Triassic plants and Pangea

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Comparison between conclusions of palaeobotany and plate tectonics covering the position of Mesozoic continents shows some disagreements. Existing palaeomagnetic reconstructions differ from one another as well as from the picture received on the basis of palaeoobotany. Various palaeomagnetic reconstructions for the Permian and Triassic differ from one another in showing less or more compact Pangea, different width of Tethys Ocean, and in the form of relative position of Cathaysia. There are also contradiction between palaeomagnetic reconstructions and palaeontological data.

Palaeobotanical investigations show that in the end of Palaeozoic there were four first order phytochoria in Eurasia with very different composition of floras which suggest high isolation of these phytochoria. In the beginning of Triassic former isolation of floras of different areas disappeared. The floras of Europe, China and Indochina and also North America became quite similar. At this time a new united Laurasian Kingdom had originated.

Distribution of plants in the Mesozoic Era suggests the existence of united continent — Laurasia. The separation of North America from Laurasia took place after Triassic. Nevertheless, united Eurasia existed from the Triassic till now.

Palaeomagnetic reconstructions for the Mesozoic do not reflect changes in the distribution of plants and animals as we see from Triassic. From this point of view all reconstructions showing isolated plates (similar to Paleozoic ones) in the Mesozoic, instead of united Eurasia, and the reconstructions showing isolation of Cathaysia from other Eurasia are doubtful. Similarly, the gradual union of isolated plates to united Eurasia during Mesozoic and Cenozoic also seems doubtful.

Key-words — Palaeobotany, Continental drift, Pangea, Eurasia, Cathaysia, Triassic.

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सारांश

त्रिसंघी कालीन पौधे एवं पैंगिआ

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पुरावनस्पति से प्राप्त निष्कर्ष एवं मध्यजीवी कल्प के महाद्वीपों की स्थिति (प्लेट विवर्तनिक गतिविधि) की तुलना से कुछ अलग परिणाम मिले हैं। वर्तमान पुराचुम्बकीय पुनर्रचनायें अन्य तथा पुरावनस्पतिविज्ञान के आधार पर संश्लेषित रूप रेखा से भिन्न हैं। परमी एवं त्रिसंघी कल्प की विभिन्न पुराचुम्बकीय पुर्नरचनायें भी एक दूसरे से भिन्न हैं जो कि कम अथवा अधिक संहत पैंगिआ, टेथीय समुद्र की भिन्न-भिन्न चौड़ाई तथा कैथेसिआ की आपेक्षिक स्थिति के कारण हैं। इसी प्रकार पुराचुम्बकीय पुनर्रचनाओं एवं पुराजन्तु वैज्ञानिक आँकडों में ऐक्यता नहीं है।

पुरावनस्पतिक अन्वेषणों से व्यक्त होता है कि पुराजीवी कल्प के अन्त में यूरेशिया में चार फाइटोकोरिया विद्यमान थे और इनके वनस्पतिजात भी भिन्न-भिन्न थे। त्रिसंघी कल्प के प्रारम्भ में विभिन्न क्षेत्रों के वनस्पतिजातों का पूर्व पृथककरण समाप्त हो गया था। यूरोप, चीन, इन्डोचीन तथा उत्तर अमेरिका के वनस्पतिजात एक जैसे थे और इसी समय एक नये संयुक्त लॉरेशिआ प्रदेश की उत्पत्ति हुई।

मध्यजीवी कल्प में पौधों के वितरण से संयुक्त लॉरेशिआ का होना प्रस्तावित होता है। त्रिसंघी कल्प के बाद ही उत्तर अमेरिका लॉरेशिआ से अलग हो गया। तथापि, संयुक्त यूरेशिआ त्रिसंघी कल्प से लेकर आज तक विद्यमान है।

जैसा कि त्रिसंघी कल्प से विदित है मध्यजीवी कल्प के लिए पुराचुम्बकीय पुनर्रचनाओं से पौधों एवं जन्तुओं के वितरण में परिवर्तन इंगित नही होते। इस दृष्टिकोण से सभी पुनर्रचनायें संदेहजनक हैं। इसी प्रकार मध्यजीवी एवं नूतनजीवी कल्प में पृथक प्लेटों का संयुक्त यूरेशिया में शनैःशनैः विलय भी संदेहयुक्त लगता है।

PLATE tectonics establishes the position of continents by means of geophysical (palaeomagnetic) methods. Palaeobotany, as a part of palaeontology, uses for this purpose distribution of fossils in space and time, their similarities and differences, their migration paths.

The following considerations seem to contradict some of plate tectonic reconstructions (Krassilov & Markevitch, 1984):

(i) Fossil floras of Laurasia and Gondwana differ most in the time of their assumed Pangeic union or less when they drifted apart.

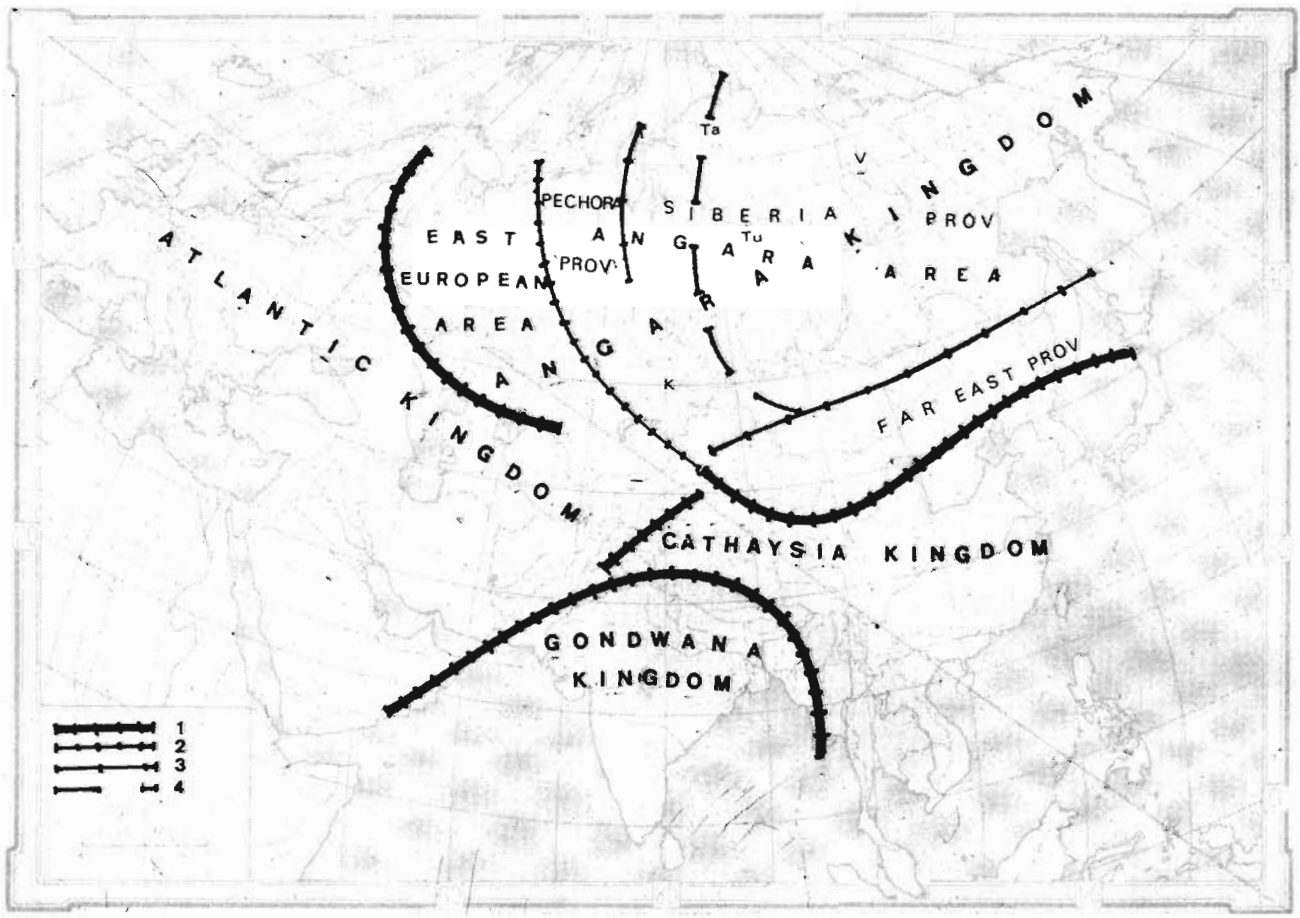
(ii) Floristic similarities across the Tethys ophiolitic belt contradict the interpretation of this belt as a suture of the closed ocean.

(iii) A steady position of the boundary between temperate and subtropical zones from the Late Palaeozoic to Neogene is incompatible with large longitudinal displacements of the continents.

(iv) Mesozoic isofloras are in better agreement with modern latitudes than with contemporaneous palaeolatitudes.

On the other hand, a comparison of Cretaceous floras of the Soviet Far East, Japan and the Yamato suggests the spreading of Japan Sea which can be tentatively attributed to transform faulting and anticlockwise rotation of the island arc.

Analysing biogeographic relations between the northern and southern continents during the Mesozoic and Cenozoic Hallam (1981) concludes that in some plate tectonics reconstructions (Smith & Briden, 1977) the width of the Tethyan barrier may have been overestimated for the Jurassic and Cretaceous. Hallam claims that similarity of land vertebrates and land plants of Europe and Africa suggests the existence of land corridors between these two continents, which are not shown in the discussed reconstructions. The reconstruction by Owen (1976) shows agreement as it eliminates Tethys,



Text-figure 1— Late Permian phytochoria in Eurasia (after Meyen, 1970): **1** - boundaries between paleofloristic kingdoms, **2** - boundaries between paleofloristic areas, **3** - boundaries between paleofloristic provinces, **4** - boundaries between paleofloristic counties. **Ta** - Taymyr peninsula, **K** - Kuznetsk basin, **Tu** - Tunguska basin, **V** - Verkhoyanye.

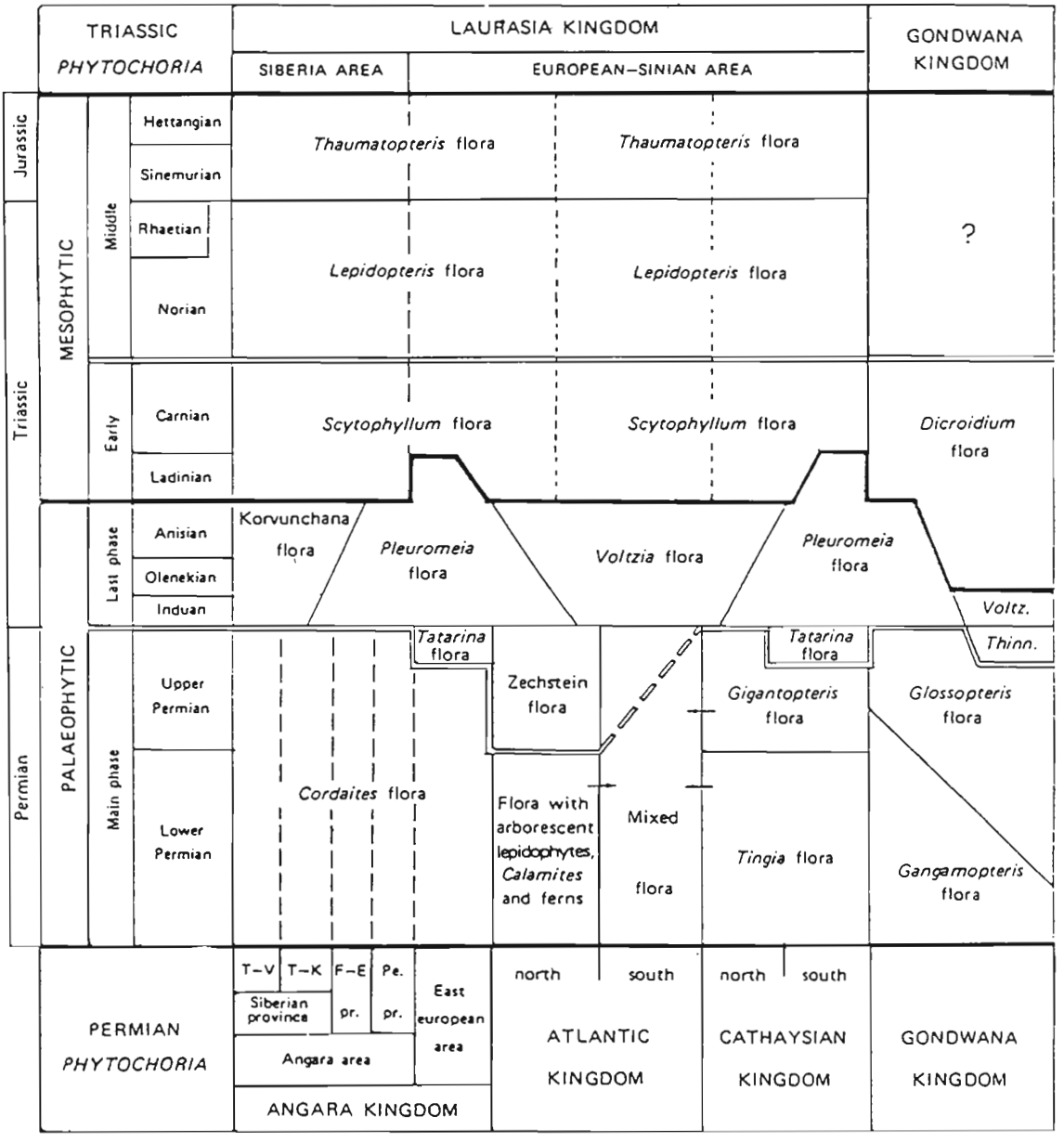
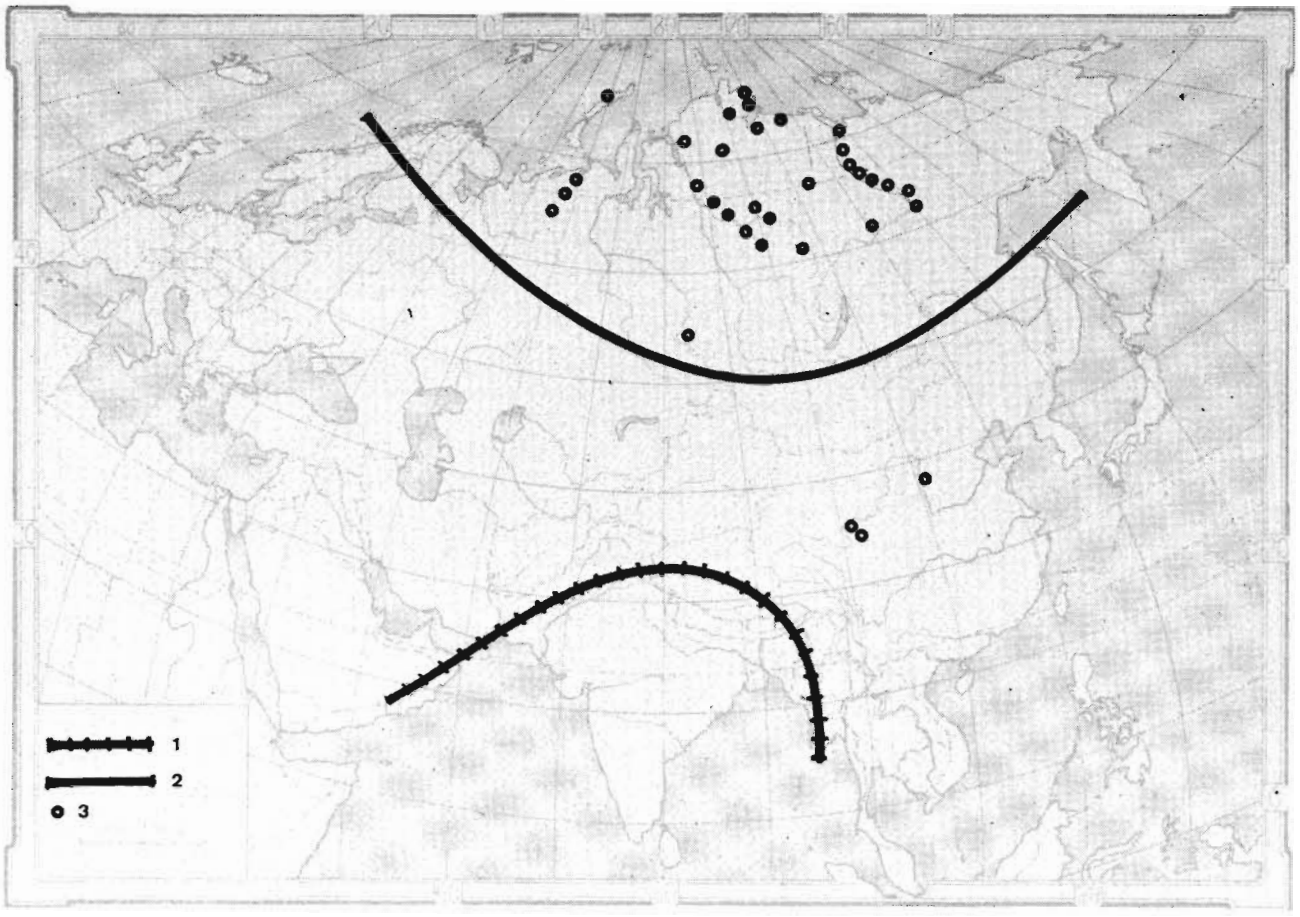


Chart 1—The stages of development of the floras at the Paleophytic-Mesophytic transition: Phytochoria in the Permian, after Meyen (1970), Gondwana Kingdom, after Retallack (1977). Abbreviations: **T-V**: Taymyr-Verkhoyansk count; **T-K**: Taymyr-Kuznetsk count; **F-E**: Far East province; **Pe**: Pechora province; *Voltz.*: *Voltziopsis* flora; *Thinn.*: *"Thinnfeldia" callipteroides* flora.

though it assumes 20 per cent expanding of the Earth from the Triassic, an idea not accepted by Hallam as well as by the majority of geophysicists.

There are also contradictions between palaeomagnetic reconstructions and palaeontological data with the position of Afghanistan, Iran and the Northern Limestones Alps during Triassic on the southern shore of the Tethys Ocean, while the Pamirs, Transcaucasus and Switzerland remain on its northern shore. This seems impossible in view of close similarity of the flora of Iran and Afghanistan with the flora of Pamirs and Transcaucasus on one hand and Austria and Switzerland on the other (Dobruskina, 1980, 1982).

Necessity of palaeontological (palaeobotanical) control on palaeomagnetic reconstructions follows from the fact that various palaeomagnetic reconstructions differ from one another (Atlas..., 1987; Atlas..., 1989; Condie, 1988; Khramov, 1982; Owen, 1976; Smith &

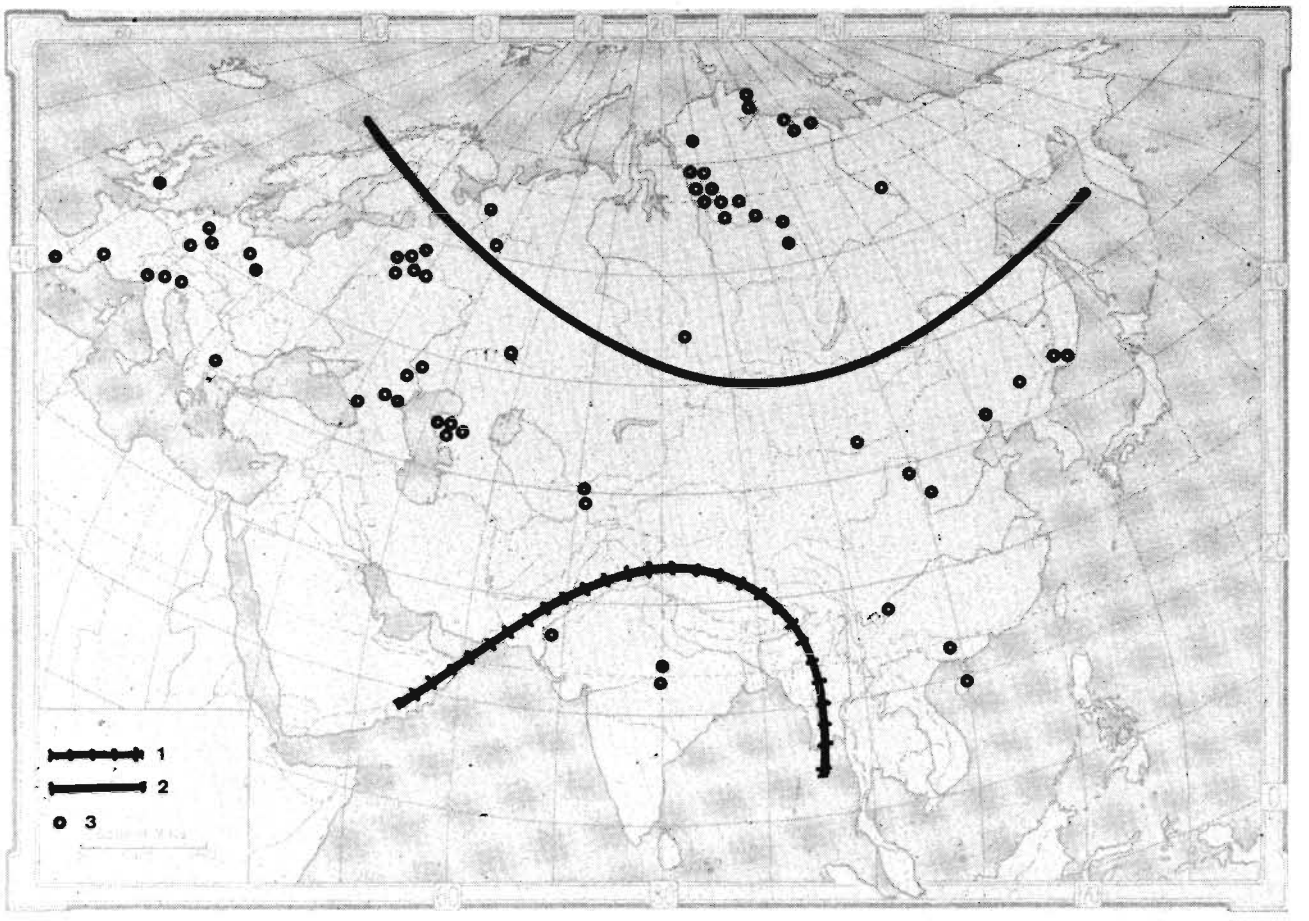


Text-figure 2 — Phytogeography of Eurasia in the Early Triassic, Induan stage (after Dobruskina, 1994, simplified) 1 - boundaries between paleofloristic kingdoms, 2 boundaries between paleofloristic areas, 3 - plant localities.

Briden, 1977). Various palaeomagnetic reconstructions for the Permian and Triassic periods differ from one another in showing less or more compacted Pangea, different width of the ocean Tethys, and in the relative position of Cathaysia. Within geophysics there are no criteria to judge which one is more correct. For such purposes we need data from other fields of geology, other than geophysics.

Palaeobotanical investigations in Eurasia show that in the end of Paleozoic there were four first order phytochoria — ("plant kingdoms" in terms of Russian paleobotanists) with some phytochoria of second ("areas"), third ("provinces") and forth ("counties") order (Text-figure 1). Atlantic Kingdom includes Western Europe, Cathaysia Kingdom comprises southern China and Indochina, Angara Kingdom includeş Siberia and northern China, and the Gondwana Kingdom consists of Indian Peninsula. Each of these kingdoms was characterized by specific flora which differed much from the flora of other areas. It seemed to me earlier that it is possible to explain the high isolation of the Late Palaeozoic floras by the existence of isolated plates, isolated continents at that time. But more detailed comparison of outlines of tectonic plates (Atlas..., 1987) and that of the Permian phytochoria do not show any coincidence. Palaeŏmagnetic reconstructions for the Mesozoic also do not reflect changes in distribution of plants and animals which we see beginning from the Triassic. Let us look at history of plants in the Triassic.

In the Triassic plant history we can distinguish three stages (Chart 1). The reasons for recognition of such stages and their age were discussed earlier (Dobruskina, 1980, 1982, 1993). The first stage is closely connected with the Permian and may be considered as the last phase



Text-figure 3 — Phytogeography of Eurasia in the Early-Middle Triassic, Olenekian and Anisian stages (after Dobruskina, 1994, simplified): **1** - boundaries between paleofloristic kingdoms, **2** boundaries between paleofloristic areas, **3** - plant localities.

of the Paleophytic. The second one is the initial phase of the Mesophytic; the third is the beginning of the main phase, i.e., the beginning of the "real" Mesophytic.

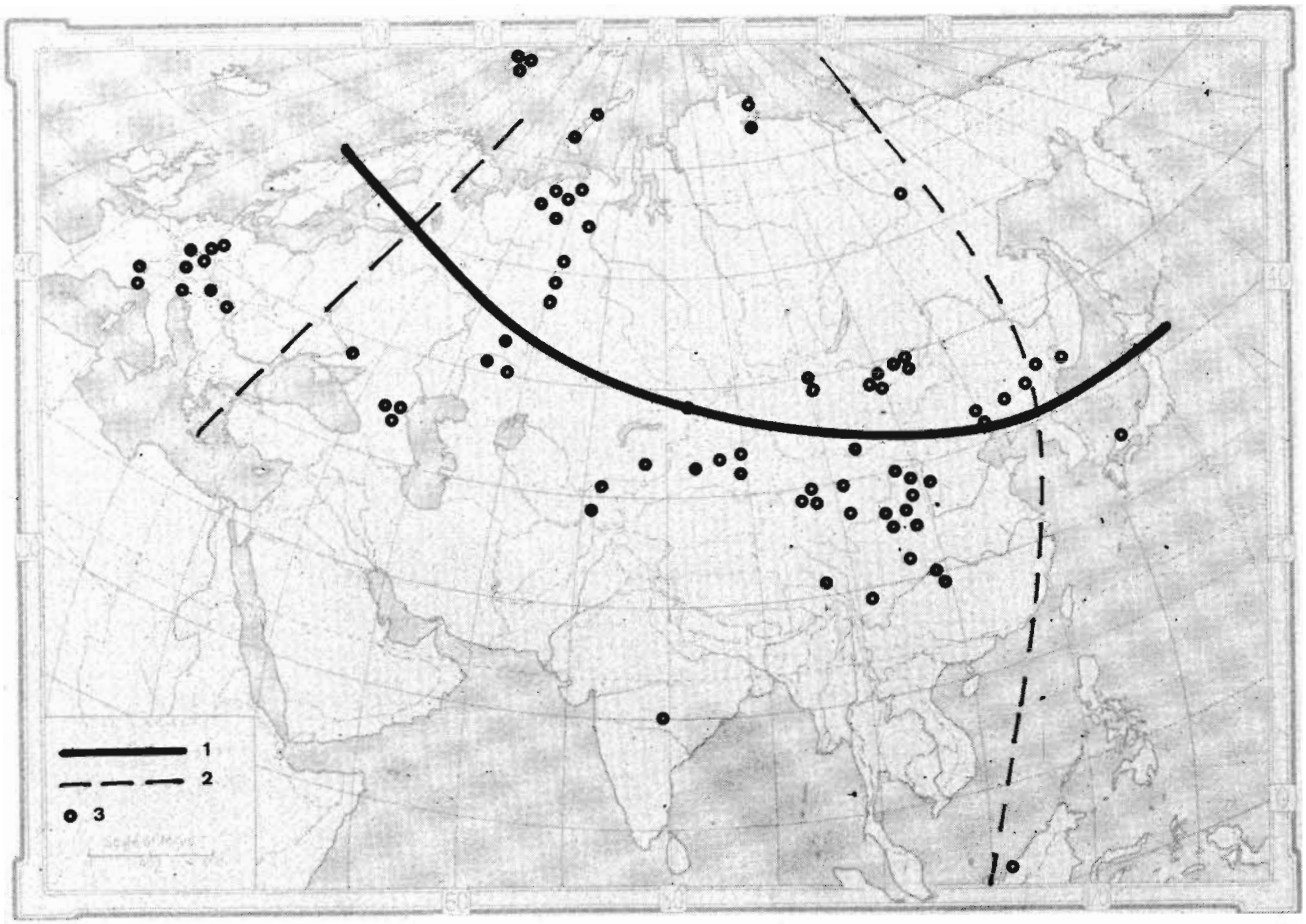
During these three stages high differentiation of Paleophytic phytochoria (i.e., abundance of phytogeographic areas with different floras) is replaced by large areas with homogeneous floras. In the Triassic we already see phytogeographic zonation similar to modern one.

Geological age of the most important events in Triassic plant history has also been shown in Chart 1 which exhibits important changes in the Triassic history of plants and can be compared with other events in the geological history of the Earth.

What is the essence of these changes? What happened at these well-dated boundaries? The first boundary — the boundary between main phase of Paleophytic and its last phase is the time of extinction of plants which were dominant in the Paleophytic plant kingdom. On this boundary new plant groups do not appear, but the groups which were not significant earlier came to the foreground. Only one new group, very specific family of lepidophytes, suddenly appeared in the beginning of the first stage. It also suddenly disappeared in the end without leaving any significant descendants.

It is worth to pay attention on the fact that extinction of Paleophytic groups took place at different time in different regions with different phytochoria. The process of extinction began in Western Europe, then captured the Eastern Europe and south of Cathaysia and only afterwards spread to Angarida.

As a result of this process, the composition of flora in different phytochoria became more similar. In the beginning of Triassic there were only two phytogeographic areas instead of many isolated phytochoria in Eurasia, Siberia and European-Sinian (Text-figures 2,



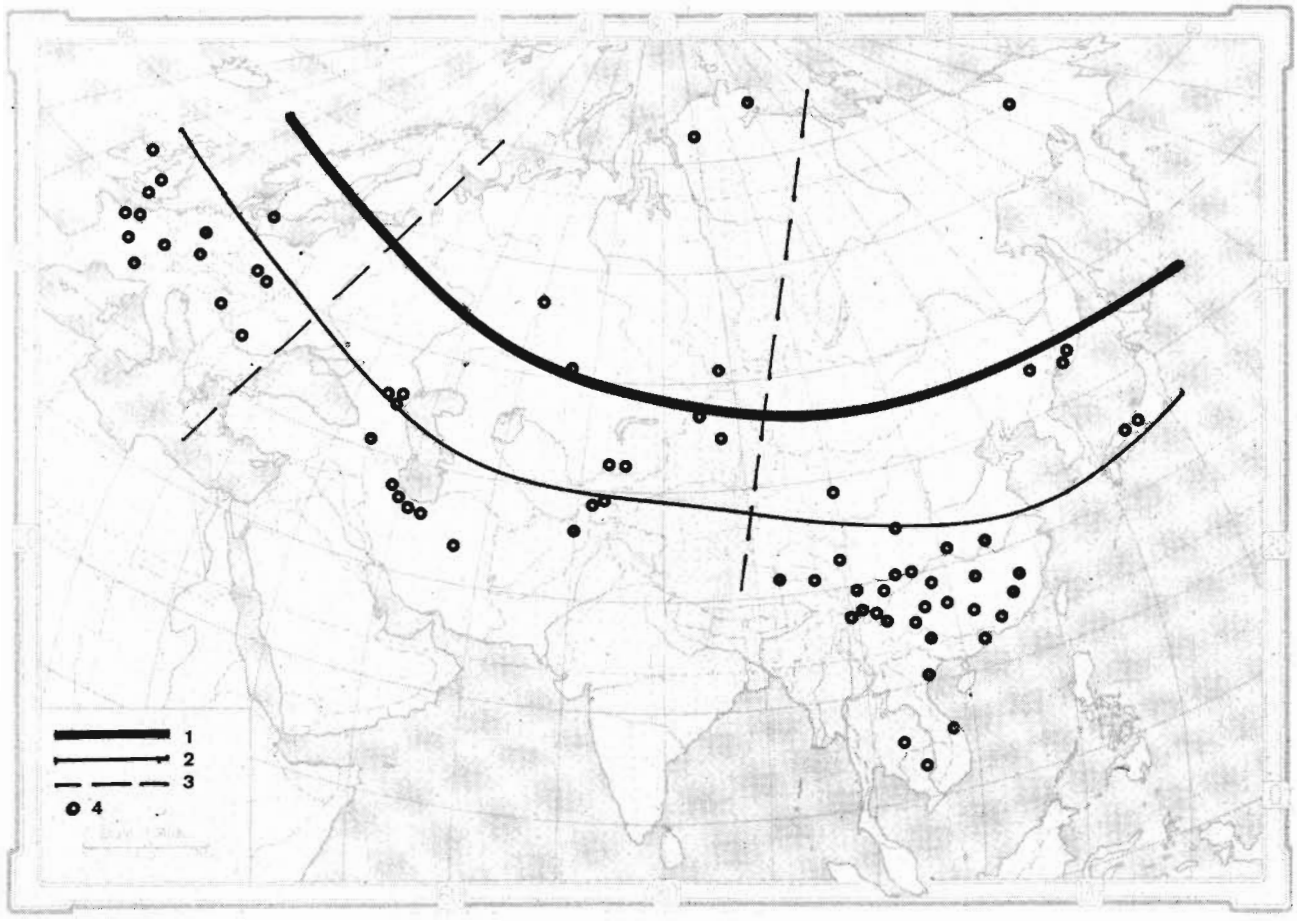
Text-figure 4 — Phytogeography of Eurasia in the Middle-Late Triassic, Ladinian and Karnian stages (after Dobruskina, 1994, simplified): **1** - boundaries between paleofloristic areas, **2** - boundaries between paleofloristic sectors, **3** - plant localities.

3). It is easy to explain the differences in floral composition in these two areas by climatic differences. Distribution of Pleuromeiaceae (Dobruskina, 1994, fig. 52) was not connected with climate; they lived exclusively on sea shores or on the shores of salt lakes.

The second boundary, the boundary between the Paleophytic and Mesophytic, has quite different connotation. At this boundary the most important event is the appearance of new plant groups. The plants belonging to this group were not known before this time but were widely distributed in the Mesozoic. These are called "Mesozoic groups". The first representative of such plants come in the Early Mesophytic. On this boundary we do not see any significant extinction, not counting Pleuromeiaceae. Old boundaries between phytochoria ceased to exist. New-meridional-boundaries appeared (Text-figure 4). During the next stage — Middle Mesophytic, these meridional boundaries gradually disappeared (Text-figure 5), though their influence existed even during the whole Jurassic. So, the change of mode of zonation on the Anisian-Ladinian boundary was less significant as compared to the change on the Permian-Triassic boundary. During the Middle Mesophytic we see gradual development of new, Mesozoic plant groups and gradual extinction of the rest of old, Paleozoic plant groups are seen.

The map of distribution of plants in the very end of the Paleozoic (Text-figure 1), decifers all Permian phytochoria which are shown in Table 1. The Chart also shows floral composition of each phytochoria. It is very different in various kingdoms and areas.

If we look on the plates reconstructions for the Permian (Atlas..., 1989) we see the single continent, including Angara and Atlantic kingdoms. Cathaysian



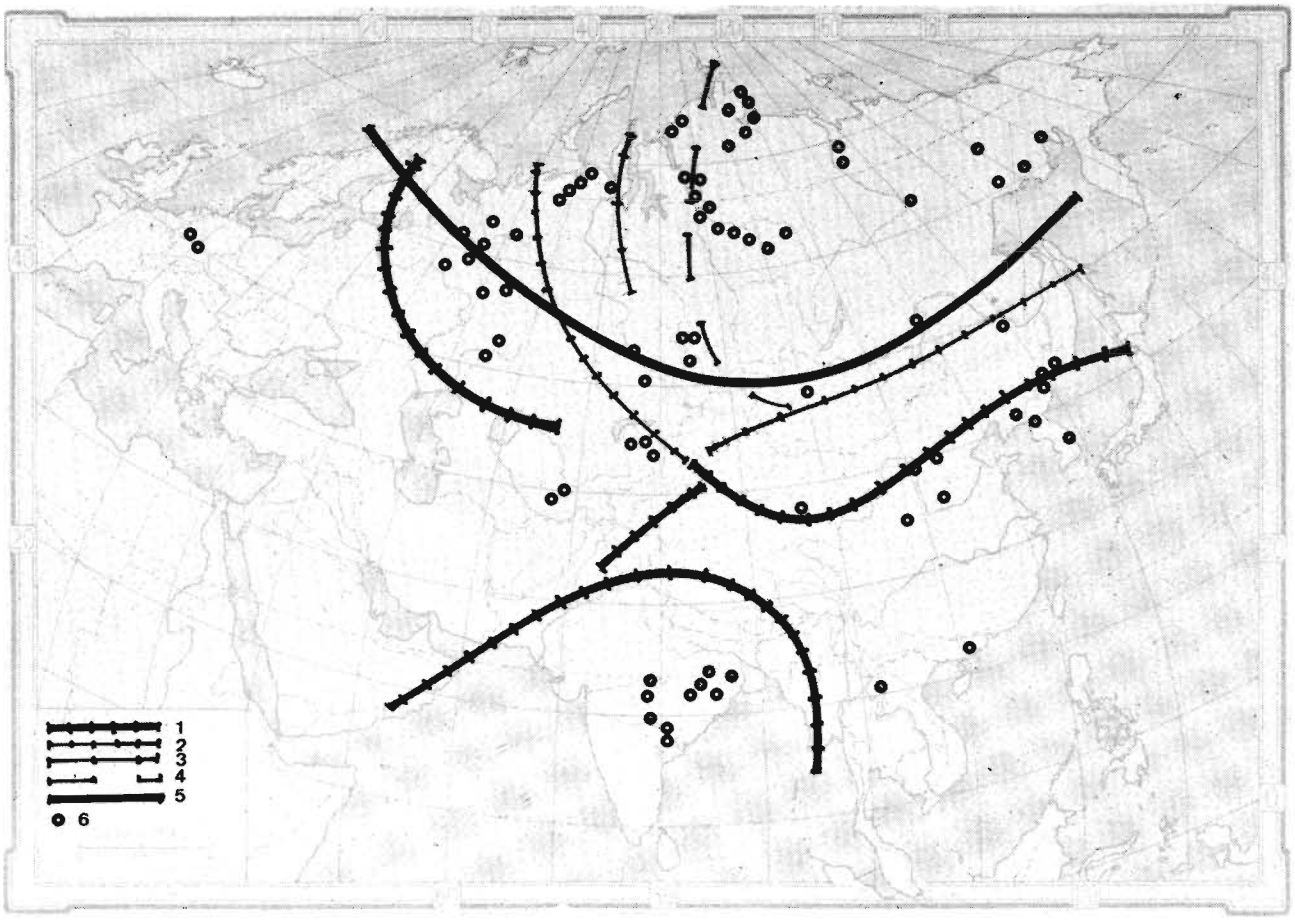
Text-figure 5 — Phytogeography of Eurasia in the Late Triassic, Norian and Rhaetian stages (after Dobruskina, 1994, simplified): **1** - boundaries between paleofloristic areas, **2** - boundaries between paleofloristic belts, **3** - boundaries between paleofloristic sectors, **4** - plant localities.

and Gondwana kingdoms are situated very far from them. The position of Gondwana Kingdom has no doubt, but a great distance between Angara and Cathaysia kingdoms seems strange because in the latest Permian, mixed floras in the so-called Cathaysian Plate are seen. These floras contain Cathaysian as well as Angarian plants.

If we look on the plates reconstruction for the Triassic (Atlas..., 1987; Condie, 1988)), nearly the same picture may be seen as for the end of the Paleozoic: isolation of Cathaysian Kingdom from Siberia (Angara) Kingdom and isolation of the former one from Atlantic Kingdom.

This picture does not correspond to Triassic phytogeography. Beginning from the Induan stage, and especially from the Anisian stage floras of Western Europe, Middle Asia and China became very similar. Thus a boundary between palaeofloristic areas in the Lower Triassic on the phytogeographical map has been shown with localities of the Late Paleozoic (Text-figure 6). It has nothing in common with the Permian boundaries. Only India is still in the Southern Hemisphere.

If the phytogeographical zonation during Triassic (Text-figures 2-5) is compared with that in the Late Paleozoic, it becomes clear that there is a remarkable difference. In the beginning of the Triassic the boundary between Atlantic and Cathaysian kingdoms disappeared, because similar plants are found in the very west (Germany, France) and east of European-Sinian area (China). From this point of view the reconstruction proposed by Khramov (1982)) which shows the whole Cathaysia together, looks more convincing, though he also showed isolation of Cathaysia from the main Eurasia. More suitable is the reconstruction of Smith and Briden (1977).

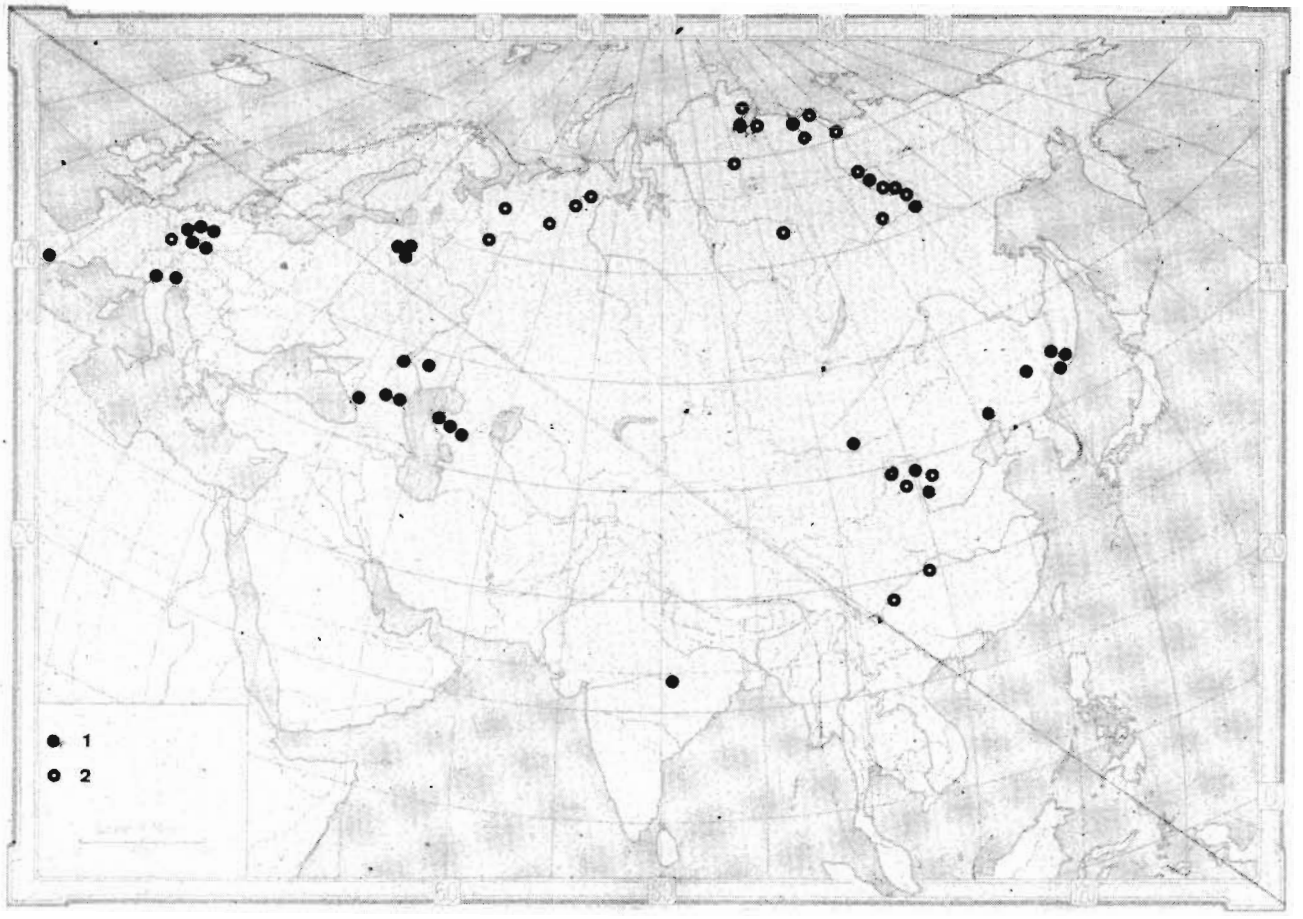


Text-figure 6 — Comsparison between Late Permian (after Meyen, 1970) and Early Triassic phytochoria (after Dobruskina, 1982, 1994) in Eurasia: **1-4** — boundaries between Late Permian phytochoria: **1** - boundaries between paleofloristic kingdoms, **2** - boundaries between paleofloristic areas, **3** - boundaries between paleofloristic provinces, **4** - boundaries between paleofloristic counties, **5** - boundary between Early Triassic phytochoria (areas), **6** - Late Permian plant localities (after Meyen, 1970).

Distribution of Pleuromeiaceae (Text-figure 7) corresponds to the northern shore of the Tethys Ocean and to the southern shore of northern ocean on the map of Smith and Briden. Distribution of Pleuromeiaceae also suggests the existence of sea basin in Verkhoyanye and on the boundary between Angarida and Cathaysia. We know nothing about Triassic plants eastward from Verkhoyanye, so it is impossible to say what kind of basin should be there. Nevertheless, we cannot exclude the possibility of these two basins, i.e., possibility of the margin, and boundary of the "Angara Plate" according these basins. In this case, isolation of Cathaysia from Angarida may be justified, but the isolation of Cathaysia from Europe may not be possible. The position of Cathaysia should be different even in this case.

The maps of Smith and Briden (1977) connect the position of Iran and Afghanistan with the southern shore of the Tethys showing their isolation from Pamir and Transcaucasus, where similar Triassic floras exist. The same can be commented about similar floras of Austrian Limestone Alps and Jura Mountains in Switzerland, which also are put on different shores of the Tethys; but it seems doubtful.

It is necessary to pay attention to the fact that beginning from the Lower Triassic, the phytogeo-graphical zonation did not change principally and remained nearly the same till now. Text-figure 8 shows the position of the northern boundary of equatorial belt during 250 million years from the Late Paleozoic till the Middle Cretaceous. Shifts of this line were not significant: they were connected with the rise or fall of temperature. The same



Text-figure 7 — Localities of Pleuromeiaceae in Eurasia (after Dobruskina, 1994) 1 - *Pleuromeia, Lycomeya,* and 2 - *Tomiostrobus, Annalepis.*

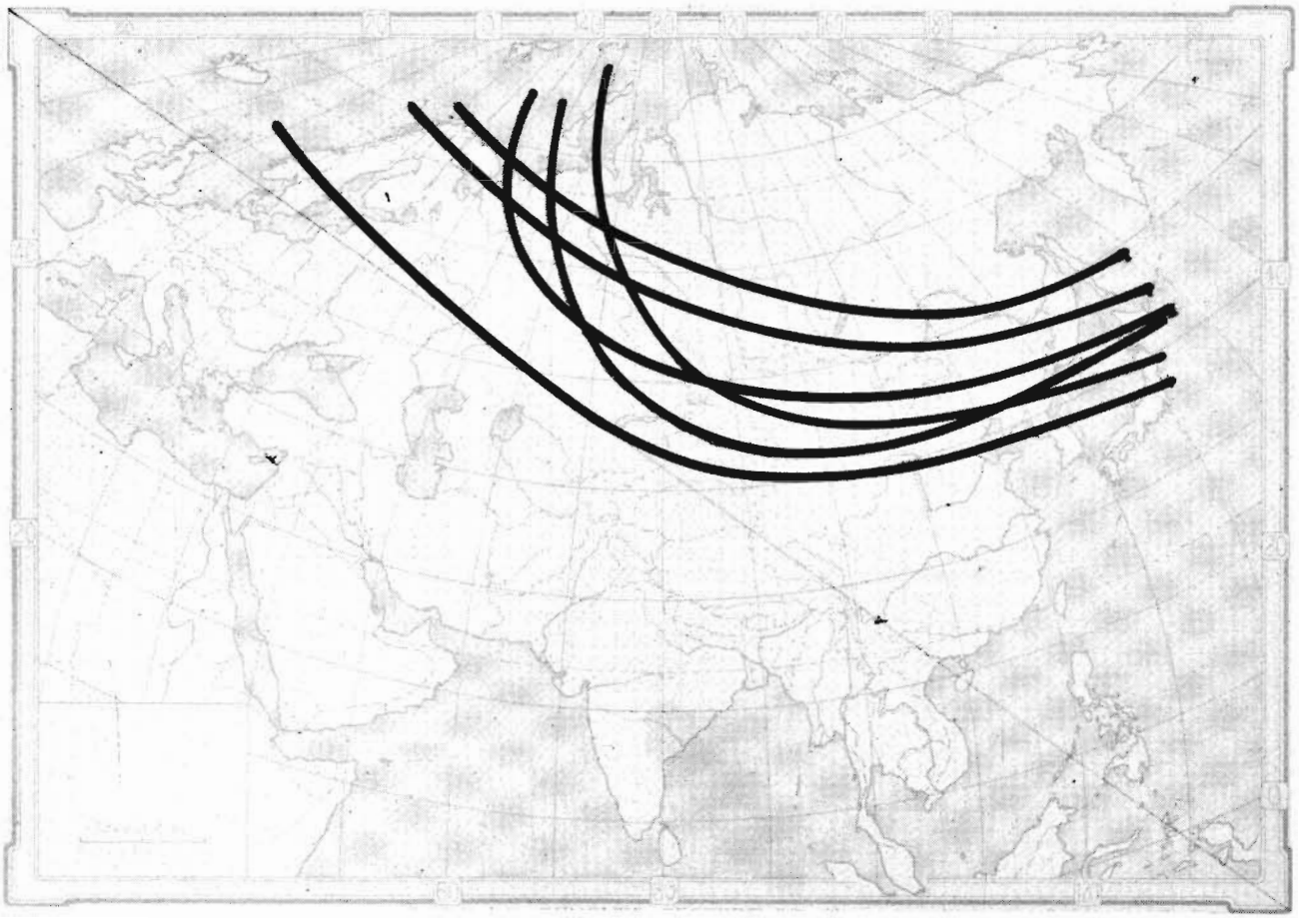
small difference in the position of phytogeographic boundary in the Late Triassic and Early Jurassic is shown in Text-figure 9. This difference has also been concluded on warmer Triassic as compared to the Jurassic.

This principal change in palaeogeographical zonation on the Permian-Triassic boundary is not reflected in the plate tectonics reconstructions. During the second stage of development of the Triassic plants (Early Mesophytic, Ladinian-Karnian) one more interesting event which also cannot be explained by isolation of plates, has been noticed. It is a meridional zonation caused by the appearance of new plant groups at that moment. The problem of meridional zonation itself was discussed earlier (Dobruskina, 1982, 1993). Their relatively long existence, small shift and gradual disappearance means that migration of new taxa from the places of their origin took some time. As in Text-figure 9, it is possible to compare these boundaries in the Middle Triassic and Lower Jurassic.

More eastern position of the boundary between Middle Asian and eastern Asian sectors (provinces) in the Ladinian-Karnian may show that the Far East and Japan did not join the rest of Eurasia by that time. We see this connection in the Lower Jurassic (and already in the Norian-Rhaetian). The number of similar taxa also increases from the Triassic to Jurassic.

It seems that these boundaries were caused by the existence of sea basins, because they were not acting as bariers for sphenopsids, only for this one group of plants. And this group usually is considered to be related with sea shores, i.e., epicontinental platform basins.

Indirect evidence for this idea is the existence, in the Late Triassic, of two facial types of sediments with plants: continental and near-shore sediments with paralic coals. We do not see any regularity in the relative distri-

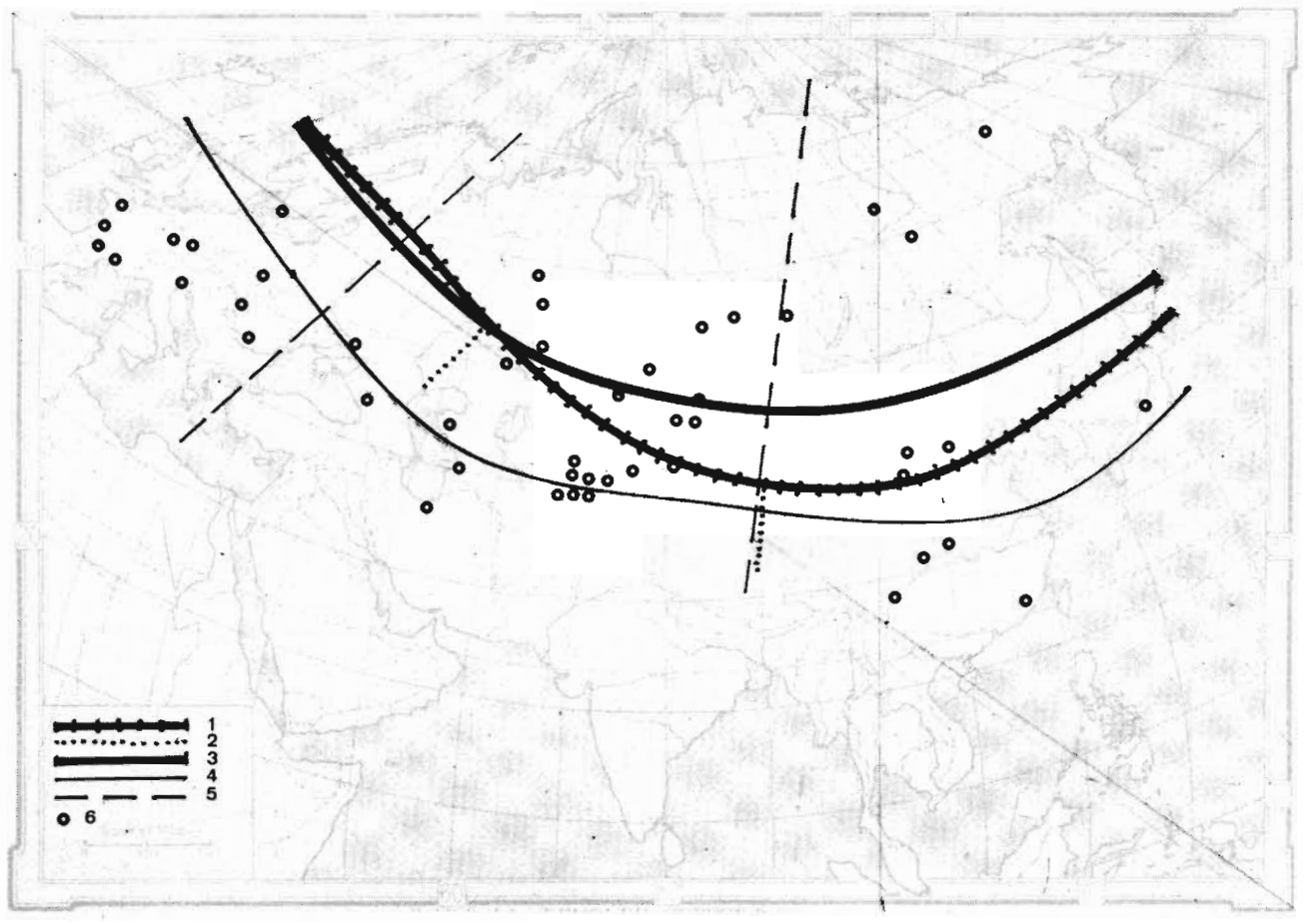


Text-figure 8 — Position of the northern boundary of equatorial belt from the Late Palaeozoic till the Middle Cretaceous during 250 Ma (after Meyen, 1981)

bution of these two kinds of sediments and no connection of the distribution of near shore sediments with these meridional boundaries. Their position is probably related with transgressions and regressions. It is difficult to connect meridional boundaries with the boundaries of plates. Furthermore, there is no correspondence of these boundaries with the boundaries of plates on the basis of palaeomagnetic reconstructions.

It is thus evident that in the beginning of Triassic the earlier isolation of floras of different areas disappeared. The floras of Europe, China and Indo-China and also of North America became quite similar. Thus a new united Laurasian Kingdom originated. Atlantic and Cathaysian kingdoms united and merged in a single one — European-Sinian area. Floras of Siberia area also became more similar to those of the European-Sinian area; differences of these floras during the Triassic seem to depend only on the climate. Tetrapods of Europe and Africa as well as tetrapods and insects throughout all Eurasia were also quite similar at this time.

From the beginning of the Triassic, new boundaries between phytochoria appeared due to the origin of new plant groups in different places. These boundaries show meridional orientation and separate phytogeographical sectors which were the centres of origin of new taxa. These meridional boundaries are recognized until the end of Jurassic. With the time, the floras became more and more similar through migration and exchange of plants between different sectors. All these differences in composition of floras in different phytogeographical areas do not show the isolation of areas as it was in Paleozoic. In other words, distribution of plants in the Mesozoic suggests the existence of united continent Laurasia from the beginning of Triassic. The breaking of Laurasia and consequently the separation of North America from Eurasia took place later, i.e., after the



Text-figure 9 — Comparison between Upper Triassic (after Dobruskina, 1982) and Early Jurassic phytochoria (after Vakhrameev, 1970) in Eurasia: **1-2** - boundaries between Lower Jurassic phytochoria: **1** - boundaries between paleofloristic areas, **2** - boundaries between paleofloristic provinces; **3-4** - boundaries between Upper Triassic phytochoria: **3** - boundaries between paleofloristic areas, **4** - boundaries between paleofloristic belts, **5** - boundaries between paleofloristic sectors, **6** - Early Jurassic plant localities (after Vakhrameev, 1970)

Triassic. Eurasia itself exists since Triassic, and continues till now. The position of the main climatic boundary between tropical and nontropical areas did not change significantly during 250 Ma.

From this point of view, all reconstructions showing isolated plates in the Mesozoic (similar to Paleozoic ones) instead of united Eurasia are doubtful, so also all reconstructions showing isolation of Cathaysia from main Eurasia. In view of this, the scheme of gradual unification of isolated plates into a united Eurasia during the Mesozoic and Cenozoic also seems doubtful.

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