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Paleocene biota of the West Siberian plain

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ABSTRACT

In the Paleocene, most of the present West Siberian plain was occupied by a vast epicontinental sea, which reached from the present Arctic and Atlantic oceans in the North to the Aral Basin in the South. Climate and ocean circulation fluctuated and affected marine and continental biota. Benthic foraminifera that occurred over a large part of the sea throughout the Paleocene were used as representatives of the marine biota, and spores and pollen of terrestrial plants as representatives of the continental biota, in order to study these environmental and biotic changes. Foraminifera and palynomorphs were studied in sedimentary sequences of Danian, Selandian, and Thanetian age. These sequences have regional names, and encompass the upper part of the Gankinskaya Stage, the whole Talitskaya Stage, and the lower part of the Lyulinvorskaya Stage.

In the southwest part of the basin (the Omsk depression), upper Gankinskaya sediments (Maastrichtian to lowermost Danian) contain calcareous benthic foraminifera. Benthic foraminiferal assemblages suggest that sea level fell during the early Paleocene, so that the West Siberian basin shallowed significantly and decreased in size. During the earliest Danian, the basin in the Ust-Tym depression also became shallower, and "primitive" agglutinated foraminifera were dominant (e.g., *Bathysiphon, Glomospira, Ammodiscus*). Sea level rose during the Selandian boreal transgression (Talitskaya Stage), and agglutinated foraminifera occurred over large areas. In the Thanetian (represented by the uppermost Talitskaya and the base of the Lyulinvorskaya Stage) the basin again shallowed, and foraminifera became rare.

The analysis of palynomorphs (spores and pollen) in allochthonous assemblages in marine sediments documents that an alluvial plain with lakes and bogs was situated on the southeast coast of the Paleocene West Siberian marine basin. The climate became more arid during the Danian and late Thanetian, with a pronounced phase of drying at the boundary between the Talitskaya and Lyulinvorskaya Stages (early Thanetian).

INTRODUCTION

Western Siberia is the part of Siberia between the Urals in the west and the Yenisey River in the east (Fig. 1A). It is largely occupied by the West Siberian plain, which can be subdivided into different biomes, from the tundra in the North to the steppe in the South. The West Siberian plain is one of the largest low-lying plains on Earth, with a north-south dimension of ~2500 km, an east-west dimension of ~1900 km, and an area of ~2.6×10^6 km^2. Its surface is flat, with few outstanding features, and only minor differences in elevation.

The West Siberian plain developed on an isolated part of the lithosphere, and remained so for an appreciable length of time. It is a part of the Epihercynian West Siberian plate, with base-

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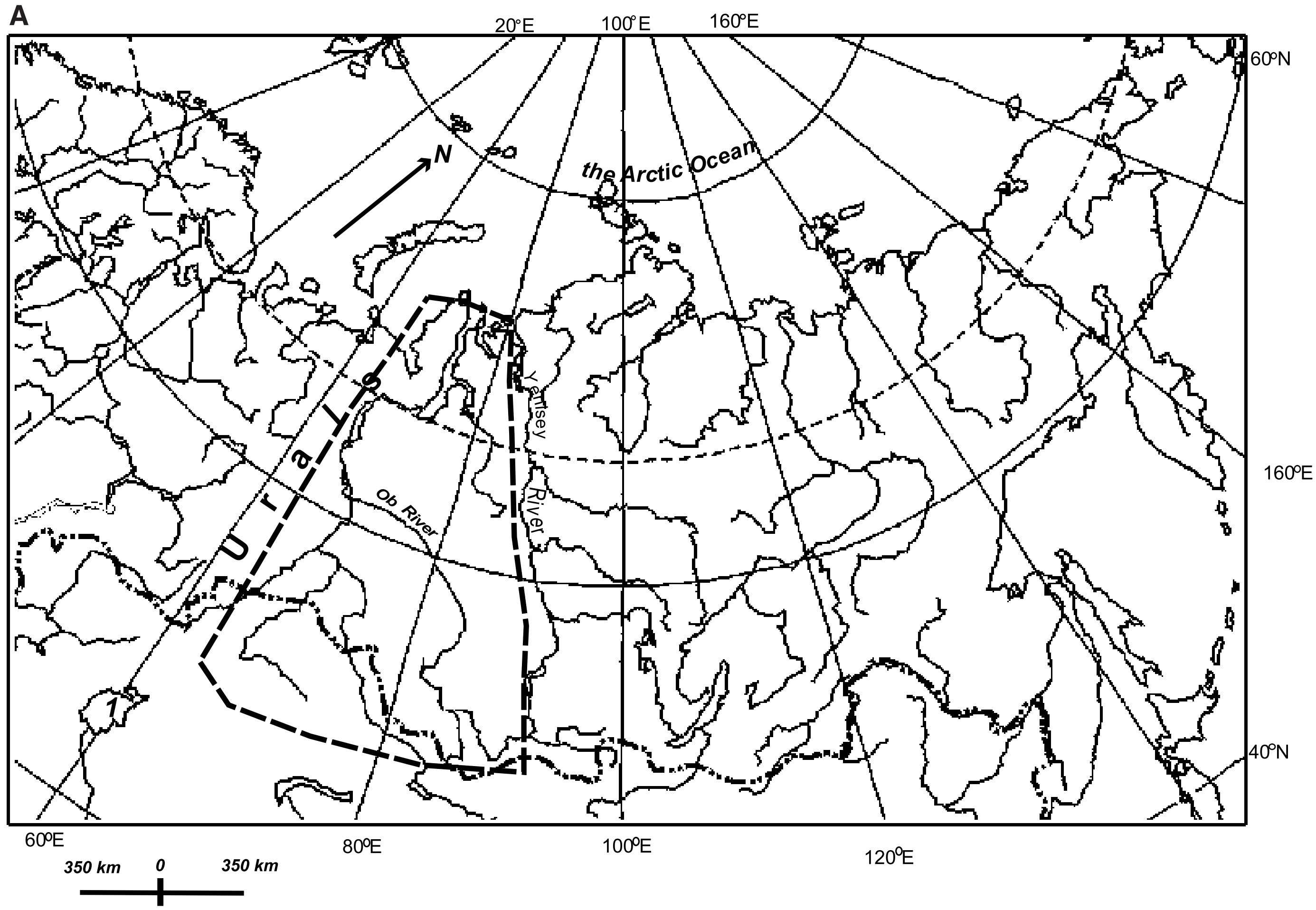

Legend: **1 -** the Aral Sea

- the frontier of Russia

- the Arctic Circle

- approximate borders of Western Siberia

Figure 1. A: Location of the West Siberian Plain, with its most important rivers. B: Location of the sections and boreholes studied, and the extent of the Omsk and Ust-Tym depressions.

ment formed by intensely deformed Paleozoic rocks covered by superficial deposits of marine and continental, Mesozoic and Cenozoic sediments, including clay, sandstone, and marl. These superficial deposits reach >1000 m in thickness, in basement troughs even up to 3000–4000 m.

Throughout the first half of the Paleogene, epicontinental seas extended over the entire plain, but the sediments deposited in the basin vary in character with space and time, dependent upon climate as well as the landscape. Lithological and paleontological studies of the Paleogene deposits formed under the diverse conditions in this vast region have elucidated the overall paleo-environmental developments (Gurova and Kazarinov, 1962). Variations in sea level and climate resulted in varying width and depth of the connections to other basins, in turn resulting in changes in ocean currents, and migration of marine and continental biota.

Most of the Paleogene deposits in the West Siberian plain are buried under a thick cover of Neogene-Quaternary deposits, and can be studied only in boreholes (Shatskiy, 1973), many of which have been drilled in the southern part of the West Siberian plain. Their locations are spread evenly over this part of the plain, in Transuralia and, to a lesser extent, over the northern

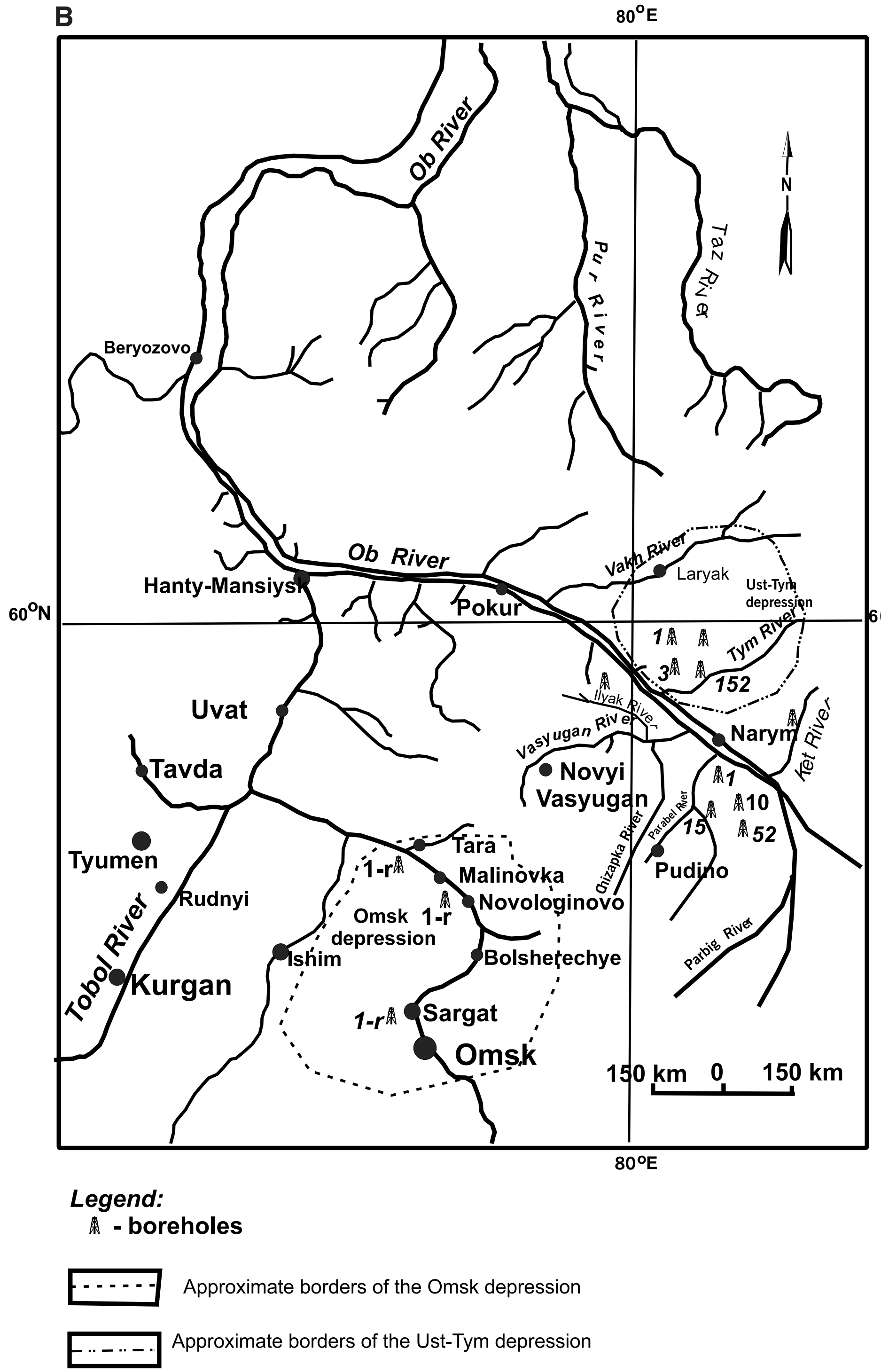

Figure 1. *(continued)*

plains (Figs. 1A, B). Cores from these boreholes have been studied over many years, so that the general stratigraphy of the Paleo-gene deposits is well known (e.g., Podobina, 1998).

In micropaleontological studies of the Paleogene of West Siberia, benthic foraminifera have been used most extensively to investigate paleogeographical changes, because they are widely distributed and evolved relatively rapidly (Podobina, 2000a). Mollusca are rare or absent. The palynological assemblages have been found only in sediments deposited in the shallow, marginal parts of the basin.

Foraminiferal and palynological assemblages have been studied in many different West Siberian sections from the Omsk and Ust-Tym depressions, but the two microfossil groups have usually been studied in separate sections and boreholes. The results of detailed investigations of the micropaleontology of the region, including data on several Paleogene sections, have been reported in numerous works published earlier (e.g., Podobina, 1998; Kabanova and Kostesha, 1988).

In this paper foraminiferal and palynological data from several borehole sections in the Omsk depression are combined for the first time (Fig. 2). The data in this paper and their paleoecological interpretation are preliminary, because this is probably the first attempt to combine and compare the results of foraminiferal and palynological studies of West Siberia, and correlate the early Paleogene foraminiferal and palynological assemblages from different areas of the West Siberian plain.

GEOLOGICAL SETTING; MATERIAL AND METHODS

Samples for the investigations of foraminiferal assemblages as well as palynomorphs were obtained from cores drilled in the Omsk and Ust-Tym depressions, in the Parbig and Ket river basins and other districts (Fig. 1), where these sediments have been preserved from erosion because of their location in basement depressions. The foraminiferal assemblages have been studied in many sections from this region (Podobina, 1998; Fig. 1B). In this paper, foraminiferal assemblages (Figs. 3, 4) are investigated from locations that also contain palynomorphs (Fig. 5) (Podobina et al., 1997).

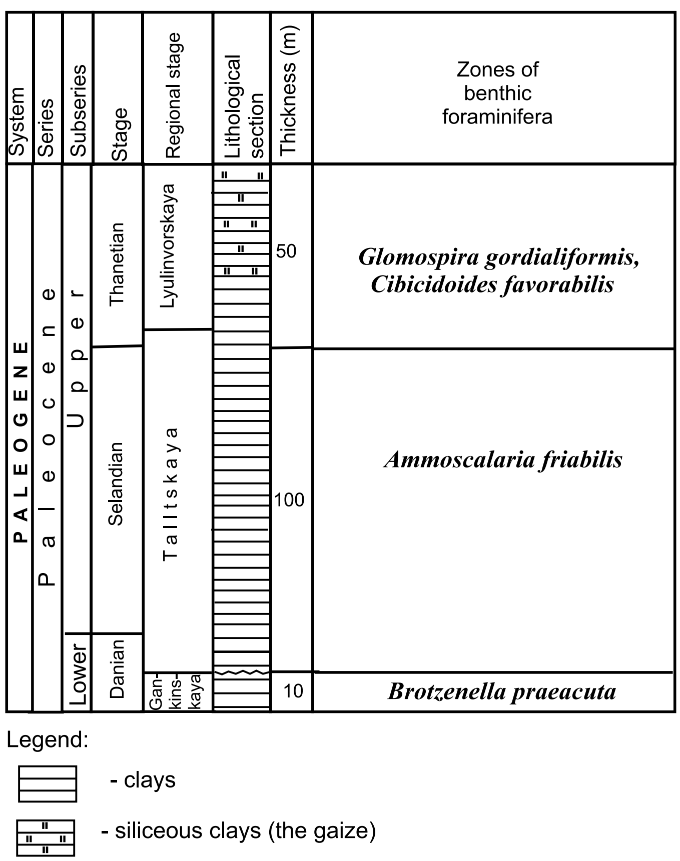

Figure 2. Representative section of the formations in the West Siberian plain, with benthic foraminiferal zonation.

Sediments deposited during the Gankinskaya, Talitskaya and Lyulinvorskaya regional stages vary considerably in lithology, with a typical Paleocene section with its foraminiferal zones from the Omsk depression illustrated in Figure 2. This paper is not intended to present detailed lithological descriptions, because these have been presented earlier in lithological columns and stratigraphy (e.g., Gurova and Kazarinov, 1962; Shatskiy, 1973). Within the sections in the Omsk depression, the Gankinskaya Stage consists of dark-grey and grey, slightly calcareous clays with silt, and with sandy, noncalcareous layers (~10 m thick) in its upper parts. The sediments were assigned to the lowermost Danian because of their planktonic foraminiferal faunas, which include *Subbotina varianta* (Subbotina), *S. trivialis* (Subbotina), *S. triculinoides* (Plummer) as well as a few other species (Subbotina and Kiselman, 1961; Podobina, 1998).

The Talitskaya Stage is represented by dark-grey, almost black, noncalcareous clays (10–100 m thick). The lowermost part of Lyulinvorskaya Stage consists of grey, siliceous rocks (35–110 m thick) (Podobina, 1975, 1998; Ilyenok, 1968; Ilyenok et al., 1989).

About 10,000 samples for the micropaleontological analysis were taken at 5 m intervals from each borehole in all three regional stages. Close to the stage boundaries samples were taken at 1–2 m intervals. All core samples were processed in the same way. The dry weight of the samples was ~100 g. Samples were soaked and boiled in a solution of baking soda for 3–5 hours, then washed and sieved into two size fractions: 1–3 mm, and between 1 mm and 0.63 mm. Both fractions were oven-dried (~300°C). Foraminifera were picked from the dried residues of both fractions for further investigations.

The dry weight of the samples for palynological analyses was ~50 g. They were crushed and treated with nitric acid (HNO_3 65% w/v, 3–7 min) and an alkaline solution (10% solution of NaOH). The fraction with the lowest density (macerate rich in organic matter) was separated by centrifuging in a heavy liquid (2.3–2.35 g/cm) for 40 min and then in distilled water for 5 min. All data on palynomorphs were provided by the palynological laboratory of Siberian Paleontological Scientific Center of Tomsk State University.

EARLY PALEOCENE

Danian

Marine Danian deposits occur in the region to the East of the Ural Mountains (Transuralia), and in various places in the central and southern regions of the West Siberian plain (Fig. 1A, B). The lower part of the Danian is represented by sediments of the Gankinskaya regional stage, which escaped erosion only in

System	Series	Stage	Regional stage	Zones and layers of benthic foraminifera	
				South-Western region (the Omsk depression)	**Eastern region (the Ust-Tym depression)**
Paleogene	Paleocene	Thanetian	Lyulinvorskaya	***Glomospira gordialiformis, Cibicidoides favorabilis***	Layers with ***Glomospira gordialiformis, Cyclammina coksuvorovae***
		Selandian	Talitskaya	***Ammoscalaria friabilis***	Layers with ***Cyclammina coksuvorovae***
				Layers with ***Cibicidoides incognitus***	
		Danian	Gankinskaya	***Brotzenella praeacuta***	Layers with ***Bathysiphon nodosarieformis, Glomospira charoides***

Figure 3. Paleocene foraminiferal zones and layers of the West Siberian plain.

the regions where Mesozoic and Cenozoic deposits occur in pronounced basement depressions (e.g., the Omsk depression). The deposits include sediments assigned to the *Brotzenella praeacuta* benthic foraminiferal zone (Subbotina and Kiselman, 1961; Podobina, 1998), characterized by the following species: *Gaudryina gigantica* Subbotina, *Clavulina parisiensis* Orb., *Lenticulina inusitata* (Kisselman), *Parrella lens* Brotzen, *Anomalina danica* (Brotzen), *Cibicides spiropunctatus* Gallowey and Morrey, *Brotzenella praeacuta* (Vassilenko). Typical for this zone is the presence of species that survived from the late Maastrichtian, and that have a wide distribution in the southern part of West Siberia (Podobina, 2000b). The most characteristic of these Cretaceous-Paleocene species are *Heterostomella foveolata* (Marsson), *Valvulineria imitata* (Olsson), *Valvulinoides umovi* (Kyprianova), *Gyroidinoides turgidus* (Hagenow), *Eponides sibiricus* Neckaja, *Cibicides gankinoensis* Neckaja, *Anomalinoides pinguis* (Jennings), *A. neckajae* Vassilenko, *A. justus* Podobina, *Pullenia americana* Cushman, *Nonionellina pseudoinsecta* (Putrja), *Bulimina rozenkrantzi* Brotzen, *Reussella minuta* (Marsson), *Bolivina plaita* Carsey and other species (Figs. 3, 4). These faunas thus include both calcareous and agglutinated taxa.

In the eastern part of the basin (the Ust-Tym depression; Figure 1B), "simple" forms of the genera *Bathysiphon, Hyperammina, Ammodiscus, Glomospira* with relatively "primitive" construction (one or two chambers only) dominate (95%). The term "primitive" is used here to mean that these forms form relatively simple tests consisting of few chambers and without a complex wall structure. More "highly evolved" species co-occur (5%), such as *Heterostomella aff. foveolata* (Marsson) and *Spiroplectammina kasanzevi* Dain in the *Bathysiphon nodosarieformis* and *Glomospira charoides* assemblage (Plates 1–4, Figures 3, 4). The species composition in the western and eastern foraminiferal faunas suggest that the shallow basin had a relatively low salinity, as documented by the absence of planktonic forms and the common occurrence of such "primitive" genera as *Bathysiphon, Hyperammina, Ammodiscus* (Podobina, 1998).

Up-section in the Omsk depression (in the lowermost Talitskaya regional stage), the foraminiferal assemblage with *Cibicidoides incognitus* occurs (Freiman, 1960), which also contains planktonic foraminifera: *Subbotina varianta* (Subbotina), *S. trivialis* (Subbotina), *Morozovella* cf. *inconstens* (Subbotina) and other species (Podobina, 1998). These planktonic foraminifera indicate that these sediments can be dated as early Paleocene (Podobina, 1998). The *Cibicidoides incognitus* assemblage has been detected only in two sections in the Omsk depression.

The palynological assemblage was studied in the marine sediments containing the foraminifera and is thus allochthonous. In the uppermost part of the Gankinskaya Stage (the *Brotzenella praeacuta* Zone) the palynomorph assemblage is largely the same as that in Upper Cretaceous sediments, and many of these Cretaceous palynomorphs may be reworked. Sporophytes are dominated by bog mosses (30%): *Sphagnum regium* Drozh, and *Sph. australe* (Cook) Drozh. Occasionally

System	Series	Stage	Regional stage	Zones of benthic foraminifera	Characteristic foraminiferal assemblages
Paleogene	Paleocene	Thanetian	Lyulinvorskaya	***Glomospira gordialiformis, Cibicidoides favorabilis***	***Glomospira gordialiformis*** Podobina, ***Asanospira grzybowski*** (Mjatliuk), ***Adercotryma horrida*** (Grzybowski), ***Cyclammina coksuvorovae*** Uschakova, ***Trochammina intacta*** Podobina, ***Cibicidoides favorabilis*** (Vassilenko)
		Selandian	Talitskaya	***Ammoscalaria friabilis***	***Ammodiscus glabratus*** Cushman et Jarvis, ***Trochamminoides lamentabilis*** Podobina, ***Labrospira granulosa*** (Lipman), ***Haplophragmoides fastosus*** Podobina, ***Asanospira grzybowski*** (Mjatliuk), ***Cyclammina coksuvorovae*** Uschakova, ***Ammoscalaria friabilis*** (Ehremeeva), ***Ammomarginulina brevis*** (Lipman), ***Trochammina pentacamerata*** Lipman, ***T. intacta*** Podobina, ***Verneuilinoides paleogenicus*** (Lipman), ***Bolivinopsis scanica*** Brotzen, ***Donsissonia laxata*** Podobina, ***Eponides lunatus*** Brotzen, ***Gavelinella umbilicata*** (Brotzen), ***Cibicides simplex*** Brotzen, ***Cibicidoides proprius*** Brotzen, ***Nonionellina ovata*** (Brotzen)
		Danian	Gankinskaya	***Brotzenella praeacuta***	**Characteristic Danian species:** ***Bathysiphon nodosarieformis*** Subbotina, ***Glomospira charoides*** Parker & ***Jones, Trochamminoides labentabilis*** Podobina, ***Gaudryina gigantica*** (Subbotina), ***Clavulina parisiensis*** Orb., ***Parrella lens*** (Brotzen), ***Cibicides spiropunctatus*** Gallowey & Morrey, ***Anomalina danica*** (Brotzen), ***Brotzenella praeacuta*** (Vassilenko), ***Subbotina varianta*** (Subbotina), ***S. trivialis*** (Subbotina), ***S. triloculinoides*** (Plummer) **Species inherited from Maastrichtian:** ***Heterostomella foveolata*** (Marsson), ***Valvulineria imitata*** (Olsson), ***Valvulinoides umovi*** (Kyprianova), ***Gyroidinoides turgidus*** (Hagenow), ***Eponides sibiricus*** Neckaja, ***Cibicides gankinoensis*** Neckaja, ***Anomalinoides pinguis*** (Jennings) ***neckajae*** Vassilenko, ***A. justus*** Podobina, ***Pullenia americana*** Cushman, ***Nonionellina pseudoinsecta*** (Putrja), ***Bulimina rozenkrantzi*** Brotzen, ***Reussella minuta*** (Marsson), ***Bolivina plaita*** Carsey

Figure 4. Paleocene foraminiferal assemblages of the West Siberian plain.

Gleichenia, Cyathea, Matonia, and *Osmunda* are present (5%–10%). Among the gymnosperm pollen, there are abundant *Taxodiaceae, Pinaceae* (25%), rare *Ephedra* (5%) and a few specimens (up to 3%) of *Cedrus, Podocarpus,* and *Caytonia.* Among the angiosperms, there are abundant *Orbiculapollis globosus* Chlonova (20%), and *Triprojectacites, Mancicorpus* and *Aquilapollenites* are rare (5%).

Up section, the relative abundance and diversity of pollen of the group of *Normapolles* Pfl. and *Ulmoideipites* And., which are typical for the Paleocene, increases to 20%. Rare *Myricaceae, Ulmaceae, Betulaceae, Triatriopollenites* spp., and *Triporopollenites robustus* Pfl. (up to 3%) occur consistently throughout the section (Fig. 5).

The analysis of these assemblages is rather difficult, because the assemblage was influenced by taphonomic processes. The assemblages, however, include palynomorphs characteristic for plant communities living on a coastal lacustrine-alluvial plain, locally occupied by bogs. The presence in the marine deposits of palynomorphs (miospores) that are not easily transported by winds (*Ephedra, Orbiculapollis, Sphagnum, Tax-*

System	Series	Stage	Regional stage	Palynological assemblages of eastern region
				The Parbig River basin
Paleogene	Paleocene	Thanetian	Lyulinvorskaya	Predominant: ***Triatripollenites exelsus*** (R.Rot.) Pfl., ***Myrica*** spp., Characteristic: ***Triporopollenites*** spp., ***Trudopollis pompeckji*** (R.Rot) Pfl., ***Castanea crenataeformis*** Samig., ***Quercus gracilis*** Boitz. Rare: ferns and gymnospermae
		Selandian	Talitskaya	Predominant:Taxodiaceae, Pinaceae, Normapolles Characteristic: ***Extratriporopollenites*** spp., ***Trudopollis menneri*** (Martyn) Zakl., ***T. conrector*** Pfl., ***Nudopollis endangulatus*** Pfl., ***N. thirgartii*** Pfl., ***Oculopollis sibiricus*** Zakl., ***Basopollis*** sp., ***B. vestibulatus*** Pfl., ***Postnormapollis*** spp., Myricaceae, Ulmaceae, Juglandaceae, Betulaceae.
		Danian		**Palynological assemblage 1***
			Gankinskaya	Predominant: Taxodiaceae, Pinaceae. Characteristic: ***Orbiculapollis globosus*** Chlonova, ***Wodehouseia*** spp., ***Tricolporites gracilis***, ***Aquilapollenites*** spp., ***Ulmoideipites*** spp., ***Ephedra*** sp. Rare: ***Normapolles*** Pfl. Abundant: ***Membranosphera maastrichtica*** Samoil.

***Palynological assemblage 1:**
Predominant: Taxodiaceae, Pinaceae
Characteristic: ***Normapolles*** spp., ***Orbiculapollis globosus*** Chlonova, ***Ulmoideipites tricostatus*** And., ***Trudopollis menneri (*** Martin) Zakl., ***T. nonperfectus*** Pfl., ***T. conrector*** Pfl., ***T. fossulotrudens***, ***Nudopollis enangulatus*** Pfl., ***Oculopollis giganteus*** Zakl., ***Oculopollis sibiricus*** Zakl., ***Anacolosidites*** sp., ***Triporopollenites robustus*** Pfl., ***Myrica*** spp., ***Triporopollenites*** spp.
Rare: ***Mancicorpus, Aquilapollenites***

Figure 5. Paleocene palynological assemblages of the West Siberian plain.

odium, etc.) indicates that these palynomorphs represent the vegetation of the nearest coast, especially because these taxa may be dominant in some samples (>30%).

Nagorskaya et al. (1978) studied the coeval continental deposits on the eastern bank of the river Ob in the Ket river basin, close to the Ust-Tym depression. These deposits are characterized by a palynological assemblage with *Triporopollenites robustus* pfl.–*Ulmoideipites tricostatus* And. The floral composition is very similar to that of the assemblage described above, but it represents a different environment, probably because these regions further away from the coast were less boggy.

There are few spores (5%) in this assemblage. Gymnosperm pollen is represented mainly by *Pinaceae* (16%) and to a lesser degree by *Taxodiaceae* (12%). Angiosperm pollen is highly diverse; *Ulmoideipites tricostatus* And., and *U. krempi* And. are the most abundant taxa (13%). There are few *Myrica intermedia* Glad. (5%), *Triporopollenites robustus* Pfl. (6%), *T.* spp., and single specimens of *Alnus* sp., *Platycarya* sp., *Juglans* sp., *Engelhardtia* sp.

The palynological assemblage in the lowermost Talitskaya stage of the northern West Siberian plain is characterized by the occurrence of *Trudopollis menneri* (Martyn) Zakl., *Nudopollis endangulatus* Pfl., and *Oculopollis giganteus* Zakl., as was first described by Ilyenok (1967) for the basin of the Taz river (Fig. 1B) in a continuous section of Cretaceous-Paleogene deposits (Podobina et al., 1997).

This palynological assemblage contains equal portions of spores and pollen of gymnosperm and angiosperm plants. Among the spores there is relatively much *Sphagnum* (20%), less *Lycopodium* (10%) and *Selaginella* (5%), but ferns are also present (3%). Gymnosperm pollen has common Taxodiaceae (25%), and lower percentages of Pinaceae (10%). Angiosperm

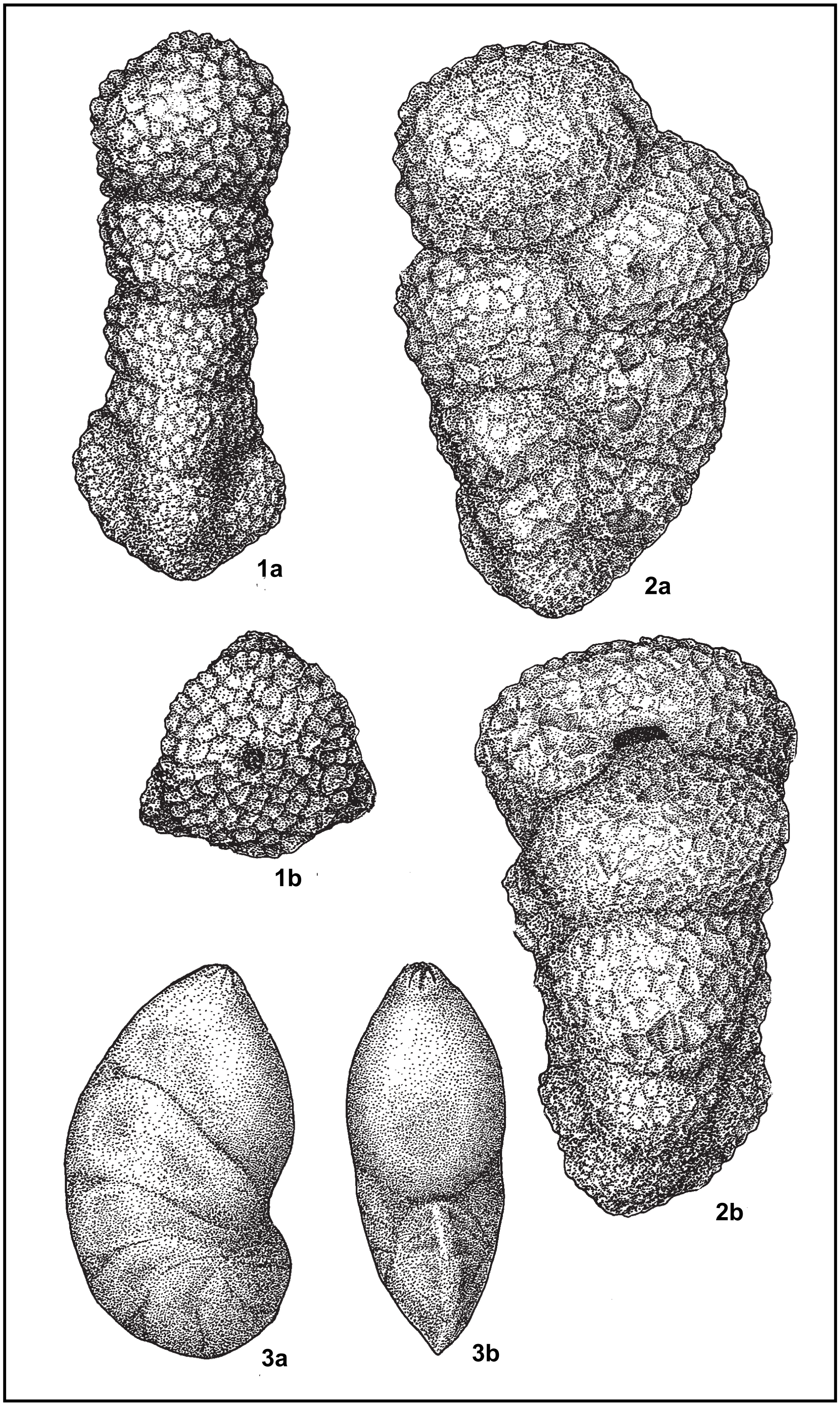

Plate 1. West Siberian Plain; early Paleocene; *Brotzenella praeacuta* zone, magnification ×80. (All specimens are deposited in the Micropaleontological Laboratory and Paleontological Museum of Tomsk State University.) Figure 1. *Clavulina parisiensis* Orbigny; a, lateral view; b, apertural view. Figure 2. *Gaudryina gigantica* (Subbotina); a, lateral view; b, apertural view. Figure 3. *Astacolus elatus* Podobina; a, lateral view; b, apertural view.

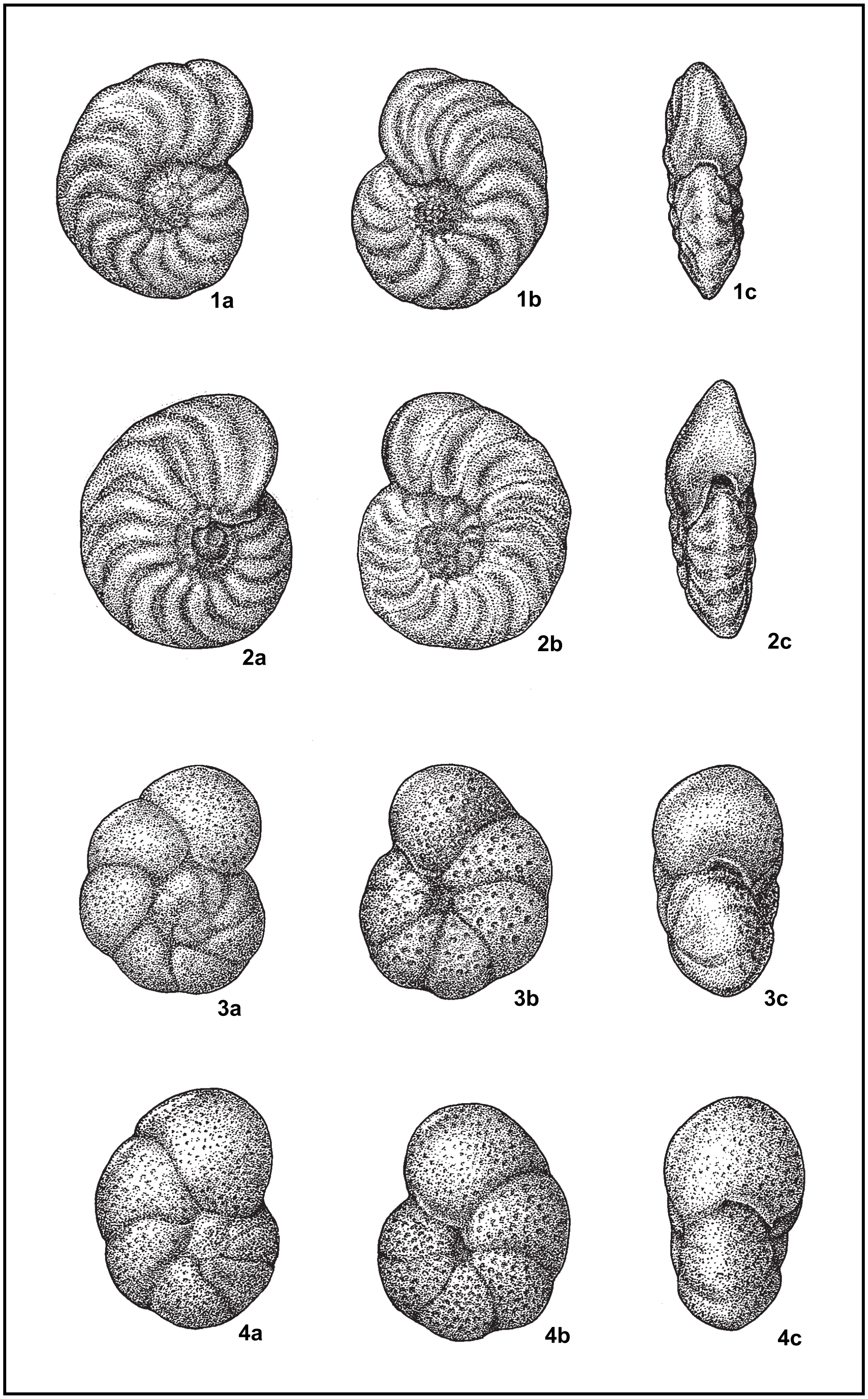

Plate 2. West Siberian Plain; early Paleocene; *Brotzenella praeacuta* zone, magnification ×80. (All specimens are deposited in the Micropaleontological Laboratory and Paleontological Museum of Tomsk State University.) Figures 1–2. *Brotzenella praeacuta* (Vassilenko); a, dorsal view; b, ventral view; c, apertural view. Figures 3–4. *Anomalina danica* (Brotzen); a, dorsal view; b, ventral view; c, apertural view.

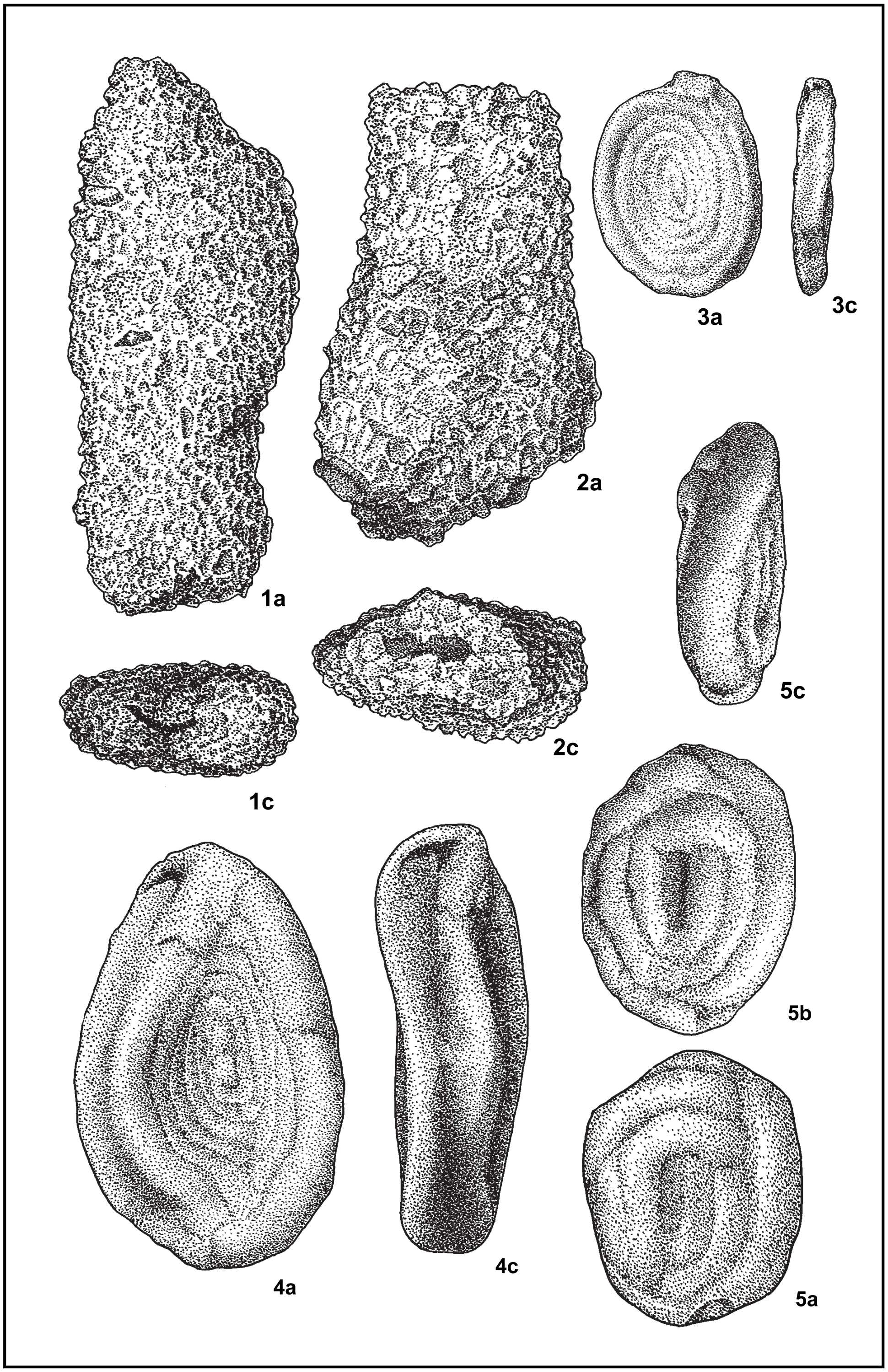

Plate 3. West Siberian Plain; early Paleocene; strata with *Bathysiphon nodosarieformis* and *Glomospira charoides,* magnification ×100. (All specimens are deposited in the Micropaleontological Laboratory and Paleontological Museum of Tomsk State University.) Figure 1. *Bathysiphon nodosarieformis* Subbotina; a, lateral view; c, apertural view. Figure 2. *Hyperammina elongata* Brady; a, lateral view; c, apertural view. Figure 3. *Ammodiscus glabratus* Cushman and Jarvis; a, lateral view; c, apertural view. Figure 4. *Ammodiscus incertus* (Orbigny); a, lateral view; c, apertural view. Figure 5. *Glomospira gordialiformis* Podobina and Kabanova; a, dorsal view; b, ventral view; c, apertural view.

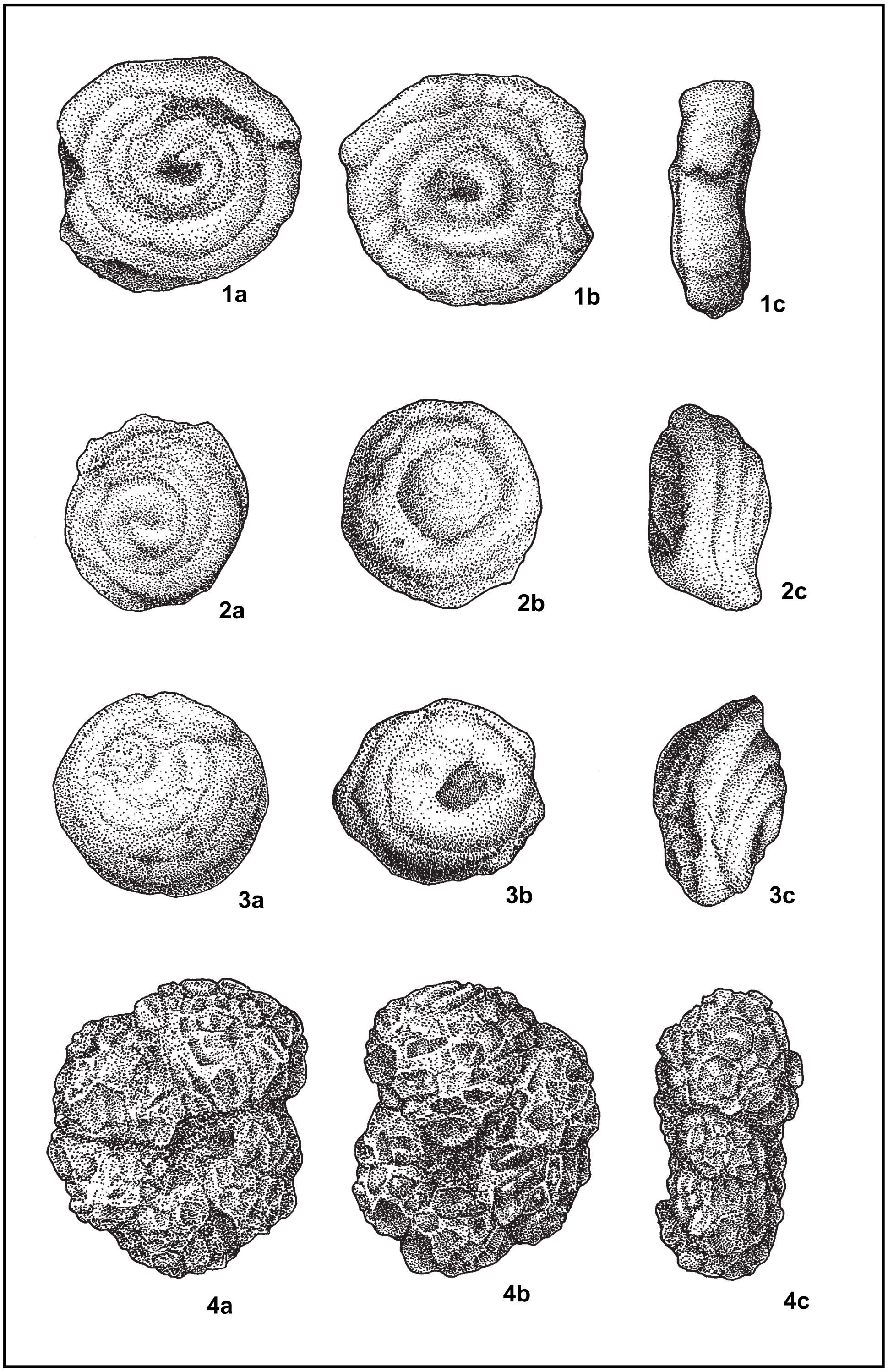

Plate 4. West Siberian Plain; early Paleocene; strata with *Bathysiphon nodosarieformis,* and *Glomospira charoides,* magnification ×80. (All specimens are deposited in the Micropaleontological Laboratory and Paleontological Museum of Tomsk State University.) Figure 1. *Glomospira gordialiformis* Podobina; a, dorsal view; b, ventral view; c, apertural view. Figures 2–3. *Glomospira charoides* (Parker and Jones); a, dorsal view; b, ventral view; c, apertural view. Figure 4. *Labrospira granulosa* (Lipman); a, dorsal view; b, ventral view; c, apertural view.

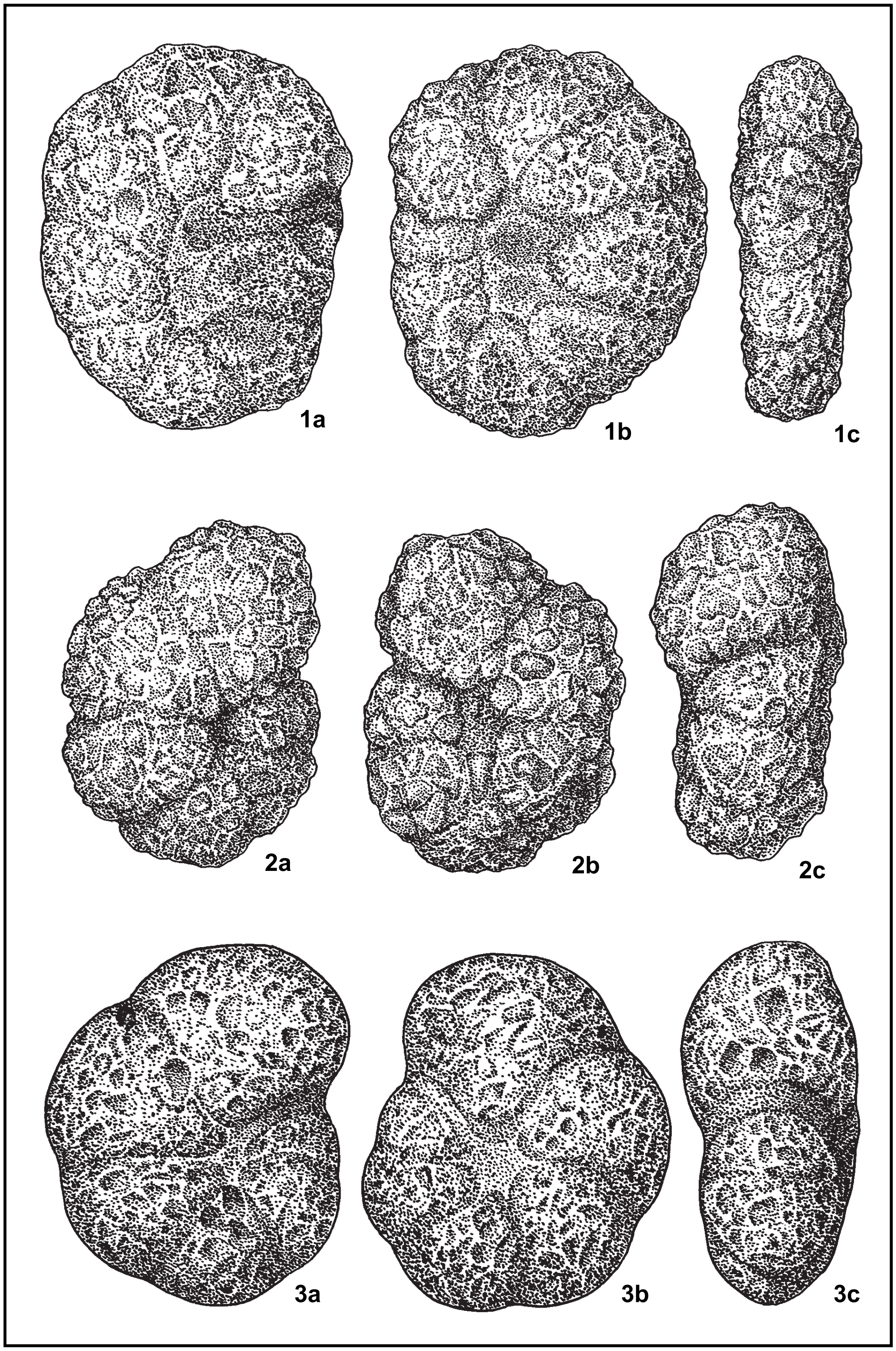

Plate 5. West Siberian Plain; late Paleocene; *Ammoscalaria friabilis* zone, magnification ×100. (All specimens are deposited in the Micropaleontological Laboratory and Paleontological Museum of Tomsk State University.) Figure 1. *Trochamminoides lamentabilis* Podobina; a, dorsal view; b, ventral view; c, apertural view. Figure 2. *Labrospira granulosa* (Lipman); a, dorsal view; b, ventral view; c, apertural view. Figure 3. *Haplophragmoides fastosus* Podobina; a, dorsal view; b, ventral view; c, apertural view.

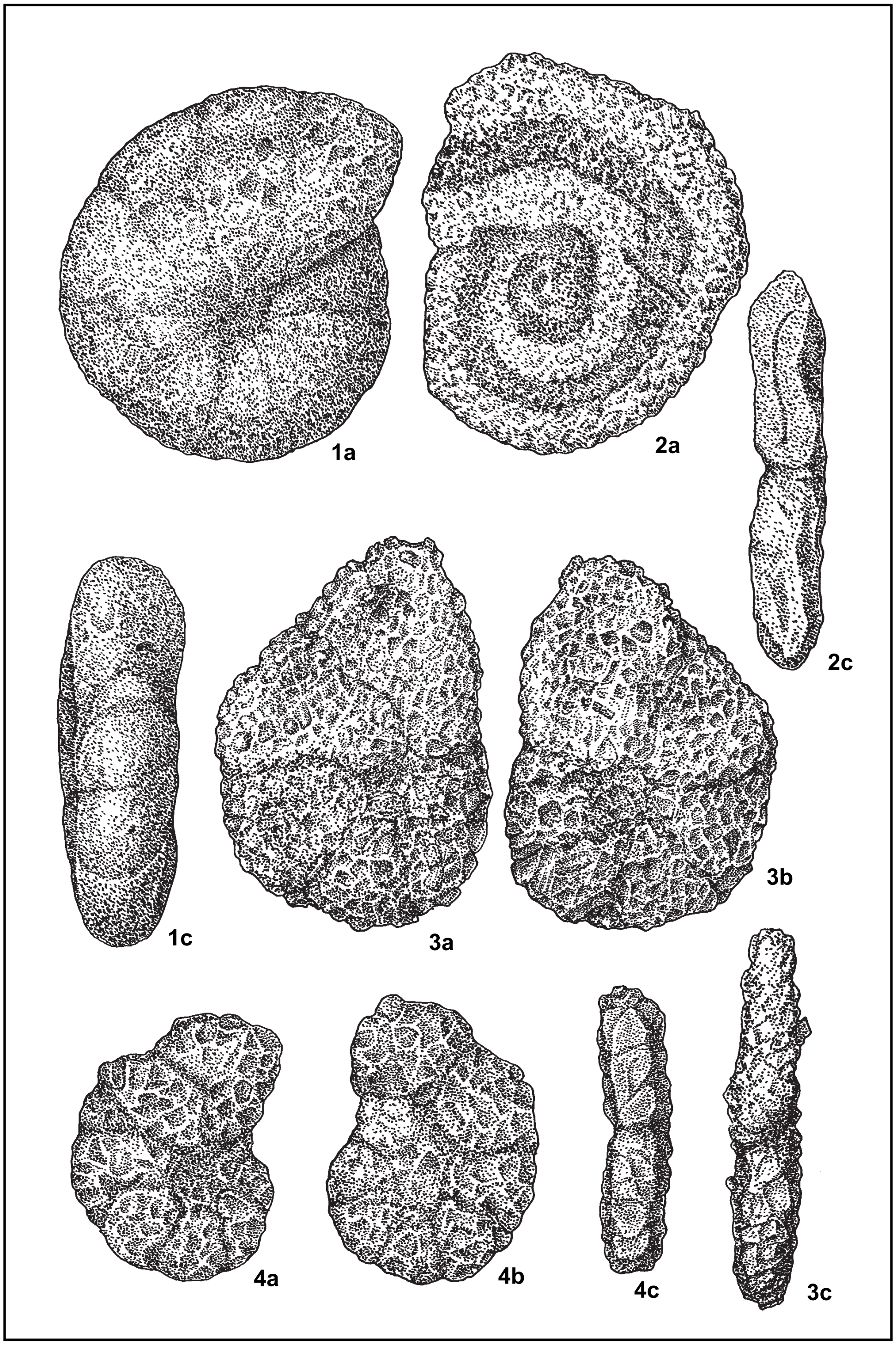

Plate 6. West Siberian Plain; late Paleocene; *Ammoscalaria friabilis* zone, magnification ×100. (All specimens are deposited in the Micropaleontological Laboratory and Paleontological Museum of Tomsk State University.) Figure 1. *Cyclammina coksuvorovae* Uschakova; a, dorsal view; c, apertural view. Figure 2. *Ammoscalaria friabilis* (Ehremeeva); a, dorsal view; c, apertural view. Figures 3–4. *Ammomarginulina brevis* (Lipman); a, dorsal view; b, ventral view; c, apertural view.

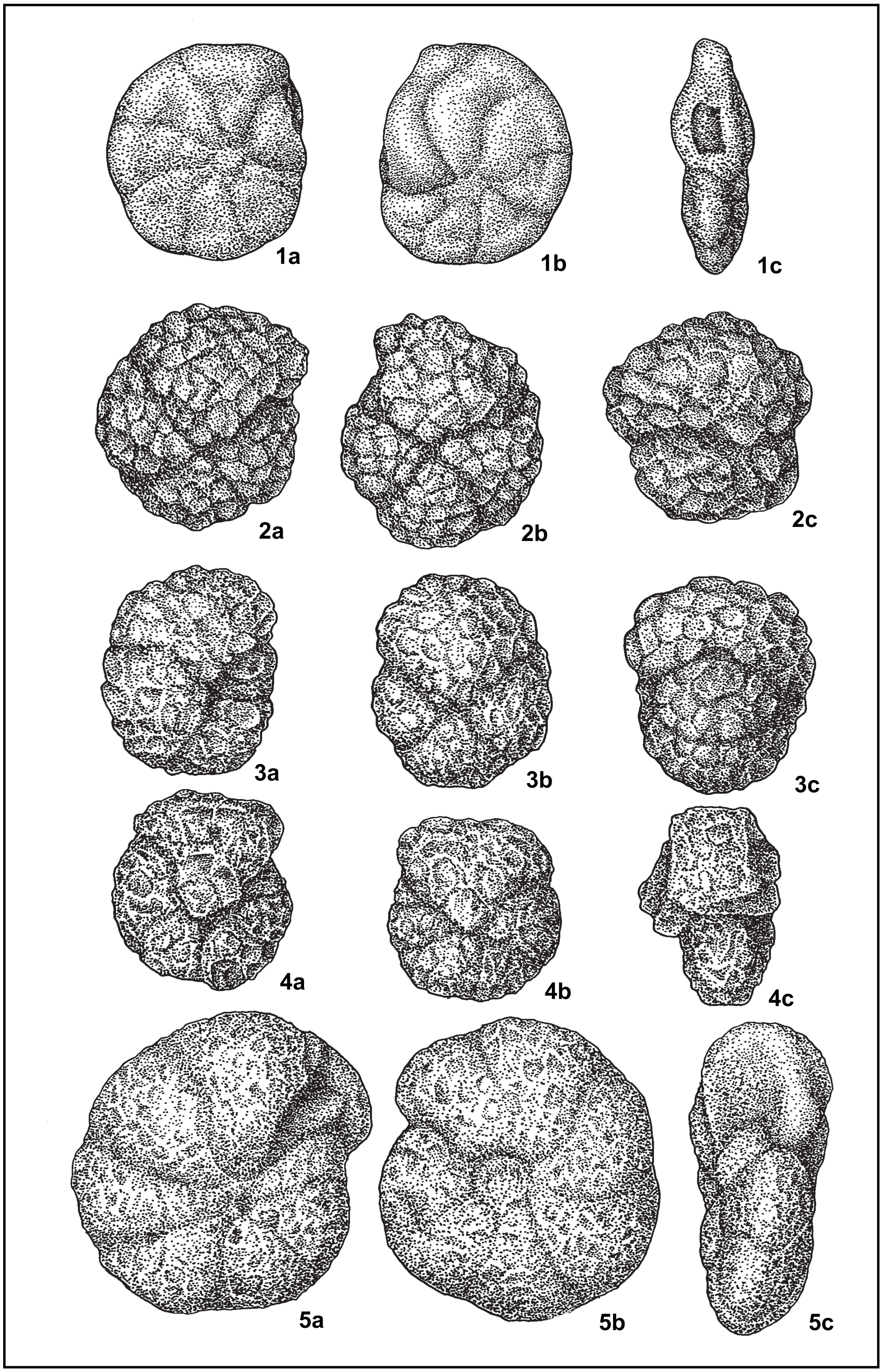

Plate 7. West Siberian Plain; late Paleocene; *Ammoscalaria friabilis* zone, magnification ×100. (All specimens are deposited in the Micropaleontological Laboratory and Paleontological Museum of Tomsk State University.) Figure 1. *Asanospira grzybowski* (Mjatliuk); a, dorsal view; b, ventral view; c, apertural view. Figures 2–4. *Adercotryma horrida* (Grzybowski); a, dorsal view; b, ventral view; c, apertural view. Figure 5. *Haplophragmoides stomatus* (Grzybowski); a, dorsal view; b, ventral view; c, apertural view.

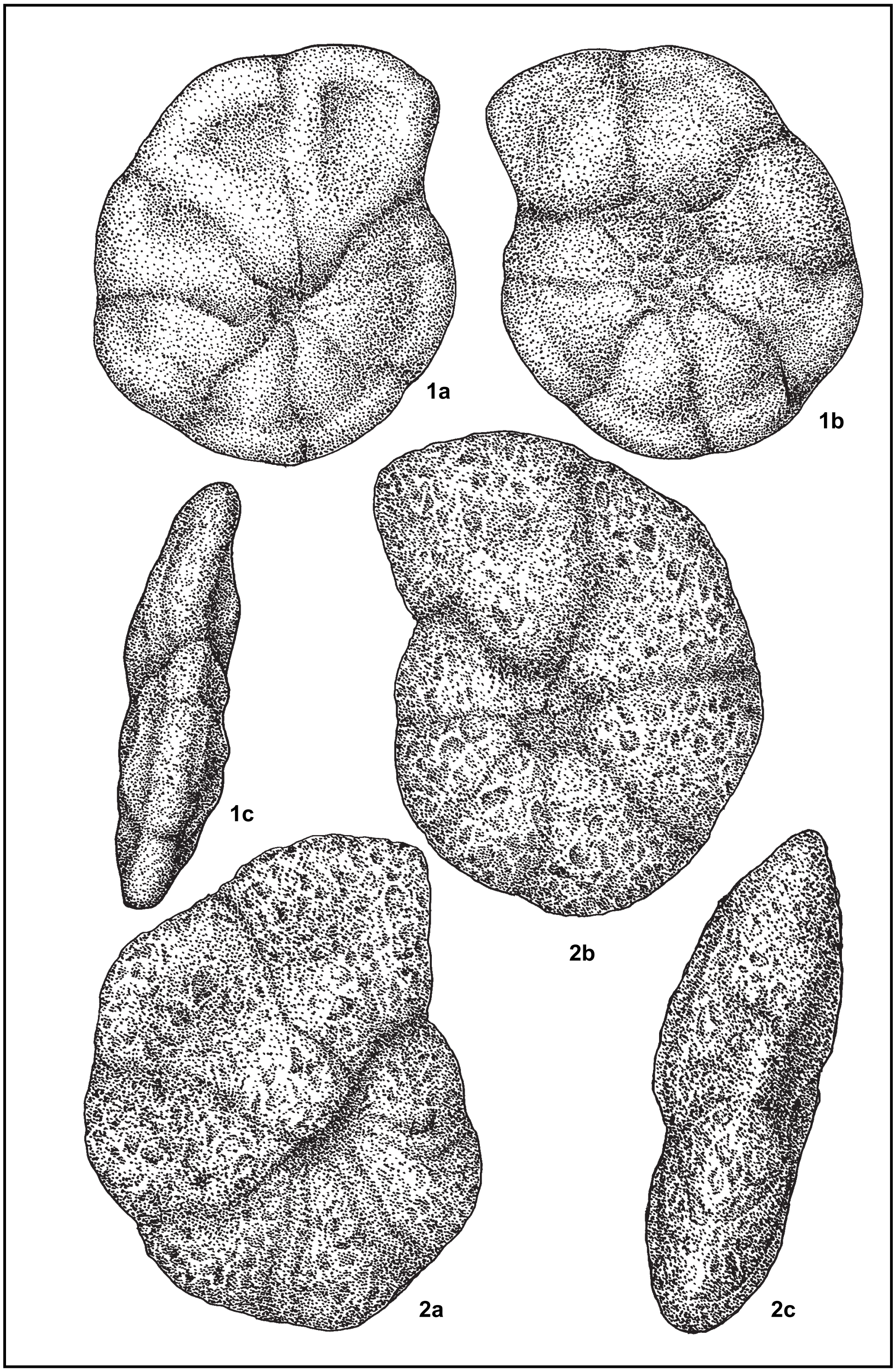

Plate 8. West Siberian Plain; late Paleocene; *Ammoscalaria friabilis* zone, magnification ×100. (All specimens are deposited in the Micropaleontological Laboratory and Paleontological Museum of Tomsk State University.) Figures 1–2. *Cyclammina coksuvorovae* Uschakova; a, dorsal view; b, ventral view; c, apertural view.

pollen is mainly represented by diverse *Normapolles,* some *Quercites sparsus* (Mart.) Samoil. (20%), and sparse *Salix, Myrica,* and *Betulaceae* (10%).

In the Parbig river basin in the southeastern reaches of West Siberia (Fig. 1B) the following coeval palynological assemblages occur: *Normapolles* spp., *Orbiculapollis globosus*, *Chlonova, Ulmoideipites tricostatus* And., *Trudopollis nonperfectus* Pfl., *T. conrector* Pfl., *T. fossulotrudens* Pfl., *Oculopollis sibiricus* Zakl., *Anacolosidites* sp., *Triporopollenites robustus* Pfl., *Myrica* spp., *Triporopollenites* spp.; *Mancicorpus* and *Aquilapollenites* are rare (up to 5%) (Fig. 5; Plates 9–11).

This palynological assemblage has been dated as early Paleocene (Danian), because it occurs in sediments containing *Cibicidoides incognitus* (Fig. 4). Planktonic foraminifera co-occurring with this species at other locations (see above) indicate that these samples have a Danian age. The assemblage represents the evolution of the flora throughout the early Paleocene, during which time the *Normapolles* vegetation became more common. During the whole time of deposition of the sediments with this assemblage, the southeastern coast of the basin remained a lacustrine-alluvial plain with bogs, from where spores and pollen were transported into the epicontinental marine basin.

LATE PALEOCENE

Selandian

Most of the lower part of the Talitskaya Stage is characterized by a foraminiferal assemblage with *Ammoscalaria friabilis* (Figs. 3, 4; Podobina, 1975, 1998). In the deeper, western parts of the basin (East of the Ural Mountains) and in the central region of the West Siberian plain, these sediments are thicker (80–100 m) than in the eastern regions (10–20 m). In northern Transuralia (close to the settlement of Beryozovo, Fig. 1B) the *Ammoscalaria friabilis* assemblage contains agglutinated taxa as well as abundant (30%) calcareous forms of the *Cibicidoides proprius* assemblage, many species of which are known from the Selandian stratotype of Denmark and Sweden (Brotzen, 1948; Frenzel, 2000).

The calcareous taxa (10%–15%) of the *Cibicidoides proprius* assemblage occur in the central West Siberian plain (the basin of the Vasyugan river) together with agglutinated ones. In these sediments *Ammoscalaria friabilis* is rare (5%), while the fine-grained tests of the agglutinated genera *Psammosphaera, Ammodiscus, Haplophragmoides* and *Trochammina* (Plates 5–8) are abundant (80%–85%; Podobina, 1998).

Toward the East, the thickness of the Talitskaya stage sediments decreases down to ~10–20 m, but the foraminiferal assemblage with *Ammoscalaria friabilis,* consisting mainly of agglutinated forms, occurs throughout the basins of the Ilyak, Chizhapka and other rivers (Fig. 1B). Each species is represented by several individuals (5–10 specimens in a sample), resulting in a diverse assemblage with fairly even distribution of specimens over species, suggesting that salinity and oxygen levels were normal marine. The predominance of medium-grained quartz in the agglutinated tests indicate that paleo-depths were about inner shelf.

Most of deposits of the Talitskaya stage with the *Ammoscalaria friabilis* assemblage, and the coeval deposits of the Central Priobye (the Ob riverside territory) are characterized by a palynological assemblage with *Trudopollis menneri* (Martyn) Zakl., *Anacolosidites insignis* Samoil., and *Triatriopollenites aroboratus* Pfl., taxa that survived from the early Paleocene. The assemblages are present in marine sediments, thus allochthonous, and may contain common reworked elements.

There are many *Sphagnum* spores (20%), as in the lower Paleocene, and Taxodiaceae and Pinaceae pollen are abundant and predominant (50%). Angiosperm pollen remained highly diverse, but the abundance of *Normapolles* pollen decreased to 20%. *Basopollis triangularis* Pfl. occurs as well as rare *Anacolosidites insignis* Samoil., *Regina exelsa* Samoil., *Projectoporites spinulosus* N. Mtchedlishvili. (5%–10%), which are typical late Paleocene taxa. The species richness of *Postnormapolles* species increased, and in marine and littoral deposits, microphytoplankton (microscopic algae) is present.

On the east bank of the river Ob the thickness of deposits with this palynological assemblage decreases to ~10 m. In the Ust-Tym depression, strata with palynological assemblages containing *Trudopollis menneri–Anacolosidites insignis–Triatriopollenites aroboratus* directly overlie Maastrichtian deposits. They are pinching out toward the East, where they remain only locally as separated lenses in depressions in the Cretaceous sediments.

Between the Ket and the Tym rivers (Fig. 1B), deposits with this assemblage occur in a lenticular body of dark-brown sands with thin lignite intercalations, overlain by dark-brown clay (Kabanova and Kostesha, 1988; Ilyenok et al., 1989). This body occurs within an eroded channel in Maastrichtian-Danian sediments, and is overlain by Oligocene channel deposits. In these eastern deposits there are few spores (10%–20%) and abundant pollen (80%–90%), with a floral composition very similar to that in the sediments described above, although the relative abundance of taxa differs. Gymnosperms are represented by Pinaceae (50%): Mostly *Pinus,* rarely *Picea, Abies, Keteleeria, Cedrus,* less common Taxodiaceae. Angiosperm pollen (30%) are more diverse.

Thanetian

The upper Paleocene Talitskaya sediments and the lower part of the Lyulinvorskaya sediments in the central region of Western Siberia contain a foraminiferal assemblage characterized by the index species *Glomospira gordialiformis* and *Cibicidoides favorabilis.* The agglutinated, sugary-white tests of the genera *Psammosphaera, Ammodiscus, Glomospira, Asanospira* and *Cyclammina* dominate (90%) the assemblage, and calcareous species are rare (10%), but the index species *Cibicidoides favorabilis* (Vassilenko) is present (Podobina, 1998). Calcareous

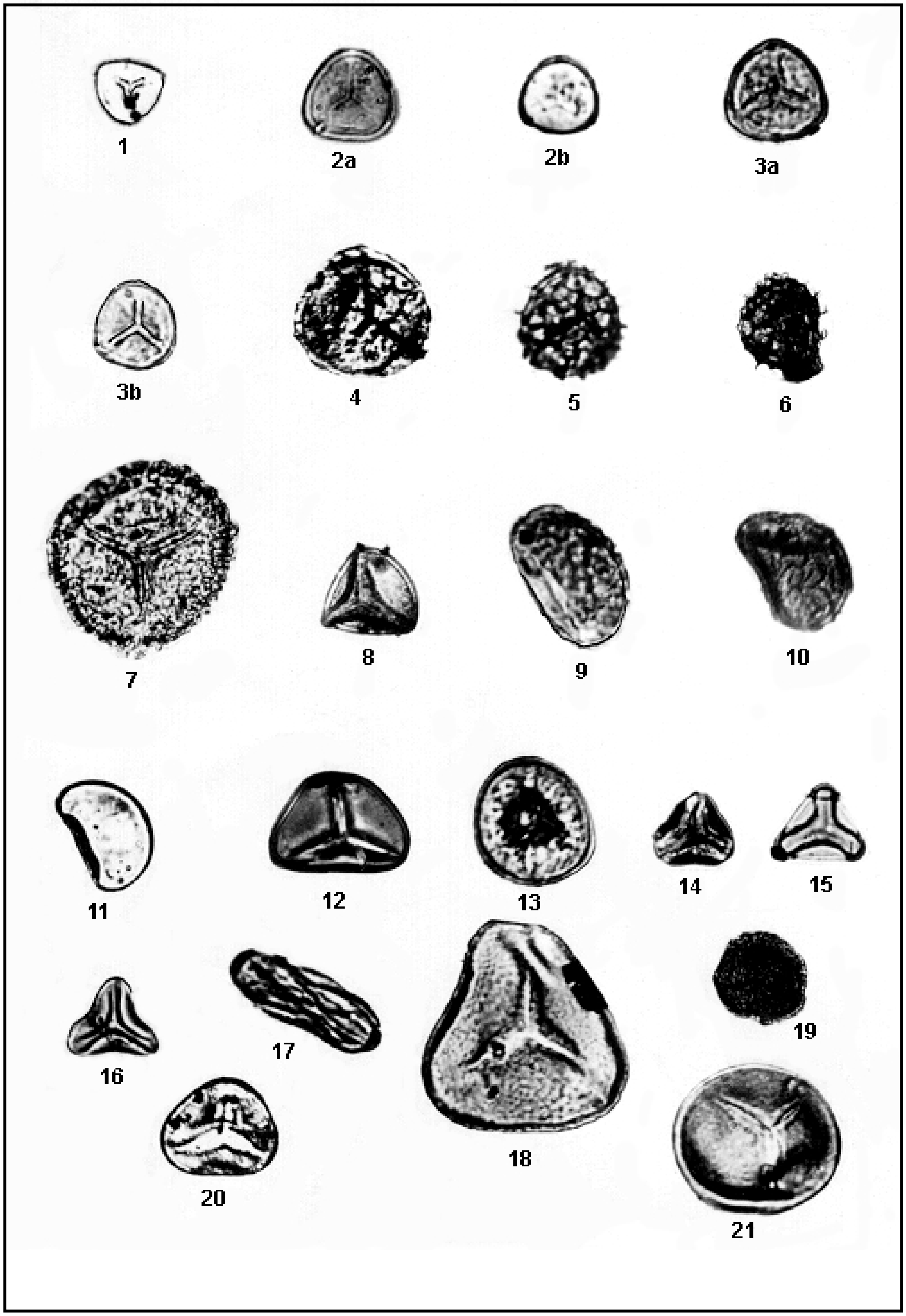

Plate 9. West Siberian Plain; early Paleocene; Sporae (magnification ×600). (All specimens are deposited in the Micropaleontological Laboratory and Paleontological Museum of Tomsk State University.) Figure 1. *Sphagnum australe* (Cook) Drozh; Figure 2a, b. *Sphagnum putillum* Drozh. et Purt. Figure 3a, b. *Sphagnum regium* Drozh. Figures 4–6. *Lycopodium* sp. Figure 7. *Selaginella* sp. Figure 8. *Cyathea* sp. Figures 9–10. Polypodidiaceae. Figures 11–12. *Adiantum* sp. Figure 13. *Cheiropleuria* sp. Figure 14. *Gleichenia umbonata* Bolch. Figure 15. *Gleichenia rara* Chlon. Figure 16. *Gleichenia* sp. Figure 17. *Schizaea dorogensis* (R. Pot.) Chlon. Figure 18. *Lygodium* sp. Figure 19. *Osmunda* sp. Figure 20. *Leiotriletes* Naum. Figure 21. *Stenozonotriletes* Naum.

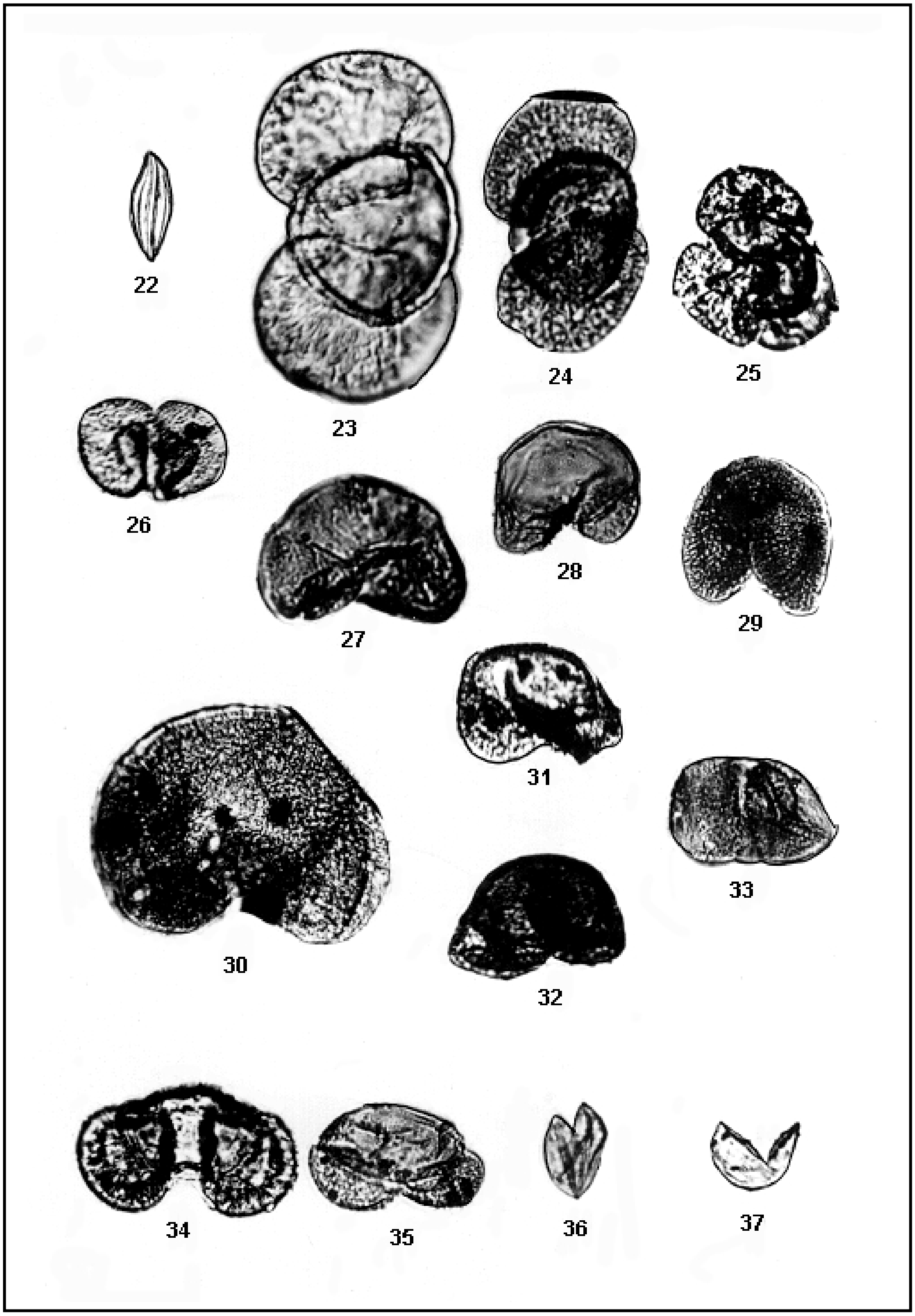

Plate 10. West Siberian Plain; early Paleocene; Gymnospermae Pollen (magnification ×600). (All specimens are deposited in the Micropaleontological Laboratory and Paleontological Museum of Tomsk State University.) Figure 22. *Ginkgo* sp. Figure 23. *Podocarpus unica* Bolch. Figures 24–26. *Podocarpus* sp. Figures 25–27. Pinaceae. Figure 28. *Cedrus parvisaccata* Sauer. Figures 29–32. *Cedrus* sp. Figure 33. *Pinus aequelis* (Naum.) Bolch. Figure 34. *Pinus vulgaris* (Naum.) Bolch. Figure 35. *Pinus* n./p. Dyploxylon. Figure 36. Taxodiaceae. Figure 37. *Taxodium* sp.

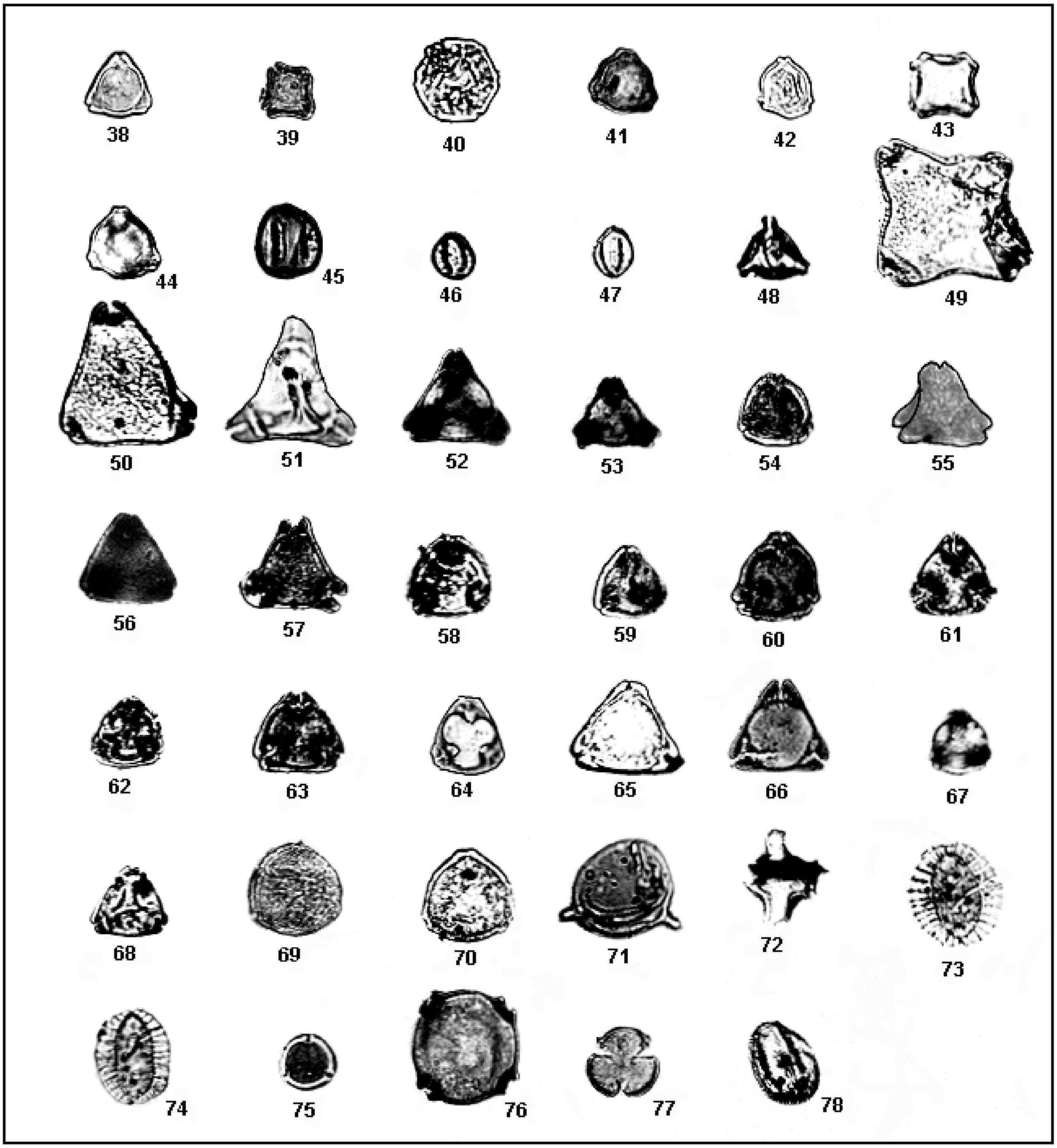

Plate 11. West Siberian Plain; early Paleocene; Angiospermae Pollen (magnification ×600). (All specimens are deposited in the Micropaleontological Laboratory and Paleontological Museum of Tomsk State University.) Figure 38. *Myrica* sp. Figure 39. *Myricacites* sp. Figure 40. *Juglans* sp. Figures 41–42. Betulaceae. Figure 43. *Alnus* sp. Figure 44. *Betula* sp. Figure 45. *Quercus* sp. Figures 46–47. *Quercites sparsus* (Martyn) Samoil. Figure 48. *Santalacites* sp. Figure 49. Proteacea. Figure 50. *Protea* sp. Figure 51. *Nudopollis endangulatus* Pfl. Figures 52–53. *Nudopollis* sp. Figure 54. *Basopollis vestibulatus* Zalkl. Figure 55. *Basopollis* sp. Figure 56. *Oculopollis praedicatus* Weil et Krieg. Figure 57. *Oculopollis torosus* Zakl. Figure 58. *Oculopollis* sp. Figure 59. *Vacuopollis* sp. Figure 60. *Trudopollis conrector* Pfl. Figures 61–64. *Trudopollis* sp. Figures 65–66. *Extratriporopollenites* sp. Figure 67. *Triatriopollenites aroboratus* Pfl. Figure 68. *Triatriopollenites.* Figure 69. *Trioropollenites robustum* Pfl. Figure 70. *Tricolpites* sp. Figure 71. *Triporina globosa* Chlon. Figure 72. *Aquilapolenites* sp. Figures 73–74. *Kryshtofoviana vera* Samoil. Figure 75. *Triporopollenites* sp. Figure 76. *Tetraporopollenites* sp. Figures 77–78. *Tricolpopollenites* sp.

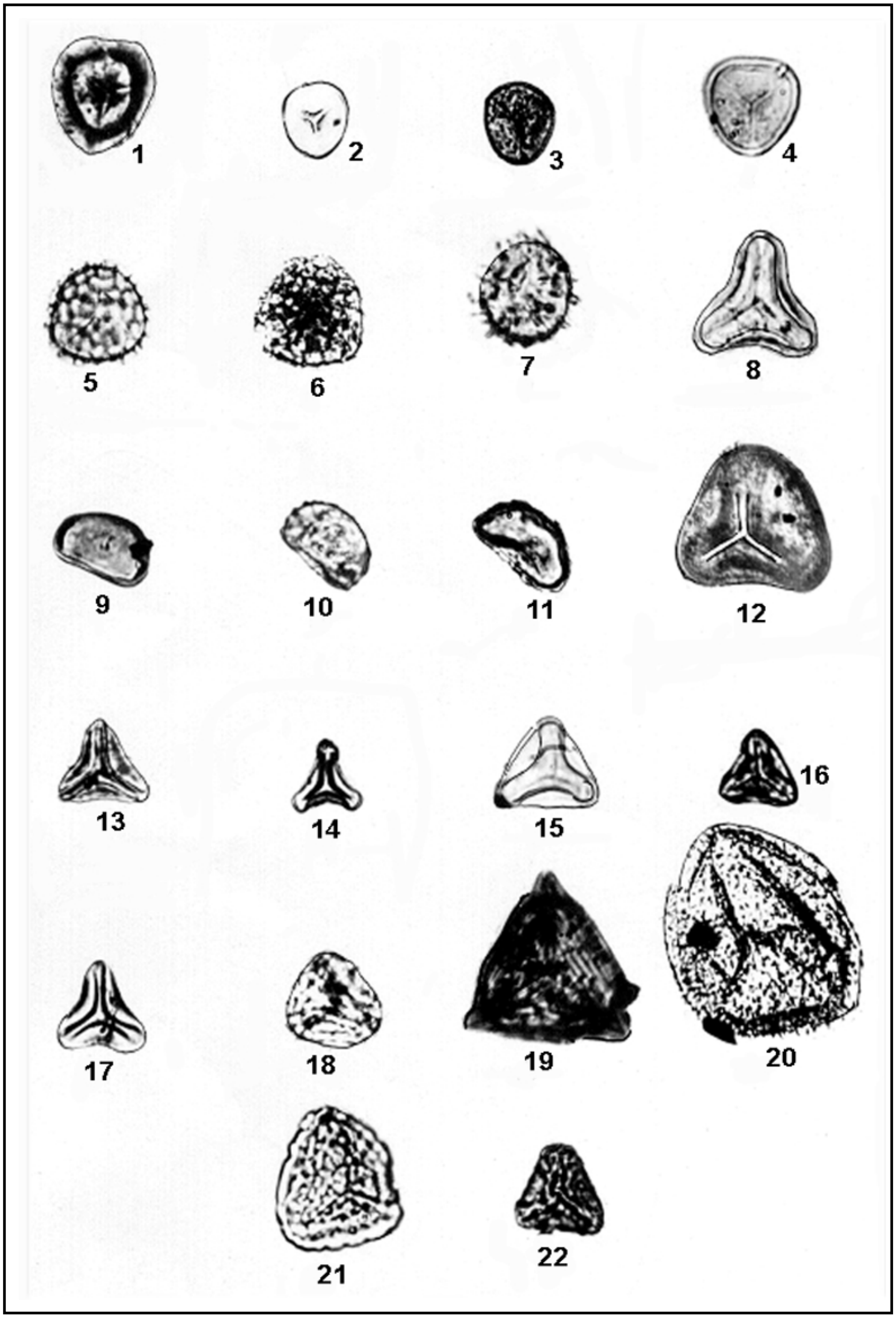

Plate 12. West Siberian Plain; late Paleocene; Sporae (magnification ×600). (All specimens are deposited in the Micropaleontological Laboratory and Paleontological Museum of Tomsk State University.) Figure 1. *Sphagnum australe* (Cook) Drozh. Figure 2. *Sphagnum putillum* Drozh. et Purt. Figure 3. *Sphagnum regium* Drozh. Figure 4. *Sphagnum putillum* Drozh. et Purt. Figures 5–6. *Lycopodium* sp. Figure 7. *Selaginella diuturna* Bolch. Figure 8. *Cyathea* sp. Figures 9–11. Polypodidiaceae. Figure 12. *Matonia* sp. Figure 13. *Gleichenia umbonata* Bolch. Figure 14. *Gleichenia laeta* Bolch. Figure 15. *Gleichenia rara* Chlon. Figures 16–17. *Gleichenia* sp. Figure 18. *Mohria* sp. Figure 19. *Aneimia* sp. Figure 20. *Osmunda* sp. Figures 21–22. *Lophotriletes* Naum (magnification ×600).

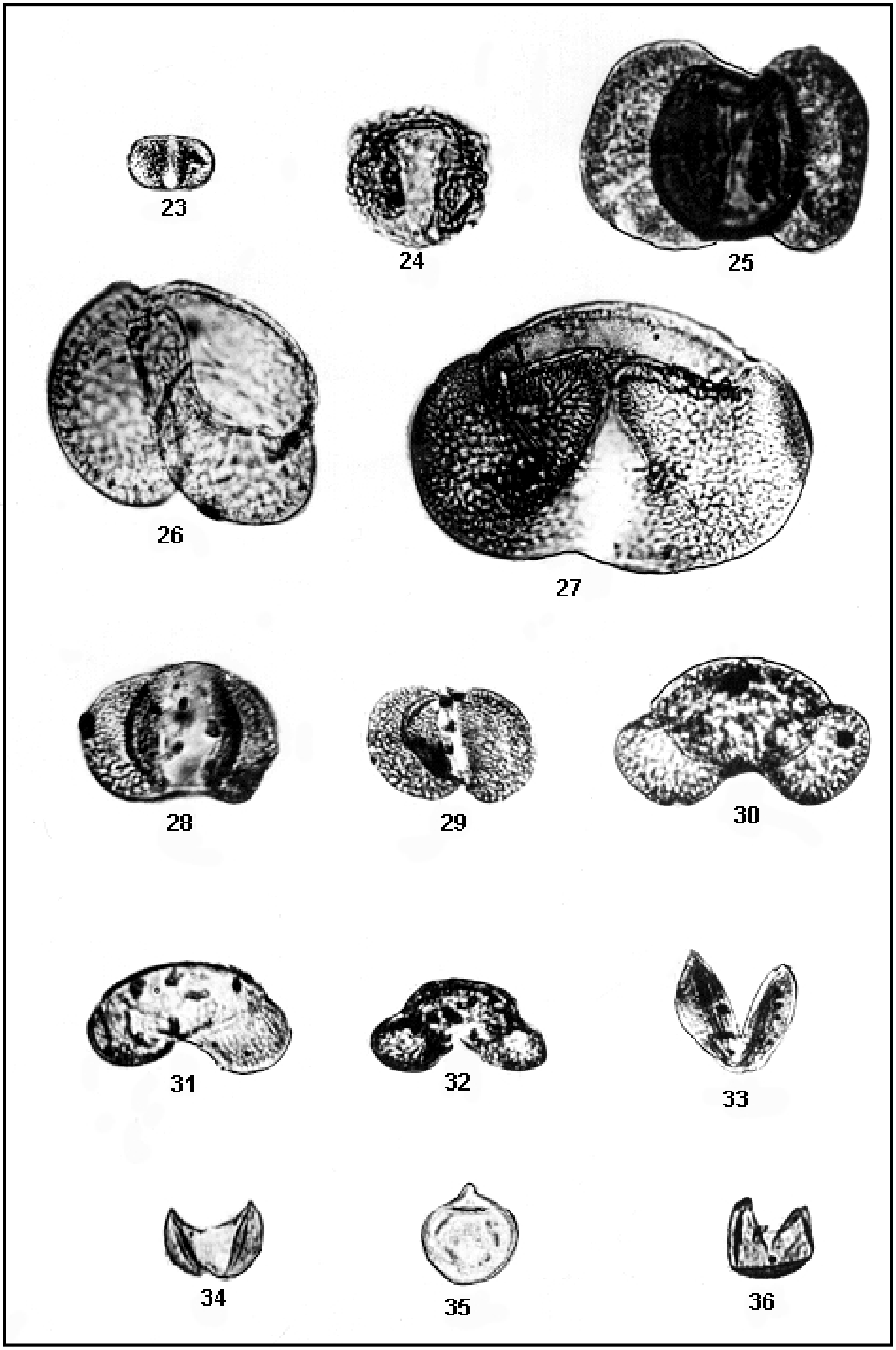

Plate 13. West Siberian Plain; late Paleocene; Gymnospermae Pollen (magnification ×600). (All specimens are deposited in the Micropaleontological Laboratory and Paleontological Museum of Tomsk State University.) Figure 23. *Caytonia* sp. Figure 24. *Dacrydiumites* sp. Figure 25. *Podocarpus* sp. Figure 26. Pinaceae. Figure 27. *Picea* sp. Figures 28–29. *Pinus* n./p. Haploxylon. Figure 30. *Pinus aralica* Bolch. Figures 31–32. *Pinus* n./p. *Diploxylon.* Figures 33–34. Taxodiaceae. Figures 35–36. *Taxodium* sp.

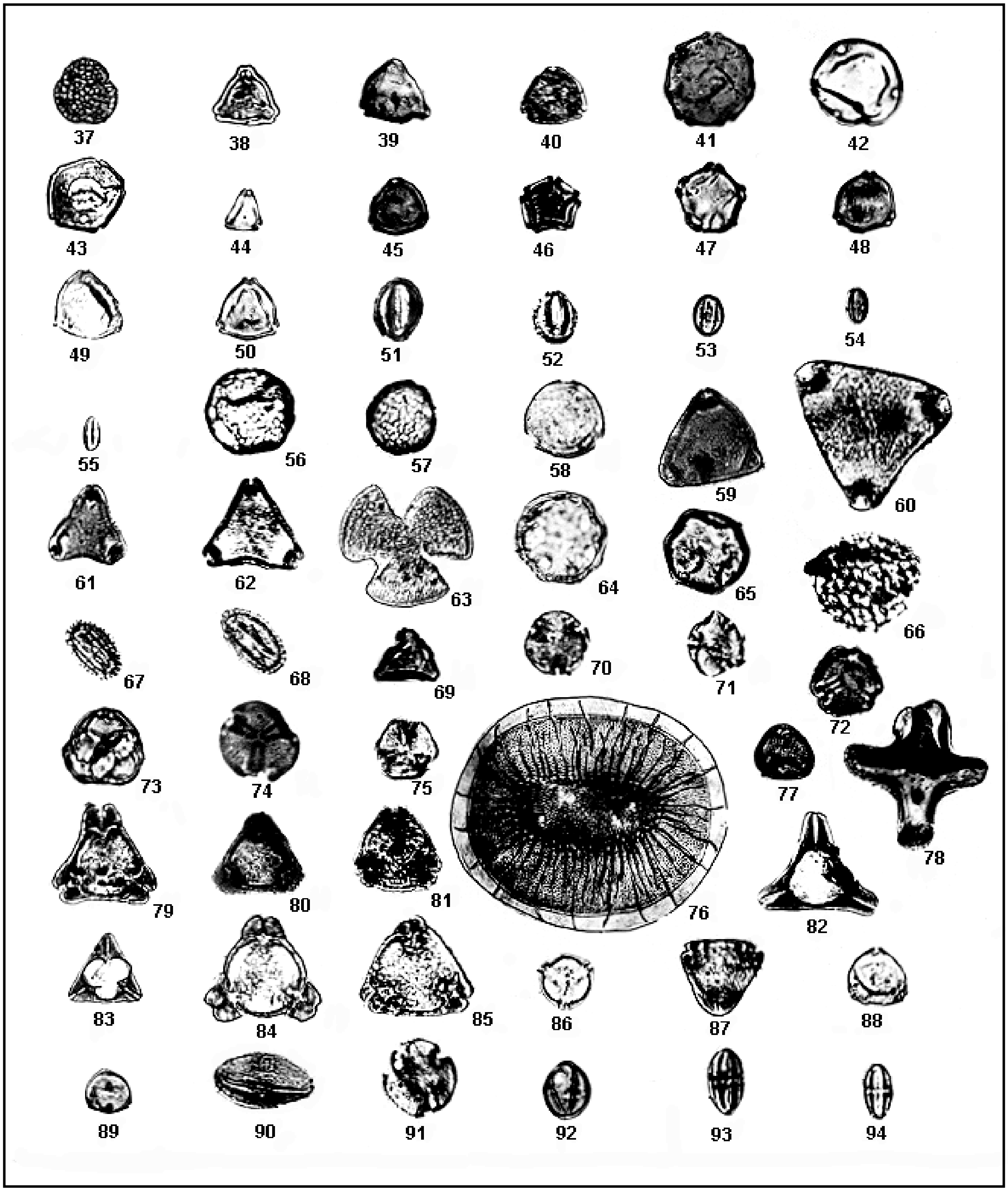

Plate 14. West Siberian Plain; late Paleocene; Angiospermae Pollen (magnification ×600). (All specimens are deposited in the Micropaleontological Laboratory and Paleontological Museum of Tomsk State University.) Figure 37. Solicaceae. Figures 38–40. *Myrica* sp. Figure 41. *Pterocarya* sp. Figure 42. *Carya* sp. Figure 43. *Juglans* sp. Figure 44. *Engelhardtia* sp. Figure 45. Betulaceae. Figures 46–47. *Alnus* sp. Figure 48. *Betula* sp. Figure 49. *Betulites* sp. Figure 50. *Corylus* sp. Figure 51. *Quercus* sp. Figures 52–53. *Quercites sparsus* (Martyn) Samoil. Figures 54–55. *Castanea* sp. Figures 56–57. Ulmaceae. Figure 58. Moraceae. Figures 59–62. Protaceae. Figure 63. Homamelidaceae. Figures 64–65. *Liquidambar* sp. Figure 66. Buxaceae. Figures 67–68. *Ilex* sp. Figure 69. *Santalacites* sp. Figures 70–71. *Tilia* sp. Figure 72. *Nyssa* sp. Figure 73. Ericaceae. Figures 74–75. Euphorbiaceae. Figure 76. *Regina exselsa* Samoil. Figure 77. *Anacolosidites insignis* Samoil. Figure 78. *Aquilapollenites* sp. Figure 79. *Trudopollis conrector* Pfl. Figure 80. *Trudopollis* sp. Figure 81. *Oculopollis* sp. Figures 82–83. *Nudopollis* sp. Figures 84–85. *Basopollis* sp. Figure 86. *Extratriporopollenites pompeckjic* Pfl. Figure 87. *Extratriporopollenites* sp. Figures 88–89. *Triorites* sp. Figures 90–94. *Tricolporopollenites* spp.

species including this index species dominate in the areas adjacent to the Urals (Ehremeyeva and Belousova, 1961; Subbotina, 1964). In that region, the representative species *Haplophragmoides excavatus* Cushman and Waters [=*Asanospira grzybowski* (Mjatliuk)], which is widely distributed, cooccurs with other agglutinated taxa.

In the eastern part of the plain, the upper Talitskaya sediments consist of lighter-colored clays, and the lower parts of the Lyulinvorskaya grey siliceous clays contain foraminiferal assemblages with *Glomospira gordialiformis* and *Cyclammina coksuvorovae,* dominated by the sugary-white, fine-grained tests of the genera *Bathysiphon, Glomospira, Ammodiscus, Asanospira* and *Cyclammina.* Calcareous forms are represented by rare specimens of *Eponides* and *Cibicidoides* only (Podobina, 1998). The foraminiferal species composition, as well as features of the test walls (fine-grained, sugary-white), point to a low salinity (10‰–15‰), at water depths corresponding to these on the outer shelf (Podobina, 1998).

In the palynological assemblage at the very top of the Talitskaya sediments, spores of sphagnum and gymnosperm pollen are predominant (~40% of the assemblage). The relative abundances of Taxodiaceae and Coniferae are about equal (20%) in most samples, although in some samples conifer pollen predominates (25%). *Classopollis* has its first appearance. In angiosperm pollen, the percentage of pollen of subtropical sclerophylls and *Postnormapollis* increases (up to 30%). This floral species composition indicates changes in ecology, probably a decrease in the extent of swamps and wetlands and an increase in more arid lands, as supported by Podobina (1995).

In the east and southeast of the West Siberian plain a palynological assemblage with *Triatriopollenites exelsus* (R.Rot) Pfl.–*Myrica* spp. occurs in the lower layers of the Lyulinvorskaya sediments. This assemblage differs qualitatively from the palynomorph assemblages described above, because it is dominated by angiosperm pollen (60%). There is much pollen of *Myrica* and of the artificial taxon *Triatriopollenites; Triporopollenites* are less abundant (20%) but diverse. *Trudopollis pompeckji* (R.Rot) Pfl., *Castanea crenataeformis* Samig., *C. stelmakae* Boitz., *Castanopsis pseudocingulum* (R.Rot.) Boitz., *Quercus gracilis* Boitz., which are common in early Eocene assemblages, have their first appearances. Ferns (10%–15%) and gymnosperms (25%) are relatively rare.

In contrast to the spectra of the relatively large (>40 m) pollen described above, the palynological assemblage with *Triatriopollenites exelsus* and *Myrica* spp. is rich in diverse species of small pollen (20–25 mm). The abundance of the artificial taxa restricts applying the principle of actualism in reconstructing the paleo-environments. Pollen of subtropical plants (Myricaceae, Moraceae, Hamamelidaceae, Cletraceae, Myrtaceae, Araliaceae, Aquifoliaceae, Nyssaceae, Loranthaceae, Oleaceae, Palmae, Vitaceae and others) account for about a third of the assemblage. In conclusion, a subtropical sclerophyllous plant association developed on the southeastern coast of the West Siberian basin during the late Paleocene (Plates 7–14).

CONCLUSIONS

In the early Paleocene, sediments of the Gankinskaya regional stage were deposited continuously in the southwest of the West Siberian plain, but sea level was falling so that the basin became shallower and during the Thanetian its size decreased slightly. Calcareous benthic foraminifera (occurring since the Maastrichtian) were preserved in the deepest southwestern part of the basin. The late Paleocene (Selandian) boreal transgression led to deposition of Talitskaya sediments with widespread agglutinated foraminifera.

In the western region of the West Siberian plain, close to the Ural Mountains, calcareous foraminiferal species occurred together with agglutinated taxa. Thanetian foraminifera with sugary-white, fine-grained agglutinated tests occur in the uppermost part of the Talitskaya and in the lowermost part of the Lyulinvorskaya regional stages. This assemblage is unusual because it contains a single calcareous species: *Cibicidoides favorabilis* (Vassilenko), especially in the western part of the West Siberian plain.

Data on spores and pollen suggest that in the early Paleocene, the southeastern coastal regions of the West Siberian epicontinental sea consisted of lacustrine-alluvial plains with local *Sphagnum* bogs. During the Danian and toward the end of the Thanetian the climate became drier. The largest changes in flora occurred at the boundary between the Talitskaya sediments and the lower Lyulinvorskaya sediments. During the deposition of the latter sediments, sclerophyllous subtropical plant communities were well developed, and the bogs were much less widespread.

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