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Global changes

Evolution of the biosphere

Radiolarians as Indicators of Triassic Climate in Northeast Asia

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Abstract – Known assemblages of the Triassic radiolarians from different regions of the world are analyzed. A considerable geographic differentiation of radiolarian faunas in the middle and late Triassic is shown to result from their distribution throughout different climatic belts. Boreal faunas are known in northeast Asia (except the Koryak Upland) and north Alaska. Tropical faunas are distributed throughout the Mediterranean region and along the Asian and North American margins of the Pacific ocean. Owing to significant taxonomic differences between the boreal and tropical assemblages, the Triassic radiolarians can serve as biotic indicators of paleoclimates.

Various Triassic deposits, most of which contain radiolarians, are widespread in northeast Asia. The most abundant assemblages come from siliceous and volcanogenic-siliceous formations, which, in general, occur in areas adjacent to the Pacific ocean: the Koryak Upland, Sakhalin, the lower course of the Amur River, eastern Primor'e, and eastern Japan. The great similarity between the radiolarian assemblages of these regions allowed us to trace recognized biostratigraphic units from Japan to the Koryak Upland (Bragin, 1991). Triassic radiolarians were also studied in many regions of various paleogeographic and paleoclimatic belts: North America, the Mediterranean belt, the Philippines, and northeast Siberia. Therefore, it seems pertinent to compare radiolarian assemblages from northeast Asia with those from other regions in order to find out whether those assemblages can be confidently correlated with paleoclimate environments.

So far, radiolarians of the early Triassic and early-middle Anisian age have only been studied in a few localities of Japan and the Sikhote-Alin' area, and in many cases the data are incomplete. Therefore, the middle Triassic (late Anisian–early Ladinian) assemblages, which are the most thoroughly studied, should be analyzed first. Typical assemblages of this age are known from sequences of the Sikhote-Alin' area (the Dal'negorsk Settlement), Sakhalin (the Yunona Mountain), and Japan (Bragin, 1991, 1991; Blome, 1987; Nishizono *et al.*, 1982; Takashima and Koike, 1982; Yao, 1982). These assemblages are dominated by various species of the *Pseudostylosphaera* (*P. japonica, P. tenue, P. acrior, P. spinulosa,* and others) and *Triassocampe* (*T. deweveri, T. scalaris,* and others) genera. Representatives of the Eptingiidae (*Eptingium manfredi*) and Pentactinocarpidae (*Pentactinocarpus fusiformis, P. acanthicus*) families, and genus *Yeharaia* (*Y. japonica, Y. elegans, Y. annulata*) are typical. The assemblages from the above regions differ insignificantly in composition. An assemblage from the upper Anisian–lower Ladinian strata of the Koryak Upland (Bragin, 1991) is identical to them.

A comparative analysis of the Pacific and coeval Mediterranean assemblages of Italy (De Wever *et al.*, 1990; Dumitrica *et al.*, 1980; Martini *et al.*, 1989) and Slovenia (Gorican, 1990) shows that the latter are dominated by the same taxa, except for genus *Yeharaia*, which is rare in the Tethys area. In addition, members of the Oertlispongiidae family are common in the Mediterranean area (Dumitrica *et al.*, 1980), but sporadic in eastern Russia and Japan. This, however, can be explained by a better preservation of thin skeletal elements of Oertlispongiidae in the Tethyan carbonate rocks than jaspers and siliceous rocks of other regions. The northeast Asian genus *Yeharaia* is also present in the middle Triassic assemblages from the Philippines (Cheng, 1989; Yeh, 1990), similar to those from Japan, the Sikhote-Alin' area, and Sakhalin. So, in general, the late Anisian–early Ladinian assemblages from the Pacific margins and the Alpine region are very similar in composition.

Let us now consider the late Ladinian–early Karnian interval. An assemblage of this age dominated by diverse Muelleritortiidae (*Muelleritortis cochleata, Tritortis kretaensis*) and Pseudostylosphaera (*P. inaequata, P. imper-*

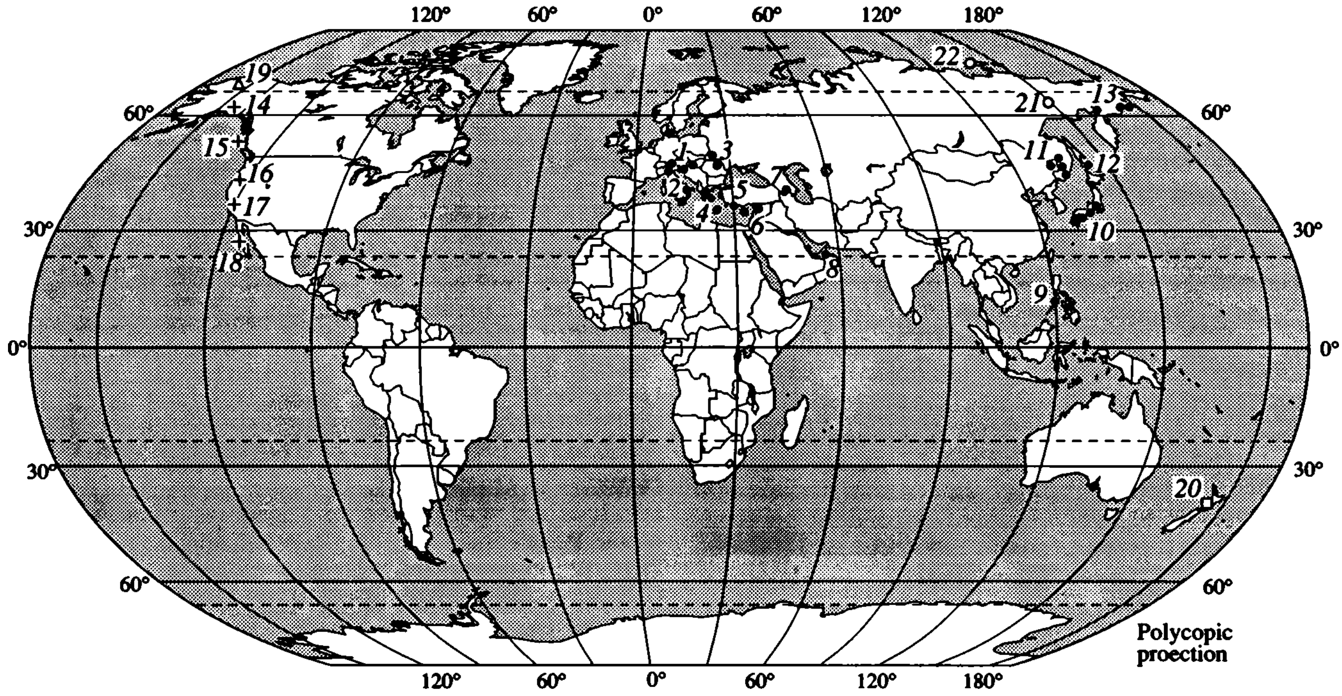
spicua) is known from sequences of the Dal'negorsk Settlement (the Primor'e), the Yunona Mountain (Sakhalin), the Koryak Upland (Bragin, 1991), and different regions of Japan (Nakaseko and Nishimura, 1979; Nishizono *et al.*, 1982). The assemblage contains also *Triassocampe* deweveri, *Yeharaia elegans*, and *Pentactinocarpus fusiformis* inherited from the underlying beds, and in addition the representatives of genus *Xiphotheca* (*X. dimidiata, X.* sp.). The above taxa (except *Xiphotheca*) are characteristic of the upper Ladinian–lower Carnian strata of the Alpine–Mediterranean area (De Wever, 1984; Kazintsova and Lozynyak, 1986; Kozur, 1988, 1988; Kozur and Krahl, 1984), where they occur together with abundant Oertlispongiidae and representatives of the genus *Ditortis*, unknown in the Pacific area. Finally, late Ladinian assemblages were recorded in western Canada and are similar in composition to those from northeastern Asia (Cordey *et al.*, 1988).

The late Carnian–early Norian assemblages were described from key sections of the Triassic siliceous strata in the Sikhote-Alin' area and Sakhalin (Bragin, 1991). Assemblages from the Koryak Upland (Bragin, 1991, 1991) and Japan (Nakaseko and Nishimura, 1970, Nishizono *et al.*, 1982; Takashima and Koike, 1982; Yao, 1982; Yoshida, 1986) are also well studied. The assemblages are dominated by Capnuchosphaeridae (*Capnuchosphaera triassica, C. theloides, C. lea*, and others) and Capnodocinae (*Capnodoce anapetes, C. antiqua*, and others). Representatives of the genera *Japonocampe*, *Xiphotheca*, and *Syringocapsa* are common in them. This composition of radiolarian assemblages is typical of most localities in northeast Asia. However, a more diverse assemblage was found in the eastern section of Koryak Upland (Bragin, 1991). In addition to the mentioned taxa, this assemblage contains the genera *Pentaspongodiscus, Orbiculiforma, Veghicyclia*, and *Karnospongella*. This assemblage is identical to the Tethyan assemblages of Sicily, Greece, Turkey, and Austria, and, having a more diverse composition, differs from most of the east Asian assemblages (De Wever *et al.*, 1979; Kozur and Mostler, 1972, 1979, 1981). The late Carnian–early Norian radiolarians also occur in many regions of North America: Oregon, California, and Mexico (Blome, 1984; Pessagno *et al.*, 1979). Similar in composition to the assemblages from Japan and east Russia, they are characterized by a particular abundance of Capnuchosphaeridae and Capnodocinae. The separate assemblages of north Alaska (Blome, 1987) have a taxonomic composition similar to the above assemblages, but show a relative scarcity of members from the Capnodocinae family. Thus, in the late Carnian–early Norian time interval, the Pacific and Tethyan radiolarian faunas differ mainly at the species level (Blome, 1987). Only the north Alaskan assemblages differ at the genus and family ranks.

The early Norian–Rhaetian (?) assemblages are known in the same regions and sequences of northeast Asia as the older ones (Bragin, 1991). Abundant representatives of the Saturnalidae family (*Praemesosaturnalis, Pseudoheliodiscus, Mesosaturnalis*, and others), the Pantanelliinae subfamily (*Betraccium* and *Pantanellium*), and the genera *Canoptum* (*C. rhaeticum*) and *Livarella* (*L. longus, L. gifuensis*, and *L. densiporata*) are typical of these assemblages. Their composition remains the same in localities from the Koryak Upland to Japan and the Philippines (Bragin, 1991; Yao, 1982; Yeh, 1992; Yoshida, 1986). The coeval Tethyan assemblages are known in the Alps (Kozur and Mostler, 1972, 1979, 1981). They are generally similar with a slight difference in the species composition, particularly members of the family Saturnalidae. In contrast, most of the North American assemblages differ notably from both the east Asian and Tethyan ones, having a greater abundance and diversity of the subfamilies Pantanelliinae (*Betraccium, Cantalum*, and *Pantanellium*) and multicyrtid nassellarians (*Laxtorum*). These assemblages are known in Mexico, Oregon, British Columbia, and south Alaska (Blome, 1984, 1987; Carter, 1990; Carter *et al.*, 1989; Pessagno *et al.*, 1979; Pessagno and Blome, 1980). At the same time, very poor assemblages with a low diversity of genera *Pantanellium* and *Ferresium* are found in the Brooks Range, north Alaska (Blome, 1987). A similar assemblage was discovered in the upper Norian strata of New Zealand (Blome *et al.*, 1987).

This analysis permits the following conclusions. The late Anisian–early Ladinian time is characterized by an extraordinary similarity between the east Asian, North American, and Tethyan radiolarian assemblages. The same is true for the late Ladinian–early Carnian. In the late Carnian–middle Norian, the assemblages of the different regions began to be diverge; the Brooks Range assemblage of Alaska being the most specific. The differences became more distinct in the late Norian–Rhaetian, when one can distinguish at least three groups of assemblages restricted to certain provinces: Tethys–east Asia, North America, and north Alaska (the figure). The New Zealand assemblage is referred to the last province. The regional distribution and fauna differentiation in the Triassic was already recognized using Ammonoidea, Nautiloidea, Bivalvia, and other fossils as examples (Dagys *et al.*, 1979). In the case of radiolarians this can be observed only in the late Triassic, and is characteristic of the north Alaskan and New Zealand faunas.

The rest of the regions are characterized by a great similarity in fauna, perhaps caused by their location in a single climatic belt, in this case, the tropical one. The especially strong similarity of east Asian and Tethyan assemblages has long attracted the attention of biostratigraphy, paleontology, and tectonics specialists. It should be emphasized that the middle and especially upper Triassic strata of the Koryak Upland and other regions of northeast Asia adjacent to the Pacific ocean are characterized by tropical associations of diverse organisms (not only radiolarians): cephalopods, bivalves, conodonts, corals, and foraminifers (Bragin, 1991). The occurrence of such faunas in these regions is



Localities of the middle and late Triassic radiolarians.

The Mediterranean and East Asian tropical provinces: *1* – the Alps and Hungary; *2* – Southern Italy and Sicily; *3* – the Carpathians; *4* – Greece and Crete; *5* – Turkey; *6* – Cyprus and Syria; *7* – Lesser Caucasus; *8* – Oman; *9* – the Philippines; *10* – Japan; *11* – Sikhote-Alin' and western Manchuanguan; *12* – Sakhalin; *13* – the Koryak Upland. The North American tropical-subtropical province: *14* – southern Alaska; *15* – British Columbia; *16* – Oregon; *17* – California; *18* – Mexico. The North American boreal province: *19* – the Brooks Range. The Notal province: *20* – New Zealand. The East Siberian boreal province: *21* – the Omolon massif; *22* – Kotel'nyi Island.

anomalous, as the polar area is thought to have existed in the Koryak–Kamchatka region at that time (Zakharov and Sokarev, 1990). The plate tectonics reconstructions discussed earlier (Bragin, 1991) were introduced into the discussion as a possible explanation of this phenomenon. Up to now, in spite of their evidently controversial character, there is no convincing alternative to these reconstructions.

Nevertheless, whether the composition of the Triassic radiolarian assemblage can indicate their climatic distribution, or, in other words, whether the radiolarians can serve as reliable climatic indicators is an issue that needs clarification. This is a question of the utmost importance because radiolarians are often the only group of organisms occurring in siliceous rocks unaccompanied by other fossils. The above analysis does not suggest considerable differences between radiolarian assemblages of different and very remote regions. These faunas do not seem promising as climatic indicators. Yet new radiolarian occurrences were recently discovered in the boreal Triassic strata of northeast Siberia (Bragin, 1990). The composition of these assemblages is essentially different from previously known assemblages, and requires special discussion.

The most diverse assemblages were distinguished from the upper Anisian–lower Ladinian beds of the Omolon massif. Contemporaneous faunas occur in Kotel'nyi Island. Poorly preserved and less diverse radiolarian assemblages of the early (Olenekian) and late (Carnian) Triassic also are known from this region. The upper Anisian–lower Ladinian strata contain spherical spumellarians with archaic skeletal spicula similar to Paleozoic Entactiniidae, spherical and diskoidal forms with spongy shells assigned to the subfamily Spongodiscoidea, various spherical spicula-free spumellarians with several lattice shells, as well as rare representatives of the genera *Pseudostylosphaera*, *Archaeothamnulus*, *Pentactinocarpus*, *Hozmadia*, and *Triassocampe*. The Omolon massif has no taxa characteristic of the deposits of the tropical Tethyan and Pacific regions, such as the Eptingiidae, Oertlispongiidae, and Foremanelliidae families, and the genera *Yeharaia*, *Anisicyrtis*, *Poulpus*, and others. The species composition of the genera *Pseudostylosphaera* and *Triassocampe* is considerably less diverse. The assemblage has a peculiar archaic character, and is, in general, impoverished. These features allow us to recognize the regions of its distribution as a special, boreal province (the figure). The boreal character of this province, as well as the north Alaska (the Brooks Range) region is indicated by both the composition of fossils (Ammnonoidea and other mollusks, see Dagys *et al.*, 1979), and the type of lithogenesis characterized by the intensive development of terrigenous deposits along with a minimum carbonate accumulation. Regions like

British Columbia show specific assemblages of ammonoids (and possibly radiolarians) including both tropical and boreal elements (Dagys *et al.*, 1979).

Thus, the great difference in high-level taxonomy between the boreal and tropical Triassic radiolarian assemblages confirms earlier conclusions that the similarity between the Mediterranean and Koryak Upland assemblages suggests a tropical origin of the latter. The wide geographical distribution of the tropical radiolarian assemblages supports the notion that a warm, glaciation-free climate existed during the Triassic, when there was only a small boreal area. Some of the dominant thermophilic assemblages are present, which can be interpreted to be transitional (subtropical, southern boreal, etc.); for example, those of north Alaska and New Zealand. Finally, from all that has been stated it is clear that the composition of the Triassic radiolarian assemblages is to a great extent dependent on their occurrence in a given climatic province, and that the Triassic radiolarians can be considered biotic indicators of climate.

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