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GEOGRAPHICAL DIFFERENTIATION OF EARLY CRETACEOUS PALYNOFLORAS OF WEST SIBERIA

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Early Cretaceous palynological assemblages of West Siberia were compared by statistical processing of numerical data. Modern methods of biometry permitted us to analyze a great body of information and to recognize palynological associations within West Siberia on the basis not only of qualitative but also quantitative criteria. Lateral distribution of these associations is controlled by a combination of both paleoclimatic and paleogeographical factors. As a result, the interpretation of palynological material is rather ambiguous. Reasons for the differentiation of the Early Cretaceous palynoflora are discussed in terms of the obtained results and existing paleofloristic models.

Palynology, paleogeography, paleoclimatology, cluster analysis, Early Cretaceous, West Siberia

INTRODUCTION

The palynological method is traditionally used in stratigraphy and paleogeography, much contributing to the study of plant evolution and to the reconstruction of paleolandscapes. Some techniques have been developed to map the paleovegetation at different stratigraphic levels. First publications on the reconstruction of Cretaceous flora history and paleofloristic models for West Siberia appeared in the early 1960s [1–3].

The pattern of distribution of microphytofossils in the Lower Cretaceous deposits is rather complicate because of the peculiar vegetation development in different paleofloristic regions. In the Early Cretaceous, the West Siberian plain was occupied by a shallow-water epicontinental sea. The composition of palynological assemblages (PA) reflects the character of sedimentation and hydrodynamic conditions. The pollen grains and spores of land plants were brought there from vast sourcelands, resulting in rather homogeneous taxonomical composition of PA though with considerable fluctuations in quantitative proportions of the main components.

Diverse methods and principles of paleofloristic reconstructions and a variety of initial palynological data lead to different palynofloristic models (Fig. 1). Obviously, the PA composition depends on many factors such as conditions of transportation, burial, and conservation in the sediment, as well as climatic zonation.

In addition, palynologists have to use a formal classification as they deal with fossil plants, whose botanical affinities are either questionable or impossible. Some taxa include a lot of natural systematic units, even at the species level. The high-rank taxa are useless for environmental reconstructions as they include plants of different styles of life and ecology. Only few species are good indicators of life conditions. As a consequence, the reconstructions of plant communities based on palynological data are rather formal.

Another difficulty that palynologists encounter on interpretation is an ample volume of the material to be processed. The systematic composition of PA often includes hundreds of taxonomic units, and it is rather difficult to analyze the changes in their structure over a vast territory of West Siberia. At the same time, the present-day computer technologies intensely developing in the past decades may be a good tool to analyze large arrays of palynological data. This paper is aimed at recognizing palynological associations and studying their distribution within West Siberia in the Early Cretaceous by methods of biometry, as well as at comparing the obtained results with the existing paleofloristic models.

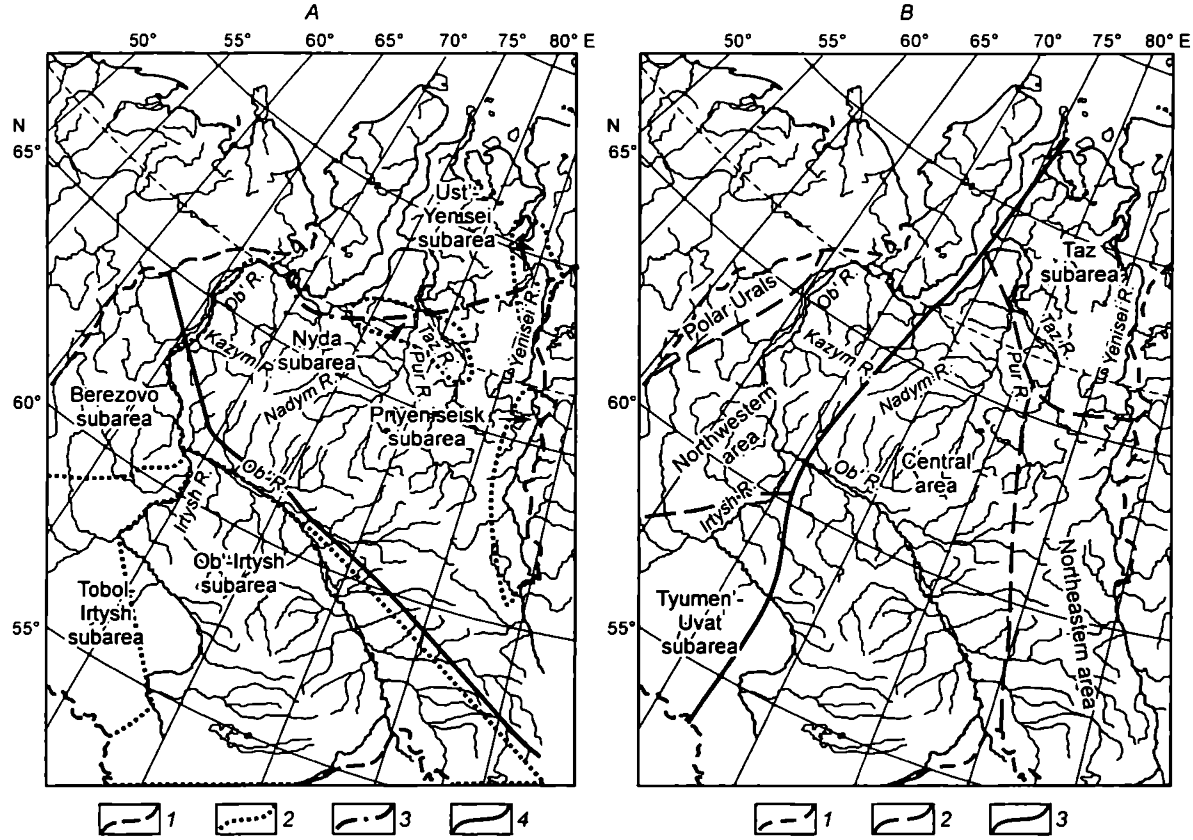


Fig. 1. A schematic map of paleofloristic models of West Siberia. ***A*** **— Valanginian [5]. Boundaries of:** ***1*** **— West Siberia,** ***2*** **— paleofloristic regions,** ***3*** **— Indo-European paleofloristic province [5], and** ***4*** **— Siberian paleofloristic province [4].** ***B*** **— Early Cretaceous. Based on palynological data by Purtova [12]. Boundaries of:** ***1*** **— West Siberia,** ***2*** **— paleofloristic regions,** ***3*** **— paleofloristic provinces.**

REVIEW OF PREVIOUS PALEOFLORISTIC MODELS

First paleofloristic subdivision of the Early Cretaceous flora on the basis of palynological data was proposed by Boitsova et al. [1]. These authors considered the territory of the West Siberian Lowland within two paleofloristic subregions: Ural-Siberian and Ural-Turgai. This reconstruction based on the first appearance of angiosperms was carried out for a wide age range (Berriasian—Albian).

Kotova [3] considered the West Siberian Lowland as part of two paleofloristic regions: subtropical Indo-European and temperate warm Siberian-Canadian ones, recognized by Vakhromeev [4] from paleobotanical data. They are distinguished by the wide occurrence of ferns of the genus *Lygodium* in the northern areas and high percentage of *Classopollis* pollen grains in the south. In Kotova's opinion, the changes in the systematic composition of palynological assemblages are due mostly to climatic conditions.

Using palynological data, Markova [5] drew a boundary between the Indo-European and Siberian-Canadian paleofloristic provinces much farther northward than Vakhromeev did [4, 8–8] (see Fig. 1, *A*). In addition, based on the percentage of the main taxa of PA, she recognized six paleofloristic zones within these regions, almost all over West Siberia, with the exception of central regions lacking palynological material.

A distinctive feature of the **Ob'-Irtysh** region is a high percentage of *Classopollis* and Pinaceae (20–26%) as well as abundant *Ginkgo*. Ferns of the families Schizaeaceae and Gleicheniaceae are rare (2%). The southern subregion is recognized on the basis of higher amount of *Classopollis* (20%) as compared with that in the northern subregion (7%).

The palynological assemblage of **Tobol-Irtysh** region includes the microphytofossils which are characteristic for palynofloral associations of southwestern area of the plain. The amount of *Classopollis* remains rather high (16%), but the percentage of Schizaeaceae and Gleicheniaceae increases (4.5%).

The most abundant spores of Gleicheniaceae (11%) were revealed in **Berezovo** region distinguished by a considerable amount of microphytoplankton and higher percentage of *Leiotriletes* (7%) and Schizaeaceae (5%).

The palynological association in the **Yenisei** region is dominated by Coniferales (37%) containing less abundant fern spores (8% *Leiotriletes*, 3% Schizaeaceae, 3% Gleicheniaceae) and *Classopollis* pollen grains (2%).

The flora of the **Nyda** region, which occupies the northwestern area of West Siberia, is characterized by considerable amounts of *Leiotriletes* (11%) and Schizaeaceae (7%) as well as by low percentage of *Classopollis* (4%).

The flora of the **Ust'-Yenisei** region, which belongs to the Siberian paleofloristic province, is dominated by *Leiotriletes* (~20%) and Schizaeaceae (up to 25%), with abundant *Lygodium* (15%) producing large granulate spores. The percentage of Pinaceae is relatively low (~15%); *Classopollis* pollen grains are extremely rare.

However, the proposed paleofloristic model does not reflect the variety of the available palynological data, which sometimes evidence rare *Classopollis* in southern regions and its abundance in northern regions [9–11].

According to Purtova [12], the differentiation of paleofloristic units based on palynological data is rather problematic for West Siberia, because in the Early Cretaceous this large territory was occupied by an epicontinental sea. Therefore the assemblages of spores and pollen grains of terrestrial plants reflect the taxonomical composition of the vegetation on the adjacent land areas, which were the sources of sedimentary material transported to the paleobasin. Purtova believed that the best way to solve this confusion situation was to recognize the areas of influence of paleofloristic provinces.

Therefore, Purtova suggests the meridional position of the boundary between the areas influenced by Indo-European and Siberian-Canadian paleofloristic provinces (see Fig. 1, *B*). It is based on the distinctive feature of palynological assemblages. Western areas are characterized by high abundance of Gleicheniaceae, Schizaeaceae, Dicksoniaceae and Coniferales, which is a distinctive feature of Early Cretaceous paleoflora of Indo-European province. Palynological assemblages of eastern and northeastern areas with predominant *Leiotriletes—Cyathidites* group and rather abundant Schizaeaceae reflect the character of Early Cretaceous vegetation of the Siberian-Canadian province. The palynological assemblages of the areas, which are adjacent to the boundary and therefore influenced by both provinces, are characterized by a mixed composition. The abundance of the *Classopollis* pollen in the southern parts of the lowland (Tyumen'-Uvatsky and Central regions), evidencing a hot dry climate, allowed Purtova [12] to recognize two paleofloristic provinces, southern and northern within the Siberian-Canadian and Indo-European provinces.

Thus, first attempts to analyze Early Cretaceous palynological assemblages led to several paleofloristic models [1, 3]. They were based on analysis of lateral distribution of palynological assemblages including taxonomic units of different ranks.

Later models [5, 12] take into account both systematic composition of palynological assemblages and the percentage ratio of some taxa, allowing a more detailed differentiation of the Early Cretaceous palynofloras. Quantitative analysis of palynological assemblages is used in botanic-geographical researches, since the percentage ratio of palynological taxa reflects to some extent the composition of paleocenoses. However, the recognition of botanic-geographical regions for ancient epochs on the basis of palynological data is rather problematic or even impossible [13, 14]. The composition of palynological spectra does not always reflect the natural character of plant communities. It is related to different pollen productivity of plants, to different ability of spore and pollen grains to be transported by air and water streams and to be fossilized as well as to specific features of sedimentation and many other factors often discussed in the publications. Apparently, it explains the fact that the palynological regions recognized by Purtova often coincide with the lithofacies regions.

MATERIALS AND METHODS

This paper is based on the original author's material on the Pur-Taz interfluve [15, 16] and the palynological data available from the literature. Unfortunately, most of publications lack of the numerical data on relative proportions of basic taxa. Therefore, the analysis of the structure of palynological assemblages is based on the data of Markova [5] providing a table of percentages of the main taxa for most part of West Siberia. In the paper the palynological data from 51 well sections have been used with 14 sections being studied by authors. The stratigraphic coverage is mostly restricted to the Valanginian, probably including the uppermost Berriasian and the lowermost Hauterivian. More precise stratigraphic definition for a number of wells is impossible because of the lack of detailed macrofauna dating.

Percentages of all taxa or their groups were calculated from a total amount of grains, including spores of mosses and fernlike plants, pollen grains of gymnosperms, and microphytoplankton. The percentage of each taxon was averaged over the palynological assemblage. To define the pattern of the distribution of spores and pollen grains of terrestrial plants over West Siberia, statistical methods of data processing were used.

The term *association* was used to denote the lateral groups of monotypic even-aged palynological spectra as distinct from the term *assemblage* traditionally used in stratigraphy.

Well sections have been classified according to the type of palynological associations into uniform classes, number of these classes has been defined, and their structure and hierarchic subordination have been analyzed, taking into account both systematic composition of palynological associations and the percentage of the taxa. To distinguish monotypic palynological associations characterizing different regions of West Siberia, the method of cluster analysis was used (package BioDiversity Professional, 1997 The Natural History Museum and The Scottish Association For Marine Science). The clusters were hierarchically arranged by the method of group average links, which is the most efficient when the natural objects have naturally no hierarchic subordination.

Before the procedure of cluster analysis was applied, the systematic composition of spores and pollen grains had been formalized. Different ways of classification result in the situation when morphologically similar palynomorphs are defined as different taxa. Today palynologists often use artificial systematics, because they deal with morphological features of fossil spores and pollen grains only. According to Markova [5], the reconstruction of the evolution of ancient plants and vegetation as well as the paleofloristic models should be based on the natural systematics. However, it is often impossible. Many ancient taxa have no modern analogs, and morphological similarities of modern and fossil palynomorphs do not evidence the same botanical affinity. Moreover, even the data on modern plants do not allow the development of a morphological classification with taxonomic units strictly corresponding to the natural genera and species. Thus, to recognize Valanginian palynological associations and to analyze their distribution over West Siberia, an artificial taxonomy has been used.

Unfortunately, the complete taxonomical composition of palynological assemblages is impossible to treat by cluster analysis, because the publications often lack information on microphytoplankton. Thus, the classification of palynological associations is based on characteristic Early Cretaceous taxa of terrestrial plants (see Table 1).

The spores of mosses and fernlike plants are represented by *Leiotriletes*, *Concavisporites*, Selanginellaceae, *Lycopodiumsporites*, *Gleicheniidites*, *Osmundacidites*, *Lygodiumsporites*, and Schizaeaceae. The group *Leiotriletes* includes smooth trilete spores, which are defined in the literature as *Cyathidites* or *Coniopteris*. The group *Concavisporites* contained morphologically similar spores of *Tripartina* and *Cibotium*. The group Selaginellaceae is represented by the genera *Aequitriradites*, *Densoisporites* and others, earlier defined in the natural systematics as *Selaginella*. The group *Cicatricosisporites* includes costate spores of the artificial genera *Cicatricosisporites* and *Appendicisporites* defined in the natural systematics as *Anemia*, *Mohria*, and *Pelletieria*. The group *Lygodiumsporites* contains large trilete spores of the genera *Impardecispora*, *Trilobosporites*, and *Lygodium* characterizing by tubercular exine. The last taxon also includes large smooth spores. Two latter groups enter into a higher taxonomic subdivision, Schizaeaceae, which also included the fern spores not identified to the genus rank.

The most important taxa among the gymnosperms are Podocarpaceae, *Piceapollenites*, *Pinuspollenites*, *Alisporites*, *Ginkgocycadophytus*, and *Classopollis*. The saccate pollen grains of bad preservation or unclear systematic position are attributed to *Coniferales*.

It should be noted once more that this grouping is artificial, combining both natural and formal taxa. But this is dictated by the necessity to unify various definitions that stemmed from the application of different classification systems.

To denote the territories characterized by monotypical palynological associations recognized by mathematical methods on the basis of formal features the terms of loose usage, *area* and *subarea*, have been used. Other terms, such as region and province, denote floristic and botanic-geographical units included into a strict system of hierarchically co-subordinated categories recognized according to special criteria.

RESULTS

The final result of cluster analysis is a dendrogram, a graphic representation of the existing relationships between the objects and their hierarchy (Fig. 2). Horizontal lines show a degree of similarity between the objects, i.e. palynological assemblages. Even for the most remote objects it is rather high (70%), reflecting the homogeneity of Early Cretaceous palynological associations, which differ mostly in quantitative ratios of some taxa. The compact grouping of the objects is quite natural because West Siberia was a single paleobasin in the Early Cretaceous. Experimental data show that the composition of palynological spectra from the deposits of recent sea basins is characterized by a high degree of similarity. It may be explained by the bed movement, transportation by streams

Table 1

Groups of Taxa Involved in Cluster Analysis

Spores		Gymnosperm pollen	
Formalized groups of taxa involved in cluster analysis	Natural and formal taxa included into the formalized groups	Formalized taxa groups involved in cluster analysis	Natural and formal taxa included into the formalized groups
Lycopodiaceae	*Lycopodiumsporites*, Lycopodiaceae	*Ginkgocycadophytus*	*Ginkgocycadophytus*, Cycadales, Ginkgoales, Bennettitales
Selaginellaceae	*Selaginella*, *Aequitriradites*, *Densoisporites*	*Alisporites*	*Alisporites*, *Protoconiferus*, *Pseudopicea*, *Pseudopinus*
Concavisporites	*Concavisporites*, *Tripartina*, *Cibotium*, *Obtusisporis*	Coniferales	Coniferales, Dissacites
Gleicheniaceae	*Gleicheniidites*, *Gleichenia*	*Classopollis*	*Classopollis*, *Brachyphyllum*, *Pagiophyllum*
Schizaeaceae	*Cicatricosisporites*, *Lygodiumsporites*, indetermined spores of Schizaeaceae ferns	Podocarpaceae	Podocarpaceae, *Podocarpidites*
Cicatricosisporites	*Cicatricosisporites*, *Anemia*, *Pelletieria*, *Mohria*	*Piceapollenites*	*Piceapollenites*, *Picea*
Lygodiumsporites	*Lygodiumsporites*, *Lygodium*, *Trilobosporites*, *Impardecispora*	*Pinuspollenites*	*Pinuspollenites*, *Pinus*
Osmundacidites	*Osmundacidites*, Osmundaceae		
Leiotriletes	*Leiotriletes*, *Cyathidites*, *Coniopteris*		

and winds resulting in mixed composition of palynological spectra. As a result, the palynological spectra from sea deposits reflect the composition of the vegetation of large land territories.

Interpretation is mostly based on large clusters because systematic groups of spores and pollen of rather high taxonomic rank have been treated by cluster analysis. Smaller palynological associations should be recognized using the taxa of species rank.

As a result, three types of palynological associations have been recognized, which are distributed over the West Siberian Plain as three large regions covering its northwestern, southern, and central parts (Fig. 3). The name **Central area** is rather conventional, because this region occupies not only vast territories of the interior of West Siberia but also the narrow westernmost part of the plain. This region is characterized by a slight predominance of the pollen of gymnosperms (57%) over fern spores (40%) (Fig. 4, *A*). The spore association is dominated by *Leiotriletes* (25%). The percentage of Schizaeaceae is about 5%, and the other taxa are rare. The pollen part of the association is dominated by saccate pollen of Coniferales (33%), with *Classopollis* and *Piceapollenites* being less abundant (6%). The **Southern area** is characterized by a very high percentage of gymnosperms (85%), including abundant Coniferales (48%) as well as numerous *Classopollis* (18%) and *Gingkocycadophytus* (12%). Fern spores are rare (15%). The percentages of *Leiotriletes* and Selaginellaceae are relatively low: 5 and 3%, respectively. The **Northwestern area** is distinguished by the predominance of gymnosperm pollen (60%) over fern spores (31%). The spores are represented by a rather high percentage of *Leiotriletes* (8%), Gleicheniaceae (7%), and Schizaeaceae (5%). The gymnosperms are dominated by saccate pollen of conifers (38%); *Piceapollenites* (6%), *Classopollis* (4%), and *Ginkgocycadophytus* (3%) are rather numerous.

On the basis of dendrogram analysis, smaller subdivisions are recognized within these large areas. The **Southern area** includes the **Omsk** and **Irtysh-Tym subareas**. The Omsk subarea is characterized by considerable amounts of *Leiotriletes* (5%) and Selaginellaceae (4%) (see Fig. 4, *B*). The pollen association is dominated by

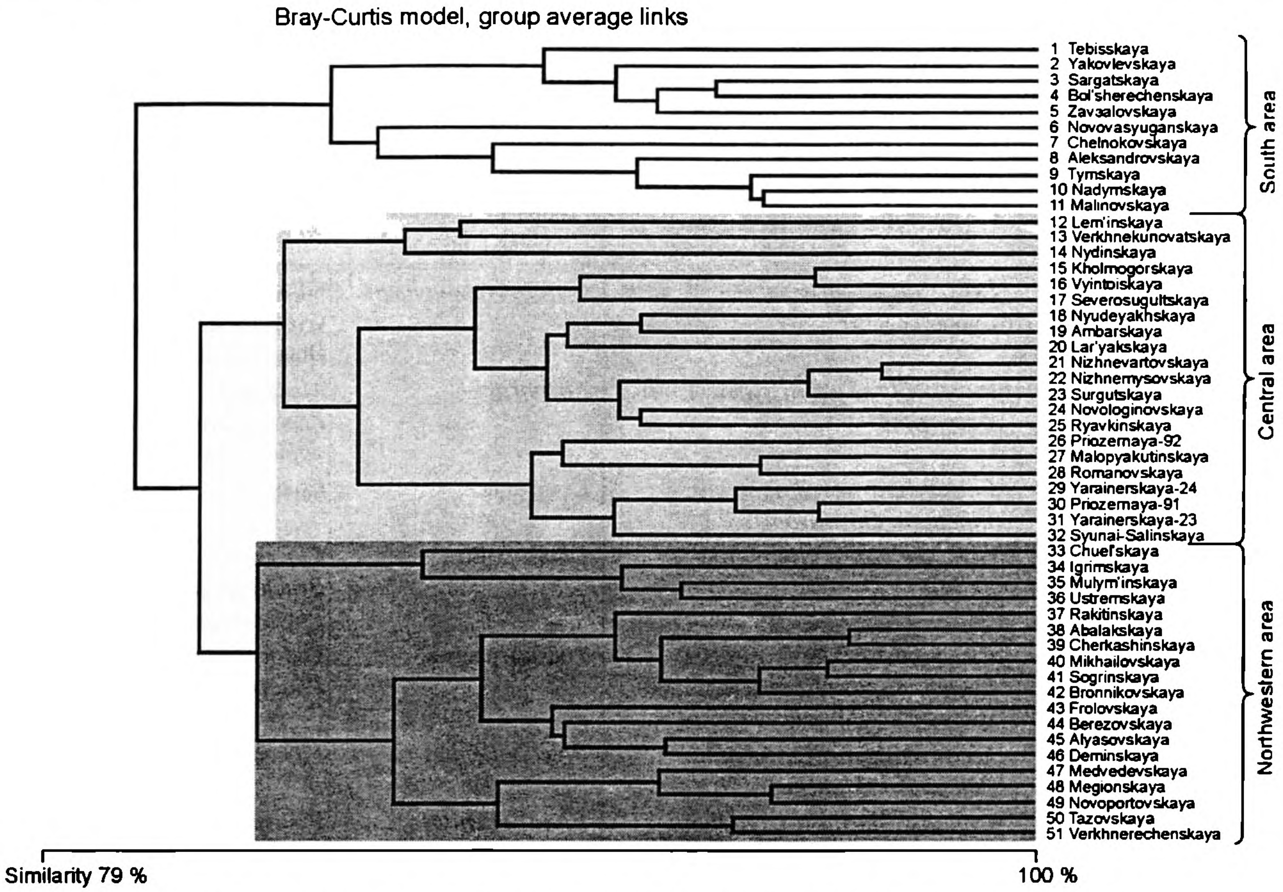


Fig. 2. A dendrogram of similarity of palynological associations from West Siberian wells.

Coniferales (39%), including abundant *Classopollis* (25%), and considerable amount of *Ginkgocycadophytus* (7%). In the palynological association of the Irtysh-Tym subarea, only *Leiotriletes* reaches a rather significant percentage, 5%. The abundance of *Classopollis* pollen drops (11%), while the percentage of *Ginkgocycadophytus* increases (17%). This association is still dominated by Coniferales (57%). *Piceapollenites* and *Pinuspollenites* are quite rare, 6% and 4%, respectively. The increased amount of *Classopollis* in the Omsk subarea may be explained by bad transportation characteristics of *Classopollis* pollen grains as compared with Coniferales and *Ginkgocycadophytus*, whose amount increases with a distance from the shore.

The Central area is subdivided into three subareas: **Ob'-Irtysh**, **Nadym-Taz**, and **near-Urals**. The first subarea is characterized by a considerable predominance of gymnosperm pollen (69%) over fern spores (28%) within the Central area (see Fig. 4, *B*). The spore association is dominated by *Leiotriletes* (16%). The percentage of *Osmundacidites* is relatively low (3%), the other taxa are rare. The pollen association is dominated by Coniferales (36%) and *Ginkgocycadophytus* (18%). In the Nadym-Taz subarea, the amount of gymnosperm pollen decreases (51%) while the fern spores become more abundant (43%). The spores are dominated by *Leiotriletes* (27%), the percentage of *Osmundacidites* (3%), Schizaeaceae (4%), and Gleicheniaceae (3%) are rather low. In the pollen association, the amount of Coniferales is somewhat lower (22%). The percentage of *Ginkgocycadophytus* reaches 13%. In the near-Urals subarea the abundances of fern spores and gymnosperm pollen are nearly equal, 49 and 51%, respectively. The spore association is represented by predominant *Leiotriletes* (31%) as well as rather abundant Gleicheniaceae (8%) and Schizaeaceae (8%). The pollen association is dominated by Coniferales (42%), and *Piceapollenites* are rather abundant (10%). Apparently, this palynological association reflects the characteristic features of the paleovegetation of nearby land areas with abundant water-loving ferns. This is confirmed by paleogeographical data, thus allowing this region to be reconstructed as a denudation lowland partly swamped [17].

The Northwestern area includes three subareas: **Ob'-Tavda**, **Yamal-Taz**, and **Mulym'ya**. The three subareas are dominated by gymnosperm pollen (see Fig. 4, *D*). The spore association of the Ob'-Tavda subarea contains

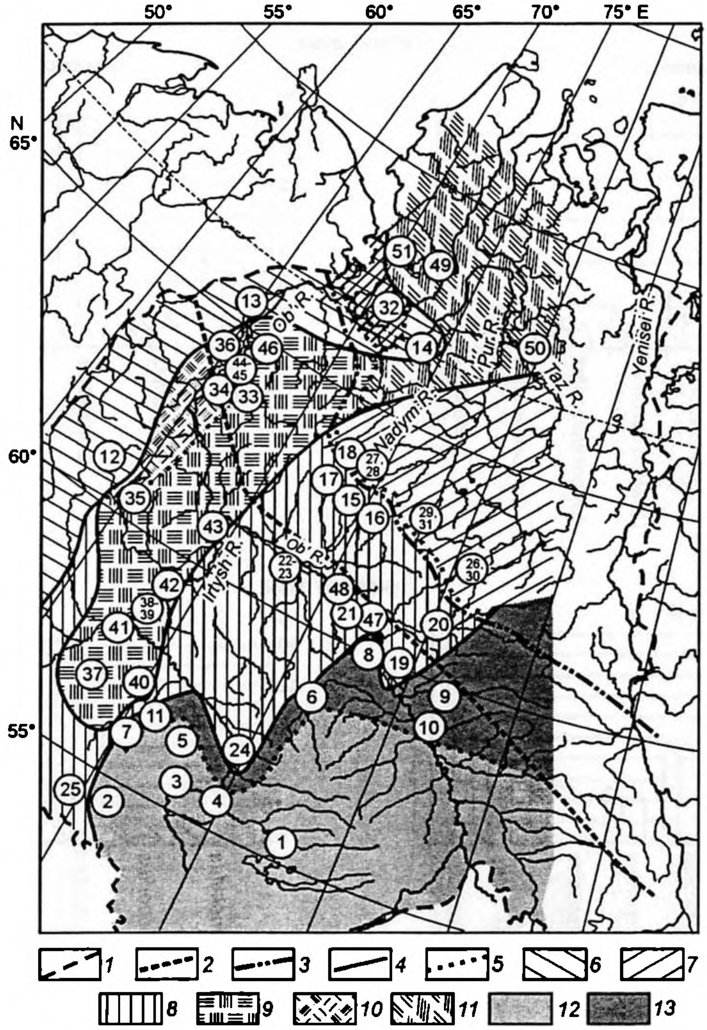


Fig. 3. Differentiation of palynological associations on the territory of West Siberia in the Early Cretaceous. Boundaries of: *1* — West Siberia, *2* — boundary between Indo-European and Siberian-Canadian paleofloristic provinces, *3* — proposed boundary between the zones influenced by paleofloristic provinces based on palynological data, *4* — established areas, *5* — subareas. *Central area*: *6* — near-Urals subarea, *7* — Nadym-Taz subarea, *8* — Ob'-Irtysh subarea. *Northwestern area*: *9* — Ob'-Tavda subarea, *10* — Mulym'ya subarea, *11* — Yamal-Taz subarea. *Southern area*: *12* — Omsk subarea, *13* — Irtysh-Tym subarea. Encircled digits are well numbers (for explanation see Fig. 2). The position of the boundary between the Ob'-Irtysh and near-Urals subareas as well as the eastward continuation of the Nadym-Taz subarea are rather conventional because of no palynological data for these areas.

considerable amounts of Gleicheniaceae (6%), *Leiotriletes* (4%), Schizaeaceae (5%), *Lygodiumsporites* (5%). Gymnosperms are dominated by Coniferales (31%). *Classopollis* is rather abundant (8%). *Piceapollenites* (5%) and *Ginkgocycadophytus* (3%) are less numerous. The spore association of the Yamal-Taz subarea is represented by rather numerous *Leiotriletes* (11%) as well as abundant Schizaeaceae (5%) and *Osmundacidites* (4%). The gymnosperms are characterized by predominant Coniferales (52%), abundant *Piceapollenites* (12%) and *Ginkgocycadophytus* (8%), and less numerous *Pinuspollenites* (4%). The Mulym'ya subarea is distinguished by abundance of Gleicheniaceae (14%) and *Leiotriletes* (9%). The pollen association is dominated by Coniferales (33%), while other taxa are rather barren.

The distribution of Early Cretaceous palynological associations over the territory of West Siberia can be explained from different points of view.

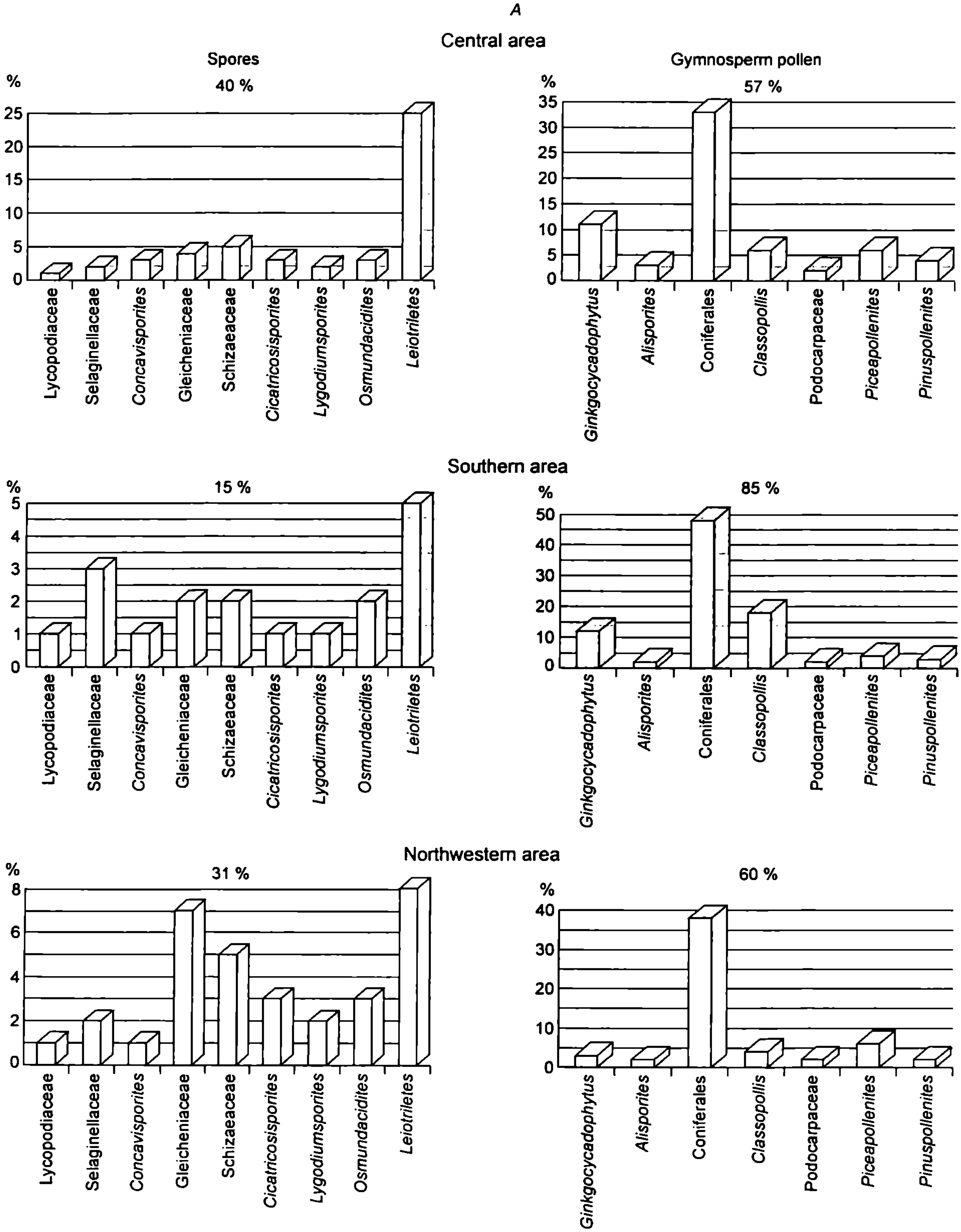
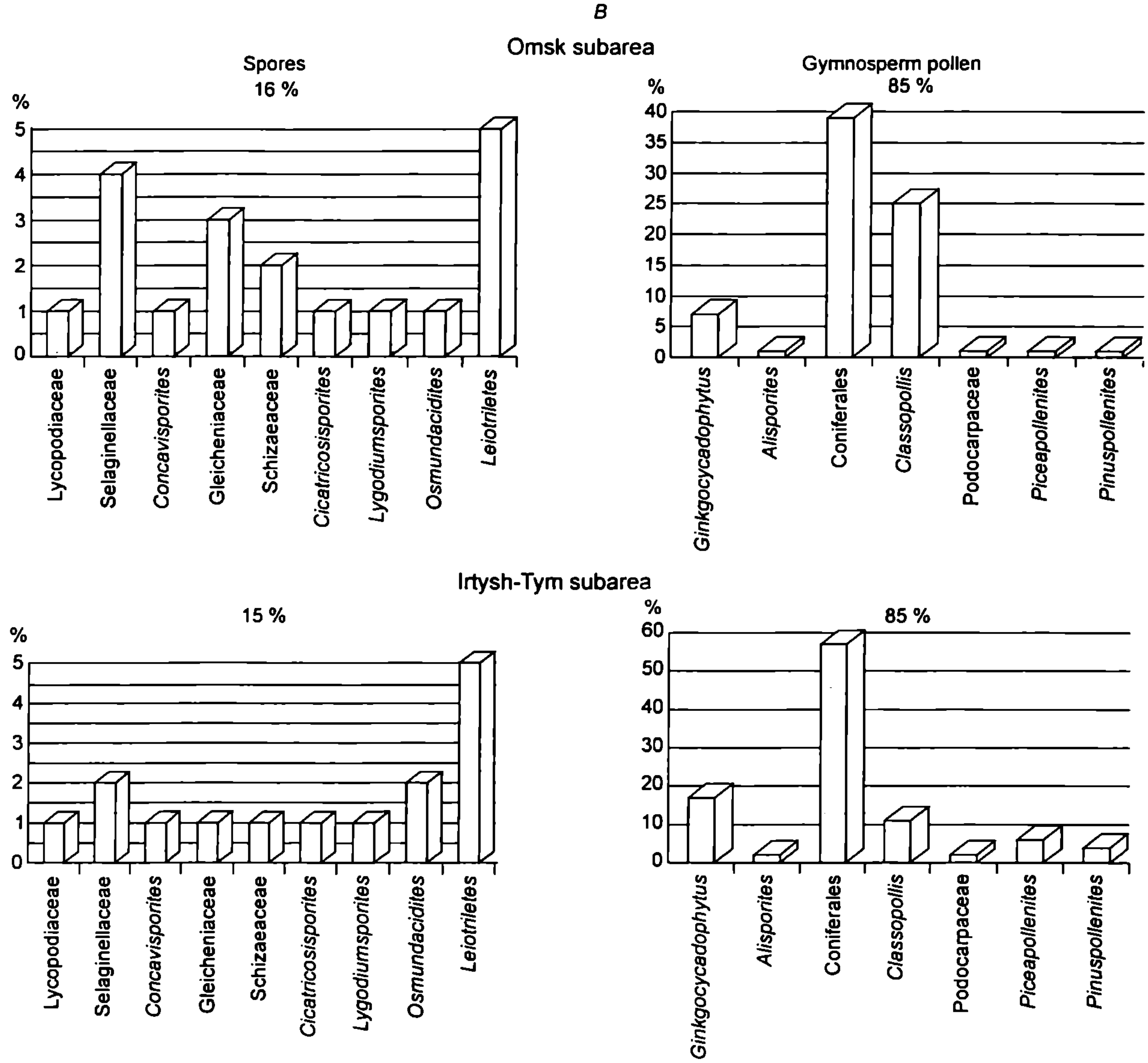
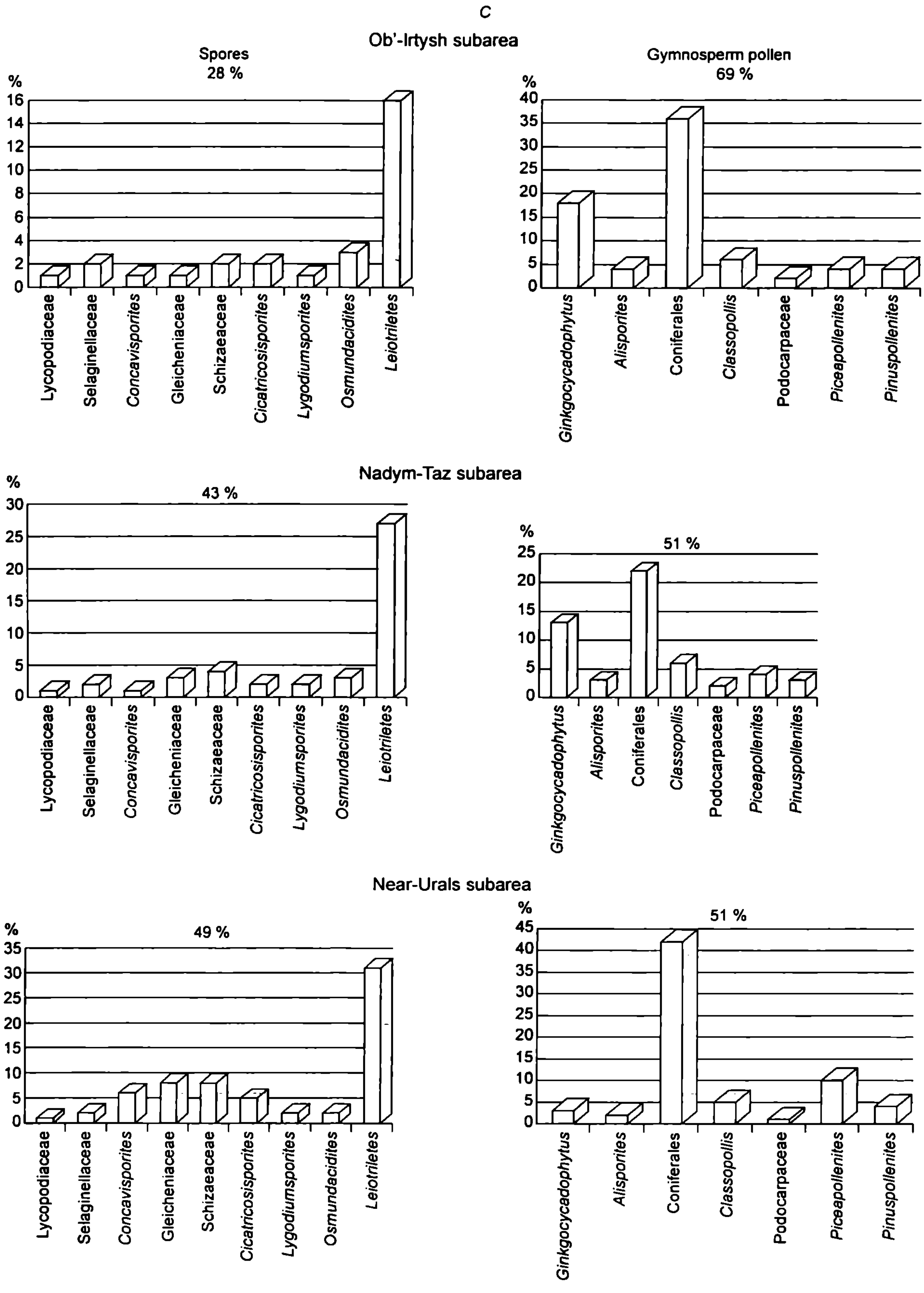


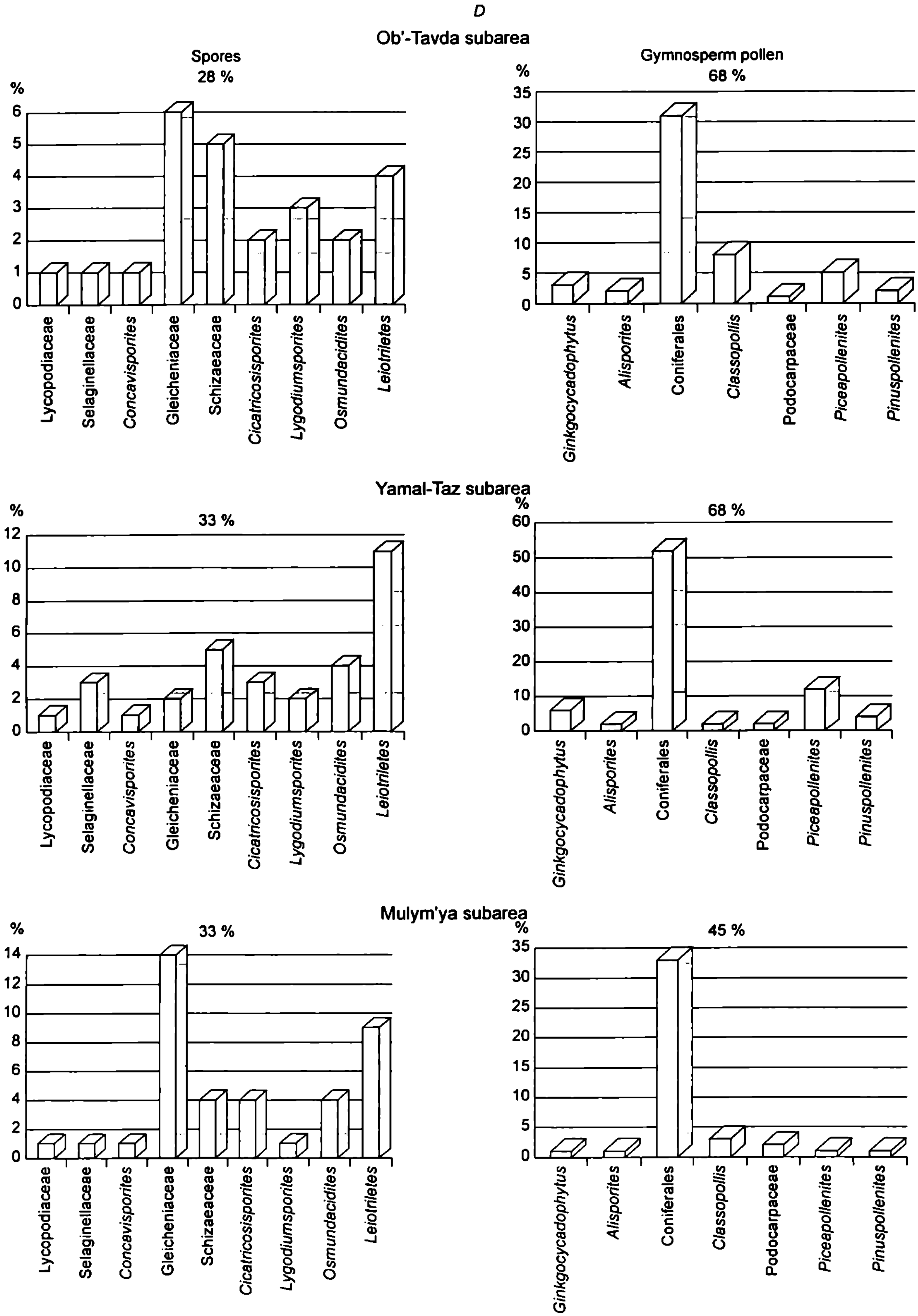
Fig. 4. Percentages of spores and pollen of terrestrial plants in palynological associations of: *A* — Central, Southern, and Northwestern areas; *B* — Omsk and Irtysh-Tym subareas (Southern area); *C* — Ob'-Irtysh, Nadym-Taz, and near-Urals subareas (Central area); *D* — Ob'-Tavda, Yamal-Taz, and Mulym'ya subareas (Northwestern area). The sum of spores and gymnosperm pollen does not always equal 100%, since no data on microphytoplankton are given in histograms.



On the one hand, it reflects the direction of transport and facies features of the West Siberian paleobasin in the Early Cretaceous. According to data of complex geological studies [17, 18], vast territories in the south and east of the West Siberian Plate were occupied chiefly by a shallow-sea terrigene-calcareous-oligomictic formation (Fig. 5). The western and northwestern parts are characterized by the development of the most marine facies represented by black bituminous mudstones. Remarkably, the territory of occurrence of these facies corresponds, in a rough approximation, to the Northwestern area recognized according to palynological data. At the extreme northwest and northeast of the plate, a neritic formation existed, represented by terrigene-glauconite sediments. It is possible that similar palynological associations of the central and extreme western regions of West Siberia evidence that they are confined to this facies. The mixed composition of two types of palynological associations in the central part of the plate may be caused by sediment transportation from different regions (see Fig. 3, wells 48 and 47).

On the other hand, the recognized areas of monotypic palynological associations can be considered as zones of influence of certain paleofloristic provinces. Palynological associations of southern West Siberia are characterized by abundant *Classopollis* (Southern area) and diverse spores of warm-loving lycopodiums and ferns, represented by Lycopodiaceae, Schizaeaceae, Gleicheniaceae (southern subareas of the Central and Northwestern areas: near-Urals, Ob'-Irtysh and Mulym'ya, Ob'-Tavda, respectively), reflecting hot and even arid (in the south) climate of the Indo-European paleofloristic province. The palynological associations of northern and northwestern West


C
Ob'-Irtysh subarea
Spores
28 %
Gymnosperm pollen
69 %
Nadym-Taz subarea
43 %
51 %
Near-Urals subarea
49 %
51 %
%
Lycopodiaceae
Selaginellaceae
Concavisporites
Gleicheniaceae
Schizaeaceae
Cicatricosisporites
Lygodiumsporites
Osmundacidites
Leiotriletes
Ginkgocycadophytus
Alisporites
Coniferales
Classopollis
Podocarpaceae
Piceapollenites
Pinuspollenites


D
Ob'-Tavda subarea
Spores
28 %
Gymnosperm pollen
68 %
Yamal-Taz subarea
33 %
68 %
Mulym'ya subarea
33 %
45 %
%
Lycopodiaceae
Selaginellaceae
Concavisporites
Gleicheniaceae
Schizaeaceae
Cicatricosisporites
Lygodiumsporites
Osmundacidites
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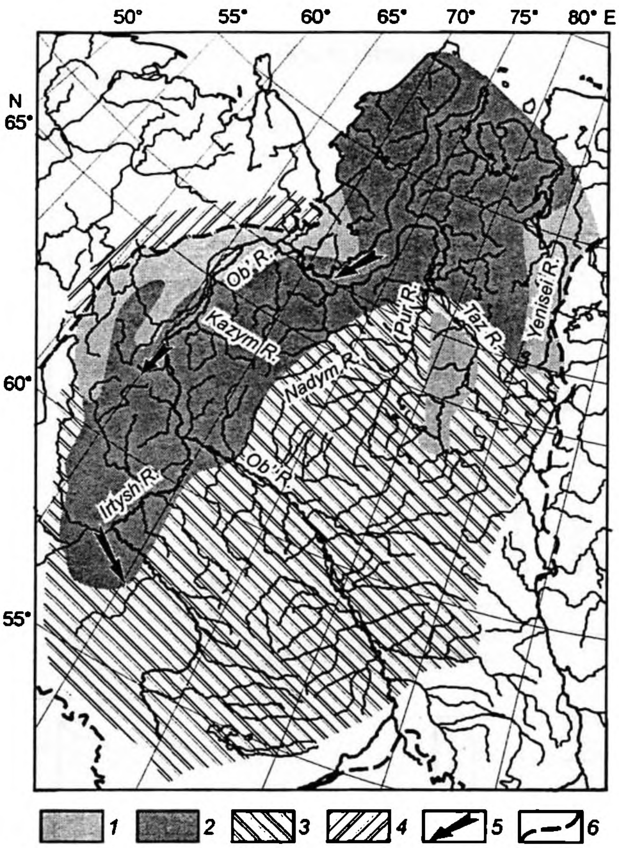

Fig. 5. Lithological and paleogeographic map of West Siberia in the Valanginian [23]. ***1*** **— neritic (terrigene-glauconite) formation,** ***2*** **— relatively deep-water formation (black bituminous mudstones),** ***3*** **— shallow-marine (terrigene-calcareous-oligomictic) formation,** ***4*** **— low denudation plain recurrently flooded by sea,** ***5*** **— paleocurrents,** ***6*** **— boundary of West Siberia.**

Siberia (Nadym-Taz and Yamal-Taz subareas) are characterized by very high percentage of *Leiotriletes*, which is a distinguishing feature of the Siberian-Canadian paleofloristic province with a temperate humid climate.

Thus, the boundary separating northern and northwestern parts of West Siberia (Nadym-Taz and Yamal-Taz subareas) may be considered the boundary of influence of two paleofloristic provinces: Indo-European and Siberian-Canadian (see Fig. 3). In this case it will run farther in the north as compared with the boundary drawn by Vakhromeev [8]. The fact that the southern subareas, characterized by abundant *Classopollis*, and the western subareas, where this pollen is less numerous, are considered as a single paleofloristic zone does not contradict the paleobotanical data since the distribution of *Classopollis* is controlled by both temperature and humidity. Most likely, within the Indo-European paleofloristic province the climate on the land framing the West Siberian paleobasin in the Early Cretaceous was different: arid in the south and hot wet in the west. Remarkably, the southern terrains (Southern area) are well distinguished in a dendrogram. The boundaries of the Southern area seems to coincide with the boundaries of influence of the arid zone.

Worthy of note is that the supposed boundary between the zones influenced by the Indo-European and Siberian-Canadian paleofloristic provinces has a sublatitudinal direction if we take into account the position of the North Pole in the Early Cretaceous epoch. Its position in the Valanginian is reconstructed in the eastern Arctic Ocean north of the island of Wrangel (~79°/177° N [19]; 73°/182° N [20]) or near the New Siberian Islands [21]. In this case, the southern parts of the Central and Northwestern areas occur approximately at one latitude, which may evidence a similar paleotemperature regime of these territories.

The Early Cretaceous vegetation communities, which are reconstructed on the basis of palynological data for the near-shore territories limiting the West Siberian paleobasin in the south and west, are characterized by abundance of warm-loving forms. The *Classopollis* pollen is compared with xerophilous and thermophilous ancient gymnosperms of the Cheirolepidiaceae family. The modern ferns of the families Schizaeaceae, Gleicheniaceae, and Dicksoniaceae grow in low-latitude tropical and subtropical regions (0°–40° N). The relict forms displaced to colder regions of highlands [22] are not tolerant to considerable temperature drops either. In the Valanginian, this flora occurred at higher latitudes (50°–60° N), now characterized by stable negative temperatures during the winter period (1–4 months).

As suggested by palynologists and paleobotanists [7, 8, 13], the Early Cretaceous climate was milder and more uniform, therefore, no drastic latitudinal differences in vegetation communities are observed. Another explanation is also possible: In the past, the fernlike plants had different ecological requirements and occupied more diverse ecological niches, from where they were later displaced by more progressive angiosperms.

CONCLUSIONS

Thus, based on the cluster analysis of palynological data from Early Cretaceous well sections over the vast territory of West Siberia, three areas and eight subareas have been recognized, characterized by monotypic palynological associations. Studies have shown that the differentiation of palynological associations on the territory of West Siberia in the Early Cretaceous was due to a combination of factors. The distribution of spores and pollen of terrestrial plants over the West Siberian paleobasin was influenced by paleoclimatic and paleogeographical parameters as well as by postsedimentary processes resulting in complicate and mixed pattern of palynological associations. On the one hand, this complicates the work of palynologists but, on the other hand, this allows interpretation of initial material from different viewpoints and examination of the dependence of palynofloras on different factors. It is this situation that seems to be responsible for the diversity of palynofloristic models of West Siberia based on palynological data.

It is also worthy of note that whatever principles make the basis for interpretation of initial palynological data, paleoreconstructions were traditionally carried out at the level of qualitative estimates. In this work we made an attempt to use biometric methods for processing a large massif of numerical characteristics of palynological associations over the vast territory of West Siberia. This permitted us to classify rather heterogeneous material, to characterize the recognized palynological associations in detail, and to establish regularities of their distribution taking into account the percentage of typical Early Cretaceous taxa.

Using of mathematical methods, we have distinguished monotypical palynological associations and analyzed their lateral differentiation, taking into consideration the distribution of facies that existed on the territory of West Siberia in the Early Cretaceous as well as climatic and paleofloristic zonation. It has been established that the distribution of spores and pollen of terrestrial plants within large territorial divisions (areas) is controlled chiefly by facies. Analysis of the systematic composition of palynological associations of subareas permitted a detailed configuration of the boundary of influence of the Indo-European and Siberian-Canadian paleofloristic provinces earlier established by Vakhromeev. Indirect support for this position of the boundary comes from geophysical data. Taking into account the location of the North Pole in the Early Cretaceous epoch, we see that the supposed boundary of influence of the Indo-European and Siberian-Canadian paleofloristic provinces extends sublatitudinally. Its position seems to be controlled chiefly by latitudinal climatic zonation. The data of cluster analysis also confirm the climate differentiation within the Indo-European paleofloristic province, locating more precisely the areas with hot arid climate in the south and wet tropical climate in the west.

Computer processing does not only simplify the process of labor-consuming analysis of a large data array thus escaping the palynologist from a routine at this step but also makes palynological interpretations more effective and precise by providing a possibility to rely equally upon qualitative and quantitative parameters.

For processing the palynological material, mathematical and computer methods have only recently been used, but gradually they become a common tool in palynological analysis, improving the methodology and opening new perspectives for paleoclimatic and paleogeographic reconstructions. An ambiguous interpretation of the results of computer processing is possibly caused by complex influence of paleoclimatic and paleogeographical parameters leading to the heterochronous composition of Early Cretaceous palynological associations.

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