* sp. 1., fragment of sterile frond, Ilyichevka coal field.

All scale bars are 1 cm.

### Plate II

- ① *Cycadites sulcatus* (Krysht. et Pryn.) Krassilov, Podgorodnenka coal field.
- ② *Nilssonina densinervis* (Font.) Berry, Podgorodnenka coal field.
- ③ *Nilssonina acutiloba* Heer, Lipovtsy coal field.
- ④ *Dictyozamites cordatus* (Krysht.) Prynada, Podgorodnenka coal field.
- ⑤ *Pterophyllum sutschanense* Prynada, Lipovtsy coal field.
- ⑥ *Nilssoniopteris rhitidorachis* (Krysht.) Krassilov, Ilyichevka coal field.
- ⑦ *Zamites borealis* Heer, Ilyichevka coal field.
- ⑧ *Pterophyllum burejense* Prynada, Podgorodnenka coal field.
- ⑨ *Zamiophyllum buchianum* (Ett.) Nathorst, Ilyichevka coal field.

All scale bars are 1 cm.

### Plate III

- ① *Athrotaxites berryi* Bell, Ilyichevka coal field.
- ② *Mirovia orientalis* (Nosova) Nosova, Lipovtsy coal field.
- ③ *Torreya nicanica* Krassilov, Lipovtsy coal field.
- ④ *Tomharrisia florinii* Krassilov, Lipovtsy coal field.
- ⑤ *Araucariodendron angustifolium* Krassilov, specimen # 27-137 (Krassilov, 1967, Plate LXII, Fig. 1), Lipovtsy coal field.

### Plate IV

- ① *Elatides asiatica* (Yokoyama) Krassilov, fragment of lower cuticle with two stomatal bands, Ilyichevka coal mine. Scale bar 200  $\mu$ .
- ② *Elatides asiatica*, stoma, Ilyichevka coal mine. Scale bar 50  $\mu$ .
- ③ *Athrotaxites orientalis* Deng et Chen, fragment of leaf, Poltavka coal mine. Scale bar 100  $\mu$ .
- ④ *Athrotaxites orientalis*, two stomata, Poltavka coal mine. Scale bar 20  $\mu$ .
- ⑤ *Araucariodendron heterophyllum* Krassil., fragment of lower cuticle with three stomatal bands, Porechye coal mine. Scale bar 500  $\mu$ .
- ⑥ *Araucariodendron heterophyllum*, two stomata, Porechye coal mine. Scale bar 20  $\mu$ .
- ⑦ Platanaceae sp. indet., fragment of lower cuticle with hair bases, Porechye coal mine. Scale bar 100  $\mu$ .
- ⑧ Platanaceae sp. indet., fragment of lower cuticle with stoma (A) and hair bases (B), Porechye coal mine. Scale bar 20  $\mu$ .

### Plate V

- ① *Nilssoniopteris rhitidorachis* (Kryshtofovich) Krassilov, fragment of lower cuticle with stomata and bases of hairs, Porechye coal

mine. Scale bar 200  $\mu$ .

- ② *Nilssoniopteris rhiidorachis*, lower cuticle with stomata and bases of hairs, Porechye coal mine. Scale bar 20  $\mu$ .
- ③ *Nilssoniopteris rhiidorachis*, outside view of lower cuticle with stomata and hairs, Porechye coal mine. Scale bar 100  $\mu$ , SEM.
- ④ *Nilssoniopteris rhiidorachis*, inner view of stoma, Porechye coal mine. Scale bar 10  $\mu$ , SEM.
- ⑤ *Mirovia orientalis* (Nosova) Nosova, inner view of lower cuticle with stomata, Lipovtsy coal mine. Scale bar 100  $\mu$ , SEM.
- ⑥ *Mirovia orientalis*, inner view of stoma, Lipovtsy coal mine. Scale bar 20  $\mu$ , SEM.
- ⑦ *Pagiophyllum* sp., inner view of cuticle with stoma, Porechye coal mine. Scale bar 100  $\mu$ , SEM.
- ⑧ *Pagiophyllum* sp., inner view of stomata, Porechye coal mine. Scale bar 20  $\mu$ , SEM.
- ⑨ *Araucarioendron heterophyllum* Krassilov, inner view of lower cuticle with stomata, Porechye coal mine. Scale bar 20  $\mu$ , SEM.
- ⑩ *Araucarioendron angustifolium* Krassilov, inner view of stoma, Porechye coal mine. Scale bar 10  $\mu$ , SEM.

Plate I Ferns of late Lipovtsy floral assemblage

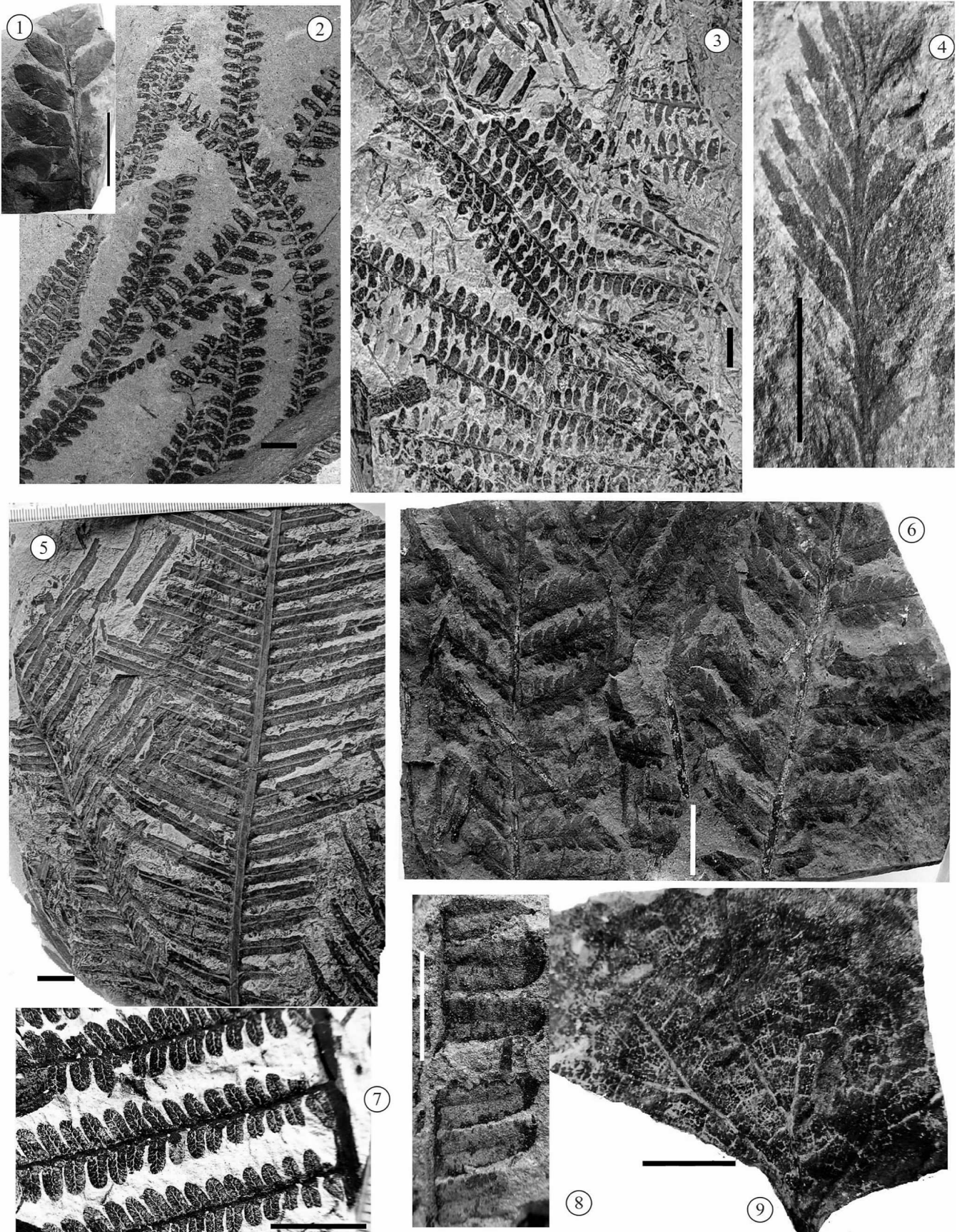


Plate II Cycadophytes of late Lipovtsy floral assemblage

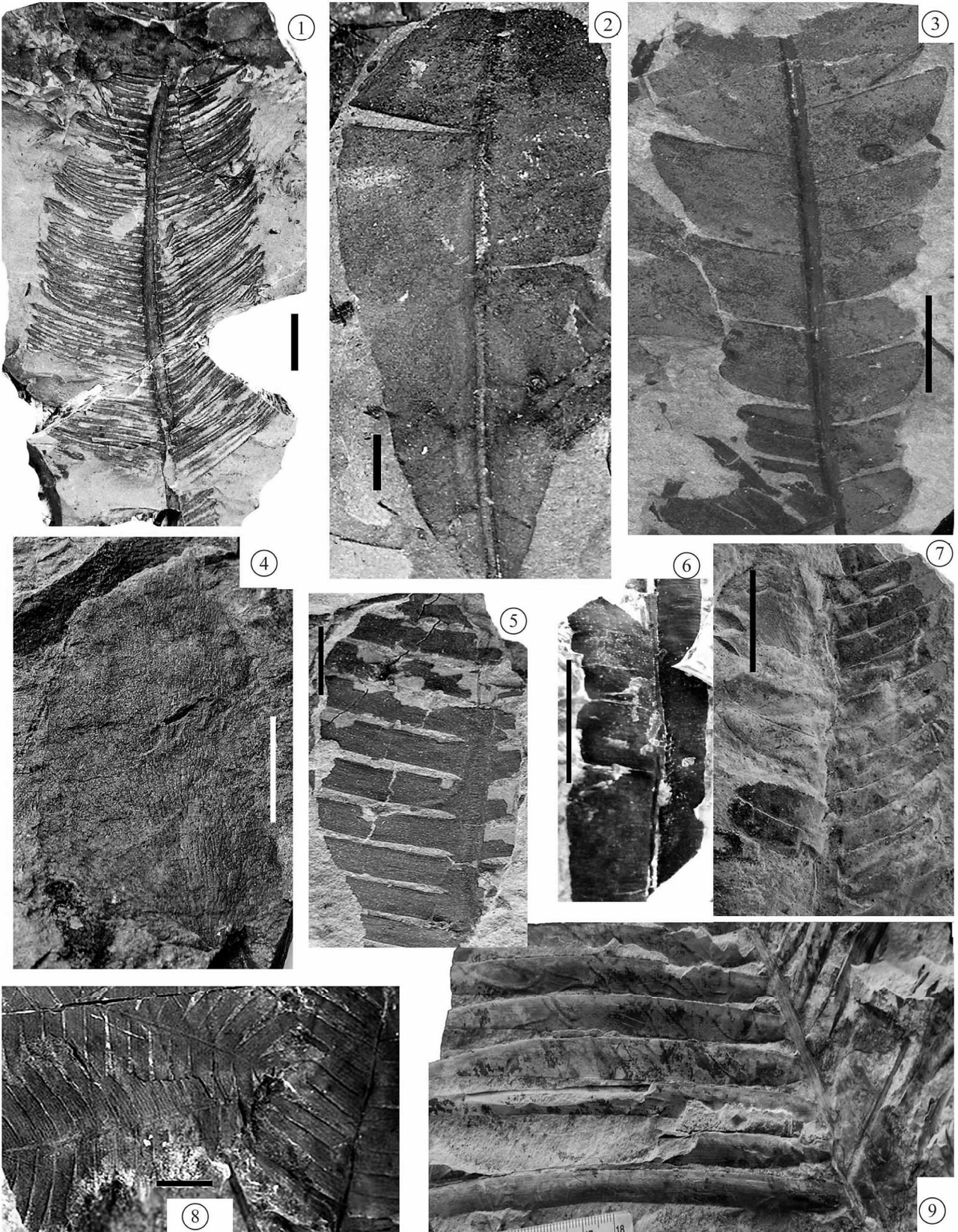


Plate III Conifers of late Lipovtsy floral assemblage



**Plate IV Peat-forming plants of Lipovtsy Formation**

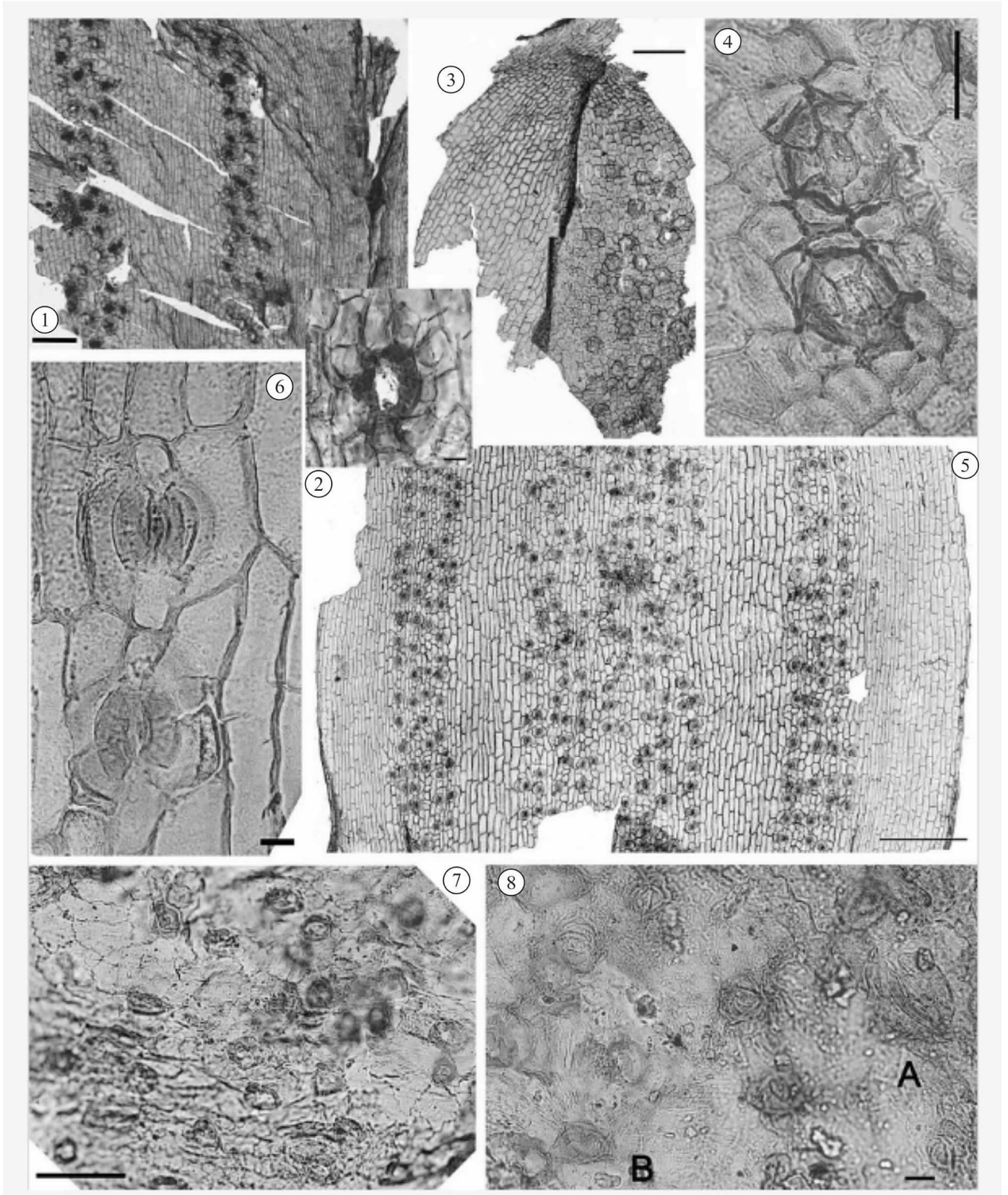
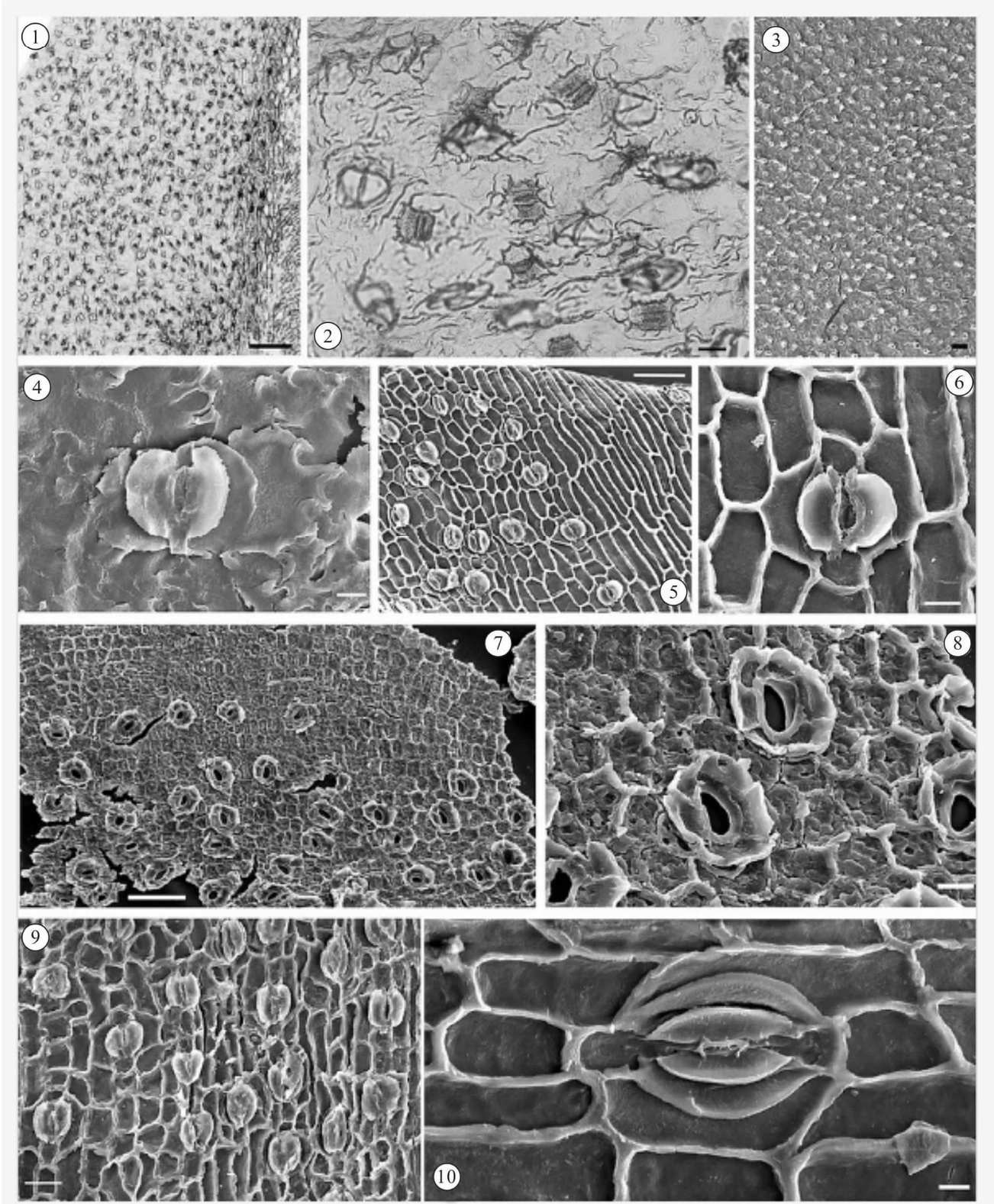


Plate V Peat-forming plants of Lipovtsy Formation



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