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TRANSITIONAL PERMIAN-TRIASSIC DEPOSITS IN EUROPEAN RUSSIA, AND NON-MARINE CORRELATIONS

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Key words – Permian; Triassic; stratigraphic correlation; fossil flora; palynology; magnetostratigraphy.

Abstract – A recent discovery of a relatively complete transitional Permian-Triassic (Tatarian-Vetlugian) sequence in the Vologda region, European Russia, bears on the problem of non-marine PTB correlation. It shows a zone of reversed polarity at the base of the Vetlugian.
The plant megafossil assemblage of the transitional interval is dominated by Tatarian survivors, with a few conifer species with affinities to the Zechstein flora.
The palynological assemblage is of mixed Upper Permian-lowest Triassic aspect.
The megaspore assemblage contains *Otynisporites eotriassicus*, a zonal index species of the lowermost Buntsandstein, occurring also in the Tesero Oolite, Southern Alps, with conodonts *Hindeodus praeparvus* (Kozur, 1998), as well as in the Upper Guodikeng Formation of the Junggar Basin with *Dicynodon* and *Lystrosaurus* (Liu, 1994).
These occurrences are considered to mark a stratigraphic level corresponding to the conodont zone *Clarkina meishanensis* of the Meishan section, south China.

Parole chiave – Permiano; Triassico; correlazioni stratigrafiche; flora fossile; palinologia; magnetostratigrafia.

Riassunto – Il recente rinvenimento di una successione relativamente completa in corrispondenza della transizione tra il Permiano e il Trias (Tatariano-Vetlugiano) nella regione di Vologda (Russia europea) porta al problema di una correlazione relativa al limite P/T in ambiente continentale. Essa mostra una zona di polarità inversa alla base del Vetlugiano. L'associazione fossilifera a piante dell'intervallo di transizione è dominato da organismi superstiti del Tatariano, con poche specie di conifere affini alla flora dello Zechstein. L'associazione palinologica mostra un aspetto misto tra quella del Permiano superiore e quella inerente alla parte più bassa del Trias. L'associazione a megaspore contiene *Otynisporites eotriassicus*, un indice zonale della parte più bassa del Buntsandstein, che è anologamente presente sia nell'Oolite di Tesero, delle Alpi Meridionali, dove sono stati recentemente rinvenuti conodonti del tipo *Hindeodus praeparvus* (Kozur, 1998), e sia nella porzione superiore della Formazione di Guodiken, del Bacino di Junggar, che include *Dicynodon* e *Lystrosaurus* (Liu, 1994). Questi eventi sono considerati come indicatori di un livello stratigrafico corrispondente alla zona a conodonti *Clarkina meishanensis* della sezione di Meishan, in Cina meridionale.

INTRODUCTION

In European Russia the Tatarian deposits are unconformably overlain by the Lower Triassic Vetlugian Series. Paleomagnetic correlation indicates a hiatus at the boundary encompassing most of the Changhsingian-Dorashamian stages (Lozovsky & Esaulova, 1998). Equivalents of the upper Zechstein seemed likewise lacking in the transboundary Tatarian to Vetlugian sections. A find of *Lystrosaurus (Paralystrosaurus) georgi* (Kalan.) in the lower Astashikhinsk Member of the Vetlugian Series was taken as evidence of the lowermost Triassic age (Lozovsky, 1998). Our new data indicate that relatively complete sequences, supposedly continuous over the PTB, occur in the central part of the Permian–Triassic basin at about the Volga–Severnaya Dvina watershed (Krassilov *et al.*, 1999). This conclusion is based on the results of paleobotanical and magnetostratigraphic studies, supplemented by a few faunistic finds, in the Nedubrovo Section, Vologda region.

TRANSBOUNDARY SECTION AT NEDUBROVO

The Nedubrovo Section is exposed in a series of large outcrops on the left bank of the Kichmenga River (left tributary

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of the Yug River), northeast of Vologda City between the Glebovo and Nedubrovo riverside villages. Here the uppermost Tatarian (Vyatkian) variegate marls and clays with small carbonate nodules are overlain, at a sharp contact, by: (1) the basal Vetlugian cross-bedded sands with gravel and pebbles, up to 8 m thick; (2) reddish-brown micaceous clays and siltstones about 3 m thick; (3) alternating thinly-bedded grey (in the lower part), greenish-grey and purple siltstones and silty clays, 2.5 m thick, with abundant plant debris on the bedding planes and with ostracods *Gerdalia* sp., conchostracans, aquatic beetles and a few remains of terrestrial insects (under study at present); (4) red clay containing thin interbeds of bluish siltstones, with crack-fill wedges penetrating the underlying deposits; (5) cross-bedded polymictic sand beds with gravel, more than 2.5 m thick, starting the second sedimentary cycle, with a few vertebra of amphibians *Tupilakosaurus* sp. and the *Procolophonidae* gen. sp. indet. (defined by M. A. Shishkin). These vertebrate fossils first appear in the latest Tatarian and are widespread in the Early Triassic.

MAGNETOSTRATIGRAPHY

Magnetostratigraphic studies of the Nedubrovo Section have shown a high magnetic susceptibility (mean χ 159.5 $\cdot 10^{-5}$) that is more typical of the Vetlugian deposits than of the Tatarian (Burov *et al.*, 1998). However, the polarity is reversed, while all the hitherto-studied lower Vetlugian sections fall in the direct polarity zone NPT (Lozovsky & Esaulova, 1998). We therefore designate the basal Vetlugian of Nedubrovo as a new reversed polarity zone R_0T, supposedly correlatable with the upper basalts of the Tchernyshov Ridge in the Timano-Petchorsk region.

A reversed polarity zone probably corresponding to R_0T at Nedubrovo was also found at the base of the Nyamunsk Formation in Lithuania, the stratigraphic equivalent of the lowermost Vetlugian, as well as of the basal Buntsandstein of Poland (Kisnerius & Saidakowsky, 1972; Katinas, 1997).

FOSSIL FLORA

The plant mega- and mesofossils occur abundantly in the grey laminated siltstones and clays (bed 3). These accumulations of plant debris on bedding planes locally appear as a thin, lenticular coal. The plant remains are fragmentary but with well-preserved cuticles providing epidermal characteristics that are crucial for classification of the Permian and Triassic gymnosperms. A classification by S. Meyen (in Gomankov & Meyen, 1986; Meyen, 1992) is followed here for the sake of comparison with the Tatarian flora, although some generic assignments are in need of revision.

The plant megafossils constitute an essentially peltasperm–conifer assemblage with a few fern remains. The assemblage is dominated by peltasperms *Tatarina conspicua* S. Meyen, *T. lobata* S. Meyen, *Phylladoderma (Aequistomia) annulata* Meyen, *Raphidopteris antiqua* S. Meyen, *Peltaspermopsis buevichiae* (Gomankov et S. Meyen) Gomankov, and *Salpingocarpus variabilis* S. Meyen (Plate I). These species, with the single exception of *Tatarina lobata*, are known from the uppermost Tatarian (Vyatkian) localities (we accept the Vyatkian age for a controversial Aristovo locality with *Phylladoderma annulata* and *Peltaspermopsis buevichiae*). The cuticles of a

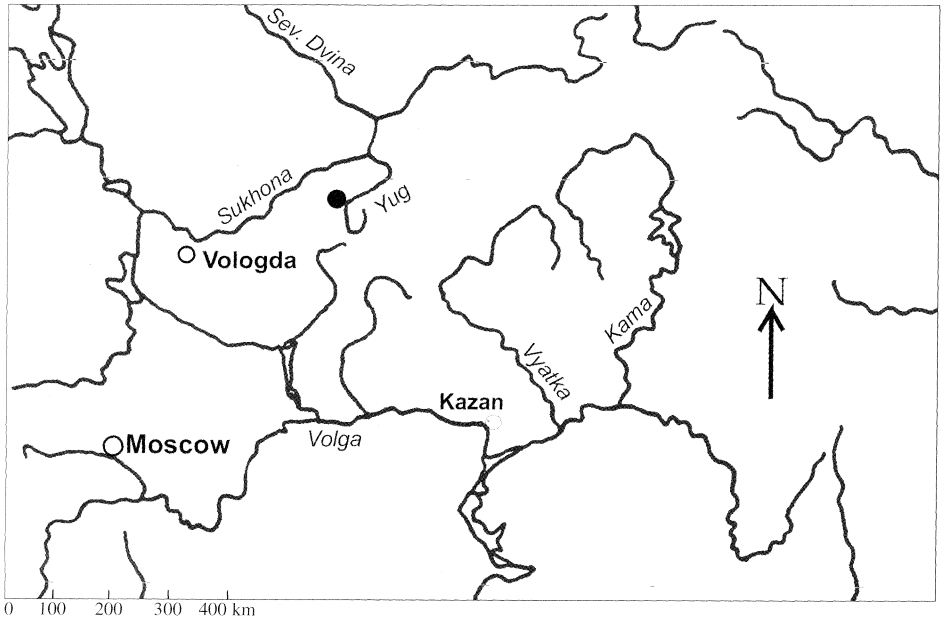
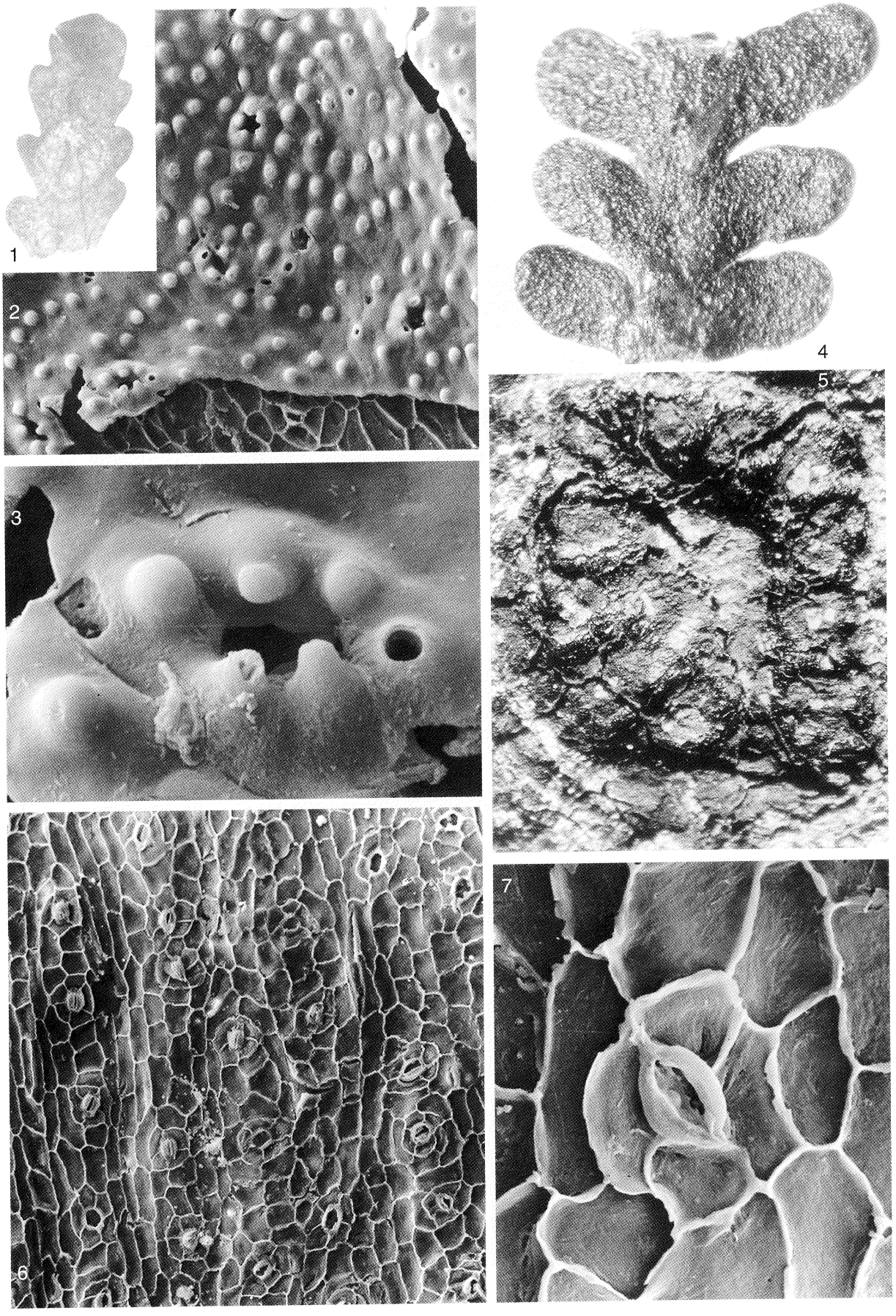


Fig. 1 – Sketch map of the Volga-Severnaya Dvina watershed region showing the geographical position of the Nedubrovo Section (black circle).

Plate I – Peltasperms from the fossil plant bed of Nedubrovo.

1. *Tatarina lobata* S. Meyen, leaf fragment, x15. 2, 3. *Tatarina (Tatarinopsis)* cuticle, x230, and stoma with hollow papillae, 1200. 4. *Rhaphidopteris antiqua* S. Meyen, pinna with decurrent pinnules, x10. 5. *Peltaspermopsis buevichiae* (Gomankov et S. Meyen) Gomankov, pelta with ovules, x20. 6, 7. *Tatarina conspicua* S. Meyen, cuticle, x110, and stoma, x700.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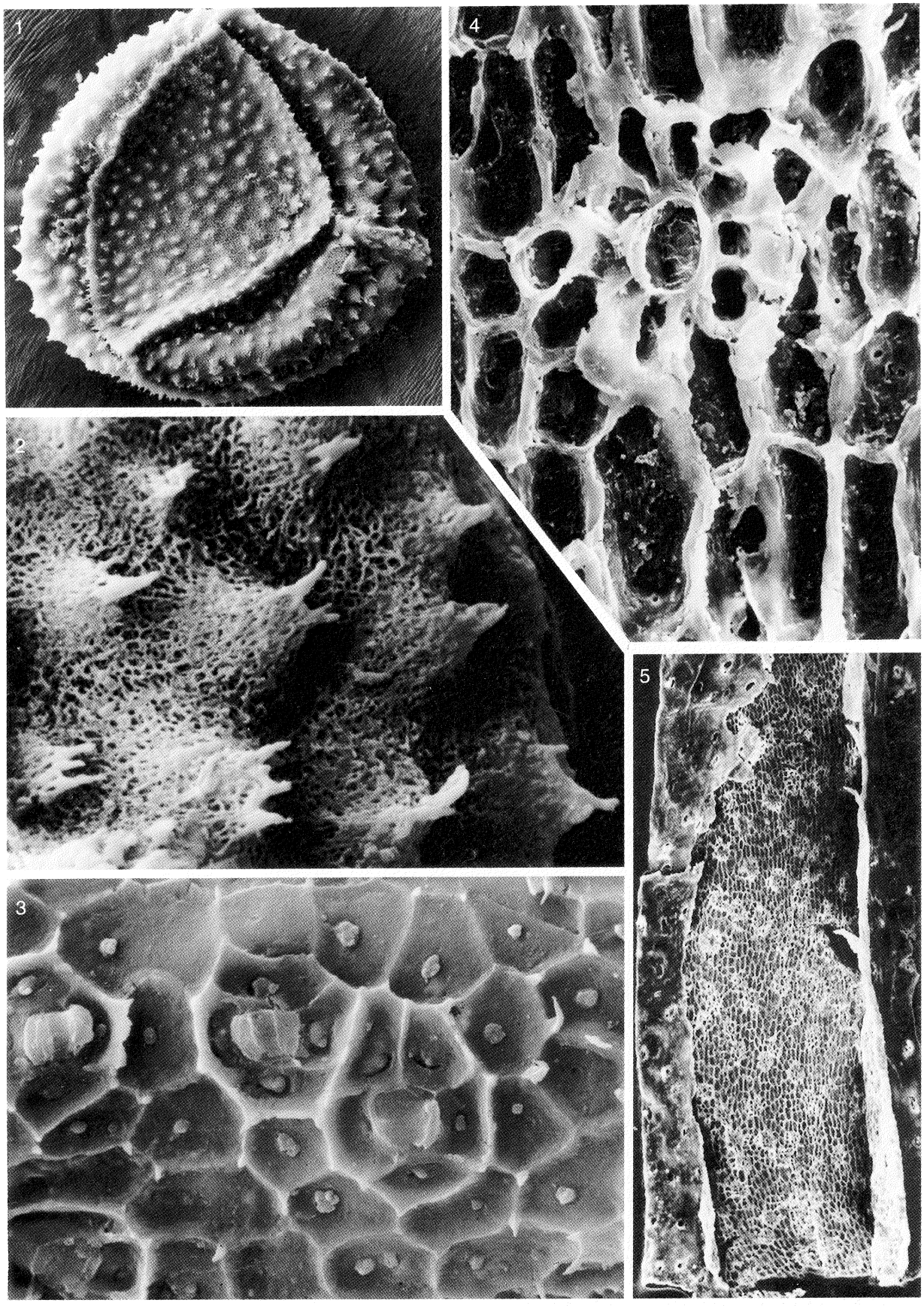
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dominant Tatarian species *T. conspicua* are also fairly common in the Nedubrovo locality. *T. lobata* was originally described from the Korvunchan Formation of the Tungusska Basin (Meyen & Gomankov, 1980). In Nedubrovo, the peltasperm leaves and reproductive organs are somewhat smaller than in typical Tatarian material and the cuticles often show anomalous cell patterns.

The conifers are represented by scattered leaves, the taxonomic assignments of which are based solely on epidermal characteristics (Plate II). Alongside a typically Tatarian *Quadrocladus dvinensis* S. Meyen there are *Ullmannia.* cf. *bronnii* Goepert and *Quadrocladus* cf. *solmsii* (Gothan et Nagalhard) Schweitzer, both comparable with the Zechstein conifers.

Thus the Nedubrovo megafossil flora is still essentially Permian, with a number of species surviving from the Tatarian. However, a few Zechstein and Korvunchan forms indicate a younger age than the uppermost Tatarian. It bears a general similarity to the late Changhsingian flora of Tieqiao Section, Laibin County, south China, dominated by the Permian peltasperms, gigantopterids and conifers, with conifer assemblages of Zechstein aspect (Jin *et al.*, 1998 and our unpublished data).

Prominent in the plant mesofossil assemblage of bed (3) is *Otynisporites eotriassicus* Fugl. (Plate II), the index species of a megaspore zone comprising the basal Suboolitic Member of Buntsandstein immediately above the Zechstein (Fuglewicz, 1977).

PALYNOLOGY

The spore-pollen assemblages were obtained from the beds (2-4), with insignificant variation from bed to bed (Plate III). They are dominated by *Klausipollenites schaubergeri* (Potonié et Klaus) Jansonius and *Cycadopites* sp., summarily including more than 50% of the palynomorphs. Non-taeniate pollen is also represented by the subordinate *Klausipollenites decipiens* Jansonius, *Alisporites nuthallensis* (Clarke) Balme, *A. grauvogelii* Klaus, *Falcisporites zapfei* Potonié et Klaus, and *Platysaccus queenslandii* de Jersey. The taeniate pollen grains are assigned to *Protohaploxypinus* cf. *pantii* (Jansonius) Orlowska-Zwolinska, *Lueckisporites virkkiae* Potonié et Klaus, *Lunatisporites noviaulensis* (Leschik) Foster, and *L. transversmundatus* (Jansonius) Fisher, ranging from 0.5% to 2% each, *Striatoabieites richteri* (Klaus) Hart, up to 3%, and *L. pellucidus* (Goubin) Helby, locally up to 12-15%. Occasional grains belong to *Ephedripites permasensis*, *E.* sp., *Striomonosaccites* sp. and *Triadispora* cf. *crassa* Klaus.

Spores are less diverse, with a few numerically prominent forms, such as *Apiculatisporis*, up to 30%, and *Limatulasporites fossulatus* (Balme) Foster, up to 15%. *Punctatisporites triassicus* Schulz, *Polycingulatisporites densatus* (de Jersey) Playford et Dettmann, *Leptolepidites jonkeri* (Jansonius) Yarosh. et Golubeva, *Proprisporites pocockii* Jansonius, *Densoisporites playfordii* (Balme) Dettmann and *Pechorosporites disertus* Yarosh. et Golubeva amount to 1-2% each.

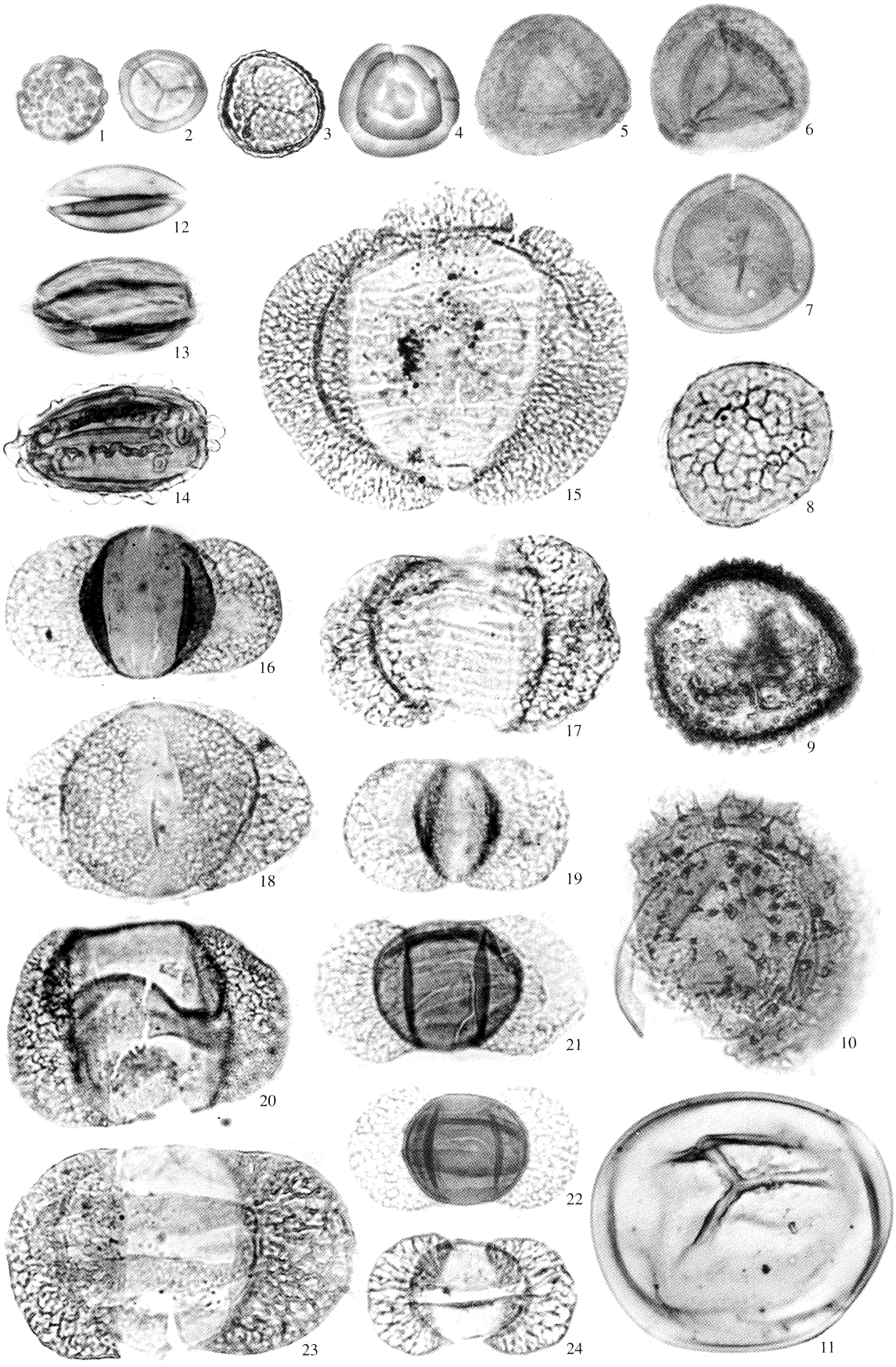
Common in the assemblage are *Tympanicysta stoschiana* Balme as well as the planktonic prasinophytes *Pterospermella*, *Pilasporites* and *Inaperturopollenites nebulosus* Balme.

The association of the prevailingly Permian *K. schaubergeri* (with a few reliably-dated Early Triassic records in the early Griensbachian of Arctic Canada and the Induan Panchet Formation with *Lystrosaurus:* Fisher, 1979; Tiwari & Tripathi, 1992), *Lueckisporites virkkiae*, *Falcisporites zapfei* and *Alisporites nuthallensis* with the Early Triassic *Proprisporites pocockii, Leptolepidites jonkeri, Polycingulatisporites densatus, Densoisporites playfordii, Pechorosporites disertus, Lunatisporites pellucidus, L. transversmundatus, Ephedripites permasensis* and abundant *Cycadopites*, indicate a transitional uppermost Permian to lowermost Triassic age for the Nedubrovo palynological assemblage. It is closely comparable to palynofloras from the lowermost Buntsandstein of Poland (Orlowska-Zwolinska, 1984), *Otoceras* beds of western Canada (Jansonius, 1962), Arctic Canada (Fisher, 1979; Utting, 1994) and the *Protohaploxypinus* zone of eastern Greenland (Balme, 1979).

CORRELATION

A correlation of the major continental sequences is shown in Fig. 2. In a relatively complete Permian-Triassic sequence of the Junggar Basin, northern China, the fossiliferous transitional deposits are exposed in two limbs of the Dalongkou Anticline (Yang *et al.*, 1986; Cheng *et al.*, 1989). A graphical correlation made by the senior author has shown that the megaspore zone *Otynisporites eotriassicus* of the Upper Guodikeng Formation (Liu, 1994) comprises the interval of joint occurrences of *Dicynodon* and *Lystrosaurus* and extends upsection with *Lystrosaurus* alone. Thus the FAD of *Lystrosaurus* coincides with that of *Otynisporites eotriassicus.* Paleomagnetic zonation is not yet completed for Junggar Basin. However, the Upper

Plate II – Megaspore and cuticles from the fossil plant bed of Nedubrovo: 1, 2. *Otynisporites eotriassicus* Fugl., proximal aspect, x280, and distal appendages, x2000. 3. *Quadrocladus dvinensis* S. Meyen, group of stomata, x 480. 4, 5. *Ullmannia* cf. *bronnii* Goepp., stoma with a ring of subsidiary cells anomalously intruded by an ordinary cell, x800, and whole leaf cuticle showing the arrangement of stomata, x53.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Guodikeng, as well as the overlying basal Jiucaiyuan Formation, show a reversed polarity (Cheng *et al.*, 1989).

Of a certain importance for the non-marine to marine PTB correlations is the occurrence of *Otynisporites eotriassicus* in the marginal marine Tesero Oolite near the base of the Werfen Formation, Southern Alps, at about the PTB position as defined by Broglio Loriga & Cassinis (1992). According to Kozur (1989, 1998), the megaspores were found in the Tesero section about 1.8-2.2 m above the boundary with the underlying Bellerophon Formation. They associate with a palynological *Lundbladispora obsoleta-Lunatisporites noviaulensis* assemblage similar to that of the lower Buntsandstein, with a mass occurrence of *Tympanicysta stoschiana,* as well as with conodonts *Hindeodus praeparvus* Kozur and *Isarcicella? prisca* Kozur. These species indicate the conodont zone *Clarkina (Neogondolella) meishanensis-Hindeodus praeparvus* (Kozur, 1998), the base of which correlates with the first appearance of *Otoceras* (zone *O. concavum/latilobatum*). This level corresponds to the PTB as defined by Orchard & Tozer (1997) and Orchard & Krystyn (1998). In the Meishan Section of south China, the *Clarkina meishanensis* zone (Mei, 1996) falls in the interval of reversed polarity (Zhu & Liu, 1999). It should be noted that a previous report of direct polarity in the lower part of the *O. concavum* zone of Arctic Canada was not confirmed by the recent studies (Ogg & Steiner, 1991).

This level is also marked by the appearance of *Lystrosaurus* in continental facies (Lozovsky & Esaulova, 1998) and, in terms of event stratigraphy, by the onset of a widespread transgression, trap basalt eruptions, a peak of *Tympanicysta* and the prominent isotopic excursions (Fig.

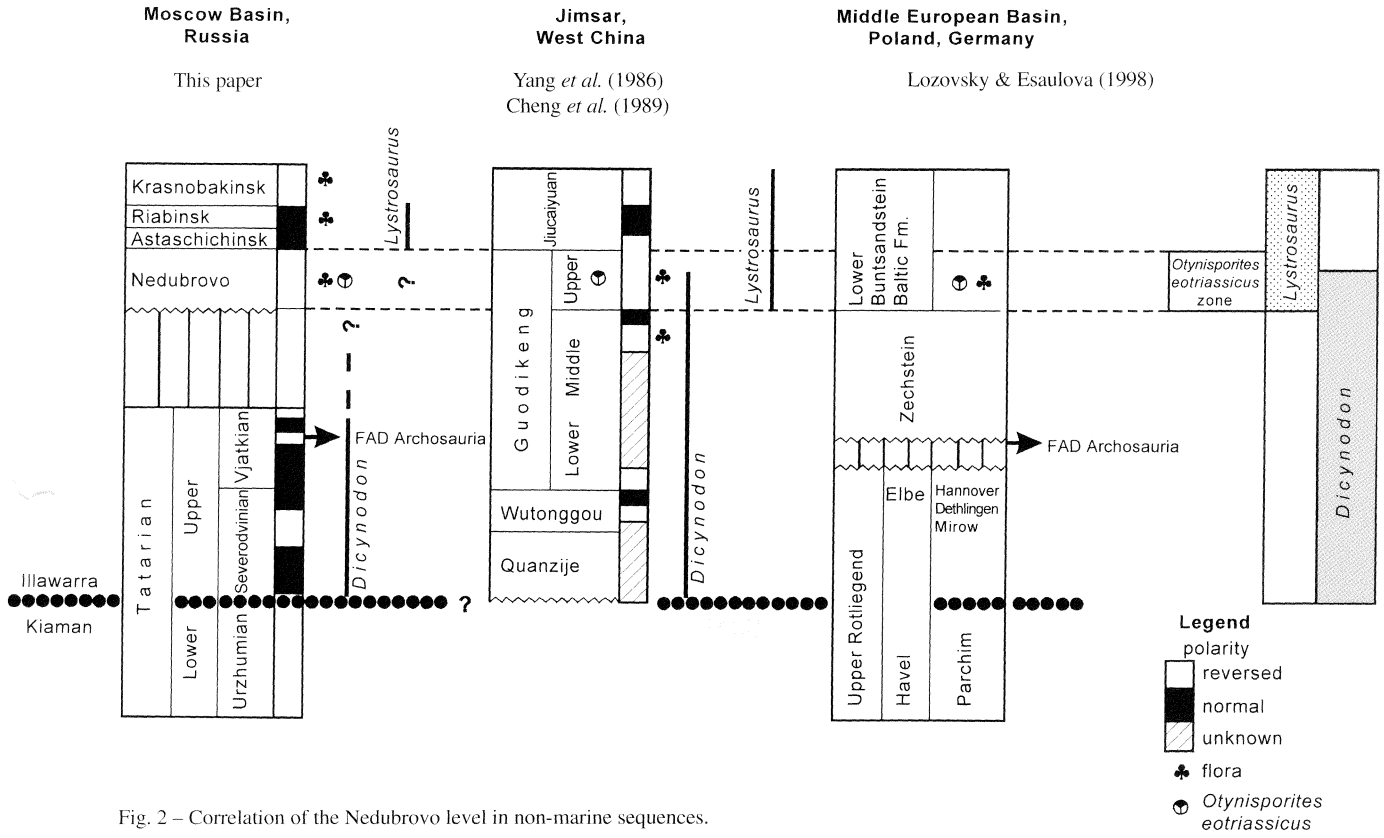

Fig. 2 – Correlation of the Nedubrovo level in non-marine sequences.

Plate III – Palynological assemblage of Nedubrovo, x625.

1. *Leptolepidites jonkeri* (Jansonius) Yarosh. et Golubeva, 2. *Limatulasporites fossulatus* (Balme) Helby et Foster, 3. *Apiculatisporis* sp., 4. *Polycingulatisporites densatus* (de Jersey) Playford et Dettmann, 5. *Densoisporites* sp., 6. *Densoisporites* sp., 7. *Densoisporites playfordii* (Balme) Dettmann, 8. *Proprisporites pocockii* Jansonius, 9. *Pechorosporites* sp., 10. *Pechorosporites disertus* Yarosh. et Golubeva, 11. *Punctatisporites triassicus* Schulz, 12. *Cycadopites* sp., 13. *Ephedripites* sp., 14. *Ephedripites permasensis* Yarosh., 15. *Striomonosaccites* sp., 16. *Falcisporites zaptei* Potonié et Klaus, 17. *Striatoabieites richteri* (Klaus) Hart., 18. *Klausipollenites schaubergeri* (Potonié et Klaus) Jansonius, 19. *Platysaccus* sp., 20. *Scutasporites* sp., 21. *Protohaploxypinus* sp., 22. *Lunatisporites noviaulensis* (Leschik) Foster, 23. *Lunatisporites pellucidus* (Goubin) Helby, 24. *Lueckisporites virkkiae* Potonié et Klaus.

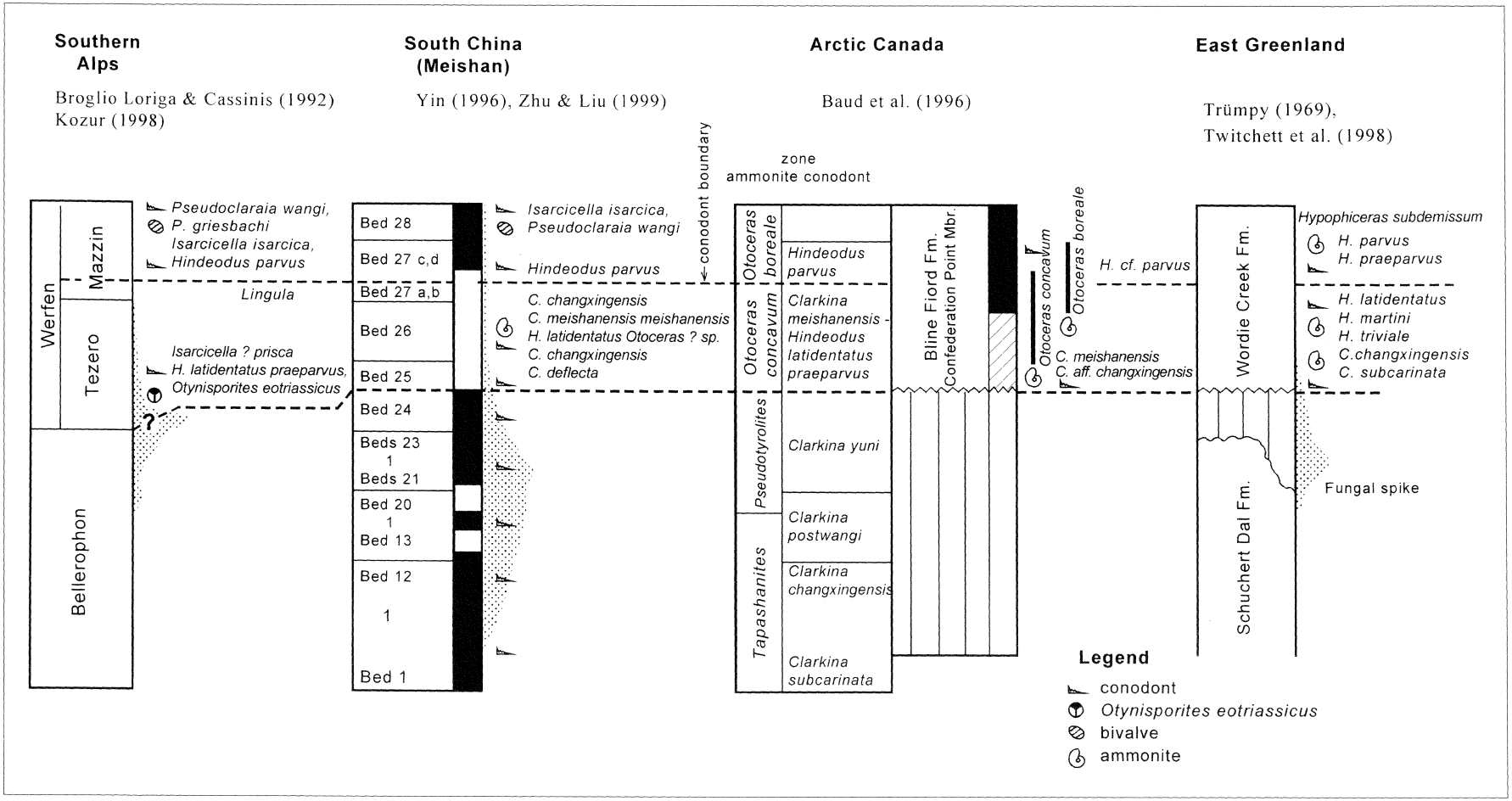

Fig. 3 – Correlation of the Nedubrovo (*Otynisporites eotriassicus*) level in marine sequences.

3). However, in the widely accepted conodont zonation, the PTB is drawn above this level, at the base of the next conodont zone *Hindeodus parvus*. Whatever the final decision on the PT GSSP, it has to be taken into consideration that at the level of the earliest *Otoceras, Lystrosaurus* and *Otynisporites* records, both marine invertebrate assemblages and terrestrial flora still retained the Late Permian aspect, with subordinate Triassic newcomers.

CONCLUSIONS

The Nedubrovo Section on the Kichmenga River, Vologda region, represents a relatively complete transboundary PT sequence, with the upper Tatarian overlain by the basal Vetlugian which contains a plant megafossil assemblage of Permian aspect, with most species having survived from the Late Tatarian, megaspores of *Otynisporites* zone (basal Buntsandstein of Poland), and a rich palynological assemblage of a mixed Zechstein-Lower Griesbachian character. The relatively diverse planktonic Prasinophyceae probably indicate a marine influence at a high stand of the end-Permian boreal transgression. A reversed polarity zone is established for these deposits. The Nedubrovo sequence thus appears older than the basal Vetlugian elsewhere in European Russia. It conceivably represents a stratigraphic interval missing in the less complete transboundary sections.

On the basis of the evidence, the Nedubrovo sequence is correlated with the upper Guodikeng Formation of the Junggar Basin in China, both showing a reversed polarity. It is stratigraphically equivalent to or somewhat older than the lowermost Buntsandstein of Western Europe. Probable marine correlates of Nedubrovo are the lowermost part of the *Otoceras* zone as well as the Tesero Oolite and the Transitional beds 1 and 2 below the *Hindeodus parvus* FAD in the Meishan Section of south China. This stratigraphic level is traceable by the joint occurrences of *Otynisporites*, the earliest *Lystrosauridae* and, in marginal marine deposits, conodonts of the *Clarkina (Neogondolella) meishanensis-Hindeodus praeparvus* zone. It is also marked by the onset of a widespread transgression, trap eruptions in Siberia and prominent isotopic anomalies. There may have been a certain time lag between these events and biotic change, since the biota was still of a prevailingly Permian character.

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