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# Radiolarian Biostratigraphy at the Triassic/Jurassic Period Boundary in Bedded Cherts from the Inuyama Area, Central Japan

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**Abstract**

Vertical distributions of microfossils such as radiolarians and conodonts across the Triassic/Jurassic (T/J) boundary were clarified through the biostratigraphic study of two continuous sequences of bedded cherts in the Inuyama area, central Japan. Three types of taxons were recognized around the T/J boundary, 1) Upper Triassic type such as *Squinabolella*, 2) Upper Triassic-Lower Jurassic type such as *Canoptum*, and 3) Transition type (possibly earliest Jurassic type) such as *Parahsuum* and *Bipedis*. The radiolarian fossils changed gradually, not drastically, from Triassic type into Jurassic ones during the interval (ca. 7 m.y.) from the extinction of conodonts to the first appearance of a species of *Bagotum*.

## Introduction

Distinctive faunal change, such as a "Mass Extinction," at the end of the Triassic period began within the Late Triassic (Norian and Rhaetian) and crossed the Triassic/Jurassic (T/J) period boundary. It has been documented among various kinds of marine faunas, Cephalopoda, Bivalvia, Gastropoda and so on (e.g., SEPKOSKI and RAUP, 1986). This event is one of the major mass extinctions through the geologic time boundary such as those at Permian/Triassic or Cretaceous/Tertiary boundaries. Paleontological studies of the T/J boundary have been well documented for shallow marine or platform sediments, e.g., New York Canyon in Nevada (TAYLOR *et al.*, 1983). These shallow marine sediments are excellent for age determinations owing to the abundance of diagnostic macrofossils. However, it is not good to examine the continuous change of individual fauna due to frequency of facies changes. Deep-sea sediments, such as bedded cherts are available for faunal observations because of the lack of distinct facies changes. The first preliminary report of the T/J boundary in deep-sea sediments was carried out at the Inuyama area, central Japan (YAO, MATSUDA and ISOZAKI, 1980). They examined the vertical distribution of conodonts and radiolarians in a continuous sequence of bedded cherts, and clarified a successive change of latest Triassic to early Jurassic radiolarians. Unfortunately, their section was not long enough for examination of faunal changes during early Jurassic time. To study faunal changes spanning early Jurassic time, we found two complete sections in the Inuyama area, namely the Katsuyama Section and the Kurusu

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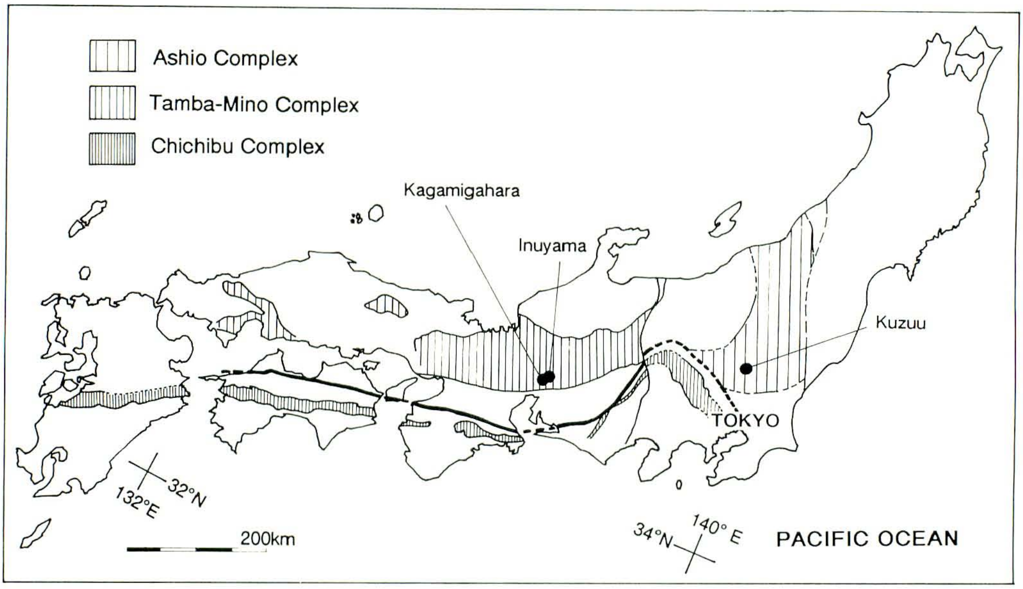


Fig. 1 Index map of the study area and the mentioned localities of the Triassic/Jurassic boundary in Japan. Striped areas indicate Mesozoic subduction-related complexes.

Section.

In Japan there are many continuous sequences of deep-sea sedimentary rocks such as bedded radiolarian chert. These sequences span middle Triassic to early Jurassic time. These bedded cherts occur as tectonic blocks or pile sheets within the Mesozoic subduction-related complexes. However, they show coherent sequences possessing abundant microfossils. Hence, they are available for biostratigraphical analysis. Few stratigraphic sections of deep-sea sediments crossing the T/J boundary are known. They were reported only from Japan, China and possibly from Alaska. A famous one is located in the Inuyama area (YAO, MATSUDA and ISOZAKI, 1980) and other two are in the Kagamigahara area (YOSHIDA, 1986) and the Kuzuu area (IGO and NISHIMURA, 1984) (Fig. 1). Our sections are the most complete ones because there are no tight folds, no distinct facies change across the T/J boundary, and their time-interval range is more than 30 m.y.

The purpose of this study is to clarify in detail the appearance and disappearance pattern of radiolarians and conodonts around the T/J boundary. These results will therefore contribute ot the relative age-determination of the geologic time scale.

## Stratigraphic Sections of the T/J boundary

The sections of the T/J boundary in Japan are observed within deep-sea sedimentary rocks such as bedded chert. The bedded cherts are included as tectonic blocks or pile sheets within the Mesozoic subduction-related complexes (Ashio, Tamba-Mino, and Chichibu Complexes) which consist of mixtures with pillow lavas, deep-sea sediments (bedded cherts), hemipelagites, trench-fill deposits and so on. These complexes are interpretated as an accretionary prizume formed along the eastern margin of Asia during late Mesozoic time (MATSUDA and ISOZAKI, 1991).

The present author measured two best sections of the T/J boundary in the Inuyama area (Fig. 2) where is the famous type-area of Early and Middle Jurassic radiolarian fossils such as *Parahsuum simplum* Yao and *Unuma echinatus* Ichikawa and Yao.

Katsuyama Section (UF Section of Hori, 1990)

A sketch map of the outcrop is shown in Fig. 3 and sampling points are marked on it. One supplementary section (Kb1–16) was measured for detail. The lithologic column of this section and stratigraphic distribution of representative radiolarian species are illustrated in Fig. 4.

Lithology: The Katsuyama Section comprises upper Triassic-lower Jurassic bedded cherts (31m) and middle Jurassic siliceous mudstone (2m) which is conformably underlaid by lower Jurassic chert. The bedded cherts are composed of a rhythmically interbedded sequence of chert (1–10 cm) and mudstone (1–3 mm). The upper Triassic bedded cherts exhibit light red and while the lower Jurassic bedded cherts are dark one. The extinction horizon of conodont species (*Axiothea posthernsteini*) was marked by the dusty red bed.

We found manganiferous chert layers at uppermost Lower Jurassic cherts which consist of three elements in this section; black chert layers including pyrite nodules, a massive white chert layer and chert layers containing rhodochrosite, in ascending order (around UFI19–UFI21 in Fig. 3). Many Mn-ore layers like this example were reported among the bedded cherts from Mesozoic accretionary complexes of Japan. However, the stratigraphy of these three rock-types is still uncertain. This section provides the clear stratigraphy of Mn-deposit in bedded cherts above-mentioned.

Minor lithologic change near the T/J boundary level was observed in this section. A red claystone layer (several centimeters thick) lies on the distinctive extinction level of conodonts (UFI13 and Kb1 in Fig. 3).

Biostratigraphy: Four radiolarian assemblage-zones of late Triassic to early Jurassic age, namely the *Canoptum triassicum* Assemblage-zone (UF1–5), the *Parahsuum simplum* Assemblage-zone (UF6–19), the *Mesosaturnalis hexagonus* Assemblage-zone (UF21–22) and the *Parahsuum* (?) *grande* Assemblage-zone (UF23–24) in ascending order, were recognized in this section.

Kurusu(KU) Section (Hori, 1988)

This is a complete section of Upper Triassic to Lower Jurassic strata spanning the T/J boundary. It is located on the left bank of the Kiso River, about 0.4 km north of the Kurusu village, Inuyama City, Aichi Prefecture. A sketch map of this section and sam-

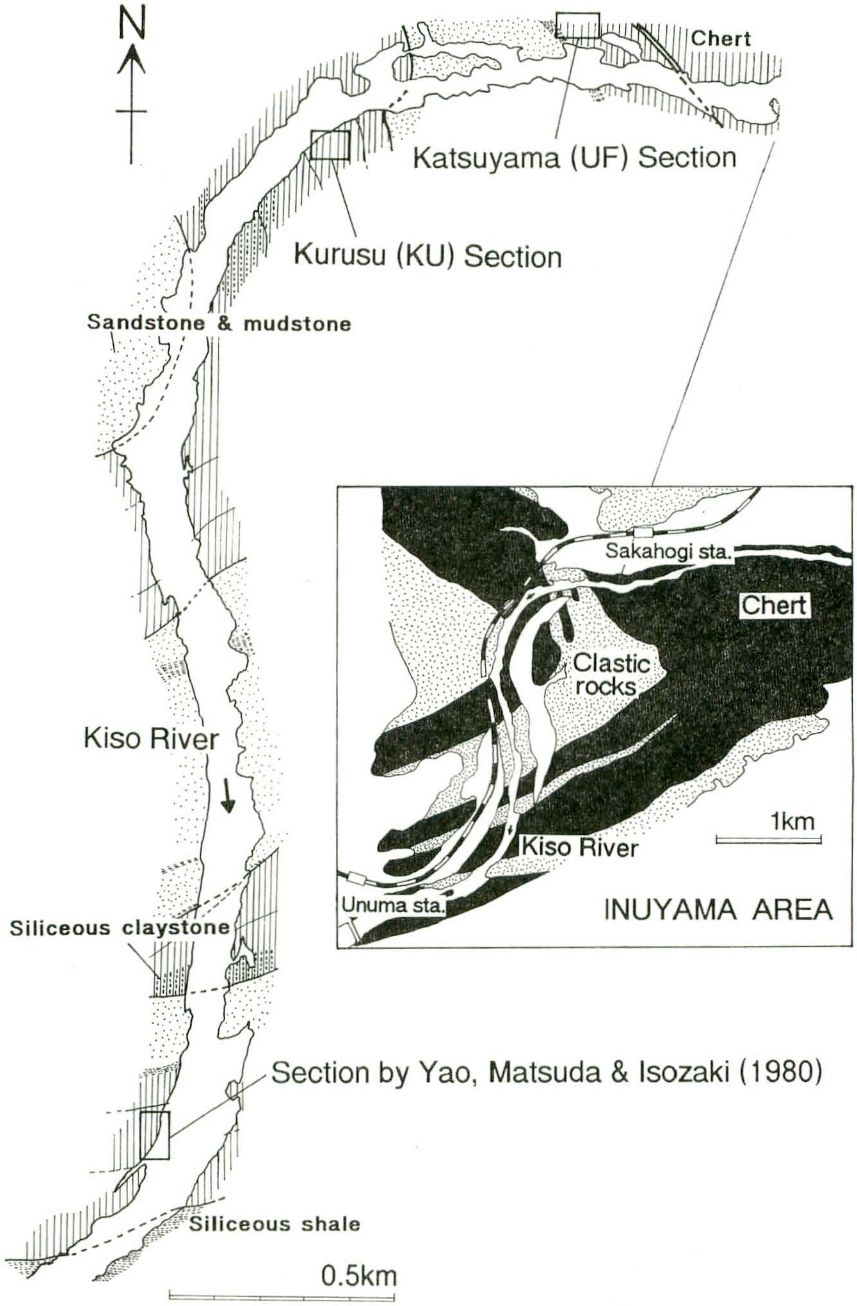


Fig. 2. Geologic and route maps along the Kiso River of the Inuyama area, central Japan (modified from Kondo & Adachi, 1975 and Kimura & Hori in press). The representative T/J boundaries are also shown on it.

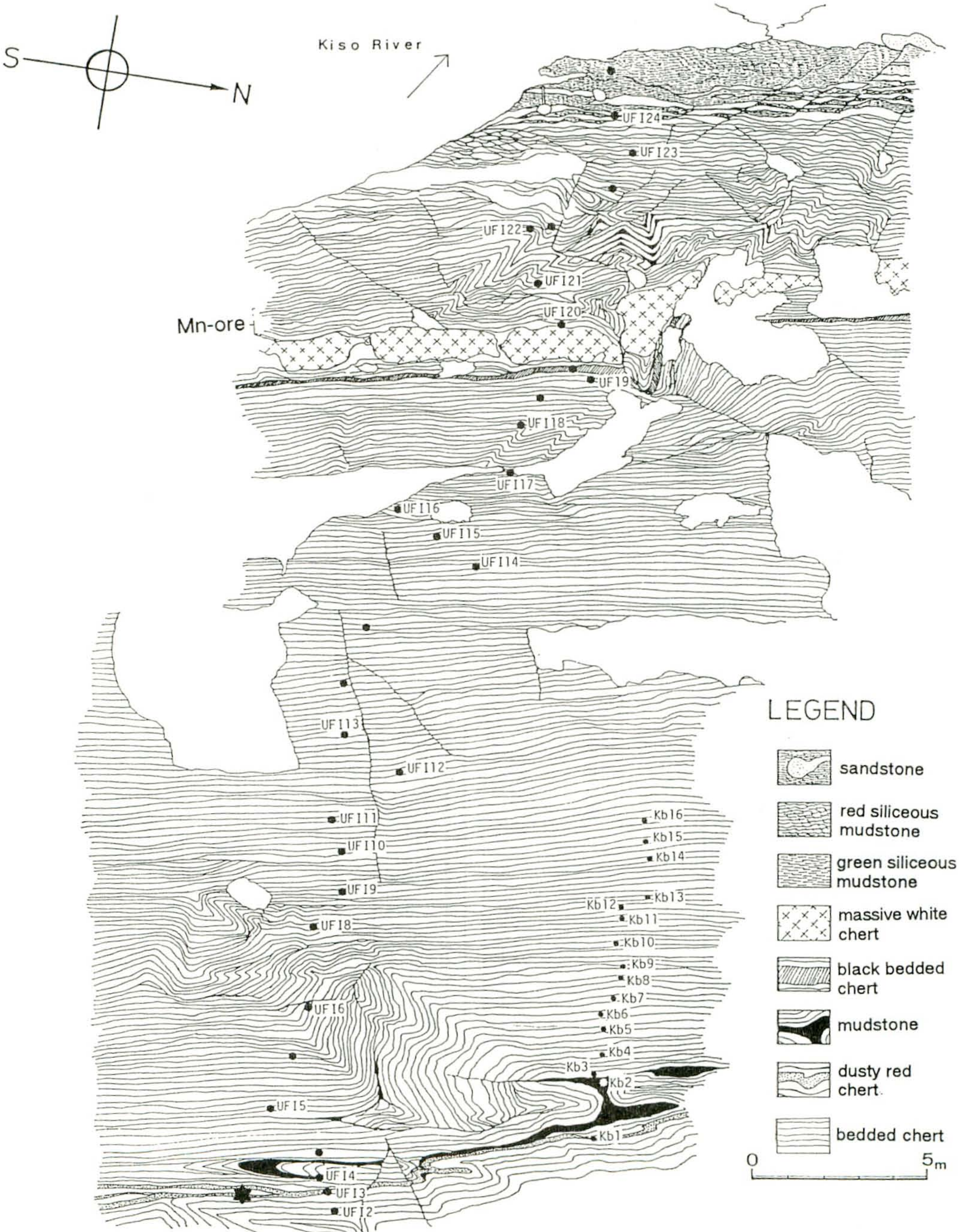


Fig. 3 Sketch map of the Katsuyama(UF) Section showing sample points(solid circles). A solid star is shown the final occurrence of *Axiothea posthernsteini*, representing the last survivor species of conodonts.

pling points are given by Hori(1988).

Lithology: This section is a 35 m thick rhythmically interbedded sequence of chert and mudstone. The cherts exhibit gray or green in color. The thickness of individual chert layer varies considerably from 1 to 7 cm, and the mudstone layer is very thin (ca. 1–3 mm) except for one thick layer (ca. 10–20 cm) occurring below KU23. The average of each couplet (mudstone-chert) is 4 cm in thickness. No facies change was observed

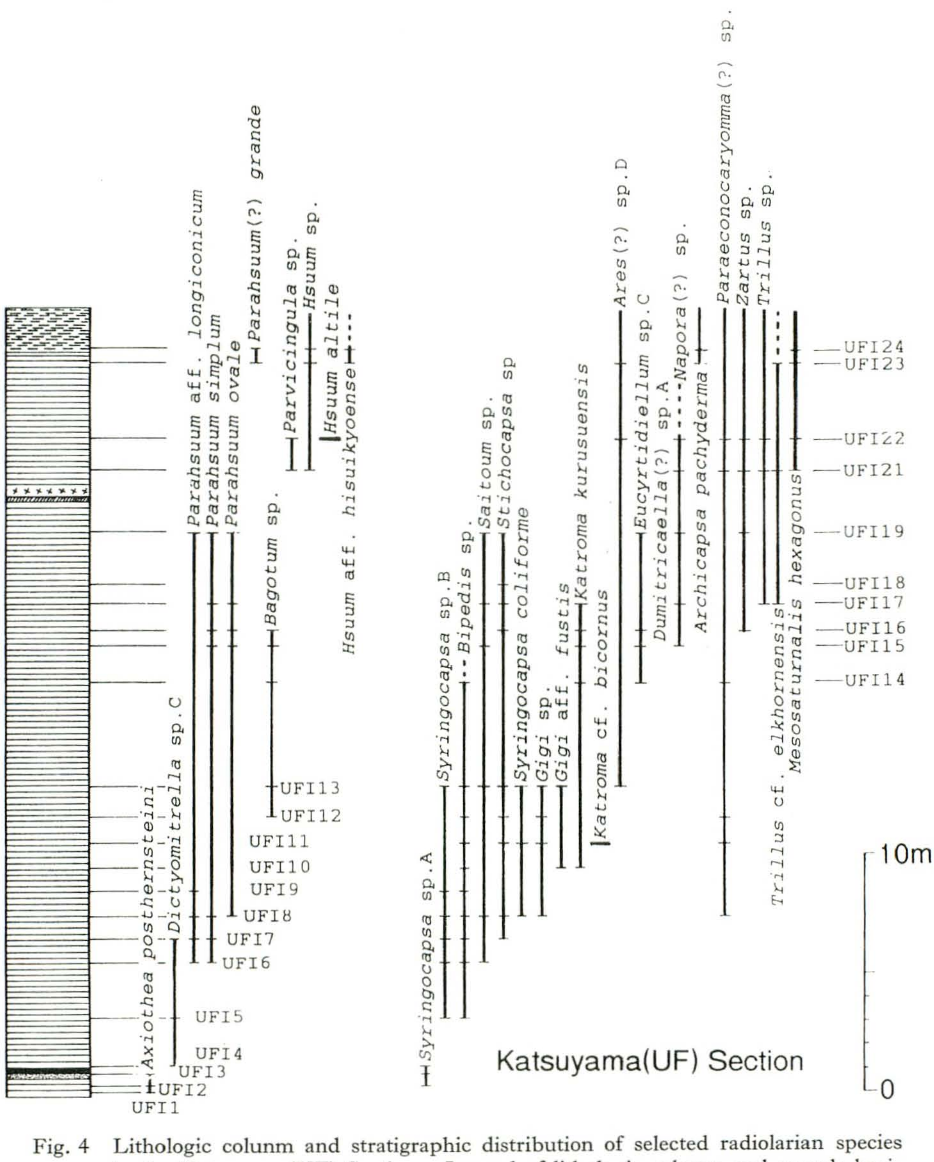


Fig. 4 Lithologic colunm and stratigraphic distribution of selected radiolarian species in the Katsuyama(UF) Section. Legend of lithologic column and sample horizons refer to Fig.3.

across the T/J boundary in this section.

Biostratigraphy: Three radiolarian assemblage-zones, the *Canoptum triassicum* Assemblage-zone (KU1–12), the *Parahsuum simplum* Assemblage-zone (KU13–22) and the *Mesosaturnalis hexagonus* Assemblage-zone (KU23–27) in ascending order, are recognized in this section(See details for Hori, 1990).

## Faunal changes of radiolarians and conodonts at T/J boundary

Occurrences of representative radiolarians and conodonts around the T/J boundary are given in Tables 1 and 2, and Fig. 5.

Conodonta: The extinction of conodonts is characterized by the last occurrence of *Misikella posthernsteini* (=Pectiniform element of *Axiothea posthernsteini* (Kozur and Mock), FAHRAEUS and RYLEY, 1989) in deep-sea sedimentary rocks from Japan. As discussed by ISOZAKI nad MATSUDA (1982, 1983), successive disappearances of *Epigondolella bidentata* Mosher, *Parvigondolella andrusovi* Kozur and Mock, *Axiothea hernsteini* (Mostler) and *Axiothea posthernsteini* (Kozur and Mock) were recognized in continuous sequences of Japan, and uppermost Triassic is represented by the occurrence of *A. posthernsteini* without *A. hernsteini*. In this study, except for reworked factor, the final occurrence of conodonts was observed in the lower part of measured sections (Kb01 and KU09).

Radiolaria: Vertical distribution of radiolarian fossils shows almost the same pattern in both sections.

Around the final occurrences of conodont (=*Axiothea posthernsteini*), the Triassic radiolarians such as genera *Deflandrecyrtium, Squinabolella* and *Livarella* make their final occurrences. The disappearances of them are relatively abrupt.

The first appearances of the folloiwng taxons are observed within the interval from the horizon a few meters below or at the final occurrence of conodont (FOC) to the horizon of the first occurrence of *Parahsuum simplum* Yao (KU04–KU13 and Kb01–Kb09): Affinities of *Gorgansium gongyloideum* Kishida and Hisada; affinities of *Pantanellium kluense* Pessagno and Blome; *Xenorum* sp. A; *Parahsuum* with a small shell; species of *Bipedis; Syringocapsa coliforme*; *Dictyomitrella* sp. C of YAO(1982).

At genus level, three types were recognized among taxons obtained from the interval from a few meters below of the FOC to the first occurrenec of a species of *Bagotum* crossing the T/J boundary. The interval is roughly estimated at 7 m.y. because the 1m-thickness of bedded chert in both sections equals to the 1m.y. (HORI and CHO, 1991).

1) Upper Triassic type: Some taxons with a hat shell such as *Deflandrecyrtium* and *Squinabolella*, and *Livarella*, these taxons occurred in Upper Triassic and disappeared at or immediate above the FOC.

2) Upper Triassic-Lower Jurassic type: Genus *Canoptum* are a representative taxon both of Upper Triassic and Lower Jurassic. Species of *Canoptum* often occurred in the bedded cherts of Japan, however, it is difficult to identify their species names because

Table 1 Radiolarian and conodont species from KU01-KU13 of the Kurusu(KU) Section, Inuyama area, central Japan.

| Sample number | KU01 | KU02 | KU03 | KU04 | KU05 | KU06 | KU07 | KU08 | KU09 | KU10 | KU11 | KU12 | KU13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rock facies | ch | ch | ch | ch | ch | ch | ch | ch | ch | ch | ch | ch | ch |
| Horizon (cm) | 0 | 55 | 115 | 160 | 195 | 319 | 332 | 380 | 438 | 460 | 500 | 550 | 670 |
| Fragments of conodont | + | | | + | | | + | | + | | | | |
| Axiothea posthernsteini (Kozur & Mock) | + | | | | | | | | + | | | | |
| Triassocampe (?) sp. | | + | | | | | | | | | | | |
| Canoptum triassicum Yao | + | | cf | | | | | | | | | | |
| Canoptum sp. | + | | | | + | | | | + | | + | | |
| Deflandrecyrtium sp. A of (Yao,1982) | + | + | + | + | | | | | + | | | | |
| D. sp. B of (Yao, 1982) | + | + | + | + | + | | | | | | cf | | |
| Squinabolella (?) sp. C of Yao(1982) | + | + | + | | | | | + | + | | cf | | |
| Livarella sp. | + | + | | + | | | | | | | + | | |
| Palaeosaturnalis aff. tenuispinosus (Donofrio & Mostler) | | + | | | | | + | + | | | | | |
| Gorgansium aff. gongyloideum Kishida & Hisada | | | | + | + | + | + | | + | | + | + | |
| Pantanellium aff. kluense Pessagno & Blome | | | | | + | + | + | + | + | | | + | |
| Xenorum sp. A | | | | | + | | + | | | | | + | |
| Pantanellium cf. kluense Pessagno & Blome | | | | | | | + | | | | | | |
| Gorgansium cf. gongyloideum Kishida & Hisada | | | | | | | + | | | + | + | + | |
| Parahsuum (?) sp. | | | | | | | + | ? | | | | | |
| P. sp. | | | | | | | + | | | + | | | |
| Bipedis sp. B | | | | | | | ? | | + | | + | | |
| B. sp. A | | | | | | | | | + | | + | + | + |
| Syringocapsa coliforme Hori | | | | | | | | | | + | + | | + |
| Dictyomitrella sp. C of Yao(1982) | | | | | | | | | | | + | + | + |
| Parahsuum simplum Yao | | | | | | | | | | | | | + |

Table 2 Radiolarian and conodont species from Kb01-Kb-15 of the Katsuyama (UF) Section, Inuyama area, central Japan.

| Sample number | Kb01 | Kb03 | Kb04 | Kb05 | Kb06 | Kb07 | Kb09 | Kb10 | Kb11 | Kb12 | Kb13 | Kb14 | Kb15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rock facies | ch | ch | ch | ch | ch | ch | ch | ch | ch | ch | ch | ch | ch |
| Horizon (cm) | 0 | 48 | 113 | 183 | 228 | 281 | 368 | 419 | 493 | 543 | 575 | 679 | 724 |
| Total number | 35 | 53 | 61 | 43 | 38 | 105 | 79 | 13 | 39 | 25 | 54 | 53 | 35 |
| Axiothea posthernsteini (Kozur & Mock) | 1 | | | | | | | | | | | | |
| Canoptum (?) sp. | 1 | | | | | 1 | | | 1 | | | | |
| Dictyomitrella sp. C of Yao(1982) | 5 | 1 | 13 | 8 | 1 | 15 | 2 | | 1 | 1 | 1 | 5 | 1 |
| Deflandrecyrtium sp. A of (Yao,1982) | 2 | | | | | | | | | | | | |
| Haeckelicyrtium (?) sp. A of Yao(1982) | 1 | | | | | | | | | | | | |
| Nassellaria gen. et sp. indet. A of Yao(1982) | 1 | | | | | | | | | | | | |
| Livarella sp. | 2 | | | | | 1 | | | | | | | |
| Squinabolella (?) sp. C of Yao(1982) | 3 | | | | | | | | | | | | |
| Syringocapsa sp. A of Yao(1982) | 4 | | | | | | | | | | | | |
| S. coliforme Hori | | | 2 | | 1 | 5 | | 1 | 2 | 1 | 3 | 3 | 1 |
| S. sp. B of Yao(1982) | | | | | 2 | 8 | 1 | | 1 | 1 | 6 | 3 | 2 |
| S. sp. D | | | | 1 | 2 | | | | | | | | |
| S. (?) sp. | | 1 | | | 1 | | | | | | | 1 | |
| S. sp. | | | | | | 1 | | | | | | 2 | |
| Bipedis sp. A | | 3 | 12 | 9 | 4 | 1 | 4 | 1 | 2 | 1 | 1 | 1 | 1 |
| B. sp. B | | | 1 | | | 3 | 2 | | 3 | 2 | 7 | 4 | 3 |
| B. sp. | | | | | 4 | 2 | 2 | | | | | | |
| Dumitricaella (?) sp. | | 2 | | 11 | 1 | 2 | | | | | | | |
| Nassellaria gen. et sp. indet. B | | 2 | | | | | | | | | | | |
| Parahsuum (?) sp. | | 1 | | | | 3 | | 3 | 1 | 5 | 2 | | |
| P. sp. | | | 2 | | 4 | 5 | 3 | | | | 1 | 3 | 1 |
| P. aff. longiconicum Sashida | | | | | | | 8 | | | | | 3 | |
| P. cf. levicostatum Takemura | | | | | 1 | 4 | | | | 1 | | | |
| P. ovale Hori & Yao | | | | | | 3 | | | | | 1 | | |
| P. simplum Yao | | | | | | . | 27 | 2 | 2 | | 9 | 3 | 1 |
| P. cf. simplum Yao | | | | | | 4 | | | 2 | 1 | | | |
| Laxtorum (?) sp. A | | | | 2 | | | 1 | | | | | | |
| Gigi (?) sp. | | | | | 1 | | | | 1 | 1 | 1 | 1 | |
| G. aff. fustis DeWever | | | | | | | | | 1 | | 3 | 5 | |
| Saitoum cf. keki DeWever | | | | | 3 | 2 | | | | 2 | | | |
| S. sp. | | | | | | | | | | | | 4 | |
| Perseus (?) sp. | | | | | | 1 | 1 | | 4 | 2 | | 1 | |
| Sthicocapsa sp. | | | | | | 1 | | | | | | | |
| S. sp. A of Yao(1982) | | | | | | | 2 | | | | | | |
| S. sp. B | | | | | | | | | | | | 1 | |
| Farcus sp. | | | | | | | 1 | | 2 | 1 | 1 | 4 | 1 |
| Katroma (?) sp. | | | | | | | 1 | | | | 2 | 2 | |
| K. sp. | | | | | | | | | | | | | 1 |
| K. kurusuensis Hori | | | | | | | | | | | | 3 | 6 |
| K. cf. kurusuensis Hori | | | | | | | | | | | | | 2 |
| K. sp. N of Hori(1988) | | | | | | | | | | | | | 1 |
| Podobursa sp. | | | | | | | 2 | | | | | | |
| Bagotum sp. | | | | | | | | | | | | | 1 |
| Kozurastrum sp. 1 | | | | | | | 1 | | 1 | | | | |
| Palaeosaturnalis aff. tenuispinosus (Donofrio & Mostler) | | 1 | | | | | | | | | | | |
| Astrocenturnus sp. | | 1 | | | | | | | | | | | |
| Crucella (?) sp. | | 1 | 1 | | | | | | | | | | |
| Gorgansium sp. | | | | | | | 1 | | | | | | |
| G. gongyloideum Kishida & Hisada | | 11 | | | | 2 | | | | | | | |
| G. cf. gongyloideum Kishida & Hisada | | 5 | | | | | | | | | | | |
| G. aff. gongyloideum Kishida & Hisada | | | 3 | | | | | | | | | | |
| Pantanellium sp. | | | | 2 | | | | | | | 1 | | 1 |
| P. cf. kluense Pessagno & Blome | | 1 | 1 | | 1 | | | | | | | | |
| P. aff. kluense Pessagno & Blome | | | | | | 3 | | 1 | | | | | |
| P. cf. rothwelli Pessagno & Blome | | 1 | | | | | | | | | | | |
| Welirella sp. | | 2 | | | | | | | | | | | |
| Xenorum sp. A | | | 1' | | 1 | | 2 | | 1 | | 3 | | |
| Orbiculiforma sp. | | | | 1 | | 1 | | | | | | | 1 |
| Palaeosaturnalis cf. fluegeli (Kozur & Mostler) | | | | 1 | | | | | | | | | |
| P. aff. prinevillensis (Blome) | | | | | | 1 | | | | | | | |
| P. sp. D of Yao(1982) | | | | | | | | 1 | 1 | | | | |
| P. aff. karnicus (Kozur & Mostler) | | | | | | | | | | | | 2 | |
| P. sp. | | | | | | 2 | | | | | | | |
| Paronaella sp. (P) of DeWever(1982) | | | | | | 1 | | | | | | | 1 |
| Hagiastrum sp. 1 | | | | | | 2 | | | | | | | |
| Pseudocrucella sp. | | | | | | 1 | | | | | | | |
| Praeconocarynmma (?) sp. | | | | | | | | | | | 1 | | 1 |
| Zartus (?) sp. | | | | | | | | | | | | 1 | |

of poor preservation.

3) Transition type (possibly earliest Jurassic type): *Parahsuum* and *Bipedis* make their first occurrences at or immediate below the FOC. At species level, many spumellarians are included in this type.

## Recognition of the T/J boundary

Because of lacking of other diagnostic fossils (e.g., ammonites), it is difficult for us to determine the precise horizon of the T/J boundary on the sequences of deep-sea sedimentary rocks in Japan.

The most important point in placing of the T/J boundary is the recognition of Rhae-

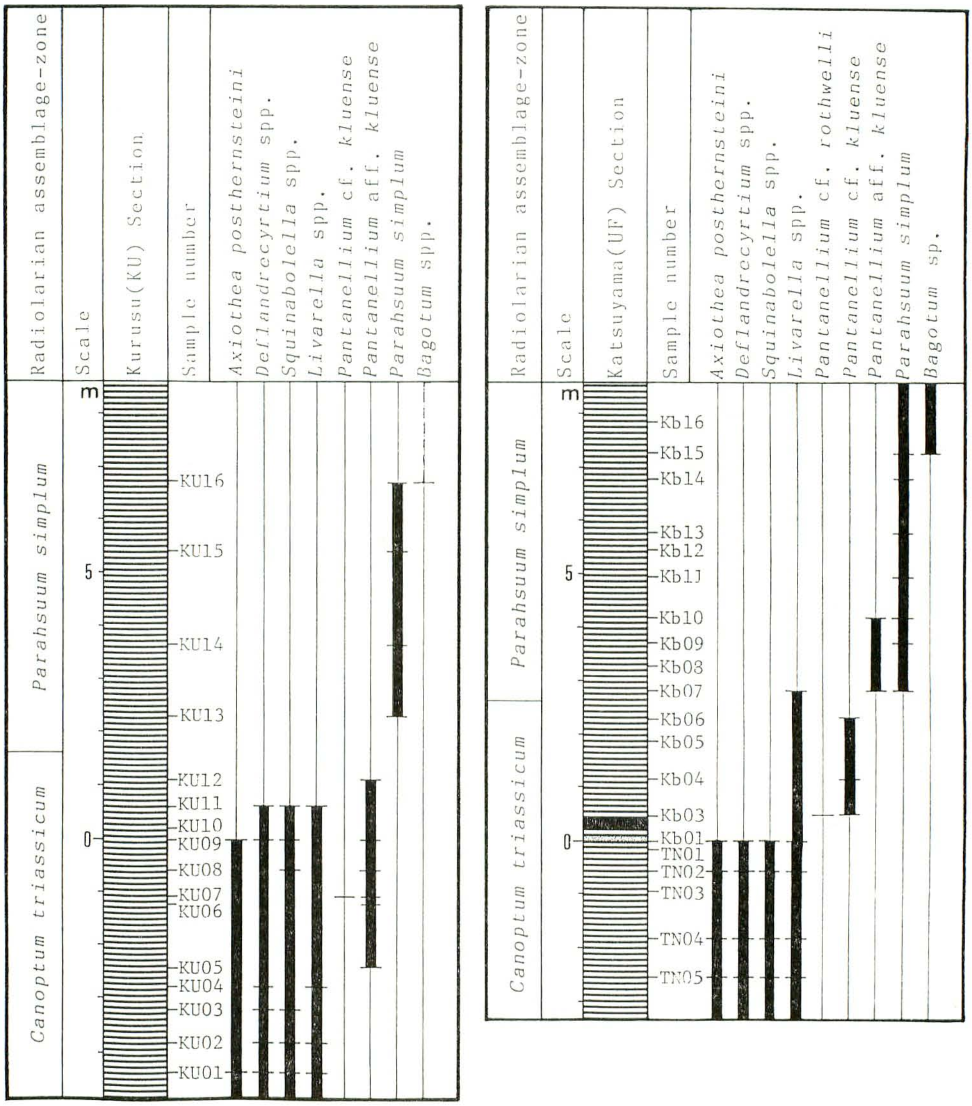


Fig. 5 Lithologic column and stratigraphic distributions of selected radiolarian and conodont species spanning the Triassic/Jurassic bonudary in the Kurusu and Katsuyama Sections from Inuyama area, central Japan.

tian stage (=the last stage of Triassic) and Hettangian stage (=the first stage of Jurassic). The horizon of FOC and radiolarian occurrence of affinities of *Pantanellium kluense* Pessagno and Blome give us a clue to suggest the boundary. *P. kluense* has been reported from the Hettangian Graylock Formation, east-central Oregon (PESSAGNO and BLOME, 1980). In addition, *P. kluense* and/or its affinities do not occur in the Rhaetian, and they begin to occur in Hettangian in the Queen Charlotte Islands, Canada (Carter, written communication, 1989). Hence, *P. kluense* seems to be an index marker of Hettangian stage in North America.

In Japan, the horizons of the first occurrence of affinities of *P. kluense* and *P.* cf. *kluense* are situated below that of FOC (KU05 and KU07 in Krursu Section).

Two interpretations are raised to explain these facts.

1) Affinities of *P. kluense* and *P.* cf. *kluense* have already appeared in Late Triassic age.

2) The extinction event of conodont did not occur in Late Triassic age but in Early Jurassic age.

We take the former one at present because of the following reasons. In European biostratigraphic section, the horizon of FOC which represents the last occurrence of *Axiothea posthernsteini* has been placed within Upper Triassic (e.g., KOVACS and KOZUR, 1980). Except for reworking fossils, no conodont has been reported from post-Triassic formations. For example, Late Triassic conodonts occasionally occurred in upper Lower Jurassic (post-l. Toarcian stage) beedded cherts of Japan. Occurrences of Triassic radiolarians such as *Deflandrecyrtium* and *Squinabolella* were observed around the horizon of FOC, Species belonging to these taxons were documented from Carnian formations of Europe (KOZUR and MOSTLER, 1979, 1981). We suggested most reworked conodont occurred in the post-l. Toarcian horizons due to the reworking process concerning the Toarcian oceanic anoxic event.

If the former interpretation is valid, the T/J boundary will be placed at least above the horizon of FOC. According to PESSAGNO and WHALEN (1982), the oldest species of *Bagotum* was documented from the Sinemurian, North America. Hence, the lowest horizons of occurrence of *Bagotum* (KU16 and Kb15) in the above-mentioned two sections are assigned to the Sinemurian or post-Sinemurian. Therefore the boundary can be drawn within the intervals of KU09–KU16 in the Kurusu Section and of Kb01–Kb15 in the Katsuyama Section.

## Conclusion

We newly recognized two stratigraphic sections of bedded cherts from the Inuyama area, central Japan for the study of the T/J boundary. They are complete sections without distinct facies change at the boundary horizon. Through this detail study of radiolarians, the following results were obtained.

1) The transition from Triassic fauna to Jurassic one gradually occurred among radiolarians. The transition time probably ranged at least from late Norian to pre-Sinemurian (ca. 7 m.y.=7 m-interval of bedded cherts).

2) Within the transition-interval, three types of radiolarians were recognized; Upper Triassic type such as *Squinabolella*, Upper Triassic-Lower Jurassic type such as *Canoptum*, and transition type such as *Bipedis*.

3) The Japanese T/J boundary in bedded cherts can be placed at least within the

interval from the final occurrence of conodonts (FOC) to the first one of the Genus *Bagotum*.


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