Conodont-based age calibration of the Middle Triassic Anisian radiolarian biozones in pelagic deep-sea bedded chert

Shun Muto¹*, Satoshi Takahashi¹, Satoshi Yamakita², Katsuhito Soda³ and Tetsuji Onoue³

Shun Muto, Satoshi Takahashi, Satoshi Yamakita, Katsuhito Soda and Tetsuji Onoue (2019) Conodont-based age calibration of the Middle Triassic Anisian radiolarian biozones in pelagic deep-sea bedded chert, Bull. Geol. Surv. Japan, vol. 70 (1/2), p. 43–89, 14 figs, 2 tables, 10 plates.

Abstract: The age of pelagic Panthalassic deep-sea bedded chert has been assigned based on radiolarian biostratigraphy. However, Triassic radiolarian biostratigraphy is in many cases not precisely correlated to the conodont zones and the standard geological timescale. In this study, we investigated the conodont biostratigraphy of two radiolarian-controlled bedded chert sections of Anisian age: the Ajiro Island section in Oita Prefecture and the Kurusu section in Aichi Prefecture. We recognised six conodont biozones in the studied sections: the upper Olenekian Novispathodus brevissimus-Icriospathodus collinsoni and Triassospathodus homeri Zones, the lower Anisian Chiosella timorensis Zone, the middle Anisian Paragondolella bulgarica Zone, the upper Anisian Paragondolella excelsa Zone and the uppermost Anisian to lowermost Ladinian Paragondolella trammeri Zone. These conodont zones were successfully correlated to the standard Triassic radiolarian zonation proposed by Sugiyama (1997, Bull. Mizunami Foss. Mus., vol. 24, p. 79–193). Sugiyama’s radiolarian TR 1 Zone, previously considered to be of Olenekian age, extends to the middle Anisian. The TR 2A Zone, the TR 2B Zone and the lower part of the TR 2C Zone are correlated to the middle Anisian, while the upper part of the TR 2C Zone and the lower part of the TR 3A Zone are correlated to the upper Anisian. The upper part of the TR 3A Zone and the lower part of the TR 3B Zone are probably correlative to the uppermost Anisian, but the possibility that they are correlative to the lowermost Ladinian cannot be ruled out.

Keywords: biostratigraphy, conodont, radiolarian biozone, Panthalassa, Middle Triassic

1. Introduction

Carboniferous to Jurassic pelagic deep-sea bedded chert preserved in the accretionary complex of Japan provides precious sedimentary records of the Panthalassa sea floor (Kojima et al., 2016; Matsuda and Isozaki, 1991; Wakita and Metcalfe, 2005) (Fig. 1A). For instance, evidence of oceanic anoxia (Fujisaki et al., 2016; Takahashi et al., 2009), bolide impact (Sato et al., 2013, 2016) and climate change (Nakada et al., 2014) have been documented from Triassic bedded chert in Japan. The prerequisite for such studies is the recognition of reliable geochronological controls for the bedded chert sequence, which was attempted by biostratigraphic correlations. The age assignment of bedded chert is commonly based on radiolarian biostratigraphy, which has been successfully established in many regions due to the abundant occurrence of radiolarians from bedded chert (e.g. Matsuoka and Yao, 1986; Sugiyama, 1997). Currently, the radiolarian biozones of Sugiyama (1997) established in the Inuyama area in central Japan are regarded as the most complete radiolarian zonation of Triassic deep-sea bedded chert deposited in the pelagic Panthalassa (e.g., O’Dogherty et al., 2010). However, the Triassic radiolarian biozones of Sugiyama (1997) is not precisely correlated to the global standard geological timescale (Ogg, 2012). Hence, it is necessary to calibrate the radiolarian biozones based on geochronological controls that can be robustly correlated to the global standard geological timescale. Calibration by conodont biostratigraphy as in Sato et al. (2013, 2016) and Nakada et al. (2014) is a useful method, because although much rarer than radiolarians, conodont fossils occur reasonably frequently from deep-sea bedded chert (Hayashi, 1968; Isozaki and Matsuda, 1982, 1983;
In this article, we focused on the radiolarian biozones previously assigned to the Anisian Age (the TR 2A to TR 3A Zones of Sugiyama, 1997), and calibrated their ages based on conodont biostratigraphy. Previous reports of Anisian conodonts from bedded chert have been sporadic (Ando et al., 2001; Matsuda and Isozaki, 1982; Mizutani and Koike, 1982; Sugiyama, 1997; Tanaka, 1980). The conodont Chiosella timorensis, which has been proposed as a marker for the base of the Anisian (Ogg, 2012; Orchard, 2010) has been found from pelagic deep-sea sediments including bedded chert in the Kuzuu area in east Japan (Muto et al., 2018), the Nichihara area in southwest Japan (Tanaka, 1980) and the Kamiaso area in central Japan (Matsuda and Isozaki, 1982). In particular, Muto et al. (2018) indicated that the radiolarian based Olenekian-Anisian boundary, which is placed at the base of the TR 2A Zone of Sugiyama (1997) is within the middle Anisian. Therefore, the age of the “lower Anisian” radiolarian biozones of Sugiyama (1997) needs to be reinvestigated. On the other hand, the finding of middle Anisian conodonts Paragondolella bulgarica and Nicoraella kockeli from the TR 2B and TR 2C Zones in the Inuyama area (Ando et al., 2001; Mizutani and Koike, 1982; Sugiyama, 1997) ensures that a part of these zones is correlative to the Anisian. Unfortunately, throughout the range of these conodonts with regard to the radiolarian biozones remains unknown. The occurrence of the late Anisian conodont Paragondolella excelsa followed by that of the Ladinian conodont Budurovignathus hungaricus from a continuous bedded chert section in the Nichihara area (Tanaka, 1980) likely indicates the presence of the Anisian-Ladinian boundary. Unfortunately, radiolarians were not reported from this section, and the boundary cannot be correlated with radiolarian biozones. A more intensive investigation on conodont biostratigraphy and its correlation with radiolarian biozones based on high-resolution sampling are required to calibrate the age of the radiolarian biozones.

Two sections were selected for investigation of conodont biostratigraphy in this study. The first is the Ajiro Island section in the Tsukumi area, southwest Japan (Onoue et al., 2011; Soda et al., 2015; Uno et al., 2012) (Figs. 1B, 2). This section was chosen because the TR 2A to TR 3A Zones can be collectively observed in one continuous section (Onoue et al., 2011). Although the stratotype of the radiolarian biozones of Sugiyama (1997) was defined in the Inuyama area, the stratotype sections of the TR 2A to TR 3A Zones were defined in separate outcrops, which is a large disadvantage to the Ajiro Island section. In addition, the Ajiro Island section was logged bed-by-bed in Onoue et al. (2011) and Soda et al. (2015). Radiolarian biostratigraphy was based on their logs, which meant that we could compare conodont and radiolarian biostratigraphy at bed-by-bed resolutions. The second section is the Kurusu section in the Inuyama area in central Japan (Yao and Kuwahara, 1997) (Figs. 1B, 3). Although this is not one of the stratotype sections of Sugiyama (1997), it provides crucial evidence on the age of the TR 2A Zone, as detailed below. The stratotype section of the TR 2A Zone is Section M in the Inuyama area, but the base of this zone is not observed there (Sugiyama, 1997). In the Ajiro Island section, the base of the TR 2A section was determined, but the underlying TR 1 Zone did not yield the radiolarian Parentactinia nakatsugawaensis, which is the species that most characterises the TR 1 Zone. Therefore, the TR 1 Zone in the Ajiro Island section may not be directly correlative to its type section in the Inuyama area. In contrast, in the Kurusu section, the Pa. nakatsugawaensis Assemblage Zone is overlain by the Hozmadia gifuensis Assemblage Zone (Yao and Kuwahara, 1997) and the boundary of the two zones can be approximated as the base of the TR 2A Zone. The boundary of the Pa. nakatsugawaensis Assemblage Zone
and the H. gifuensis Assemblage Zone was also reported from the Momotaro-jinja section in the Inuyama area (Fig. 3; Yao and Kuwahara, 1997). However, the H. gifuensis Assemblage Zone in this section did not yield the nominal species H. gifuensis. Furthermore, according to Sugiyama (1997) who investigated the lateral extension of the Momotaro-jinja section (Section T of Sugiyama (1997)), the interval assigned to the H. gifuensis Assemblage Zone by Yao and Kuwahara (1997) is within the TR 1 Zone. In sum, the Kurusu section is the only well-studied section that includes the base of the TR 2A Zone.

In this article, we present the lithostratigraphy and conodont biostratigraphy of the Ajiro Island and Kurusu sections. The conodont biostratigraphy is illustrated parallel to previous results on radiolarian biostratigraphy. Based on correlation with conodont biostratigraphy established in the Tethys region and North America, including the global boundary stratotype section and point (GSSP) candidate for the base of the Anisian and the GSSP of the base of the Ladinian, the radiolarian biozones were calibrated to the global standard geological timescale.

2. Geologic setting of the study sections

The studied sections belong to the Jurassic accretionary complex in southwest Japan. The Jurassic accretionary complex is mainly composed of Carboniferous to Middle Jurassic oceanic rocks (ocean floor basalt, deep-sea chert, hemipelagic siliceous mudstone, seamount basalt and seamount-capping carbonate), and Middle Jurassic to lowermost Cretaceous trench-fill terrigenous clastic rocks (mudstone and sandstone) (Isozaki et al., 2010; Wakita and Metcalfe, 2005). Of the Carboniferous to Middle Jurassic oceanic rocks, the deep-sea sedimentary rocks were deposited in the pelagic Panthalassa superocean several thousand kilometres away from the nearest continent (Fig. 1A), after which they traveled to a subduction zone along the paleo-continent and formed part of accretionary complexes by the tectonic movement of the oceanic plates (Isozaki et al., 2010; Matsuda and Isozaki, 1991; Wakita and Metcalfe, 2005).

2.1 Ajiro Island section

The Ajiro Island section is located in Ajiro Island (Ajiro Jima in Japanese) on the northern coast of the Youra Peninsula, Tsukumi City, Oita Prefecture, Kyushu District (33°4′10″N 131°55′10″E). The studied section belongs to the Southern Chichibu Belt (Fujii, 1954; Hoshizumi et al., 2015; Kambe and Teraoka, 1968: Matsuoka et al., 1998), which is mostly composed of a Jurassic accretionary complex (Isozaki et al. 2010; Matsuoka and Yao, 1990; Matsuoka et al., 1998). The studied section is a part of the Shakumasan Group, which preserves the upper part of the original sequence on the oceanic plate (Nishi, 1994). The Shakumasan Group is further subdivided into the lower Enoura Formation and the upper Youra Formation (Nishi, 1994). The Enoura Formation is composed of Lower Triassic to Middle Jurassic pelagic deep-sea sedimentary rocks (mostly chert) (Matsuoka, 1986; Nishi, 1994), and is overlain conformably by trench-fill clastic rocks of the Youra Formation (Fig. 2; Nishi, 1994). The succession of these two formations occurs repeatedly due to the imbricate structure formed by thrusts (Fig. 2; Nishi, 1994).

The section investigated in this study belongs to the lowermost part of the Enoura Formation (Fig. 2B). The Ajiro Island section is located in the southernmost part of the Ajiro Island on the northern coast of the Tsukumi area. The studied outcrop corresponds to the "alternation beds of siliceous claystone and chert" and "red chert" in Fig. 2 of Uno et al. (2012). According to the age assignment based on radiolarian biostratigraphy, the bedded chert of the Ajiro Island has been dated as latest Spathian to early Ladinian, and has a northward younging trend (Onoue et al., 2011; Takahashi et al., 1998). The palaeolatitude of the depositional grounds have been estimated to be 2.1 ± 5.2°S based on rock magnetic records (Uno et al., 2012).

2.2 Kurusu section

The Kurusu section (Kr-2 section of Yao and Kuwahara, 1997) is located on the eastern bank of the Kiso River in Inuyama City, Aichi Prefecture, Chubu District (35°25′8″N 136°57′50″E). The Kurusu section belongs to the Mino-Tamba-Ashio Belt, which is mostly composed of a Jurassic accretionary complex (Isozaki et al., 2010; Yamakita and Otto, 2000; Kojima et al., 2016). The Kurusu section is a part of the Kamiaso Unit (Wakita, 1988), which is a coherent tectonostratigraphic unit composed of Lower Triassic siliceous claystone, Middle Triassic to Lower Jurassic pelagic deep-sea bedded chert, Middle Jurassic hemipelagic siliceous shale and Upper Jurassic turbidite and massive sandstone in ascending order (Yao et al., 1980). Thus, the upper part of the original sequence on the oceanic plate is preserved in the Kamiaso Unit. The Kamiaso Unit in the Inuyama area has been studied in detail by Kimura and Hori (1993). They clarified that the coherent sequence from pelagic siliceous claystone and chert to trench-fill clastic rocks ("Inuyama Sequence" in their paper) repeated six times as thrust sheets, which together form a synclinal structure with a W-plunging, WNW-ESE trending axis (the Sakahogi syncline; Mizutani, 1964). The Kurusu section corresponds to the lowermost strata of "sheet 4" in Kimura and Hori (1993), and is located on the northern wing of the Sakahogi syncline, close to the axis (Fig. 3).

Yao and Kuwahara (1997) studied the radiolarian biostratigraphy of the Kurusu section and indicated that the section is correlated to the Parentactinia nakatsugawaensis Zone and the Hozmadia gifuensis Zone. The radiolarian biostratigraphy indicates a southward younging trend for this section. This younging trend is consistent with the fact that the south of the section faces the axis of the Sakahogi syncline. The palaeolatitude of the depositional site of the Anisian bedded chert in the Inuyama area has been estimated to be 12.3 ± 15.6°N.
or S (Oda and Suzuki, 2000) or 5.6 ± 2.2° S by (Ando et al., 2001) based on palaeomagnetic records. Ikeda et al. (2010) investigated the “Kr-2 section of Yao and Kuwahara (1997)” for cyclostratigraphy, but their section was observed in a different part of the outcrop (compare Fig. 4 of Yao and Kuwahara (1997) and Fig. 1S in the supplementary materials of Ikeda et al. (2010)). In this study, we investigated the studied section of Ikeda et al. (2010) in addition to the section of Yao and Kuwahara (1997).

3. Methods

3.1 Field mapping

For both the Ajiro Island and Kurusu sections, geological maps of the outcrop were made based on examination of the geological structure and lithology at the sub-metre scale. For the major part of the Ajiro Island section, detailed lithostratigraphy has been reported by Onoue et al. (2011), Soda et al. (2015) and Uno et al. (2012). We conducted a biostratigraphic investigation building on the lithostratigraphic section constructed by these studies. For the lower part of the Ajiro Island section, lithostratigraphy has not been investigated thoroughly by previous studies. Therefore, we reconstructed the lithostratigraphy of this part of the outcrop based on detailed mapping with careful attention to deformation and continuity. Lithostratigraphy of the Kurusu section has been reported by Yao and Kuwahara (1997) and Ikeda et al. (2010). However, both studies did not investigate the entire outcrop. In this study, we present an original outcrop sketch map and lithostratigraphic columns that include, but are not restricted to, stratigraphic intervals that were investigated by these studies.

3.2 Conodont biostratigraphy

Conodonts were found by observing the surfaces of sample rocks cleaved parallel to the bedding into small “chips” (the “chip method”; Muto et al., 2018; Takemura et al., 2001). This method allows us to find conodonts that are cracked or preserved as moulds and impossible to extract by dissolving the host rock. A preliminary search for conodonts by the “chip method” was conducted at the outcrop using a hand lens (20 magnifications), and horizons that yielded conodonts were selected for further investigation. Following Muto et al. (2018), 2–5 kg blocks of the selected horizons were brought back to the laboratory, and then cleaved into thin planar chips. These chips were moistened with tap water and then examined under a stereoscopic microscope of 20 to 60 magnifications. Early attempts of the “chip method” resulted in larger numbers of specimens from greenish grey parts of the bedded chert compared to red or purple parts. This is probably because conodont fossils have more chances of being found in the more transparent greenish
grey chert compared to purple or red chert. Therefore, the parts of strata that have been altered to greenish grey were targeted in the later attempts to find conodonts from dominantly purple or red intervals.

For specific identification, the chips were observed under a stereoscopic microscope of 100 magnifications. The surface of the chips were dried, soaked with water or coated with oil depending on the type of host rock and the state of preservation of the specimens. Moulds in siliceous claystone without grey fillings were best observed on dry surfaces, while moulds in siliceous claystone with grey fillings were better observed when soaked with water. Specimens in chert were best observed when the surface of the chert was coated with oil.

4. Results

4.1 Ajiro Island section

4.1.1 Field mapping

The Ajiro Island section is exposed on the southern coast of Ajiro Island, Tsukumi City, Oita Prefecture (Fig. 2). The outcrop of the Ajiro Island section consists of two parts that have different geological structure and lithology. The main part of the section (the AJR section), which is exposed along the south to southeast coast of Ajiro Island, comprises bedded chert (Fig. 4). The AJR section
has already been studied in detail by previous studies (Onoue et al., 2011; Soda et al., 2015; Uno et al., 2012), and therefore we will only give a brief description of the outcrop. The other part is exposed at the southern tip of Ajiro Island, and comprises alternating beds of siliceous claystone and chert that are more intensely folded and faulted compared to strata of the AJR section (Figs. 4, 5). This part has been mapped by Onoue et al. (2011) and Uno et al. (2012), but lithostratigraphy was not examined in detail. Here, we provide a more detailed geological map and lithostratigraphic columns for this part of the section (the AJ-1, AJ-2, AJ-3-1 and AJ-3-2 sections). In the following text, we will explain the geological structures and lithofacies of the Ajiro Island section in stratigraphically ascending order (stratigraphic order is explained in Section 4.1.2.).

The lower part of the Ajiro Island section corresponds to the AJ-1, AJ-2, AJ-3-1 and AJ-3-2 sections exposed at the southern tip of Ajiro Island (Fig. 5). The strata here generally strike ENE-WSW and dip steeply to the north, apart from the northwestern part where the strata strike E-W to WNW-ESE. Isoclinal folds with wavelengths up to 2 m are present throughout the outcrop, and the strata are locally overturned. The axial planes of these folds are almost parallel to the bedding. The faults in this part of the outcrop can be distinguished into the following
two types. Major faults with displacements of at least several metres were identified in the northern part. These faults are characterised by sheared zones about 50 cm wide on either side of the fault plane. Minor faults with displacements of up to 2 m are present throughout the outcrop. These faults are not accompanied by wide sheared zones. Recognition of three key beds (Figs. 5, 6) revealed that strata in the western half of the outcrop are relatively weakly deformed. Therefore, we observed the lithostratigraphy in the western half of the outcrop, avoiding areas where strata are deformed by faults and folds. The reconstructed lithostratigraphic column comprises four continuous sequences: AJ-1 section, AJ-2 section, AJ-3-1 section and AJ-3-2 section in ascending order (Figs. 5, 9). On the other hand, in the eastern part of the outcrop, strata in the lower part of the AJ-1 section are repeated by faults and folds, while the upper part of the AJ-1 section, the AJ-2 section, the AJ-3-1 section and most of the AJ-3-2 section are missing.

The AJ-1 section is approximately 8.4 m thick, and is composed mainly of alternating beds of grey siliceous claystone and dark grey chert (Fig. 7A). An interval composed of black siliceous claystone and black chert occurs in the lower part of this sequence. The AJ-2 section is approximately 4.8 m thick, and is composed mainly of alternating beds of grey siliceous claystone and dark grey
or black chert (Fig. 7B). Thin (~10 mm thick) red siliceous claystone beds occur characteristically in this section. The AJ-3-1 section is approximately 2.0 m thick, and is composed mainly of alternating beds of grey siliceous claystone and grey or dark grey chert (Fig. 7C). The AJ-3-2 section lies directly above the AJ-3-1 section, but a slip plane exists between the two sections, and therefore they are not confirmed to be continuous (Fig. 7C, D). The AJ-3-2 section is approximately 3 m thick, and is composed of dark grey bedded chert with intercalations of grey siliceous claystone (Fig. 7D). This section is in fault contact with greenish grey bedded chert to the north.

In the outcrop of the AJR section, the strata strike ENE-WSW and dip steeply to the north (Fig. 4). A major fault with an apparent displacement of ~10 m occurs in the northern part. Minor faults with apparent displacements of up to 2 m occur throughout the outcrop. Deformation of the strata is negligible, apart from drags and shears near faults. The colour of bedded chert changes from greenish grey to purple, then to red in ascending order (Figs. 8A–D, 9). Some white highly recrystallised chert beds occur in the red bedded chert. Some parts of the purple and red bedded chert are altered to greenish grey (Fig. 8D). Our study section mostly corresponds to the section illustrated in previous studies (Onoue et al., 2011; Soda et al., 2015; Uno et al., 2012). However, we observed an additional ~2 m of red bedded chert above the top of their section. In addition, we identified a stratigraphic discontinuity at the basal part of the lithologic column by Onoue et al. (2011) (the two faults within the AJR section in Fig. 9). Our reinvestigation of the geological structure showed that the stratigraphic intervals corresponding to the TR 1 and TR 2A Zones in their section are separated by a fault. Furthermore, a block of greenish grey bedded chert occurs structurally between these two intervals. The lithostratigraphic column illustrated in this study incorporates this new finding.

4. 1. 2 Conodont biostratigraphy
Conodont fossils were found from all of the investigated
samples (more than 2000 specimens in total). Conodonts in siliceous claystone were preserved as moulds, while those in chert were dark grey skeletons or white or orange casts. Although most of the specimens were broken and unidentifiable, 194 specimens were identified at the species level (Table 1; Plates 1–7). Conodont animals are taxonomically classified based on their apparatuses that comprise an assemblage of conodont elements (Clark et al., 1981; Orchard, 2005; Sweet, 1988), but some morphologically distinguishable elements are yet to be assigned to any apparatus. Such elements are classified as form groups and are indicated in this paper with quotation marks.

Conodonts from the siliceous claystone that alternates
Fig. 8 Outcrop photographs of the AJR section. (A) The upward lithofacies change from greenish grey bedded chert to purple and red bedded chert. (B) Greenish grey bedded chert. (C) Purple and red bedded chert. (D) Red bedded chert. Note that the colour is altered to greenish grey in some parts. The stratigraphic way up is to the right in (A) and (C), and to the top in (B) and (D). The black ruler and board in the photos as scale are the same as that in Fig. 7.

(p.53) Fig. 9
Lithostratigraphy, conodont biostratigraphy, radiolarian biostratigraphy and magnetostatigraphy of the Ajiro Island section. The range chart for conodonts excludes some specimens that were not identified at the species level. See Table 1 for full list and numbers of identified conodonts. Radiolarian biostratigraphy is after Onoue et al. (2011) and Uno et al. (2012). Magnetic polarity zones are after Uno et al. (2012). *brevissimus-collinsoni* Zone; *Nv. brevissimus-I. collinsoni* Zone; *timorensis* Z.; *Ch. timorensis* Zone; *excelsa* Z.; *Pg. excelsa* Zone. The species names denoted in quotation marks are form species defined based on discrete conodont elements.
Table 1. Occurrence list of conodonts from the Ajiro Island section. Underlined numbers indicate the number of conferred specimens. Bracketed numbers indicate the number of questionable specimens. The species names denoted in quotation marks are form species defined based on discrete conodont elements.

| AJR724+2.4m | 1 | 2 | 1 | 1 | 3 | (13) |
| AJR724+1.9m | 1 | 2 | 1 | 3 | 7 | (8) |
| AJR722 & 723 | 1 | 1 | 1 | 6 | 1 |
| AJR669 & 670 | 1 | 1 | 1 | 1 |
| AJR630 & 631 | 3 | 3 | (2) | (1) |
| AJR603-605 & 606 | 2 | 1 | 3 | (2) |
| AJR577 & 578 | 2 | 1 | 3 | 1 | (2) |
| AJR517 & 518 | 1 | 5 | 1 | (1) | 2 | 6 | (1) | 3 | 1 |
| AJR408 & 409 | 3 | (3) | 3 | 3 |
| AJR377 & 378 | 2 |
| AJR310 & 311 | 3 | 1 | 1 |
| Sample Code | Conodonts |
|-------------|-----------|
| 170627-03   | 1 2 2 4 2 5 2 5 3 |
| 170627-02   | 2 3 2 2 1 1 |
| AJR144      | 1 1 7 1 |
| AJR101      | 2 1 |
| AJR0        | 2 1 1 3 3 |
| Ajr01       | |
| 160818-02   | no identifiable elements |
| 170627-01   | no identifiable elements |
| 151015-08.5 | |
| AjL1-B      | 2 1 |
| AjL1-A      | 1 1 |
| 160819-03   | 1 8 5 2 1 1 |
| 151005-13   | 1 9 12 2 2 3 1 1 |
| AjL-B       | 1 2 5 1 |
| AjL-A       | 1 2 |
| 150616-29   | 1 1 1 2 1 |
| 151005-03   | 1 |
| 150615-27   | no identifiable elements |
| 150614-06   | |
| AjL-C       | 1 1 1 2 |
| 150615-21   | 2 1 3 1 |

Conodont-based age calibration of Anisian radiolarian biozones (Muto et al.)
with chert in the AJ-1, AJ-2 and AJ3-1 sections include many adult specimens, but conodonts from the bedded chert in the AJR section are mostly juvenile forms. Especially, species of Paragondolella, which occurred abundantly from the AJR section, are almost entirely represented by juvenile stages with incomplete platform development.

Species belonging to the genus Paragondolella are difficult to distinguish in juvenile forms. Identification of our specimens is further hindered by the fact that they are partly immersed in the host rock. Hence, in the case of specimens of Paragondolella, we referred to a group of species that share some important morphological characters (see the palaeontological notes in Chapter 9 for details). Specifically, three “Groups” are used in this paper: the Paragondolella bulgarica Group (Pg. bulgarica, Paragondolella bifurcata and Paragondolella hanhulogi), the Paragondolella excelsa Group (Pg. excelsa, Paragondolella fueloepi and Paragondolella liebermanii), and the Paragondolella trammeri Group (Pg. trammeri and Paragondolella alpina). Note that these “Groups” do not necessarily represent taxonomic lineages.

Based on the occurrence of conodonts, six conodont biozones were recognised in the Ajiro Island section: the Novispathodus brevissimus-Icriospathodus collinsoni Zone, the Triassospathodus homeri Zone, the Chiosella timorensis Zone, the Pg. bulgarica Zone, the Pg. excelsa Zone and the Pg. trammeri Zone in ascending order (Fig. 9).

The Nv. brevissimus-I. collinsoni Zone is characterised by the occurrence of Nv. brevissimus and I. collinsoni. Its base is not defined in the Ajiro Island section and its top is defined by the last occurrence (LO) of the two species. This zone is recognised in the lowermost part of the AJ-1 section (Fig. 9). Other associated species are Novispathodus abruptus, Novispathodus symmetricus and T. homeri.

The T. homeri Zone is characterised by the occurrence of Nv. abruptus, Nv. symmetricus and T. homeri. Its base is defined by the LO of Nv. brevissimus and I. collinsoni and its top is defined by the first occurrence (FO) of Ch. timorensis. This zone is recognised in the main part of the AJ-1 section and the lower part of the AJ-2 section (Fig. 9). Other associated species are Chiosella gondolelloides, Triassospathodus anhuiensis and “Neohindeodella benderi”.

The Ch. timorensis Zone is characterised by the occurrence of Ch. timorensis. Its base is defined by the FO of the nominal species and its top is defined by the FO of the Pg. bulgarica Group. This zone is recognised in the AJ-3-1 section (Fig. 9). T. homeri also occurred from this zone.

The Pg. bulgarica Zone is characterised by the occurrence of the Pg. bulgarica Group. Its base is defined by the FO of the Pg. bulgarica Group and its top is defined by the FO of the Pg. excelsa Group. This zone is recognised in the AJ-3-2 section and the lower to middle part of the AJR section (Fig. 9). “Nh. benderi”, Cornudina? igoi and “Kamuellerella gebezensis” occurred from the lower part of this zone. The middle part of this zone yielded Neogondolella cf. hastata, in addition to Ng. aff. hastata and Neogondolella cf. regale, as well as species of Neogondolella with a large cusp that is fused to the posterior platform brim (post-Bithynian type Neogondolella; detailed explanation in Section 5.3.). Other associated species are Cornudina breviramulis, “Neohindeodella aequiramosa” and “Neohindeodella triassica”.

The Pg. excelsa Zone is characterised by the occurrence of the Pg. excelsa Group. Its base is defined by the FO of the Pg. excelsa Group and its top is defined by the FO of the Pg. trammeri Group. This zone is recognised in the upper part of the AJR section (Fig. 9). Other associated conodonts are the Pg. bulgarica Group, Co. breviramulis, “Nh. aequiramosa” and “Nh. triassica”.

The Pg. trammeri Zone is characterised by the occurrence of the Pg. trammeri Group. Its base is defined by the FO of the Pg. trammeri Group and its top is defined by the FO of Budurovignathus cf. hungaricus. This zone is recognised in the uppermost part of the AJR section (Fig. 9). Other associated conodonts are the Pg. excelsa Group, Co. breviramulis, Cornudina tortilis and “Nh. triassica”.

At the top of this zone, Neogondolella aequidentata and Neogondolella pridaensis co-occurred with B. cf. hungaricus.

4.2 Kurusu section

4.2.1 Field mapping

The Kurusu section is exposed on the east bank of the Kiso River in Kurusu, Inuyama City, Aichi Prefecture, Chubu District (Fig. 3). Strata in this outcrop are deformed by many faults and folds (Fig. 10). The outcrop is divided into two parts that have different lithology by a fault (“dividing fault” in Fig. 10). The eastern part includes the area mapped by Yao and Kuwahara (1997), and the section observed in this part of the outcrop is named the Kr-2-YK section (Fig. 10). The western part was studied by Ikeda et al. (2010), and the section observed here is named the Kr-2-1 section.

The outcrop of the Kr-2-YK section has a complicated geological structure (Fig. 10). The orientation of the bedding plane is variable due to folding. Tracing of characteristic black claystone and black chert beds revealed that the lower part of this section is repeated by folds. In some parts, the bedding of the strata was difficult to identify due to strong deformation. The Kr-2-YK section was observed in parts of the outcrop where deformation was minimal, which include the area studied by Yao and Kuwahara (1997). The Kr-2-YK section is composed mainly of grey bedded chert with intercalations of grey siliceous claystone (Fig. 11A). Black claystone and black chert beds also occur in several horizons. The transition between grey chert layers and grey siliceous claystone layers is gradual. Therefore, the contrast
between the chert layers and the siliceous claystone layers is not strongly expressed in the configuration of the outcrop surface. This may have led to the description of the strata as "siliceous claystone" by Yao and Kuwahara (1997). However, the rocks have moderate vitreous luster and are not fissile, which indicate that its lithology is better described as chert. This is further supported by the presence of numerous radiolarian tests and quartz matrix confirmed in thin sections (Fig. 11D). Dolomite occurs as beds or planar nodules in two horizons. The lithology of the Kurusu section deserves further detailed observation, because it likely represents a transitional lithofacies between the Lower Triassic siliceous claystone ("Toishi"; Imoto, 1984) and Middle Triassic bedded chert. However, it is beyond the scope of this paper, and we will tentatively refer to the chert beds that grade into siliceous claystone as "muddy" chert.

The section studied by Yao and Kuwahara (1997), which corresponds directly to the upper 7 m of the Kr-2-YK section, was regarded as continuous in the previous studies. However, a fault was identified in the middle part of this interval (Fig. 11C). This fault is accompanied by a highly deformed sheared zone on both sides of the fault plane. Therefore, the displacement and consequent stratigraphic gap of this fault could be considerable.

The Kr-2-I section is composed mainly of "muddy" chert with intercalations of black claystone (Figs. 10, 11B). Intense folding such as that observed in the outcrop of the Kr-2-YK section is not observed in this part of the outcrop. However, the strata have experienced significant deformation, represented by the distortion of the bedding by numerous cm-scale faults and slip planes (Fig. 11B). The Kr-2-I section corresponds almost exactly to the section reported by Ikeda et al. (2010), but was not observed in exactly the same part of the outcrop, because some parts that they observed had become covered by thick gravel. Ikeda et al. (2010) assumed that the stratigraphic way up in this section is to the northeast. However, the general younging of the strata is to the southwest in this part of the Inuyama area (see Section 2.2.), which is consistent with outcrop-scale biostratigraphy in the Kurusu section (Yao and Kuwahara, 1997). Therefore, it would be more orthodox to assume that the stratigraphic way up is to the southwest, which will be adopted in this study. Nonetheless, it should be noted that the way up in the Kr-2-I section remains indeterminate, even considering our biostratigraphic data presented in Subsection 4.2.2.

4.2.2 Conodont biostratigraphy

Conodonts were found from all of the investigated samples (more than 200 specimens in total). Conodonts occurred as dark grey skeletons. Although most conodonts were broken, 28 specimens were identified at the species level (Table 2; Plates 8–10). Since conodont occurrence from the Kurusu section is sporadic, independent zonation for this section will not be defined. Instead, we will refer to the conodont biozones recognised in the Ajiro Island section (Fig. 12).

The Kr-2-YK section yielded Ch. timorensis and “Nh. aequiramosa”. These conodonts indicate that the Kr-2-YK section is mostly correlative to the Ch. timorensis Zone.

The Kr-2-I section yielded Nv. symmetricus, T. homeri, Ch. gondolelloides and “Nh. benderi”. These conodonts indicate that the Kr-2-I section is referable to the T. homeri Zone. Co. breviramulis, Co.? igoi, Neostrachanognathus tahoensis and “K. gebzeensis” also occurred from this section. Since the Kr-2-YK section is referable to the Ch. timorensis Zone, the Kr-2-I section is stratigraphically below the Kr-2-YK section. Ikeda et al. (2010) and Ikeda and Tada (2014) argued that the Kr-2-I section and Section M of Sugiyama (1997) in the Inuyama area can be partly correlated by key beds to produce a continuous biostratigraphy, based on the assumption that the Kr-2-I section is equivalent to the Kr-2-YK section. However, since the Kr-2-I section does not overlap with the Kr-2-YK section, their correlation is not valid. Consequently, the lowermost part of the composite section of the Inuyama bedded chert by Ikeda et al. (2010) and Ikeda and Tada (2014) that concerns the Kr-2-I section is not continuous.

5. Age assignment of the conodont biozones

5.1 The Lower-Middle Triassic (Olenekian-Anisian) boundary (OAB)

The global boundary stratotype section and point (GSSP) for the Olenekian-Anisian boundary (OAB) is yet to be ratified. The Desli Caira section in north Dobrogea, Romania has been proposed as a candidate (Gradinaru et al., 2007), while the Guandao section in Guizhou Province, South China is a potential reference section (Ogg, 2012). The OAB is classically defined by the ammonoid Japanites welteri (Balini et al., 2010; Bucher, 1989). This has been applied to the Desli Caira section (Gradinaru et al., 2007), but the Guandao section lacks a significant ammonoid fauna (Ogg, 2012). On the other hand, Orchard et al. (2007a, b) and Orchard (2010) proposed that the first appearance datum (FAD) of Chiosella timorensis, that occurs readily from both Desli Caira and Guandao, can be used as a marker for the OAB. Subsequently, Goudemand et al. (2012) concluded that the FAD of Ch. timorensis is very close to, but is slightly below the ammonoid-defined OAB and is within the uppermost Spithian. Based on high-resolution investigation of conodont biostratigraphy in the Desli Caira section and the Guandao section, Goudemand et al. (2012) placed the OAB above the FAD of Ch. timorensis and below the last appearance datum (LAD) of Novispathodus symmetricus and Triassosphadus homeri, so that the ammonoid based age assignment (Bucher, 1989) is followed. Our definition of the OAB will follow that by Goudemand et al. (2012).

In the Ajiro Island section, the first occurrence (FO) of Ch. timorensis and the last occurrence (LO) of T. homeri are both at the level of Sample AjL1-B, which is the base of the Ch. timorensis Zone (Fig. 9). Therefore, the OAB
is placed between the level of Sample AjL1-B and the level of Sample AjL1-A. The placement of the OAB at the base of the *Ch. timorensis* Zone indicates that the underlying *Novispathodus brevissimus-Icriospathodus collinsoni* Zone and the *T. homeri* Zone are of Olenekian age. The occurrence of *Nv. brevissimus* and *I. collinsoni* is confined to the basal part of the Spathian (Chen et al., 2015; Koike, 1981, 2004; Orchard, 1995, 2007; Zhao et al., 2007). Therefore, the *Nv. brevissimus-I. collinsoni* Zone is correlated to the lower Spathian, and the succeeding *T. homeri* Zone to the upper Spathian.

In the Kurusu section, *Nv. symmetricus* and *T. homeri* did not co-occur with *Ch. timorensis*. Therefore, the interval referred to the *Ch. timorensis* Zone in this section is likely to be of Anisian age. Thus, the OAB is in the lower 1 m or below the base of the Kr-2-YK section (Fig. 12).

The thickness of the *Ch. timorensis* Zone is different between the Ajiro Island and Kurusu sections. An explanation can be given by the slip plane between the AJ-3-1 section and the AJ-3-2 section at Ajiro Island. That is, lowermost Anisian strata are missing at the slip plane above the *Ch. timorensis* Zone in the Ajiro Island section. If this is the case, the *Ch. timorensis* Zone in the Kurusu section mostly corresponds in age to an interval that is missing at the slip plane in the Ajiro Island section.

5.2 The Anisian-Ladinian boundary (ALB)

The Anisian-Ladinian boundary (ALB) was ratified at the base of the *Eoprotrachyceras curionii* ammonoid zone in the Bagolino section in Brescia, Northern Italy (Brack, 2010; Brack et al., 2005). This horizon is above the FO of species belonging to the *Paragondolella trammeri* Group.
Fig. 11  (A–C) Outcrop photographs of the Kurusu section. (A) The Kr-2-YK section. (B) The Kr-2-I section. (C) The fault in the Kr-2-YK section. The fault runs between the arrows. Broken lines represent bedding planes. (D) Photo-micrograph of muddy chert from the Kr-2-YK section viewed in plane-polarised light.
and below the FO of *Budurovignathus hungaricus* (Brack et al., 2005). The same is true for the ALB (the base of the *curionii* ammonoid zone) in the Balaton Highland, Hungary (Kovács, 1994). Therefore, the ALB can be placed within the *Pg. trammeri* Zone in the Ajiro Island section (Fig. 9).

In the GSSP, the FO of the conodont *Budurovignathus praehungaricus* is very close to the ALB (Brack et al., 2005), and provides a good correlation marker for the boundary (Chen et al., 2016b; Ogg, 2012; Orchard, 2010). However, this species has not been found from the Ajiro Island section. Another potentially useful marker species is *Neogondolella aequidentata*, which has a short range straddling the ALB (Chen et al., 2016b; Muttoni et al., 2004; Orchard, 2010). In the Ajiro Island section, *Ng. aequidentata* occurred from the top of the *Pg. trammeri* Zone, suggesting that the ALB is near this horizon in the upper part of the zone.

### 5.3 The Anisian substages

The Anisian Stage is divided into four substages:

- **Cornudina breviramulis** (Tatge)
- **Cornudina gigoi** Koike
- **Neostrachanognathus taobensis** Koike
- **Novispathodus symmarius** (Orchard)
- **Novispathodus sp.**
- **Triassospathodus homeri** (Bender)
- **Chiosella gondoleilloides** (Orchard)
- "*Kamuellerella gorbacevi* Gedik"
- "*Neohindeodella benderi* (Kozur & Mostler)"
- "*Nh. aequirostrata* Kozur & Mostler"
- "*Ch. timorensis* (Nogami)"
- Chiosella sp.
- "*Neohindeodella sp.*"

#### Table 2 Occurrence list of conodonts from the Kurusu section. Underlined numbers indicate the number of conferred specimens. The species names denoted in quotation marks are form species defined based on discrete conodont elements.

| Kr2-YK section |  |
|----------------|---|
| Kr1-02         | 2 1 |
| Kr1-03         | 1  |
| Kr1-04         | 3 1 |
| Kr1-05         | no identifiable elements |

| Kr2-I section |  |
|---------------|---|
| Kr2-03        | 3 1 1 1 |
| Kr2-01        | 2 1 1 3 |

Aegean, Bithynian, Pelsonian and Illyrian in ascending order. The Aegean is characterised by *Ch. timorensis* all over the world (Chen et al., 2016b; Lehrmann et al., 2015; Nicora, 1977). In Europe and North America, the Bithynian is characterised by *Paragondolella bulgarica* (Nicora, 1977), and the Pelsonian is characterised by *Nicoraella kockeli* (Nicora, 1976; Pisa et al., 1980). On the other hand, *Ni. kockeli* occurs from below the FO of *Pg. bulgarica* in South China (Lehrmann et al., 2015). Hence, the stratigraphic order of the FOs of these species requires further investigation, and the recognition of the Pelsonian based on the occurrence of *Ni. kockeli* may not be valid on the global scale. In any case, the occurrence of *Ni. kockeli* from our studied sections is too sporadic to determine substage boundaries. Therefore, we refrain from conclusively determining the Bithynian-Pelsonian boundary. Based on the fact that species of the *Paragondolella excelsa* Group characterises the Illyrian (Kozur, 1980), the *Pg. bulgarica* Zone is correlated to the Bithynian to Pelsonian interval, and the *Pg. excelsa*
Zone to the lower Illyrian (the Illyrian likely extends to the lower part of the *Pg. trammeri* Zone; see section 5.2) (Fig. 9).

It is notable that a type of *Neogondolella* characteristic to the Pelsonian and younger age occurs from the upper part of the *Pg. bulgarica* Zone. These are species of *Neogondolella* that possess a large cusp that is fused to the posterior platform margin and occupies the posterior end of the element. Such forms can be referred to species such as *Neogondolella cornuta*, *Neogondolella constricta* and *Neogondolella shoshonensis*. In fact, some of our specimens have characteristics that may be referable to *Ng. shoshonensis* (Plate 3, Figs. 5, 6). The species of *Neogondolella* mentioned above are known only from the Pelsonian and younger strata (Chen et al., 2016b). Therefore, we refer to them as post-Bithynian type *Neogondolella*. In the Ajiro Island section, the FO horizon of the post-Bithynian type *Neogondolella* is sample 170627-03 and the Bithynian-Pelsonian boundary may be placed at this horizon (Fig. 9).

### 6. Age calibration of the radiolarian biozones

According to the radiolarian zonation proposed by Sugiyama (1997), the OAB was regarded to be correlative to the TR 1-TR 2A radiolarian biozone boundary, and the ALB to the TR 3A-TR 3B radiolarian biozone boundary. Our conodont-based age control proved that the age assignment is erroneous for the TR 1-TR 2A boundary, and probably also for the TR 3A-TR 3B boundary (Fig. 13). In the following text, the age calibration of the radiolarian biozones TR 1 to TR 3B (Sugiyama, 1997) is discussed in ascending order.

In the Ajiro Island section, the TR 1 Zone was
recognised in the Paragondolella bulgarica Zone, well above the OAB (Onoue et al., 2011; Uno et al., 2012) (Fig. 9). In the Kurusu section, the TR 1-TR 2A boundary is approximated by the boundary between the Parentactinia nakatsugawaensis Assemblage Zone and the Hozmadia gifuensis Assemblage Zone (Yao and Kuwahara, 1997), which is well above the base of the Chiosella timorensis Zone (Fig. 12). Thus, the TR 1 Zone includes part of the Pg. bulgarica Zone, which is of Bithynian to Pelsonian age. This age assignment is consistent with the occurrence of Pg. bulgarica from the TR 2B and TR 2C Zones reported from bedded chert sections in the Inuyama area (Mizutani and Koike, 1982; Sugiyama, 1997). If the placement of the Bithynian-Pelsonian boundary at the FO of post-Bithynian type conodonts in the Ajiro Island section is correct, this boundary is within the TR 2B Zone (Figs. 9, 13). The TR 3A Zone is mostly correlated to the Illyrian Paragondolella excelsa Zone, but its base may be within the uppermost part of the Pg. bulgarica Zone, and its top is in the basal part of the Hozmadia gifuensis Zone (detailed in Section 5.4.). It is possible that the upper part of the TR 3A Zone extends into the Ladinian (Fig. 13), but this is unlikely given that the ALB is probably in the upper part of the Pg. trammeri Zone (detailed in Section 5.4.).

The top of the TR 3B Zone was not recognised in the Ajiro Island section (Onoue et al., 2011; Uno et al., 2012). We assume that only the lower part of the TR 3B Zone of Sugiyama (1997) is present in the Ajiro Island section, because it lacks radiolarians such as Triassocampe.

---

**Table 1. Age calibration of the Anisian radiolarian biozones.**

| Age            | This study                        | Sugiyama (1997) | Yao & Kuwahara (1997) |
|----------------|----------------------------------|-----------------|-----------------------|
| Ladinian       |                                  |                 |                       |
|                | Paragondolella trammeri Zone      | ?               | TR 3B                 |
| Illyrian       |                                  | TR 3A           |                       |
|                | Paragondolella excelsa Zone       | TR 2C           |                       |
|                |                                  | TR 2B           |                       |
| Bithynian      |                                  | TR 2A           | HOZMADIA GIFUENSIS Assemblage Zone |
| Aegean         | Chiosella timorensis Zone         | TR 1            |                       |
|                |                                  | TR 0            |                       |
| Spathian       | Triassospathodus homeri Zone      |                 |                       |
|                |                                  | TR 0            |                       |
|                | NV. brevissimus-I. collinsoni Zone|                 |                       |

Fig. 13  Age calibration of the Anisian radiolarian biozones. Dashed lines represent uncertain boundaries. The NV. brevissimus-I. collinsoni Zone was not recognized in the sections of Sugiyama (1997), but is inferred to be encompassed in the TR 0 Zone, because conodonts from the Momotaro-jinja section indicate that the TR 0 Zone extends to the Smithian (Yamakita et al., 2010).
postdewerveri that appear in the upper part of the TR 3B Zone (Onoue et al., 2011; Uno et al., 2012). The lower part of the TR 3B Zone is within the Pg. trammeri Zone, and therefore falls within the upper Illyrian to the lower Fassanian (lower substage of the Ladinian). Since the ALB is possibly in the upper part of the Pg. trammeri Zone, the lower part of the TR 3B Zone is likely to be correlative to the upper Illyrian (uppermost Anisian). Unfortunately, radiolarian biostratigraphy has not been investigated for the upper part of the Pg. trammeri Zone. Therefore, we cannot determine whether the TR 3B Zone extends above the top of the Pg. trammeri Zone. Further study is needed in order to clarify the age of the top of the TR 3B Zone.

7. Correlation with rock magnetic records

The Ajiro Island section has been studied for rock magnetic records by Uno et al. (2012), who recognised two magnetic polarity zones in the red bedded chert. A reference record of Middle Triassic magnetic reversals was compiled by Hounslow and Muttoni (2010) based mainly on sedimentary records of the Tethys, many of which have been studied also for conodont biostratigraphy. We attempted to correlate the rock magnetic records of the Ajiro Island section to the reference record by Hounslow and Muttoni (2010) based on the framework of conodont biostratigraphy (Fig. 14). However, a single solution was not obtained and there are two possible options, as detailed below.

In Option 1 (Fig. 14A), polarity zone \( \beta \) in the Ajiro Island section is correlated to the reversed polarity in magnetozone MT4 to MT5. The two stratigraphically isolated intervals of polarity zone \( \alpha \) are either correlated to the two separate normal polarities in magnetozones MT6 and MT7, or together correlated to the normal polarity in magnetozone MT7. In this case, the ALB in the Ajiro Island section is above polarity zone \( \alpha \) and below the FO of Budurovignathus cf. hungaricus, within the upper 1.5 m of the Pg. trammeri Zone. This option agrees with Uno et al. (2012) in that polarity zone \( \alpha \) is correlated to a normal polarity and polarity zone \( \beta \) to a reversed polarity, suggesting deposition in the southern hemisphere.

In Option 2 (Fig. 14B), polarity zone \( \beta \) in the Ajiro Island section is correlated to the normal polarity in magnetozone MT6, whereas zone \( \alpha \) of the Ajiro Island section is correlated to the reversed polarity in magnetozones MT6 to MT8. In this case, the ALB is placed in the lower part of the Paragondolella trammeri Zone, ~1 m above its base. This option assumes that polarity zones \( \alpha \) and \( \beta \) are correlated to reversed and normal polarities, respectively, contradictory to Uno et al. (2012). Hence, this option suggests the deposition of the bedded chert of the Ajiro Island section took place in the northern hemisphere.

The ambiguity in the correlation of magnetic polarities results mainly from two reasons. Firstly, the gaps in the polarity zones in the Ajiro Island section due to the difficulty in recovering primary magnetic records from deep-sea chert (Uno et al., 2012) allow a considerable amount of speculation in the correlation. Another reason is the lack of both biostratigraphic and magnetostratigraphic data within the MT6 magnetozone of the reference magnetostratigraphy from the Tethys sections (Hounslow and Muttoni, 2010). Thus, further studies in both the Panthalassic deep-sea sections in Japan and the reference Tethyan sections are required to establish a conclusive correlation of integrated Anisian bio-magnetostratigraphy between the two regions.

8. Conclusions

We investigated conodont biostratigraphy in the Ajiro Island section in Oita Prefecture and the Kurusu section in Aichi Prefecture. Six conodont biozones were recognised: the lower Spathian Novispathodus brevissimus-Icriospathodus collinsoni Zone, the upper Spathian Triassospathodus homeri Zone, the Aegean Chiosella timorensis Zone, the Bithynian to Pelsonian Paragondolella bulgarica Zone, the lower Illyrian Paragondolella excelsa Zone, and the upper Illyrian to basal Fassanian Paragondolella trammeri Zone, in ascending order. The age of the radiolarian biozones previously recognised in the studied sections were assigned based on conodont biostratigraphy. The TR 1 Zone was assigned to the upper Spathian to Bithynian (or Pelsonian) and thus the Olenekian-Anisian boundary is within this zone. The TR 2A Zone, the TR 2B Zone and most of the TR 2C Zone are correlated to the Bithynian to Pelsonian interval. The uppermost part of the TR 2C Zone and the lower part of the TR 3A Zone are definitely correlated to the Illyrian. The upper part of the TR 3A Zone and the lower part of the TR 3B Zone fall within the upper Illyrian to the basal Fassanian, while the possibility that both intervals are correlative to the upper Illyrian is more likely. The Anisian-Ladinian boundary is within the TR 3B Zone or above it, and further study is needed to clarify its position relative to the radiolarian biozones. Our conodont data are helpful in correlating the magnetic polarity zones detected from the Ajiro Island section to the reference magnetostratigraphy of the Triassic obtained in the Tethys realm. Further studies will establish an integrated bio-magnetostratigraphic correlation between the pelagic Panthalassic deep-sea sections and the Tethyan sections.

9. Palaeontological notes

(Form species defined by discrete elements rather than multi-element apparatuses are shown in quotation marks.)

Budurovignathus cf. hungaricus (Kozur & Vegh)
(Plate 1, Figs. 1, 2.)

Epigondolella hungarica Kozur & Vegh in Kozur & Mock, 1972. p. 8–9, Plate 2, Figs. 3–7.
Remarks: This species is distinguished by a short free blade, a sinuous but unornamented platform and a posterior process. The platform margins are unornamented unlike...
younger species of *Budurovignathus*.

The specimen illustrated in Plate 1, Fig. 1 has a short free blade and a sinuous but unornamented platform. The posterior denticles are broken, and therefore the presence of a posterior process is not confidently confirmed. The specimen illustrated in Plate 1, Fig. 2 has a sinuous platform and a posterior process extending behind the basal pit, which are characteristics of *Budurovignathus*. The posterior platform margin is not pointed, which is a characteristic only seen in *B. hungaricus*. The anterior part is broken, and therefore the presence of a free blade cannot be confirmed.

**Chiosella gondolelloides** (Bender)

(Plate 1, Figs. 3, 4, Plate 9, Figs. 1, 2.)

*Spathognathodus gondolelloides* Bender, 1970, p. 529–530,

Plate 10, Figs. 17, 19, 20.

*Neospathodus gondolelloides* (Bender). Orchard, 1995. p. 115, Figs. 2.4, 2.5.

**Remarks**: The specimens are pectiniform elements characterised by a faint mid-lateral rib. *Chiosella timorensis* is similar to *Ch. gondolelloides*, but the former has a more developed mid-lateral rib that rises sharply from the blade, a higher length: height ratio (greater than 2.5:1) and a smaller basal cavity. *Ch. gondolelloides* differs from *T. brochus* also in having more fused denticles.

**Chiosella timorensis** (Nogami)
Conodont-based age calibration of Anisian radiolarian biozones (Muto et al.)

(Plate 1, Fig. 5, Plate 8, Figs. 1–6.)

_Gondolella timorensis_ Nogami, 1968. p. 127–128, Plate 10, Figs. 17–21.

_Neogondolella timorensis_ (Nogami). Koike, 1981. Plate 2, Fig. 7.

_Chiosella timorensis_ (Nogami). Goudemand _et al._, 2012. Figs. 2.1–14, 3.1–8.

**Remarks:** The specimens are pectiniform elements characterised by a prominent mid-lateral rib, small basal cavity and increasingly inclined denticles at the posterior end. The specimen illustrated in Plate 1, Figure 5 is a juvenile form, which is shorter and has a less prominent mid-lateral rib compared with adult forms. The basal cavity, which is terminally located, is relatively small. The specimen is similar to juvenile forms of _Ch. gondolelloides_, _T. homeri_, _T. brochus_ and _Nv. symmetricus_, but can be distinguished from the latter four species by the narrower basal cavity.

_Cornudina breviramulis_ (Tatge)  
(Plate 1, Figs. 6–8, Plate 9, Figs. 3, 4.)

_Ozarcodina breviramulis_ Tatge, 1956. p. 139, Plate 5, Figs. 12.

_Cornudina breviramulis_ (Tatge). Koike, 1996. p. 118–119, Figs. 3.1–3.21.

_Cornudina breviramulis_ (Tatge). Koike, 2016. p. 168–170, Figs. 4.1–4.3.

**Remarks:** The specimens are angulate pectiniform elements with a thick long cusp and short anterior and posterior processes. The anterior process bears up to four small discrete denticles that increase in size and inclination to the posterior. The posterior process bears up to three denticles that are smaller than those of the anterior process.

_Cornudina tortilis_ Kozur & Mostler  
(Plate 2, Figs. 2, 3.)

_Cornudina tortilis_ Kozur & Mostler, 1970. p. 432–433, Plate 1, Figs. 10, 16, 20, 24.

_Cornudina tortilis_ Kozur & Mostler. Koike, 1981. Plate 1, Fig. 34.

**Remarks:** The specimens are characterised by a short anterior process and a very long and curved cusp. The posterior process bears small denticles of equal size. _Cornudina tortilis_ is considered to be the P2 element of _Co. breviramulis_ (Koike, 1996, 2016).

_Cornudina?_ _igoi_ Koike  
(Plate 1, Figs. 9, Plate 2, Fig. 1, Plate 9, Fig. 5.)

_Cornudina?_ _igoi_ Koike, 1996. p. 119–120, Figs. 4.1–4.20.

**Remarks:** The specimens identified as this species is distinguished by a long cusp and a very short anterior process that bears only two denticles. Although this species may not belong to the genus _Cornudina_, which typically has a posterior process, it is tentatively included in this genus following the original description.

_Icriospathodus collinsoni_ (Solien)  
(Plate 2, Fig. 5.)

_Neopathodus collinsoni_ Solien, 1979. p. 302–303, Plate 3, Figs. 10, 12–20.

_Neopathodus?_ _collinsoni_ Solien. Koike, 1981. Plate 1, Figs. 42–44.

**Remarks:** _Icriospathodus collinsoni_ (Solien) is a species characterised by a biserial row of denticles that form ridges extending laterally across the element, that commonly possess short lateral processes. Although the biserial nature of the denticles cannot be observed in lateral view, the ridge-like form of the denticles and the lateral process can be observed in the specimen illustrated in Plate 2, Fig. 5. This specimen also shows affinity to the holotype in that the element is relatively low and decreases height gradually to the anterior. The specimen illustrated in Plate 2, Fig. 6 also shows affinity to the holotype in lateral view, but the biserial nature and ridge-like form of the denticles cannot be confirmed.

“_Kamuellerella gebzeensis Gedik_” (form species)  
(Plate 2, Fig. 4, Plate 9, Fig. 6.)

_Kamuellerella gebzeensis_ Gedik, 1975. p. 124–125, Plate 8, Figs. 1, 2, 4.

**Remarks:** The specimens are bipennate ramiform elements characterised by an anterior process that is bent downwards and bears relatively high denticles, and a posterior process that bears numerous thin erect denticles.

_Neogondolella aequidentata_ Kozur _et al._  
(Plate 2, Fig. 7.)

_Neogondolella aequidentata_ Kozur _et al._, 1994a. p. 278–279, Plate 2, Figs. 5–9.

**Remarks:** This species is characterised by a curved element with a platform that runs its entire length and a high carina of uniform height. The lateral platform margins are sub-parallel. _Neogondolella regale_ also has a carina of uniform height, but it is not arched and it has more fused denticles.

_Neogondolella ct. hastata_ Golding & Orchard  
(Plate 2, Figs. 8–11.)

_Neogondolella hastata_ Golding & Orchard, 2016. p. 1205–1206, Fig. 9.

**Remarks:** The specimens are characterised by a platform that extends from the anterior end to the anterior side of the base of the large terminal cusp and a uniform carina of discrete denticles. The platform is widest around mid-length. It does not surround the cusp, and terminates before the cusp in juvenile forms. The cusp is conspicuously higher and thicker than the other denticles.

_Neogondolella aff. hastata_ Golding & Orchard  
(Plate 3, Figs. 1, 2.)

**Remarks:** The specimens are similar to _Neogondolella hastata_ in having a platform that is widest around mid-length and terminates at the anterior base of the conspicuously large cusp, and a relatively low carina of uniform height. However, their carina is composed of fused denticles as opposed to discrete denticles in _Ng._
Other specimens identified as the specific identification of these specimens is pending. Neogondolella

Some of the specimens identified as

mid-length and an enormous, posteriorly reclined cusp

Remarks: Ajiro Island sections show these characteristics, although

surround the terminal denticle. The specimens from the

mostly uniform width throughout its length, and does not

straight to the posterior. There is a short anterior process

Remarks: This specimen is considered to be the S3/4 elements

This form species is identical to the S elements of the apparatus of Neostrachanognathus sp. A in Agematsu et al. (2008), which is referred to as Neostrachanognathus tahoensis in this paper.

Remarks: The specimens are bipennate ramiform elements marked by a short anterior process that is conspicuously downturned and bears an enormous denticle at the anterior end. Apart from this large denticle, there are no denticles or only one or two minute denticles on the anterior process.

This form species is identical to the S elements of the apparatus of Neostrachanognathus sp. A in Agematsu et al. (2008), which is referred to as Neostrachanognathus tahoensis in this paper.

Remarks: The specimens are bipennate ramiform elements characterised by an anterior process that bears relatively large, anteriorly reclined denticles. The basal margin is deflected downwards below the cusp and forms a convex down outline below the anterior process. The specimen illustrated in Plate 8, Fig. 8 is identical to "Neohindeodella aequiramosa" in the configuration of the basal margin and the denticulation of the anterior process, but its cusp and much of the posterior process is broken.

Remarks: The specimens are bipennate ramiform elements distinguished by a large cusp and denticles that are upright at the anterior and become reclined in the posterior part. The basal margin is convex under the cusp, and is relatively straight to the posterior. There is a short anterior process with relatively large denticles near the anterior end. "Nh. aequiramosa" differs from this species in the bending of the element below the cusp and the configuration of the basal margin, which is convex downwards below the anterior process and not below the cusp.

This form species is considered to be the S3/4 elements of Cornudina breviramulis (Koike, 2016), and also shows affinity to the S3 element of the apparatus of Triassospathodus reconstructed by Orchard (2005).

Neostrachanognathus tahoensis Koike.

(Plate 10, Fig. 3.)

Neostrachanognathus tahoensis Koike, 1998. p. 127–128, Figs. 9.10, 9.14, 9.16–23.

Neostrachanognathus sp. A. Agematsu et al., 2008. Fig. 8.

Remarks: This specimen is a coniform element with a posteriorly elongated basal area. Agematsu et al. (2008)

---

Neostrachanognathus tahoensis Koike.

(Plate 10, Fig. 3.)

Neostrachanognathus tahoensis Koike, 1998. p. 127–128, Figs. 9.10, 9.14, 9.16–23.

Neostrachanognathus sp. A. Agematsu et al., 2008. Fig. 8.

Remarks: This specimen is a coniform element with a posteriorly elongated basal area. Agematsu et al. (2008)

---

"Neohindeodella benderi" (Kozur & Mostler)" (form species) (Plate 3, Figs. 12, 13, Pl. 10, Figs. 1, 2.)

Hindeodella benderi Kozur & Mostler, 1970 p. 440–441, Plate 2, Figs. 10, 11, 13.

Neohindeodella benderi (Kozur & Mostler). Koike, 1981. Plate 1, Fig. 14.

Remarks: The specimens are bipennate ramiform elements

This form species is identical to the S elements of the apparatus of Neostrachanognathus sp. A in Agematsu et al. (2008), which is referred to as Neostrachanognathus tahoensis in this paper.

"Neohindeodella triassica" (Müller)" (form species) (Plate 4, Fig. 1–3.)

Hindeodella triassica Müller, 1956. p. 826, Plate 96, Figs. 4, 5.

Neohindeodella triassica (Müller). Koike, 1981. Plate 1, Fig. 25.

Neohindeodella triassica (Müller). Koike, 1982. Plate 8, Figs. 21–30.

Remarks: The specimens are bipennate ramiform elements distinguished by a large cusp and denticles that are upright at the anterior and become reclined in the posterior part. The basal margin is convex under the cusp, and is relatively straight to the posterior. There is a short anterior process with relatively large denticles near the anterior end. "Nh. aequiramosa" differs from this species in the bending of the element below the cusp and the configuration of the basal margin, which is convex downwards below the anterior process and not below the cusp.

This form species is considered to be the S3/4 elements of Cornudina breviramulis (Koike, 2016), and also shows affinity to the S3 element of the apparatus of Triassospathodus reconstructed by Orchard (2005).

Neostrachanognathus tahoensis Koike.

(Plate 10, Fig. 3.)

Neostrachanognathus tahoensis Koike, 1998. p. 127–128, Figs. 9.10, 9.14, 9.16–23.

Neostrachanognathus sp. A. Agematsu et al., 2008. Fig. 8.

Remarks: This specimen is a coniform element with a posteriorly elongated basal area. Agematsu et al. (2008)

---

Neostrachanognathus tahoensis Koike.

(Plate 10, Fig. 3.)

Neostrachanognathus tahoensis Koike, 1998. p. 127–128, Figs. 9.10, 9.14, 9.16–23.

Neostrachanognathus sp. A. Agematsu et al., 2008. Fig. 8.

Remarks: This specimen is a coniform element with a posteriorly elongated basal area. Agematsu et al. (2008)
redefined the original definition of Neostrachanognathus tahoensis by Koike (1998), and argued that the P1 element of this species is a coniform element without a posterior elongation of the basal area. However, the holotype of Nc. tahoensis has a posterior elongation of the basal area. Agematsu et al. (2008) also described another species of Neostrachanognathus (Neostrachanognathus sp. A), which has a coniform P1 element with a posterior elongation of the basal area, and is assigned here to Nc. tahoensis. The S element of Nc. tahoensis in Agematsu et al. (2008) (their Neostrachanognathus sp. A) is identical to “Nh. benderi”.

Nicoraella kockeli (Tatge) (Plate 4, Fig. 4.)
Ozarkodina kockeli Tatge, 1956. p. 137, Plate 5, Figs. 13, 14.
Neostraphodus kockeli (Tatge). Koike, 1982. Plate 6, Figs. 2–11.
Remarks: The specimens are pectiniform elements characterised by an angular profile of the upper margin due to the denticles decreasing in height in both anterior and posterior directions from the conspicuously wide cusp. The cusp is located posterior to the mid-length of the elements. The decrease in height of the denticles is rapid to the posterior side of the cusp. The basal cavity is not expanded laterally, and is positioned slightly anterior from the posterior end. This species is distinguished from Neostraphodus abruptus by the forward-shifted position and unflared configuration of the basal cavity, and from T. homeri by the small basal cavity.

Neostraphodus abruptus (Orchard) (Plate 4, Fig. 5.)
Neostraphodus abruptus Orchard, 1995. p. 118–119, Figs. 3.16–3.19, 3.23–3.26.
Remarks: The specimens are pectiniform elements characterised by denticles that decrease height rapidly at the posterior end, resulting in the arcuate outline of the upper margin. This species is distinguished from T. homeri by the lack of a distinct posterior process.

Neostraphodus brevissimus (Orchard) (Plate 4, Fig. 6.)
Neostraphodus triangularis (Bender). Koike, 1981. Pl. 1, Fig. 6.

Neostraphodus brevissimus Orchard, 1995. p. 119, Figs. 3.14–3.15, 3.20–3.22.
Remarks: The specimen is characterised by a blade composed of thin fused denticles and a basal cavity that expands widely in lateral directions and truncates abruptly at the posterior end. The height of the blade is equal for almost its entire length, giving the element a quadratic outline in lateral view.

Neostraphodus symmetricus (Orchard)
(Plate 4, Figs. 7–10, Plate 10, Figs. 4, 5.)
Neostraphodus symmetricus Orchard, 1995. p. 120–121, Figs. 2.6, 2.10–2.13, 2.18.
Remarks: The specimens are pectiniform elements characterised by sub-equal denticles that are slightly to moderately inclined to the posterior. This species is distinguished from T. homeri by the lack of a posterior process and abrupt truncation of the basal cavity, and from T. brochus by the more fused denticles and the lack of radiating denticles at the posterior end. Orchard (2007) assigned Nv. symmetricus to the genus Triassopathodus, which was distinguished from Novispathodus based on differences in their multielement apparatus (Orchard, 2005), but the apparatus of this particular species is yet to be reconstructed. As far as the P1 element is concerned, Nv. symmetricus is closer to Nv. abruptus than to T. homeri in that it lacks a well-developed posterior process. Hence, we include Nv. symmetricus in Novispathodus.

Novispathodus triangularis (Bender)
Spathognathodus triangularis Bender, 1970. p. 530, Plate 5, Fig. 22.
Novispathodus triangularis (Bender). Orchard, 1995. p. 116, 118, Figs. 3.1–3.4.
Remarks: Novispathodus triangularisi (Bender) was redefined by Orchard (1995) as a species with a conspicuous fold on the upper surface of the basal cup, that extends vertically to a sub-terminal cup. The specimen illustrated in Plate 4, Figure 11 has a vertical groove above the basal cup, which may be the “fold” described by Orchard (1995). The specimen also has a length-height ratio similar to the specimens illustrated by Orchard (1995). However, the poor preservation of the specimen makes it difficult to make a conclusion.

Paragondolella bulgarica Group (Plate 5, Fig. 2–8.)
Paragondolella cf. bulgarica Group (Plate 5, Fig. 1.)
Paragondolella bulgarica Budurov & Stefanov. Chen et al., 2016a. p. 728, Fig. 2.
Paragondolella bifurcata Budurov & Stefanov. Gedik, 1975. p. 133–134, Plate 1, Figs. 9–25.
Paragondolella unilobata Budurov & Stefanov. Kodak, 1979. p. 50–51, Plate 1, Figs. 9, 10, Plate 2, Figs. 1–9, Plate 3, Figs. 1–12.
Remarks: This group is distinguished by an arched element and a high-carina of moderately fused denticles that ends with a strong terminal cusp. A small denticle is often present behind the cusp. The last denticle is sometimes fused to the posterior brim of the platform. In juvenile specimens, the platform is not developed (Plate 5, Fig. 6) or confined to the posterior part (Plate 5, Figs. 4, 5). In later stages, the platform runs almost its entire length. These characteristics match with those of Paragondolella
In juvenile stages, *Pg. bulgarica* is very similar to *Paragondolella bifurcata*, which is considered as a descendant of the former species (Chen et al., 2016a). Since our specimens are almost entirely juveniles, it is impossible to separate them into the two species. We also follow Nicora (1977) and Chen et al., (2016a) in treating *Paragondolella unilobata* as a junior synonym of *Pg. bulgarica*. Therefore, we will include *Pg. bifurcata* and *Pg. unilobata* in the *Pg. bulgarica* Group. In addition, Kovács and Rálish-Felgenhauer (2005) reported transitional morphotypes between both these two species and *Paragondolella hanbulogi*. Hence, *Pg. hanbulogi* is also included in the *Pg. bulgarica* Group.

*Paragondolella excelsa* Group (Plate 5, Figs. 9–14.)  
*Paragondolella excelsa* Mosher, 1968a. p. 938–939, Plate 118, Figs. 1–8.  
*Paragondolella excelsa* Mosher. Mosher, 1968b. Plate 120, Figs. 1–7.  
*Gondolella liebermani* Kovács & Krystyn in Kovács, 1994. p. 492–493, Plate 6, Figs. 1–3.  
*Gondolella fueloepi* Kovács, 1994. p. 493.  
*Gondolella fueloepi fueloepi* Kovács, 1994. Plate 7, Figs. 2, 3, Pl. 8, Fig. 4.  
*Gondolella fueloepi pseudobifurcata* Kovács, 1994. Plate 8, Figs. 1, 3.

**Remarks:** The specimens are segminiplanate elements with a high blade and a thick platform developed in the posterior part of the element that surrounds the terminal cusp. The cusp is thick, reclined posteriorly and its tip is lower than the anterior denticles. These characteristics match with juvenile forms of *Paragondolella excelsa*. In adult forms, this species is characterised by a carina that is high at the anterior and decreases height posteriorly ending in a node-like cusp, and a massive platform that surrounds the terminal denticle. The low, thick cusp and well-developed platform in our specimens are regarded as a precursor of these adult characters. *Paragondolella liebermani* and *Paragondolella fueloepi* also has a carina that decreases to a low, node-like cusp and a thick platform that surrounds the posterior end. Hence, we treat *Pg. excelsa*, *Pg. liebermani* and *Pg. fueloepi* as the *Pg. excelsa* Group, although juvenile characters of the latter two species have not been thoroughly investigated.

In juvenile stages, the *Pg. excelsa* Group somewhat resembles the *Pg. bulgarica* Group, but the former has a thicker platform and a lower and more reclined cusp.

*Paragondolella trammeri* Group (Plate 6, Figs. 1–7.)  
*Gondolella haslachensis trammeri* Kozur and Mock, 1972. p. 13, Plate 1, Figs. 3–7.  
*Paragondolella trammeri* (Kozur) Kozur et al., 1994b. p. 176–178, Plate 2, Figs. 19, 23, 24. Plate 3, Figs. 10, 13, 16.  
*Gondolella alpina* Kozur & Mostler, 1982. p. 292–293, Plate 1, Fig. 1, Plate 2, Figs. 4, 5.

**Gondolella alpina alpina** Kozur & Mostler. Kovács, 1994. p. 488–489, Plate 4, Figs. 2, 4, Plate 5, Figs. 1–3.  
**Remarks:** The specimens are segminiplanate elements characterised by a large posteriorly reclined cusp and a platform that merges at the posterior end into a pointed denticle behind the cusp. The platform is thicker in larger specimens (Plate 6, Fig. 6) reflecting ontogenic growth. These characters match with those of *Paragondolella trammeri*. *Paragondolella alpina* is similar to *Pg. trammeri*, but can be distinguished from the latter in adult specimens by the presence of a free blade. Immature specimens of *Pg. alpina* have not been well studied. We withhold from conclusively differentiating the two species in our specimens, and refer to them as the *Pg. trammeri* Group.

In earliest growth stages, the *Pg. trammeri* Group somewhat resembles late juvenile stages of the *Pg. bulgarica* Group in having a pointed posterior platform end behind the cusp. However, the former differs from the latter in the lower and more discrete denticles, and the higher cusp. In later juvenile stages, the *Pg. trammeri* Group differs from the *Pg. bulgarica* Group in having a thicker platform. *Pg. trammeri* Group is distinguished from the *Pg. excelsa* Group in having a small terminal denticle fused to the posterior brim of the platform.

*Triassospathodus anhuinensis* (Ding) (Plate 6, Fig. 8.)  
*Neospathodus anhuinensis* Ding, 1983. p. 44, Plate 5, Figs. 9, 10.  
**Remarks:** The specimen is characterised by a blade composed of small and fused denticles and a well-developed posterior process that occupies around one third of the element. It differs from *T. homeri* in having a much longer posterior process and smaller denticles.

*Triassospathodus brochus* (Orchard) (Plate 7, Fig. 1.)  
*Triassospathodus cf. brochus* (Orchard) (Plate 7, Fig. 2.)  
*Neospathodus brochus* Orchard, 1995. p. 119, Figs. 3.27, 3.28, 3.35, 3.36.  
**Remarks:** This species is distinguished by a pectiniform element that possesses relatively discrete denticles that become increasingly reclined near the posterior end, so that the terminal denticle is orientated at a low angle to the basal margin. This species is distinguished from *T. homeri* by the more discrete denticles and radiating denticles at the posterior end.

The specimen illustrated in Plate 7, Fig. 2 is partly broken at the anterior side, but the observed features are identical to those of *T. brochus*.

*Triassospathodus homeri* (Bender)  
(Plate 7, Figs. 3–6, Pl. 10, Figs. 6, 7.)  
*Spathognathodus homeri* Bender, 1970. p. 528–529, Plate 5, Figs. 16, 18.  
*Neospathodus homeri* (Bender). Orchard, 1995. p. 115–116, Figs. 2.1–2.3, 2.7–2.9, 2.14–2.17, 2.20–2.21.
Remarks: The specimens are pectiniform elements marked by a short posterior process that bears up to five denticles. The posterior process is commonly downturned and bears denticles that are sometimes smaller than the anterior process. This species is distinguished from *Nv. abruptus* and *Nv. symmetricus* by the presence of the distinct posterior process.

Acknowledgements

We are grateful for an anonymous reviewer who provided many fruitful comments. Sincere gratitude is expressed to H. Shiroyu, H. Matsumoto, K. Yoshizawa and residents of the Enoura district in Tsukumi City for their kind support during fieldwork. This study was partly supported by Grant-in-aid for JSPS Research Fellow Number 16J04796 (to S. Muto) and 16J09728 (to K. Soda).

References

Agematsu, S., Orchard, M. J. and Sashida, K. (2008) Reconstruction of an apparatus of Neostrachanognathus tahoensis from Oritate, Japan and species of Neostrachanognathus from Oman. *Palaeontologia*, **51**, 1201–1211.

Ando, A., Kodama, K. and Kojima, S. (2001) Low-latitude and Southern Hemisphere origin of Anisian (Triassic) bedded chert in the Inuyama area, Mino terrane, central Japan. *Jour. Geophys. Res. Solid Earth*, **106**, 1973–1986.

Balini, M., Lucas, S. G., Jenks, J. F. and Spielmann, J. A. (2010) Triassic ammonoid biostratigraphy: an overview. *Geolo. Soc. London, Spec. Publ.*, **334**, 221–262.

Bender, H. (1970) Zur Gliederung der Mediterranen Trias II. Die Conodontenchronologie der Mediterranen Trias. *Annales Géologiques des Pays Hélleniques, Serie 1*, **19**, 465–540.

Brack, P. (2010) The “golden spike” for the Ladinian is set! *Albertiana*, **38**, 8–10.

Brack, P., Rieber, H., Nicora, A. and Mundil, R. (2005) The global boundary stratotype section and point (GSSP) of the Ladinian Stage (Middle Triassic) at Bagolino (Southern Alps, Northern Italy) and its implications for the Triassic time scale. *Episodes*, **28**, 233–244.

Bucher, H. (1989) Lower Anisian ammonoids from the northern Humboldt Range (northwestern Nevada, USA) and their bearing upon the Lower-Middle Triassic boundary. *Eclogae Geologicae Helvetiae*, **82**, 945–1002.

Budurov, K. and Stefanov, S. (1975) Neue Daten über die Conodontenchronologie der Balkaniden Mittleren Trias. *Doklady Bolgarskoi Akademii Nauk*, **28**, 791–794.

Chen, Y., Jiang, H., Lai, X., Yan, C., Richoz, S., Liu, X. and Wang, L. (2015) Early Triassic conodonts of Jiariong, Nanpanjiang Basin, southern Guizhou Province, South China. *Jour. Asian Earth Sci.*, **105**, 104–121.

Chen, Y., Neubauer, T. A., Krystyn, L. and Richoz, S. (2016a) Allometry in Anisian (Middle Triassic) segminiplanate conodonts and its implications for conodont taxonomy. *Palaeontology*, **59**, 725–741.

Chen, Y., Krystyn, L., Orchard, M. J., Lai, X. L. and Richoz, S. (2016b) A review of the evolution, biostratigraphy, provincialism and diversity of Middle and early Late Triassic conodonts. *Papers in Palaeontology*, **2**, 235–263.

Clark, D. L., Sweet W. C., Bergström, S. M., Klapper, G., Austin, R. L., Rhodes, F. H. T., Müller, K. J., Ziegler, W., Lindström, M., Miller, J. F. and Harris, A. G. (1981) *Treatise on invertebrate paleontology. Part W Miscellaneous, Supplement 2, Conodonta*. Geol. Soc. Amer. and Univ. Kansas, Boulder Colorado, and Lawrence, Kansas, 1–202.

Ding, M. (1983) Lower Triassic conodonts from the Mountain Majiashan in Anhui Province and their stratigraphic significance. *Earth Science-Journal of China University of Geosciences*, **2**, 37–48 (in Chinese).

Fujii, K. (1954) Stratigraphy and geological structure of the Usuki area, Oita Prefecture, Kyushu (1). *Jour. Geol. Soc. Japan*, **60**, 413–427 (in Japanese with English abstract).

Fujisaki, W., Sawaki, Y., Yamamoto, S., Sato, T., Nishizawa, M., Windley, B. F. and Maruyama, S. (2016) Tracking the redox history and nitrogen cycle in the pelagic Panthalassic deep ocean in the Middle Triassic to Early Jurassic: Insights from redox-sensitive elements and nitrogen isotopes. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, **449**, 397–420.

Gedik, I. (1975) Die Conodonten der Trias auf der Kocaeli-Halbinsel (Türkei). *Palaeontographica, Abteilung A*, **150**, 99–160 (in German with English summary).

Golder, M. L. and Orchard, M. J. (2016) New species of the conodont Neogondolella from the Anisian (Middle Triassic) of northeastern British Columbia, Canada, and their importance for regional correlation. *Jour. Paleontol.*, **90**, 1197–1211.

Goudemand, N., Orchard, M. J., Bucher, H. and Jenks, J. (2012) The elusive origin of *Chiosella timorensis* (Conodont Triassic). *Geobios*, **45**, 199–207.

Gradianaru, E., Orchard, M. J., Nicora, A., Gallet, Y., Besse, J., Krystyn, L., Sobolev, E. S., Atdouere, N.-V. and Ivanova, D. (2007) The global boundary stratotype section and point (GSSP) for the base of the Anisian stage: Deșli Caira Hill, North Dobrogea, Romania. *Albertiana*, **36**, 54–71.

Hayashi, S. (1968) Permian in the chert of the Adoyama section and point (GSSP) for the Ladinian is the golden spike. *Eclogae Geologicae Helvetiae*, **82**, 945–1002.

Hoshizumi, H., Saito, M., Mizuno, K., Miyazaki, K., Toshimitsu, S., Matsumoto, A., Ohno, T. and Miyakawa, A. (2015). *Geological map of Japan*
and geochronology) for the Permain-Upper Triassic strata of Guandao section, Nanpanjiang Basin, south China. Jour. Asian Earth Sci., 108, 117–135.

Matsuda, T. and Isozaki, Y. (1982) Radiolarians around the Triassic-Jurassic boundary from the bedded chert in the Kamiiso area, Southwest Japan. Appendix: "Anisian" radiolarians. News Osaka Micropaleontol., Spec. Vol., no. 5, 93–101 (in Japanese with English abstract).

Matsuda, T. and Isozaki, Y. (1991) Well-documented travel history of Mesozoic pelagic chert in Japan: from remote ocean to subduction zone. Tectonics, 10, 475–499.

Matsuoka, A. (1986) Mesozoic strata of the Southern Chichibu Terrane in the Tsukumi area, Oita Prefecture. News Osaka Micropaleontol., Spec. Vol., no. 7, 219–223.

Matsuoka, A. and Yao, A. (1986) A newly proposed radiolian zonation for the Jurassic of Japan. Marine Micropaleontol., 11, 91–106.

Matsuoka, A. and Yao, A. (1990) Southern Chichibu Terrane. In Ichikawa, K., et al., eds., Pre-Cretaceous Terranes of Japan. Tokai Univ. Press, Tokyo, Japan, 203–216.

Matsuoka, A., Yamakita, S., Sakakibara, M. and Hisada, K. (1998) Unit division of the Chichibu Composite Belt from a view point of accretionary tectonics and geology of western Shikoku, Japan. Jour. Geol. Soc. Japan, 104, 634–653 (in Japanese with English abstract).

Mizutani, S. (1964) Superficial folding of the Paleozoic system of central Japan. Jour. Earth Sci., Nagoya Univ., 12, 17–83.

Mizutani, S. and Koike, T. (1982) Radiolarians in the Jurassic siliceous shale and in the Triassic bedded chert of Unuma, Kakamigahara City, Gifu Prefecture, central Japan. News Osaka Micropaleontol., Spec. Vol., no. 5, 117–134 (in Japanese with English abstract).

Mosher, L. C. (1968a) Triassic conodonts from western North America and Europe and their correlation. Jour. Paleontol., 42, 895–946.

Mosher, L. C. (1968b) Evolution of Triassic platform conodonts. Jour. Paleontol., 42, 947–954.

Mosher, L. C. (1970) New conodont species as Triassic guide fossils. Jour. Paleontol., 44, 737–742.

Müller, K. J. (1956) Triassic conodonts from Nevada. Jour. Paleontol., 30, 818–830.

Muto, S., Takahashi, S., Yamakita, S., Suzuki, N., Suzuki, N. and Aita, Y. (2018) High sediment input and possible oceanic anoxia in the pelagic Panthalassa during the latest Olenekian and early Anisian: Insights from a new deep-sea section in Ogama, Tochigi, Japan. Palaeogeogr., Palaeoclimatol., Palaeoecol., 490, 687–707.

Muttoni, G., Nicora, A., Brack, P. and Kent, D. V. (2004) Integrated Anisian–Ladinian boundary chronology. Palaeogeogr., Palaeoclimatol., Palaeoecol., 208, 85–102.

Nakada, R., Ogawa, K., Suzuki, N., Takahashi, S. and Takahashi, Y. (2014) Late Triassic compositional changes of aelolian dusts in the pelagic Panthalassa: response to the continental climatic change. Palaeogeogr., Palaeoclimatol., Palaeoecol., 393, 61–75.

Nicora, A. (1976) Conodont-fauna, stratigraphic position and relations to the Tethyan successions of the Shoshonensis Zone (Pelsonian) of Nevada. Rivista Italiana di Paleontologia e Stratigrafia, 82, 627–650.

Nicora, A. (1977) Lower Anisian platform-conodonts from the Tethys and Nevada: Taxonomic and stratigraphic revision. Palaeontographia Abteilung A, 157, 88–107.

Nicora, A., Kozur, H. and Mietto, P. (1981) Gondolella pridaensis sp. n.: A new conodont species from the Middle Triassic. Rivista Italiana di Paleontologia e Stratigrafia, 86, 761–768.

Nishi, T. (1994) Geology and tectonics of the Sambosan Terrane in eastern Kyushu, Southwest Japan—stratigraphy, sedimentological features of the depositional setting of the Shakusan Group. Jour. Geol. Soc. Japan, 100, 199–215.

Nishikane, Y., Kailo, K., Takahashi, S., Henderson, C. M., Suzuki, N. and Kanno, M. (2011) The Guadalupian–Lopingian boundary (Permian) in a pelagic sequence from Panthalassa recognized by integrated conodont and radiolarian biostratigraphy. Marine Micropaleontol., 78, 84–95.

Nogami, Y. (1968) Trias-Conodonten von Timor, Malaysien und Japan (Paleontological Study of Portuguese Timor, 5). Mem. Fac. Sci. Kyoto Univ., Ser. Geol. Mineral., 34, 115–136 (in German with English abstract).

Oda, H. and Suzuki, H. (2000) Paleomagnetism of Triassic and Jurassic red bedded chert of the Inuyama area, central Japan. Jour. Geophys. Res.: Solid Earth (1978–2012), 105, 25743–25767.

O’Dogherty, L., Carter, E. S., Gorican, Š. and Dumitrica, P. (2010) Triassic radiolarian biostratigraphy. Geol. Soc., London, Spec. Publ., 334, 163–200.

Ogg, J. G. (2012) The Triassic period. In Gradstein, F. M., et al., eds., A Geologic Time Scale. Cambridge Univ. Press, Cambridge, UK, 681–730.

Onoue, T., Nakamura, T., Haranono, T. and Yasuda, C. (2011) Composition and accretion rate of fossil micrometeorites recovered in Middle Triassic deep-sea deposits. Geology, 39, 567–570.

Orchard, M. J. (1995) Taxonomy and correlation of Lower Triassic (Spathian) segminate conodonts from Oman and revision of some species of Neospathodus. Jour. Paleontol., 69, 110–122.

Orchard, M. J. (2005) Multielement conodont apparatuses of Triassic Gondolelloidea. Special Papers in Palaeontol., 73, 73–101.

Orchard, M. J. (2007) Conodont diversity and evolution through the latest Permian and Early Triassic upheavals. Palaeogeogr., Palaeoclimatol.,
Orchard, M. J. (2010) Triassic conodonts and their role in stage boundary definition. *Geol. Soc. London, Spec. Publ.*, **334**, 139–161.

Orchard, M. J., Gradinariu, E. and Nicora, A. (2007a) A summary of the conodont succession around the Olenekian-Anisian boundary at Desli Caira, Dobrogea, Romania. *New Mexico Museum of Natural History and Science Bulletin*, **41**, 341–346.

Orchard, M. J., Lehrmann, D. J., Wei, J., Wang, H. and Taylor, H. J. (2007b) Conodonts from the Olenekian-Anisian boundary beds, Guandao, Guizhou Province, China. *New Mexico Museum of Natural History and Science Bulletin*, **41**, 347–354.

Pisa, G., Perri, C. and Veneri, P. (1980) Upper Anisian conodonts from Dout and M. Bivera Formations, Southern Alps (Italy). *Rivista Italiana di Paleontologia e Stratigrafia*, **85**, 807–828.

Sato, H., Onoue, T., Nozaki, T. and Suzuki, K. (2013) Osmium isotope evidence for a large Late Triassic impact event. *Nature Communications*, **4**, doi: 10.1038/ncomms3455.

Sato, H., Shirai, N., Ebihara, M., Onoue, T. and Kiyokawa, S. (2016) Sedimentary PGE signatures in the Late Triassic ejecta deposits from Japan: Implications for the identification of impactor. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, **442**, 36–47.

Soda, K., Onoue, T. and Ikeda, M. (2015) Cyclostratigraphic examination of Middle Triassic (Anisian) bedded chert in the Chichibu Belt from Tsukumi area, eastern Kyushu, Japan. *Jour. Geol. Soc. Japan*, **121**, 147–152 (in Japanese with English abstract).

Solien, M. A. (1979) Conodont biostratigraphy of the Lower Triassic Thaynes FFormation, Utah. *Jour. Paleontol.*, **53**, 276–306.

Sudar, M. N. and Budurov, K. (1979) New conodonts from the Triassic in Yugoslavia and Bulgaria. *Geologica Balcanica*, **9**, 47–52.

Sugiyama, K. (1997) Triassic and Lower Jurassic radiorian biostratigraphy in the siliceous claystone and bedded chert units of the southeastern Mino Terrane, Central Japan. *Bull. Mizunami Fossil Museum*, **24**, 79–193.

Sweet, W. C. (1988) *The Conodonta: morphology, taxonomy, paleoecology, and evolutionary history of a long-extinct animal phylum*. Oxford Monogr. Geol. Geophysics. 10, Clarendon Press, Oxford.

Takahashi, O., Kawarazaki, T. and Ishii, A. (1998) Middle Triassic radiorians from the Tsukumi area, eastern Kyushu, southwest Japan. *News Osaka Micropaleontol., Spec. Vol.*, no. **11**, 115–121.

Takahashi, S., Obi, M., Kaiho, K., Yamakita, S. and Sakata, S. (2009) Panthalassic oceanic anoxia at the end of the Early Triassic: A cause of delay in the recovery of life after the end-Permain mass extinction. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, **274**, 185–195.

Takemura, A., Aita, Y., Sakai, T., Hori, S. R., Kodama, K., Yamakita, S., Kamata, Y., Suzuki, N., Spörli, K.B and Campbell, H. J. (2001) Radiorians from the Waiapapa Terrane in North Island, New Zealand. *Topics on Palaeontology*, **2**, 17–24 (in Japanese).

Tanaka, K. (1980) Kanoshi Group, an olistostrome, in the Nichihara area, Shimane Prefecture. *Jour. Geol. Soc. Japan*, **86**, 613–628 (in Japanese with English abstract).

Tatge, U. (1956) Conodonten aus dem germanischen Muschelkalk. *Palaontologische Zeitschrift*, **30**, 108–147 (in German).

Unom, K., Onoue, T., Hamada, K. and Hamami, S. (2012) Paleomagnetism of Middle Triassic red bedded cherts from southwest Japan: equatorial palaeolatitude of primary magnetization and widespread secondary magnetization. *Geophys. Jour. Internat.*, **189**, 1383–1398.

Wakita, K. (1988) Origin of chaotically mixed rock bodies in the Early Jurassic to Early Cretaceous sedimentary complex of the Mino terrane, central Japan. *Bull. Geol. Surv. Japan*, **39**, 675–757.

Wakita, K. and Metcalfe, I. (2005) Ocean plate stratigraphy in East and Southeast Asia. *Jour. Asian Earth Sci.*, **24**, 679–702.

Yao, A. and Kuwahara, K. (1997) Radiolarian faunal change from Late Permian to Middle Triassic times. *News Osaka Micropalaeontol., Spec. Vol.*, no. 10, 87–96 (in Japanese with English abstract).

Yao, A., Matsuda, T. and Isozaki, Y. (1980) Triassic and Jurassic radiorians from the Inuyama area, central Japan. *Jour. Geosci. Osaka City Univ.*, **23**, 135–154.

Yamakita, S. and Otoh S. (2000) Tectonostratigraphic division of accretionary-sedimentary complex of the Tamba-Mino-Ashio Belt and comparison with the Northern and Southern Chichibu Belts. *Structural Geology*, **44**, 5–32 (in Japanese with English abstract).

Yamakita, S., Takahashi, S. and Kojima, S. (2010) Conodont-based age-determination of siliceous claystone in the lower part of the Momotaro-jinjia section, Inuyama, central Japan. *Abstract, The 2010 Annual Meeting of the Palaeontological Society of Japan*, 47 (in Japanese).

Zhao, L., Orchard, M. J., Jinnan, T., Zhiming, S., Jinxun, Z., Suxin, Z. and Ailing, Y. (2007) Lower Triassic conodont sequence in Chaohu, Anhui Province, China and its global correlation. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, **252**, 24–38.

Ziegler, A. M., Gibbs, M. T. and Hulver, M. L. (1998) A mini-atlas of oceanic water masses in the Permian Period. *Proc. Royal Society of Victoria*, **110**, 323–343.

Received December 19, 2017
Accepted January 18, 2019
コノドント生層序による中部三畳系アニシアン遠洋深海層状チャートにおける放散虫化石帯年代の再検討

武藤 俊・高橋 聡・山北 聡・曽田勝仁・尾上哲治

要旨
超海洋パンサラッサの遠洋域深海で堆積した層状チャートは、放散虫化石層序により年代が決められてきた。一方で、三畳系の放散虫化石帯は国際基準の地質年代との厳密な対比には用いられない場合が多い。本研究は、放散虫化石帯が確立され、中部三畳系アニシアン階に対比されていた大分県津久見地域の網代島セクションと愛知県犬山地域の栗栖セクションの珪質粘土岩・層状チャートにおいてコノドント化石層序を検討した。結果、オレネキアン階の上部のNovispathodus brevissimus-Icriospathodus collinsoni帯とTriassospathodus homeri帯、アニシアン階の下部のChiosella timorensis帯、アニシアン階の中部のParagondolella bulgarica帯、アニシアン階の上部のParagondolella excelsa帯、パレドニアン階の最上部からラディニアン階の最下部のParagondolella trammeri帯が認識された。また、コノドント化石層序との比較により、Sugiyama (1997, Bull. Mizunami Foss. Mus., vol. 24, p. 79–193) による放散虫化石帯の年代を再検討した。従来オレネキアン階に対比されていたTR 1化石帯はオレネキアン階の上部からアニシアン階の中部に対比された。TR 2A化石帯、TR 2B化石帯、及びTR 2C化石帯の下部はアニシアン階の中部に対比され、TR 2C化石帯の上部とTR 3A化石帯の下部はアニシアン階の上部に対比された。TR 3A化石帯の上部とTR 3B化石帯の下部はアニシアン階の最上部に対比される可能性が高いが、ラディニアン階の最下部に対比される可能性も否めない。

難読・重要地名
Tsukumi：津久見、Youra：四浦、Sambosan：三宝山、Yukagi：床木、Tsui：津井、Shakumasan：尺間山、Enoura：江ノ浦、Ajiro：網代、Kurusu：栗栖、Inuyama：犬山、Kamiaso：上麻生
Plate 1  Stereo-photographs and sketches of conodonts from the Ajiro Island section. Figs. 3–5 are reversely arranged so that the moulds appear as casts. All other figures are normally arranged. Scale bars are 200 µm.

1, 2: *Budarovignathus* cf. *hungaricus* (Kozur & Vegh). Sample AJR 724+2.4m.
3, 4: *Chiosella gondolelloides* (Bender). 3. Sample AjL-B. 4. Sample 151005-13.
5: *Chiosella timorensis* (Nogami). Sample AjL-1-B.
6–8: *Cornudina breviramulis* (Tatge). 6. Sample 170627-02. 7. Sample 170627-03. 8. Sample AJR 724+1.9m.
9: *Cornudina? igoi* Koike. Sample AJR 0.
Conodont-based age calibration of Anisian radiolarian biozones (Muto et al.)
Plate 2  Stereo-photographs and sketches of conodonts from the Ajiro Island section. Fig. 5 is reversely arranged so that the mould appears as a cast. All other figures are normally arranged. Scale bars are 200 µm.

1: *Cornudina? igoi* Koike. Sample AJR 144.
2, 3: *Cornudina tortilis* Kozur & Mostler. 2. Sample AJR 722. 3. Sample AJR 724+1.9m.
4: “*Kamuellerella geheensis* Gedik”. Sample 170627-02.
5: *Icriospathodus collinsoni* (Solien). Sample AjL-C.
6: *Icriospathodus* sp.? Sample AjL-C.
7: *Neogondolella aequidentata* Kozur. Sample AJR 724+2.4m.
8–11: *Neogondolella* cf. *hastata* Golding & Orchard. 8, 9. Sample 160627-02. 10, 11. Sample 160627-03.
Plate 3   Stereo-photographs and sketches of conodonts from the Ajiro Island section. Fig. 12 is reversely arranged so that the mould appears as a cast. All other figures are normally arranged. Scale bars are 200 µm.

1, 2: *Neogondolella aff. hastata* (Golding & Orchard). Sample 170627-03.

3: *Neogondolella pridaensis* (Nicora, Kozur & Mietto). Sample AJR 724+2.4m.

4: *Neogondolella cf. regale* Mosher. Sample 170627-03.

5–9: post Bithynian type *Neogondolella*. 5, 7. Sample 170627-03. 6. Sample AJR 577. 8. Sample AJR 310. 9. Sample AJR 517.

10, 11: “*Neohindeodella aequiramosa* Kozur & Mostler”. 10. Sample AJR 144. 11. Sample 170627-02.

12, 13: “*Neohindeodella benderi* (Kozur & Mostler)”. 12. Sample 151005-13. 13. Sample AJR 0.
Plate 4  Stereo-photographs and sketches of conodonts from the Ajiro Island section. Figs. 5, 7–11 are reversely arranged so that the moulds appear as casts. All other figures are normally arranged. Scale bars are 200 µm.

1–3: “Neohindeodella triassica” (Müller). 1. Sample AJR 144. 2. Sample AJR 517. 3. Sample AJR 724+1.9m.
4: Nicoraella kockeli (Tatge). Sample AJR 101.
5: Novispathodus abruptus (Orchard). Sample 150615-21.
6: Novispathodus brevissimus (Orchard). Sample AjL-C.
7–10: Novispathodus symmetricus (Orchard). 7. Sample 150615-21. 8. Sample AjL-B. 9. Sample 151005-13. 10. Sample 160819-03.
11: Novispathodus sp. indet. Sample AjL-B.
Plate 5  Stereo-photographs and sketches of conodonts from the Ajiro Island section. All figures are normally arranged. Scale bars are 200 µm.

1: *Paragondolella* sp. cf. *Paragondolella bulgarica* Group. Sample 151015-08.5.  
2–8: *Paragondolella bulgarica* Group. 2. Sample AJR 0. 3, 4. Sample AJR 144.  
  5. Sample AJR 310. 6, 7. Sample AJR 517. 8. Sample AJR 577.  
9–14: *Paragondolella excelsa* Group. 9. Sample AJR 517. 10–12. Sample AJR 577.  
  13. Sample AJR 722. 14. Sample AJR 724+2.4m.
Plate 6  Stereo-photographs and sketches of conodonts from the Ajiro Island section. Fig. 8 is reversely arranged so that the mould appears as a cast. All other figures are normally arranged. Scale bars are 200 µm.

1–7: *Paragondolella trammeri* Group. 1. Sample AJR 603–605. 2–4. Sample AJR 630. 5. Sample AJR 722. 6, 7. Sample AJR 724+1.9m.
8: *Triassospathodus anhuinensis* (Ding). Sample 150616-29.
Plate 7  Stereo-photographs and sketches of conodonts from the Ajiro Island section. All figures are reversely arranged so that the moulds appear as casts. Scale bars are 200 µm.

1: *Triassospathodus brochus* (Orchard). Sample 151005-13.
2: *Triassospathodus cf. brochus* (Orchard). Sample 151005-13.
3–6: *Triassospathodus homeri* (Bender). 3. Sample 150615-21. 4. Sample AjL-B. 5. Sample 151005-13. 6. Sample AjL1-A.
Plate 8  Stereo-photographs and sketches of conodonts from the Kr-2-YK section. All figures are normally arranged. Scale bars are 200 µm.

1–6: *Chiosella timorensis* (Nogami). 1–3. Sample Kr1-04. 4. Sample Kr1-03. 5, 6. Sample Kr1-02.
7: *Chiosella* sp. Sample Kr1-04.
8: “*Neohindeodella cf. aequiramosa* Kozur & Mostler”. Sample Kr1-03.
Plate 9  Stereophotographs and sketches of conodonts from the Kr-2-I section. All figures are normally arranged. Scale bars are 200 µm.

1, 2: *Chiosella gondolelloides* (Bender). 1. Sample Kr2-01. 2. Sample Kr2-03.

3, 4: *Cornudina breviramulis* (Tatge). Sample Kr2-01.

5: *Cornudina? igoi* Koike. Sample Kr2-01.

6: “*Kamuellerella gebzeensis* Gedik”. Sample Kr2-03.
Plate 10  Stereo-photographs and sketches of conodonts from the Kr-2-I section. All figures are normally arranged. Scale bars are 200 µm.

1, 2: “Neohindeodella benderi (Kozur & Mostler)”. Sample Kr2-01.
3: Neostrachanognathus tahoensis Koike. Sample Kr2-01.
4, 5: Novispathodus symmetricus (Orchard). Sample Kr2-01.
6, 7: Triassospathodus homeri (Bender). 6. Sample Kr2-01. 7. Sample Kr2-03.
