西西伯利亚东南部早凡兰吟期孢粉地层学，古环境和植被再造①

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摘 要：分析了西西伯利亚东南地区的下凡兰吟阶的两个剖面的陆相孢粉型化石的分布。依据西伯利亚北部已经定年的剖面中动物群建立起来的孢粉组合的对比，确定了孢粉标志层的定义，并与北方区的菊石带相对应的孢粉组合进行了对比。这一工作为早凡兰吟期与气候变化息息相关的植被和景观的短期变化以及周边古盆地变迁的重建，提供了地层依据。欧亚大陆中部和东部地区凡兰吟期孢粉组合的横向对比显示：西西伯利亚东南地区的植被具有印度–欧洲和西伯利亚–加拿大两大古植物地理区的过渡性质，显有这两区的典型特征。

关 键 词：孢粉地层学，古植物，古植物区，凡兰吟期，白垩纪，西西伯利亚
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LOWER VALANGINIAN PALYNOSTRATIGRAPHY OF SOUTH-EASTERN REGIONS OF WEST SIBERIA: PALAEOENVIRONMENT AND VEGETATION RECONSTRUCTIONS

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Abstract The distribution of terrestrial palynomorphs is analyzed in two Lower Valanginian sections from south-eastern areas of West Siberia. Comparison with the palynological zonation developed on fauna in the dated sections of North Siberia allows the definition of palynological marker levels and calibration of southern palynological zones against the Boreal ammonite standard. It provides a stratigraphic basis for the reconstruction of short-time fluctuations of the Early Valanginian vegetation and landscape related to climatic changes and the dynamics of the neighboring palaeobasin. Lateral comparison of Valanginian palynological assemblages of central and eastern regions of Eurasia shows the transitional character of the vegetation in the southeastern region of West Siberia, demonstrating typical features of both the Indo-European and the Siberian-Canadian palaeofloristic provinces.

Key words palynostratigraphy, paleovegetation, palaeofloristic provinces, Valanginian, Cretaceous, West Siberia

The paper presents the first palynological results of a detailed subdivision of the Lower Valanginian in the south-eastern regions of West Siberia, where it is composed of continental and nearshore deposits. The systematic composition of micro- and macrofauna assemblages of these territories is very specific precluding zonal subdivision (Nesterov, 1991). Palynological assemblages previously provided the subdivision only at the stage level (Markova, 1971; Nesterov, 1991). Detailed faunistic and palynological zonations

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(Fig. 1) are established only in the northern regions of Siberia and the Subpolar Urals, where the Boreal zonal standard was developed (Zakharov et al., 1997; Pestchevitskaya, 2007a, 2010). Comparative analysis of spore-pollen successions allows the definition of palynological marker levels in the southeastern regions of West Siberia and calibration of southern palynological zones against the boreal ammonite scale. Based on detailed stratigraphy, the short-termed facial and climatic changes are studied for nearshore and inland areas.

1 Material and methods

Material comes from two wells situated in the southeastern region of West Siberia (Fig. 2). In the Vostok-4 well, the Lower Valanginian is represented by the deposits of the marginal shallow-water zone of the West Siberian palaeobasin. They consist of light grey sandstone and fine alternation of grey and greenish mudstone and siltstone of the Kulomsino and Tarskaya formations, which overlies the Upper Jurassic deposits of the Naunak Formation with a stratigraphic unconformity (Fig. 3). The Lower Valanginian section of the R-6 well is composed of yellowish and greenish sandstone and alternating mudstone and siltstone of the Ilek Formation (Fig. 3). Sandstones are from fine- to coarse-grained, with basal gravelites and conglomerates. Mudstones and siltstones are mostly greenish grey in the lower part and variously colored (cherry-red, brown, grey, bluish-green) in the upper part. Lithological composition and texture indicate their shallow-water lacustrine origin.

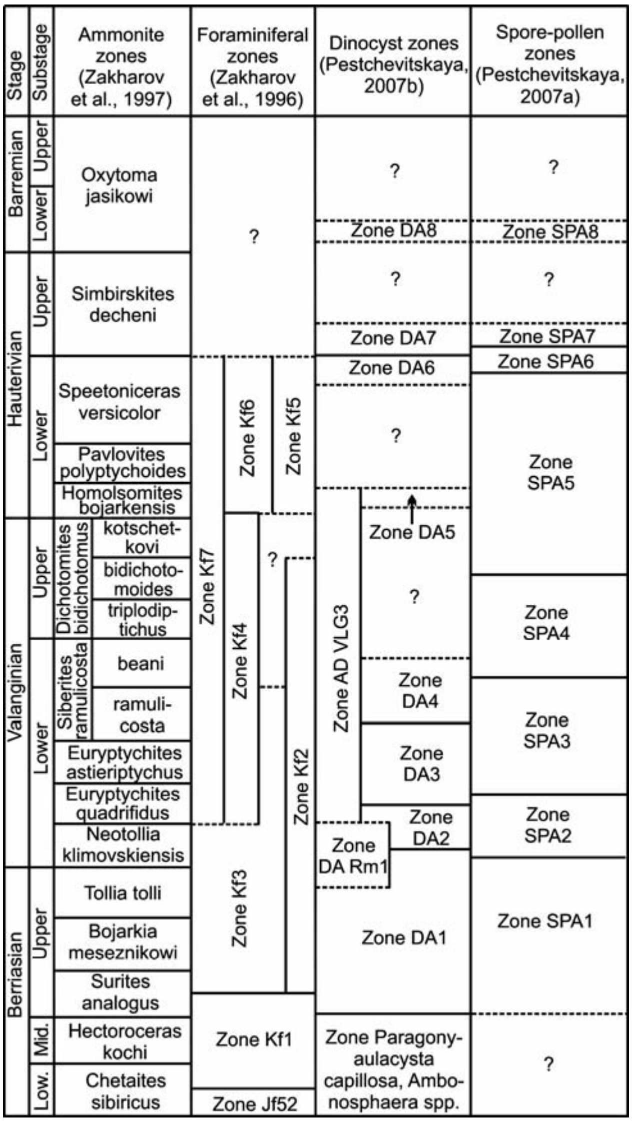

Fig. 1 Calibration of northern Siberian palynological zones against standard ammonite and foraminiferal zones

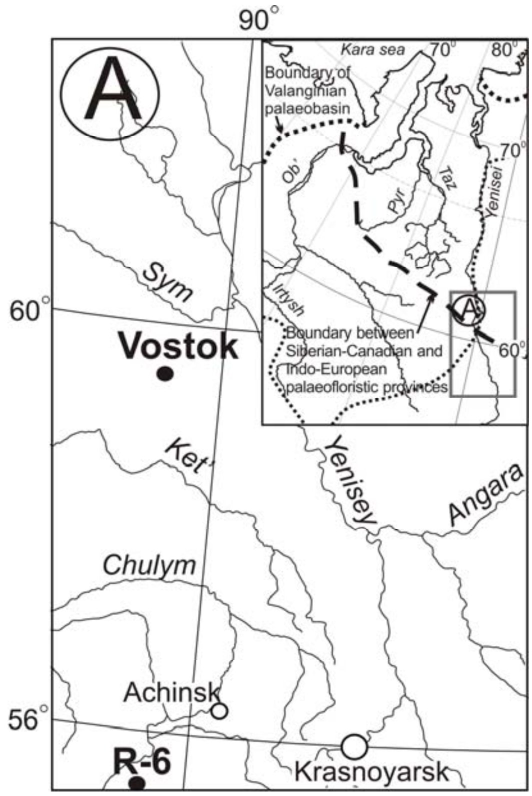

Fig. 2 The localities of the wells Vostok and R-6

Palynological samples were prepared using palynological techniques, including the treatment with hydrofluoric and hydrochloric acids and natrium pyrophosphate. Organic and mineral fractions were separated through centrifugation in heavy cadmium liquid (specific gravity: 2.25). All samples yielded rich assemblages of terrestrial palynomorphs. At least 200 specimens were counted per sample to establish taxon abundances. The palynological zonation is mostly based on the first and last occurrences of stratigraphically important taxa, whose stratigraphic potential for Siberia was previously estimated on the basis of comparative analysis of spore-pollen assemblages from different regions of West and East Siberia (Pestchevitskaya, 2007a, 2010). Percentage relations are only used as subsidiary stratigraphic characters as they mostly reflect facial features as well as floristic and ecological peculiarities of land vegetation. Hence, percentage relations are analyzed to reconstruct the succession of facial and climatic changes for the Lower Valanginian of the southeastern regions of West Siberia. Botanical affinities and palaeoecological attribution of palynomorphs accepted here are derived from literature analysis and the authors' observations of Jurassic and Cretaceous spores and pollen (Fig. 4).

2 Spore-pollen zonation of the Lower Valanginian sections in the Vostok-4 and R-6 wells and correlation against northern palynological successions and boreal ammonite standard

Four spore-pollen zones are defined in the studied Lower Valanginian sections (Fig. 5). The main palynological features important for the determination of their stratigraphic position are the occurrences of key taxa (Fig. 5). Subsidiary stratigraphic characters are the percentage of ancient morphotypes of bisaccate pollen of conifers and pteridosperms (*Alisporites*, *Pseudopicea*, *Protopinus*), reducing upward in the sections and the percentage of Taxodiaceae increasing in the upper part of the section in the Vostok-4 well.

The studied spore-pollen assemblages are dominated by gymnosperm pollen mostly represented by abundant bisaccate pollen of conifers, *Classopollis*, Taxodiaceae, and Bennettitaceae (Fig. 5). The Lower Valanginian spore-pollen assemblages from the reference sections situated in northern areas of West Siberia and dated by ammonites differ in less abundant gymnosperms, especially *Classopollis* and Taxodiaceae, which is related to palaeofloristic zonality. In the Valanginian, two palaeofloristic provinces are established for West Siberia on palaeobotanical data: the temperate warm Siberian-Canadian for the north and the subtropical Indo-European for the south (Vakhrameev, 1988). The location of the boundary is evaluated on the basis of palynological material (Fig. 1) (Pestchevitskaya & Lebedeva, 2003). The humid climate of the Siberian-Canadian province was favorable for the development of rich fern floras, and the northern palynological assemblages contain diverse fern spores providing detailed zonation of the Lower Cretaceous deposits in these regions (Pestchevitskaya, 2007a, 2010). It is mainly based on striate, granular and spinous spores of Schizaeaceae, which are almost absent in the south of Siberia. Nevertheless several stratigraphically important taxa are defined in the studied spore-pollen assemblages from the sections of the Vostok-4 and R-6 wells. These are spores of liwerworts (*Foraminisporis asymmetricus*, *Aequitriradites verrucosus*, Hepaticae), and gleicheniaceous and polypodiaceous ferns (*Clavifera triplex*, *Laevigatosporites* sp.), which are minor stratigraphic groups in northern regions,

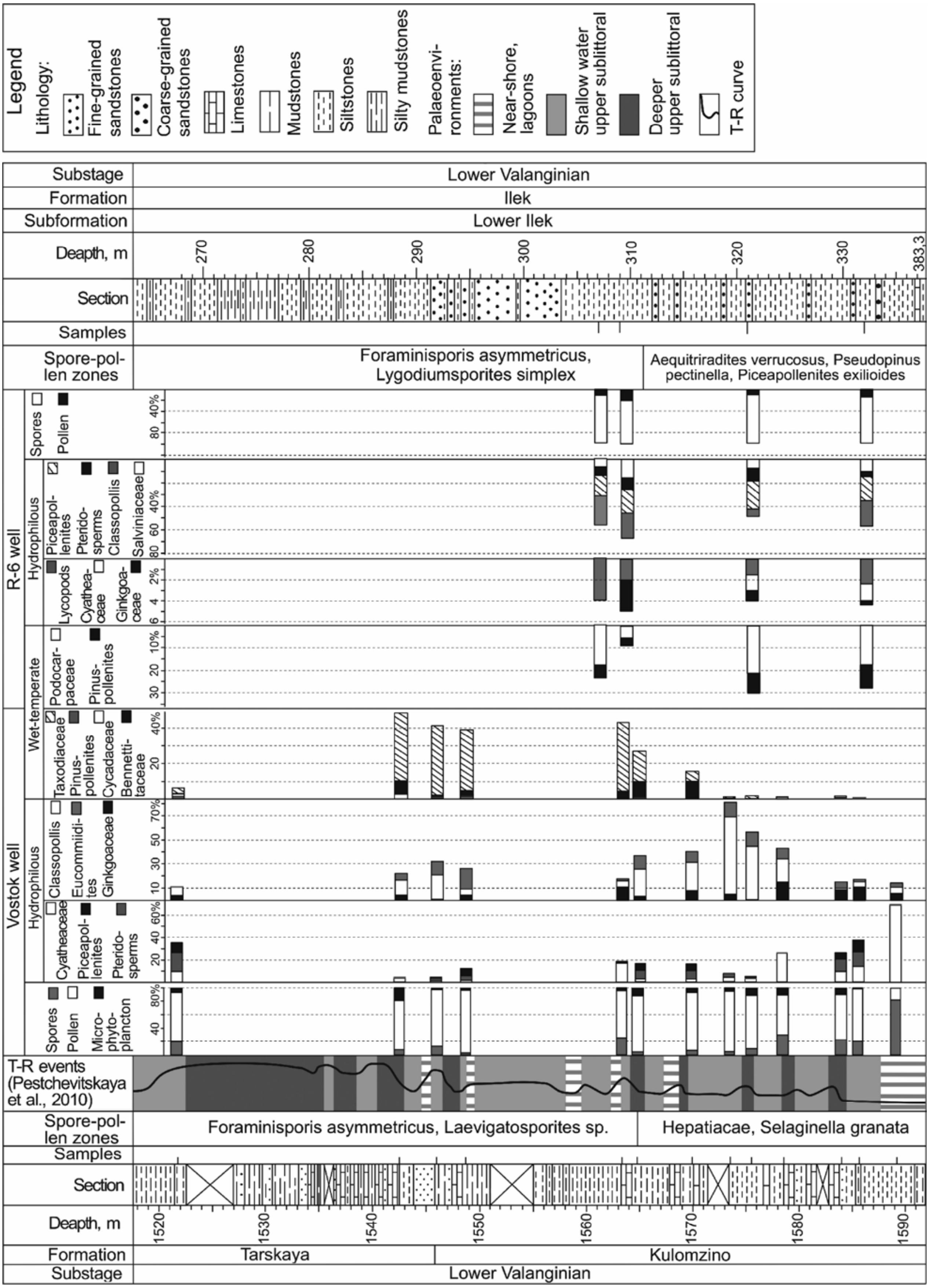

Fig. 3 Valanginian sections in the Vostok-4 and R-6 well and distribution of main terrestrial palynomorphs

Probable affinities of studied palynotaxa	Life forms of probable parent plants	Ecology of probable parent plants
Moses:	Recent: herbaceous; Fossil: small herbaceous plants (evidenced by the lack of developed conductive system).	Recent: mainly wet, sometimes aquatic or, in opposite, dry conditions; can occupy poor soils; abundant in bogs and in wet forests, especially in tropics and subtropics, which are regarded as the areas of their origin. Fossil: indicate wet conditions.
Liverworts (*Foraminisporis*, *Aequitriradites*, Hepaticae, *Rouseisporites*, *Triporoletes*)		Recent: mainly temperate wet conditions (shores of lakes and rivers). Fossil: regarded as indicators of wet conditions, sometimes drowned lowland and bogs.
Sphagnaceae (*Stereisporites*)		Recent: mainly wet conditions; can form continuous herbage on the bogs, less abundant on the shores of lakes and rivers (mainly in tropics and subtropics). Fossil: regarded as indicator of wet conditions, sometimes bogs.
Lycopods (*Lycopodiumsporites*, *Densoisporites*, *Selaginella*, *Hymenozonotriletes*, *Leptolepidites*, *Neoraistrickia*)	Recent: herbaceous; Fossil: small herbaceous plants (evidenced by the lack of developed conductive system).	Recent: mainly wet conditions; shade-requiring plants (wet forests). Fossil: regarded as indicator of wet conditions, sometimes coastal lowland; some species of *Densoisporites* are attributed to Pleuromeiaceae and hence regarded as indicators of coastal zone (halophytes) or dry environments (xerophytes).
Ferns:		Recent and fossil: mainly wet and shady environments, indicators of humid climate, but few of them can occupy light and dry environments, abundant ferns and drought-resistant plants evidence seasonal climate with dry periods.
Cyatheaceae and Dicksoniaceae (*Cyathidites*, *Biretisporites*, (?) *Leiotriletes*, *Concavisporites*)	Recent: more than half are trees; Fossil: trees and crawlers (Dicksoniaceae).	Recent: hydrophilous, mainly tropical (some are subtropical), abundant in wet and temperate warm highlands; form one-layered wet forests with abundant mosses and epiphytes; can form pioneer vegetation after fire and quickly occupy large territories. Fossil: indicate warm and humid climate; some (Dicksoniaceae) were able to live in periodically drowned coastal lowland.
Dipteridaceae (*Tripartina*, *Eboraciasporites*)	Recent: herbaceous; Fossil: sometimes high trees.	Recent: light-requiring; highlands and plains (glades, more rare banks of wide rivers). Fossil: humid and temperate warm climate; some were adapted to periodically drowned coastal lowland or relatively dry environments.
Gleicheniaceae (*Gleicheniidites*, *Clavifera*)	Recent: herbaceous; many are lianes.	Recent: temperate warm conditions; prefer slightly shaded conditions and poor soils; can form continuous herbage on the rocks. Fossil: regarded as indicators of warm and temperate wet climate; preferred slightly shaded conditions; some formed thick tangles or savanna, can formed pioneer vegetation.
Schizaeaceae (*Klukisporites*, *Trilobosporites*)	Recent: herbaceous, more rare lianes; Fossil: herbaceous and lianes.	Recent: mailnly tropical and subtropical; often plains and foothills, rare highland, some are epiphytes; can occupy poor acid and sandy soils or peats; prefer temperate wet conditions, some are drough-resistant (especially *Mohria* and *Anemia* producing striate spores). Fossil: were adapted to different climate; preferred wet and warm condition; mainly river banks, more rare marshy lowland near the lakes and river deltas; formed undergrowth.
Osmundaceae (*Osmundacidites*, *Todisporites*)	Recent: herbaceous; Fossil: herbaceous (in the Mesozoic)	Recent: hydrophilous, temperate warm and tropical; forests, ravines, marshes, near the rivers; can form continuous herbage in the forest margins. Fossil: hydrophilous, temperate warm and tropical; river banks, periodically drowned lowland, peatbog; regarded as indicators of temperate wet conditions, dry areas can be the barriers for their distribution.
Salviniaceae	Recent and fossil: herbaceous.	Recent and fossil: aquatic plants; heat-loving (mainly tropic and subtropic); lakes, to 1,5-2 m depth.
Gymnosperms (in general)		Recent and fossil: in general, adapted to drier condition, than ferns.
Cycadaceae (?) (*Cycadopites*, but there are evidences of its attribution to Bennettitaceae, Ginkgoaceae, Czekanowskiaceae)	Recent: mainly trees; Fossil: trees and bushes.	Recent: tropical and subtropical; adapted to dry conditions. Fossil (very diverse in the Cretaceous): regarded as indicators of arid subtropical and tropical climate, possibly with wet seasons; xeromorphic adaptations are regarded as evidence of dry conditions (mountain slopes, uplands) or overwetting (peat or coastal vegetation).
Bennettitaceae (?) (*Bennettiteaepollenites*, but there are evidences of its attribution to Cycadaceae, Ginkgoaceae, Czekanowskiaceae)	Fossil: bushes.	Fossil (widespread in the Mesozoic): bushes; mainly subtropic; have xeromorphic adaptations; dry or overwetting conditions; mainly wet conditions in the Triassic and Jurassic, extinction in the Cretaceous is regarded as the result of aridization; adapted to dry conditions in the Cretaceous, but also was able to occupy wet lowland and form mangrove.
Ginkgoaceae (?)(*Ginkgocycadophytus*, but there are evidences of its attribution to Cycadaceae, Bennettitaceae, Czekanowskiaceae)	Recent: deciduous trees; Fossil: trees and bushes.	Recent (only 1 species): restricted to small area in S-E Asia; mountain temperate wet forests with coniferous and broad-leaved trees. Fossil (widespread in the Cretaceous): mainly in northern hemisphere in temperate and temperate warm climate, but some are subtropic; mainly deciduous trees; sometimes are regarded as the indicator of temperate wet climate; possibly were able to form the undergrowth in gymnosperm forests; can occupy coastal plains with saline soil.
Eucommiidites (Bennettitaceae, Erdtmanithecaceae, Gnetaceae, Cycadaceae, Angiospermae)		Fossil: Regarded as indicator of lowland, warm and 1) wet, 2) temperate conditions.
Pteridosperms (*Alisporites*, *Vitreisporites* (?), *Pseudopicea* (?))	Fossil: small plants, possibly bushes.	Fossil: hydrophilous; coastal plains or mangrove; some occupied upland.
Podocarpaceae (*Podocarpidites*, *Quadraequlina*)	Recent: evergreen and deciduous trees or bushes; Fossil: trees.	Recent: subtropics of southern hemisphere, rare in northern hemisphere; wet and warm climate; can occupy mountain slopes and marshes. Fossil: more diverse in southern hemisphere in the Mesozoic; regarded as indicator of 1) temperate warm climate with dry seasons, 2) temperate dry conditions (mountain slopes, upland).
Cheirolepidiaceae (*Classopollis*)		Fossil: regarded as indicator of hot arid and semiarid climate; had xerophytic adaptations; dry or overwetting conditions; related to 1) coastal land (possibly marsh or mangrove), 2) humid savanna (heavy seasonal rains and dry periods), 3) dry inner land (upland, mountain slope).
Taxodiaceae (*Taxodiaceaepollenites*)	Recent: evergreen and deciduous trees or bushes; Fossil: trees or bushes.	Recent: warm and temperate wet climate; sometimes dominate marsh communities; can grow in the mountains, but not further then 200 m from the coast (humid zone); Fossil: warm and humid climate; possibly upland and mountain slopes, sometimes occupied marshy lowland near the lakes; sometimes (Sequoia) formed pioneer vegetation.
Pinaceae (*Pinuspollenites*, *Piceapollenites*)	Recent: mainly trees; Fossil: mainly trees.	Recent: widespread; temperate and subtropical climate, different conditions, shade- and drought-induring, cold-resistant. Fossil: widespread in the plains and upland in the Cretaceous, especially in the areas with temperate climate; mainly trees; forest with undergrowth of Ginkgoaceae and Cycadaceae; wet and temperate dry conditions; dominance is regarded as 1) indicator of cool conditions and upland somewhat distant from the palaeobasins, 2) high pollen productivity and adaptation to the transportation.

Fig. 4　Probable botanical affinities of studied palynotaxa, life forms and ecology of parent plants (Based on: Bolkhovitina, 1961, 1963; Cornet & Traverse, 1975; Plant's life, 1978; Ilyina, 1979; Alvin, 1982; Vakhrameev, 1988; Duane, 1996; Abbink, 1998; Vajda, 2001; Deng, 2002; Van Konijnenburg-Van Cittert, 2002; Li & Batten, 2004, 2007; Kvaček et al., 2005; Barrón et al., 2006; Bugdaeva et al., 2006; Nagalingum & Cantrill, 2006; Nichols et al., 2006; Saiki & Okubo, 2006; Pott et al., 2008; Prakash, 2008; Wang et al., 2008, and others)

but turned out to be important for the correlation of southern spore-pollen successions. The comparison with the northern palynological successions allows the calibration of southern spore-pollen zones against the boreal ammonite standard (Fig. 5).

Additional stratigraphic control of spore-pollen zones in the Vostok-4 section comes from the succession of transgressive-regressive (T-R) events based on the analysis of microphytoplankton and macrofauna fluctuations (Pestchevitskaya et al., 2010). The T-R succession defined in the Vostok-4 well is correlated on microphytoplankton with those established in northern sections dated both by palynomorphs and fauna (Pestchevitskaya & Khafaeva, 2008; Pestchevitskaya & Gnoeva, 2010). We can't state the coincidence of all minor T-R events, as we can't collect the samples accurately from the same stratigraphic levels. Nevertheless, similar regularities in T-R successions can be observed in the northern and southern regions of Siberia: on the background of general regression increasing from the Berriasian to the Hauterivian, a number of minor T-R events is defined including more pronounced regression in the middle part of the zone SPA2 and more pronounced transgression in the upper part of the zone SPA3, that is also identified in Vostok-4 well (Fig. 3). Thus, the more precise stratigraphic range of this section is defined as the middle part of the zone SPA2 (approximately base of the ammonite zone Euryptychites quadrifidus): the uppermost part of the zone SPA3 (middle part of the ammonite zone Siberites ramulicosta).

3 Early Valanginian palaeoenvironments and vegetation of coastal areas in the southeastern regions of West Siberia

In the Valanginian, the southeastern regions of West Siberia were occupied by the marginal shal- low-water part of an epicontinental sea and lacustrine-alluvial plain with low coastal gradient (Golbert, 1987), which is confirmed by the palynological data.

Apart from abundant terrestrial palynomorphs, palynological assemblages from the Vostok-4 well comprise microphytoplankton (0~16%) represented by almost permanent *Leiosphaeridia* (0~9%), *Ovoidites* (0~2%), *Schizosporis* (1%~2%) and rare dinoflagellates (*Pareodinia*, 0~1%; *Sentusidinium*, 0~1%; *Fromea*, 0~1%; *Jansonia*, locally 8%), that indicate nearshore

Stage	Substage	Boreal zonal standard (Zakharov et al., 1997)	N Siberian spore-pollen zones (Pestchevitskaya, 2008)	Vostok-4 well: Spore-pollen zones	Vostok-4 well: Spore-pollen assemblage	Vostok-4 well: Stratigraphically important features	R-6 well: Spore-pollen zones	R-6 well: Spore-pollen assemblage	R-6 well: Stratigraphically important features
Valanginian	Lower	Siberites ramulicosta Euryptychites astieriptychus	Cicatricosisporites australiensis, Cicatricosisiporites dorogensis, Foraminisporis dailyi (SPA 3)	Foraminisporis asymmetricus, Laevigatosporites sp.	SPORES (3-25%). C- *Cyathidites minor* ; F- *Foraminisporis* sp., *Cyathidites australis, Leiotriletes* spp.,*Leptolepidites proxigranulatus*; R- *Foraminisporis wonthaggiensis, F. asymmetricus, Stereisporites psilatus, Densoisporites velatus, Leptolepidites verrucatus, Selaginella utriculosa, S. granata, Neoraistrickia* sp., *Lycopodiumsporites* sp., *Eboracia granulosa, Dictyophyllidites* spp., *Osmundacidites* spp., *Gleicheniidites senonicus, Clavifera* spp., *Laevigatosporites* sp., *Klukisporites* spp.,*Trilobosporites* spp., POLLEN (71-93%). A- Taxodiaceae; SD- Coniferales; C- *Classopollis* spp., C- *Eucommiidites* spp., *Pseudopicea* spp., Bennettitaceae, *Piceapollenites* spp., *Ginkgocycadophytus* spp.; F- *Sequoiapollenites* spp., *Cycadopites* spp., *Alisporites* spp.; R- *Protoconiferus* spp., *Pinuspollenites* spp., *Piceapollenites valanjinicus, Podocarpidites multesimus, P. luteus, Podocarpus unica, Quadraeculina limbata, Vitreisporites pallidus, Callialasporites dampieri, Sciadopityspollenites* spp., *Araucariacidites* spp., *Gnetaceaepollenites* spp.	First appearance of *Foraminisporis asymmetricus.* First appearance of *Clavifera triplex* First appearance of *Laevigatosporites* sp. Increased percentage of *Pinuspollenites* and *Piceapollenites*, considerable percentage of ancient bisaccate gymnosperms	Foraminisporis asymmetricus, Lygodiumsporites simplex	SPORES (11.5-2 0%). C-Salviniaceae; R- *Leptolepidites major* ; *Foraminisporis asymmetricus, Densoisporites velatus, Selaginella utriculosa, Neoraistrickia* sp., *Lygodiumsporites simplex, Hymenozonotriletes bicycla* POLLEN (80-88.5%). A- *Classopollis* spp., SD- Coniferales, *Piceapollenites* spp.; C- *Podocarpidites* spp., *Pinuspollenites* spp., *Protoconiferus funarius*; F- *Ginkgocycadophytus* spp., *Podocarpidites unicus;* R- *Podocarpidites lunata, Protopinus* spp. (*P. subluteus, P. vastus*), *Quadraeculina limbata, Vitreisporites pallidus, Araucariacidites pexus, Pseudowalchia* spp.	First appearance of *Foraminisporis asymmetricus.* High percentage of *Piceapollenites*, considerable percentage of ancient bisaccate gymnosperms
		Euryptychites quadrifidus	Rouseisporites spp., Cicatricosisporites minutaestriatus, Pilosisporites spp., Ornamentifera granulata (SPA 2)	Hepaticae, Selaginella granata	SPORES (6-33%) C - *Leiotriletes* spp., *Cyathidites australis,C. minor, Densoisporites velatus*; F- *Biretisporites* spp., *Stereisporites psilatus, Concavisporites junctum*; R- Hepaticae, *Densoisporites microrugulatus, Hymenozonotriletes bicycla, Selaginella granata, S. utriculosa, Leptolepidites verrucatus, Neoraistrickia* sp., *Todisporites minor, Dictyophyllidites* spp., *Eboraciasporites* spp., *Gleicheniidites senonicus, Klukisporites variegatus, Trilobosporites valanjinensis*; POLLEN (56-89%) D- *Classopollis* spp.; A- Coniferales, C- *Eucommiidites* spp., *Ginkgocycadophytus* spp., Bennettitaceae, *Piceapollenites* spp.; F- *Piceapollenites valanjinicus, Pseudopicea* spp.,Taxodiaceae, *Cycadopites* spp., *Alisporites* sp., *Protopicea* spp.; R- *Protopodocarpus* spp., *Podocarpus unica, Dipterella oblatinoides, Quadraeculina limbata, Pinuspollenites* spp.,*Vitreisporites pallidus, Protoconiferus* spp., *Sequoiapollenites* spp., *Callialasporites dampieri*	Occurrences of *Selaginella granata.* Occurrences of Hepaticae. Considerable percentage of Taxodiaceae. Abundance and diversity of ancient bisaccate gymnosperms	Aequitriradites verrucosus, Pseudopinus pectinella, Piceapollenites exilioides	SPORES (10-14.8%). C- Salviniaceae; F- *Leptolepidites major, Duplexisporites* spp., R- *Cyathidites* sp., *Dicksonia, Densoisporites velatus, Osmundacidites* sp., *Aequitriradites verrucosus* POLLEN (85.2-90%). SD- *Classopollis* spp., *Podocarpidites* spp., *Piceapollenites* spp.; C- Coniferales, *Piceapollenites exilioides, Pinuspollenites* spp., *P. divulgata, Pseudopicea magnifica*; F- *Protoconiferus funarius, Pinites distorus, Podocarpidites unicus*; R- *Piceapollenites complanatiformis, Podocarpidites major, P. enodata, Pseudopinus* spp.(*P. pectinella, P. textilis*), *Ginkgocycadophytus* spp., *Cycadopites* sp., *Quadraeculina limbata, Piceites podocarpoides, Vitreisporites pallidus, Piceapollenites variabiliformis, Callialasporites dampieri, Pseudowalchia* spp.	Occurrences of *Aequitriradites verrucosus* Abundance and diversity of ancient bisaccate gymnosperms

Fig. 5 Palynological zones and their characteristic features

A. abundant (20%~40%), C. considerable (3%~10%), D. dominant (> 40%), F. few (2%~3%), R. rare (0~1%), SD. subdominant (10~20%)

environments. Spore-pollen assemblages, including rather abundant spores of lycopods and ferns along with dominant gymnosperms pollen mainly comprising Taxodiaceae, Bennettitaceae and *Classopollis*, indicate hot arid and seasonal climate with alternation of dry and wet periods.

Detailed stratigraphy and reconstruction of short-termed T-R events allow the analysis of temporal changes of nearshore vegetation and landscapes in relation to palaeobasin dynamic. Low coastal gradient resulted in a wide distribution of wet and locally swampy lowlands during the regressions that are evidenced by dominant spores and pollen of hydrophilous plants (Fig. 3). In the early *Euryptychites quadrifidus* time, the landscape was rather uniform bringing to the development of homogeneous floras mostly constituted of ancient pteridosperms (*Alisporites*, *Pseudopicea*) and dicksonialean tree ferns (*Cyathidites*). The occurrence of coastal hydrophilous vegetation adapted to overwetting and specific salt regime is indicated by rather abundant *Densoisporites* (10%), since it is regarded as an indicator of coastal zone (Abbink, 1998; Saiki & Okubo, 2006).

In the middle of the *Euryptychites quadrifidus* time, the restricted links with an open basin resulted in the periodic occurrence of lagoonal environments that is reconstructed from the benthic fauna (Pestchevitskaya et al., 2010). These conditions in tropical and subtropical regions are favorable for the development of mangroves. It is interesting to note that these levels in the Vostok-4 well section are marked by the acmes of *Classopollis*, which is often regarded as a typical component of coastal pioneer vegetation and mangroves (Cornet & Traverse, 1975; Duane, 1996; Abbink, 1998; Prakash, 2008 and others). Frequent finds of *Classopollis* tetrads confirm its short distance transportation and nearshore derivation. T-R fluctuations caused frequent changes of coastal landscapes and vegetation recorded in quantitative changes of the components in palynological assemblages. The lowland relief becomes more differentiated: the composition of the hydrophilous flora is more diverse comprising plants of different ecological requirements. The diversity of lycopods and ferns increases, and they are represented by *Hymenozonotriletes*, *Selaginella*, *Leptolepidites*, *Neoraistrickia* and *Todisporites*, *Dictyophyllidites*, *Cyathidites*, *Eboraciasporites*, *Gleicheniidites*, *Klukisporites*, *Trilobosporites* respectively.

In the *Euryptychites astieriptychus* time, the lowland was mostly flooded during the transgressions, and coastal areas became more elevated. In arid conditions, these territories were occupied by gymnosperms with certain adaptations to withstand drought conditions. It is indicated by wide distribution of Taxodiaceae, Bennettitaceae and Cycadaceae (Fig. 3). Nevertheless, it does not exclude the occurrence of swampy lowland and mangroves, as some fossil representatives of these families are regarded as their indicators (Cornet, Traverse, 1975; Kvaček et al., 2005; Bugdaeva et al., 2006, and others). Seasonal climate possibly caused the formation of swampy and well-drowned lowland in wet periods and their desiccation in dry periods.

Ginkgophytes probably preferred more humid conditions, as they are generally more abundant in regressive stages correlated to the occurrences of broad wet lowland. However, the ecological heterogeneity of their parent plants can be implied from a considerable percentage variation of this pollen in the assemblages. An increased percentage of *Eucommiidites* is often observed in transgressive stages. Low percentages (0.5%~1.5%) of *Pinuspollenites* and *Podocarpidites* in spore-pollen assemblages indicate rare occurrences of their parent plants in Early Valanginian coastal floras in the studied regions.

4 Early Valanginian palaeoenvironments and vegetation of inner-land areas in south-eastern regions of West Siberia

The Early Valanginian vegetation of inner-land areas is studied on the basis of palynological material from the R-6 well. Aquatic environments are evidenced by abundant Salviniaceae (7%~16%), which is a typical component of the contemporary shallow-water biota of tropical and subtropical lakes, where they grow in shallow areas down to 1.5~2.0 m. The wide distribution of variously colored red, brown and blue sediments, containing poor nutrients as well as poor accumulations of coal particles and organic detritus, implies the absence of thick forest. Spore-pollen assemblages comprising abundant *Podocarpidites* (5%~20%), *Piceapollenites* (18%~24%) and *Pinuspollenites* (4%~10%) show that the landscape was mostly represented by open coniferous woodland. Domination of gymnosperms with a high percentage of *Classopollis* (6%~25%) indicates an arid climate.

Drier environments in the *Euryptychites quadrifidus* time can be inferred from more abundant *Pinuspollenites* (10%) in the assemblage of the *Aequitriradites verrucosus*, *Pseudopinus pectinella*, *Piceapollenites exilioides* zone (Fig. 3). Contemporary pines prefer temperate dry conditions, but are well adapted to a dry climate. Drier conditions resulted in a decrease of lake size, evidenced by lower percentage of Salviniaceae (7%~9%), and exposure of nearshore lowlands, which could be periodically swamped during wet seasons. Desiccation of near-shore areas in dry seasons precluded the wide distribution of dicksoniaceous ferns and liverworts represented in the spore-pollen assemblage by rare *Cyathidites*, *Aequitriradites* and *Leptolepidites*. The main body of lowland and swamp vegetation was possibly constituted by podocarpaceans, which now prefer wet and warm conditions, but can withstand dry periods. The occurrence of wet environments is evidenced by the presence of *Osmundacidites*.

In the *Euryptychites quadrifidus* time, a period of more humid conditions can be identified by a decreased percentage of *Pinuspollenites* and increased percentage of *Ginkgocycadophytus* (Fig. 3). The quantitative peak of Salviniaceae (up to 16%) evidences an enlargement of the lake. Wet and swampy lowland was mostly drowned, which is indicated by the absence of Dipteridaceae, Cyatheaceae, Osmundaceae and a reduced percentage of *Podocarpidites* in the spore-pollen assemblage. Surrounding land became more elevated. More humid conditions caused the formation of mixed and possibly marginal forest of fir trees and undergrowth consisted of ginkgophytes and pteridosperms. Temperate wet conditions are also indicated by the occurrences of *Lygodiumsporites*.

5 Comparison of Early Valanginian terrestrial vegetation of coastal and inner-land areas in southeastern regions of West Siberia

The Early Valanginian flora of inner-land areas (R-6 well) is characterized by a strong dominance of conifers, especially podocarpaceans. They are replaced by Taxodiaceae, Bennettitaceae, Cycadaceae and *Eucommiidites*-producing plants in coastal regions (Vostok-4 well) forming specific plant communities (Fig. 6). These taxa typical for coastal vegetation are almost absent in spore-pollen assemblages from the R-6 well (Fig. 3). Contemporary taxodiaceans also grow in humid areas under the influence of marine basins, great rivers or lakes, no farther than 200 km away (Plant's life, 1978). There are interesting discussions on the occurrence of a great river in the south-eastern region of West Siberia in the Valaginian, that turns out to be unlikely on palynological material.

Lowlands in coastal regions were occupied by abundant dicksoniaceous ferns, which were rare in inner-land areas with restricted humid environments.

Cheirolepidiaceans producing *Classopollis* pollen were widespread in the Early Valanginian arid vegetation of the southeastern region of West Siberia both in coastal and inner-land areas. Nevertheless, they are much abundant in coastal floras that imply their high water requirement.

Ginkgophytes apparently can be regarded as humid indicators in southern regions of Siberia: they are more abundant in coastal communities, and their increased percentage in inner-land assemblages is correlated to the reduced percentage of *Pinuspollenites* indicating more humid conditions.

6 Comparison of lateral distribution of Valanginian spore-pollen assemblages of central and eastern regions of Eurasia

Comparison of the distribution of the Valanginian palynological assemblages in central and eastern regions of Eurasia shows the transitional character of the vegetation in the southeastern region of West Siberia, demonstrating typical features of both the Indo-European and the Siberian-Canadian plaeofloristic provinces.

A considerable amount of cyatheaceous ferns revealed in the palynospectra from the Vostok-4 section is a characteristic feature of the Siberian-Canadian province (Figs. 6, 7). They are most abundant in northern areas of Siberia reflecting the temperate warm and humid climate of these territories. Palynological assemblages from the Indo-European province and ecotone regions contain different quantities of cyatheaceous spores, which are more abundant in coastal and near-shore environments with humid conditions and rather barren or even absent in inner-land areas (Figs. 6, 7).

Another feature, typical of the Siberian-Canadian province and revealed in the studied sections, is the high percentage of *Piceapollenites* (Figs. 6, 7). It is interesting to note its dominance in the assemblages from inner continental depressions, which well reflect the adaptation of parent plants to dry environments. In the southeastern region of West Siberia, the abundant *Piceapollenites* is also revealed from continental deposits of the R-6 well.

The abundance of *Classopollis* is usually regarded as the most pronounced palynological characteristic of the Indo-European palaeofloristic province, especially of its arid areas. However, the comparison of its lateral distribution demonstrates its uneven distribution over these regions revealing its high percentage in near-shore and coastal areas and less abundance in inner-land ones (Figs. 6, 7). The assemblages from the Hailar Basin contain a low percentage of *Classopollis*, and it has not been reported from the Valanginian deposits of Transbaicalia. These data confirm an assumption of coastal or humid habitats of their parent plants (Fig. 4). Palynological material obtained from south Siberian sections also implies their humid requirements, as the abundance peaks of *Classopollis* in the palynospectra of Vostok-4 section are correlated to the development of wet lowland or even mangrove in coastal areas. The nearshore origin of *Classopollis* grains in south Siberian sections is also confirmed by frequent finds of their tetrads.

The quantity of ginkgophytes is generally higher in the Siberian-Canadian province, but they are most abundant in eastern areas, in the Primorye region and Bureya Basin, reflecting specific Valanginian vegetation on these territories (Figs. 6, 7). In the Indo-European province and ecotone regions, they are more abundant in coastal and near-shore environments, and it is also shown in the studied material. Therefore, abundance peaks of *Ginkgocycadophytus* can be regarded as an indicator of humid environments for the Indo-European province. The wide distribution of ginkgophytes in the Siberian-Canadian province and considerable percentage variations of their pollen in Siberian sections, characterized by different facies, give us the basis to suggest ecological heterogeneity of this plant group in northern regions.

The low percentage of Schizaeaceae and Osmundaceae in the studied spore-pollen assemblages is another feature, which is also characteristic for the Indo-European palaeofloristic province. The abundance of Osmundaceae typical in the north of Siberia gradually reduces in a S-W direction (Figs. 6, 7). The spore-pollen assemblages of central Siberian areas (Nadym and Surgut regions), situated close to the boundary of the provinces, contain both abundant Osmundaceae and *Classopollis*. It is also revealed in some Indian sections in West Bengal (Vijaya & Bhattacharji, 2002) and probably related to the symmetrical latitudinal position of these regions in the northern and southern hemispheres respectively. Schizaeaceae shows a similar distribution over Siberia reducing in quantity in a S-W direction (Figs. 6, 7). In western areas, the representatives of these families are replaced by Gleicheniaceae, which becomes very abundant in the assemblages from the Ural regions, the Russian Platform, Ukraine and the Caucasus.

Taxodiaceae is most abundant in central areas of Eurasia: the Caucasus, south of West Siberia, and Transbaicalia (Figs. 6, 7). Its quantity is also rather high in neighboring areas (Ukraine, Uzbekistan, Caspian regions) and in Primorye.

A specific feature of the spore-pollen assemblages from the R-6 well is the abundance of Podocarpaceae showing a low percentage in other regions, both in the Indo-European and Siberian-Canadian provinces, except for the Khatanga and Lena-Anabar regions in the north of Siberia (Figs. 6, 7). Therefore, Podocarpaceae was possibly one of the main components of the Valanginian tree communities in the western and sout-western areas of East Siberia. The dominance of Podocarpaceae, along with abundance of Araucariaceae, Schizaeaceae and *Classopollis*, is typical for the Indian vegetation of Gondwana type.

In general, two large areas can be recognized on palynological data for the Valanginian vegetation of Laurasian type (Fig. 7). The northern area was occupied

Regions	Gymnosperms										Ferns					Mosses		Lycopods: Densoisporites,Lycopodiumsporites,Leptolepidites,Selaginella,Neoraistrickia
	Picea-pollenites	*Pinus-pollenites*	*Alisporites, Pseudopicea*	*Podocarpidites*	*Ginkgocycadophytus, Cycadopites, Bennettiteaeapollenites*	*Dicheiropollis*	*Classopollis*	*Eucommiidites*	*Taxodiaceaepollenites*	*Araucariacidites*	*Concavissimisporites, Trilobosporites, Appendicisporites, Cicatricosisporites*	*Cyathidites, Biretisporites, Concavisporites*	*Osmundacidites, Todisporites*	*Gleicheniidites, Clavifera*	Salviniaceae	*Stereisporites*	*Foraminisporis, Aequitriradites, Rouseisporites*	
Vostok well	3-10%	1-2%	1-12%	1-2%	3-15%	0%	4-60%	2-17%	2-35%	1%	1%	3-60%	1%	1%	1%	1-5%	1%	1-5%
R-6 well	17-25%	6-10%	7-11%	8-30%	1-3%	0%	6-20%	0%	0%	1%	1-3%	1-2%	1%	0%	7-16%	0%	1%	1-4%
Lena-Anabar region, 1	6-10%	3-10%	10-25%	15%	6%	0%	1-3%	1%	1%	1-3%	1-5%	20-30%	3-20%	1-3%	0,5%	1-3%	1-3%	3-5%
Khatanga depression, 2	6-17%	3-10%	10-40%	4-12%	5-16%	0%	1-3%	1%	1-2%	1%	1-12%	20-40%	3-16%	1-3%	0,5%	1-5%	1-3%	8-9%
NW Yakutia, 3	5-10%	3-5%	20-22%	4-6%	1-7%	0%	1%	0%	0%	0%	0%	10-15%	11%	1-3%	4%	1-3%	1-3%	3-5%
Transbaikalia, 4	20-77%	1-8%	5-17%	1-5%	0-2%	0%	0%	0%	1-40%	0%	0-1%	0-1%	0-1%	0-1%	1-3%	0%	0%	0-1%
Vilyui region, 5		3-45%	10-40%	1-3%	5-30%	0%	1%	0%	0%	0%	1-12%	10-40%	5-30%	1-12%	0,5%	1-3%	1-3%	8-9%
Yenisey mouth, 6	5-8%	2-4%	10-20%	2-5%	3-11%	0%	1-5%	1%	1%	1%	1-12%	10-30%	3-12%	1-3%	0%	1-3%	1-3%	3-9%
Nadym and Pur regions, 7	5-10%	2-5%	3-15%	3-10%	3-10%	0%	4-20%	1%	1-6%	1%	1-14%	15-40%	5-15%	2-8%	0,5%	1-3%	1-2%	3-6%
Yamal, Gydan regions, 8	5-15%	3-10%	10-20%	1-3%	1-4%	0%	1-4%	0%	1-6%	0%	1-5%	10-30%	1-3%	34-60%	0%	1-3%	1-3%	1-3%
Surgut region, 9	5-14%	3-5%	3-15%	1-4%	3-20%	0%	4-20%	0%	1-2%	0%	1-10%	10-30%	3-10%	1-5%	0%	1-3%	1-3%	1-3%
Berjozovo region,10	5-10%	2-4%	10-20%	1-4%	3-10%	0%	1-3%	0%	1-2%	0%	1-5%	3-10%	1-3%	12-48%	0%	1-3%	1-3%	1-3%
Subpolar Urals, 11	5-8%	2-5%	10-20%	1-4%	1-4%	0%	1-3%	0%	1-8%	0%	1-5%	10-20%	2-6%	12-30%	0%	1-3%	1-3%	1-3%
Tyumen region, 12	5-20%	2-4%	10-20%	1-4%	3-10%	0%	5-40%	0%	3-30%	0%	1-5%	1-10%	1-5%	1-7%	0%	1-3%	1-3%	1-6%
Volga region, 13	0%	1-7%	0%	1-4%	1-4%	0%	1-4%	0%	1%	0%	0%	1-14%	1%	30-60%	0%	0%	0%	1%
Pechora region, 14	significant	significant	dominant	dominant	no data	0%	abundant	no data	no data	no data	rare	abundant	no data	abundant	no data	no data	no data	significant
Dnepr-Donezk depression, 15	2-5%	3-10%	3-5%	3-10%	3-10%	0%	3-11%	0%	3-10%	1%	1-5%	3-7%	1-2%	10-20%	0%	1%	0%	1-14%
Caucasus, 16	0%	1-4%	1-4%	1-4%	1-5%	0%	5-75%	0%	5-80%	0%	1-3%	1-5%	0%	1-30%	0%	1-3%	1-3%	1-3%
E Caspian,17	Pinaceae 3-10%				3-15%	0%	4-60%	0%	3-10%	1%	1-5%	1-5%	0%	1-10%	0%	1-3%	no data	no data
Uzbekistan,Us-tyurt plateau,18	Pinaceae 3-10%				3-11%	0%	5-75%	0%	1-6%	0%	1-3%	1-8%	0%	1-7%	0%	0%	no data	no data
Primorye region,19	Pinaceae 4-60%				5-34%	0%	14-40%	1%	1-8%	1%	3-10%	10-30%	significant	significant	significant	1-3%	no data	no data
Bureya Basin, 20	Pinaceae 4-60%				abundant	0%	5-15%	1%	no data	no data	5-10%	50-80%	significant	1-10%	0%	1-9%	0%	4-30%
Zyryanka Basin,21	dominant				dominant	0%	1-3%	0%	0%	no data	0%	significant	no data	significant	no data	no data	no data	1-3%
Tarim, 22	0%	2-8%	3-10%	0%	0%	1-5%	68-78%	0%	0%	0%	6-12%	2-5%	1-2%	0%	0%	0%	0%	5-12%
Tibet, 23	0%	0%	1%	0%	4-18%	8-80%	10-70%	1%	1-3%	0%	1-6%	3-9%	1-2%	0%	0%	1-6%	0%	1-3%
Hailar Basin,24	5-30%	1-5%	5-35%	1-5%	1-7%	0%	1%	0%	0%	0%	1-3%	5-11%	1-4%	1%	0%	1-2%	1%	1-3%
India, Bengal region, 25	absent	absent	absent	dominant	significant	absent	abundant	absent	absent	dominant	abundant	significant	abundant	rare	absent	absent	abundant	abundant
Central India, 26	conifers45%		2%	significant	30%	0%	present	absent	absent	dominant	significant	dominant	significant	rare	absent	absent	dominant	dominant
Tailand, 27	absent	absent	absent	absent	absent	abundant	dominant	rare	absent	rare	abundant	rare	rare	rare	absent	rare	absent	abundant

Fig. 6 Main components of spore-pollen assemblages from Valanginian sections of central and eastern areas of Eurasia. Numbers correspond to those on the map (Fig.7)

1. by author's material, Lyubomirova & Kislyakov, 1985, and others; 2. by author's material, Chirva et al., 1979, and others; 3. by Pervuninskaya, 1966, and others; 4. by Sedova & Sirotenko, 1967, and others; 5. by Fradkina, 1967, and others; 6. by author's material, Sheiko, 1970, and others; 7. by author's material, Sologub, 1989, and others; 8. by Strepetilova, 1989, and others; 9. by Bezrukova, 1994, and others; 10.by Shirokova, 1973, and others; 11-12. by Markova, 1971, and others; 13. by author's material, 14. by Gryazeva, 1980, and others; 15. by Voronova, 1971, and others; 16. by Yaroshenko, 1970, and others; 17. by Fedorova-Shakhmundes, 1976, and others; 18. by Polyakov et al., 1969, and others; 19-21.by Markevich, 1995; 22. by Jiang De-xin et al., 2007; 23. by Jianguo Li & Batten, 2004; 24. by Meng Qi-An et al., 2003; 25.Vijaya & Bhattacharji, 2002; 26. by Prakash, 2008; 27.by Racey, 2009

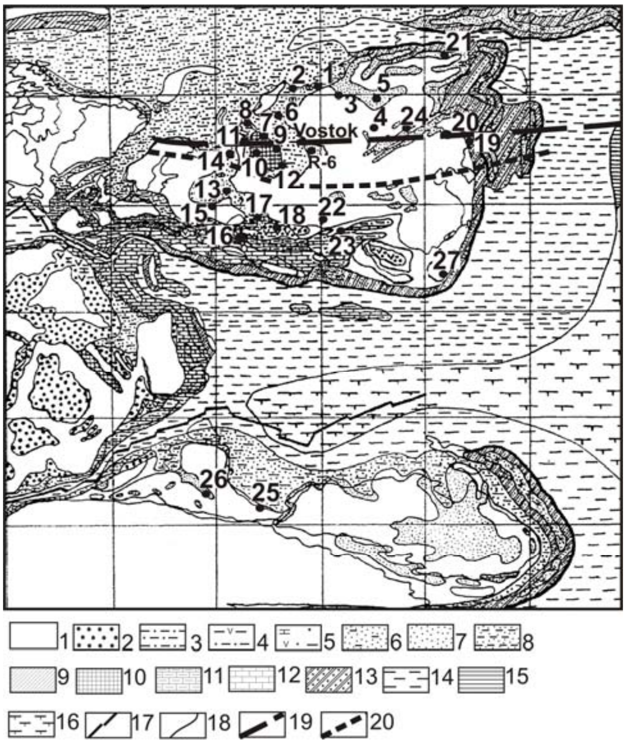

Fig. 7 Preliminary position of Valanginian sections according to palaeogeography and paleofacies (paleofacies on Zharkov et al., 1998)

Numbers on the map correspond to those on Fig. 6. 1. land; 2-5 deposits of alluvial–proluvial plains, depressions, lakes, sebkhas, and lagoons in arid zones: 2. redbed conglomerates, gritstones, and sandstones; 3. red-bed and variegated sandstones, siltstones, and clays; 4. sandstones, siltstones, and clays with gypsum; 5. gypsiferous calcareous, and terrigenous-calcareous sediments; 6-7 deposits of alluvial and lacustrine plains, marshland, coastal plains intermittently flooded by the sea, and lagoons: 6. gray conglomerates, gritstones, and sandstones; 7. grey sandstones, siltstones, and clays; 8-12 deposits of shelf and epicontinental seas: 8. sandstones, siltstones, and clays; 9. turbidites of shelf slopes and back-arc basins; 10. carbonaceous clayey, clayey-calcareous, and calcareous-siliceous sediments (black shales); 11. clayey limestones and marls; 12. carbonate platforms; 13-16 deposits of the continental and island-arc slope and peripheral zones of oceans: 13. turbidites; 14. hemipelagic clayey, calcareous-clayey, calcareous sediments; 15. pelagic (red) clays; 16. pelagic calcareous and siliceous–calcareous sediments; 17. midocean ridges; 18. boundaries between lithologic complexes; 19. boundary between Siberian-Canadian and Indo-European palaeofloristic provices; 20. boundary of the areas based on palynological data

by vegetation dominated by pteridosperms and conifers producing bisaccate pollen, which must have formed forests of different types, with abundant gleicheniaceous ferns in the west, abundant osmundaceous ferns in the north, and abundant ginkgophytes in the east. Cyatheaceous ferns were one of the main forest components in the Siberian-Canadian province, but keep their abundance in the Indo-European province only in humid near-shore environments. The southern areas were mostly occupied by specific vegetation dominated by gymnosperms producing *Classopollis* and *Dicheiropollis* pollen. Specific vegetations of savanna type on the territory of Russian Platform can be inferred from the overwhelming dominance of gleicheniaceous ferns in their spore-pollen assemblages.

7 Conclusion

Biostratigraphic analysis of spore-pollen assemblages from the Vostok-4 and R-6 wells and their comparison to a reference palynological succession, developed in the sections of North Siberia dated by fauna, allow detailed palynological zonation of the Lower Valanginian in the southeastern areas of West Siberia. The proposed zonation is based on the occurrences of key taxa, which are the groups of minor stratigraphic significance in northern regions of Siberia, but turned out to be important for the correlation of southern spore-pollen successions.

Detailed zonation provides a stratigraphic basis for the reconstruction of short-time fluctuations of the Early Valanginian vegetation and landscape related to climatic changes and dynamics of the neighboring palaeobasin. During the regressions, the southeastern shore of the West Siberian palaeobasin was occupied by wet and swampy lowland favorable for the wide distribution of hydrophilous vegetation mostly represented by dicksoniaceous ferns and pteridosperms. In transgressive periods, coastal relief was more diverse including more elevated areas, possibly desiccated in dry periods. Inner-land areas were occupied by coniferous light forest. Wet and periodically swampy lowland with hydrophylous vegetation occurred only near the lakes.

The comparison of lateral distribution of Valanginian palynological assemblages of central and eastern regions of Eurasia shows the transitional character of the vegetation in the southeastern region of West Siberia, demonstrating typical features of both Indo-European and Siberian-Canadian palaeofloristic provinces. In general, two large areas can be defined on palynological data for the Valanginian vegetation of Laurasian type: 1) northern area, which was occupied by vegetation dominated by pteridosperms and conifers producing bisaccate pollen, 2) southern area characterized by specific vegetation with abundant *Classopollis* and *Dicheiropollis*.

Summary

Stratigraphic analysis of spore-pollen assemblages from the Vostok-4 and R-6 wells and their comparison to reference palynological succession developed in faunally-dated sections of North Siberia allow detailed palynological zonation of the Lower Valanginian in south-eastern areas of West Siberia. The proposed zonation is based on the occurrences of key taxa, which are of minor stratigraphic significance in northern regions of Siberia, but turned out to be important for the correlation of southern spore-pollen successions. These are spores of liwerworts (*Foraminisporis asymmetricus, Aequitriradites verrucosus*, Hepaticae), gleicheniaceous and polypodiaceous ferns (*Clavifera triplex*, *Laevigatosporites* sp.). Subsidiary stratigraphic characters are the percentage of ancient morphotypes of bisaccate coniferous pollen (*Alisporites*, *Pseudopicea*, *Protopinus*) reducing upward in the sections and the percentage of Taxodiaceae increasing in the upper part of the section in the Vostok-4 well.

Detailed zonation provides a stratigraphic basis for the reconstruction of short-time changes of Early Valanginian vegetation and landscape related to the climatic fluctuations and dynamics of the neighboring palaeobasin. Spore-pollen assemblages evidence arid and seasonal climate. The Early Valanginian flora of inner-land areas is characterized by strong domination by conifers, especially podocarpaceans, which were replaced by Taxodiaceae, Bennettitaceae, Cycadaceae and *Eucommiidites*-producing plants in coastal regions (Vostok-4 well), forming specific plant communities. During the regressions, the southeastern shore of the West Siberian palaeobasin was occupied by wet and swampy lowland favorable for wide distribution of hydrophilous vegetation mostly represented by pteridosperms and dicksoniaceous ferns. In transgressive periods, coastal relief was more diverse, including more elevated areas, possibly desiccated in dry periods. Coastal floras were dominated by gymnosperms comprising abundant Taxodiaceae, apparently constituted the main body of tree communities. Inner-land areas were characterized by arid and seasonal climate. Wet and periodically swampy lowland occupied by hydrophilous vegetation with dicksoniaceous ferns and abundant podocarpaceans occurred in near-shore areas. Upland was occupied by coniferous light forest. Climate humidification in the Euryptychites quadrifidus time resulted in lake high stand and formation of mixed forest with conifers, ginkgophytes and pteridosperms.

The comparison of lateral distribution of the Valanginian palynological assemblages of the central and eastern regions of Eurasia shows the transitional character of the vegetation in the southeastern region of West Siberia demonstrating typical features of both the Indo-European and Siberian-Canadian palaeofloristic provinces. In general, two large areas can be defined on palynological data for the Valanginian vegetation of Laurasian type: 1) northern area, which was occupied by vegetation dominated by pteridosperms and conifers producing bisaccate pollen, 2) southern area characterized by specific vegetation with abundant *Classopollis* and *Dicheiropollis.*

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References

Abbink O A. 1998. Palynological investigations in the Jurassic of the North Sea region. Utrecht: LPP Foundation. 1-192

Alvin K L. 1982. Cheirolepidiaceae: biology, structure and paleoecology. Review of Palaeobotany and Palynology, **37**: 71-98

Barrón E, Gómez J J, Goy A & Pieren A P. 2006. The Triassic-Jurassic boundary in Asturias (northern Spain): palynological characterisation and facies. Review of Palaeobotany and Palynology, **138**: 187-208

Bezrukova T S. 1994. Palynological basis for stratigraphic subdivision of Early Cretaceous deposits of Yukyaunskaya area. In: Palynological indicators in West Siberian biostratigraphy. Tyumen: ZapSibNIGNI. 84-88 (in Russian)

Bolkhovitina N A. 1961. Fossil and recent spores of Schizaeaceae. Moscow: GIN.1-176 (in Russian)

Bolkhovitina N A. 1968. Spores of Gleicheniaceae and their stratigraphic significance. Moscow: GIN. 1-120 (in Russian)

Bugdaeva E V, Volynets E B, Golozubov V V, Markevich V S & Amelchenko G L. 2006. Flora and geological events of the Mid-Cretaceous time (Alchan basin, Primorye). Vladivostok: Dalnauka. 1-204 (in Russian)

Chirva S A, Gryazeva A S, Samojlovich S R & Fedorova V A. 1979. Structure and correlation of Lower Cretaceous deposits of North Siberia. In: Stratigraphy of Lower Cretaceous deposits of oil- and gas-bearing areas of USSR. Leningrad: VNIGRI. 31-62 (in Russian)

Cornet B & Traverse A. 1975. Palynological contributions to the chronology and stratigraphy of the Hartford Basin in Connecticut and Massachusetts. Geoscience and Man, **11**: 1-33

Deng S. 2002. Ecology of the Early Cretaceous ferns of Northeast China. Review of Palaeobotany and Palynology, **119**: 93-112

Duane A M. 1996. Palynology of the Byers Group (Late Jurassic – Early Cretaceous) of Livingston and Snow islands, Antarctic peninsular: its biostratigraphical and palaeoenvironmental significance. Review of Palaeobotany and Palynology, **91**: 241-281

Fedorova-Shakhmundes V A. 1976. The main stages of composition changes of Early Cretaceous microphytoplankton of Caspian depression. Biostratigraphy of Mesozoic deposits of oil and gas regions of USSR. Leningrad: VNIGRI. 130-139 (in Russian)

Fradkina A F. 1967. Mesozoic spore-pollen assemblages of Western Yakutia. Leningrad: Nedra. 1-220 (in Russian)

Golbert A V. 1987. Bases of regional palaeoclimatology. Moscow: Nedra. 1-222 (in Russian)

Gryazeva A S. 1980. Palynological basis for stratigraphy of Lower Cretaceous deposits of Pechora region. In: Microphytofossils in petroleum geology. Leningrad: VNIGRI. 96-113 (in Russian)

Jiang De-xin, Wang Yong-dong, He Zhuo-sheng & Dong Kai-lin. 2007. Early Cretaceous sporopollen assemblages from the Shushanhe Formation in Baicheng area of the tarim basin, Xinjiang. Acta Micropalaeontologica Sinica, **24**: 247-260

Kvaček J, Falcon-Lang H & Daškova J. 2005. A new Late Cretaceous Ginkgoalean reproductive structure *Nehvizdyella* gen. nov. from Czech Republic and its whole-plant reconstruction. American Journal of Botany, **92**: 1958-1969

Li Jian-guo & Batten D. 2004. Early Cretaceous palynofloras from the Tanggula Mountains of the northern Qinghai-Xizang (Tibet) Plateau, China. Cretaceous Research, **25**: 531-542

Li Jian-guo & Batten D J. 2007. Palynological evidence of an Early Cretaceous age for the Yixian Formation at Sihetun, Western Liaoning, China. Cretaceous Research, **28**: 333-338

Lyubomirova K A. & Kislyakov V N. 1985. Results of palynological studies of Lower Cretaceous deposits of northern Leno-Anabar area. In: Palynological studies of the Paleozoic and Mesozoic of the North of USSR and Caspian region. Leningrad: VNIGRI. 70-79 (in Russian)

Markevich V S. 1995. Cretaceous palynoflora of north Eastern Asia. Vladivostok: Dalnauka. 1-200 (in Russian)

Markova L G. 1971. The history of the development of Early Cretaceous flora of West Siberia (on palynology). Moscow: Nedra. 1-100 (in Russian)

Meng Qi-An, Wan Chuan-Biao, Qiao Xiu-Yun, Sun Yue-Wu, Shan Xuan-Long, Xu Yan-Bin, Ren Yan-Guang & Zhao Chuan-Beng. 2003. Palynological assemblages from the Damoguaihe Formation in Hailar Basin, Inner Mongolia. Journal of Stratigraphy. **27**(3): 173-184

Nagalingum N S. & Cantrill D J. 2006. Early Cretaceous Gleicheniaceae and Matoniaceae (Gleicheniales) from Alexander Island, Antarctica. Review of Palaeobotany and Palynology, **138**: 73- 93

Nesterov I I ed. 1991. Regional stratigraphic schemes of Mesozoic deposits of West-Siberian plain. Tyumen: ZapSibNIGNI. 1-30 (in Russian)

Nichols D J, Matsukawa M & Ito M. 2006. Palynology and age of some Cretaceous nonmarine deposits in Mongolia and China. Cretaceous Research, **27**: 241-251

Pervuninskaya N A. 1966. Stratigraphic subdivision of Lower Cretaceous coal-bearing deposits of Zhigansk region on spore-pollen data. Scientific letters of NIIGA, **15**: 41-47 (in Russian)

Pestchevitskaya E B. 2007a. Lower Cretaceous biostratigraphy of Northern Siberia: palynological units and their correlation significance. Russian Geology and Geophysics, **48**: 941-959

Pestchevitskaya E B. 2007b. Dinocyst biostratigraphy of the Lower Cretaceous in North Siberia. Stratigraphy and Geological Correlation, **15**: 577-609

Pestchevitskaya E B. 2010. Dinocysts and palynostratigraphy of the Lower Cretaceous of North Siberia. Novosibirsk, GEO. 1-230 (in Russain)

Pestchevitskaya E & Gnoeva A. 2010. Lower Cretaceous detailed stratigraphy and palaeoenvironments of Siberia on dinocysts and terrestrial palynomorphs. In: 8th European Palaeobotany-Palynology Conference 2010. Program and Abstracts. Budapest: Hungarian Natural History Museum. 1-190

Pestchevitskaya E B & Khafaeva S N. 2008. Palaeofacial analysis of Lower Cretaceous section from Severo-Vologochanskaya-18 well (West Siberia) on foraminifers and playnomorph. News on palaeontology and stratigraphy. Supplement to Russian Geology and Geophysics, **49**: 273-279 (in Russain)

Pestchevitskaya E B & Lebedeva N K. 2003. Differentiation of Early Cretaceous palynofloras of West Siberia. Russian Geology and Geophysics, **44**: 525-538

Pestchevitskaya E B, Urman O S & Shurygin B N. 2010. Combined analysis of Early Cretaceous benthos and palynomorphs from south-eastern marginal area of West Siberia palaeobasin (on the example of Vostok-4 well). In: Proceedings of IV International symposia “Life evolution on the Earth”. Tomsk: TGU. 385-388 (in Russain)

Plant’s life. 1978. Moscow: Prosveschenie. **4**: 1-656 (in Russain)

Polyakov V N, Mamaeva S A, Rodovilskiy M S & Shvetcova E M. 1969. Materials on Cretaceous stratigraphy of terrigenous deposits of East Ustyurt. In: Paleontological basis of Mesozoic and Cenozoic stratigraphy of Uzbekistan. Tashkent: Fan. 87-151 (in Russian)

Pott C, Krings M & Kerp H. 2008. The Carnian (Late Triassic) flora from Lunz in Lower Austria: Paleoecological considerations. Palaeoworld, **17**: 172-182

Prakash N. 2008. Biodiversity and palaeoclimatic interpretation of Early Cretaceous flora of Jabalpur Formation, Satpura Basin, India. Palaeoworld, **17**: 253-263

Racey A. 2009. Mesozoic red bed sequences from SE Asia and the significance of the Khorat Group of NE Thailand. Geological Society, London, Special Publications, **315**: 41-67

Saiki K & Okubo A. 2006. Lower Cretaceous flora of the Choyr Basin, Mongolia. Cretaceous Research, **27**: 252-261

Sedova M A & Sirotenko A A. 1967. Palynological assemblages of continental Jurassic and Cretaceous deposits of Baikal region and their stratigraphic significance. In: Stratigraphy and palaeontology of continental Mesosoic and Paleogene-Neogene deposits of Asial regions of USSR. Leningrad: Nauka. 119-125 (in Russian)

Sheiko L N. 1970. Volgian and Valanginian spore-pollen assemblages from Dolganskaya and Sukhaya-Dudinka areas of Yenisei mouth region. In: Materials on stratigraphy and paleontology of Mesozoic and Cenosoic deposits of West Siberia. Tyumen: ZapSibNIGNI. 118-122 (in Russian)

Shirokova Yu F. 1973. Palynological features of the Frolovo Formation (the Lower Cretaceous). In: Proceedings of III International palynological conference. Moscow: Nauka. 149-153 (in Russian)

Sologub T A. 1989. Spore-pollen features of Cretaceous deposits of Nadym area. In: Biostratigraphy of sedimentary cover of West Siberia plane. Tyumen: ZapSibNIGNI. 93-99 (in Russian)

Strepetilova T G. 1989. Spore-pollen assemblages of Jurassic and Cretaceous deposits of Tambey oil-bearing area. In: Biostratigraphy of sedimentary cover of West Siberia plane. Tyumen: ZapSibNIGNI. 58-64 (in Russian)

Vajda V. 2001. Aalenian to Cenomanian terrestrial palynofloras of SW Scania, Sweden. Acta Palaeontologica Polonica, **46**: 403-426

Vakhrameev V A. 1988. Jurassic and Cretaceous flora and climate of the Earth. Moscow: Nauka. 1-210 (in Russain)

Van Konijnenburg-Van Cittert J H A. 2002. Ecology of some Late Triassic to Early Cretaceous ferns in Eurasia. Review of Palaeobotany and Palynology, **119**: 113-124

Vijaya & Bhattacharji T K. 2002. An Early Cretaceous age for the Rajmahal traps, Panagarh area, West Bengal: palynological evidence. Cretaceous Research, **23**: 89-805

Voronova M A. 1971. Palynological basis for stratigraphic subdivision of Lower Cretaceous deposits of Dnepr-Donezk region. Kiev: Naukova Dumka. 1-112 (in Russian)

Wang Yong-dong, Ni Q, Jiang Z-k & Tian Ning. 2008. Diversity variation and tempo-spatial distribution of *Otozamites* (Bennettitales) in the Mesozoic of China. Palaeoworld, **17**: 222-234

Yaroshenko O P. 1970. Spore-pollen assemblages of Jurassic and lower Cretaceous deposits of North Caucasus and their stratigraphic significance. Moscow: GIN. 1-108 (in Russian)

Zakharov V A, Bogomolov Yu I, Ilyina V I, Konstantinov A G, Kurushin N I, Lebedeva N K, Meledina S V, Nikitenko B L, Sobolev E S & Shurygin B N. 1997. Boreal zonal standard and biostratigraphy of the Siberian Mesozoic. Russian Geology and Geophysics, **38**: 965-993

Zakharov V A, Nikitenko B L, Aleynikov A N, Bogomolov Y I & Meledina S V. 1996. Biostratigraphy of the Upper Jurassic and Neocomian. In: Geology and problems of prospecting of new great oilfields in Siberia **1**. Novosibirsk: SNIIGGiMS. 75-78 (in Russian)

Zharkov M A, Murdmaa I O & Filatova N I. 1998. Paleogeography of the Berriasian–Barremian ages of the Early Cretaceous. Stratigraphy and Geological Correlation, **6**: 47-69