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The morphological diversity and distribution of the genus *Menispermites* (Magnoliopsida) in the Cretaceous of Northern Asia

A.A. Zolina, L.B. Golovneva, and A.A. Grabovskiy

ABSTRACT

Eleven species of *Menispermites* from Kazakhstan, Siberia, North-East of Russia and Sakhalin distributed from the upper Albian up to Maastrichtian–Danian were restudied based on original materials and published data to analyze their morphological diversity and stratigraphic and geographical occurrence. English diagnoses of five species are presented for the first time. A new species, *M. temlyanensis* Zolina, Golovneva et Grabovskiy, sp. nov. from the Maastrichtian–Danian Tanyurer Formation of Chukotka is described. The greatest number of species is confined to the North-East of Russia. In this territory, short-lived species with limited ranges predominated. *M. sibiricus* had the widest geographical and stratigraphic range: from Kazakhstan to Chukotka and from the Cenomanian to Coniacian. In other regions of Northern Asia, the stratigraphic distribution of *Menispermites* was limited. In Kazakhstan and Siberia, it is known from the Cenomanian to Turonian. On Sakhalin, *Menispermites* was recorded from the Campanian to the Maastrictian–Danian. The greatest number of species and morphological diversity of *Menispermites* occured in the Cenomanian–Turonian of the North-East of Russia.

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Keywords: new species; *Menispermites*; Menispermaceae; Ranunculales; North-East of Russia; paleogeography

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INTRODUCTION

The genus *Menispermites* Lesquereux was described from the Albian–Cenomanian Dakota Formation, USA (Lesquereux, 1874). The leaves are characterized by lobate or unlobate, usually peltate leaves with actinodromous venation and numerous primary veins. *Menispermites* originally included three species (Lesquereux, 1874). One of them, *M. obtusilobus* Lesquereux, was chosen later as a type species (Knowlton, 1919). This species has broadly ovate, trilobate peltate leaves with obtuse apex, low pelta, truncate base and crenate margin.

Menispermites were widely distributed in the Late Cretaceous and Paleogene. Nowadays this genus includes more than 30 fossil species. About 15 of them are known from North and South America (Lesquereux, 1874, 1892; Hollick, 1930; Berry, 1916; Hollick, 1930; Bell, 1956, 1962; Doyle and Hickey, 1976; Doria, et al., 2008; Guzmán-Vázquez et al., 2018; Del Rio et al., 2021). In the Upper Cretaceous deposits of Europe, the genus was represented by *M. summesbergeri* Herman et J. Kvaček from the lower Campanian Grünbach Formation (Herman and Kvaček, 2010). More than 10 species were described from Northern Asia (Vachrameev, 1952; Kryshtofovich and Baikovskaya, 1960; Budantsev, 1968; Zhilin, 1974; Krassilov, 1979; Shilin, 1986; Herman and Lebedev, 1991; Philippova and Abramova, 1993; Golovneva, 2006; Golovneva et al., 2011; Moiseeva, 2014; Golovneva, 2019). The greatest number of *Menispermites* species comes from the Albian and Cenomanian. The latest Cretaceous and Paleogene representatives are less numerous.

Menispermites have a significant morphological resemblance to leaves of modern genus *Menispermum L.* (Menispermaceae, Ranunculales), that are characterized by a mostly entire margin, actinodromous primary and brochidodromous secondary venation (Ortiz et al., 2007; Doria et al., 2008).

The oldest clearly attributed fossil evidence of Menispermaceae is an endocarp of the extant genus *Stephania* Loureiro found in the lower Paleocene of Patagonia (Jud et al., 2018). Endocarps of different Menispermaceae *(Stephania, Palaeosinomenium* Chandler and *Tinospora* Miers) were also found in the lower Paleocene of Paris Basin, Europe (Kara et al., 2023). Since the Eocene, endocarps of Menispermaceae are abundant in Europe and North America (Chandler, 1964; Collinson, 1983; Manchester, 1994; Mai, 1995; Jacques and De Franceschi, 2005). The earliest record, which was interpreted as Menispermaceae wood, comes from the latest Cretaceous–early Paleocene Deccan Intertrappean beds, India (Bonde, 1997). This material is characterized by alternating rings of phloem and xylem that resemble modern lianas.

Therefore, the Paleogene records of *Menispermites* are usually assigned to the family Menispermaceae and this attribution is confirmed by findings of corresponding reproductive structures in the same deposits (Doria, et al., 2008; Guzmán-Vázquez et al., 2018; Del Rio et al., 2021). But the attribution of Cretaceous finds of *Menispermites* to Menispermaceae is debatable. Indeed, the leaves of *Menispermites* are also similar to leaves of some modern representatives of Nymphaeaceae and Piperaceae. However, the Cretaceous representatives of these families differ rather well from *Menispermites*. Besides, the relationships of the Cretaceous finds with modern families Nymphaeaceae and Piperaceae is also questionable, as is the relationships of *Menispermites* and Menispermaceae. Thus, some authors consider *Menispermites* as a morphological taxon of unclear systematic position (Herman et al., 2016).

The first endocarps with affinity to Menispermaceae were recorded from the Turonian of Europe (Knobloch and Mai, 1984) and were attributed to the genus *Prototinomiscium* Knobloch et Mai. However, endocarps of *Prototinomiscium* do not have a well-developed condyle, and this makes the assignment of this genus to Menispermaceae doubtful (Herrera et al., 2011; Wefferling et al., 2013).

Actually, many Cretaceous genera have characters that preclude their direct assignment to the extant families. For example, small actinomorphic pistillate flowers of *Callicrypta chlamydea* Krassilov et Golovneva from the Cenomanian Timmerdyakh Formation of the Lena-Vilyui depression are characterized by a significant similarity to the flowers of Menispermaceae but also share diagnostic features with several other ranunculid families (Krassilov and Golovneva, 2004). Floral and fruit morphology of the early eudicot *Ranunculaecarpus quinquecarpellatus* Samylina from the lower-middle Albian Buor-Kemyus Formation of the North-East of Russia support possible affinity of this species to extant Ranunculaceae, but it is distinguished from modern members of the family by some features of the perianth and pollen (Manchester et al., 2018).

Similarity of *Menispermites* with Menispermaceae in leaf morphology and association of Paleo-

gene representatives of *Menispermites* with reproductive structures of Menispermaceae suggest that the Cretaceous representatives of this genus could also be related to ancestral forms of Menispermaceae. Their detailed study could allow us to consider their taxonomic affinity more precisely. Unfortunately, many Cretaceous species, especially from North America, are represented by fragmentary material, have nomenclature problems and need reinvestigation. The Cretaceous records of *Menispermites* from Northern Asia are represented by numerous whole leaves. In this paper, we attempt to analyze changes in the morphological diversity and stratigraphic and geographical distribution of the genus *Menispermites* at the end of the Early Cretaceous and during the Late Cretaceous. In addition, we describe a new species, *M. temlyanensis* Zolina, Golovneva et Grabovskiy, sp. nov. from the Maastrichtian–Danian Tanyurer Formation of Chukotka.

MATERIAL AND METHODS

Species of *Menispermites* from Northern Asia were restudied based on original material and published data. Full and abbreviated names of institutions, where studied specimens of *Menispermites* are stored, are given in Table 1, and all localities are shown in Figure 1.

Four species of *Menispermites* come from the upper Albian–lower Turonian Krivorechenskaya Formation, Grebenka River, Anadyr River basin (Philippova and Abramova, 1993; Golovneva et al., 2015): *M. minutus* (Kryshtofovich) Shczepetov, Herman et Belaya, *M. vasetskii* Philippova, *M. marcovoensis* Philippova, and *M. orientalis* Golovneva. The last species was also found in the upper Turonian–Coniacian Zarya and Arman formations of the Magadan Region, and in the lower Coniacian Poperechnenskaya Formation, Pekulney Ridge, Chukotka (Philippova, 2010; Golovneva et al., 2015).

M. ginterensis Herman is present in the Cenomanian Ginter Formation in the northeastern part of the Koryak Upland (Herman, 1988; Moiseeva, 2010).

Leaves of *M. sibiricus* (Heer) Golovneva were originally described from the Cenomanian–Turonian Simonovo Formation of Eastern Siberia under the name *Acer sibiricum* Heer (Heer, 1878; Golovneva, 2006; Golovneva and Nosova, 2012). Later, this species was also found in the Cenomanian Timmerdyakh Formation of the Lena-Vilyui depression (Golovneva, 2006), in the Cenomanian Altykuduk Formation and in the Turonian Zhirkindek Formation of Kazakhstan (Vachrameev, 1952; Shilin, 1986; Golovneva, 2006), in the upper Turonian–Coniacian Valizhgen Formation of northwestern Kamchatka (Herman and Lebedev, 1991), and in the upper Turonian–Coniacian Chingandzha and Arman formations of the Magadan Region (Golovneva et al., 2011; Herman et al., 2016; Golovneva, 2019), In this paper, we also referred to this species leaves from the Coniacian Poperechnenskaya Formation.

Two species of *Menispermites* were described from Sakhalin Island. *M. sachalinensis* Kryshtofovich ex Zhilin comes from the Campanian Zhonk'er Formation (Kryshtofovich and Baikovskaya, 1960; Zhilin, 1974; Krassilov, 1979). *M. favosus* Krassilov was reported from the Maastrichtian–Danian Boshnyakovo Formation (Vachrameev, 1966; Krassilov, 1979).

TABLE 1. Names of institutions, in which studied material are stored.

Abbreviation	Institute	City
BIN	Komarov Botanical Institute, Russian Academy of Sciences	Saint Petersburg
GIN	Geological Institute, Russian Academy of Sciences	Moscow
FSCEATB, (previously IBSS)	Federal Scientific Center of the East Asia Terrestrial Biodiversity, Far East Branch, Russian Academy of Sciences	Vladivostok
IBP	Institute of Botany and Phytointroduction	Astana
IUT	Industrial University of Tyumen	Tyumen
NEISRI	The North-East Interdisciplinary Research Institute, Far East Branch, Russian Academy of Sciences	Magadan
TFGI	Geological Museum of the Territorial Fund of Geological Information for the Far Eastern District Branch	Magadan
TPU	Tomsk Polytechnic University	Tomsk
TSNIGRM	F. N. Chernyshev Central Scientific Research Geological Survey Museum	Saint Petersburg

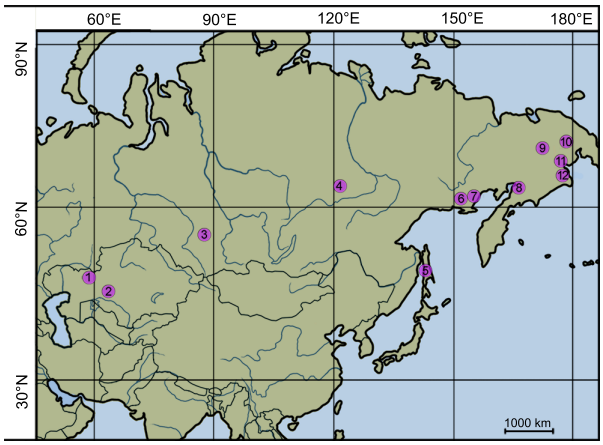

FIGURE 1. Distribution of the genus *Menispermites* in Northern Asia: 1, 2 – Altykuduk Formation; 3 – Simonovo Formation; 4 – Timmerdyakh Formation; 5 – Zhonk'er and Boshnyakovo formations; 6 – Arman Formation; 7 – Chingandzha Formation; 8 – Valizhgen Formation; 9 – Krivorechenskaya, Zarya and Poperechnenskaya formations; 10 – Emuneret Formation; 11 – Tanyurer Formation; 12 – Barykov and Ginter formations.

M. lebedevii Moiseeva comes from the Santonian–Campanian Emuneret Formation, Enmyvaam River, Chukotka. A leaf fragment of *Menispermites*, described as *M. cf. sachalinensis* (Moiseeva and Sokolova, 2007) was found from the Campanian Barykov Formation of the Ugolnaya Bay, North-East of Russia.

Leaves of the new species, *M. temlyanensis,* sp. nov., were collected by A. Grabovskiy from the Tanyurer Formation, distributed in the northern part of the Pekulney Ridge and between the Pekulney Ridge and the Zolotoy Ridge near Anadyr town, Chukotka. This formation is 550–2200 m thick and consists of andesites, pyroxene and olivine basalts, tuffs and volcano-sedimentary deposits (Zvizda et al., 1974). In the lower part of the section, there are beds of conglomerates with interlayers of coaly siltstones and grey sandstones. Plant fossils are confined to the volcano-sedimentary layers in the base of the Tanyurer Formation, which are exposed in the road quarry near Ugolnye Kopi settlement (Figure 2).

The meaning of Latin abbreviations using in chapter “Systematic Palaeontology” is given in Table 2. The terminology follows Ellis et al. (2009), except we use 'entire' in the sense of being unlobed. Photographs of the specimens were made using a Canon 6D camera with low angle illumination.

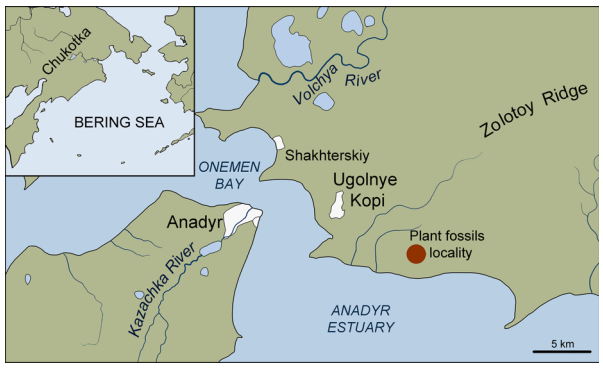

FIGURE 2. Locality of *Menispermites temlyanensis* Zolina, Golovneva et Grabovskiy, *sp. nov.* in the territory of Anadyr district, Chukotka.

TABLE 2. The meaning of Latin abbreviations in the systematic chapter.

Abbreviation	Meaning
non rite publ.	not correctly published
auct. non	not by authors
designat. typi omissa	type designation missing
cf.	similar
ex gr.	from the group

Registry

New species name *Menispermites temlyanensis* Zolina, Golovneva et Grabovskiy, described in this paper, is registered with a unique PFN number in the Plant Fossil Names Registry, hosted and operated by the National Museum, Prague for the International Organisation of Palaeobotany.

SYSTEMATIC PALAEONTOLOGY

Class MAGNOLIOPSIDA Brongniart, 1843
MAGNOLIOPSIDA incertae sedis
Genus *MENISPERMITES* Lesquereux, 1874
Menispermites sibiricus (Heer) Golovneva
Figure 3A–G, Figure 4E

1878 *Acer sibiricum* Heer, p. 46, pl. 10, figure 4b, 5a, pl. 12, figure 1b.

1878 *Nymphaeites tener* Heer, p. 44, pl. 13, figure 7.

1952 *Menispermites kryshtofovichii* Vachrameev, p. 194, pl. 14, figure 5, 6, pl. 15, figure 6, text-figure 41.

1955a *Menispermites sibiricus* (Heer) I. Lebedev non rite publ., p. 199, pl. 30, figure 1.

1955b *Cissites sibirensis* I. Lebedev, p. 203, pl. 31, figure 4.

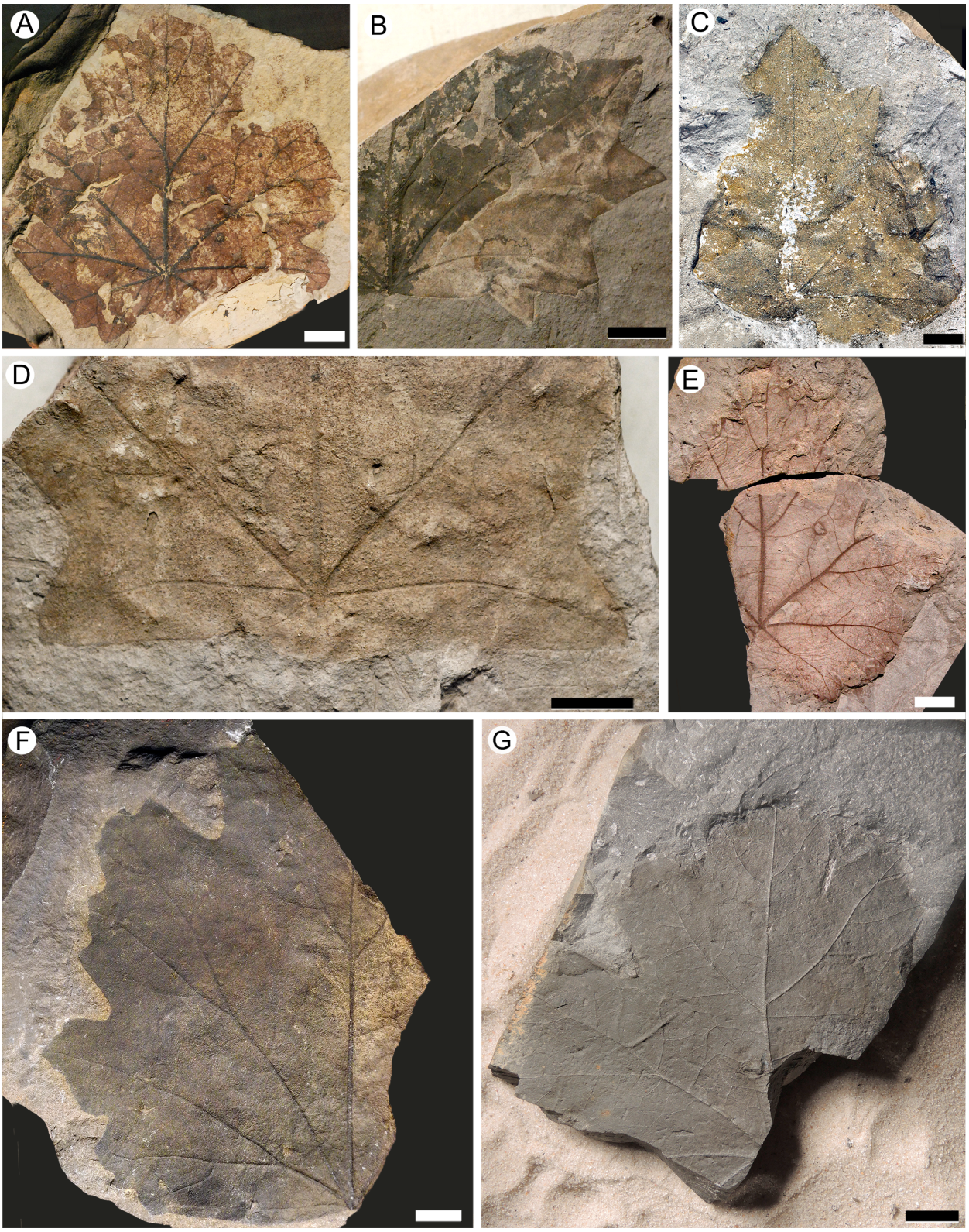

FIGURE 3. *Menispermites sibiricus* (Heer) Golovneva (A–D – Simonovo Formation, Cenomanian-Turonian; E – Altykuduk Formation, upper Albian-Cenomanian; F – Poperechnenskaya Formation, Coniacian; G – Chingandzha Formation, upper Turonian– Coniacian): A – spec. TPU 29/3; B – spec. IUT 252; C – spec. GIN 1800/11, lectotype; D – spec. IUT 245; E – spec. IBP 313/452; F – spec. TFGI 63/1; G – BIN 1565/383. Scale bar is 1 cm.

1962 *Menispermites sibiricus* (Heer) I. Lebedev non rite publ. p. 258, pl. 49, figure 1.

1962 *Menispermites simonovskiensis* I. Lebedev, p. 258, pl. 65, figure 2.

1962 *Menispermites tschulimensis* I. Lebedev, p. 258, pl. 49, figure 5.

1968 *Menispermites ribesifolius* Budantsev, p. 11, pl. 2, figure 3.

1968 *Menispermites stellatus* Budantsev, p. 12, pl. 2, figure 4.

1974 *Menispermites kryshtofovichii* Zhilin, p. 99, pl. 37, figure 5, pl. 40, figure 7.

1974 *Protoacerophyllum sibiricum* (Heer) Iljinskaja, p. 151, text-figure 96, figure 4.

1975 *Menispermites* sp., Philippova, p. 64, pl. 9, fig. 1; text-figure 3.

1986 *Menispermites kryshtofovichii* Shilin, pl. 8, figure 2, 4, pl. 9, figure 1.

1986 *Menispermites syrdariensis* Shilin, p. 113, pl. 9, figure 3, pl. 10, figure 4.

1991 *Menispermites kryshtofovichii* Vachrameev; Herman and Lebedev, p. 67, pl. 2, figure 5, text-figure 13.

2006 *Menispermites sibiricus* (Heer) Golovneva, p. 1733, pl. 1, figure 1–3; 2010 *Cissites* cf. *inscissus auct. non* Herman; Philippova, pl. 28, figure 2.

2012 *Menispermites sibiricus* (Heer) Golovneva; Golovneva and Nosova, p. 115, pl. 43, figure 1–7, pl. 84, figure 5–9, text-figure 8.1, 8.2.

2016 *Menispermites sibiricus* (Heer) Golovneva; Herman et al., p. 727, pl. 23, figure 10, 11, text-figure 18.

2019 *Menispermites sibiricus* (Heer) Golovneva, p. 66, pl. 41, figure 1–5.

Lectotype (designated by Golovneva, 2006). Specimen GIN 1800/11, Eastern Siberia, Chulym River basin, Simonovo Formation, Cenomanian–Turonian; figure 3C.

Diagnosis (Golovneva, 2006). Leaves rounded or broadly ovate in outline, usually broader than long, 3–7 lobate or entire, with peltate, rounded, cordate or truncate base and broadly triangular obtuse apex; lobes radially divergent, decreasing downwards, with additional secondary lobes or lobe-like teeth, which are rounded or triangular with obtuse apex; sinuses between lobes rounded; margin entire or irregularly coarsely dentate, varying in different leaves; venation palmate with 5–7 straight basal veins, which have several lateral branches on each side in the distal part; basal veins usually craspedodromous, other ones form loops near the margin; peltate base innervated by 2–5 thin veins, running from the beginning of basal veins.

Range and occurrence. Kazakhstan, Altykuduk Formation, Cenomanian, Zhirkindek Formation, Turonian; Western Siberia, Simonovo Formation, Cenomanian–Turonian; Eastern Siberia, Timmerdyakh Formation, Cenomanian; North-East of Russia, Valizhgen, Chingandzha and Arman formations, upper Turonian–Coniacian, Poperechnenskaya Formation, lower Coniacian.

Menispermites minutus (Kryshtofovich) Shczepetov, Herman et Belaya
Figure 4G, Figure 5D, F

1958 *Menispermites septentrionalis* auct. non Hollick; Kryshtofovich, p. 53, pl. 11, figure 2, 3.

1958 *Populus minuta* Kryshtofovich, p. 42, text-figure 19.

1992 *Menispermites* ex gr. *septentrionalis* Hollick; Shczepetov et al., pl. 41, figure 2, pl. 42, figure 1, pl. 44, figure 1, pl. 49, figure 1, pl. 50, figure 3, 4, pl. 59, figure 4, 5.

1992 *Menispermites minutus* (Kryshtofovich) Shczepetov, Herman et Belaya, p. 44, pl. 41, figure 6.

1993 *Menispermites septentrionalis* auct. non Hollick; Philippova and Abramova, pl. 31, figure 1–3. 2015 *Menispermites minutus* Golovneva et al., p. 431, pl. 7, figure 1–7, pl. 8, figure 1–3.

Neotype (designated by Golovneva et al., 2015). Specimen NEISRI PF1/688a, North-East of Russia, Anadyr River basin, Grebenka River, Krivorechenskaya Formation, upper Albian–lower Turonian; Golovneva et al., 2015, pl. 7, figure 4.

Emended diagnosis (Golovneva et al., 2015). Leaves entire, broadly ovate, sometimes with lobe-like extensions in upper part, with cordate, rounded or truncate base and broadly triangular obtuse or attenuate apex; margin dentate; teeth broadly triangular, with concave sides, an acute apex with glands and wide low sinuses; venation palmate, craspedodromous, with 7–9 basal veins; midvein straight with 2–3 pairs of secondary branches in upper part; other basal veins curved, decreasing downwards, with 2–3 basi- and 1–3 acroscopic branches or dichotomizing 1–3 times.

Range and occurrence. North-East of Russia, Krivorechenskaya Formation, upper Albian–lower Turonian.

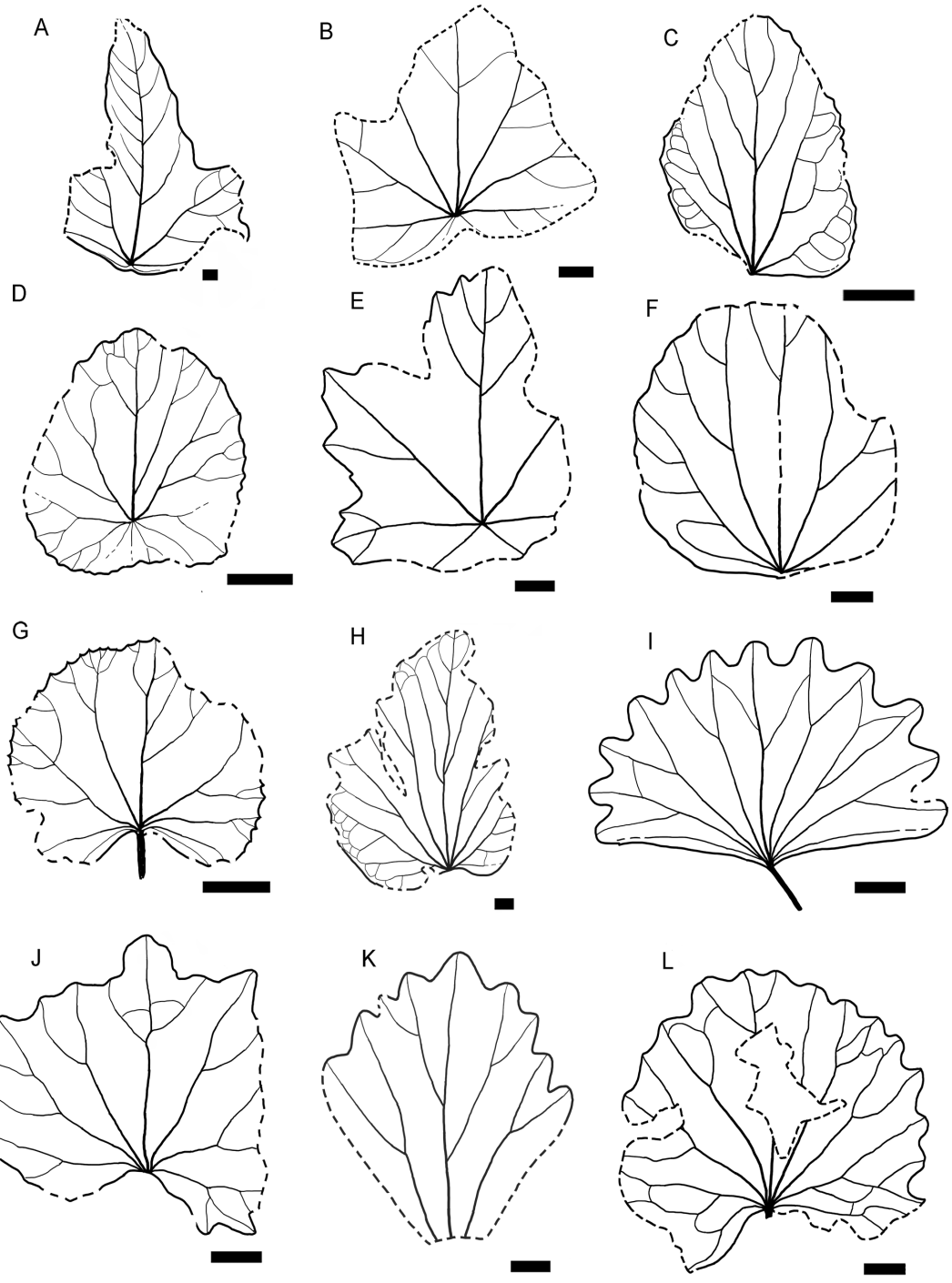

FIGURE 4. Morphological diversity of the genus Menispermites in Northern Asia: A –*M. obtusilobus* Lesquereux (after Lesquereux, 1874, pl. 25, figure 1); B – *M. septentrionalis* Hollick (after Hollick, 1930, pl. 42, figure 4); C – *M. ginterensis* Herman, GIN 3385/203 (after Herman, 1988, text-figure 2); D – *M. lebedevii* Moiseeva, spec. GIN 3392/68, holotype (after Moiseeva, 2014); E – *M. sibiricus* (Heer) Golovneva, spec. IUT 243; F – *M. favosus* Krassilov, spec. FSCEATB 330/377, holotype; G – *M. minutus* (Kryshtofovich) Shczepetov, Herman et Belaya, spec. NEISRI PF1/688a, neotype; H – *Menispermites* sp., spec. GIN 3385/85, (after Moiseeva and Sokolova, 2007, figure 6i); I – *M. marcovoensis* Philippova, spec. TFGI 622/3, holotype; J – *M. sachalinensis* Kryshtofovich ex Zhilin, spec. TSNIGRM 6256/149, lectotype; K – *M. vasetskii* Philippova (after Philippova and Abramova, 1993, pl. 107, figure 1); L – *M. orientalis* Golovneva, spec. NEISRI PF1/505, holotype. Scale bar is 1 cm.

Menispermites orientalis Golovneva
Figure 4L, Figure 5G, H

1993 *Menispermites septentrionalis* auct. non Hollick; Philippova and Abramova, pl. 83, figure 1.

2010 *Menispermites efimovae* Philippova, non rite publ., p. 94, pl. 17, figure 5, 6.

2015 *Menispermites orientalis* Golovneva; Golovneva et al., p. 434, pl. 8, figure 4–6.

2016 *Menispermites orientalis* Golovneva*;* Herman et al., p. 726, pl. 23, fig. 9, text-figure 17.

Holotype. SSpecimen NEISRI PF1/505; North-East of Russia, Anadyr River basin, Grebenka River, Krivorechenskaya Formation, upper Albian–lower Turonian; Golovneva et al., 2015, pl. 8, figure 4.Holotype. Specimen NEISRI PF1/505; North-East of Russia, Anadyr River basin, Grebenka River, Krivorechenskaya Formation, upper Albian–lower Turonian; Golovneva et al., 2015, pl. 8, figure 4.

Diagnosis (Golovneva et al., 2015). Leaves entire, broadly ovate, with cordate base and obtuse or rounded apex; margin crenate; teeth rounded or broadly triangular, with convex sides and rounded apex with glands; venation palmate, craspedodromous, with 9 basal veins; midvein straight with 1–2 pairs of secondary branches; other basal veins curved, decreasing downwards, with 2–3 basiscopic branches or dichotomizing 1–2 times.

Range and occurrence. North-East of Russia, Krivorechenskaya Formation, upper Albian–lower Turonian, Zarya and Arman formations, upper Turonian–Coniacian, Poperechnenskaya Formation, lower Coniacian.

Menispermites vasetskii Philippova
Figure 4K

1993 *Menispermites vasetskii* Philippova; Philippova and Abramova, p. 122, pl. 32, fig. 1, pl.38, figure 5, 6, pl. 40, figure 4, pl. 56, figure 5, pl. 57, figure 1, 2.

Holotype. Specimen TFGI 622-1-40/225a, North-East of Russia, Bystraya River, Krivorechenskaya Formation, upper Albian–lower Turonian; Philippova and Abramova, 1993, pl. 32, fig. 1.

Diagnosis (presented here). Leaves entire, broadly ovate, with cordate or truncate base and rounded or acute apex; margin dentate; teeth evenly spaced, high, triangular, with rounded apex; sinuses rounded; venation palmate, craspedodromous, with 5–7 basal veins, midvein with 1–2 pairs of dichotomizing secondary branches in upper part; lateral veins dichotomously branching 2–3 times.

Range and occurrence. North-East of Russia, Krivorechenskaya Formation, upper Albian–lower Turonian.

Menispermites marcovoensis Philippova
Figure 4I, Figure 5E

1978 *Menispermites marcovoensis* Philippova, p. 141, pl. 10, figure 1, 2.

1993 *Menispermites marcovoensis* Philippova*;* Philippova and Abramova, p. 121, pl. 32, figure 3–5, pl. 56, figure 4.

2010 *Menispermites marcovoensis;* Philippova Moiseeva, pl. 15, figure 12, 13, text-figure 3l–3n.

Holotype. Specimen TFGI 622/3, North-East of Russia, Anadyr River basin, Grebenka River, Krivorechenskaya Formation, upper Albian–lower Turonian; Philippova, 1978, pl. 10, figure 1, text-figure 1.

Diagnosis (presented here). Leaves entire, fan-shaped, usually the width is twice the length, with broadly cuneate or truncate base and obtuse rounded apex; margin dentate; teeth evenly spaced, high, broadly triangular with rounded apex; sinuses rounded; venation palmate, craspedodromous, with 7–11 basal veins dichotomously branching in upper part.

Range and occurrence. North-East of Russia, Krivorechenskaya Formation, upper Albian–lower Turonian, Ginter Formation, Cenomanian.

Menispermites ginterensis Herman
Figure 4C

2010 *Menispermites ginterensis* Herman, 1988, p. 112, text-fig. 2, 3. – Moiseeva, pl. 15, fig. 11, text-figure 4g.

Holotype. Specimen GIN 3385/203, North-East of Russia, Koryak Upland, Ugol'naya Bay, Ginter Formation, Cenomanian; Herman, 1988, text-figure 2, 3.

Diagnosis (presented here). Leaves entire, widely ovate, with truncate base and obtuse apex; margin dentate; teeth small, no evenly spaced, triangular, with acute or rounded apex; sinuses rounded; venation palmate, brochidodromous or semi craspedodromous in lower part of lamina and craspedodromous in its upper part, with 5 basal veins; midvein with 3 pairs of secondary branches in upper part; lower basal veins curved, with several basiscopic branches.

Range and occurrence. North-East of Russia, Ginter Formation, Cenomanian.

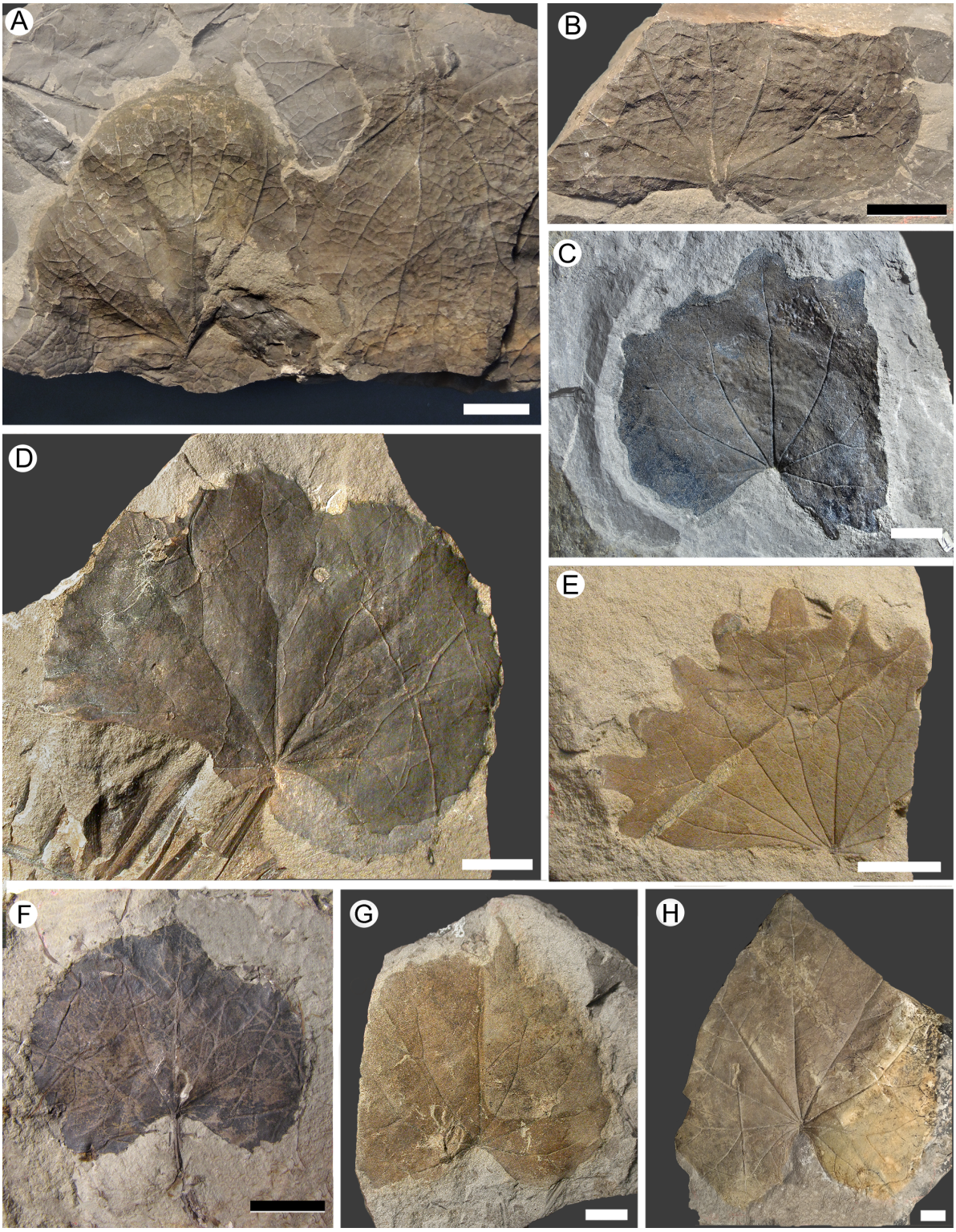

FIGURE 5. Species of the genus *Menispermites* from Northern Asia: A, B – *M. favosus* Krassilov, Boshnyakovo Formation, Maastrichtian-Danian: A – spec. GIN 58/33; B – spec. GIN 58/53a; C – *M. sachalinensis* Kryshtofovich ex Zhilin, spec. TSNIGRM 6256/149, lectotype, Zhonk'er Formation, Campanian; D, F – *M. minutus* (Kryshtofovich) Shczepetov, Herman et Belaya, Krivorechenskaya Formation, upper Albian-lower Turonian: D – spec. TFGI 223/1; F – spec. NEISRI PF1/688a, neotype; E – *M. marcovoensis* Philippova, spec. TFGI 622/3; G, H – *M. orientalis* Golovneva: G – spec. TFGI 622/13, Krivorechenskaya Formation, upper Albian-lower Turonian; H – spec. TFGI 403/1, Poperechnenskaya Formation, Coniacian. Scale bar is 1 cm.

Menispermites lebedevii Moiseeva
Figure 4D

2014 *Menispermites lebedevii* Moiseeva, p. 681, pl. 15, figure 1–5, 9.

Holotype. Specimen GIN 3392/68, North-East of Russia, Enmyvaam River, Emuneret Formation, Santonian–Campanian; Moiseeva, 2014, pl. 15, fig. 1, 5, text-figure 3b.

Diagnosis (Moiseeva, 2014). Leaves entire, rounded or ovate, slightly asymmetric; leaf base peltate eccentric; leaf apex rounded; margin irregularly dentate, partly undulate; teeth usually flat, rounded-triangular with rounded or more rarely acute apex; venation palmate, craspedodromous or semicraspedodromous, with 7–9 basal veins decreasing downwards; midrib prominent, with 2–3 pairs of secondary veins; lower basal veins thin and short, running to base of leaf lamina into pelta.

Range and occurrence. North-East of Russia, Emuneret Formation, Santonian–Campanian.

Menispermites sachalinensis Kryshtofovich ex Zhilin
Figure 4J, Figure 5C

1918 *Hedera macclurii auct non* Heer; in Kryshtofovich, p. 59, text-figure 14.

1960 *Menispermites sachalinensis* Kryshtofovich, non rite publ., designat. typi omissa; Kryshtofovich and Baikovskaya, p. 81, pl. 17, fig. 2, text-figure 28.

1974 *Menispermites sachalinensis* Kryshtofovich ex Zhilin; Zhilin p. 100, pl. 38, figure 6.

1979 *Menispermites sachalinensis* Kryshtofovich ex Zhilin; Krassilov, p. 108, pl. 30, figure 11.

Lectotype (designated by Zhilin, 1974). Specimen TSNIGRM 6256/149, Sakhalin, Cap Jonquiere, Zhonk'er Formation, Campanian; Zhilin, 1974, pl. 38, figure 6.

Diagnosis (presented here). Leaves entire, rounded in outline, with cordate base, apex acute with big rounded tooth in the top; margin dentate or undulate; teeth large, distantly spaced, broadly triangular with rounded apices, different in size; sinuses rounded; venation palmate, craspedodromous, with 5–7 basal veins; midvein with 1–2 pairs of secondary veins in upper part; lateral veins producing 1–3 basiscopic branches or dichotomizing.

Range and occurrence. Sakhalin, Zhonk'er Formation, Campanian.

Menispermites favosus Krassilov
Figure 4F, Figure 5A, B

1979 *Menispermites favosus* Krassilov, p. 108, pl. 31, figure 1.

Holotype. Specimen FSCEATB 330/377, Sakhalin, Avgustovka River, Boshnyakovo Formation, Maastrichtian–Danian; Krassilov, 1970, pl. 31, figure 1.

Diagnosis (presented here). Leaves entire, broadly ovate; base rounded or truncate, peltate or non-peltate; pelta (if present) small, 2–3 mm high; apex rounded with small triangular tooth in top; margin undulate; venation palmate, craspedodromous, with 5–7 basal veins; midvein producing 2–3 pairs of secondary veins; outer lateral basal veins providing 3–5 basiscopic brochidodromous branches.

Range and occurrence. Sakhalin, Boshnyakovo Formation, Danian.

Menispermites temlyanensis
Zolina, Golovneva et Grabovskiy, sp. nov.
Figure 6A–E, Figure 7A–E, Figure 8A–F

Plant Fossil Registration number PFN003476

Etymology. After Temlyan Mountain.

Holotype (designated here). Specimen BIN 1588/263, North-East of Russia, Anadyr district of Chukotka, Tanyurer Formation, Maastrichtian–Danian; figure 6A, 8B.

Material. Collection BIN 1588, specimens 218, 221, 241, 250–266, 410, 411.

Diagnosis. Leaves trilobate or unlobate, broadly ovate with rounded, peltate base with high pelta; lobes (if presents) small, broadly triangular with rounded apices; central lobe bigger than lateral ones; apex of unlobate leaves attenuate; margin entire; venation palmate, with 3–5 basal veins; midvein producing 3–5 pairs of secondary veins; inner lateral veins straight, terminated in the lobes apices; outer lateral basal veins curved, connected with inner lateral veins; pelta innervated by 2–4 pairs of thin veins.

Description. Leaves are simple, 3–12 cm in length and 3–9 cm in wide. The leaf lamina is broadly ovate in outlines, trilobate, more rarely unlobate. Lobes (if presents) are small, broadly triangular with rounded apices and strait or slightly convex sides (Figure 6A, D, Figure 7C, Figure 8B, C, E). Central lobe is significantly bigger than lateral ones. Unlobate leaves have attenuate apex with rounded tip (Figure 7A, B). The leaf base is rounded, peltate. The height of the pelta ranges

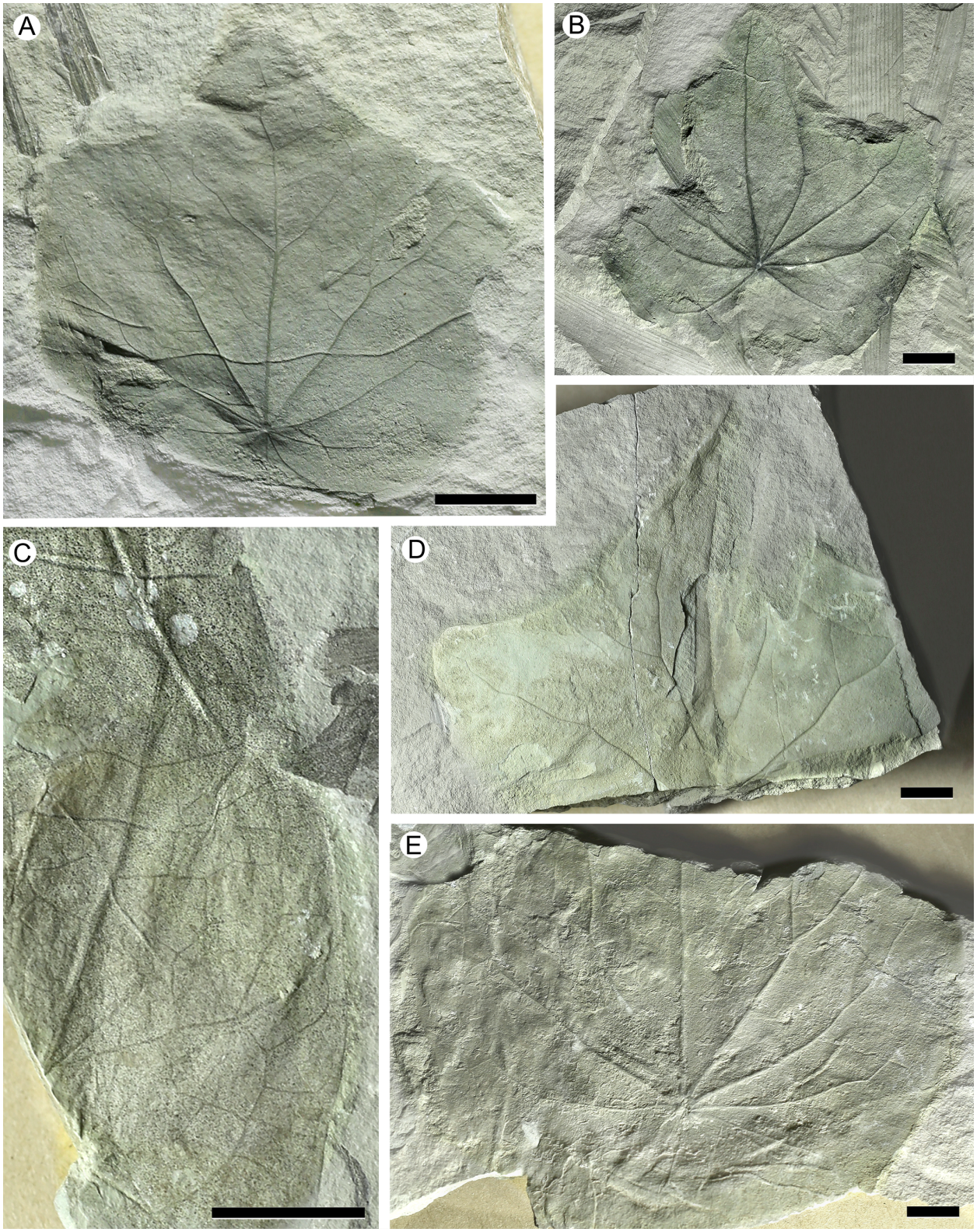

FIGURE 6. *Menispermites temlyanensis* Zolina, Golovneva et Grabovskiy, sp. nov.: A – spec. BIN 1588/263, holotype; B – spec. BIN 1588/218; C – spec. BIN 1588/251; D – spec. BIN 1588/265; E – spec. BIN 1588/261. Scale bar is 1 cm.

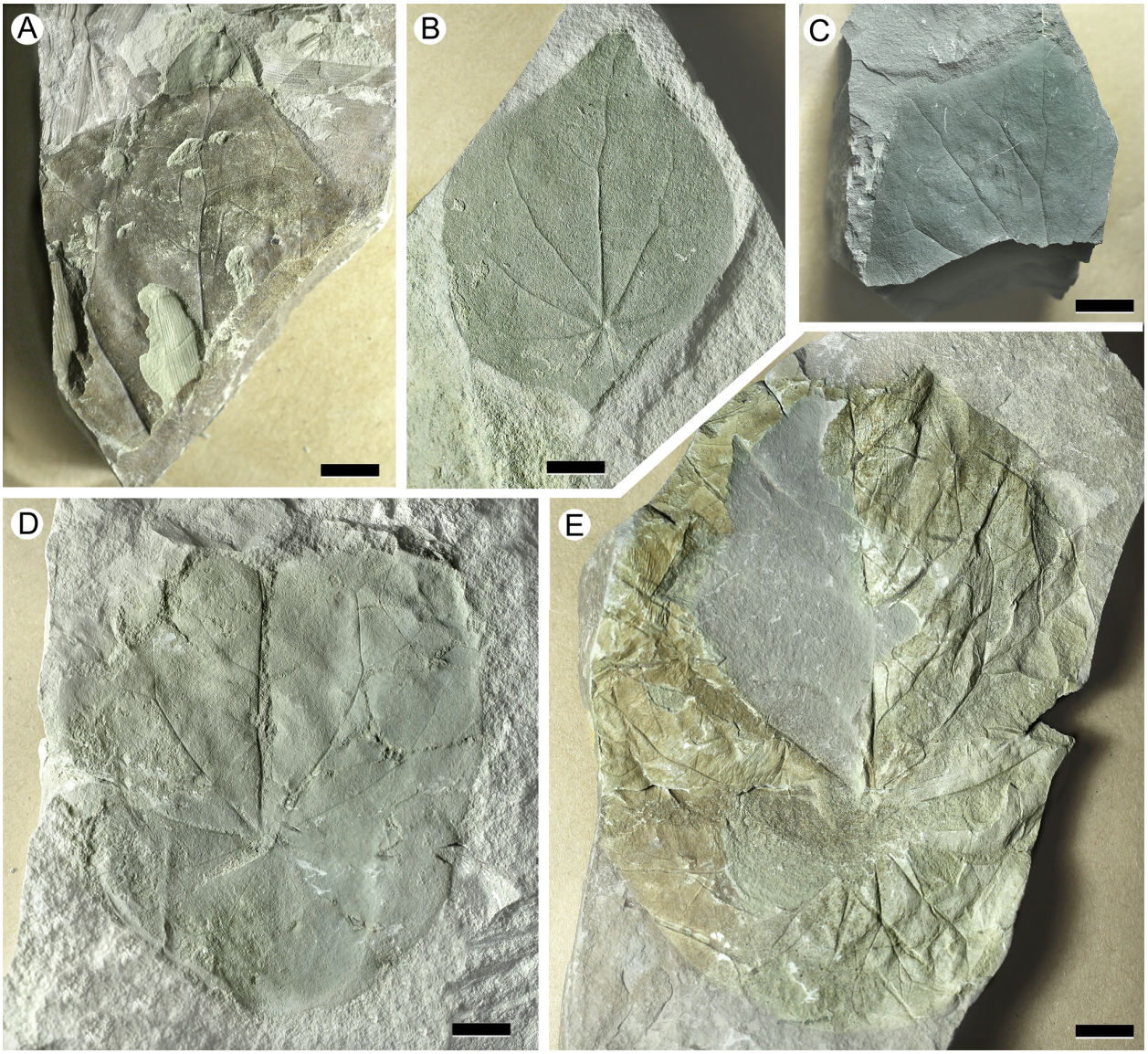

FIGURE 7. *Menispermites temlyanensis* Zolina, Grabovskiy et Golovneva, sp. nov.: A – spec. BIN 1588/254; B – spec. BIN 1588/262; C – spec. BIN 1588/411; D – spec. BIN 1588/410; E – spec. BIN 1588/266. Scale bar is 1 cm.

from one quarter to one third of the leaf length. The margin is entire (Figure 6C).

Venation is palmate, with 3–5 basal veins. The midvein is straight or slightly curved. It is thicker and longer that other veins, running to the leaf apex, producing 3–5 pairs of alternate or subopposite secondary veins in the upper one-quarter of the lamina. These secondary veins are connected to each other and form series of loops near leaf apex. Inner basal lateral veins are thick, straight, diverging from the midvein at an angle 35–45°, running to the lobe's apices. They produce 1–3 pairs of short curved brochidodromous secondary veins in upper part, which innervate lobes. The lowest acroscopic secondary veins are connected with the lowest secondary veins extending from the midvein. Outer lateral basal veins are curved, thinner and shorter than inner lateral basal veins. They diverge from the midvein at an angle about 75–85° and join with inner lateral veins near the leaf margin. They provide 3–5 thin basiscopic brochidodromous branches. Pelta is innervated by 2–4 pairs of thin, radiating, dichotomously branching veins (Figure 6A, B, E, Figure 7D, B, E, Figure 8B, D, F). Tertiary veins form an alternating series of meshes (Figure 6C, Figure 8B).

Remarks. The type species of the genus *Menispermites, M. obtusilobus* (Figure 4A) from the Dakota Formation has broadly ovate, trilobate peltate leaves with obtuse apex, low pelta (3–4 mm),

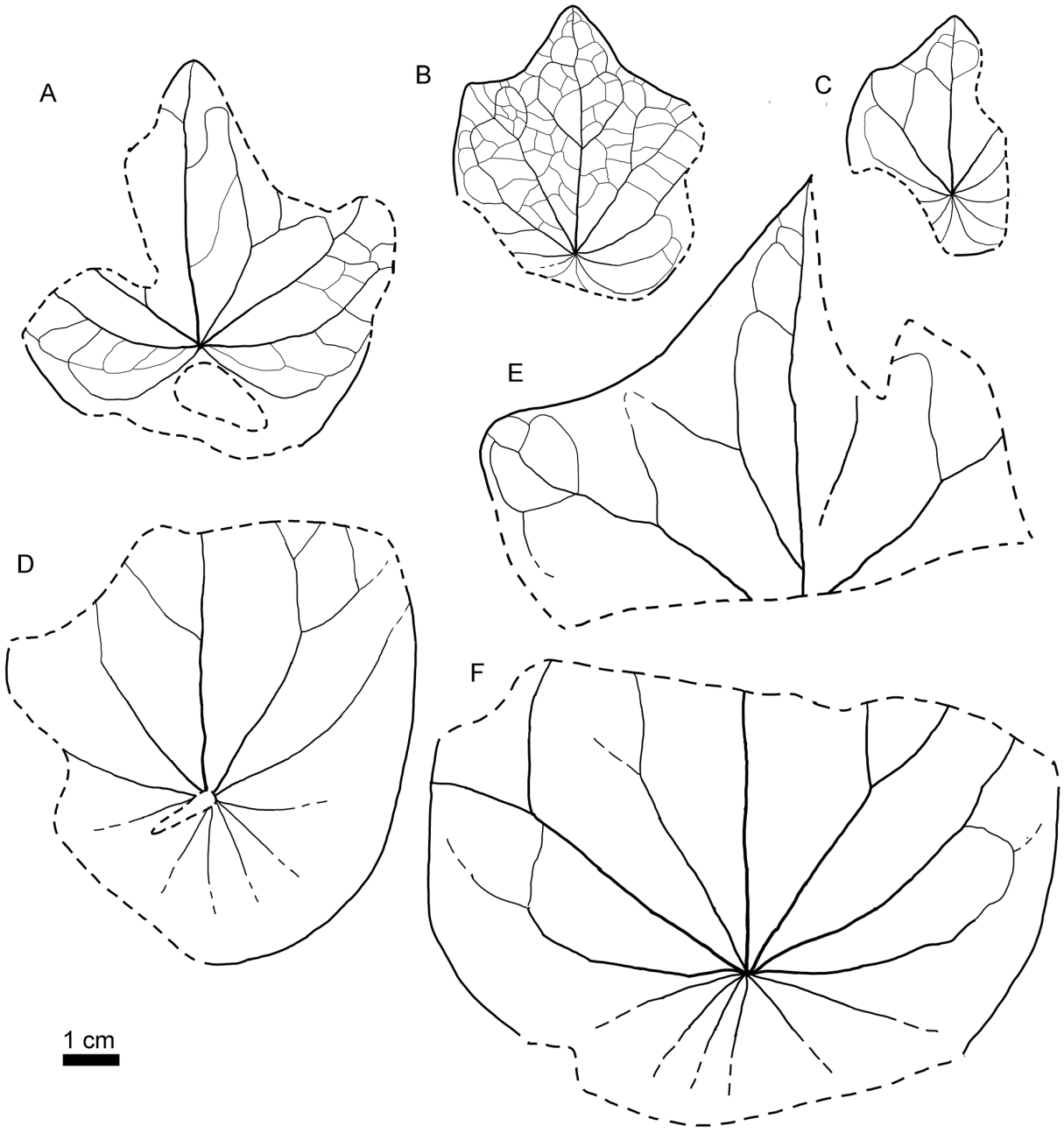

FIGURE 8. *Menispermites temlyanensis* Zolina, Golovneva et Grabovskiy, sp. nov.: A – spec. BIN 1588/218; B – spec. BIN 1588/263, holotype; C – spec. BIN 1588/259; D – spec. BIN 1588/410; E – spec. BIN 1588/265; F– spec. BIN 1588/261. Scale bar is 1 cm.

truncate base and crenate or undulate margin (Lesquereux, 1874). *M. temlyanensis* is similar to the type species in its trilobate shape and in the presence of a pelta. The new species differs from *M. obtusilobus* by its small lobes, high pelta (2–4 cm) and entire margin. Two species *M. salinensis* Lesquereux and *M. acerifolius* Lesquereux were described from the Dakota Formation together with the type species (Lesquereux, 1874). Both species are characterized by nonpeltate leaves.

Most species of *Menispermites* have entire leaves. Since the leaves of the new species are trilobate, they have the greatest resemblance to *M. sibiricus.* TThis species has broadly ovate 3–5 lobate leaves, with rounded, cordate or truncate base, broadly triangular obtuse lobes and dentate

margin (Figure 4). Both species are characterized by well-developed pelta. However, *M. temlyanensis* is distinguished from *M. sibiricus* by less developed lobes and by entire margin

Range and occurrence. North-East of Russia, Tanyurer Formation, Maastrichtian–Danian.

Menispermites sp.
Figure 4H

2007 *Menispermites* cf. *sachalinensis* Kryshtofovich ex Zhilin; Moiseeva and Sokolova, pl. 4, figure 12, text-figure 6i.

Range and occurrence. North-East of Russia, Barykov Formation, Campanian.

DISCUSSION

The earliest occurrences of *Menispermites* in the North-East of Russia appeared in the upper Albian–lower Turonian Krivorechenskaya Formation. Here four species were recorded: *M. minutus, M. vasetskii, M. marcovoensis,* and *M. orientalis.* The first three of them were found only in this formation. Thus, they are endemic to the Grebenka flora (Shczepetov et al., 1992; Philippova and Abramova, 1993), while *M. orientalis* was also discovered in several late Turonian–Coniacian floras in the North-East of Russia. The leaves of these four species are rather diverse in morphology, from fan-shaped with truncate base to widely ovate with deeply cordate base. However, all of them are entire (have no lobes) and have no pelta (Figure 9).

M. ginterensis Herman was found in the Cenomanian Ginter Formation and is not recorded in other places.

In western Kazakhstan and Siberia, *Menispermites* appeared in the Cenomanian and is represented by *M. sibiricus.* This species is characterized by very variable peltate and lobate leaves with entire or dentate margin. It persisted in Kazakhstan and Siberia up to the Turonian and appeared in the North-East of Russia in the upper Turonian–Coniacian.

After the Turonian, *Menispermites* did not occur in Kazakhstan and Siberia. In the North-East of Russia two species of *Menispermites* were found in the Santonian and Campanian: *M. lebedevii* from the Emuneret Formation and *Menispermites* sp. from the Barykov Formation (Figure 9). The first species is characterized by entire ovate leaves with dentate margin and high pelta, and second species had also entire ovate leaves, but with entire margin and nonpeltate.

In the Campanian *Menispermites* first appears on Sakhalin, where two species are known. *M. sachalinensis,* with entire widely ovate nonpeltate leaves, was described from the Campanian Zhonk'er Formation. The second species, *M. favosus,* with entire ovate leaves and with very small pelta, was found in the Maastrichtian–Danian Boshnyakovo Formation.

At the same time, *M. temlyanensis* was distributed in the North-East of Russia. Its lobate leaves with very high pelta and entire margin were found in the Maastrichtian–Danian Tanyurer Formation. Later findings of *Menispermites* in Northern Asia are not known. *Menispermites* from Northern Asia are characterized by significant morphological diversity.

Among the representatives of *Menispermites* from Northern Asia, four species have a pelta: *M. sibiricus, M. lebedevii, M. temlyanensis,* and *M. favosus.* This suggests that they may have been lianas like many modern Menispermaceae, which also have peltate leaves (Givnish and Vermeij, 1976). Leaves with this morphological feature are observed from the Cenomanian to the Maastrichtian–Danian. Nowadays, lianas are mainly distributed in tropical climates, although they are also found in both subtropical and temperate climates. During the Late Cretaceous, the climate in the different parts of Northern Asia was humid, subtropical or temperate (Moiseeva and Sokolova, 2007; Spicer and Herman, 2010; Zolina et al., 2020). The analysis of fossil floras suggests that polydominant deciduous forests with an admixture of evergreen species were widespread in this territory (Spicer and Herman, 2010; Golovneva and Nosova, 2012; Golovneva, 2019).

Thus, *Menispermites* in Northern Asia is known from the late Albian up to the Maastrichtian–Danian. The greatest number of species is confined to the North-East of Russia.

In other regions of Northern Asia, stratigraphic distribution of *Menispermites* was limited. In Kazakhstan and Siberia, it is known from the Cenomanian to Turonian. On Sakhalin, *Menispermites* is known from the Campanian to the Maastrictian–Danian.

Eleven species of *Menispermites* are known from Northern Asia. Among them, *M. sibiricus* had the widest geographical and stratigraphic distribution. The other species of the genus had narrow geographic and stratigraphic ranges.

In other regions of Eurasia, the species diversity of *Menispermites* was significantly lower. Only one species was described from the Upper Creta-

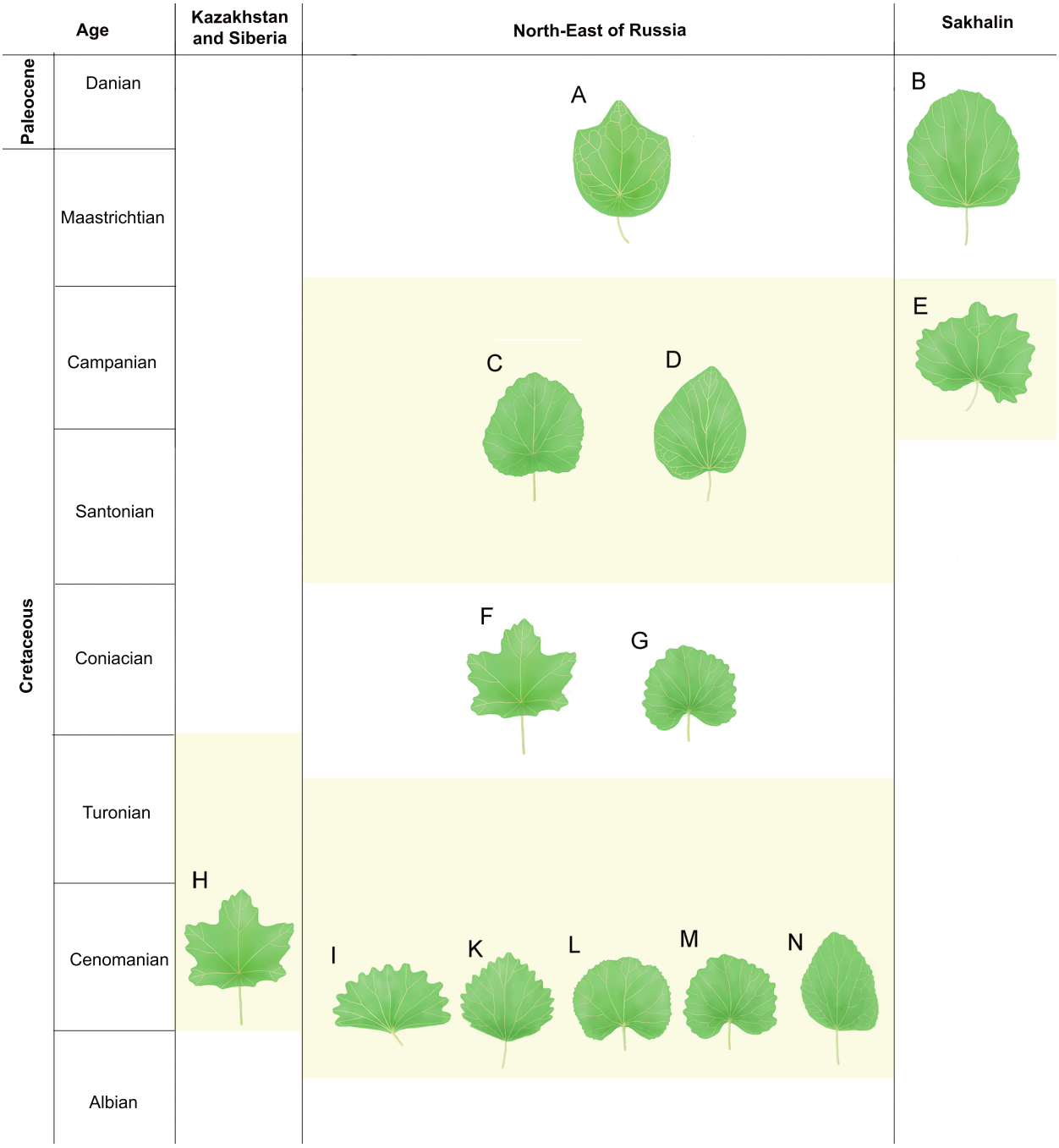

FIGURE 9. Distribution of the genus *Menispermites* in Northern Asia. A – *M. temlyanensis* Zolina, Golovneva et Grabovskiy, sp. nov.; B – *M. favosus* Krassilov; C – *M. lebedevii* Moiseeva; D – *Menispermites* sp.; E – *M. sachalinensis* Kryshtofovich ex Zhilin; F, H – *M. sibiricus* (Heer) Golovneva; G, M – *M. orientalis* Golovneva; I – *M. marcovoensis* Philippova; K – *M. vasetskii* Philippova; L – *M. minutus* (Kryshtofovich) Shczepetov, Herman et Belaya; N – *M. ginterensis* Herman.

ceous of Europe – *M. summesbergeri* from the Campanian Grünbach Formation (Herman and Kvaček, 2010). In North America, the greatest species diversity of the genus occurs in the late Albian–Cenomanian (Lesquereux, 1874; Knowlton, 1919; Doria et al., 2008). Later finds are rare. The youngest Cretaceous species is *M. olmosensis* from the Campanian–Maastrichtian deposits of Mexico (Guzmán-Vázquez et al., 2018).

CONCLUSIONS

In Northern Asia, *Menispermites* was distributed from the late Albian up to the Maastrichtian–Danian. During this time, the territory of the North-East of Russia was the center of species diversity of this genus. Short-lived species with limited ranges predominated. Members of *Menispermites* had diverse leaf morphology. *M. sibiricus* had the widest geographical and stratigraphic ranges from Kazakhstan to Chukotka and from Cenomanian to Coniacian. The greatest species and morphological diversity of *Menispermites* occurs in the Cenomanian–Turonian of the North-East of Russia.

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