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Biostratigraphic Correlation between the Nadanhada Terrane of NE China and the Mino Terrane of Central Japan

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ABSTRACT

A biostratigraphic analysis of available data from the Nadanhada terrane, northeast China, and the Mino terrane, central Japan, shows that the Paleozoic limestone strata occurring in exotic blocks in both terranes contain similar fusulinid zones, ranging in age from Late Carboniferous Moscovian to Late Permian Changhsingian; but so far, no Permo-Carboniferous radiolarian chert has been reported from the Nadanhada area. Triassic and lower Jurassic radiolarian chert strata from both areas contain identical radiolarian faunas. Lower Jurassic and Middle Jurassic fine clastic sediments of the two areas have similar radiolarian and ammonite faunas, although there are a few differences in faunal composition. Late Jurassic and Early Cretaceous biostratigraphy of the two areas shows discernibly diverging features.

INTRODUCTION

The biostratigraphic framework makes indispensable reference coordinates for geological research works. During the 1970's and 80's, intensive radiolarian biostratigraphic investigations in Japan led to a revolutionary new understanding of the geology of Japan by the discovery of Jurassic fossils in the "Paleozoic provinces" (Mizutani and Yao, 1991).

Mizutani (1987) first suggested that the Mino terrane in central Japan and the Nadanhada terrane in northeast China together with the neighboring Russian area (west Sikhote-Alin) were separate parts of an original superterrane during Mesozoic. Kojima and Mizutani (1987) reported, using scanning electron photomicrographs, the Triassic and Jurassic radiolarian assemblages of the Nadanhada terrane, after Li et al. (1979) first illustrated the radiolarians in thin sections which were dated as of Paleozoic. Yang et al. recently carried out the biostratigraphic studies of the Nadanhada terrane in the hope to establish a detailed biostratigraphic framework of the area (Yang and Mizutani, 1991; Cheng et al., 1991; Yang et al., 1991, 1992; Yang, 1993a,b) and to correlate it with other terranes of the neighboring areas in east Asia (Fig. 1). On the other hand, biostratigraphic studies of the Mino terrane have been carried out extensively, especially of Radiolaria (Yao, 1972, 1986; Mizutani et al., 1981; Mizutani and Kido, 1983; Hori, 1986; Nagai and Mizutani, 1990, 1991, 1993).

This paper is a result of our collaborative investigation after Nagai's visit to Nanjing in 1993 for discussions and comparison of the faunas from the study areas and Yang's visit to the Mino terrane in 1992 for a field collection.

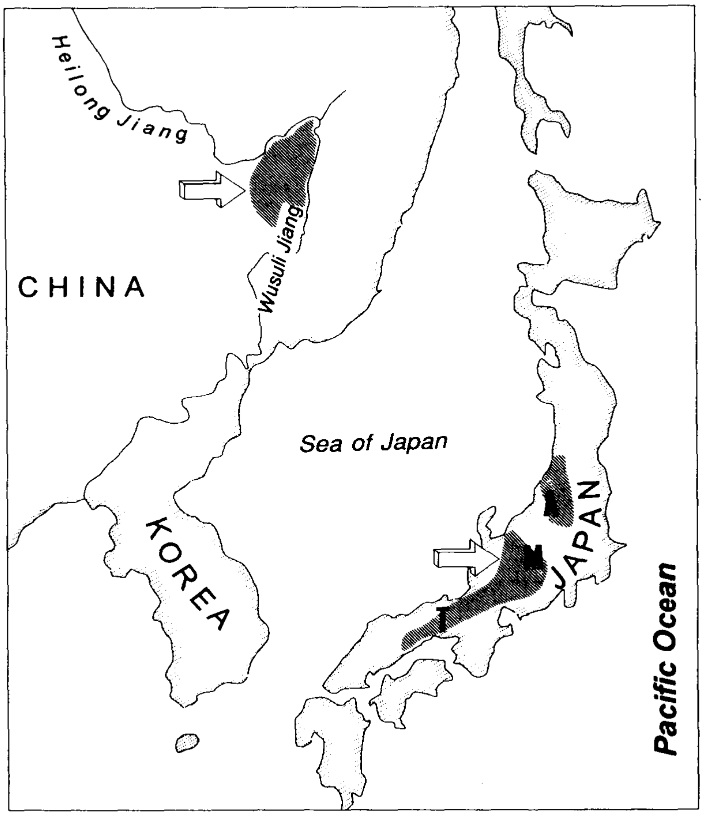


Fig. 1. Index map showing the study areas: the Nadanhada terrane in northeast China and the Mino terrane in central Japan (arrow-pointed hatched areas). A, M and T in Japan stand for the Ashio, Mino and Tamba areas in the Mino terrane, respectively.

BIOSTRATIGRAPHY OF NADANHADA TERRANE

In the Nadanhada terrane, chert and siliceous mudstone formations constitute the major components of the sedimentary sequence, ranging in age from Middle Triassic to Middle Jurassic or lower Upper Jurassic, based on radiolarians and conodonts contained therein. A minor amount of lenticular block of limestone containing conodonts and radiolarians is present in the Upper Triassic part of the chert sequence. These rocks are of oceanic, deep water origin. Carboniferous and Permian limestone blocks of up to several hundreds of meters in size seen at surface exposures, with fusulinids, corals and crinoids, occur sporadically in the Nadanhada area and are now commonly recognized as exotic blocks incorporated in the Mesozoic melange complex; these Paleozoic rocks are apparently shallow water sediments, probably formed on some ancient oceanic plateaus in the eastern Tethys. Uppermost Jurassic to Lower Cretaceous clastic sediments, including mudstone, siltstone, sandstone and conglomerate, contain bivalves and ammonites, presumably formed in a neritic environment with terrestrial source of clastics. These coarse clastic deposits are present in northeast China (including the Jiamusi terrane to the west, the Xingkai [Khanka] terrane to the south as well as the Nadanhada terrane) and in adjacent areas of the Far East region of Russia (the Khabarovsk terrane and the west Sikhote-Alin terrane); therefore, such Late Jurassic – Cretaceous strata represent deposits formed after the terrane's arrival to the present place of the continental margin in this region; in other words, they make the cover strata (Fig. 2).

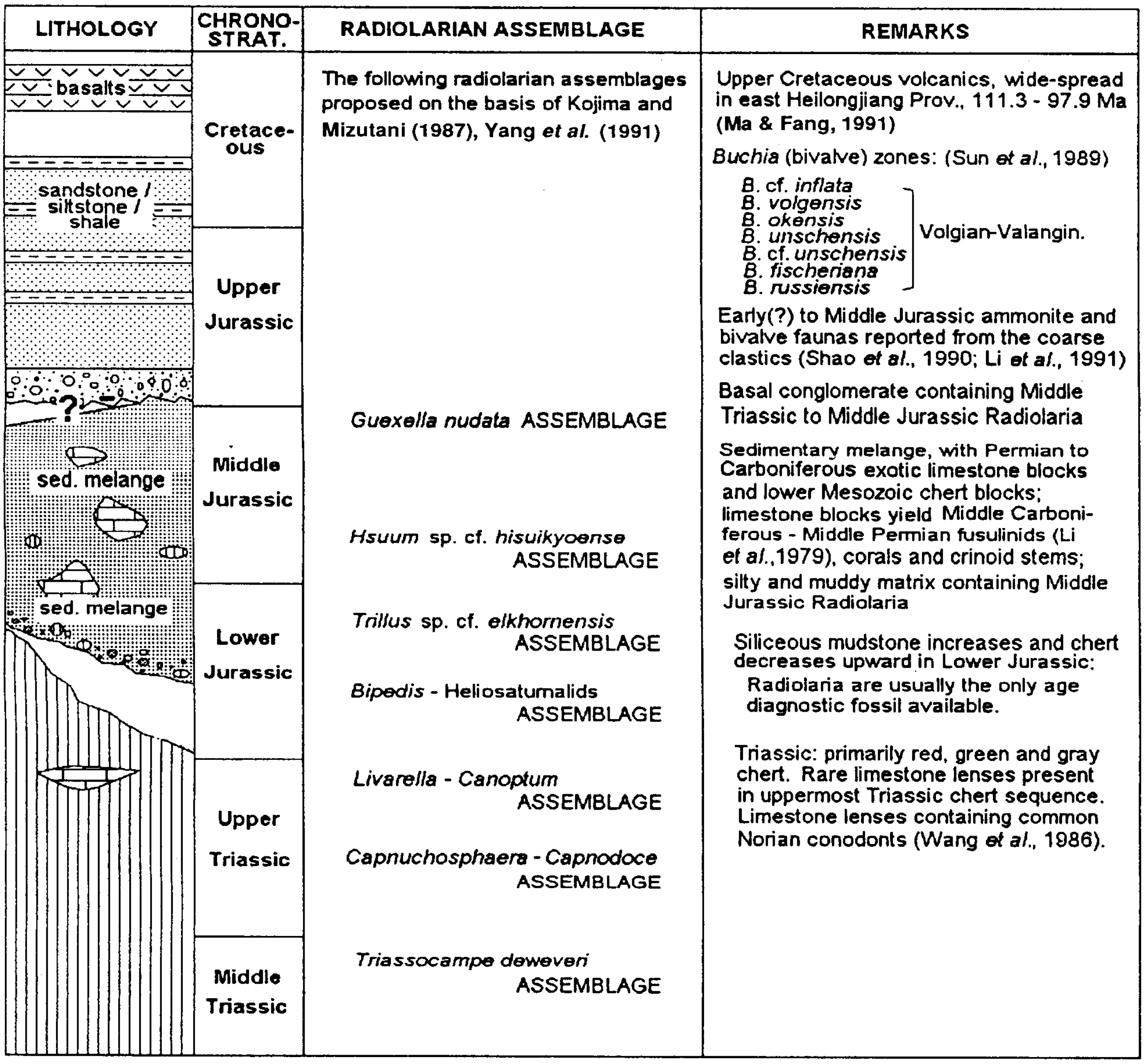


Fig. 2. Composite stratigraphic column and radiolarian assemblages of the Nadanhada terrane, northeast China (modified from Yang, 1993a).

Paleozoic

Li et al. (1979) made a detailed biostratigraphic study of the Paleozoic limestone strata in the Nadanhada terrane on the basis of the well-established fusulinid biochronology, although their understanding of the general stratigraphy of the area at that time was radically different from the way we view it today. According to their report, the Paleozoic limestone of the Nadanhada [illegible]

1) *Fusulinella – Fusulina* zone: Upper Carboniferous Weiningian or Moscovian stage (upper part); previously assigned to Middle Carboniferous. This assemblage includes *Eostaffella iranae* Ganelina, *Fusulinella eopulchra* Rauser, *F. subpulchra submesopachis* Putrja and *Protofusulinella* sp., associated with corals (*Donophyllum* sp., *Koninckocarinia* sp. and *Paralithostrotion* sp.).

2) *Triticites – Pseudoschwagerina* zone: Upper Carboniferous Xiaodushanian (or Kasimovian-Gzhelian) stage to Lower Permian Mapingian (or Asselian) stage. This assemblage includes *Triticites* sp., *Schwagerina scitula* Sheng & Sun, *S. plicatissima* (Rauser), *S. pseudoexilis* (Chen), *S. callosa* (Rauser), *S. ischimbajevi* (Rorzhenevski), *S.* sp., *Pseudofusulina amdrupensis* Ross & Dunbar, *P. isomie* Igo, *P.* aff. *japonica* (Gümbel), *Pseudoschwagerina* sp., *Paraschwagerina qinghaiensis* Chang, *Chalaroschwagerina nelsoni* (Dunbar & Skin- [illegible]

central Japan are more closely similar to those of the North American Cordillera than they are to those of South China in terms of species composition, although the mentioned areas are generally typical representatives of the Tethyan faunal realm (Prof. Sheng Jinzhang, verbal communication).

Li et al. (1979) postulated that the Dadaihe Group in the northern part of the Nadanhada range, consisting of slate, siltstone and chert with meta-volcanic, pyroclastic and minor crystalline limestone intercalations, was of Devonian to Early Carboniferous age, although no age-diagnostic fossils have been found there. Our recent field observations suggest, however, that these rocks include pillow basalt and radiolarian chert, representing a suite of ophiolite complex. Radiometric dates from the basalt (Ma and Fan, 1991) and radiolarian assemblages from the chert strata indicate that the complex is Triassic to Jurassic in age.

Triassic to Middle Jurassic

Kojima and Mizutani (1987) was probably the first to report a specialized paleontological study on the radiolarians of the chert formations in the Nadanhada terrane, although earlier workers such as Wang (1959) and Li et al. (1979) reported radiolarians in thin sections. In recent years, Yang et al. (e.g. Yang et al., 1991; Yang and Mizutani, 1991; Yang et al., 1992; Yang, 1993a,b) have been investigating much more extensively on the Radiolaria-bearing strata of the Nadanhada terrane. According to these studies, the Radiolaria-bearing chert, siliceous mudstone and siltstone formations contain the radiolarians of the following assemblages:

1) *Triassocampe deweveri* assemblage: Middle Triassic Carnian. Common components of Radiolaria in this assemblage are *Triassocampe deweveri* (Nakaseko & Nishimura), *Pseudostylosphaera helicatum* (Nakaseko & Nishimura), *Pseudostylosphaera japonica* (Nakaseko & Nishimura), *Silicarmiger costatus* (Dumitrica, Kozur & Mostler), *Yeharaia annulata* Nakaseko & Nishimura, *Plafkerium* spp., *Sarla* spp. and *Triassobipedis* sp.

2) *Capnuchosphaera* – *Capnodoce* assemblage: Upper Triassic Norian. Common elements of Radiolaria in this assemblage are *Capnuchosphaera* spp., *Capnodoce ruesti* Kozur & Mostler, *Capnodoce crystallina* Pessagno, *Ferresium* spp., *Parasaturnalis* sp., *Saturnosphaera* spp., *Livarella* sp. and *Katroma* sp.

3) *Livarella* – *Canoptum* assemblage: Upper Triassic upper Norian/Rhaetian. Common elements are *Livarella validus* Yoshida, *Livarella longa* Yoshida, *Livarella gifuensis* Yoshida, *Canoptum rhaeticum* Kozur & Mostler, *Saturnosphaera shengi* Yang & Mizutani, *S. zhangi* Yang & Mizutani, *Praemesosaturnalis heilongjiangensis* Yang & Mizutani, *Deflandrecyrtium* sp. and *Squinabolella* sp.

4) *Bipedis* – Heliosaturnalids assemblage. Lower Jurassic Hettangian – early Pliensbachian. Common radiolarian components are *Bipedis calvabovis* DeWever, *B.* sp., *Pseudoheliodiscus* spp., *Saturnosphaera* spp., *Stauracanthocircus* spp., *Palaeosaturnalis liassicus* Kozur & Mostler, *Ferresium* spp., *Canoptum dixoni* Pessagno & Whalen, *C. merum* Pessagno & Whalen, *Paracanoptum*

spp., *Lupherium* cf. *officerense* Pessagno & Whalen, *L.* spp., *Parahsuum simplum* Yao and *P. ovale* Hori & Yao.

5) *Trillus* sp. cf. *elkhornensis* assemblage: Lower Jurassic late Pliensbachian. This assemblage is characterized by the first revolutionary appearance of Genus *Trillus* and by the disappearance of the majority of Heliosaturnalinae (parasaturnalids with additional rays beside the two primary polar rays on the inner margin of the peripheral ring). Genera *Praemesosaturnalis, Staurancanthocircus* and *Saturnosphaera,* which are important components of the lower zone, do not appear in this assemblage zone; only rare individuals of *Pseudoheliodiscus* extend to this zone.

6) *Hsuum* sp. cf. *hisuikyoense* assemblage: Middle Jurassic Aalenian. Major components include *Hsuum* sp. cf. *hisuikyoense, Unuma* sp. and *Canoptum* spp.

7) *Guexella nudata* assemblage: Middle Jurassic Bathonian – Callovian to lower part of Upper Jurassic. Major radiolarian components of this assemblage include *Guexella nudata* (Kocher), *Tricolocapsa plicarum* Yao, *Eucyrtidiellum ptyctum* (Riedel & Sanfilippo), *Ristola dhemenaensis* (Baumgartner), *Archaeodictyomitra* sp.

Assemblages 1–5 occur in strata primarily composed of chert or highly siliceous mudstone, while assemblages 6–7 occur in mudstone, siltstone or clasts of conglomerate. Various formal lithostratigraphic names such as the Shibaxiangdi, Dababeishan, Dajiahe and Dalingqiao formations have been applied to the Radiolaria-bearing strata (Zhang et al., 1991).

Upper Triassic (Norian) conodonts occur in limestone lenses in the primarily siliceous chert sequence, assignable to four conodont zones, i.e., in descending order, the *Epigondolella bidentata, Epigondolella postera, Epigondolella multidentata* and *Epigondolella abneptis* zones (Wang et al., 1986). Middle and Upper Triassic conodonts are also present in chert formations occurring near the limestone lenses (Wang et al., 1986).

Uppermost Middle – Upper Jurassic to Lower Cretaceous

The Upper Jurassic (probably also uppermost Middle Jurassic) and Lower Cretaceous strata in the Nadanhada terrane are coarse clastic bivalve- and ammonite-bearing strata. According to Sha (1985) and Sun et al. (1989), the *Buchia*-bearing strata discovered near Dong'anzhen are uppermost Jurassic (Volgian) to Lower Cretaceous (Valanginian) in age. The strata include the following *Buchia* zones listed in ascending order:

1) *Buchia russiensis – B. fischeriana* zone: Upper Jurassic middle Volgian; including *Buchia russiensis* (Pavlow), *B. fischeriana* (d'Orbigny), *B.* sp. and *Thracia*(?) sp.

2) *Buchia fischeriana – B.* cf. *unschensis* zone: Upper Jurassic upper Volgian; including *Buchia fischeriana* (d'Orbigny), *B. terebratuloides* (Lahusen), *B.* cf. *unschensis* (Pavlow), *B.* sp. and *Palaeoneilo* sp.

3) *Buchia okensis – B. unschensis* zone: Lower Cretaceous Berriasian; including *Buchia okensis* (Pavlow), *B.* cf. *okensis, B. unschensis* (Pavlow) and

Parvamussium sp.

4) *Buchia volgensis* – *B.* cf. *inflata* zone: Lower Cretaceous upper Berriasian – Valanginian; including *Buchia* cf. *inflata* (Toula), *B. volgensis* (Lahusen), *B. okensis* (Pavlow), *B. fischeriana* (d'Orbigny), *B.* spp., *Solemya*? sp., *Mesosaccella* sp. associated with ammonites (Lytoceratidae gen. and sp. indet.).

Li et al. (1991) suggested that the ammonite- and bivalve-bearing strata (Dajiashan Group) discovered at Mt. Dajiashan, are assignable to Lower Jurassic based on the ammonites and bivalves discovered therein, which contradicts the dating (Middle Jurassic Bathonian – Callovian or later) from the radiolarians derived from the basal conglomerate of the Dajiashan Group at the same location. The radiolarian assemblage (Yang et al., in preparation) includes a mixture of Middle Triassic to Middle Jurassic radiolarians, indicating the maximal age of the conglomerate being Middle Jurassic or later. The youngest radiolarians extracted from the conglomerate include *Eucyrtidiellum* sp., *Tricolocapsa plicarum* Yao, *Hsuum maxwelli* Pessagno, *Unuma* spp. and *Ristola dhemenensis* (Baumgartner). According to Baumgartner (1984) and Matsuoka and Yao (1986), *Ristola dhemenensis* ranges from Bathonian to Lower Tithonian in Mediterranean and Atlantic region; *Hsuum maxwelli* ranges from *Tricolocapsa conexa* zone (upper Middle Jurassic) to *Cinguloturris carpatica* zone (middle Upper Jurassic) in Japan; *Tricolocapsa plicarum* ranges from Middle Jurassic to lower Upper Jurassic; furthermore, the present radiolarian assemblage is assignable to the *Dictyomitrella*(?) *kamoensis* – *Pantanellium foveatum* assemblage zone of Mizutani and Kido (1983). Additionally, according to Pessagno et al. (1993), the *Pantanellium foveatum* assemblage ranges from uppermost Callovian to middle Oxfordian in North America. Therefore, we have reached a preliminary conclusion that the basal conglomerate of the Dajiashan Group is not older than late Middle Jurassic.

BIOSTRATIGRAPHY OF THE MINO TERRANE

Since Gümbel reported the finding of fusulinid fossils in "marble stone" from Japan in 1874 (Kobayashi, 1980), the basement rocks of the Japanese Islands have been believed to be late Paleozoic in age. In central Japan, the geology was first studied by Ban (1887) who described the occurrence of fusulinids in limestone in his explanatory text of the geological map and treated all the rock formations carrying the lenticular blocks of limestone as of Paleozoic in age. During an early half of the twentieth century and until the '70s, however, Triassic and Jurassic fossils such as plants (Kimura and Ohana, 1990), bivalves (Hayami, 1990; Tamura, 1990) and ammonites (Sato, 1974; Sato et al., 1985) have been known, though very sparsely. They are usually recorded as isolated occurrence, and they have not been fully understood in respect to the biostratigraphy, because the stratigraphic relationship between the fossil-bearing formation and the underlying one is not clearly detected owing to restricted small exposures.

It was the conodont biostratigraphy done in the early 70's by Hisayoshi Igo and his co-workers that most, if not all, of the chert formations in this "Paleozoic" group are assigned to Triassic in age. And in the early 80's, it was confirmed that these basement rock formations occupying the Ashio, Mino and Tamba areas make up collectively, as will be described later, a melange or disrupted terrane (or non-stratigraphic terrane) composed of greenstone, limestone, chert, siliceous shale, sandstone and conglomerate. The terrane was named the Mino terrane by Mizutani and Hattori (1983), and Mizutani (1987, 1990); it is one of the units in the tectonic collage of Mesozoic Japan which was formed along the eastern margin of the Asian continent prior to the opening of the Sea of Japan (Kojima, 1989; Mizutani, 1987; Mizutani et al., 1989; Mizutani and Kojima, 1992).

Biostratigraphic data of the Mino terrane collected and registered in universities and the Geological Survey of Japan are mainly fusulinids contained in limestone (Carboniferous – Permian), conodonts (Permian – Triassic), and radiolarians (Carboniferous – Jurassic), and infrequently ammonites and other fossils (Triassic and Jurassic). Since development of the radiolarian biostratigraphic investigation and re-examination of the Mino terrane, it has been confirmed that (i) the main part of the Mino terrane consists of a Jurassic melange carrying blocks of Permian greenstone-limestone complex and of Triassic bedded chert, (ii) the restored integrated stratigraphy of the Mino terrane, when reconstructed on the basis of the conodonts and radiolarians, is made up of early Triassic siliceous mudstone, middle Triassic to early Jurassic bedded chert, middle to late Jurassic siliceous shale, all intermingled within the clastic rocks which sometimes bear intercalated conglomerate in several horizons. Ammonites, very rarely found in the clastic facies of central Japan, are supposed to represent the near-continent facies in contrast to the coeval Radiolaria-bearing formation of pelagic facies, both having been interdigitated or mixed with each other in a complicated fashion in the convergent continental margin during the late Jurassic time.

Fusulinid Biozone of the Mino Terrane

Isomi (1977) and Yoshida (1977) summarized and outlined the bio- and lithostratigraphy of the Japanese Upper Paleozoic. It has been conveniently divided into two lithologic units in the Mino terrane on the basis of the abundance of occurrence of limestone, i.e., calcareous complex in which the limestone facies is prevalent, and non-calcareous complex in which the limestone is much less in amount or entirely lacking. Wider ranges of fusulinid zonations have been established in limestone sequence of the calcareous complex or in large blocks of limestone such as the Ibuki, Akasaka and Funabuse limestone areas. Biostratigraphical zoning of the Upper Paleozoic has been done exclusively by the fusulinid fauna, and the following zones are recognized in the Ashio, Mino and Tamba areas: the *Fusulinella-Fusulina* zone of middle Carboniferous, the *Triticites* zone of upper Carboniferous, the *Pseudoschwagerina* zone of lowest Permian, the *Parafusulina* zone of lower Permian, the

Neoschwagerina zone and the *Yabeina* zone of middle Permian.

According to Isomi (1988) who has made a paleontological study of the fusulinid limestone distributed in the northern marginal part of the Mino terrane, there occur many lenticular blocks of limestone ranging in age from Carboniferous to Permian, all embedded in the Jurassic olistostromal sedimentary complex. He has successfully restored the fusulinid zones in those limestone blocks stating that the original biostratigraphy can be established as follows: the *Fusulinella-Fusulina* zone (middle part of the Upper Carboniferous), the *Triticites* zone (upper part of the Upper Carboniferous), the *Pseudoschwagerina* zone (the lower Permian), the *Neoschwagerina* zone (middle-upper part of the Middle Permian), the *Yabeina* zone (lower part of the Upper Permian). In the *Fusulinella-Fusulina* zone *Fusulinella bocki* Möller and *F. pseudobocki* Lee & Chen are found, while in the *Triticites* zone *Triticites nakatsugawaensis* Morikawa, *T. opparensis* Kanuma and *T. kiyomiensis* Kanuma are found. The Permian fusulinid zone, conformably covering the underlying zone, starts with the *Pseudoschwagerina* zone in which found are *Triticites subobsoleta* (Ozawa), *T. haydeni* (Ozawa) and *Pseudoschwagerina* sp. As Isomi (1988) noted, there is not found the *Parafusulina* zone in the northern marginal part of the Mino terrane, but the *Neoschwagerina* zone and the succeeding *Yabeina* zone are found there. In the main part of the Mino terrane, however, many lenticular bodies of limestone containing the fusulinid fauna belonging to the *Pseudofusulina ambigua* zone and to the *Parafusulina* zone are prevalent (Isomi, 1977), in which *Misellina claudiae* (Deprat) is also abundant. In Akasaka, a classical location of the fusulinid paleontology in the central part of the Mino terrane, the following zones are described by Ozawa and Nishiwaki (1992) in ascending order: the *Parafusulina nakamigawai* zone, *Cancellina nipponica* zone, *Pseudodoliolina ozawai* zone, *Neoschwagerina craticulifera* zone, *Colania amucula* – *C. gifuensis* zone, *Neoschwagerina margaritae* zone, *Yabeina globosa* zone, *Sichotenella* sp. zone, *Codonofusiella kueichowensis* – *Reichelina changhsingensis* zone.

Permian and Triassic Conodont Biostratigraphy

Since Müller (1964) first discovered the conodont fossil in the Japanese Triassic limestone in Shikoku (Nogami, 1968), and since Japanese geologists (Nakazawa and Nogami, 1967) reported the fossil from the Tamba area, the conodont paleontology became a routine method for the study of the upper Paleozoic and Triassic biostratigraphy in Japan. The conodonts have been found so far mostly in the Upper Paleozoic and Triassic formations in Japan, but the occurrence of pre-Carboniferous conodonts is found in a different tarrane of NE Japan.

The stratigraphic studies of the Paleozoic group on the basis of conodont paleontology in the Japanese Islands are summarized by Igo (1979) and Igo and Koike (1983); Carboniferous conodonts have been found in so-called "Paleozoic" group, sporadically though, and Permian conodonts have been reported in chert or limestone in various parts of the Ashio, Mino and Tamba areas. The conodont zones of the Permian are, in ascending order, the *Streptognathodus elongatus* fauna, the *Neogondolella bisselli – Sweetognathus whitei* zone, the *Diplognathodus oertlii – Neogondolella pequopensis* zone, the *Diplognathodus lanceolatus – Diplognathodus nodosus* zone, the *Anchignathodus typicalis – Diplognathodus* sp. fauna. As was stressed previously, these chert or limestone strata in the Mino terrane always occur as exotic blocks in matrix of shale of melange nature, and they do not form a stratigraphic succession with the underlying or overlying strata of different lithology. The stratigraphic correlation has been carried out by these authors between the fusulinid fauna and conodonts.

Conodonts are most prevalent in Triassic bedded chert, and they are described also in many localities of the Mino terrane. As summarized by Koike (1979, 1981) and also noted by Yao (1986), the following conodont zones have been recognized in chert formations in Japan in ascending order: the *Neospathodus dieneri* zone (Smithian), the *Neospathodus homeri* zone (Spathian), the *Neogondolella timorensis* zone (Smithian – Anisian), the *Neogondolella bulgarica* zone (Anisian), the *Neogondolella excelsa* zone (Anisian – Ladinian), the *Carinella hungarica* zone (Ladinian), the *Neogondolella foliata* zone (Ladinian – Carnian), the *Neogondolella nodosa* zone (upper Carnian), the *Epigondolella spatulata* zone (lower Norian), the *Epigondolella bidentata* zone (Norian), the *Misikella hernsteini* zone (upper Norian), and the *Misikella posthernsteini* zone (Rhaetian). Triassic chert or siliceous shale in the Mino terrane commonly contain Radiolaria; as the result of our studies, the comparative biostratigraphic data have been accumulated in these decades.

Radiolarian Biozonation

Ishiga and Imoto (1980) was the first to describe the Permian Radiolaria in Japan from bedded chert and siliceous shale in the Tamba area. Ishiga (1990) later summarized the Paleozoic radiolarian biostratigraphic studies, showing a biostratigraphic correlation chart of the fusulinid, conodont and radiolarian zonations particularly of Carboniferous and Permian age. Interestingly, the Carboniferous radiolarian zone begins with a horizon equivalent to the fusulinid zone of *Fusulinella – Fusulina* zone, successively (probably, continuously if reconstructed) covered by overlying formations up to the *Paleofusulina sinensis* zone, which is correlative with the *Neoalbaillella ornithoformis* zone. In the Mino area, the Permian radiolarians sporadically occur in lenticular blocks of chert which are found infrequently in clastic rocks of later ages. As described by Sano (1988), Permian chert facies sometimes represents the oceanic group of rocks together with the greenstone-limestone complex of the coeval age, all of which are, taken as a whole, embedded in the Jurassic melange complex.

Triassic radiolarians in Japan, i.e., in the Mino terrane and the other terranes in SW Japan, were first reported by Nakaseko and Nishimura (1979). Detailed examinations of the Triassic radiolarian biostratigraphic sections have been done by Yoshida (1986) and Sugiyama (1992) in the Mino terrane, and

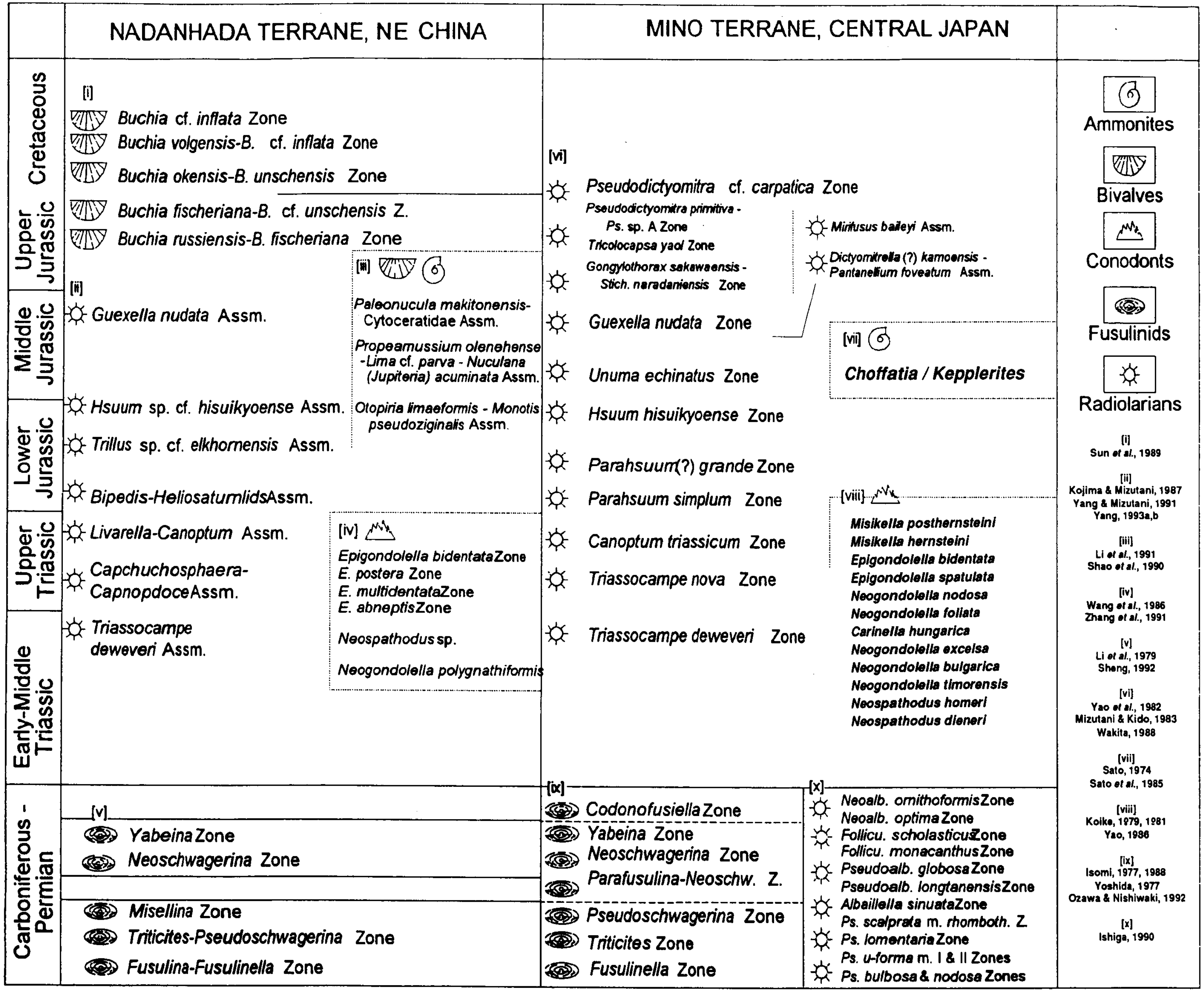
Sashida (1983, 1991) and Sashida et al. (1993) in the Kanto and Kiso areas. All these works together with the summarized review of the Triassic and Jurassic radiolarians made by Yao (1990) indicate that the Triassic Radiolaria-bearing formations range in age from Spathian (rarely Smithian) to Rhaetian, which corresponds to just the same biozones of the conodont stratigraphy of the Triassic chert strata.

Occurrence of Jurassic radiolarians was first debated in a paper by Ichikawa and Yao (1976); in their report, the senior author was "inclined to regard the material concerned is Triassic in age", because "the occurrence of Triassic conodonts from the vicinity" has been reported, but the junior author (Yao, 1972) implied the age assignment of the microfossils to late Mesozoic. In the early 1980's, however, the age of these Jurassic radiolarians was approved by many students who have been working in the Mino terrane. In this decade, a large amounts of Jurassic radiolarian data in the Japanese Islands have been accumulated which urged us to re-examine the stratigraphy and the tectonics of the Paleozoic – Mesozoic groups not only in Japan but also in continental areas. According to Matsuoka and Yao (1986) and Yao (1990), the Radiolaria-bearing formations range in age from Hettagian to Tithonian. However, the age assignment of the Jurassic formations particularly in the younger half of the Jurassic age by means of the radiolarians includes some discrepancy between Japan and North America as discussed by Pessagno and Mizutani (1992). This stratigraphic difference of correlation is not attributed to the age assignment of the fossils, but to the isotopic ages they have dealt with in the establishment of the stratigraphic framework.

SYNTHESIS

Mizutani et al. (1989) was the first to point out that the tectonostratigraphic characteristics of the Nadanhada terrane and those of the Mino terrane are same, including Permo-Carboniferous limestone and greenstone, Triassic bedded chert and Jurassic siliceous shale which are all enclosed in Late Jurassic – Cretaceous clastic matrix in both areas. Thus, they proposed that the Nadanhada terrane, together with west Sikhote-Alin, and the Mino terrane comprise a unified superterrane, which was later dispersed and disrupted along the east Asian continental margin. In this report, we attempt to compare the detailed biostratigraphic zones throughout the Paleozoic and Mesozoic strata of the two areas concerned. After assembling all available data as shown in Figure 3, we find that –

(1) The biochronological ranges of the Permo-Carboniferous limestone of the Nadanhada and those of the Mino terrane are generally same. In the Nadanhada area, the limestone strata include five fusulinid zones (Fig. 3), which are assignable to upper Moscovian stage (Upper Carboniferous) to Capitanian stage (uppermost Middle Permian; cf. Sheng, 1992). In the Mino terrane (Tamba-Mino-Ashio area), the limestone strata include seven fusulinid zones (Fig. 3), which are assignable to upper Moscovian stage to Changhsingian


NADANHADA TERRANE, NE CHINA
MINO TERRANE, CENTRAL JAPAN
Cretaceous
Upper Jurassic
Middle Jurassic
Lower Jurassic
Upper Triassic
Early-Middle Triassic
Carboniferous - Permian
[i]
Buchia cf. inflata Zone
Buchia volgensis-B. cf. inflata Zone
Buchia okensis-B. unschensis Zone
Buchia fischeriana-B. cf. unschensis Z.
Buchia russiensis-B. fischeriana Zone
[ii]
Guexella nudata Assm.
Hsuum sp. cf. hisuikyoense Assm.
Trillus sp. cf. elkhornensis Assm.
Bipedis-HeliosaturnlidsAssm.
Livarella-Canoptum Assm.
Capchuchosphaera-CapnopdoceAssm.
Triassocampe deweveri Assm.
[iii]
Paleonucula makitonensis-Cytoceratidae Assm.
Propeamussium olenehense -Lima cf. parva - Nuculana (Jupiteria) acuminata Assm.
Otopiria limaeformis - Monotis pseudoziginalis Assm.
[iv]
Epigondolella bidentataZone
E. postera Zone
E. multidentataZone
E. abneptisZone
Neospathodus sp.
Neogondolella polygnathiformis
[v]
Yabeina Zone
Neoschwagerina Zone
Misellina Zone
Triticites-Pseudoschwagerina Zone
Fusulina-Fusulinella Zone
[vi]
Pseudodictyomitra cf. carpatica Zone
Pseudodictyomitra primitiva - Ps. sp. A Zone
Tricolocapsa yaoi Zone
Gongylothorax sakawaensis - Stich. naradaniensis Zone
Guexella nudata Zone
Unuma echinatus Zone
Hsuum hisuikyoense Zone
Parahsuum(?) grande Zone
Parahsuum simplum Zone
Canoptum triassicum Zone
Triassocampe nova Zone
Triassocampe deweveri Zone
Mirifusus baileyi Assm.
Dictyomitrella (?) kamoensis - Pantanellium foveatum Assm.
[vii]
Choffatia / Kepplerites
[viii]
Misikella posthernsteini
Misikella hernsteini
Epigondolella bidentata
Epigondolella spatulata
Neogondolella nodosa
Neogondolella foliata
Carinella hungarica
Neogondolella excelsa
Neogondolella bulgarica
Neogondolella timorensis
Neospathodus homeri
Neospathodus dieneri
[ix]
Codonofusiella Zone
Yabeina Zone
Neoschwagerina Zone
Parafusulina-Neoschw. Z.
Pseudoschwagerina Zone
Triticites Zone
Fusulinella Zone
[x]
Neoalb. ornithoformisZone
Neoalb. optimaZone
Follicu. scholasticusZone
Follicu. monacanthusZone
Pseudoalb. globosaZone
Pseudoalb. longtanensisZone
Albaillella sinuataZone
Ps. scalprata m. rhomboth. Z.
Ps. lomentariaZone
Ps. u-forma m. I & II Zones
Ps. bulbosa & nodosa Zones
Ammonites
Bivalves
Conodonts
Fusulinids
Radiolarians
[i] Sun et al., 1989
[ii] Kojima & Mizutani, 1987 Yang & Mizutani, 1991 Yang, 1993a,b
[iii] Li et al., 1991 Shao et al., 1990
[iv] Wang et al., 1986 Zhang et al., 1991
[v] Li et al., 1979 Sheng, 1992
[vi] Yao et al., 1982 Mizutani & Kido, 1983 Wakita, 1988
[vii] Sato, 1974 Sato et al., 1985
[viii] Koike, 1979, 1981 Yao, 1986
[ix] Isomi, 1977, 1988 Yoshida, 1977 Ozawa & Nishiwaki, 1992
[x] Ishiga, 1990

stage (upper Permian). Although the Nadanhada area lacks two fusulinids zones when compared with the Mino, we believe that this is likely due to relatively incomplete investigation in the Nadanhada area, considering the fact that only one fusulinid biostratigraphic report is available.

(2) The Triassic through Middle Jurassic radiolarian biostratigraphy of the two study areas is essentially same, including the same or correlative radiolarian zones (Fig. 3); however, the abundant radiolarian assemblage assigned to the *Unuma echinatus* assemblage found in the manganese nodules in the Mino terrane has not been discovered so far in the Nadanhada area, probably owing to the lack of similar lithology. On the other hand, the limestone lens containing abundant conodonts and radiolarians of uppermost Triassic age (Fig. 2) discovered in the Nadanhada area is much less in amount in the Mino terrane. Lenticular blocks of limestone irregularly intercalating with chert bands in the Mino terrane contain upper Triassic conodonts but no Radiolaria (Koike, 1979).

(3) Middle Jurassic ammonite-bearing clastic strata have been reported from both the Nadanhada and Mino terranes; but according to available data, far more abundant ammonite and bivalve faunas of Jurassic to Early Cretaceous ages are present in the Nadanhada than in the Mino terrane (Fig. 3).

(4) Upper Jurassic to Lower Cretaceous radiolarian faunas assignable to (or correlative with) the *Pseudodictyomitra primitiva* zone and the *Pseudodictyomitra* cf. *carpatica* zone (Wakita, 1988; Fig. 3) have not been so far reported from the Nadanhada area. On the other hand, Upper Jurassic to Lower Cretaceous *Buchia*-bearing strata have not been so far reported from the Mino terrane.

The above observations, which we have made based on available data and from a biostratigraphic viewing stand, suggest that the Nadanhada terrane and the Mino terrane are closely related biostratigraphically. The differences in the biozonal composition as indicated above may be due to 1) local variations in paleoecological and sedimentary environment; 2) possible segregation of the two terranes during Late Jurassic and Early Cretaceous; 3) bias in separate investigations of the two areas.

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← Fig. 3. Chart showing biostratigraphic correlation between the Nadanhada terrane, northeast China, and the Mino terrane, central Japan. In fusulinid nomenclature widely used as an international standard, the *Triticites* zone represents the uppermost Carboniferous (Kasimovian + Gzelian stages), while the *Pseudoschwagerina* zone represents the lowermost Permian (Asselian stage) (Sheng, 1992).

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REFERENCES

Ban I. (1887) Report on the geology of the Hida Province and its environs. *Chishitsu-Yoho* (*Bull. Geol.*) **3**, 205–326 (in Japanese).

Baumgartner P.O. (1984) A Middle Jurassic – Early Cretaceous low latitude radiolarian zonation based on unitary association and age of Tethyan radiolarites. *Eclog. Geol. Helvet.* **77**, 729–837.

Cheng Y.N., Wang Y.J., Yang Q., and Yeh K.Y. (1991) Preliminary studies on Radiolaria from the eastern margin of Asia and adjacent borderlands. *Interrad VI, Abstract Volume*, Florence, Italy, 26.

Hayami I. (1990) Geographic distribution of Jurassic bivalve faunas in Eastern Asia. In *Pre-Cretaceous Evolution of Eastern Asia. Publication of IGCP Project, No.224: Pre-Jurassic Evolution of Eastern Asia* (ed. K. Ichikawa et al.), pp.361–369.

Hori R. (1986) *Parahsuum simplum* assemblage (Early Jurassic radiolarian assemblage) in the Inuyama area, central Japan. *News, Osaka Micropaleont.*, Sp. Vol. no.7, 45–52.

Ichikawa K. and Yao A. (1976) Two new genera of Mesozoic cyrtoid radiolarians from Japan. In *Progress in Micropaleontology* (ed. Y. Takayanagi and T. Saito), pp.110–117. Micropaleontology Press.

Igo Hh. (1979) Permian conodont biostratigraphy. In *Biostratigraphy of Permian and Triassic Conodonts and Holothurian Sclerites in Japan. Special Publication for Celebration of Prof. Dr. M. Kanuma's Retirement*, pp.5–20.

Igo Hy. and Koike T. (1983) Conodont biostratigraphy of cherts in the Japanese Islands. *Development in Sedimentology* **36**, 65–77.

Ishiga H. (1990) Paleozoic radiolarians. In *Pre-Cretaceous terranes of Japan. Publication of IGCP Project, No.224: Pre-Jurassic Evolution of Eastern Asia* (ed. K. Ichikawa et al.), pp.285–295.

Ishiga H. and Imoto N. (1980) Some Permian radiolarians in the Tamba Belt, Southwest Japan. *Earth Sci.* (*Chikyu Kagaku*) **34**, 333–345.

Isomi H. (1977) Permian System. In *Geology and Mineral Resources of Japan, 3rd Ed.* (ed. K. Tanaka and T. Nozawa), Vol.1, Geology, pp.107–146. Geol. Surv. Japan.

Isomi H. (1988) Fusulinid-bearing limestones in the Hagiwara District – Appendix to Geology of Hagiwara District. pp.83–122, In *Geology of the Hagiwara district, with Geological Sheet Map at 1:50,000* (ed. K. Katada et al.), pp.83–122. Geol. Surv. Japan (in Japanese with English abstract 10 p.).

Kimura T. and Ohana T. (1990) Triassic – Jurassic plants in Japan. In *Pre-Cretaceous Evolution of Eastern Asia. Publication of IGCP Project No.224: Pre-Jurassic Evolution of Eastern Asia* (ed. K. Ichikawa et al.), pp.371–379.

Kobayashi T. (1980) *Fusulina japonica* Gümbel, 1874 and the beginning of palaeontology in Japan and her adjacency. *J. Geogr. Tokyo* **89**, 124–131 (in Japanese).

Koike T. (1979) Triassic conodont biostratigraphy. In *Biostratigraphy of Permian and Triassic Conodonts and Holothurian Sclerites in Japan. Special Publication for Celebration of Prof. Dr. M. Kanuma's Retirement*, pp.21–77.

Koike T. (1981) Biostratigraphy of Triassic conodonts in Japan. *Sci. Rept. Yokohama Nation. Univ.*, sec.II no.28, 25–46.

Kojima S. (1989) Mesozoic terrane accretion in Northeast China, Sikhote-Alin and Japan regions. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **69**, 213–232.

Kojima S. and Mizutani S. (1987) Triassic and Jurassic Radiolaria from the Nadanhada Range, northeast China. *Trans. Proc. Palaeont. Soc. Japan*, N.S. no.148, 256–275.

Li W.K., Han J.X., Zhang S.X., and Meng F.Y. (1979) The main characteristics of the Upper Palaeozoic stratigraphy at the North Nadanhada Range, Heilongjiang Province, China. *Bull. Chinese Acad. Geol. Sci.* **1**, 104–120 (in Chinese with English abstract).

Li W.R., Yuan F.S., and Li Z.S. (1991) The new observation of researching on Longzhaogao Group in the east of Heilongjiang Province. *Heilongjiang Geology* **2** (1), 1–7 (in Chinese with English abstract).

Ma J.J. and Fang D.H. (1991) A preliminary study of the Mesozoic volcanic rocks in Heilongjiang Province, China. *Heilongjiang Geology* **2** (2), 1–16 (in Chinese with English abstract).

Matsuoka A. and Yao A. (1986) A newly proposed radiolarian zonation for the Jurassic of Japan. *Marine Micropaleont.* **11**, 91–105.

Mizutani S. (1987) Mesozoic terranes in the Japanese Islands and neighbouring East Asia. In *Terrane Accretion and Orogenic Belts* (ed. E. C. Leitch and E. Scheibner), Geodynamics Ser., Vol.19, pp.263–273. Amer. Geophys. Union.

Mizutani S. (1990) Mino terrane. In *Pre-Cretaceous terranes of Japan. Publication of IGCP Project 224: Pre-Jurassic Evolution of Eastern Asia* (ed. K. Ichikawa et al.), pp.121–135.

Mizutani S. and Hattori I. (1983) Hida and Mino: tectonostratigraphic terranes in central Japan. In *Accretion Tectonics in the Circum-Pacific Regions* (ed. H. Hashimoto and S. Uyeda), pp.169–178. Terra Sci. Pub.

Mizutani S., Hattori I., Adachi M., Wakita K., Okamura Y., Kido S., Kawaguchi I., and Kojima S. (1981) Jurassic formations in the Mino area, central Japan. *Proc. Japan Academy*, ser.B, **57**, 194–199.

Mizutani S. and Kido S. (1983) Radiolarians in the middle Jurassic siliceous shale from Kamiaso, Gifu Prefecture, central Japan. *Trans. Proc. Palaeont. Soc. Japan*, N.S. no.132, 253–262.

Mizutani S. and Kojima S. (1992) Mesozoic radiolarian biostratigraphy of Japan and collage tectonics along the eastern continental margin of Asia. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **96**, 3–22.

Mizutani S., Shao J.A., and Zhang Q.L. (1989) The Nadanhada terrane in relation to Mesozoic tectonics on continental margins of East Asia. *Acta Geol. Sinica* **63**, 204–216 (in Chinese with English abstract).

Mizutani S. and Yao A. (1991) Radiolarians and terranes: Mesozoic geology of Japan. *Episodes* **14**, 213–216.

Müller K.J. (1964) Discovery of conodonts and holothurian sclerites in Japan. *Trans. Proc. Palaeont. Soc. Japan*, N.S. no.55, p.294.

Nagai H. and Mizutani S. (1990) Jurassic *Eucyrtidiellum* (Radiolaria) from the Mino terrane. *Trans. Proc. Palaeont. Soc. Japan*, N.S. no.159, 587–602.

Nagai H. and Mizutani S. (1991) Jurassic radiolarians from Tsuzuya, Minokamo City, central Japan. *Bull. Nagoya Univ. Furukawa Museum* no.7, 1–13 (in Japanese with English abstract).

Nagai H. and Mizutani S. (1993) Early Triassic radiolarians from Tsuzuya, Minokamo City, Gifu Prefecture, central Japan. *Bull. Nagoya Univ. Furukawa Museum* no.9, 1–17.

Nakaseko K. and Nishimura A. (1979) Upper Triassic Radiolaria from Southwest Japan. *Sci. Rept. Col. Gen. Educ., Osaka Univ.* **28**, 61–109.

Nakazawa K. and Nogami Y. (1967) Problematic occurrence of the Upper Triassic fossils from the western hills of Kyoto. *Mem. Fac. Sci., Kyoto Univ.*, ser. Geol. Mineral. **34**, 9–22.

Nogami Y. (1968) Trias-Conodonten von Timor, Malaysien und Japan (Palaeontological study of Portuguese Timor, 5). *Mem. Fac. Sci., Kyoto Univ.*, ser. Geol. Mineral. **34**, 115–136.

Ozawa T. and Nishiwaki N. (1992) Permian Tethyan biota and sedimentary facies of the Akasaka Limestone Group. In *The 29th IGC Field Trip Guide Book* (ed. M. Adachi and K. Suzuki), Vol.1, pp.189–195.

Pessagno E.A.,Jr., Blome C.M., Hull D.M., and Six W.M. (1993) Jurassic Radiolaria from the Josephine ophiolite and overlying strata, Smith River subterrane (Klamath Mountains), northwestern California and southwest Oregon. *Micropaleontology* **39**, 93–166.

Pessagno E.A.,Jr. and Mizutani S. (1992) Radiolarian biozones of North America and Japan. In *The Jurassic of the Circum-Pacific* (ed. G. E. G. Westermann), World Regional Geology 3, pp.293–295 and 578–585. Cambridge Univeristy Press.

Sano H. (1988) Permian oceanic-rocks of Mino Terrane, central Japan. Part I. Chert facies. *J. Geol. Soc. Japan* **94**, 697–709.

Sashida K. (1983) Lower Triassic Radiolaria from the Kanto mountains, central Japan. Part 1 Palaeoscenidiidae. *Trans. Proc. Palaeont. Soc. Japan*, N.S. no.131, 168–176.

Sashida K. (1991) Early Triassic radiolarians from the Ogamata formation, Kanto mountains, central Japan. Part 2. *Trans. Proc. Palaeont. Soc. Japan*, N.S. no.161, 681–696.

Sashida K., Nishimura H., Igo H., Kazama S., and Kamata Y. (1993) Triassic radiolarian faunas from Kiso-fukushima, Kiso Mountains, central Japan. *Sci. Rept. Inst. Geosci., Univ. Tsukuba*, Sect. B **14**, 77–97.

Sato T. (1974) A Jurassic ammonite from near Inuyama, north of Nagoya. *Trans. Proc. Palaeont. Soc. Japan*, N.S. no.96, 427–432.

Sato T, Kasahara Y., and Wakita K. (1985) Discovery of a Middle Jurassic ammonite *Kepplerites* from the Mino Belt, central Japan. *Trans. Proc. Palaeont. Soc. Japan*, N.S. no.139, 218–221.

Sha J.G. (1985) *Buchia* fauna from Dong'anzhen Formation near Dong'an of Raohe County, Heilongjiang. *Palaeont. Sinica* **24**, 651–662 (in Chinese with English summary).

Shao J.A., Wang C.Y., Tang K.D., and Zhang Q.Y. (1990) Relationship of the stratigraphy and terrane of the Nadanhada Range. *J. Stratigr.* **14**(4), 286–291 (in Chinese with English abstract).

Sheng J.Z. (1992) Development of fusuline foraminifers in China. Studies in Benthic Foraminifera, *Benthos '90*, 11–22.

Sugiyama K. (1992) Lower and Middle Triassic radiolarians from Mt. Kinkazan, Gifu Prefecture, central Japan. *Trans. Proc. Palaeont. Soc. Japan*, N.S no.167, 1180–1223.

Sun G., Sha J.G., Wang Y.G., Yuan F.S., Xiong X.Z., and Piao T.Y. (1989) Jurassic – Cretaceous boundary of Dong'anzhen, Raohe, Heilongjiang with a new knowledge of *Buchia*. *Palaeontol. Sinica* **28**, 579–597 (in Chinese with English summary).

Tamura M. (1990) The distribution of Japanese Triassic bivalve faunas with special reference to parallel distribution of inner Arcto-Pacific fauna and outer Tethyan fauna in Upper Triassic. In *Pre-Cretaceous Terranes of Japan. Publication of IGCP Project 224: Pre-Jurassic Evolution in Eastern Asia* (ed. K. Ichikawa et al.), pp.347–359.

Wakita K. (1988) Early Cretaceous melange in the Hida-Kanayama area, central Japan. *Bull. Geol. Surv. Japan* **39**, 367–421.

Wang C.Y., Kang B.X., and Zhang H.R. (1986) A discovery of Triassic conodonts in the Nadanhada Range and the geological significance. In *Contributions to the Project of Plate Tectonics in North China* (ed. C. Y. Li et al.), pp.208–214.

Wang X.Z. (1959) Mesozoic marine strata in the Mesozoic fold belt, Raohe area, NE China. *Dizhi Kexne* 1959 (2), 50–51 (in Chinese).

Yang Q. (1993a) Radiolarian biostratigraphy of the Nadanhada terrane, NE China. *Proc. 1st Postdoct. Conf. China*, II, 1985–1988. Guofang Gongye Press, Beijing.

Yang Q. (1993b) Radiolarian assemblages from T/J boundary strata in the Nadanhada terrane, northeast China. *Palaeoworld, Ann. Rept. Lab. Palaeobiol. & Stratigr., Acad. Sinica* **2**, 270–294.

Yang Q. and Mizutani S. (1991) Radiolaria from the Nadanhada terrane, northeast China. *J. Earth Sci., Nagoya Univ.* **38**, 49–78.

Yang Q., Wang Y.J., and Liu R.Z. (1992) Transitional T/J beds from the Nadanhada terrane, Heilongjiang Province, NE China. *Kexue Tongbao*, 1992, 547–549 (in Chinese).

Yang Q., Yeh K.Y., Wang Y.J., and Liu R.Z. (1991) Radiolaria from Triassic/Jurassic transitional beds of Nadanhada terrane, NE China. *Interrad VI Abstract Volume*, 98–99, Florence Italy.

Yao A. (1972) Radiolarian fauna from the Mino belt in the northern part of the Inuyama area, central Japan. Part I: Spongosaturnalids. *J. Geosci., Osaka City Univ.* **15**, 21–64.

Yao A. (1986) Geological age of Jurassic radiolarian zones in Japan and their international correlations. *News, Osaka Micropaleont.*, Sp. Vol. no.7, 63–74 (in Japanese with English abstract).

Yao A. (1990) Triassic and Jurassic radiolarians. In *Pre-Cretaceous Terranes of Japan. Publication of IGCP Project 224: Pre-Jurassic Evolution of Eastern Asia. Osaka*, (ed. K. Ichikawa, et al.), pp.329–345.

Yao A., Matsuoka A., and Nakatani T. (1982) Triassic and Jurassic radiolarian assemblages in southwest Japan. *News, Osaka Micropaleont.*, Sp. Vol. no.5, 27–44 (in Japanese with English abstract).

Yoshida H. (1986) Upper Triassic to Lower Jurassic radiolarian biostratigraphy in Kagamigahara City, Gifu Prefecture, central Japan. *J. Earth Sci., Nagoya Univ.* **34**, 1–21.

Yoshida T. (1977) Carboniferous System. in *Geology and Mineral Resources of Japan, 3rd Edit.* (ed. K. Tanaka and T. Nozawa), Vol.1, pp.80–105. Geological Survey of Japan.

Zhang H.R., Liu R.Z. Zhang S.F., and Kang B.X. (1991) The early Mesozoic deep sea sedimentary stratum in Wandashan of Heilongjiang Province. *Heilongjiang Geology* **2**, 30–40 (in Chinese with English abstract).