THE LATE CRETACEOUS FLORAS OF THE ZEYA-BUREYA BASIN

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ПОЗДНЕМЕЛОВЫЕ ФЛОРЫ ЗЕЕ-БУРЕИНСКОГО БАССЕЙНА

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Abstract. A general characterization of the Late Cretaceous floras of the Zeya-Bureya Basin is provided based on floristic assemblages from Russia (Amur Region) and China (Heilongjiang Province). Four phases of floral evolution were revealed: the Turonian-Coniacian (the Sutara flora), the Santonian (the Yong'ancun and Middle Kundur floras), the Campanian (the Taipinglinchang and Late Kundur floras) and the late Maastrichtian (Bureya flora). This long paleofloral succession provides possibility for investigation of different trends in the evolution of the Late Cretaceous taxa, flora, and climate.

Keywords: Late Cretaceous, paleofloras, Amur Region, Heilongjiang Province

Резюме. Дана общая характеристика позднемеловых флор Зее-Буреинского бассейна по материалам из Амурской области (Россия) и провинции Хейлунцзян (Китай). Развитие флоры на этой территории подразделяется на четыре этапа: турон-коньякский (сутарская флора), сантонский (флоры Юнаньцунь и среднекундурская), кампанский (флоры Тайпинлиньчан и позднекундурская) и позднемаастрихтский (буреинская флора). Эта последовательность флор дает возможность изучения различных трендов в эволюции меловых таксонов, флоры и климата.

Ключевые слова: поздний мел, палеофлоры, Амурская область, провинция Хейлунцзян.

INTRODUCTION

The Upper Cretaceous and Cenozoic deposits are widely developed in the southeastern part of the Zeya-Bureya Basin (Fig. 1), which extends along middle stream of the Amur River (Heilongjiang River in Chinese) for more than 600 km (Sorokin, 2001; Kirillova, 2003). Most part of this basin is situated in the Amur Region in Russia and its southern margin is located in the Heilongjiang Province of China, where it is connected with the Songliao Basin.

The plant fossils of the Zeya-Bureya Basin have been studied for more than a century, starting with the papers on the Tsagayan flora published by Heer (1878) and Konstantov (1914). Kryshtofovich and Baikovskaya (1966) provided the most complete description of the Tsagayan flora, considering it as a key flora in the evolution of the Tertiary floras in the Northern Asia. The most recent monographic studies were published by Krassilov (1976) and Kamaeva (1990).

Since the beginning of the 20th century, dinosaur remains have been discovered along the Chinese and Russian banks of Amur River. The first dinosaur skeleton *Mandschurosaurus amurensis* Riabinin (1925, 1930a, b) was described after two excavation campaigns undertaken by the Russian Geological Committee in 1916 and 1917. During the last decades, discoveries of new Maastrichtian dinosaur localities in the Amur Region and China led to restudy of the Lower Tsagayan and Yuliangzi formations (Markevich et al., 1994; Flora and dinosaurs ..., 2001; Dong et al., 2003; Van Itterbeeck et al., 2005). Several new hadrosaurid

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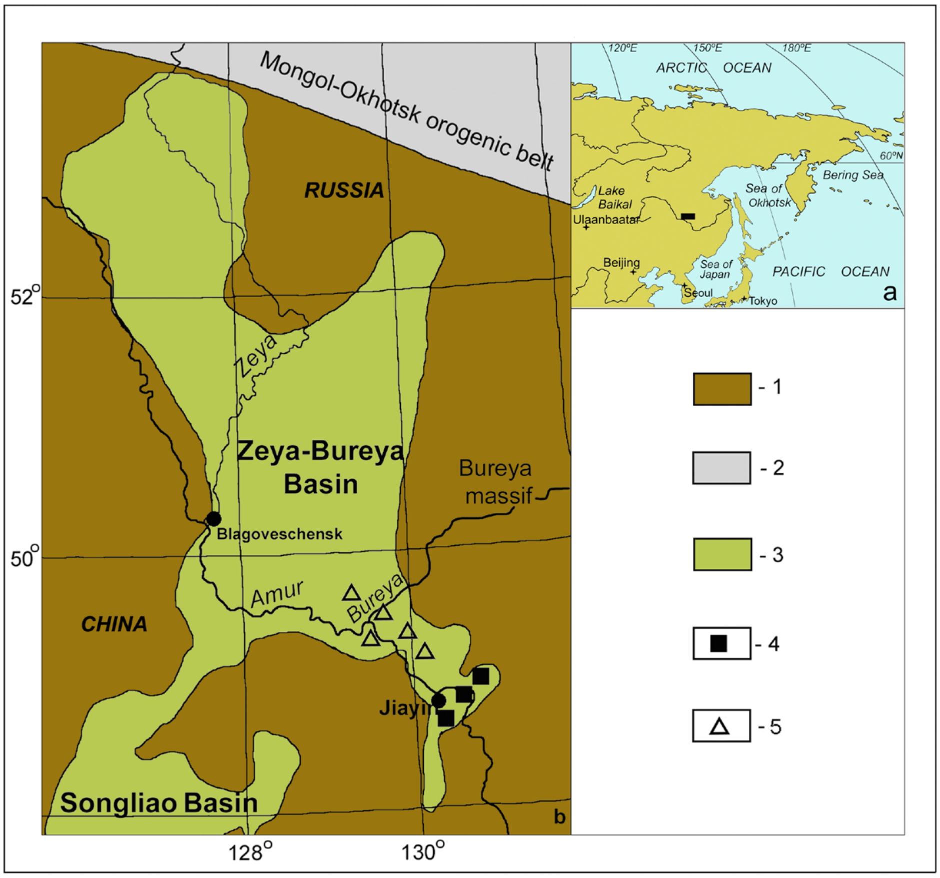

Fig. 1. a – location of the study area; b – map of the Zeya-Bureya Basin (after Kirillova, 2003): 1 – ancient cratons and massifs; 2 – orogenic belts; 3 – sedimentary basins; 4 – localities of the Late Cretaceous plant fossils; 5 – localities of the Paleogene plant fossils.

dinosaurs have been described from these deposits (Bolotsky, Kurzanov, 1991; Godefroit et al., 2000, 2001; Bolotsky, Godefroit, 2004).

Intensive studies of the Cretaceous–Paleogene boundary interval have once again attracted attention to the stratigraphy and paleontology of the Upper Cretaceous and Paleogene deposits of the Zeya-Bureya Basin. Paleobotanical studies of numerous sections in the Raichikhinsk and Arkhara districts of the Amur Region revealed the stratigraphic distribution of plant fossils, discovered a new floristic horizon in the Arkhara-Boguchan opencast coal mine, and refined the systematic position of many fossil plants (Akhmetiev et al., 2002; Manchester et al., 2002; Maslova, Krassilov, 2002; Maslova, Kodrul, 2003; Kodrul, Krassilov, 2005).

New data on the evolutionary events near Cretaceous–Paleogene boundary were obtained as the result of activity of the international research project “Late Cretaceous biota and the K–T boundary in Heilongjiang River area”, organized by the Research Center of Paleontology and Stratigraphy of Jilin University with the financial support of the Natural Science Foundation of China in 2002–2005. The representative collections of plant and vertebrate fossils were amassed and main stratigraphic units were correlated based on lithological, palynological, and plant megafossil data (Sun et al., 2002, 2003, 2007; Markevich et al., 2005a, b). The discovery and study of the Santonian and Campanian plant fossils were among important results of this project, since they were virtually unknown in the Amur Region.

After the completion of the project, the investigation of the Upper Cretaceous and Paleogene biota in the Zeya-Bureya Basin continued both in Russia and in China. As the result, many previous plant identifications have been corrected and new taxa described (Kodrul et al., 2006, 2013; Kodrul, Maslova, 2007, 2017; Maslova et al., 2007; Golovneva et al., 2008; Krassilov, Kodrul, 2008, 2009; Herman et al., 2009; Manchester et al., 2009; Krassilov et al., 2010; Sun et al., 2011, 2014, 2016; Manchester, Kodrul, 2014; Liang et al., 2015; Moiseeva et al., 2018). The present paper summarizes the data about localities and systematic composition of the Late Cretaceous floristic assemblages of the Zeya-Bureya Basin from the Turonian to the Maastrichtian.

STRATIGRAPHY

The Zeya-Bureya Basin, that began to develop in the Late Jurassic, consists of system of uplifts and grabens, filling by the Upper Jurassic, Cretaceous and Paleogene sediments (Kirillova, 2003).

The Upper Jurassic and Lower Cretaceous deposits of the depression are represented by volcanic rocks of the Itikut and Poyarkovo formations. They are overlain by the terrigenous Upper Cretaceous and Cenozoic deposits (Gorbachev, Timofeev, 1965; Flora and dinosaurs..., 2001).

In the Amur Region the Upper Cretaceous deposits include the Zavitinskaya and Kundur formations and Lower and Middle Tsagayan subformations (=Udurchukan and Bureya formations) (Flora and dinosaurs..., 2001). These strata were accumulated mostly in the terrestrial environments.

The Zavitinskaya Formation is widely distributed in the central part of the Zeya-Bureya Basin and consists of sandstones, siltstones and mudstones (Gorbachev, Timofeev, 1965; Sorokin, 2001). It is characterized by predominance of mudstones and other fine-grained sediments. Paleontological records are very poor in this stratigraphic unit. Estimations of age vary from the Cenomanian–Turonian (Resolutions...., 1994) to the Turonian–Campanian (Sorokin, 2001). Palynological data indicate the Cenomanian–early Senonian age of the Zavitinskaya Formation (Bratzeva, 1969). Megafossil plant remains occur very rare. The Zavitinskaya Formation is overlying by the Lower Tsagayan subformation (=Udurchukan Formation) of the Maastrichtian age.

In the southeastern part of the Zeya-Bureya Basin near the Lesser Khingan Ridge (Xing'an Ridge in Chinese) the upper part of the Zavitinskaya Formation is replaced by the Kundur Formation. This formation was firstly described by Krasnyanskaya based on data of borehole drilling near Kundur railway station (Kapitsa, Koshman, 1961; Sorokin, 1976). The deposits of the Kundur Formation differ from those of the Zavitinskaya Formation by prevalence of relatively coarser sediments and by admixture of tuffaceous material. Its thickness is estimated from 150 m to 900 m. The Kundur Formation is distributed in the Uril, Gryaznaya, Mutnaya, and Khingan river basins (Fig. 2). It consists of three members (Sorokin, 1976). The lower member (up to 350 m thick) includes alternating conglomerates and sandstones with sublayers of tuff rhyolites; the middle member (up to 400 m thick) is mostly composed of sandstones and siltstones; and the upper member (up to 150 m thick) is composed of sandstones, mudstones (which are occasionally carbonate and alternating with siltstones), and thin coal layers. Plant fossils, freshwater bivalves, ostracods, conchostracans, and fish were found in the upper member of the Kundur Formation.

The age of all members of the Kundur Formation and their correlation with other stratigraphic units of the Zeya-Bureya Basin have not been revealed so far. Initially, the age of the Kundur Formation was estimated as the Cenomanian–Maastrichtian based on preliminary study of poor assemblage of plant fossils (Kapitsa, Koshman, 1961). Later the Kundur Formation was dated as the early Maastrichtian (Resolutions..., 1994), or as the Turonian–Campanian and was considered to be coeval with the Zavitinskaya and Boguchan formations (Flora and dinosaurs..., 2001). The Kundur Formation overlies the volcanogenic sedimentary rocks of the Obmany Formation of the Albian–Cenomanian (Sorokin, 1976) or Coniacian–early Santonian age (Resolutions ..., 1994), and is overlain by the lower Maastrichtian Lower Tsagayan subformation (Udurchukan Formation), which yields bones of dinosaurs and other vertebrates. The Lower Tsagayan subformation is represented mostly by yellow gravels which consists of rounded metamorphic and felsic magmatic pebbles and cobbles (Van Itterbeeck et al., 2005). The non-gravelly strata are dominated by unsorted siliciclastic sediments with coarse particles dispersed in a muddy matrix (diamicts).

The Lower Tsagayan subformation (or Udurchukan Formation) is overlain by the Middle Tsagayan subformation (or Bureya Formation). The Bureya Formation is composed of coarse yellow sands, grey silts and clays. Its age is estimated as the late Maastrichtian based on palynological data (Flora and dinosaurs..., 2001).

The Upper Cretaceous deposits of the Lesser Khingan Ridge near the boundary with the Zeya-Bureya Basin are represented mainly by volcanogenic deposits, which belong to the Listvennichnaya, Yaurin, Obmany, Boguchan, and Solonechniy formations, as well as to the Sololi Unit from the Khingan-Olono volcanogenic zone (Sorokin, 2001). They consist mainly of ignimbrites with interlayers of tuffs and volcanogenic-sedimentary rocks, less often of andesites and their tuffs. Numerous localities of plant fossils are confined to these deposits (Kiriyanova, 1997). The systematic composition of most floristic assemblages is quite similar, that allows us to joint them in the single Sutara flora (Golovneva, 2019).

In northern China, the Upper Cretaceous deposits of the Zeya-Bureya Basin occur in the Jiayin County of the Heilongjiang Province and crop out mainly along right bank of the Amur (Heilongjiang) River (Fig. 3, *1, 2*). They are subdivided in ascending order into the Yong'ancun, Taipinglinchang, Yuliangzi, and Furao formations (Li, 1986; Regional geology..., 1993).

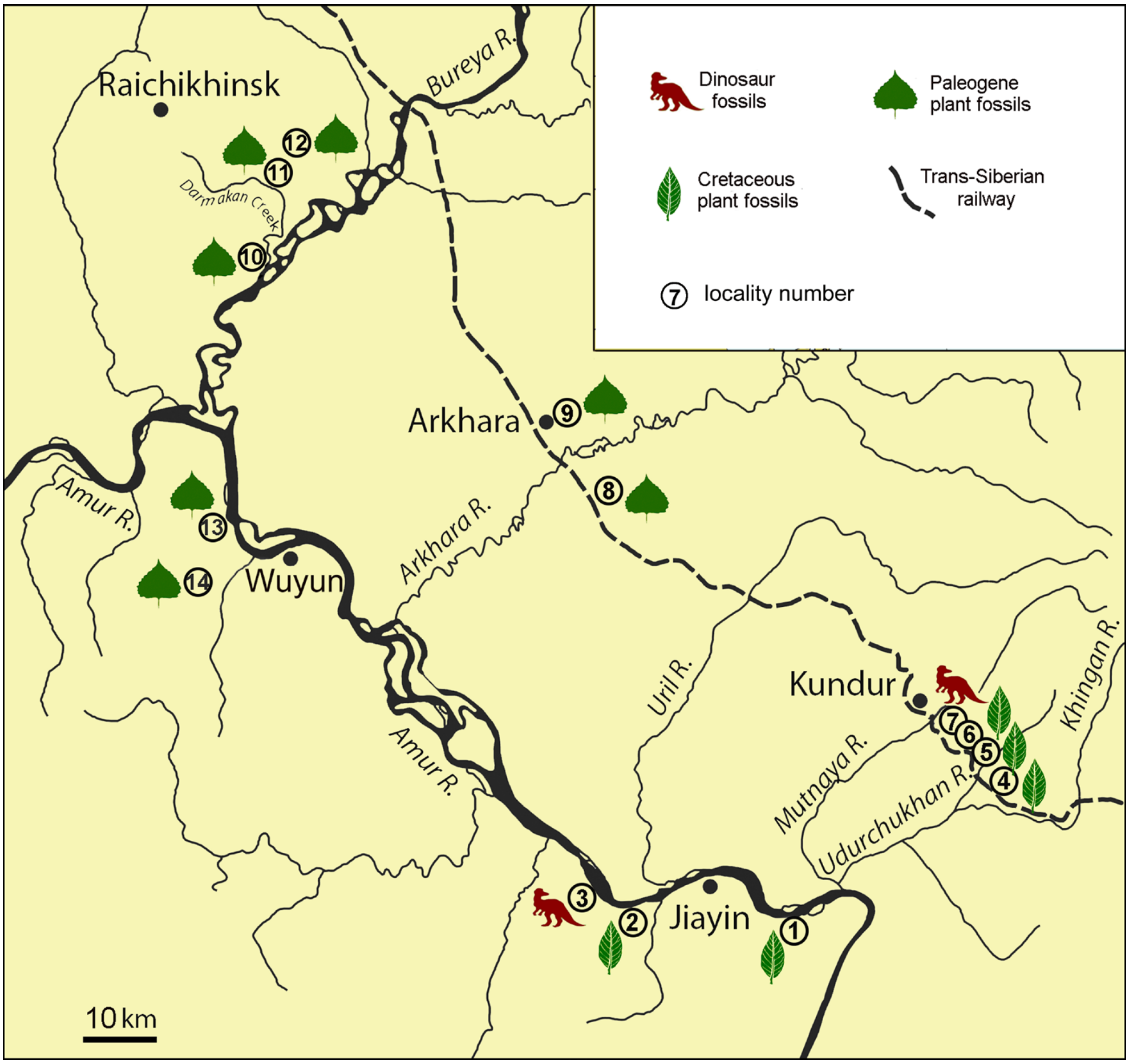

Fig. 2. Localities of the Cretaceous and Paleogene plant and dinosaur fossils: 1 – Yong'ancun village, Yong'ancun Formation; 2 – Longgushan steeps, Taipinglinchang Formation; 3 – Longgushan steeps, Yuliangzi Formation; 4 – locality 1808, middle Kundur Formation; 5, 6 – localities 15 and 16, upper Kundur Formation; 7 – locality 18, Lower Tsagayan subformation (=Udurchukan Formation); 8 – Arkhara–Boguchan coal field, Middle and Upper Tsagayan subformations; 9 – Arkhara Hill, Middle and Upper Tsagayan subformations (=Bureya and Darmakan formations); 10 – Belaya Gora, Upper Tsagayan subformation (=Darmakan Formation); 11 – Raichikhinsk coal field, Pioneer section, Upper Tsagayan subformation; 12 – Raichikhinsk coal field, Progress section, Upper Tsagayan subformation; 13 – Baishantou, lower Wuyun Formation; 14 – Wuyun coal field, upper Wuyun Formation.

Fig. 3. Outcrops of the Cretaceous fossiliferous strata of the Amur River area: 1 – section of the Yong'ancun Formation at the right bank of the Amur River, China; 2 – outcrop of the Taipinglinchang Formation in the eastern part of Longgushan, China; red dotted line – boundary between the Taipinglinchang and Yuliangzi formations; red circle – locality TP-2; 3 – the same outcrop; red circle – locality TP-1; 4 – the same outcrop; collecting of plant fossils at the locality TP-2; 5 – section of the middle part of the Kundur Formation near road point 1808, Amur Region, Russia; 6 – locality of plant fossils in the middle part of the Kundur Formation; 7 – outcrop of the upper part of the Kundur Formation along federal road M58, Amur Region, Russia; 8 – section 16, the upper part of the Kundur Formation; red circle – locality of plant fossils above coal layer.


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The Yong'ancun Formation is the lowest member of the Jiayin Group. It is underlying by white rhyolite of the Ningyuancun Formation of the Early Cretaceous age and is conformably overlying by the Taipinglinchang Formation. The thickness of this formation is about 970 m. The deposits of the Yong'ancun Formation outcrop mainly along the bank of Amur River in the east hill of the Yong'ancun villages, about 15 km to the east of the Jiayin Town (Fig. 2). This formation consists of alternated yellow brown cross-bedded sandstones, greenish-gray and brownish-gray siltstones and mudstones, intercalated by pebbled sandstones and conglomerates, representing alluvial-lacustrine facies of an intermontane depression in the Zeya-Bureya Basin (Regional geology..., 1993; Suzuki et al., 2004; Sun et al., 2011). The Yong'ancun Formation yields plant mega- and microfossils, ostracods, bivalves, conchostracans, and dinosaur footprints *Jiayinosauropsis johnsoni* Dong, Zhou et Wu (Dong et al., 2003; Sun et al., 2007, 2011; Markevich et al., 2011).

The Taipinglinchang Formation is a stratigraphic analogue of the upper member of the Kundur Formation (Sun et al., 2002; Markevich et al., 2005a, b). It is about 600 m thick and is overlain by the Yuliangzi Formation. The Taipinglinchang Formation is exposed from the Yong'ancun to Shuangle villages along the Amur River. This formation is subdivided into two members. The lower member is composed of dark gray oil shales with ostracods and conchostracans, and the upper member comprises grayish-brown siltstones and fine-grained sandstones, which yield abundant plant fossils.

The Santonian age of the Yong'ancun Formation and the Campanian age of the Taipinglinchang Formation are determined based on palynological and plant megafossils data (Markevich et al., 2005a, b; Markevich et al., 2011; Sun et al., 2011; Liang et al., 2015).

The Maastrichtian Yuliangzi Formation does not yield plant megafossils, but is rich in dinosaur remains. Main vertebrate localities are situated near Jiayin and Wulaga towns (Godefroit et al., 2008). The Furao Formation is dated as late Maastrichtian based on palynological assemblage (Markevich et al., 2011; Sun et al., 2014).

MATERIAL AND METHODS

Plant fossils were collected by participants of international research project "Late Cretaceous biota and the K–T boundary in Heilongjiang River area" during field works in 2002–2005, and subsequent investigations.

Numerous localities of the Sutara flora are distributed near the border between Amur and Khabarovsk regions, around Obluch'e Town and also along the Amur River near the Pashkovo and Radde villages (Fig. 4; Fig. 5, *2*). These localities were discovered by geologists of the Khabarovsk State Geological Survey during geological mapping. The largest collections were gathered by Valentina Kiriyanova. They are stored at the Khabarovsk Branch of the Far East Federal District Territorial Fund of Geological Information in Khabarovsk (coll. KGI), at the Komarov Botanical Institute RAS in St. Petersburg (coll. no. BIN 1570, 1571), and at the Federal Scientific Center of the East Asia Terrestrial Biodiversity FEB RAS in Vladivostok (IBSS).

The Kundur Formation was studied in the Arkhara District of the Amur Region, along federal road M58 Chita–Khabarovsk between the Udurchukan and Mutnaya rivers (Fig. 2, Fig. 6).

Two different floristic assemblages were revealed in the deposits of the Kundur Formation: the Middle Kundur floristic assemblage and the Late Kundur floristic assemblage. The first one is confined to the middle part of the formation (exposure 1808) and was dated as the Santonian based on palynological data (Markevich et al., 2005b). The second assemblage comes from the upper part of the formation (exposures 15, 16) and was dated as the Campanian based on both palynological data and plant megafossils (Markevich et al., 2005a). The detailed description of the sections and palynological data were published previously (Flora and dinosaurs..., 2001; Markevich et al., 2005a, b).

The exposure 1808 outcrops along the road M58 near road point 1808/357 km at a distance 250 m of the crossing of federal road with the railway (Fig. 3, *5, 6*). The lateral extent of this section is about 500 m and its thickness is about 40 m. The plant locality occurs at 49°01'148"N and 130°53'081"E.

The exposure 15 is located between 1020 and 1230 m northwest of the Udurchukan River bridge (49°03'04.4"N, 130°52'51.8"E). The outcrop consists of finely laminated clay, siltstone and fine sandstone layers that probably were deposited in a lacustrine environment. The beds contain remains of conchostracans, ostracods, fish, and plants. The fluvial deposits are represented by channel-form sandy bodies that are about 1 m thick. These deposits are often cemented with calcite (Flora and dinosaurs..., 2001; Van Itterbeeck et al., 2005). Rare plant fossils and abundant organic detritus are found within the sandy deposits.

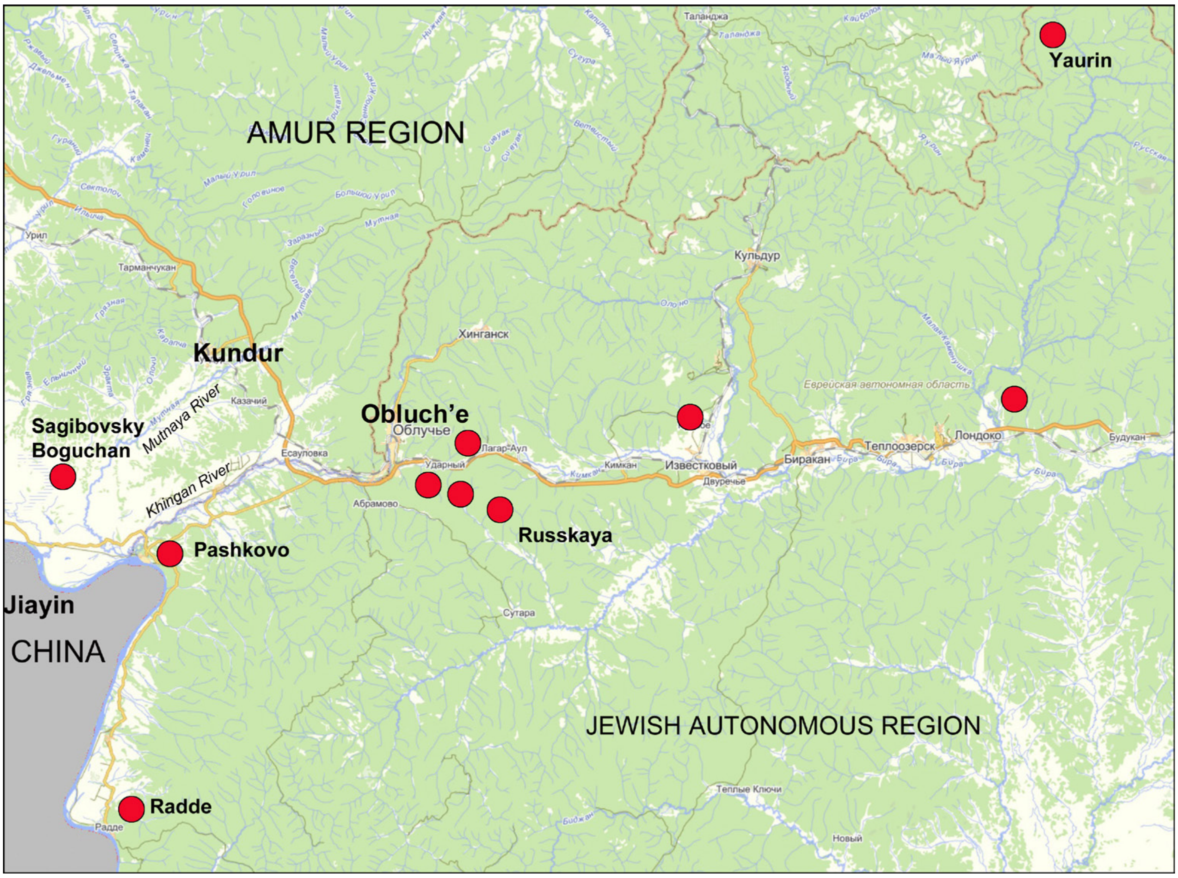


Fig. 4. Localities of the Sutara flora.

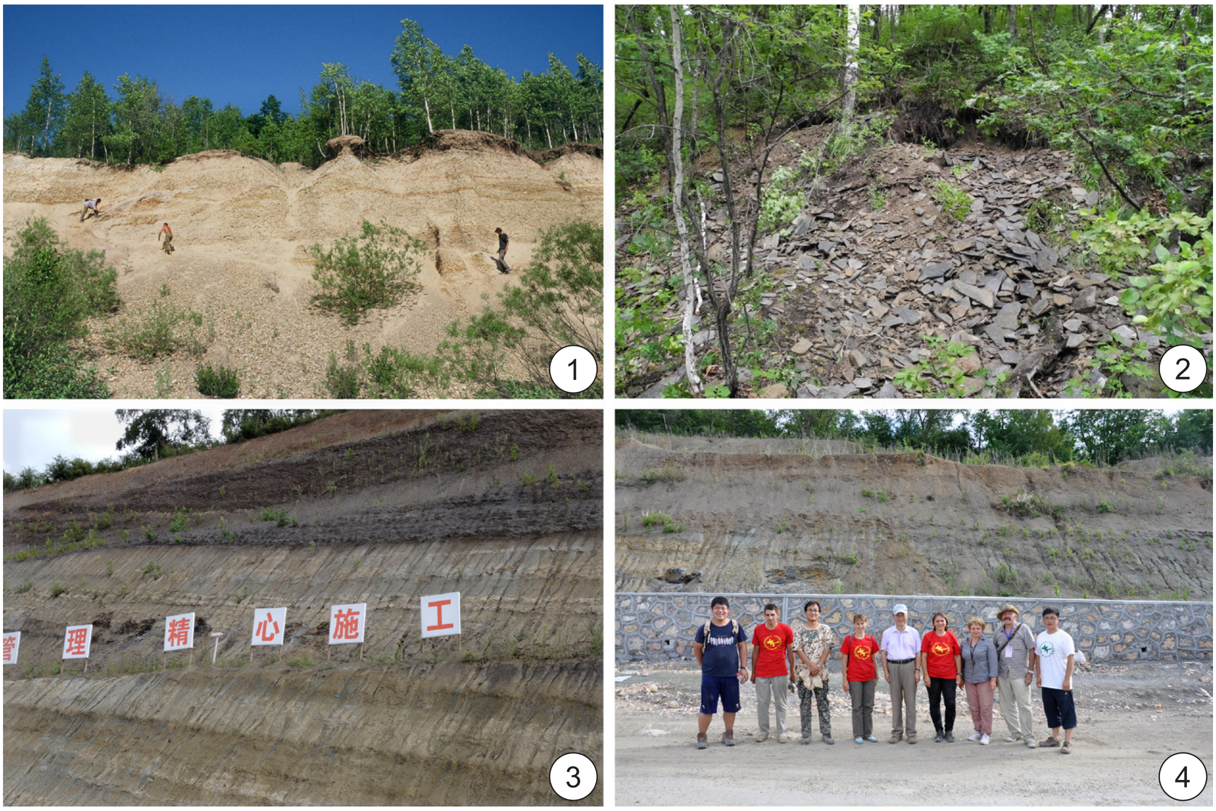


Fig. 5. Outcrops of the Cretaceous fossiliferous strata of the Amur River area: 1 – section of the Middle Tsagayan (Bureya) Formation along federal road M58, exposure 28, Russia; 2 – locality of the Sutara flora near Radde village, Russia; 3, 4 – outcrop of the lower part of the Yong'ancun Formation along new road, China.

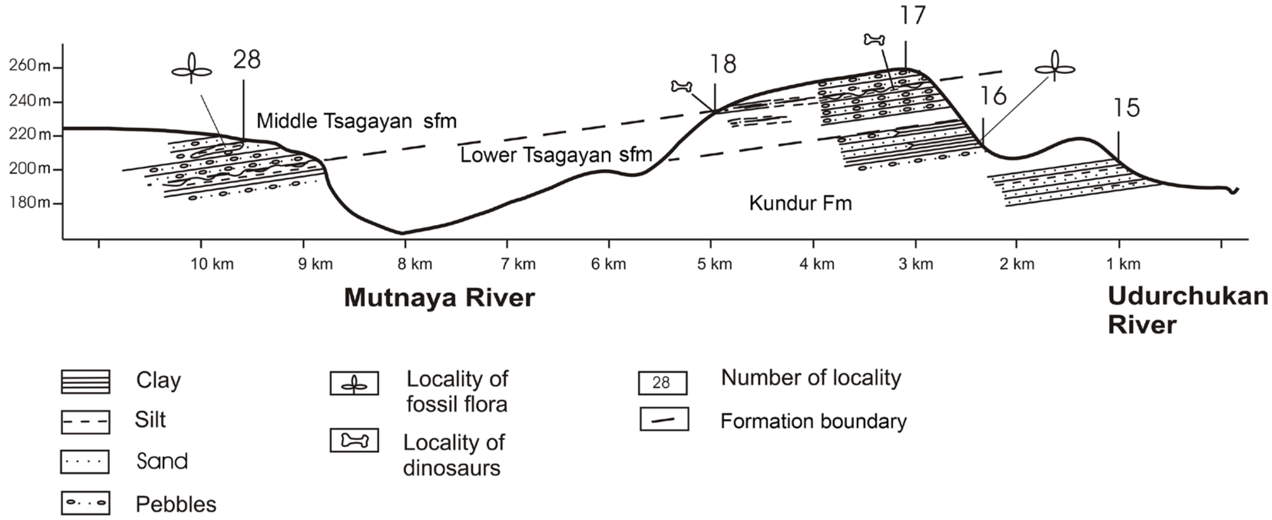


Fig. 6. Profile along federal road M58 from Udurchukan River to the Mutnaya River.

The majority of plant fossils come from exposure 16 (Fig. 6). It is located between 2380 and 2550 m northwest of the Udurchukan River bridge along the road M58 (49°03'44.6"N, 130°52'19.5"E). The lower part of exposure is dominated by thick cross-bedded sandy alluvial deposits (Fig. 5, *7, 8*). The upper part consists of clays, silts and fine sands with thin coal layer (0,4 m) in the middle of sequence. These sediments were deposited in floodplain environments including channels, levees and small lakes and ponds (Flora and dinosaurs..., 2001; Van Itterbeeck et al., 2005). In the top of this section there is a thin layer of yellow gravels which is attributed to the Lower Tsagayan subformation of the early Maastrichtian age (Flora and dinosaurs..., 2001; Bolotsky, Godefroit, 2004). Plant fossils were found in several lenses below and above coal layer. Eroded dinosaur bones are frequently found within the gravels and sandstones of the Lower Tsagayan subformation (Udurchukan Formation), whereas well-preserved bones come from clast-rich diamicts in exposure 18 (Van Itterbeeck et al., 2005).

In the upper gravel bed in exposure 28 (Fig. 5, *1*; Fig. 6), a lens of fine-grained sediments with rare plant fossils was found. These deposits are assigned to the Middle Tsagayan subformation (=Bureya Formation) and dated as the late Maastrichtian (Flora and dinosaurs..., 2001).

The collections are kept at the Komarov Botanical Institute RAS in St. Petersburg (coll. no. BIN 824, 1538, 1545), the Federal Scientific Center of the East Asia Terrestrial Biodiversity FEB RAS in Vladivostok (IBSS), and the Geological Institute RAS in Moscow (coll. no. GIN 4867).

In the Jiayin County of the Heilongjiang Province plant fossils are known from the Yong'ancun and the Taipinglinchang formations, which comprise the lower part of the Jiayin Group.

In the Yong'ancun Formation the plant fossils were found mostly in the upper member of formation, exposed on the right side of the Amur (Heilongjiang) River between Yong'ancun and Huoshaqiao villages (Fig. 2). This geological section is a stratotype of the Yong'ancun Formation. It is about 168 m thick and consists of intercalated yellow brown cross-bedded sandstones, gray green siltstones and brownish-gray siltstones and mudstones (Fig. 3, *1*). Fossiliferous beds were found at three stratigraphic levels: (1) in a 2 m-thick layer of dark grey laminated shales at the bottom of the outcrop, 165 m below the top of the Yong'ancun Formation (locality YN-1, coordinates 48°50'56.8"N, 130°31'51.0"E); (2) in a layer of gray siltstones, that occurs in 115–120 m upward from the bottom of the outcrop (locality YN-2, coordinates 48°50'59,3"N, 130°31'30,7"E); and (3) in a layer of gray siltstones, that occurs in 130 m upward from the bottom of the outcrop (locality YN-3).

In 2014, a new road construction exposed the lower layers of the Yong'ancun Formation (coordinates 48°50'57"N, 130°31'24"E), that give the opportunity to study this part of the section The thickness of sedimentary sequence in this locality is about 30 m (Fig. 5, *3, 4*). The strata consist of sandy mudstones and siltstones, intercalated with coarse sandstones (Liang et al., 2015).

A large collection of plant fossils from this locality was gathered in 2015, during field excursion after 12th Symposium on Mesozoic Terrestrial Ecosystems in Shenyang. Collections are housed in the Paleontological Museum of Liaoning (PMOL) in Shenyang, China.

The plant fossils from the upper part of the Taipinglinchang Formation were collected in 2002 and 2004. The fossil sites are located in the eastern part of Longgushan steeps – the big outcrop on the right bank of the Amur (Heilongjiang) River between the Yuliangzi and Xiagunzigou villages, 9 km downstream from the Jiayin Town (Fig. 2). This place is known as a famous dinosaur locality (Xing et al., 1994). The most part of this outcrop consists of the Yuliangzi Formation sediments, which yield the bones of vertebrates. The upper member of the Taipinglinchang Formation outcrops in the eastern part of the section near Kuangu River. Fossiliferous beds were found at two stratigraphic levels near the top of the formation: (1) locality TP-2 in a 0,8 m-thick layer in 5 m below the boundary between the Taipinglinchang Formation and overlying Yuliangzi Formation; and (2) locality TP-1 in a 0,5 m-thick layer, that occurs in 16 m below the boundary (Fig. 3, *2–4*). Coordinates of both localities are 48°51'27,5"N and 103°15'33,2"E. Besides that, two small florules were found in small quarries near Yuxing (locality YX) and Yugiang (locality YQ) villages. Plant fossils occur in beds of intercalated dark gray siltstones and brown green fine-grained sandstones and are rather rare. The collection is kept at the Research Center of Paleontology and Stratigraphy, Jilin University (RCPS) in Changchun, China.

The most part of plant fossils are leaf impressions without cuticles with the exception of ginkgoalean remains. Morphology and anatomy of some reproductive structures and leaves were studied with SEM and TEM (Krassilov, Kodrul, 2009; Kodrul et al., 2013; Kodrul, Maslova, 2017). The specimens were photographed using a digital Nikon D700 camera.

THE SUTARA FLORA, AMUR REGION

This flora, comprising several plant assemblages, was obtained from felsic tuffs and volcanogenic-sedimentary rocks of Khingan-Olono volcanogenic zone. The taxonomic study of this flora has not yet been completed. Plant fossils from tuffs of the Sagibovsky Boguchan were described by A. N. Kryshtofovich (Kryshtofovich, Baikovskaya, 1966) and later by Krassilov (1976). This assemblage includes *Asplenium dicksonianum* Heer, *Ginkgo* ex gr. *adiantoides* (Ung.) Heer, *Sequoia reichenbachii* (Gein.) Heer, *Pseudolarix* sp. Platanaceous leaves and inflorescences were described by Krassilov as *Platanus* ex gr. *newberryana* Heer. Plant assemblage from Pashkovo was studied by Kiriyanova (1999) and later partly revised (Flora and dinosaurs..., 2001).

The Sutara flora includes about 40–50 species among which gymnosperms (mostly conifers) predominate (Fig. 7; Pl. I–V). Ferns and flowering plants are rather diverse, but their remains occur rarely. Ferns are represented by the families Dipteridaceae, Aspleniaceae, Pteridaceae, Dicksoniaceae and some undetermined taxa. Gymnosperms of the Sutara flora include caytonialeans, cycadophytes, czekanowskialeans, ginkgoaleans, and conifers. Remains of gymnosperms usually lack cuticle, therefore they are assigned to form-taxa or determined at generic level.

The leaves of the Caytoniales are assigned to the cosmopolitan species *Sagenopteris variabilis* (Velen.) Velen. Cycadophytes include genera *Nilssonia, Taeniopteris*, and *Pseudoctenis*. Morphologically diverse leaves of cycadalean genus *Nilssonia* are numerous in localities. Leaves of *Taeniopteris* up to 40 cm long are sometimes found in bundles (Pl. I, fig. 3). Czekanowskialeans are represented by the genus *Phoenicopsis*. Ginkgoaleans include *Sphenobaiera* sp. (leaves in bundles) and two species of *Ginkgo* with entire and dissected leaves (Fig. 7, *3*; Pl. II, fig. 1, 5, Pl. III, fig. 3, 4).

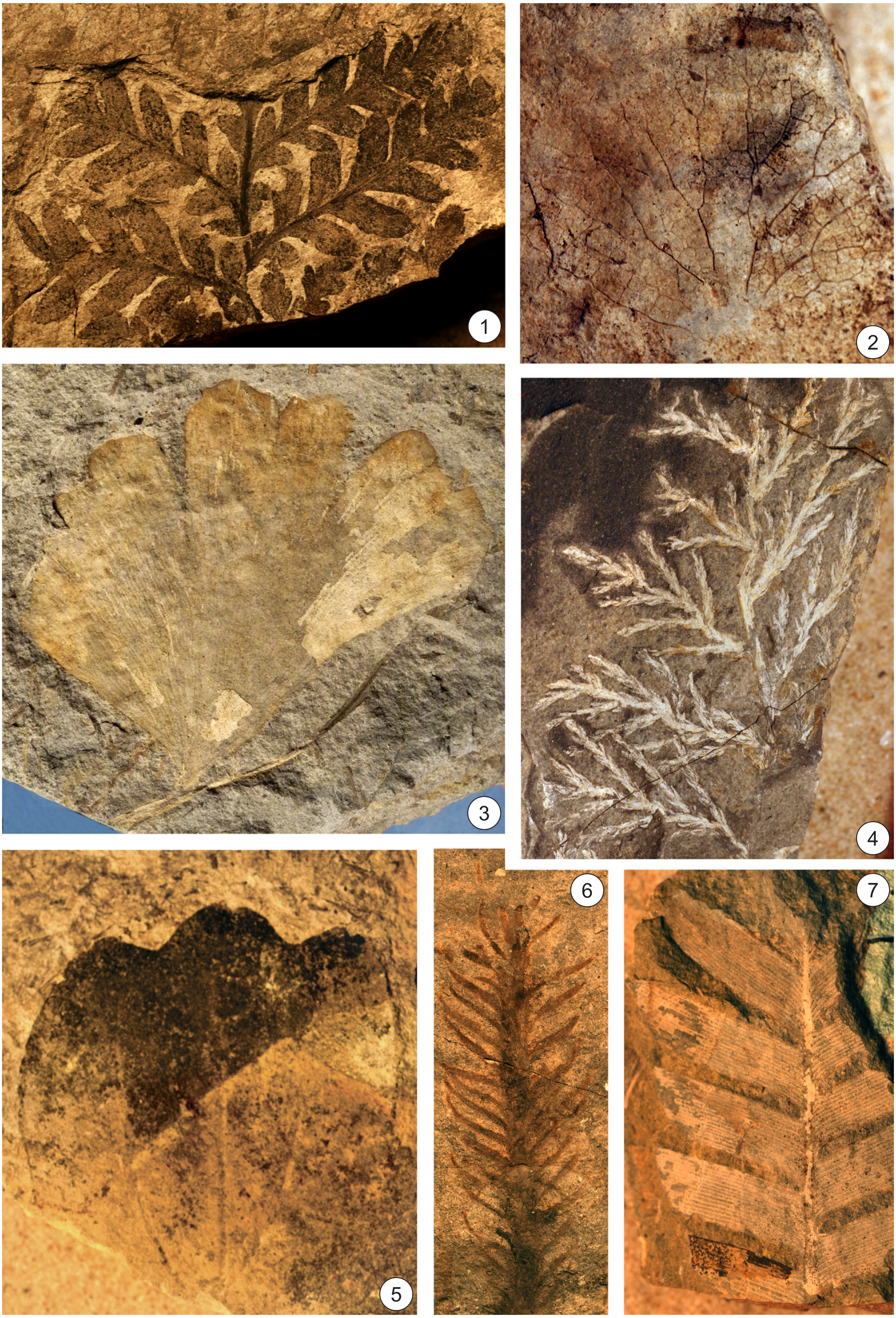
Conifers of the Sutara flora are represented by families Cupressaceae, Pinaceae, and genera of uncertain taxonomic affinity. The family Cupressaceae includes genera *Sequoia* and *Cupressinocladus*. The family Pinaceae is represented by different types of cones, dispersed scales, leaves, and shoots (Pl. II, fig. 2, 3, 6, 7, Pl. IV, fig. 3). Genera of uncertain taxonomic affinity are very diverse and represent the most conspicuous and exotic part of the Sutara flora. Coniferous shoots with evergreen scale-like, hook-shaped or linear leaves are assigned to the form-genera *Araucarites, Elatocladus,* and *Pagiophyllum*.

Angiosperms are scarse. Only representatives of the family Platanaceae predominate in several sites (Pl. V, fig. 3). They are known from Yaurin, Radde, and Sagibovsky Boguchan localities. The systematic affinity of other angiosperms remains unclear and they require further investigation.

Thus, the Sutara flora is characterized by a predominance of conifers, rarity of angiosperms (mostly Platanaceae), high endemism and presence of numerous Early Cretaceous relicts. These features are very characteristic of the Late Cretaceous floras of the Okhotsk-Chukotka volcanic belt, especially of the Coniacian Ul'ya flora (Golovneva, 2013). We preliminarily estimated the age of the Sutara flora also as the Coniacian or the Turonian–Coniacian.

THE KUNDUR FLORISTIC ASSEMBLAGES, AMUR REGION

The first data about fossil plants from the Kundur Formation were provided by Konstantov (1914) and Kryshtofovich and Baikovskaya (1966). The plant fossils were found by Konstantov near a railway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tunnel, at the 147th verst of the Amur railway. He described platanaceous leaves as *Pterospermites tschernyschewii* Konstantov and leaves of *Trochodendroides* Berry as *Grewia obovata* Heer. Kryshtofovich found in the same locality leaves of *Asplenium* sp., *Celastrinites* Saporta (reported as *Dryophyllum* cf. *D. moorii* (Lesq.) Berry), and *Trochodendroides* (described as *Zizyphus* sp). However, the systematic composition of the Late Cretaceous and Early Paleogene floras was insufficiently studied at that time, and rare Kundur plants were included into the younger Tsagayan flora. Currently, these collections are kept at the Central Scientific-Research Geological Exploration Museum named after academician F. N. Chernyshev, St. Petersburg (TsNIGR Museum).

Plant fossils in the middle part of the Kundur Formation are not numerous. The Middle Kundur flora consists of only 9 species (Pl. VI), representing horsetails (*Equisetum* sp.), ferns (*Asplenium dicksonianum* Heer), conifers (*Sequoia* sp., *Metasequoia* sp., *Cupressinocladus* sp.) and angiosperms (*Trochodendroides lanceolata* Golovn., Sun et Bugdaeva, *T. taipinglinchanica* Golovn., Sun et Bugdaeva, *Quereuxia angulata* (Newb.) Krysht. ex Baik., *Cobbania corrugata* (Lesq.) Stockey, Rothwell et Johnson). Leaves of *Asplenium dicksonianum* and shoots of *Sequoia* predominate. The shoots of *Metasequoia* and *Cupressinocladus* occur more rarely. Angiosperms are represented mostly by fragments of *Trochodendroides* leaves. Numerous remains of aquatic plants *Quereuxia angulata* and *Cobbania corrugata* were found in some layers.

The Late Kundur flora from the upper part of the Kundur Formation is more diverse and includes more than 30 species. All species known from the middle part of the Kundur Formation, are presented in its upper part.

The Late Kundur flora contains bryophytes, horsetails, ferns, ginkgoaleans, conifers, and angiosperms (Pl. VII–IX). Prevailing groups comprise conifers and angiosperms. Horsetails (*Equisetum* sp.), and bryophytes (*Thallites* sp.) occur very rare. Ferns are more common and include 6 species. Among them small fronds of a new heterosporous fern *Kundurella* (nom. nudum) are represented by hundreds of specimens in the layer occurred 2,5 m above the coal seam (Polevova et al., 2006). Other species (*Coniopteris tschuktschorum* (Krysht.) Samyl., *Cladophlebis* sp., and *Arctopteris* sp.) are not abundant. The aquatic fern *Salvinia* sp. occurs with aquatic angiosperms *Quereuxia angulata* and *Cobbania corrugata*. These plants might have formed floating mats on standing bodies of water.

Ginkgoaleans are not abundant in this flora. They are represented by *Ginkgo pilifera* Samyl., common Siberian species, widespread in the Late Cretaceous (Golovneva et al., 2008; Golovneva, 2016).

Conifers include 10 species belonging to the families Cupressaceae, Pinaceae, and taxa of unknown systematic affinity (*Elatocladus* spp.). Most of plant fossils are impressions without cuticle, therefore they can be identified only at generic level. The Cupressaceae are represented by genera *Sequoia*, *Metasequoia, Glyptostrobus, Taxodium,* and *Cupressinocladus*. The most abundant cupressoid remains are shoots of *Sequoia*. The foliage of *Metasequoia* and *Glyptostrobus* are accompanied by their cones and cone scales. The presence of genus *Taxodium* is questionable because only foliage was found. Flat shoots with decussate leaves were assigned to the genus *Cupressinocladus*. Family Pinaceae is represented by dispersed leaves, seeds and cones. All of them are determined as form-genera *Pityophyllum, Pityospermum,* and *Pityolepis*.

Angiosperms are represented by 12 species. Families, which can be recognized with reasonable confidence, are Nelumbonaceae, Platanaceae, Cercidiphyllaceae, and Araceae. Other species appear to belong to ancient groups, without clear phylogenetic links to modern orders or families. Most of them have not been studied yet.

Family Cercidiphyllaceae is represented by the genus *Trochodendroides*, which includes three species. Two of them, *T. lanceolata* and *T. taipinglinchanica*, are endemic for the Late Cretaceous floras of this region. Third species, *T. microdentata* Golovn., Sun et Bugdaeva, was also recorded in the Coniacian deposits of the Amka Formation, Okhotsk-Chukotka volcanic belt (Golovneva et al., 2017).

The remains of Platanaceae are represented by leaves of *Arthollia tschernyschewii* (Konstantov) Golovn., Sun et Bugdaeva and two types of capitate reproductive structures: infructescences *Kunduricarpus longistylium* Kodrul, N. Maslova, Tekleva et Golovn., and staminate inflorescences *Kundurianthus mirabilis* Kodrul, N. Maslova, Tekleva et Golovn. (Kodrul et al., 2013).

Fig. 7. The Sutara flora, Turonian–Coniacian, Amur Region, Russia: 1 – ***Arctopteris*** sp., spec. KGI, ×2; 2 – ***Hausmannia*** sp., spec. KGI, ×2; 3 – ***Ginkgo*** ex gr. ***adiantoides*** (Ung.) Heer, spec. KGI, ×1; 4 – ***Athrotaxopsis*** sp., spec. KGI, ×2; 5 – ***Araliaephyllum*** sp. 1, spec. KGI, ×2 ; 6 – ***Elatocladus*** sp. 1, spec. KGI, ×1; 7 – ***Pseudoctenis*** sp., spec. KGI, ×2.

Leaves of *Arthollia tschernyschewii* and two others undescribed platanoid leaf morphotypes (Pl. VIII, fig. 8, 9) occur rarely, whereas capitate reproductive structures occur frequently and usually associated with leaves of *Kunduriphyllum kundurense* (Golovn., Sun et Bugdaeva) Kodrul et N. Maslova. This species predominates among angiosperm taxa in all sedimentary facies. *Kunduriphyllum* is characterized by lanceolate entire leaves with pinnate brochidodromous or semicraspedodromous venation and untoothed, serrate or rarely dentate margin. The similarity of epidermal characteristics and identical biological damage suggests that leaves of *Kunduriphyllum* and reproductive structures *Kunduricarpus* and *Kundurianthus* could be assigned to a single plant related to Platanaceae (Kodrul, Maslova, 2017). Previously these leaves were described as *Celastrinites kundurensis* Golovn., Sun et Bugdaeva (Golovneva et al., 2008). Formal genus *Celastrinites* is known from the Late Cretaceous floras of Northern Pacific region and is especially typical for the Maastrichtian Kakanaut and the Maastrichtian–Danian Rarytkin floras of the Koryak Upland (Golovneva, 1994).

Aquatic angiosperms, besides *Quereuxia angulata* and *Cobbania corrugata,* are represented by the genus *Nelumbo*. Leaf fragments of *Nelumbo* from the Kundur Formation have a significant similarity with leaves of *Nelumbo jiayinensis* Liang, Sun, Yang et Bai from the Yong'ancun Formation (Fig. 8).

Remains of *Quereuxia* and *Cobbania* are characterized sometimes by excellent preservation. *Cobbania* is represented by free-floating rosettes of obovate to orbicular leaves with branched aquatic roots, aerenchymous tissues on abaxial leaf surface and dense trichomes on adaxial surface (Krassilov, Kodrul, 2009). Reproductive structures with cluster of seeds and dispersed seeds associated with these leaf rosettes are assigned to *Cobbanicarpites amurensis* Krassilov et Kodrul. *Cobbania corrugata* is now considered as belonging to the family Araceae (Stockey et al., 2007, 2016). *Quereuxia angulata* is represented by floating rosettes and dissected submerged leaves, attached to stems. This species is widespread in the paleofloras of Northern Hemisphere since the Coniacian. Its systematic affinity is not clear.

THE BUREYA FLORISTIC ASSEMBLAGE, AMUR REGION

The Bureya floristic assemblage comes from a lens of fine-grained sediments in gravel of the Middle Tsagayan subformation (=Bureya Formation) in exposure 28. The preliminary list of this low-diverse assemblage includes *Equisetum* cf. *arcticum* Heer, *Taxodium* sp., *Elatocladus talensis* Golovn., *Czekanowskia* (?), *Nyssa* cf. *bureica* Krassilov, *Diplophyllum amurense* Krassilov, *Trochodendroides* sp., *Platanus raynoldsii* Newb. (Flora and dinosaurs…, 2001). Conifers *Elatocladus* and *Taxodium* predominate at this locality.

Dichotomously divided narrow leaves, assigned previously to *Czekanowskia* (?), later were described by Nosova (2010) as new species of ginkgoaleans *Leptotoma samylinae* N. Nosova (Pl. X). Previously the genus *Leptotoma* was unknown in the Late Cretaceous. This find from Amur Region significantly expanded our understanding of the geographic and stratigraphic distribution of this genus.

Fig. 8. ***Nelumbo*** leaves from the Late Kundur (1) and Yong'ancun (2) floras: 1 – ***Nelumbo*** sp., spec. GIN K15-1, ×1; 2 – ***Nelumbo jiayinensis*** Liang, Sun, Yang et Bai, spec. PMOL YX-B-300, holotype, ×1.

THE YONG'ANCUN FLORISTIC ASSEMBLAGE, HEILONGJIANG PROVINCE

The Late Cretaceous plant fossils in the Jiayin County of the Heilongjiang Province were firstly found by Z. C. Zhang (1983). Later Upper Cretaceous stratigraphy and fossil flora were studied by participants of the international project (Sun et al., 2002, 2007, 2014; Golovneva et al., 2004, 2008; Quan, Sun, 2008; Liang, Sun, 2015).

Plant fossils are quite rare in the bank outcrops of the middle part of the Yong'ancun Formation. The preliminary study reveals the following taxa: *Asplenium dicksonianum* Heer, *Metasequoia* sp., *Taxodium* sp., *Sequoia* sp., *Cupressinocladus* sp., *Ginkgo* ex gr. *adiantoides* (Ung.) Heer, *Trochodendroides* sp., *Quereuxia angulata*. Plant fossils are more diverse along road outcrops, in the lower part of the Yong'ancun Formation. In 2015 numerous impressions of leaves and fruits were found, including horsetails (*Equisetum*), ferns (*Asplenium, Osmunda*), ginkgoaleans (*Ginkgo*), conifers (*Cupressinocladus, Taxodium, Metasequoia, Sequoia, Pityophyllum*), and angiosperms (*Nelumbo, Trochodendroides, Jenkinsella, Platanus, Arthollia, Dalembia, Quereuxia,* and *Cobbania*).

Hence, the Yong'ancun flora contains horsetails, ferns, ginkgoaleans, conifers, and angiosperms (Pl. XI, XII). Remains of *Equisetum* stems and rhizomes occur rarely. Ferns include three genera: *Osmunda, Asplenium,* and aquatic fern *Salvinia*. Fronds of *Asplenium dicksonianum* Heer and *Osmunda* are rather frequently found, but they are fragmentary. Leaves of *Ginkgo* are not abundant and belong to the new species, that differs from widespread Siberian species *G. pilifera* Samylina (Samylina, 1967) in straight anticlinal cell walls of epidermal cells on both abaxial and adaxial sides of the leaves, in small papillae on the periclinal walls of the ordinary epidermal cells, and also in short papillae on subsidiary cells leaving most of the guard cells visible.

The conifers are mostly represented by members of family Cupressaceae including genera *Sequoia, Metasequoia, Taxodium,* and *Cupressinocladus*. Most remains of conifers are impressions lacking preserved cuticle, and therefore their species identity cannot be determined. Representatives of the family Cercidiphyllaceae dominate the Yong'ancun plant assemblage in terms of abundance and diversity and include three species of *Trochodendroides* and associated fruits *Jenkinsella*. Zhang (1983) figured several fragments of leaves, similar to those of Platanaceae. However, their accurate taxonomic assignment is difficult, moreover, a particular position of these leaves in the Cretaceous stratigraphic sequence is not clear.

Aquatic plants are well presented in the Yong'ancun flora and are characterized by good preservation (Quan, Sun, 2008). They are represented by angiosperms (*Nelumbo, Cobbania, Quereuxia*) and by aquatic fern *Salvinia*. Small orbicular leaves of *Nelumbo* with 20–25 actinodromous primary veins were assigned to a new species *N. jiayinensis* (Liang et al., 2018). This is the first report of fossil *Nelumbo* from the Upper Cretaceous strata in China. However new species represented by fragmentary leaf material (Fig. 8), remarkably resembles *N. orientalis* Matsuo (1954) from the Coniacian deposits of Japan and *N. amurensis* Krysht. from the Tsagayan flora of Amur Region (Kryshtofovich, Baikovskaya, 1966). Since leaves of different *Nelumbo* species are characterized by significant morphological similarity, the independence of *N. jiayinensis* is questionable.

The compound, oddpinnate leaves, consisting of five leaflets, were described as new species *Dalembia jiayinensis* Sun and Golovn. (Pl. XII). This is the first occurrence of *Dalembia* in China and the most southern and youngest (Santonian) occurrence of this genus (Sun et al., 2016). Other taxa need further study.

THE TAIPINGLINCHANG FLORISTIC ASSEMBLAGE, HEILONGJIANG PROVINCE

The first plant fossils at Jiayin sites were found by Zhang (1983), who described several new species. Now the Taipinglinchang flora includes 26 species and contains bryophytes, horsetails, ferns, ginkgoaleans, conifers, and angiosperms. Conifers and angiosperms dominate in terms of abundance and diversity (Pl. XIII, XIV). Conifers include 11 species or 42% of plant assemblage composition, and angiosperms include 9 species or 35%. Horsetails, bryophytes, and ferns contain only 1–3 species in each group. Despite of long species list, this floristic assemblage actually cannot be considered as rich. Compared to other Late Cretaceous floras, angiosperms are poorly represented in the Taipinglinchang flora.

Systematic composition of floristic assemblages from the Kundur and Taipinglinchang formations are almost identical and undoubtly reflect the same phase of paleofloral development. The Taipinglinchang flora contains two taxa, which are absent in the Kundur flora: conifer genus *Larix,* represented by brachyblast with a bundle of linear leaves, and *Platanus sinensis* Zhang. The last species has both lobed and unlobed leaves about 6–8 cm in length. Platanoid leaves with similar morphology are common in many Late Cretaceous floras, but their systematics is not treated in the most cases.

The systematic list of the Taipinglinchang flora includes following taxa: BRYOPHYTA: *Thallites* sp. 1; EQUISETOPHYTA: *Equisetum* sp.; POLYPODIOPHYTA: *Asplenium dicksonianum*, *Cladophlebis* sp., *Arctopteris* sp.; GINKGOOPSIDA: *Ginkgo pilifera*; PINOPSIDA: *Larix* sp., *Pityophyllum* sp., *Pityospermum* sp., *Sequoia* sp., *Metasequoia* sp., *Glyptostrobus* sp., *Taxodium* sp., *Cupressinocladus* sp., *Elatocladus* spp.; MAGNOLIOPHYTA: *Nelumbo* sp., *Trochodendroides lanceolata*, *T. taipinglinchanica*, *T. microdentata*, *Arthollia tschernyschewii*, *Platanus sinensis*, *Kunduriphyllum kundurense*, *Cobbania corrugata, Quereuxia angulata*.

The one of the characteristic features of the Late Kundur and especially Taipinglinchang floras is the high diversity of conifers and presence among them of modern taxa, such as *Glyptostrobus, Metasequoia, Taxodium,* and *Larix*, that usually are absent in the Late Cretaceous floras of coastal lowlands. The high diversity and predominance of conifers and rarity of angiosperms are characteristic for the Cretaceous mountain paleofloras of the Okhotsk-Chukotka and Sikhote-Alin volcanic belts (Lebedev, 1987; Golovneva, 2018). The earliest appearance of *Metasequoia* and *Larix* was also recorded in the mountain floras of volcanic belts (Samylina, 1988). Probably, that the Campanian floras of the south-eastern part of the Zeya-Bureya Basin can reflect the vegetation of elevated area, situated near the Lesser Khingan Ridge.

Second characteristic feature of the Campanian Amur floras is the small size of the angiosperm leaves. The length of the platanoid leaves is usually less than 6–8 cm and no more than 10 cm. The size of *Trochodendroides* leaves is usually less than 4–5 cm. Leaf sizes are in two times less than ones for the Campanian flora of Khatanga depression (Golovneva, 2012), and in 1,5–2 times less than those for the Paleocene floras of the Amur Region. Along with other Cretaceous floras of Northeastern Asia, the predominance of small-leaved angiosperms was recorded for the Santonian–early Campanian floras of Sakhalin and Koryak Upland (Krassilov, 1979; Herman, Lebedev, 1991). The floras of this time interval are characterized not only by small sizes of leaves, but also by significant presence of entire-margined taxa with coriaceous leaf blades. These features indicate the warm subtropical climate with moderate or seasonal precipitation. But the Late Kundur and Taipinglinchang floristic assemblages contain only solitary taxa with entire-margined and coriaceous leaves and these floras can not be considered as reflecting warm and arid condition. Small sizes of angiosperm leaves and predominance toothed and thin blades usually consistent with temperate or cool climate and humid conditions.

Therefore, the Kundur and Taipinglinchang floras possibly reflect the vegetation of elevated environments in the vicinity of the ancient Lesser Khingan Ridge, similar with the Sutara flora. Diverse riparian and aquatic taxa (platanoids, *Trochodendroides*, ferns, horsetails, aquatic ferns and angiosperms) could occupy valleys of rivers and other depressions. Campanian palynological assemblages contain more diverse and thermophilic angiosperm complex then macrofossils. It is possible, that these reflect also regional vegetation of adjacent lowland (Markevich et al., 2005a, b).

DISCUSSION

The development and correlation of the Late Cretaceous and Paleogene floras of the Zeya-Bureya Basin were discussed several times (Sun et al., 2003, 2007; Markevich et al., 2005a, b; Golovneva et al., 2008; Moiseeva et al., 2018). The analysis of the systematic composition of the floristic assemblages revealed that the Middle Kundur flora can be correlated with the Yong'ancun flora and the Late Kundur flora can be correlated with the Taipinglinchang flora (Table 1). Age determination of the Late Cretaceous floras of the Zeya-Bureya Basin is mostly based on palynological data (Flora and dinosaurs..., 2001; Markevich et al., 2005a, b, 2011; Liang et al., 2015). The age of the Kundur Formation was originally determined as the Turonian–Campanian (Bugdaeva, Markevich, 2001). Later the deposits of the upper member were dated as the Campanian and the deposits of the middle member were dated as the Santonian (Markevich et al., 2011). The new palynological material from the lower part of the Yong'ancun Formation provides supplementary evidence for the Santonian age of the Yong'ancun flora (Liang et al., 2015). The palynological assemblage of the Yong'ancun Formation is comparable in general to those from the Members 2–3 of Yaojia Formation and the Member 1 of Nenjiang Formation in Songliao Basin, China, indicating the Santonian age. The stratigraphy of the Upper Cretaceous of the Songliao Basin has been studied in high resolution with radiometric dating in recent years (Wan et al., 2013).

Table 1

Correlation of the Late Cretaceous floras of the Zeya-Bureya Basin in the Amur Region and the Heilongjiang Province

Age		Amur Region, eastern part of the Zeya-Bureya Basin	Heilongjiang Province, southern part of the Zeya-Bureya Basin
Maastrichtian	l	Bureya flora	
	e		
Campanian		Late Kundur flora	Taipinglinchang flora
Santonian		Middle Kundur flora	Yong’ancun flora
Coniacian		Sutara flora	
Turonian			
Cenomanian			

Systematic compositions of the Middle Kundur and Yong’ancun floristic assemblages are very similar, but Yong’ancun flora differs in higher species diversity. Systematic composition of the Late Kundur and Taipinglinchang floras are also almost identical and undoubtedly reflect the same phase of paleofloral development (Golovneva et al., 2008). The Taipinglinchang flora is characterized by more diverse conifers compared to the Late Kundur flora, whereas the latter differs in more diverse ferns and angiosperms.

Cobbania corrugata has the greatest stratigraphic significance among plant megafossils. This species is common for the Campanian and Maastrichtian floras of North America (Bell, 1949, Stockey et al., 2007, 2016). In the Northeastern Asia it was also recorded in the lower Campanian deposits of Khatanga River in the northern part of Siberia (Abramova, 1983; Golovneva, 2005, 2012), where was found with the early Campanian mollusks *Sphenoceramus patootensiformis* (Zakharov et al., 2003).

The Campanian floras of Amur River area closely resembles the Mutino flora from the Khatanga River basin (Northern Siberia). This flora includes five taxa in common with the Campanian floras of the Amur River area: *Ginkgo pilifera, Sequoia* sp., *Arthollia*, *Trochodendroides*, *Cobbania corrugata* and *Quereuxia angulata*. However, the Mutino flora locality is the furthest of the localities of the Campanian floras of the Northeastern Asia from the Amur River area. The Zhonk'er flora from Sakhalin Island (Krassilov, 1979) differs from the Campanian Amur floras by predominance of thermophilic taxa including cycadophytes and angiosperms with entire-margined coriaceous leaves of genera *Araliaephyllum, Myrtophyllum, Thernstroemites, Magnoliaephyllum*. The Zhonk'er flora has almost no common elements with the Amur floras, besides such widespread taxa as *Sequoia* and *Quereuxia*. The thermophilic taxa are absent in the Late Kundur and Taipinglinchang floras. The more northern Barykovian flora from the Koryak Upland (Herman, Lebedev, 1991) also contains many thermophilic elements and its systematic composition is not similar with those of the Amur floras. Thus, the Campanian Amur floras have greater similarity with warm temperate flora of Northern Siberia, than with thermophilic floras of Pacific coast. The absence of thermophilic taxa in the Northern Siberia is probably related to northern position of this flora. Possibly that temperate character of floras from Zeya-Bureya Basin was consequence of their more continental position and existence in the elevated environments.

The age of the Bureya floristic assemblage was estimated as the late Maastrichtian also based on palynological data (Flora and dinosaurs..., 2001). Its diversity is too low for comparison with other Maastrichtian floras of Northeastern Asia. The presence of *Leptotoma samylinae* in this assemblage is of great interest. This taxon was widespread in Eurasia during the Jurassic and Early Cretaceous.

The age of the Sutara flora is the most controversial. Ages of separate floristic assemblages, included in this flora, were estimated very differently. Assemblage from the Sagibovsky Boguchan was dated earlier than the Maastrichtian (Krassilov, 1976) or as the Turonian–Coniacian (Flora and dinosaurs..., 2001). The Pashkovo assemblage was dated as the late Albian based on palynological data (Flora and dinosaurs..., 2001) and as the late Albian–early Turonian based on plant megafossils (Kiriyanova, 1999). Age of the Yaurin and Obmany floristic assemblages was considered as late Turonian–Santonian (Kiriyanova, 2000). We estimate the age of the Sutara flora as the Turonian–Coniacian based on the similarity this flora with the Late Cretaceous floras of the Okhotsk-Chukotka volcanic belt, especially with the Coniacian Ul'ya flora. The known $^{40}Ar/^{39}Ar$ dates for these formations ranging from 101 to 99 Ma (Sorokin et al., 2005), that corresponds to the Albian-Cenomanian boundary (Geologic Time Scale..., 2020).

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PLATE I

The Sutara flora, Turonian–Coniacian, Amur Region, Russia

1 – undetermined fern, spec. BIN 1570, ×2; 2 – ***Elatocladus*** sp. 2, spec. BIN 1570, ×1; 3 – ***Taeniopteris*** sp., spec. KGI, ×1.


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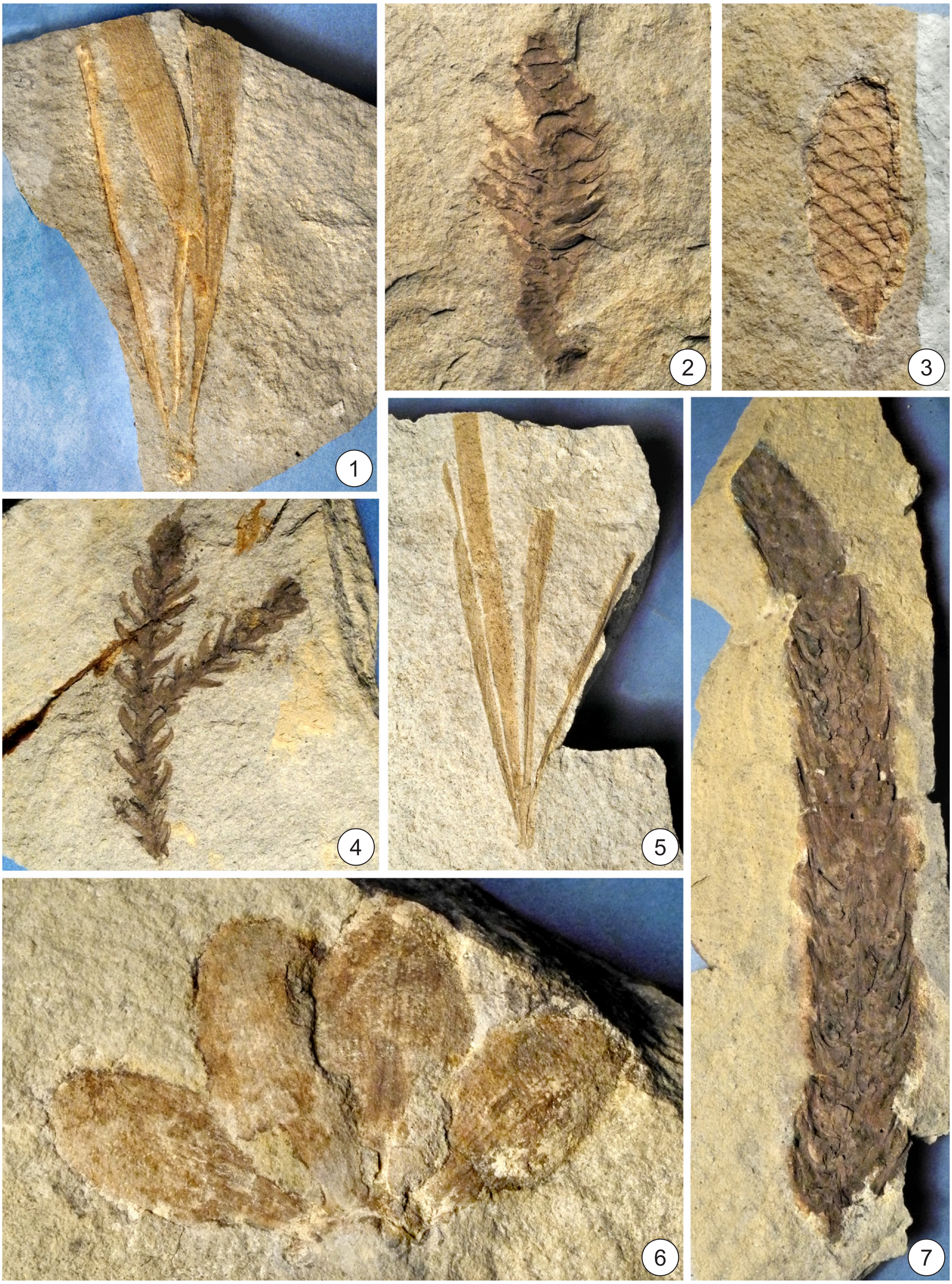
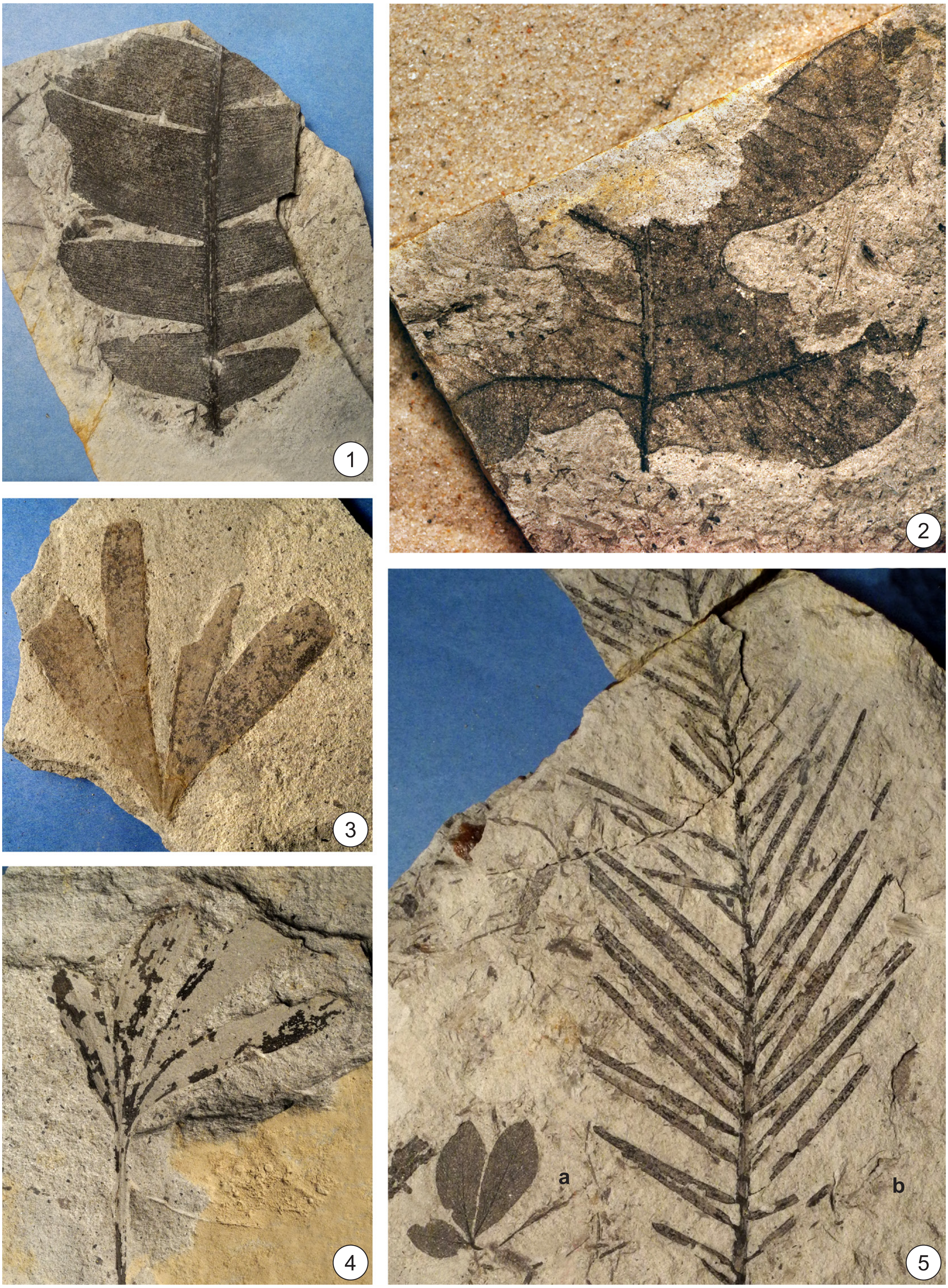


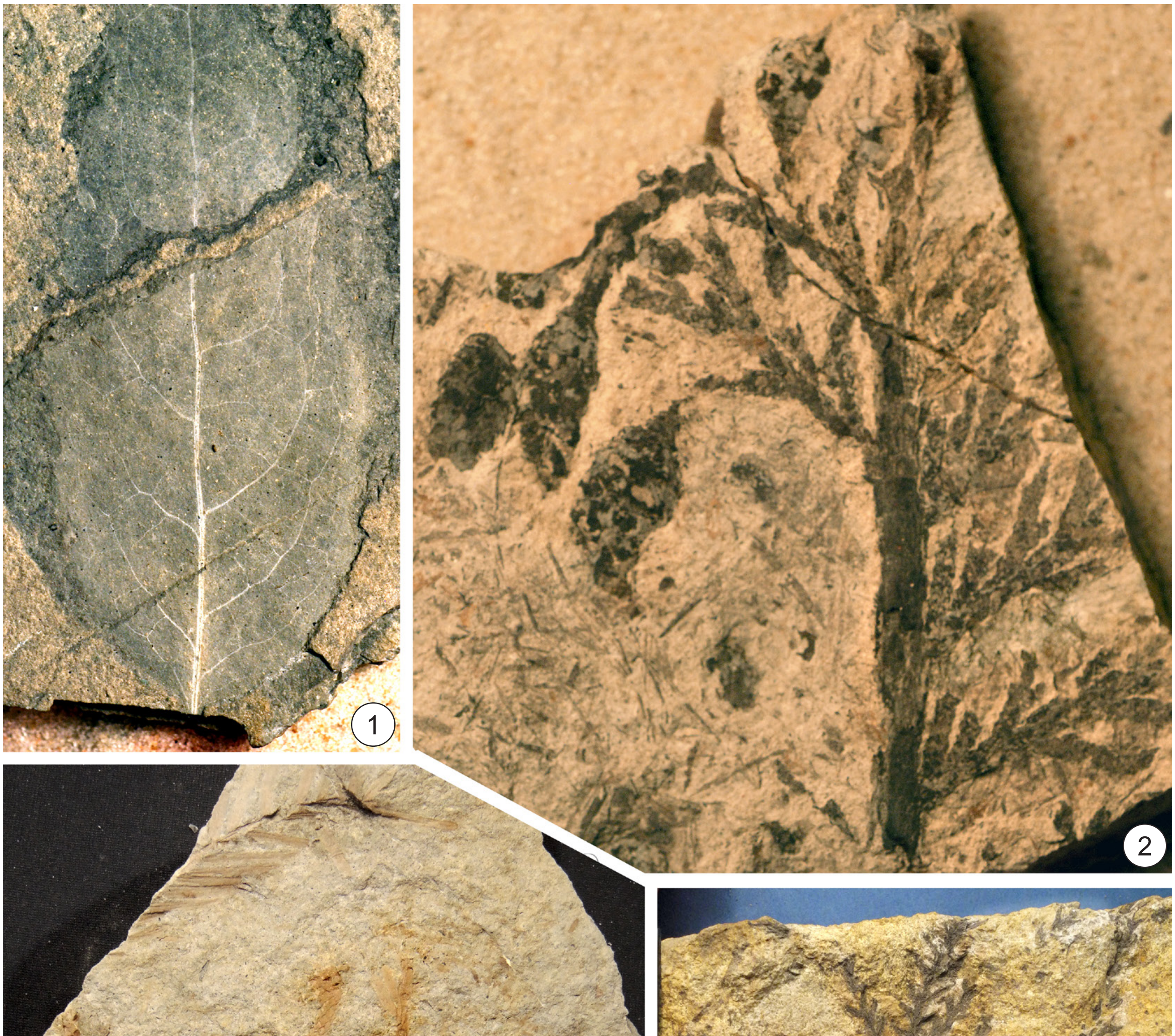
The Sutara flora, Turonian–Coniacian, Amur Region, Russia

1 – ***Sphenobaiera*** sp., spec. KGI, ×1; 2 – ***Pityostrobus*** sp. 1, spec. KGI, ×1; 3 – ***Pityostrobus*** sp. 2, spec. KGI, ×2; 4 – ***Elatocladus*** sp. 3, spec. KGI, ×1; 5 – ***Phoenicopsis*** sp., spec. KGI, ×1; 6 – ***Pityolepis*** sp., spec. KGI, ×2; 7 – ***Pityostrobus*** sp. 3, spec. KGI, ×1.



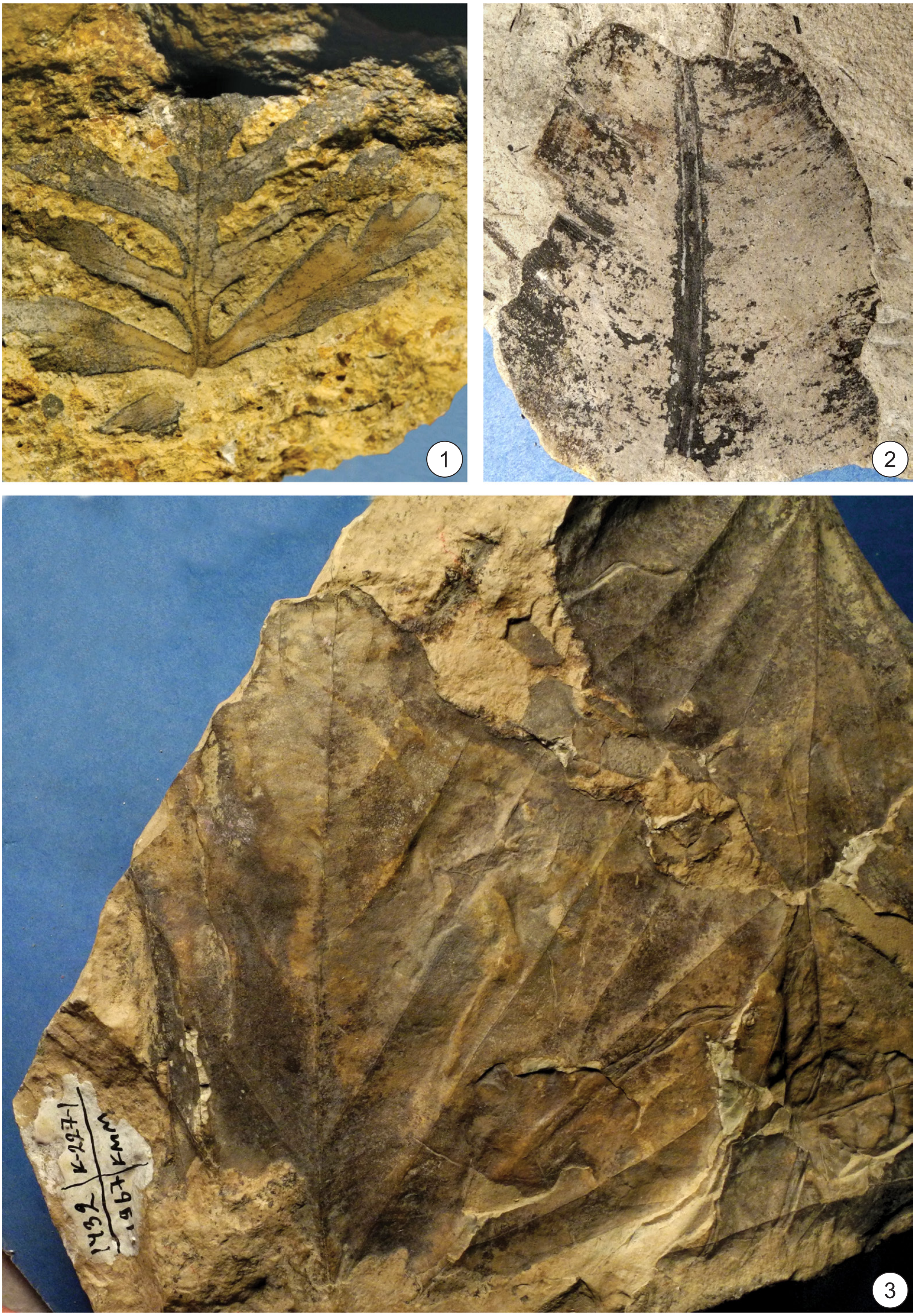
The Sutara flora, Turonian–Coniacian, Amur Region, Russia

1 – ***Nilssonia*** sp., spec. KGI, ×1; 2 – ***Dicotylophyllum*** sp. 1, spec. KGI, ×2; 3, 4 – ***Ginkgo*** ex gr. ***sibirica*** Heer, spec. KGI, ×1; 5a – ***Sagenopteris variabilis*** (Velen.) Velen., spec. KGI, ×1; 5b – ***Elatocladus*** sp. 4, spec. KGI, ×1.



The Sutara flora, Turonian–Coniacian, Amur Region, Russia

1 – ***Dicotylophyllum*** sp. 2, spec. KGI, ×2; 2 – ***Cupressinocladus*** sp. 1, spec. KGI, ×2; 3 – ***Pityocladus*** sp., spec. IBSS, ×1; 4 – ***Elatocladus*** sp. 5, spec. KGI, ×1.



The Sutara flora, Turonian–Coniacian, Amur Region, Russia
1 – ***Dicotylophyllum*** sp. 3, spec. KGI, ×2; 2 – ***Nilssonia*** sp., spec. KGI, ×2; 3 – ***Platanus*** sp., spec. KGI, ×1.

PLATE VI

Middle Kundur flora, Santonian, Amur Region, Russia

1, 2, 4 – ***Asplenium dicksonianum*** Heer: 1 – spec. BIN 1545-1, ×2; 2 – spec. BIN 1545-12, ×1,5; 4 – spec. BIN 1545-7, ×4.

3a – ***Sequoia*** sp., spec. BIN 1545-35a, ×1,3.

3b – ***Metasequoia*** sp., spec. BIN 1545-35b, ×1,3.

5 – ***Cobbania corrugata*** (Lesq.) Stockey, Rothwell et Johnson, spec. BIN 1545-64, ×2.

6 – ***Dicotylophyllum*** sp. 4, spec. BIN 1545-72, ×2.

7 – ***Sequoia*** sp., cone, spec. BIN 1545-36, ×2.

8 – ***Quereuxia angulata*** (Newb.) Krysht. ex Baik., leafleat, spec. GIN 1808-1, ×2.

9 – ***Equisetum*** sp., underground shoot, spec. BIN 1545-51, ×3.

10 – ***Trochodendroides lanceolata*** Golovn., Sun et Bugdaeva, spec. BIN 1545-94, ×3.

11 – ***Trochodendroides*** sp., leaf margin, spec. BIN 1545-99, ×2,5.

12 – ***Trochodendroides*** sp., spec. BIN 1545-69, ×2,5.

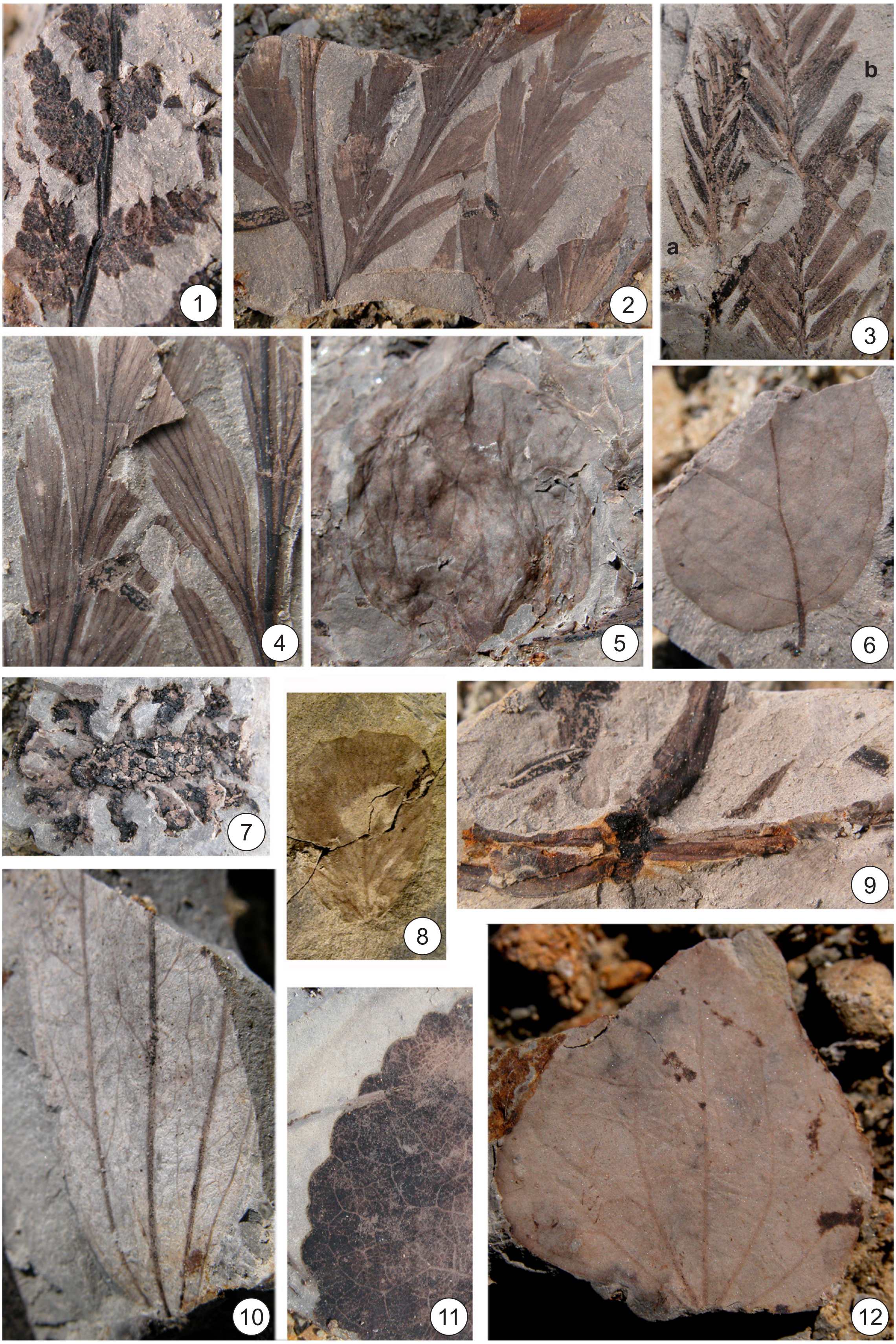

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PLATE VII

Late Kundur flora, Campanian, Amur Region, Russia

1 – ***Thallites*** sp. 2, spec. BIN 1538-16-150, ×3.
2, 3 – ***Coniopteris tschukschorum*** (Krysht.) Samyl.: 2 – spec. IBSS K16-1, ×1; spec. GIN K16(2)-28, ×1,5.
4 – ***Cladophlebis*** sp., spec. GIN K16(2)-22, ×1,5.
5 – ***Arctopteris*** sp., spec. GIN K16(2)-24, ×1,5.
6, 9 – ***Sequoia*** sp.: 6 – cone, spec. IBSS K16-2, ×0,8; 9 – shoot, spec. BIN 1538-16-159, ×1,3.
7 – ***Ginkgo pilifera*** Samyl., spec. IBSS K16-3, ×0,9.
8 – ***Cupressinocladus*** sp. 3, spec. GIN K16(2)-18, ×1,5.
10 – ***Pityospermum*** sp., spec. IBSS K16-4, ×2.
11 – ***Salvinia*** sp., spec. IBSS K16-4, ×2.
12, 13 – ***Kundurella amurensis*** Golovn.: 12 – spec. BIN 1538-16-160, ×1,2; 13 – spec. IBSS K16-5, ×1,2.
14, 15 – ***Metasequoia*** sp.: 14 – male cones, spec. BIN 1538-16-151, ×1,5; 15 – shoot, spec. BIN 1538-16-152, ×1,5.
16 – ***Elatocladus*** sp. 1, spec. BIN 1538-16-153, ×1,5.
17 – ***Elatocladus*** sp. 3, spec. BIN 1538-16-154, ×1.
18 – ***Taxodium*** sp., spec. GIN K16(2)-9, ×2.

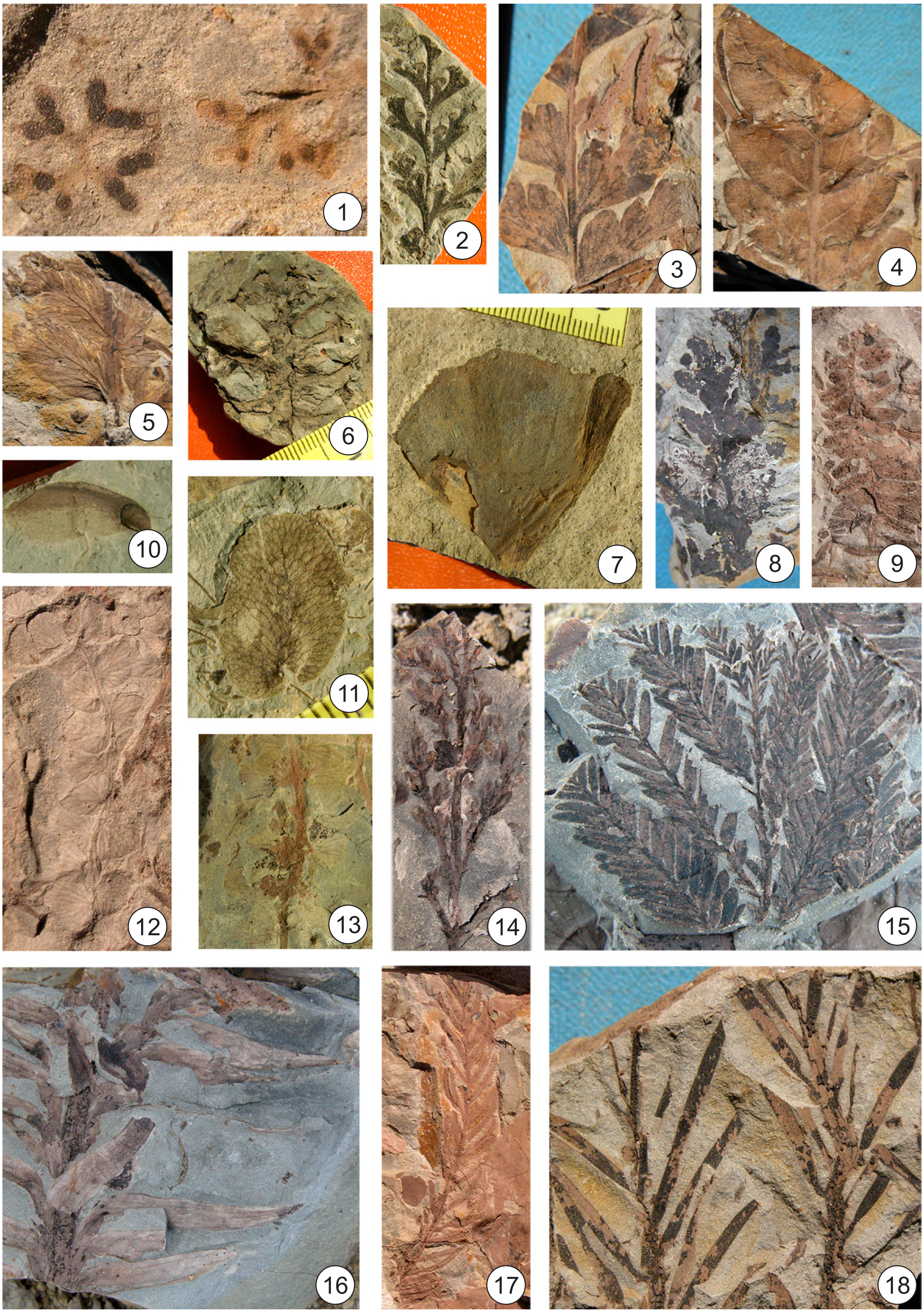
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PLATE VIII

Late Kundur flora, Campanian, Amur Region, Russia

1–3 – ***Arthollia tschernyschewii*** (Konstantov) Golovn., Sun et Bugdaeva: 1 – spec. IBSS K16-6, ×1; 2 – spec. BIN 1538-16-161, ×1; 3 – spec. BIN 1538-16-162, ×1.

4 – ***Trochodendroides lanceolata*** Golovn., Sun et Bugdaeva, spec. BIN 1538-16-158, ×1.

5 – ***Trochodendroides taipinglinchanica*** Golovn., Sun et Bugdaeva, spec. BIN 1538-16-157, ×1.

6 – ***Kundurianthus mirabilis*** Kodrul, N. Maslova, Tekleva et Golovn., spec. BIN 1538-16-385a, ×2.

7 – ***Kunduricarpus longistylium*** Kodrul, N. Maslova, Tekleva et Golovn., spec. BIN 1538-16-156, ×2.

8, 9 – platanoid leaves: 8 – spec. IBSS K16-6, ×1; 9 – spec. GIN K16(2)-7a, ×1.

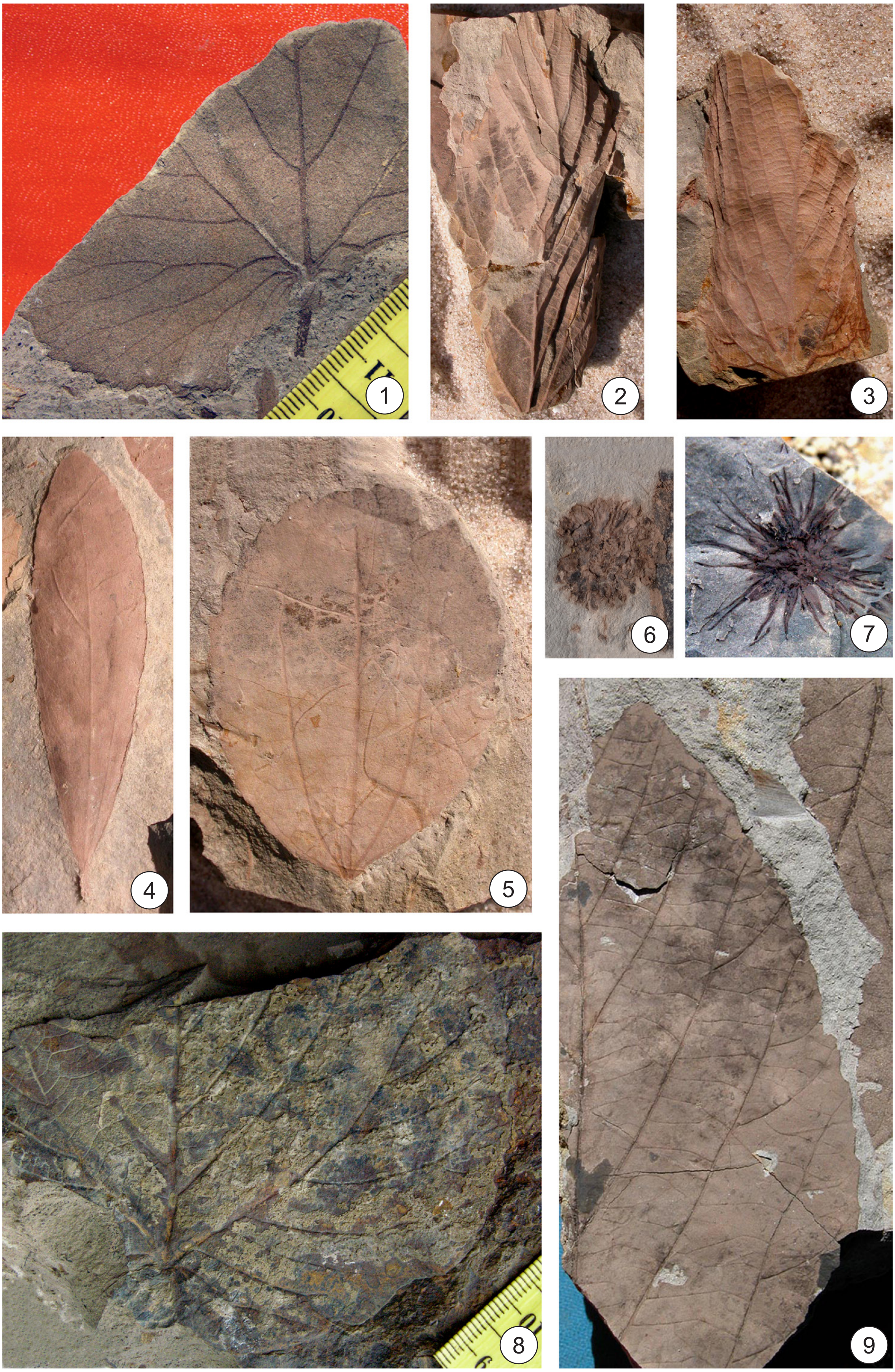
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PLATE IX

Late Kundur flora, Campanian, Amur Region, Russia

1, 5, 8, 9 – ***Cobbania corrugata*** (Lesq.) Stockey, Rothwell et Johnson: 1 – spec. GIN K16(2)-101, ×1,5; 5 – spec. GIN K16(3)-39, ×2; 8 – spec. GIN K16(3)-41(1), ×1,5; 9 – spec. GIN K16(3)-53, ×1,5.

2, 3 – ***Dicotylophyllum*** sp. 5: 2 – spec. IBSS K16-7, ×1; 3 – spec. IBSS K16-8, ×1.

4 – undetermined fruit, spec. BIN 1538-16-163, ×1,5.

6, 7 – ***Nelumbo*** sp.: 6 – petal, spec. IBSS K16-8, ×1,5; 7 – spec. IBSS K16-9, ×1,2.

10, 14 – ***Kunduriphyllum kundurense*** (Golovn., Sun et Bugdaeva) Kodrul et N. Maslova: 10 – spec. GIN K16(2)-40, ×1; 14 – spec. BIN 1538-16-108, ×1.

11–13 – ***Quereuxia angulata*** (Newb.) Krysht. ex Baik.: 11 – spec. GIN K16(3)-39, ×1,5; 12 – spec. GIN K16(3)-15, ×1,2; 13 – spec. GIN K16(3)-16, ×1,5.

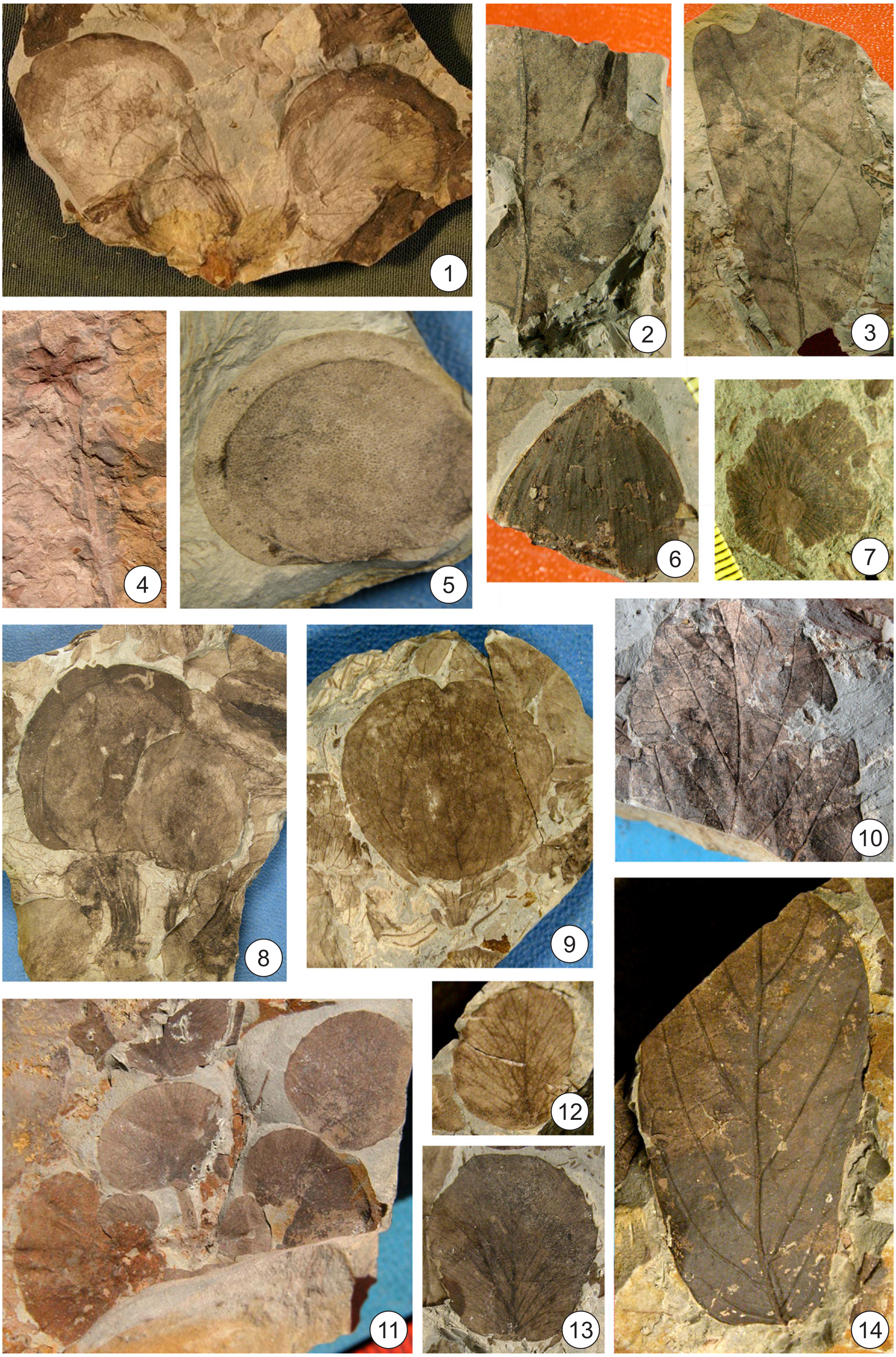
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PLATE X

The Bureya flora, Maastrichtian, Amur Region, Russia

1–15 – ***Leptotoma samylinae*** N. Nosova (after Nosova, 2010):

1–3 – leaf fragments: 1 – spec. BIN 824-1, holotype; 2 – spec. BIN 824-2; 3 – spec. BIN 824-3;
4–15 – structure of the epidermis, spec. BIN 824-1, holotype:
4, 5 – epidermis with stomata and sinuous anticlinal cell walls, SEM, inner view;
6, 7, 8 – stomata, SEM, outer view;
9 – upper epidermis and two lateral areas, crumpled into folds, LM;
10 – lower epidermis (lw) and two lateral areas(lt), crumpled into folds, LM;
11 – lower epidermis, SEM, inner view;
12 – lower (lw), lateral (lt) and upper (up) epidermis, LM;
13 – lower epidermis with stomata and sinuous anticlinal cell walls, LM;
14, 15 – stomata, LM.

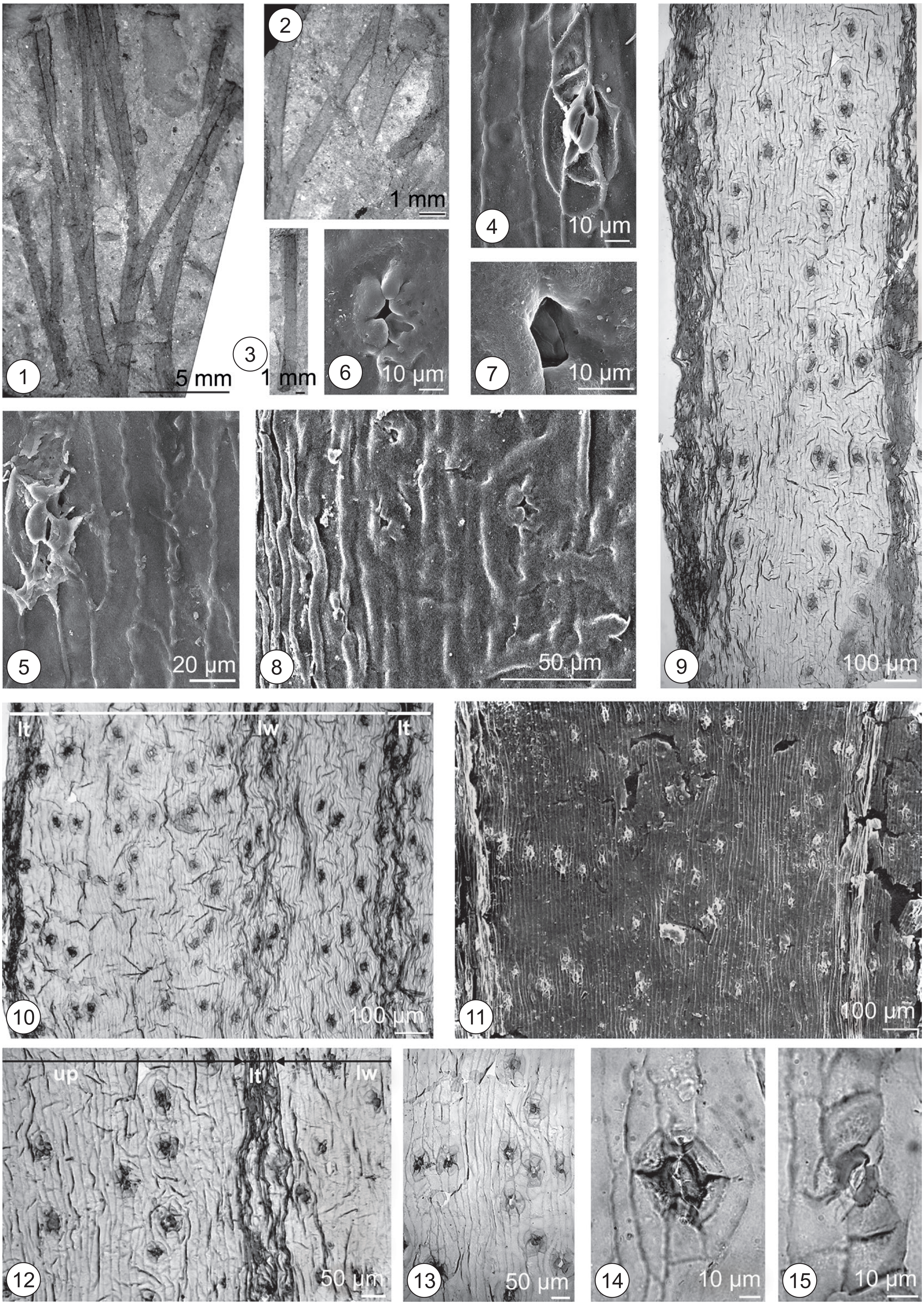
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PLATE XI

Yong’ancun flora, Santonian, Heilongjiang Province, China

1 – ***Asplenium dicksonianum*** Heer, spec. RCSP YN2-187, ×1,3.

2 – ***Salvinia*** sp., spec. RCSP YN1-125, ×3,5.

3, 4 – ***Taxodium*** sp.: 3 – spec. RCSP YN1-126, ×1; 4 – spec. RCSP YN2-180, ×1.

5 – ***Sequoia*** sp., spec. RCSP YN2-149, ×1,5.

6 – ***Metasequoia*** sp., spec. RCSP YN2-155, ×1,5.

7, 11, 15 – ***Trochodendroides*** sp.: 7 – spec. RCSP YN2-114, ×1; 11 – spec. RCSP YN2-202, ×1; 12 – spec. RCSP YN3-66, ×1.

8 – ***Pityospermum*** sp., spec. RCSP YN1-187, ×1,5.

9 – ***Cupressinocladus*** sp 1., spec. RCSP YN1-61, ×1,7.

10, 13 – ***Quereuxia angulata*** (Newb.) Krysht. ex Baik.: 10 – spec. RCSP YN1-6, ×2; 13 – spec. RCSP YN1-16, ×2.

12 – ***Jenkinsella*** sp., spec. RCSP YN1-107, ×1,5.

14 – ***Trochodendroides lanceolata*** Golovn., Sun et Bugdaeva, spec. RCSP YN2-135, ×1,5.

PLATE XI

PLATE XII

Yong'ancun flora, Santonian, Heilongjiang Province, China

1–7 – ***Dalembia jiayinensis*** Sun et Golovn.:

1 – trilobate apical leaflet, spec. PMOL YX-007, ×1;
2 – compound leaf with five leaflets, spec. PMOL YX-121, holotype, ×1;
3 – small leaflet with undulate margin, spec. PMOL YX-020, ×1;
4 – leaflet with truncate base, spec. PMOL YX-021, ×1;
5 – small leaflet with lobe-like teeth, spec. PMOL YX-005, ×1;
6 – trilobate apical leaflet, spec. PMOL YX-008, ×1;
7 – pinnately-lobed apical leaflet, spec. PMOL YX-213, ×1.

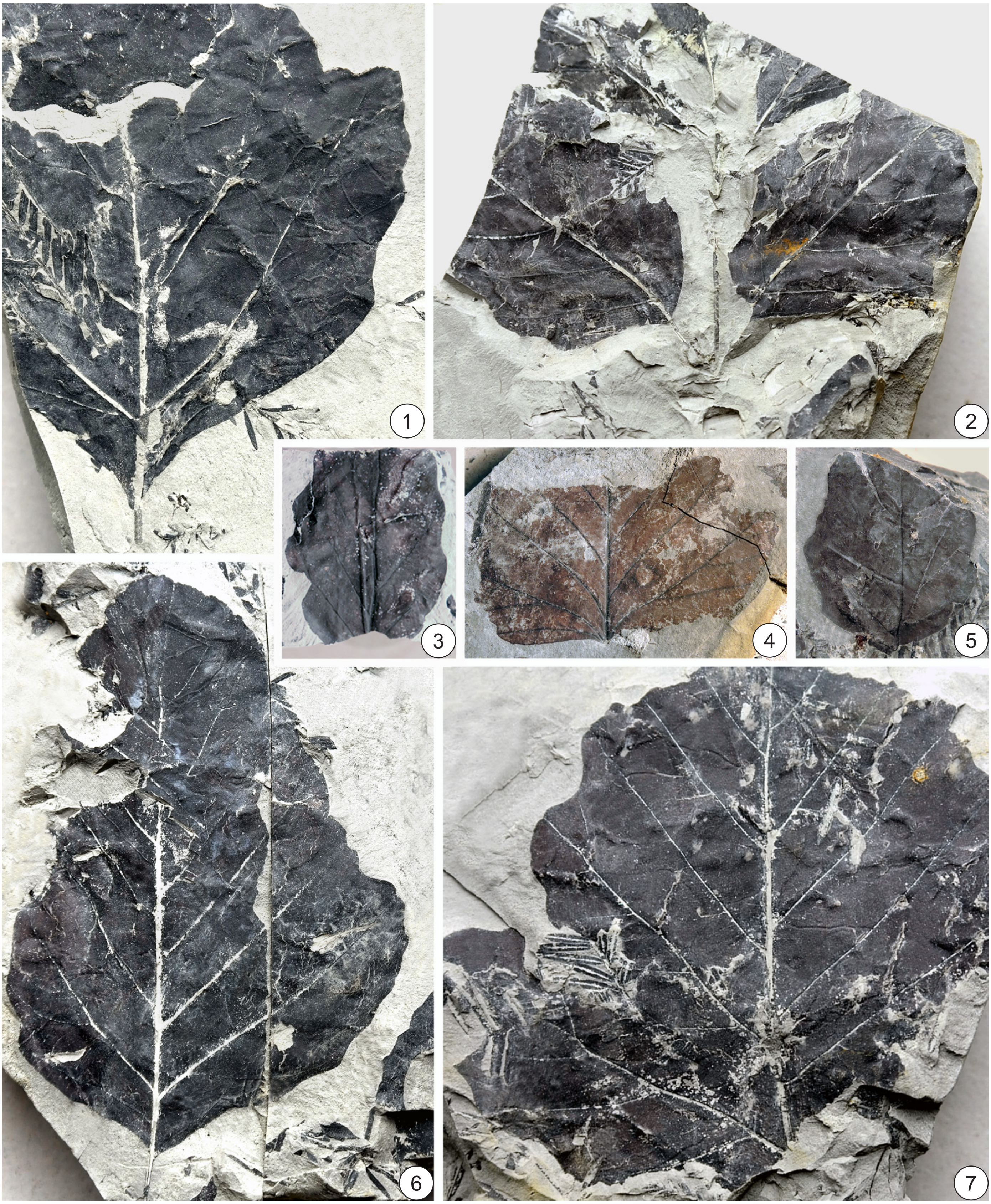
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PLATE XIII

Taipinglinchang flora, Campanian, Heilongjiang Province, China

1 – ***Thallites*** sp. 1, spec. RCPS TP2-26, ×1,3.

2 – ***Equisetum*** sp., spec. RCPS TP2-210, ×1.

3 – ***Arctopteris*** sp., spec. RCPS TP2-75, ×1.

4, 5 – ***Asplenium dicksonianum*** Heer: 4 – spec. RCPS TP2-74, ×1,8; 5 – spec. RCPS YQ-9, ×2.

6 – ***Dammarites*** sp., spec. RCPS TP2-149, ×2.

7 – ***Pityospermum*** sp., spec. RCPS TP2-305, ×2.

8, 20 – ***Glyptostrobus*** sp.: 8 – cone scale, spec. RCPS TP2-217, ×2; 20 – shoot, spec. RCPS TP2-125, ×1.

9, 25 – ***Elatocladus*** sp. 6: 9 – spec. RCPS TP2-221, ×1,3; 25 – spec. RCPS TP2-246, ×1,5.

10, 11 – ***Ginkgo pilifera*** Samyl.: 10 – spec. RCPS TP2-140, ×1; 11 – spec. RCPS TP2-136, ×1.

12, 13, 27 – ***Elatocladus*** sp. 7: 12 – spec. RCPS TP2-273, ×1; 13 – spec. RCPS TP2-103, ×1; 27 – spec. RCPS TP2-143a, ×1,5.

14, 22 – ***Taxodium*** sp.: 14 – spec. RCPS TP1-169, ×1; 22 – spec. RCPS TP2-263, ×1.

15, 19, 21 – ***Sequoia*** sp.: 15 – spec. RCPS TP2-100, ×1; 19 – spec. RCPS TP2-126, ×1; 21 – spec. RCPS TP2-101, ×1,3.

16 – ***Metasequoia*** sp., spec. RCPS TP2-222, ×1.

17 – ***Larix*** sp., shoot with leaves, spec. RCPS TP2-105, ×1.

18, 23, 24 – ***Cupressinocladus*** sp. 2: 18 – spec. RCPS TP2-234, ×1,5; 23 – spec. RCPS TP2-144, ×1,7; 24 – spec. RCPS TP2-232, ×2.

26 – ***Pityophyllum*** sp., spec. RCPS TP2-209, ×1.

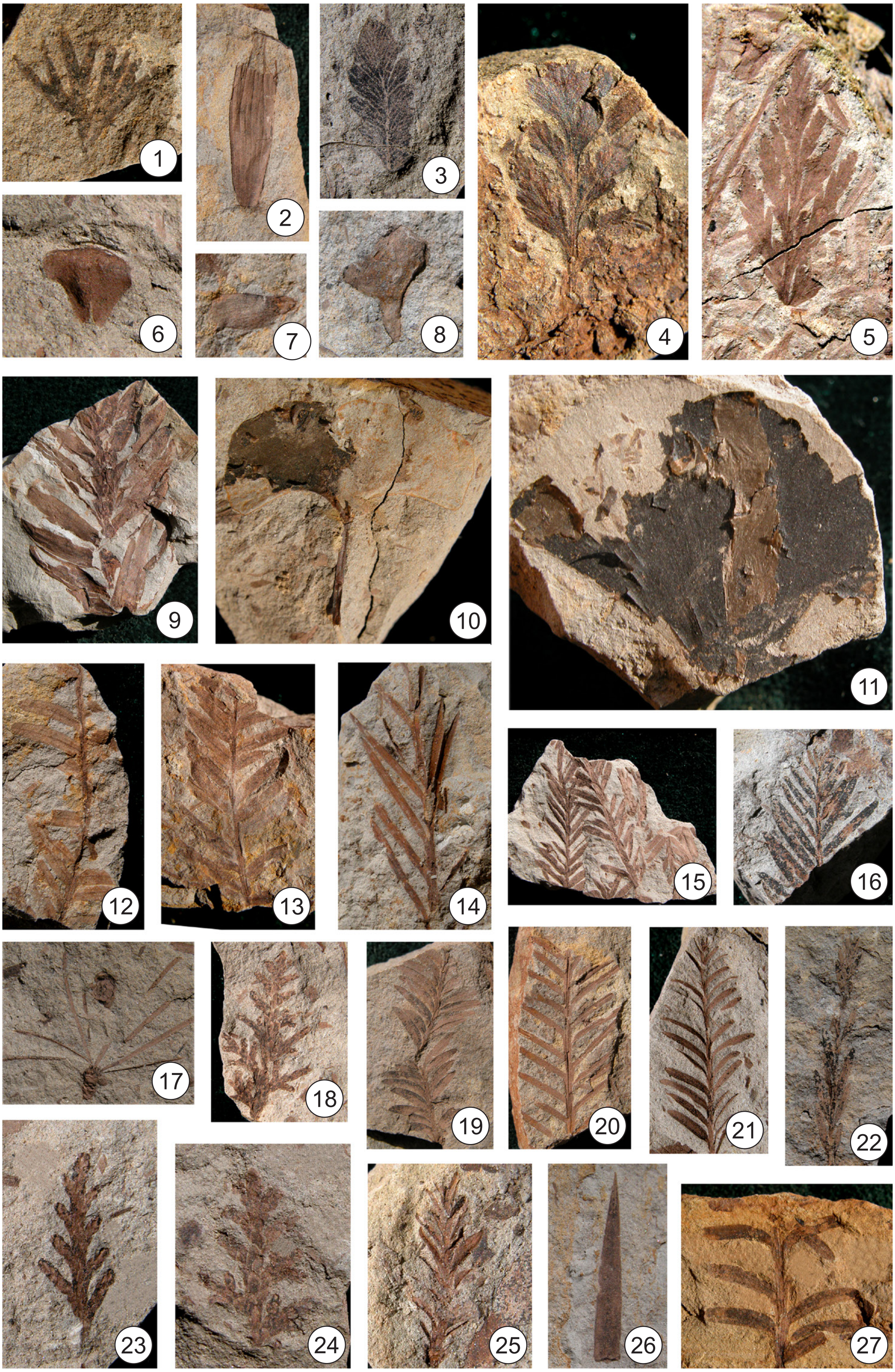
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PLATE XIV

Taipinglinchang flora, Campanian, Heilongjiang Province, China

1–4 – ***Kunduriphyllum kundurense*** (Golovn., Sun et Bugdaeva) Kodrul et N. Maslova: 1 – spec. RCPS TP2-113, ×1; 2 – spec. RCPS TP2-120, ×1; 3 – spec. RCPS TP2-114, ×1; 4 – spec. RCPS TP2-5.

5 – ***Arthollia tschernyschewii*** (Konstantov) Golovn., Sun et Bugdaeva, spec. RCPS TP2-122, ×1.

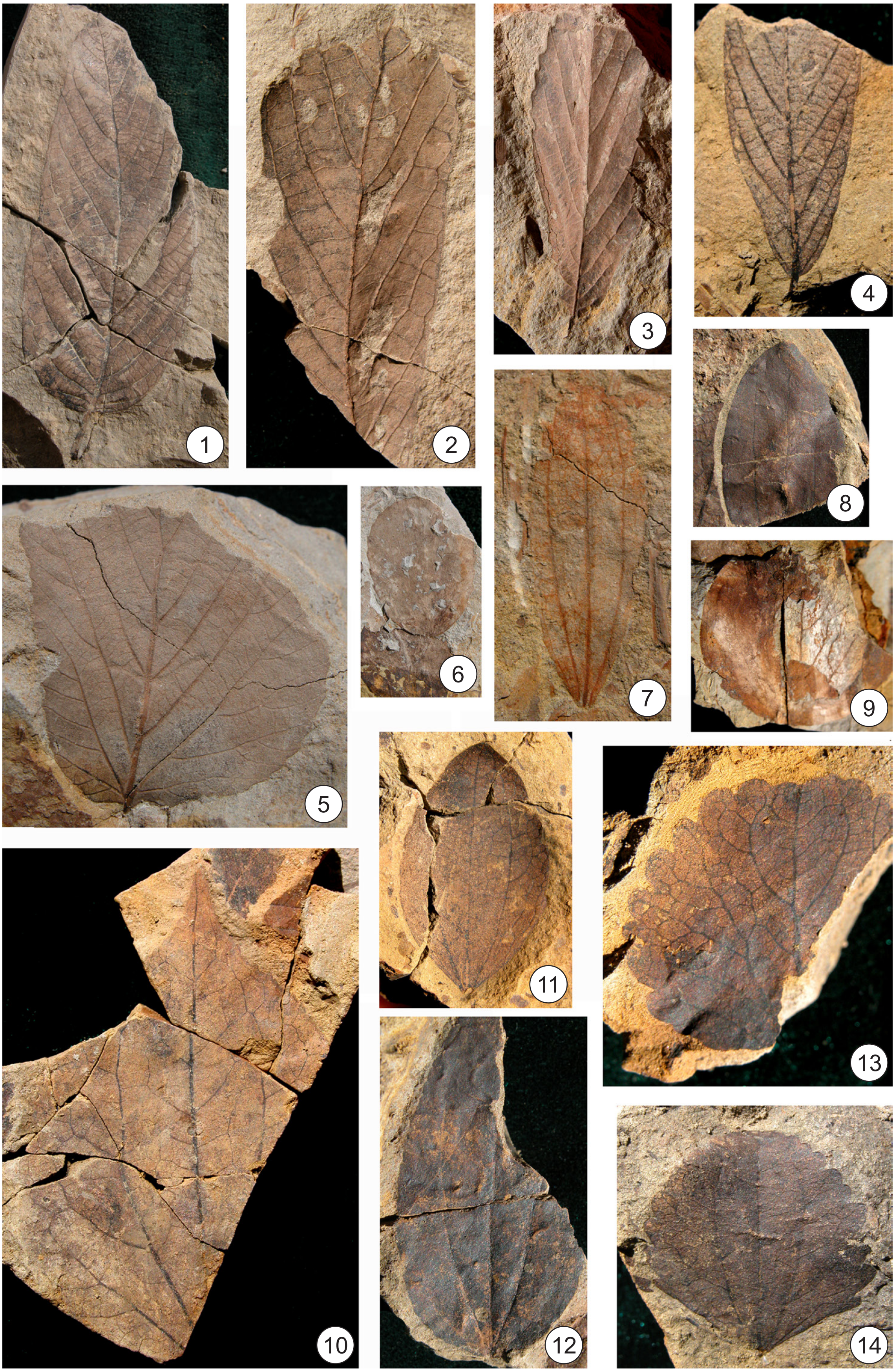
6 – ***Quereuxia angulata*** (Newb.) Krysht. ex Baik., spec. RCPS-TP1-200, ×0,8.

7, 8, 11, 12 – ***Trochodendroides lanceolata*** Golovn., Sun et Bugdaeva: 7 – spec. RCPS YQ-1, ×1,5; 8 – spec. RCPS TP2-44, ×1; 11 – spec. RCPS TP2-38. ×1; 12 – spec. RCPS TP2-46, ×1.

9 – ***Cobbania corrugata*** (Lesq.) Stockey, Rothwell et Johnson, spec. RCPS TP2-62, ×1.

10 – ***Trochodendroides microdentata*** Golovn., Sun et Bugdaeva, spec. RCPS TP2-39, ×1.

13, 14 – ***Trochodendroides taipinglinchanica*** Golovn., Sun et Bugdaeva: 13 – spec. RCPS TP2-31, ×2; 14 – spec. RCPS TP2-26.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