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Triassic Radiolarian Zonation in the Far East of Russia

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Abstract—In siliceous deposits of eastern Russia we can recognize, by means of radiolarians, the following biostratigraphic units: *Pseudostylosphaera fragilis* Beds (upper Olenekian) and zones of *Hosmardia gifuensis* (lower Anisian), *Triassocampe diordinis* (middle Anisian), *Triassocampe deweveri* (upper Anisian), *Triassocampe scalaris* (uppermost Anisian–lowermost Ladinian), *Oertlispongia inaequispinosus* (the lower part of the lower Ladinian), *Falcispongia falciformis* (the upper part of the lower Ladinian–lower part of the upper Ladinian), *Muelleritortis cochleata* (the middle–upper part of the upper Ladinian), *Tritortis kretaensis kretaensis* (lower Carnian), *Capnuchosphaera theloides* (upper Carnian), *Capnodoce crystallina* (lower–middle Norian), *Lysemelas olbia* (the lower part of the upper Norian), *Betraccium deweveri* (the upper part of the upper Norian), *Livarella densipora* (lower Rhaetian), and *Globolaxtorum tozeri* (upper Rhaetian). All zones distinguished in sections of siliceous monofacies are well correlative to those in carbonate and terrigenous sections far away. The detailed and persistent radiolarian biozonation of the Middle–Upper Triassic suggest a possibility to use this paleontological group not only for concrete stratigraphic purposes (e.g., for dating siliceous sequences), but also in a wider aspects of the global and regional Triassic stratigraphy.

Key words: radiolarians, Triassic, zones, correlation, facies, Pacific belt, Mediterranean belt.

The use of radiolarians for the Triassic zonation began 20 years ago. In the late 1970s and early 1980s, the initial regional radiolarian-based zonal schemes were elaborated for the Upper Triassic siliceous deposits of Mexico (Pessagno *et al.*, 1979) and the Middle–Upper Triassic of Japan (Yao, 1982). Resolution of these schemes was not high, as zones were equivalent in range to stages or larger intervals. The zones were distinguished by means of typical radiolarian assemblages, but some adjacent zones (e.g., the *Triassocampe deweveri* and *T. nova* zones of Japan) were lacking common species (Yao, 1982), and this was the reason of subsequent doubts about the successive character of relevant assemblages (Bragin, 1986).

The first half of the 1980s was marked by elaboration of detailed Triassic radiolarian zonations for both siliceous and terrigenous deposits. For instance, the Upper Triassic terrigenous deposits of Oregon and British Columbia were subdivided into two zones and five subzones (Blome, 1984). Detailed radiolarian zonations were elaborated also for the Middle–Upper Triassic siliceous deposits of Japan (Sato, 1986; Yoshida, 1986) and Sakhalin (Bragin, 1986). New materials obtained from earlier unstudied stratigraphic intervals (upper Ladinian, lower Carnian) provided better knowledge of radiolarian stratigraphy and grounded a more reliable subdivision and correlation of host deposits. However, there was still a problem of dating the newly found radiolarian assemblages, because they were often described from siliceous sections, stratigraphy of which was insufficiently studied.

In the late 1980s and the first half of the 1990s, the problem was solved in general owing to thorough

investigations of radiolarians from ammonoid-bearing carbonate and terrigenous sections (Carter, 1993; Kozur and Mostler, 1994) and due to the refined subdivision of Triassic siliceous deposits on the basis of conodonts with consequent correlation of conodont- and radiolarian-based stratigraphic units (Bragin, 1991). This allowed the existing schemes to be modified and correlated to each other (Bragin, 1991; Sugiyama, 1992, 1997; Carter, 1993; Kozur and Mostler, 1994; Blome *et al.*, 1995; Kozur *et al.*, 1996a, 1996b) (table).

The current stage of studies on the Triassic radiolarian biostratigraphy is as follows. Several zonations are elaborated for the Triassic System, but many of them do not characterize the system entirely, and some correspond to a series or even a stage only (Blome, 1984; Carter, 1993). In addition, the zonal scales published are unreliably correlated to each other and to standard subdivisions. Finally, paleontological characteristics of almost all radiolarian zonations should be verified, because numerous Triassic radiolarian taxa have been described recently and data on the radiolarian phylogeny and evolution are insufficiently used. All this determines principal lines of current investigations. In general, the main goal is to develop the Triassic biostratigraphy on the basis of comprehensively studied radiolarian evolution during the Triassic.

An initial picture of evolutionary stages of Triassic radiolarians was outlined more than 10 years ago (Bragin, 1988). In short, their evolution was subdivided into three major stages: Early Triassic (the time of extremely low taxonomic diversity of radiolarians in response to their great extinction at the end of the Permian), Middle Triassic (the time when conservative Paleozoic taxa

Triassic radiolarian zonation

| Stage | Substage | Bragin (this article), Southern Sikhote-Alin' | Sigiyma, 1997, Japan | Kozur et Mostler, 1994, West Europe | | |
|-----------|---------------------------|--------------------------------------------------|-----------------------------------------|----------------------------------------------------------|-----------------------------------------------------------------------------|--|
| Rhaetian | Upper | <i>Globolaxtorum tozeri</i> | <i>Haeckelicyrtium breviora</i> | | | |
| | Lower | <i>Livarella densiporata</i> | "Skirt F" | <i>Livarella densiporata</i> | | |
| Norian | Upper | <i>Betraccium deweveri</i> | <i>Praemososaturnalis pseudokahleri</i> | | | |
| | | <i>Lysemelas olbia</i> | <i>Praemososaturnalis multidentatus</i> | | | |
| | | | <i>Lysemelas olbia</i> | | | |
| | Middle | | <i>Trialatus robustus-L. olbia</i> | | | |
| | Lower | <i>Capnodoce crystallina</i> | <i>Capnodoce-Trialatus</i> | <i>Capnodoce ruesti</i> | | |
| Carnian | Upper | <i>Capnuchosphaera theloides</i> | | <i>Nakasekoellus inkensis</i> | | |
| | | | <i>Poulpus carcharus</i> | | | |
| | | | <i>Capnuchosphaera</i> | <i>Tetraporobrachia haeckeli</i> | | |
| | Lower | <i>Tritortis kretaensis kretaensis</i> | | <i>Tritortis kretaensis</i> | | |
| Ladinian | Upper | | <i>Spongoserrula dehli</i> | | | |
| | | <i>Muelleritortis cochleata</i> | <i>Muelleritortis cochleata</i> | <i>Muelleritortis cochleata</i> | | |
| | Lower | <i>Falcispongus falciformis</i> | | | <i>Ladionocampe multiperforata</i> | |
| | | <i>Oertlispongus inaequispongus</i> | <i>Yeharaia elegans</i> | | | |
| | | <i>Triassocampe scalaris</i> | | <i>Spongosili-</i> <i>carmiger</i> <i>italicus</i> | <i>O. inaequispinosus</i> <i>O. primitivus</i> <i>S. i. transitus</i> | |
| Anisian | Upper | | "Spine A2" | | | |
| | | <i>Triassocampe deweveri</i> | <i>Triassocampe deweveri</i> | <i>Tetraspinocyrtis laevis</i> | | |
| | Middle | <i>Triassocampe coronata</i> | <i>Triassocampe coronata</i> | <i>Parasepsagon robustus</i> | | |
| | | | | | | |
| Lower | <i>Hozmadia gifuensis</i> | <i>Eptingium nakasekoi</i> | | | | |
| Olenekian | Upper | <i>Pseudostylosphaera fragilis</i> | <i>Parentactinia nakatsugawaensis</i> | | | |
| | | | <i>Follicucullus</i> | | | |

coexisted with newly appeared progressive ones), and Late Triassic (the epoch of new taxa predominance and formation of typical Mesozoic fauna). Afterward, the correctness of this idea was proved, and new possibilities to detail the radiolarian-based stratigraphy, first of all, for the Middle–Upper Triassic appeared.

Taxa used most frequently to recognize biostratigraphic units are those having their first occurrences in the Triassic and distinguished from earlier forms by the essentially different morphology (Bragin, 1991, 1999).

These are families Triassocampidae, Oertlispongiidae, Muelleritortiidae, Capnuchosphaeridae, Pantanelliidae, and Saturnalidae. Most of index-species and characteristic taxa of biostratigraphic units recognized here belong to these families. The distinguished zones are in correspondence with evolutionary stages of these groups and sometimes with morphogenesis of individual taxa.

A good example is the family Oertlispongiidae characteristic of the upper Lower Triassic, the entire Middle Triassic, and the lower Carnian. The family

demonstrates changes in morphology of main spines from smooth and straight at the beginning to curved, then to blade-shaped, and finally, to lobate (Bragin, 1999). Due to a rapid substitution of allied morphotypes, several biostratigraphic units can be recognized in the Middle Triassic (table). Another example is the genus *Triassocampe*, which shows the following phylogenetic succession: *Triassocampe coronata*—*T. deweveri*—*T. scalaris*—*T. sulovens* (Bragin, 1999) also taken into account in the Triassic zonation in the Far East of Russia (table).

Analyzing the Triassic radiolarian evolution, it is possible to establish many well-traceable levels and intervals, where stratigraphically important taxa had their first or last occurrences (Bragin, 1999):

(1) The uppermost Olenekian–lowermost Anisian or the appearance period of the genus *Hozmadia* (monocyrtoid nassellarians); the interval can be recognized in the Dal'negorsk and Khabarovsk areas of Sikhote-Alin' (Bragin, 1991, 1992) and in the Kinkazan Mountain sections of central Japan (Sugiyama, 1992).

(2) The lower–middle Anisian boundary corresponding to the appearance level of the genus *Pararuesticyrtium* (the earliest multicyrtoid nassellarians) and the nassellarian families Tripedurnulidae and Eptingidae; the level is defined in the Dal'negorsk area of Sikhote-Alin' (Bragin, 1991).

(3) The middle part of the middle Anisian, when the earliest *Triassocampe* forms (*Triassocampe coronata* and *T. diordinis*) appeared; the interval is recognizable in the Dal'negorsk and Khabarovsk areas of Sikhote-Alin' (Bragin, 1991, 1992) and in the Kinkazan and Inuyama sections of Japan (Sugiyama, 1992; Matsuoka *et al.*, 1994).

(4) The middle–upper Anisian boundary marking the appearance of advanced *Triassocampe* forms (*T. deweveri*), *Hindeosphaera* genus, and families Relindellidae and Pentactinocarpidae; the level is detected in the Dal'negorsk and Khabarovsk areas of Sikhote-Alin' (Bragin, 1991, 1992), in the Kinkazan and Inuyama sections of Japan (Sugiyama, 1992; Matsuoka *et al.*, 1994), and in the Alpine–Mediterranean region (Kozur and Mostler, 1994).

(5) The upper Anisian–lower Ladinian interval, when higher *Triassocampe* forms (*T. scalaris*) and progressive Oertlispongiidae (*Oertlispongius inaequispinosus*) appear in association with genera *Pylostephanidium*, *Yeharaia*, *Silicarmiger*, and *Triassobipedis*; the interval is recognized in the Dal'negorsk area of Sikhote-Alin' (Bragin, 1991), Inuyama area of Japan (Yao, 1982; Matsuoka *et al.*, 1994), the Koryak Upland (Bragin, 1991), and northern Italy (Kozur and Mostler, 1994).

(6) The middle part of the lower Ladinian or the appearance time of Oertlispongiidae forms with flat spines (genera *Falcispongius* and *Baumgartneria*); the level is recognized in the Dal'negorsk area of Sikhote-Alin' and northern Italy (Kozur and Mostler, 1994).

(7) The middle part of the upper Ladinian characterizing the appearance interval of Muelleritortiidae, higher Oertlispongiidae forms (genera *Spongoserrula* and *Pterospongius*), and Austrisaturnalidae with parallel extinction of *Triassocampe deweveri* species; the interval is distinguished in the Dal'negorsk area of Sikhote-Alin' (Bragin, 1991), southern Sakhalin (Bragin, 1986, 1991), Hungary and Austria (Kozur and Mostler, 1994).

(8) The Ladinian–Carnian boundary corresponding to the initial dominance of the genus *Tritortis* (Muelleritortiidae) and to appearance level of the genera *Relindella* and *Pentaspogodiscus*, and also of the early *Xiphotheca* forms; the level is recognized in the Dal'negorsk area of Sikhote-Alin' (Bragin, 1991), southern Sakhalin (Bragin, 1986, 1991), Hungary and Austria (Kozur and Mostler, 1994).

(9) The upper part of the lower Carnian, when of the earliest Saturnalidae (*Palaeosaturnalis*) appeared, but Oertlispongiidae and Muelleritortiidae became extinct; the interval is recognized in Hungary (Kozur and Mostler, 1994), southern Sakhalin, and Turkey.

(10) The middle part of the upper Carnian, when families Capnuhosphaeridae and Capnodocidae appeared along with nassellarian genera *Japonocampe*, *Multimonilis*, and *Latium*; the interval is recognized in the Dal'negorsk area of Sikhote-Alin' (Bragin, 1991), southern Sakhalin (Bragin, 1986, 1991), and Japan (Yao, 1982; Matsuoka *et al.*, 1994).

(11) The Carnian–Norian boundary marking the initial bloom of subfamily Capnodocinae, extinction of Austrisaturnalidae, and appearance of genera *Squibolella* and *Nabolella*; the level is recognized in the Dal'negorsk area of Sikhote-Alin' (Bragin, 1991), southern Sakhalin (Bragin, 1986, 1991), and the Koryak Upland (Bragin, 1991, 1992).

(12) The middle–upper Norian boundary or the level marking the first occurrence of subfamily Pantanellinae and genera *Livarella*, *Praemesosaturnalis*, and *Pseudoheliodiscus*, simultaneous extinction of family Capnuhosphaeridae, subfamily Capnodocinae, and genus *Triassocampe*, as well as the prosperity time of Ferresidae; the level is recognized in the Dal'negorsk area of Sikhote-Alin' (Bragin, 1991), Southern Sakhalin (Bragin, 1986, 1991), the Koryak Upland (Bragin, 1991a, 1992), Japan (Yao, 1982; Yoshida, 1986; Matsuoka *et al.*, 1994), Oregon (Blome, 1984), and British Columbia (Blome, 1984; Carter, 1993).

(13) The Triassic–Jurassic boundary corresponding to extinction level of genera *Livarella*, *Pentactinocarpus*, *Ferresium*, *Risella*, and *Eptingium* (Bragin, 1994); the level is recognized in Japan (Yao, 1982; Yoshida, 1986; Matsuoka *et al.*, 1994), Oregon (Blome, 1984), and British Columbia (Blome, 1984; Carter, 1993).

These reliable marker intervals and levels show that the suggested zonal scheme is well substantiated. However, the distinguished biostratigraphic units are well recognizable only in the warm-water paleogeographic

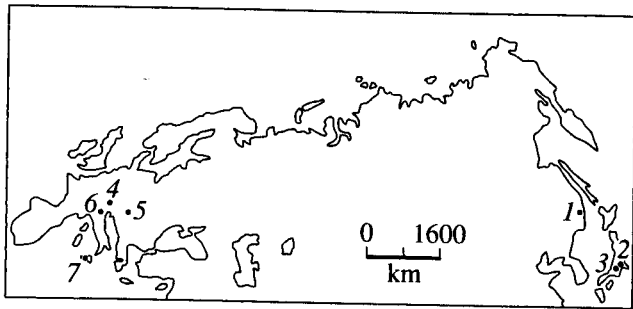


Fig. 1. The Triassic reference sections of Eurasia used as basis for radiolarian zonations: (1) Dal'negorsk of Sikhote-Alin'; (2) Kinkazan of Japan; (3) Inuyama of Japan; (4) Zlam-bachgraben of Austria; (5) Koveskal and Dallapuzhta of Hungary, Balaton Highland; (6) Passo della Gabiola of Italy; (7) Monte Cammarata of Italy, Sicily.

regions. The Boreal and Notal radiolarian assemblages of the Triassic from the Omolon massif and New Zealand have essentially different taxonomic composition (Aita, 1994; Bragin, 1994; Egorov and Bragin, 1995). The radiolarian-based correlation of boreal and tropical sections is a subject of future investigations.

This article presents the Triassic radiolarian biostratigraphic units recognized in siliceous sections, which have their own merits and shortcomings. The undoubted advantage over carbonate and terrigenous deposits is that they are of the monofacies type being characterized throughout by highly diverse radiolarian assemblages. Accordingly, we may establish biostratigraphic succession within a considerable stratigraphic interval showing only minor facies changes. On the contrary, in terrigenous and carbonate sections accumulated in shallower settings, radiolarians are often confined to separate short intervals or even to local levels, and changes in their assemblages are frequently caused by the environmental factors (e.g., by transition from nearly oceanic to neritic conditions and *vice versa*).

The main shortcoming of siliceous sections is their complicated geological structure. Mesozoic siliceous sections in mobile belts experienced different tectonic dislocations difficult for recognition and responsible for origin of frequent gaps or repeating intervals. The difficulty can be surmounted by a thorough investigation and correlation of undisturbed intervals in the sections in order to reconstruct their original succession. This approach was proved to be correct by means of independent and well compatible data on siliceous, carbonate, and terrigenous facies (Bragin, 1991; Carter, 1993; Kozur and Mostler, 1994; Blome *et al.*, 1995; Sugiyama, 1997).

The suggested zonation represents a considerably modified scheme for the Triassic siliceous deposits of eastern Russia as compared to that published more than 10 years ago (Bragin, 1988) (table). As before, the Triassic siliceous section of the Dal'negorsk area in Sikhote-Alin' (Bragin *et al.*, 1988; Bragin, 1991) was

taken as the reference one (Figs. 1–3). The current investigations of the Dal'negorsk section confirm in general the previous conclusions, though the modifications increase the resolution of the scheme. The Dal'negorsk section is correlated to other siliceous sections in the Pacific belt, including Japan, and to carbonate and terrigenous sections located occasionally very far away (table, Fig. 1).

THE TRIASSIC RADIOLARIAN ZONATION OLENEKIAN STAGE

Pseudostylosphaera fragilis Beds

Index-species: *Pseudostylosphaera fragilis* (Bragin) (=“*Stylosphaera*” *fragilis* Bragin, 1991, p. 89, Plate 1, Fig. 4).

Type area: Sikhote-Alin', the Triassic section at the Dal'negorsk Settlement, Beds 4, 5 (Bragin *et al.*, 1988; Bragin, 1991, with modifications).

Lithology: (Figs. 2, 3).¹ Red, crimson- and brick-red indistinctly bedded, locally indistinctly flaggy siliceous mudstones with interbeds of light gray–green siliceous mudstones intercalated with frequent thin interbeds of light bluish gray and light greenish gray translucent glassy cherts, and with rare interbeds of black carbonaceous mudstones (at the top of the unit). Thickness is 8.5 m.

Nomenclature. Stratigraphic range of the unit is as previously established (the upper Olenekian).

Stratigraphy and paleontological characteristics. The lower boundary of the beds is drawn at the first occurrence level of index-species in association with *Hozmadia ozawai* Sugiyama, *Parentactinia nakataugawaensis* Sugiyama, and *Pseudostylosphaera kozuri* Sugiyama (Fig. 3). Slightly above there appear *Cryptostephanidium japonicum* (Nakaseko et Nishimura), *Parasepsagon* sp. cf. *P. longidentatum* (Kozur et Mostler), *Spongostephanidium longispinosum* Sashida, and *Eptingium nakasekoi* Kozur et Mostler. The beds also yield bilaterally symmetrical forms of the genus *Follicucullus* and poorly studied abundant forms with large rod-shaped spines, which may represent the early Paurinellidae (spumellarians).

Age substantiation. Beds 4 and 5 of the Dal'negorsk section are characterized by conodonts typical of the *Neospathodus triangularis* and *N. homeri* zones of the upper Olenekian, or, according to the other terminology, of the Spathian Stage (Bragin, 1991). The siliceous sections with similar paleontological characteristics are known near the Sadovyi Settlement and Khabarovsk (Bragin, 1991, 1992), and also in the Inuyama area of central Japan (Sugiyama, 1992; Matsuoka *et al.*, 1994; Kamata, 1995).

Note. Being well traceable, this unit cannot be ranked as a zone because the underlying beds are

¹ Lithology is described only for biostratigraphic units distinguished in the Dal'negorsk stratotype.

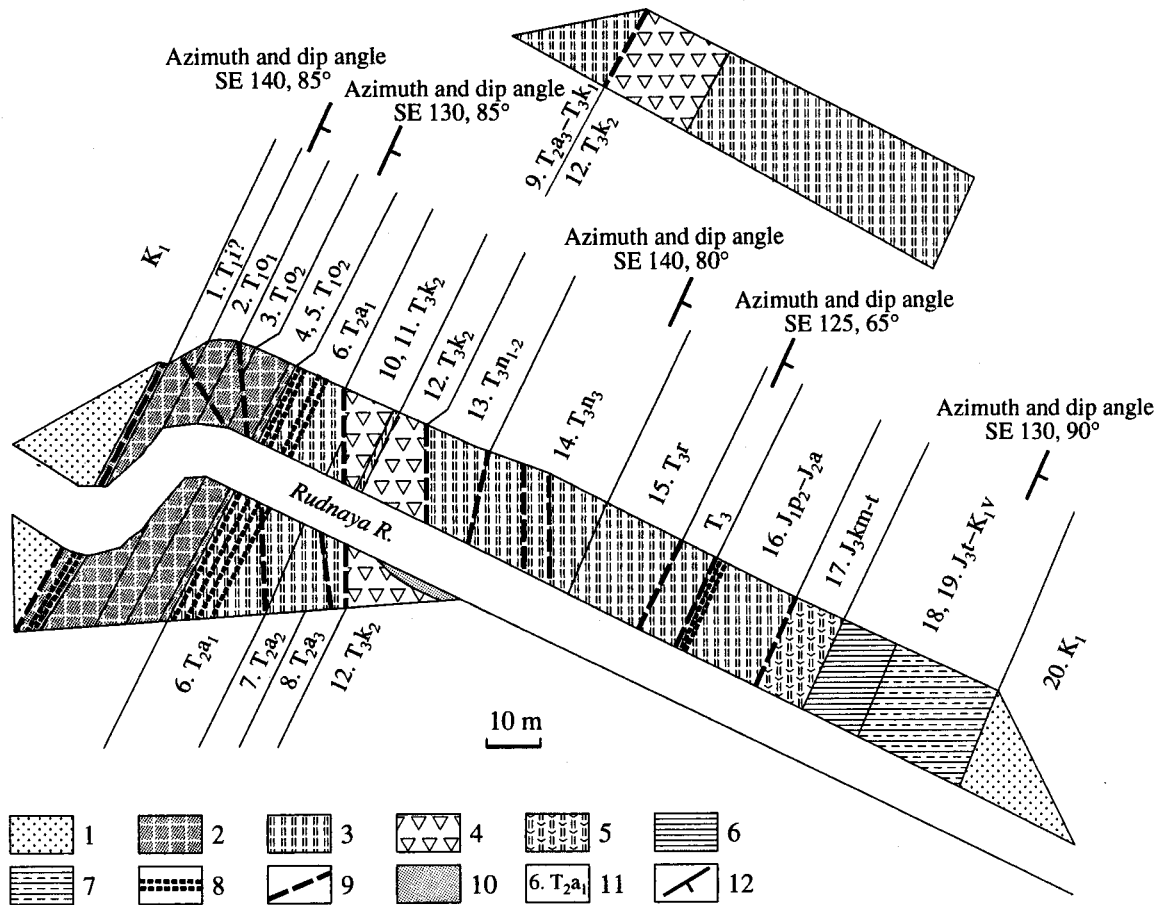


Fig. 2. The Dal'negorsk section of siliceous, volcanogenic and terrigenous Triassic–Lower Cretaceous deposits: (1) sandstone; (2) siliceous mudstone; (3) chert; (4) basalt, diabase, and hyaloclastite; (5) siliceous tuffite; (6) mudstone with siltstone interbeds; (7) siltstone with mudstone and sandstone interbeds; (8) horizons of carbonaceous rocks; (9) fault; (10), dike of intermediate composition; (11) bed number and index; (12) bed attitude.

devoid of representative radiolarians. Radiolarians of the Lower Triassic, especially the Induan and the lower Olenekian, have extremely poor taxonomic composition and are known from few localities. As many other organic groups, radiolarians became almost extinct at the end of the Permian and gained the taxonomic diversity very slowly during the Early Triassic time (Bragin, 1991; Kozur *et al.*, 1996b).

Distribution. Sikhote-Alin' is the type region (Bragin, 1991). In Japan this stratigraphic interval includes the *Follicucullus* and *Parentactinia nakatsugawaensis* zones (Sugiyama, 1992). The radiolarian assemblage of the *Parentactinia nakatsugawaensis* Zone is here similar in composition to that of the *Pseudostylosphaera fragilis* Beds but more diverse owing to occurrence of the genera *Poulpus* and *Nofrema* (nassellarians). Assemblages of the *P. nakatsugawaensis* Zone are widespread in central and southwestern Japan (Sashida, 1983, 1991; Sugiyama, 1992; Kamata, 1995).

LOWER ANISIAN

Hozmadia gifuensis Zone

Index-species: *Hozmadia gifuensis* Sugiyama (Sugiyama, 1992, p. 1194, Figs. 9, 6–8).

Type area: central Japan, Gifu Prefecture, the Kinkazan Mountain (Sugiyama, 1992).

Nomenclature. The *Hozmadia* Genus-zone of the same scope was previously established in Sikhote-Alin' (Bragin, 1991). After describing a number of new species of this genus, Sugiyama (1992) recognized the *Hozmadia gifuensis* Zone virtually correspondent to that mentioned above. It should be noted that the lower zonal boundary appears coincident in Japan with the Lower–Middle Triassic boundary, because the lower Anisian age of the conodont *Neospathodus timorensis* Zone is widely accepted (Sweet and Bergstrom, 1986; Bragin, 1991; Sugiyama, 1992; Matsuoka *et al.*, 1994).

Stratigraphy and paleontological characteristics. The lower boundary is drawn at the first occurrence level of the index-species and associated *Celluronta donax* Sugiyama (Fig. 3). Many species, such as *Eptingium nakasekoi* Kozur et Mostler, *Cryptostephanidium*

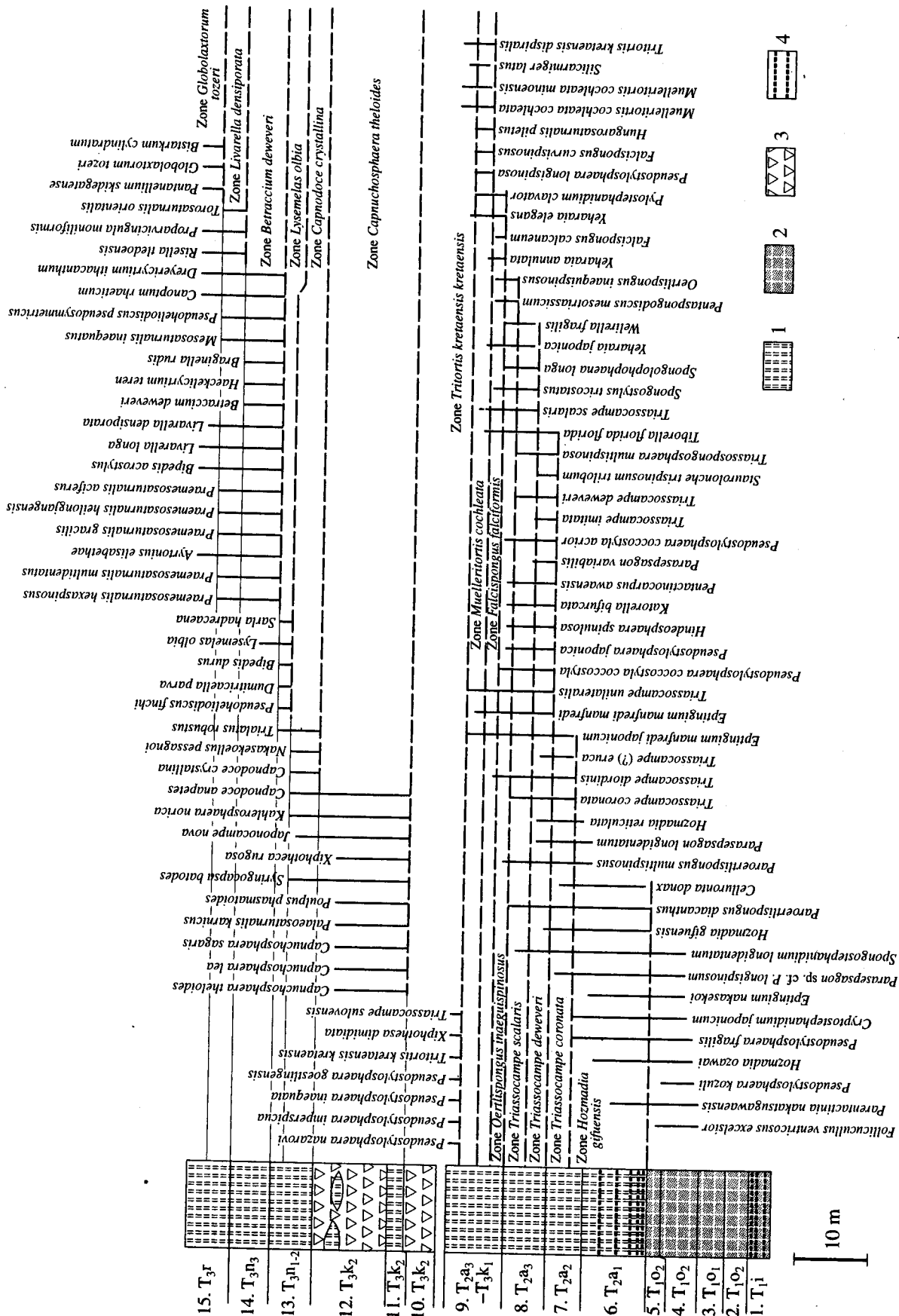


Fig. 3. Subdivision of the Dal'negorsk section on the basis of radiolarians: (1) chert; (2) siliceous mudstone; (3) basalt, diabase, and hyaloclastitic; (4) horizon of carbonaceous deposits.

japonicum, *Parentactinia nakatsugawaensis*, *Paroertlispongos diacanthus*, *Pseudostylosphaera fragilis*, and *Spongostephanidium longispinosum*, are inherited from the underlying beds. In the Dal'negorsk section (Bragin *et al.*, 1988), the upper part of the zone contains *Paroertlispongos multispinosus* Kozur et Mostler, *Hozmadia rotunda* (Nakaseko et Nishimura), and *H. reticulata dimitrica* Kozur et Mostler (Bragin, 1991). *Tiborella* sp. and *Triassocampe* (?) sp. also have their first occurrences in this zone of the Dal'negorsk section.

Age substantiation. In the Dal'negorsk and Khabarovsk sections, this interval encloses conodonts of the *Neospathodus timorensis* Zone (Bragin, 1991) universally attributed to the uppermost Olenekian-lower Anisian (Sweet, 1970; Sweet *et al.*, 1971; Clark *et al.*, 1979; Kozur, 1980; Koike, 1981; Sashida and Igo, 1992). In the Kinkazan section (Sugiyama, 1992), the corresponding deposits yielded no conodonts, and the zone scope was determined according to its position between reliably dated deposits of the lower Triassic and the middle Anisian.

Note. In Sikhote-Alin' and Japan, the early Anisian time was marked by the increasing silica accumulation and rapid diversification of radiolarians. Nassellarians were previously considered to appear at that time (Bragin, 1991), but now they are proved to occur in the upper beds of the Lower Triassic (Sugiyama, 1992; Kamata, 1995).

Distribution: central Japan (Sugiyama, 1992; Matsuoka *et al.*, 1994) and Sikhote-Alin' (Bragin, 1991a, 1992); similar radiolarian assemblage was found in Thailand (Sashida and Igo, 1992).

MIDDLE ANISIAN

Triassocampe coronata Zone

Index-species: *Triassocampe coronata* Bragin (Bragin, 1991, p. 99, Plate 1, Fig. 15).

Type area: central Japan, Gifu Prefecture, the Kinkazan Mountain (Sugiyama, 1992).

Nomenclature. An analogous *Triassocampe diordinis* Zone embracing the entire middle Anisian was previously established in Sikhote-Alin' (Bragin, 1991). Later the *Triassocampe coronata* Zone of the same scope was recognized in Japan (Sugiyama, 1992). The well-identifiable species *T. coronata* appears to be more suitable for the zonal index-species. The lower boundary cannot be precisely defined in the type area because of abnormal stratigraphic contact between this zone and underlying beds (Sugiyama, 1992). In the Dal'negorsk section, the *T. coronata* Zone rests immediately on the lower Anisian *Hozmadia gifuensis* Zone.

Stratigraphy and paleontological characteristics. The lower boundary of the zone is drawn at the first occurrence level of the index-species associated with *Eptingium manfredi japonicum* (Nakaseko et Nishimura), *Hindeosphaera spinulosa* (Nakaseko et Nishimura), *Pararuesticyrtium imitatum* (Bragin), *Pseudostylosphaera compacta* (Nakaseko et Nishimura), *Triassocampe* sp. aff. *T. diordinis* Bragin, *T. diordinis* Bragin, and *T. (?) eruca* Sugiyama (Fig. 3). The zone contains *Hozmadia gifuensis*, *H. rotunda*, *Paroertlispongos diacanthus*, *Parasepsagon antiquum* (Sugiyama), and *Katorella bifurcata* Kozur et Mostler, all inherited from the preceding zone. Species *Celluronta donax* has its last occurrence in the upper part of the zone.

Age substantiation. In the sections of Sikhote Alin' (Dal'negorsk, Vysokogorsk) and Japan (Inuyama, Kinkazan Mountain, Shikoku Island), this interval yields the middle Anisian conodont species *Neogondolella bulgarica*. In the Dal'negorsk section, this species appears before the characteristic assemblage of the *Triassocampe coronata* Zone. For this reason, the lower boundary of the zone in the suggested scheme does not coincide with the lower-middle Anisian boundary, as it does in Japan (Sugiyama, 1997). It lies within the middle Anisian (Fig. 3, table).

Note. In the Pacific belt sections, the stratigraphic interval in question is characterized by the first occurrence of abundant and diverse forms of the genus *Triassocampe* (multicyrtoid nassellarians). These primitive forms have poorly sculptured test segments and one or two pore sets. In the Tethyan area, representative of *Triassocampe* occur sporadically probably because of relative isolation of the Tethys from the Paleopacific basins. The Mediterranean *Parasepsagon robustus* Zone spanning the same interval (Kozur and Mostler, 1994) is characterized by radiolarian assemblage essentially different in taxonomic composition from that of the *Triassocampe coronata* Zone in Sikhote-Alin' and Japan. It is still difficult to correlate these units.

Distribution: central and southwestern areas of Japan (Ishida, 1984; Sugiyama, 1992; Matsuoka *et al.*, 1994), Sikhote-Alin' (Bragin, 1991).

UPPER ANISIAN

Triassocampe deweveri Zone

Index-species: *Triassocampe deweveri* (Nakaseko et Nishimura) (= *Diotyomitrella deweveri* Nakaseko et Nishimura, 1979, p. 77, Plate X, Figs. 8, 9).

Type area: central Japan, Gifu Prefecture, the Inuyama section (Yao, 1982).

Nomenclature. The zone was originally established in the scope of the Ladinian Stage (Yao, 1982). Later it was shown (Bragin, 1991) that the index-species and some accompanying forms appear for the first time in the upper Anisian deposits, whereas the upper Ladinian beds are characterized by radically different radiolarian assemblages. Accordingly, the zone was considered as corresponding to the interval of the upper Anisian-lower Ladinian (Bragin, 1991). Further, the upper part of the zone was recognized as an independent *Triasso-*

campe scalaris Zone. The initial scope of the *T. deweveri* Zone was reduced to the lower part of the upper Anisian.

Stratigraphy and paleontological characteristics. The lower boundary is drawn at the first occurrence level of the index-species and associated *Eptingium manfredi manfredi* Dumitrica, Kozur et Mostler, *Parasepsagon variabilis* (Nakaseko et Nishimura), *Pseudostylosphaera japonica* (Nakaseko et Nishimura), *P. coccostyla acrior* (Bragin), *P. coccostyla coccostyla* (Rust), *Pentactinocarpus fusiformis* Dumitrica, *P. awaensis* (Nakaseko et Nishimura), *Staurolonche trispinosum trilobum* (Nakaseko et Nishimura), *Triassistephanidium anisicum* Kozur, Krainer et Mostler, and *Triassospongospaera multispinosa* Kozur et Mostler (Fig. 3). *Triassocampe coronata*, *T. diordinis*, *Hozmadia rotunda*, *Eptingium manfredi japonicum*, and *Hindeosphaera spinulosa* still occur in the zone, but *Hozmadia gifuensis* disappears.

Age substantiation. In the Sikhote-Alin' sections, this stratigraphic interval contains conodonts of the upper Anisian *Neogondolella excelsa* Zone (Bragin, 1991). Mediterranean analogues of the zone enclose the late Anisian ammonoids and conodonts (Kozur et al., 1996a). In the scheme suggested, the lower boundary of the *T. deweveri* Zone does not lie within the middle Anisian deposits, as it does in Japan (Sugiyama, 1997), but coincides with the middle-upper Anisian boundary (Fig. 3, table). In the Japanese sections, this zone is not sufficiently characterized by other fossil groups.

Notes. The index-species *Triassocampe deweveri* shows three pore sets in segments and no dorsal ridge. These characters suggest that this species could be a descendant of primitive *Triassocampe coronata* or *T. diordinia* (Bragin, 1999) that must be verified in the future.

There are minor differences between the late Anisian radiolarian assemblages of the Pacific and Tethyan regions. Abundant and diverse *Triassocampe* forms also appeared in the Tethys, but the genus *Yehararaia* is represented there by species other than those from the Pacific belt (Kozur and Mostler, 1994; Kozur et al., 1996a).

Distribution: Sikhote-Alin', the Koryak Upland, Japan (the lower part of the analogous zone, according to Yao 1982; Matsuoka et al., 1994), and Mediterranean region (Kozur and Mostler, 1994; Kozur et al., 1996a).

UPPERMOST ANISIAN–LOWERMOST LADINIAN

Triassocampe scalaris Zone

Index-species: *Triassocampe scalaris* (Dumitrica, Kozur et Mostler, 1980, p. 26, Plate 9, Figs. 5, 6, 11).

Type area: Sikhote-Alin', the Dal'negorsk Settlement Bed 9, the lower part (Bragin, et al., 1988; Bragin, 1991, with modifications).

Lithology: light gray to gray flaggy, locally massive glassy quartzite-like cherts. The zone spans the interval of 0–1.2 m from the base of the bed (Figs. 2, 3).

Nomenclature. The zone is newly established.

Stratigraphy and paleontological characteristics. The lower boundary is drawn at the first occurrence level of the index-species in association with *Spongostylus tricostatus* Kozur et Mostler, *Spongolophphaena longa* Kozur et Mostler, *Welirella fragilis* Bragin, and *Yehararaia japonica* Nakaseko et Nishimura (Fig. 3). *Hozmadia rotunda* passes from the preceding zone. *Triassocampe coronata* disappears at the upper boundary of the zone, and *T. diordinis* passes into overlying deposits. The zone contains *Eptingium manfredi manfredi* (the species epibole is the lower Ladinian) and *Hindeosphaera spinulosa*.

Age substantiation. In the Dal'negorsk sections, this stratigraphic interval yielded early Ladinian conodonts *Neogondolella haslashensis* and *N. bakalovi* (Bragin, 1991). In the eastern shore of the Tonino-Aniva Peninsula (Sakhalin), the radiolarian assemblage of the zone is associated with the conodont species *Neogondolella transita* (the uppermost Anisian–lower Ladinian). Mediterranean analogues of the zone are characterized by ammonoids and conodonts characteristic of different levels of the upper Anisian and lower Ladinian (Dumitrica et al., 1980; Kozur and Mostler, 1994; Kozur et al., 1996a, 1996b). The lower boundary of the *T. scalaris* Zone is correlated with that of the *Tetraspinocyrtis laevis* Zone of the Mediterranean area (Kozur and Mostler, 1994).

Notes. The index-species *Triassocampe scalaris* has the well-sculptured test segments with distinct dorsal ridge thus continuing the phylogenetic line of the genus *Triassocampe* (Bragin, 1999).

Distribution: Sikhote-Alin' (the Dal'negorsk and Khabarovsk areas), Sakhalin (the Tonino-Aniva Peninsula), the Koryak Upland (the Ekonai Terrane and the Upper Khatyrka Melange) (Bragin, 1991), Japan (the Mino-Tamba and Chichibu terranes) (Yao, 1982, 1990; Matsuoka et al., 1994), the Philippines (Yeh, 1990), Northern Italy (Dumitrica et al., 1980; Kozur and Mostler, 1994), Southern Italy (De Wever et al., 1990), and Hungary (Kozur and Mostler, 1994).

BASAL LOWER LADINIAN

Oertlispongus inaequispinosus Zone

Index-species: *Oertlispongus inaequispinosus* (Dumitrica, Kozur and Mostler, 1980, p. 5, Plate 10, Fig. 7).

Type area: Italy, the Passo della Gabiola section.

Nomenclature. The unit was first established as a middle subzone of the lower Ladinian (Kozur and Mostler, 1994). In the present article, it is ranked as a zone corresponding in scope to the Mediterranean *Oertlispongus primitivus* and *O. inaequispinosus* subzones (Kozur and Mostler, 1994).

Stratigraphy and paleontological characteristics. The lower boundary is drawn at the first occurrence level of the index-species and associated *Pentaspogoniscus mesotriassicus* Dumitrica, Kozur et Mostler and *Spongostylus* sp. aff. *S. nakasekoi* Kozur et Mostler (Fig. 3). *Triassocampe coronata* and *T. deweveri* have their last occurrences at this boundary.

Age substantiation. In the type section, this stratigraphic interval corresponds to the upper part of the ammonite *Xenoprotrachyceras reitzi* Zone of the middle lower Ladinian (Kozur and Mostler, 1994). In the Dal'negorsk section, the unit is characterized by the early Ladinian conodonts (Bragin, 1991).

Notes. In addition to nassellarians, the family Oertlispongiidae appears to be of a great significance for the lower Ladinian stratigraphy. The family includes typical forms of Mesozoic spumellarians having spongy tests and complicated spines (genera *Oertlispongius* and *Falcispongius*, which substitute the primitive genus *Paroertlispongius* and are succeeded by advanced *Spongoserula* and *Pterospongius* genera). The stratigraphic range of Oertlispongiidae can serve as a base for more refined subdivision of the Ladinian Stage than it was done before (Bragin, 1999). However, such a progress is hampered by a relative scarcity of Oertlispongiidae in the Pacific region in comparison with the Mediterranean area (Bragin, 1994).

Distribution: northern Italy, Hungary (Kozur and Mostler, 1994), and Sikhote-Alin'.

TERMINAL LOWER LADINIAN AND BASAL UPPER LADINIAN

Falcispongius falciformis Zone

Index-species: *Falcispongius falciformis* (Dumitrica, 1982, p. 66, Plate 1, Fig. 5).

Type area: the Dal'negorsk section, Bed 9 (Bragin et al., 1988), above the *Oertlispongius inaequispinosus* Zone.

Lithology: light gray to gray flaggy, locally massive glassy, quartzite-like cherts. The zone embraces the interval of 2.5–6 m above the bed base (Figs. 2, 3).

Nomenclature. The zone is newly established.

Stratigraphy and paleontological characteristics. The lower boundary of the zone is drawn at the first occurrence level of the index-species and associated *Pylostephanidium clavator* Dumitrica, *Yeharaia elegans* Nakaseko et Nishimura, and *Y. (?) annulata* Nakaseko et Nishimura (Fig. 3). Some species of the preceding zone, such as *Spongostylus tricostatus* and *Spongolophophaena longa*, disappear within the unit, and but others (*Eptingium manfredi*, *Pentactinocarpus awaensis* and *Pseudostylosphaera coccostyla*) become reduced in abundance.

Age substantiation. In the Dal'negorsk section, this interval contains the early Ladinian conodonts, being overlain by deposits attributed to the middle and upper

parts of the upper Ladinian (Bragin, 1991). The lower boundary of the *Falcispongius falciformis* Zone corresponds to that of the *Ladinocampe multiperforata* Zone of the Mediterranean area (Kozur and Mostler, 1994). The mentioned zones are correlative with the upper part of the *Yeharaia elegans* Zone of Japan (Sugiyama, 1997).

Distribution: Sikhote-Alin', the Dal'negorsk area, and probably, the Mediterranean region.

MIDDLE AND UPPER PARTS OF THE UPPER LADINIAN SUBSTAGE

Muelleritortis cochleata Zone

Index-species: *Muelleritortis cochleata* (Nakaseko et Nishimura) (= *Emiluvia cochleata* Nakaseko et Nishimura, 1979, p. 70, Plate III, Figs. 2–4, 6).

Type area, Hungary, Balaton Highland, the Koveskal section (Kozur and Mostler, 1994).

Nomenclature. The zone was established by Kozur and Mostler (1994) in the scope of the middle–upper Langobardian. This interval was referred earlier to the *Sarla dispiralis* Zone of the upper Ladinian–Carnian (Bragin, 1991). The last taxon identified now as *Tritortis kretaensis dispiralis* (Bragin) is shown to be the most conservative representative of Muelleritortidae. Therefore, it seems expedient to reject the *dispiralis* Zone in favor of more detailed subdivisions distinguished by Kozur and Mostler (1994).

Stratigraphy and paleontological characteristics. The lower boundary is drawn at the first occurrence level of the index-species and its subspecies (Kozur and Mostler, 1994) associated with *Hungarosaturnalis pilatus* (Nakaseko et Nishimura), *Falcispongius curvispinosus* (Dumitrica), *Pseudostylosphaera longispinosa* Kozur et Mostler, *Silicarmiger latus* Kozur et Mostler, *Triassocampe* sp. ex gr. *T. sulovensis* Kozur, and *Tritortis kretaensis dispiralis* (Bragin). Simultaneously, this is the last occurrence level of *Falcispongius calcaneum*, *Oertlispongius inaequispinosus*, *Pseudostylosphaera japonica*, *P. coccostyla*, and *Hindeosphaera spinulosa* (Fig. 3). *Spongoserula rarauana* Dumitrica appears inside the zone, whereas *Triassocampe scalaris*, *Silicarmiger costatus*, *Pylostephanidium clavator*, and *Pentactinocarpus fusiformis* still occur in this interval.

Age substantiation. In the Sikhote-Alin' section, this stratigraphic interval corresponds to the conodont *Sephardiella mungoensis* Zone (middle and upper parts of the upper Ladinian). Conodonts of the same age were found in the *Muelleritortis cochleata* Zone of Hungary (Kozur and Mostler, 1994). The same zone was also established in Japan (Sugiyama, 1997). The lower boundary of the *M. cochleata* Zone is one of the most reliable markers in the radiolarian stratigraphy.

Notes. The upper Ladinian is the first interval of the great Triassic extinction of radiolarians. Most of conservative taxa of Paleozoic and Early Triassic origin became extinct in this interval. *Triassocampe* forms of

reduced diversity become simple in morphology (*Triassocampe* sp. ex gr. *T. sulovensis*). Typical Mesozoic taxa, e.g., Muelleritortiidae, attain increasing importance. Family Oertlispongiidae gives rise to new genera *Spongoserula*, and *Pterospongius* having main spines of complicated morphology. However, these taxa occur in abundance only in the Mediterranean region (Kozur and Mostler, 1996). In their vertical succession, radiolarians reveal distinct step-like patterns of appearance and extinction thus suggesting the short-term taxonomic renewals in composition of assemblages.

Distribution: Mediterranean region (Hungary) (Kozur, 1988a, 1988b; Kozur and Mostler, 1994), Sikhote-Alin, Sakhalin, the Koryak Upland (Bragin, 1991), Japan (Sugiyama, 1997), and Turkey (Bragin and Tekin, 1995).

LOWER CARNIAN

Tritortis kretaensis kretaensis Zone

Index-subspecies: *Tritortis kretaensis kretaensis* (Kozur) (= *Sarla kretaensis* Kozur, Krahl, 1984).

Type area: northern Hungary, the Dallapuzhta section (Kozur and Mostler, 1994).

Nomenclature. The zone was recognized by Kozur and Mostler (1994). In Primor'e, this interval was previously correlated with an upper part of the *Sarla dispiralis* Zone (Bragin, 1991).

Stratigraphy and paleontological characteristics. The lower boundary is drawn at the first occurrence level of the index-subspecies and associated *Pseudostylosphaera nazarovi* Kozur et Mostler, *P. inaequata* (Bragin), *P. goestlingensis* Kozur et Mostler, *Triassocampe sulovensis* Kozur, and *T. baldii* Kozur (Fig. 3). *Tritortis ariana* (Cordey), *Pseudostylosphaera imperispicus* (Bragin), *Xiphotheca* (?) *dimidiata* Bragin appear, and *Tritortis kretaensis dispiralis* continue to occur in the zone, whereas *Muelleritortis cochleata*, *Silicarmiger costatus* S. *latus*, and *Pylostephanidium clavator* become extinct.

Age substantiation. This stratigraphic interval yields the early Carnian conodonts *Neogondolella mostleri*, and *N. diebeli* in Hungary (Kozur and Mostler, 1994) and in Sikhote-Alin' sections.

Note. In Hungary, the lower boundary of the zone is placed at the level of sharp predominance of the index-subspecies over *Muelleritortis cochleata* (Kozur and Mostler, 1994). In the sections of Sikhote-Alin' and other eastern areas of Russia, the subspecies *Tritortis kretaensis kretaensis* has not been recorded below the lower Carnian.

Distribution: Hungary (Kozur and Mostler, 1994), Sikhote-Alin' (Dal'negorsk, Vysokogorsk), Sakhalin (Mt. Yunona) (Bragin, 1991), and Turkey (Bragin and Tekin, 1995).

UPPER CARNIAN

Capnuchosphaera theloides Zone

Index-species: *Capnuchosphaera theloides* De Wever (De Wever et al., 1979, p. 84, Plate 4, Fig. 1).

Type area: Sikhote-Alin', the Dal'negorsk Settlement, Beds 10-12 (Bragin et al., 1988; Bragin, 1991, with modifications).

Lithology: Bed 10 consists of gray-green massive diabases with inclusions of brownish green basalts and thin (0.5-1 m) interbeds and lenses of red occasionally bluish gray jaspers (7 m thick). Bed 11 of red, occasionally gray massive and indistinctly flaggy, frequently clayey jaspers is 2-4 m thick. Bed 12 is composed of dark greenish brown massive pillow-basalts with brownish to greenish red, frequently vesicular hyaloclastites between pillows, and with intercalations of bright red abiogenous jasperoids enclosing separate thin (0.5-2 m) interbeds and rare lenses of dark red indistinctly bedded jaspers. The bed is 15 m thick. (Figs. 2, 3).

Nomenclature. The zone is newly established. In scope, it corresponds to the previous *Capnuchosphaera lea* Subzone (Bragin, 1991). The easily identifiable species *Capnuchosphaera theloides* represents its index-species.

Stratigraphy and paleontological characteristics. The lower boundary of the zone is drawn at the first occurrence level of the index-species and other representatives of the genus *Capnuchosphaera*, such as *C. lea* De Wever, *C. tricornis* De Wever, *C. sagaris* Sugiyama, *C. triassica* De Wever, and others (Fig. 3). In addition, there appear many other taxa of the family Capnuchosphaeridae, e.g., *Icrioma tetrancistrum* de Wever and species of the genus *Sarla*. *Paleosaturnalis* shows its first occurrence in the zone, and *Japonocampe nova* (Yao), *Syringocapsa batodes* De Wever, and *Xiphotheca rugosa* Bragin appear among nassellarians. Last representatives of Oertlispongiidae and Muelleritortiidae completely disappear, but late species of the genus *Triassocampe* (*T. sulovensis*) continue to occur.

Note. The late Carnian radiolarian assemblage finally becomes dominated by taxa of the typical Mesozoic morphology. Radiolarians with skeletons of the initial Paleozoic type (families Pentactinocarpidae, Sepsagonidae, and others) are sporadic and not diverse.

At the base of the *Capnuchosphaera theloides* Zone in the Sikhote Alin', there may be a hiatus corresponding to the middle part of the Carnian Stage. In western Europe, this stratigraphic interval is referred to the *Tetraporobracchia haeckeli* Zone (Kozur and Mostler, 1994).

Age substantiation. In the Dal'negorsk section, the zone under consideration is characterized by late Carnian conodonts *Epigondolella abneptis* and *Neogondolella nodosa*.

Distribution: Sikhote-Alin', Sakhalin, the Koryak Upland (Bragin, 1991), Japan (Yao, 1982; Yoshida, 1986; Matsuoka *et al.*, 1994; Kamata, 1997; Sugiyama, 1997), the Philippines (Yeh, 1990). The Mediterranean *Nakasekoellus polita* Zone corresponds to the upper part of *C. theloides* Zone and contains similar radiolarian assemblage (Kozur and Mostler, 1994). In Japan, the given stratigraphic interval is subdivided to more details (Sugiyama, 1997; see the table).

LOWER-MIDDLE NORIAN

Capnodoce crystallina Zone

Index-species: *Capnodoce crystallina* Pessagno (Pessagno *et al.*, 1979, p. 176, Plate 1, Figs. 1-3).

Type area: Sikhote-Alin', the Dal'negorsk section, Bed 13 (Bragin *et al.*, 1988; Bragin, 1991 with supplements).

Nomenclature. The *Capnodoce antiqua* Subzone of the same scope was previously recognized in the type area (Bragin, 1991). The species *C. antiqua* is a junior synonym of *C. crystallina* (Sugiyama, 1997).

Lithology: gray, lilac-gray, less frequently light gray, thin- to medium-flaggy cherts with rare interbeds of yellowish gray siliceous mudstones. The zone embraces the interval of 0-6 m above the bed base (Figs. 2, 3).

Stratigraphy and paleontological characteristics. The lower boundary is drawn at the first occurrence level of the index-species and other representatives of the genus *Capnodoce*, e.g., of *C. crystallina* Pessagno, *C. ruesti* Kozur et Mostler, and *C. sarisa* De Wever (Fig. 3). In addition, *Nakasekoellus pessagnoii* (Nakaseko et Nishimura) and *Trialatus robustus* (Nakaseko et Nishimura) appear first at this boundary. Some characteristic species of the preceding zone (*Capnuhosphaera theloides* and *C. lea*) disappear. *Icrioma tetrancistrum*, *Kahlerosphaera norica*, and *Japonocampe nova* pass into the following zone.

Age substantiation. In the sections of Sikhote-Alin' (Dal'negorsk and Krasnaya Rechka) and Koryak Upland (Podgornaya), this stratigraphic interval contains conodonts of the *Epigondolella abneptis* and *E. postera* zones of the lower-middle Norian. The same interval in Japan has analogous paleontological characteristics (Yao, 1982). In the Mediterranean region and western North America, the proper radiolarian assemblages are associated with early-middle Norian ammonoids and bivalves (Kozur and Mostler, 1981, 1994; Blome, 1984; Yeh, 1989). The Mediterranean *Capnodoce ruesti* Zone corresponds to the lower Norian (Kozur and Mostler, 1994), and its lower boundary coincides with that of the *C. crystallina* Zone (table).

Distribution: Sikhote-Alin', southern Sakhalin, the Koryak Upland. The unit analogues are recognized in Mexico (Pessagno *et al.*, 1979), Oregon (Blome, 1983, 1984), Japan (Yao, 1982; Yoshida, 1986; Matsuoka

et al., 1994), and Mediterranean region (Kozur and Mostler, 1994).

BASAL UPPER NORIAN

Lysemelas olbia Zone

Index-species: *Lysemelas olbia* (Sugiyama, 1997, p. 160, Figs. 28-1, 43-6-10b).

Type area: Japan, the Inuyama section (Sugiyama, 1997).

Nomenclature. The zone was established in Japan in scope of the lower part of the upper Norian (Sugiyama, 1997).

Stratigraphy and paleontological characteristics. The lower boundary of the zone is drawn at the first occurrence level of the index-species and associated *Pseudoheliodiscus finchi* Pessagno, *Paleosaturnalis* sp. aff. *P. harrisonensis* (Blome), *Bipedis durus* Sugiyama, *Dumitricaella* (?) *parva* Sugiyama, and *Sarla hadrecaena* (De Wever) (Fig. 3). The genus *Capnodoce* disappears at this boundary. *Trialatus robustus* and *Kahlerosphaera norica* have their last occurrences in the zone. The transitory species *Pentactinocarpus sevaticus* is characteristic.

Age substantiation. The zone is characterized by the late Norian conodonts *Epigondolella bidentata*.

Distribution: Japan (Sugiyama, 1997), Sikhote-Alin'.

TERMINAL UPPER NORIAN

Betraccium deweveri Zone

Index-species: *Betraccium deweveri* Pessagno et Blome (1980, p. 235, Plate VI, Fig. 1).

Type area: eastern Oregon, the Supplee-Izee area, section of the Rail Cabin Formation.

Nomenclature. The zone was initially established in Oregon in a rank of a subzone (Blome, 1984) and recognized in the Far East of Russia as the lower subzone of the *Canoptum triassicum* Zone (Bragin, 1991). Its rank was elevated later to a zone (Carter, 1993).

Stratigraphy and paleontological characteristics. The lower boundary of the zone is drawn at the first occurrence level of the index-species. At the same level there appear abundant representatives of genera *Pantanelium* and *Praemesosaturnalis*, as well as species *Ayrtonius elisabethae* Sugiyama, *Bipedis acrostylus* Bragin, *Braginella rudis* (Bragin), *Canoptum rhaeticum* (Yao), *Livarella validus* Yoshida, and *L. densiporata* (Kozur et Mostler) (Fig. 3).

Age substantiation. In the Far East sections of Russia (Dal'negorsk, the Koryak Upland), this zone corresponds to the conodont *Epigondolella bidentata* Zone of the upper Norian. In North America, the zone is dated on the basis of concurrent late Norian conodonts (Carter, 1993).

Notes. At present, this zone is best traceable in radiolarian stratigraphy despite the slight variations in taxonomic composition of zonal assemblages. For instance, the assemblage with *Betraccium deweveri* from Cyprus is impoverished owing to its neritic origin (Bragin and Krylov, 1996).

The *B. deweveri* Zone was earlier considered as spanning the entire upper Norian. The latest investigations in Japanese sections (Sugiyama, 1997) demonstrated, however, that its index-species and typical accompanying taxa appear above the lower boundary of the upper Norian.

Distribution: Oregon, the Rail Cabin Formation (Blome, 1983, 1984; Yeh, 1989); Mexico, the California Peninsula (Pessagno *et al.*, 1979); British Columbia and Alaska (Carter, 1993); the Koryak Upland (Podgor'naya), Sakhalin (Mt. Yunona), and Sikhote-Alin' (Dal'negorsk, Khabarovsk) (Bragin, 1991); Japan (Yao, 1982; Yoshida, 1986; Matsuoka *et al.*, 1994); the Philippines (Yeh, 1990, 1992); New Zealand and Cyprus (Bragin and Krylov, 1996); Turkey (Bragin and Tekin, 1996).

LOWER RHAETIAN

Livarella densiporata Zone

Index-species: *Livarella densiporata* (Kozur and Mostler, 1981, p. 115, Plate 9, Figs. 1a, 1b).

Type area: Austria, Zlambachgraben (Kozur and Mostler, 1994).

Nomenclature. Previously this stratigraphic interval represented an upper part of the *Canoptum triassicum* Zone (Yao, 1982; Bragin, 1991) and was termed the *Livarella gifuensis* Subzone (Bragin, 1991). The species *Livarella densiporata* has a wider geographic range and, therefore, is preferable as the index-species.

Stratigraphy and paleontological characteristics. The lower boundary of the zone is drawn at the first occurrence level of *Risella tledoensis* Carter, *Orbiculiforma* aff. *multibrachiata* Carter, *Proparvicungula* sp. cf. *P. moniliformis* Carter, and *Torosaturnalis orientalis* Bragin (Fig. 3). *Betraccium deweveri* disappears in this interval, but *Bipedis acrostylus*, *Canoptum rhaeticum*, *Deflandrecyrtium nobense*, *Braginella rudis*, and *Livarella validus* are still occurring here.

Age substantiation. In the type area, the zone is characterized by Rhaetian conodonts *Misikella posthernsteini* (Kozur and Mostler, 1994). This species was also found in the Sikhote-Alin' sections (Bragin, 1991).

Distribution: Mediterranean region (Kozur and Mostler, 1994) and eastern Russia (Bragin, 1991). Analogues of this zone are recognized in British Columbia (Carter, 1993), Japan (Yoshida, 1996; Sugiyama, 1997), and the Philippines (Yeh, 1992).

UPPER RHAETIAN

Globolaxtorum tozeri Zone

Index-species: *Globolaxtorum tozeri* (Carter, 1993, p. 111, Plate 19, Figs. 14–16).

Type area: Canada, British Columbia, the Queen Charlotte Islands, sections of the Kunga Island and Kennekott Point.

Nomenclature. The zone was established in British Columbia in the scope of the upper Rhaetian (Carter, 1993).

Stratigraphy and paleontological characteristics. The lower boundary is drawn at the first occurrence level of the index-species and associated *Bistarkum* (?) *cylindratum* Carter and *Pantanellium skidegatense* Pessagno et Blome (Fig. 3). Many species of two underlying zones, e.g., *Praemesosaturnalis hexaspinosus* (Bragin), *P. multidentatus* (Kozur et Mostler), *P. gracilis* (Kozur et Mostler), *P. heilongjiangensis* Yang et Mizutani, *P. aciferus* (Bragin), and *P. diminutus* (Bragin), disappear at this level. *Bipedis acrostylus*, *Canoptum rhaeticum*, and *Dreyericyrtium ithacanthum* continue to occur in the zone. The most of Rhaetian radiolarian genera become extinct at the upper zonal boundary.

Age substantiation. In the stratotype, the zone is characterized by late Rhaetian ammonites *Choristoceras rhaeticum* Guembel and *C. nobile* Mojsisovics (Carter, 1993).

Notes. The Rhaetian radiolarian assemblages are peculiar in composition. Sharply dominant here are typical Mesozoic groups, families Pantanelliidae and Saturnalidae among them, which evolve further in the Jurassic. Many taxa, e.g., *Globolaxtorum tozeri* and *Pseudohagiastrum* (?) *tasuense* Carter, show morphological similarity with Jurassic radiolarians. Rare species with Paleozoic-type skeletons (*Braginella rudis* and *Pentactinocarpus magnus*) can be considered as relics.

At the same time, the further evolution of Late Triassic radiolarians was prevented by the great extinction event at the end of the Rhaetian. At this level, all species of the genus *Livarella* and all Ferresiidae taxa (genera *Ferresium* and *Risella*) disappear together with the latest forms of Pentactinocarpidae, Eptingiidae and Capnuchosphaeridae, whereas families Pantanelliidae and Saturnalidae show the completely renewed composition (Carter, 1993; Bragin, 1994). In contrast to the Rhaetian radiolarians, their earliest Jurassic assemblages have uniform and poor taxonomic composition (Carter, 1993; Carter *et al.*, 1998).

Distribution: British Columbia (Carter, 1993), Sikhote-Alin', and Japan (Sugiyama, 1997).

CONCLUSION

Potential of radiolarians for elaboration of the detailed Triassic biostratigraphy is not exhausted by the

described scheme. Further perspectives in this direction lie in a search of new radiolarian localities, especially in the sections of virtually unstudied Induan and lower Olenekian deposits. The Middle–Upper Triassic deposits can be successfully subdivided on the base of phylogenetic data on rapidly evolving groups, especially of the genus *Triassocampe* and families Oertlispongiidae and Saturnalidae. At present it is difficult to estimate the evolutionary rates of Triassic radiolarians because many of the taxa found has not been described yet. However, a great deal of short-living species suggests that the rates could be much higher in the Triassic time than in the Jurassic and Cretaceous periods. The detailed subdivision of the Middle–Upper Triassic on the basis of radiolarians and steadiness of radiolarian biostratigraphic units allow us to use this paleontological group not only for concrete stratigraphic purposes (e.g., for dating of siliceous deposits), but also in wider aspects of the global and regional Triassic stratigraphy.

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