Conodont fossils from the Kiryu and Ashikaga District (Quadrangle series 1:50,000), central Japan with emphasis on the reexamination of “Carboniferous” conodonts from the Ashio Belt

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Abstract: Many conodonts have been reported from the Ashio Mountains, but there have been little attempts to update the information of the specimens based on the present knowledge of conodont taxonomy and biostratigraphy. This study revisits conodont specimens reported from the Kiryu and Ashikaga District in addition to presenting a few newly obtained Early Triassic conodonts. Previously published illustrations allowed reidentification of some conodonts. The geological age of some specimens was revised based on the reidentification. Notably, many of the conodonts previously considered as “Carboniferous” species were revealed to be Permian or Triassic species, and no Carboniferous species were confirmed.

Keywords: conodont, Ashio Mountains, Jurassic accretionary complex, Ashio Belt, reexamination

1. Introduction

The basement rocks of the Ashio Mountains are composed of Palaeozoic and Mesozoic rocks that form the Jurassic accretionary complex of the Ashio Belt (e.g., Kamata, 1996). During the earliest stages of research, the rocks of the Ashio Belt were dated based mainly on fusulinids that occur primarily from limestones (e.g., Fujimoto, 1961). As stratigraphic studies of the Palaeozoic and Mesozoic in Japan commenced, the first conodonts in Japan were found from siliceous, argillaceous and tuffaceous sedimentary rocks the Ashio Belt (Hayashi, 1963). Subsequently, conodonts became acknowledged as useful index fossils due to their occurrence in siliceous and argillaceous rocks in addition to limestones (Igo, 1972). Palaeozoic and Mesozoic conodonts of the Ashio Belt have since been reported by a large number of works, many of which were published before plate tectonics and the concept of accretionary complexes were widely accepted in Japan (Hayashi, 1963, 1964, 1968a, b, 1971; Koike et al., 1971a, b, 1991; Conodont Research Group, 1972, 1974; Hayashi and Hasegawa, 1981; Aono, 1985; Hayashi et al., 1990; Kamata and Kajiwara, 1996; Motoki and Sashida, 2004; Muto et al., 2018, 2021; Ito, 2019, 2020a; Ito et al., 2021a, b).

The conodonts obtained from the Ashio Belt have been valued as a means of age determination, which is vital information for interpretation of sedimentary and tectonic history. For instance, early studies used the geochronological information of conodonts in an attempt to interpret the history of sedimentation in the Ashio Mountains in the context of geosynclines (Conodont Research Group, 1972). On the other hand, conodonts provided evidence of the thrusting of Palaeozoic strata onto Mesozoic strata, ultimately leading to the recognition of accretionary complexes (Koike et al., 1971a, b, 1974; Yanagimoto, 1973; Kamata, 1996, 1997). Following the wide acceptance of subduction-accretion as the origin of the Ashio Belt, conodonts were mainly used as a means to reconstruct the oceanic plate stratigraphy (see Isozaki et al., 1990 for terminology). Due to its widespread occurrence and high evolutionary rates, conodonts allowed researchers to determine the age of Palaeozoic to Triassic rocks in the Ashio Belt that have undergone extensive tectonic deformation and thus are otherwise difficult to understand in a stratigraphic context (Koike et al., 1971a, b, 1991; Igo, 1981; Aono, 1985; Kamata and Kajiwara, 1996; Motoki and Sashida, 2004; Muto et al., 2018, 2021). One of the notable results by previous studies is the occurrence of early Carboniferous or even Devonian conodonts from chert and limestone (Hayashi et al., 1990; Editorial team of Omama Town’s history, 1996), which is far older than the oldest radiolarians reported from the Ashio Belt (early Permian; Kamata, 1996; Ito, 2019, 2020a).

Most studies on conodonts in the Ashio Belt were

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conducted until the beginning of the 1990s. While such studies are still informative, interpreting their results based on the current knowledge of conodonts is somewhat problematic. This is because major refinements in the taxonomy of conodonts have taken place in the last three decades, which have modified the chronological significance of some taxa. For example, Permian platform conodonts previously assigned to the genus *Gondolella* (as in Clark and Mosher, 1966) were split into *Mesogondolella*, *Jinogondolella* and *Clarkina* (Kozur, 1989; Mei and Wardlaw, 1994). Triassic platform conodonts also underwent major taxonomic revisions, and genera such as *Paragondolella* and *Carnepigondolella* are now widely accepted (e.g., Chen et al., 2016). Late Triassic conodonts have recently attracted particular attention, with some debates still continuing today. For instance, Orchard (2013, 2014, 2019) revised the taxonomy of species belonging to *Paragondolella*, *Metapolygnathus*, *Carnepigondolella* and *Epigondolella*, and erected five new genera *Quadralella*, *Parapetella*, *Kraussodontus*, *Acuminatella* and *Primatella*, while Mazza et al. (2018) questioned the validity of genera such as *Quadralella*.

The refinements in the taxonomy of conodonts inevitably modify the age assignment of some conodonts previously reported from the Ashio Belt. In this study, we reinvestigate the chronological significance of previously reported conodonts from the Kiryu and Ashikaga District (Quadrangle series 1:50,000). We also report new occurrences of Early Triassic conodonts from the area. The up-to-date chronological information of conodonts provided in this study is valuable when considering the oceanic plate stratigraphy of the Ashio Belt.

### 2. Geological Setting

The Jurassic accretionary complex of the Ashio Belt (eastern part of the Tamba–Mino–Ashio Belt) is widely distributed in the Ashio Mountains (Fig. 1; Yamakita and Otoh, 2000; Isozaki et al., 2010; Kojima et al., 2016). Kamata (1996) classified the Jurassic accretionary complex of the Ashio Belt into the Kurohone–Kiryu, Omama and Kuzu complexes. Ito (2021a, this volume) newly recognised the Gyodosan Complex.

Detailed description of the lithofacies of each complex is provided in Ito (2021a), but below is a brief summary. The Kurohone–Kiryu Complex is composed of broken to coherent facies of chert and mudstone with minor amounts of siliceous claystone. The mudstone of this complex is
characterised by slaty cleavage. The Omama Complex is composed of broken to mixed facies of mafic rocks, chert and pelitic mixed rocks. The Kuzu Complex is composed of coherent to broken facies of chert, siliceous claystone, siliceous mudstone, mudstone and sandstone. The Gydosan Complex is composed mainly of pelitic mixed rocks and chert accompanied by minor amounts of siliceous mudstone, mudstone and sandstone. The age of the formation of these complexes inferred from age-diagnostic radiolarians is late Middle Jurassic for the Kurohono–Kiryu, Omama and Gydosan complexes and Late Jurassic for the Kuzu Complex (Ito, 2021b, this volume).

3. Methods

The taxonomy of the conodonts reported in previous studies were reinvestigated based on published text and illustrations. When images were not available, the taxon names are simply modified to the presently used scientific name. For Late Triassic conodonts, the taxonomy of which is still much debated, we will follow Mazza et al. (2012, 2018).

The newly obtained conodonts were found from siliceous claystone in the study area. The conodonts were obtained by the chip method (Muto et al., 2018, 2019), in which conodonts are found by examining the surface of rocks cleaved parallel to the bedding.

Individual conodont elements are dismembered parts of a skeletal feeding apparatus, and pectiniform elements of the P1 position are generally used to distinguish a taxon. However, elements from other positions that are described as form taxa are also useful in biostratigraphy. Such form taxa are referred to in brackets (e.g., "Neohindeodella benderi").

4. Newly obtained conodonts and their geological age

We obtained Early Triassic conodonts from siliceous claystone exposed in Ban-yama and Kaizawa near the border of Tochigi and Gunma prefectures (Fig. 2).

From the Ban-yama locality, we obtained the form species "Neohindeodella benderi" (Kozur and Mostler) (Fig. 3.1). "Neohindeodella benderi" has been reported from the same locality by Sahida et al. (1992). This species is known from the latest Olenekian (late Spathian) to middle Anisian (early Bithynian) in carbonates and deep-sea siliceous rocks in Japan (Koike, 1981; Maekawa et al., 2018, 2019). They also occur from Spathian strata in South China (e.g., Zhao et al., 2007; Lehrmann et al., 2015), Vietnam (Maekawa and Igo, 2014), North America (Orchard, 1995), north India (Matsuda, 1983) and elsewhere (Orchard, 1995). Hence, these species are considered as globally useful indicators of the Spathian (Orchard, 2007), although T. homeri and T. unitalatus occur partly from the lowermost Anisian (Orchard, 1995; Goudemand et al., 2012; Lehrmann et al., 2015; Ovtcharova et al., 2015). The same Spathian age is indicated by conodonts for Section 2 of Motoki and Sashida (2004), which is situated ~1.3 km to the southwest of the Kaizawa locality. In addition to the age, the attitude of the bedding plane and lithofacies of our Kaizawa locality are also similar with that of Section 2 of Motoki and Sashida (2004). Therefore, the former is considered as a lateral extension of the latter.

5. Revision of the taxonomy of previously reported conodonts

In this chapter, we mention the identification of specimens with illustrations, with emphasis on chronologically significant specimens. Unfortunately, only a few studies present photographs and, even when they are available, the poor image quality and limited picture angle hinder detailed identification in most cases. For full results, the reader is referred to Table 1. Which complex a sample belongs to is considered on the basis of Ito (2021a).

Hayashi et al. (1990) illustrated several conodonts which they assigned to the early Carboniferous, but they include specimens that are misidentified Late Triassic conodonts. For example, Figures 44, 46 and 49 in the plate of Hayashi et al. (1990) are segminiplanate elements with a well-developed keel on the lower surface and a forward-shifted pit. Such traits are characteristic to Triassic gondolellids and are clearly different from Palaeozoic segminiplanate elements that have poorly developed keels and terminal pits; Figure 44 in the plate can be compared with the Carnian conodont Paragondolella noah (Hayashi) and Figure 49 is comparable with juvenile forms of Carnian Paragondolella. Figures 45, 50, 51 and 52 in the plate of Hayashi et al. (1990) have platform ornamentations that are characteristic to Triassic conodonts, although the keel and pit are not clearly observable due to the picture angle.

Some segminiplanate elements in the Plate of Hayashi et al. (1990) were identified as the late Carboniferous Mesogondolella clarki (Koike), but none of them are identical to this species. Figures 28, 32 and 34 have more closely spaced posterior denticles and higher and more fused anterior denticles compared to M. clarki. Of these, Figures 28 and 34 are comparable to Mesogondolella guioensis (Igo), while Figure 32 cannot be identified. The locality of the specimen in Figure 28 was noted as "Omama Town, Atago-jinjiya". This is possibly Atago Shrine in Kasagake-cho Azami, Midori City (Fig. 2),
Fig. 2 Conodont occurrence sites of the present and previous studies in the Kiryu and Ashikaga District (Quadrangle series 1:50,000). Base from the Geospatial Information Authority of Japan with its approval (Approval number: 419-GISMAP 39354). This map uses GISMAP5000 R+ “Kiryu and Ashikaga” by Hokkaido-Chizu Co. Ltd.
where chert outcrops are exposed. This locality is within
the area of distribution of the Kurohone–Kiryu Complex
(Ito, 2021a). The locality of the specimen in Figure 34
was noted as “Omama Town, Odaira”. The current area
of Omama-cho Odaira is around the upper reaches of the
Odaira River (Fig. 2), which is within the area where
the Omama Complex is distributed (Ito, 2021a). Figures
29 and 30 were also identified as \( M. \ clarki \), but they are
both significantly different from this species: the former in
lacking a posterior protrusion of the platform and having a
smaller basal cavity and the latter in having parallel sides of
the posterior platform. In addition, some other specimens
that Hayashi \( et \ al. \) (1990) considered as Carboniferous
species appear similar to species of \( Neostreptognathodus \)
(Figures 38, 39 and 40) and \( Pseudosweetognathus \) (Figure
42), which both indicate the Permian (Kungurian to
Roadian).

To summarise the above, there are no illustrated
specimens that indicate the Carboniferous Period and
many that were considered to be so are in fact Permian
or Triassic conodonts. To be meticulous, it may be
inaccurate to conclude that all the conodonts assigned to
the Carboniferous are erroneously identified, since some
of the illustrated conodonts have not been confidently
reidentified. In addition, the age of the “Carboniferous”
limestone in Hayashi \( et \ al. \) (1990) was also supported by
the occurrence of corals (Fujimoto, 1960). However, the
conclusion is that none of the illustrations in the previous
studies can be undoubtedly identified as Carboniferous
conodonts. The oldest conodonts according to our
reinvestigation is the late Artinskian to early Kungurian
(middle \( \text{Cisuralian} \)). \( M. \ cf. \ gujioensis \) from the Kurohone–
Kiryu and Omama complexes.

Hayashi \( et \ al. \) (1990) also illustrated some Triassic
conodonts. While the age assignment need not be
modified, some elements can be reidentified. Figures 4 and
6 in the plate of Hayashi \( et \ al. \) (1990) have the triangular
shaped, anteriorly denticulate but posteriorly inornate
platform diagnostic to the Late Triassic \( Epigondolella \)
\( nigoi \) Noyan and Kozur. Figure 5 in the plate has a round
and denticulate platform diagnostic to the Late Triassic
\( Epigondolella \ spatulata \) (Hayashi).

Sashida \( et \ al. \) (1992) and Motoki and Sashida (2004)
illustrated conodonts obtained from siliceous claystone,
which were identified as Spathian species. While we
agree with the age assignment, as supported by conodonts

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Fig. 3 Stereo-photographs (parallel view) of conodonts obtained in this study. Figure 2 is normally arranged. 3a and 3b are
counterparts. All other figures are reversely arranged so that the moulds appears as casts. Scale bars are 200 µm.
1: “Neohindeodella benderi (Kozur & Mostler)” (form species). Ban-yama Mine.
2, 3: Triassospathodus abruptus (Orchard). 2. K96-2-B. 3. K96-2-A.
4: Triassospathodus homeri (Bender). K96-2-A.
5, 6: Triassospathodus unialatus (Mosher). K96-2-A.
7: Triassospathodus sp. K96-2-A.
Table 1  List of conodonts from the Kiryu and Ashikaga District (Quadrangle series 1:50,000) reported in previous studies (re-identified in this study) and this study. For specimens with no available images, modification of scientific names was made simply by replacing old taxon names with modern ones when possible (shown in grey). For assignments of samples to tectonostratigraphic divisions, see Ito et al. (2021a) in this volume. Question marks (?) following a species name or the abbreviation sp. shows that the identification of the specimen is questionable. Taxon names in quotation marks (e.g., “Subbyranthodus sp.”) are form species defined by discrete elements rather than multielement apparatuses.

| No. | Rock facies | Complex | Original identification | Image | Reidentification | Age | Revised age | Notes |
|-----|-------------|---------|-------------------------|-------|------------------|-----|-------------|-------|
| Hayashi (1964) | | | | | | | | |
| 1 | siliceous claystone | Lonchodina sp. | | yes | | | | |
| 2 | siliceous claystone | Neopentrodon sp. | | yes | ramiform dyrate | | | |
| 3 | siliceous claystone | Lonchodina sp. | | yes | “Subbyranthodus sp.” | | | "Lonchodina “ is a ramiform element, while the specimen is an angulate element. |
| Hayashi and Hasegawa (1981) | | | | | | | | |
| 1 | limestone | Omama (Lower part) | Idiognathodus sp. cf. i. attenuatus Harris and Hollingsworth | | | early Carboniferous | middle Carboniferous? |
| 2 | limestone | Omama (Lower part) | Idiognathodus sp. cf. i. convesa (Ellison and Craves) | | | middle Carboniferous? |
| 3 | limestone | Omama (Lower part) | Idiognathodus sp. cf. c. nodosus (Ellison and Craves) | | | middle Carboniferous? |
| 4 | limestone | Omama (Lower part) | Idiognathodus sp. cf. G. bilineatus (Roundy) | | | middle Carboniferous? |
| 5 | limestone | Omama (Lower part) | Idiognathodus sp. cf. G. osachitensis (Harron) | | | middle Carboniferous? |
| 6 | limestone | Omama (Lower part) | Idiognathodus sp. cf. P. flabellus (Branson and Mehl) | | | middle Carboniferous? |
| 7 | limestone | Omama (Lower part) | Idiognathodus sp. cf. P. symmetrica (Branson) | | | middle Carboniferous? |
| 8 | limestone | Omama (Lower part) | Idiognathodus spp. | | | late Carboniferous–early Permian |

Conodonts from the Kiryu and Ashikaga District (MUTO and ITO)
| No. | Rock facies Complex | Original identification | Image | Reidentification | Age | Revised age | Notes |
|-----|---------------------|-------------------------|-------|------------------|-----|-------------|-------|
| 9   | chert               | Gondolella (sp. of Cu. Lake) | 00    | Metapolygnathus cf. Kurohorne (1b) | 00  | 00          |       |
| 10  | chert               | Gondolella sp. | 00    | Metapolygnathus intermedia (1b) | 00  | 00          |       |
| 11  | chert               | Gondolella sp. | 00    | Metapolygnathus intermedia (1b) | 00  | 00          |       |
| 12  | chert               | Gondolella sp. | 00    | Metapolygnathus intermedia (1b) | 00  | 00          |       |
| 13  | chert               | Gondolella sp. | 00    | Metapolygnathus intermedia (1b) | 00  | 00          |       |
| 14  | chert               | Gondolella sp. | 00    | Metapolygnathus intermedia (1b) | 00  | 00          |       |
| 15  | chert               | Gondolella sp. | 00    | Metapolygnathus intermedia (1b) | 00  | 00          |       |
| 16  | chert               | Gondolella sp. | 00    | Metapolygnathus intermedia (1b) | 00  | 00          |       |
| 17  | chert               | Gondolella sp. | 00    | Metapolygnathus intermedia (1b) | 00  | 00          |       |

Table 1 Continued.

| No. | Rock facies Complex | Original identification | Image | Reidentification | Age | Revised age | Notes |
|-----|---------------------|-------------------------|-------|------------------|-----|-------------|-------|
| 90  | chert               | Gondolella (sp. of Kurohorne) | 00    | Metapolygnathus prunus (Michay) | 00  | 00          |       |
| 91  | chert               | Gondolella sp. | 00    | Metapolygnathus prunus (Michay) | 00  | 00          |       |
| 92  | chert               | Gondolella sp. | 00    | Metapolygnathus prunus (Michay) | 00  | 00          |       |
| 93  | chert               | Gondolella sp. | 00    | Metapolygnathus prunus (Michay) | 00  | 00          |       |
| 94  | chert               | Gondolella sp. | 00    | Metapolygnathus prunus (Michay) | 00  | 00          |       |
| 95  | chert               | Gondolella sp. | 00    | Metapolygnathus prunus (Michay) | 00  | 00          |       |
| 96  | chert               | Gondolella sp. | 00    | Metapolygnathus prunus (Michay) | 00  | 00          |       |
| 97  | chert               | Gondolella sp. | 00    | Metapolygnathus prunus (Michay) | 00  | 00          |       |

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| No. | Rock facies | Complex | Original identification | Image | Reidentification | Age | Revised age | Notes |
|-----|-------------|---------|-------------------------|-------|-----------------|------|-------------|-------|
| 82  | chert       | Omama (Lower part) | Neogondolella sp. cf. N. biselli | no | Neogondolella cf. N. biselli | early-middle Permian | ? | Paragondolella excelsa is a Middle Triassic (late Anisian–early Ladinian) species. |
| 83  | chert       | Omama (Lower part) | Gladigondolella tethysis | no | | Permian | Middle–Late Triassic | Slender but vertically thick platform, position of cusp and pit with respect to platform and keel make G. tethysis correctly identified even in early studies (e.g. Hayashi, 1968). |
| 84  | chert       | Omama (Lower part) | Prinsiodina sp. | no | | | |
| 2   | chert       | Karohe–Kiryu (Lower part in the Kiryu area) | Neogondolella navicula | yes | | Triassic | Late Triassic? | Upper view only, but it is similar to N. navicula. |
| 5   | chert       | Karohe–Kiryu (Lower part in the Kiryu area) | Neogondolella navicula | yes | | Triassic | Late Triassic? | Lower view only, but it is similar to Neogondolella. |
| 4   | limestone   | Karohe–Kiryu (Kurohone area) | Metapolygnathus sp. | yes | Epigondolella cf. rigoi (Budtov) | Triassic | Late Triassic (latest Carnian–Norian) | Posterior platform is not completely flat as in typical E. rigoi. Possibly transitional to E. triangularis. |
| 5   | chert       | Possibly Kurohone–Kiryu (Kurohone area) | Metapolygnathus sp. | yes | | Triassic | Late Triassic (Norian) | |
| 6   | chert       | Possibly Kurohone–Kiryu (Kurohone area) | Metapolygnathus sp. nov. | yes | Epigondolella cf. rigoi Noyan & Kozar | Triassic | Late Triassic (latest Carnian–Norian) | |
| 7   | chert       | Gyodosan | Miaskella sp. | yes | | Triassic | Late Triassic (latest Norian–Rhaetian) | |
| 8   | chert       | Gyodosan | Miaskella sp. | yes | Miaskella hermsteinii (Montler) | Triassic | Late Triassic (latest Norian–Rhaetian) | Terminant cusp; denticles decline in height towards cusp (apart from anteriormost); four denticles. |
| 9   | chert       | Omama (Lower part) | Neogondolella sp. A | yes | | Permian | Permian? | |
| 10  | chert       | Omama (Lower part) | Neogondolella sp. B | yes | | Permian | Late Carboniferous–early Permian | Low keel, terminal pri. |
| 11  | chert       | Omama (Lower part) | Neogondolella sp. C | yes | | Permian | Permian? | |
| No. | Rock facies | Complex | Original identification | Image | Redidentification | Age | Revised age | Notes |
|-----|-------------|---------|-------------------------|-------|-------------------|-----|-------------|-------|
| 12  | chert       | Omama (Lower part) | Neogondolella cf. idahoensis | yes | Mesogondolella cf. idahoensis (Youngquist et al.) | Permian | Cisuralian (Kungurian) | Low carina, terminal large and high cup. |
| 13  | chert       | Omama (Lower part) | Gnathodus sp. | yes | Sweetognathus sp. | Permian | Cisuralian–Guadalupian | Upper and basal margins meet at the posterior end. |
| 14  | chert       | Possibly Kurohone–Kiryu (Kurohone area) | Gnathodus sp. | yes | carminiscaphate element | Permian | Permian? | Sweetognathus sp.? Basal margin broken. Could also be Gnathodus sp. |
| 15  | chert       | not mentioned | not mentioned | yes | Hindeodus permicus | Permian | Cisuralian (late Kungurian) | Erect anterior and posterior margins. Small denticles at the posterior end. |
| 16  | chert       | Possibly Kurohone–Kiryu (Kurohone area) | Neogondolella cf. serrata | yes | Jinogondolella nankingensis? | Permian | Guadalupian? | Platform serration is not clearly observable, and misidentification cannot be ruled out. |
| 17  | chert       | Possibly Kurohone–Kiryu (Kurohone area) | Neogondolella cf. serrata | yes | Jinogondolella nankingensis? | Permian | Guadalupian? | Platform serration is not clearly observable, and misidentification cannot be ruled out. |
| 18  | chert       | Kurohone-Kiryu (Kurohone area) | Neogondolella sp. | yes | Mesogondolella sp. or Neogondolella sp. | Permian | Permian or Triassic | Lower surface not visible. |
| 19  | chert       | Kurohone-Kiryu (Kurohone area) | Neogondolella cf. serrata | yes | Mesogondolella sp. or Neogondolella sp.? | Permian | Permian or Triassic? | Platform serration is not visible. |
| 20  | chert       | Kurohone-Kiryu (Kurohone area) | Neogondolella sp. nov. | yes | segminiplanate element | Permian | ? | Lower surface not visible. |
| 21  | chert       | Kurohone-Kiryu (Kurohone area) | Neogondolella sp. | yes | Mesogondolella sp.? | Permian | Permian? | Partly covered. |
| 22  | chert       | Possibly Kurohone–Kiryu (Kurohone area) | Gnathodus sp. | yes | carminiscaphate element | Permian | Permian? | |
| 23  | chert       | Possibly Kurohone–Kiryu (Kurohone area) | Neogondolella sp. | yes | Mesogondolella sp.? | Permian | Permian? | |
| 24  | chert       | Kurohone-Kiryu (Kurohone area) | Neogondolella sp. | yes | Jinogondolella sp.? | Permian | Permian? | Weak serration on anterior platform. Lower surface not visible. |
| 25  | chert       | Kurohone-Kiryu (Kurohone area) | Neogondolella sp. | yes | Jinogondolella sp.? | Permian | Permian? | |
| 26  | chert       | Kurohone-Kiryu (Kurohone area) | Neogondolella sp. | yes | Segminiplanate element | Permian | ? | |
| 27  | chert       | Kurohone-Kiryu (Kurohone area) | Gnathodus sp. & Neogondolella sp. | yes | Carminiscaphate element & segminiplanate element | Permian | Permian? | Possibly Gnathodus sp. & Mesogondolella sp. |
| 28  | chert       | Kurohone–Kiryu (possibly Upper part in the Kiryu area) | Neogondolella cf. clarki | yes | Mesogondolella cf. gujioensis (Igo) | Carboniferous | Cisuralian (late Artinskian–early Kungurian) | Posterior denticles more closely spaced than M. clarki. Anterior denticles more fused and higher than M. clarki. |
| No. | Rock facies | Complex | Original identification | Image | Residentification | Age | Revised age | Notes |
|-----|-------------|---------|-------------------------|-------|-------------------|-----|-------------|-------|
| 29  | chert       | Kurohone–Kiryu (possibly Upper part in the Kiryu area) | Neogondolella cf. clarki | yes | Neogondolella sp. not M. clarki. | Carboniferous | Permian? | M. clarki has the basal part of cusp forming a conspicuous posterior projection at posterior end of platform and a larger basal cavity. |
| 30  | limestone   | Omama (Lower part) | Neogondolella cf. clarki | yes | Not M. clarki. | Carboniferous | Permian? | Parallel-sided platform. |
| 31  | limestone   | Omama (Lower part) | Neogondolella cf. clarki | yes | Neogondolella sp.? | Carboniferous | ? | Posterior denticles more closely spaced than M. clarki. Anterior denticles more fused and higher than M. clarki. |
| 32  | limestone   | Omama (possibly Upper part) | Neogondolella cf. clarki | yes | Neogondolella sp.? | Carboniferous | ? | Posterior denticles more closely spaced than M. clarki. Anterior denticles more fused and higher than M. clarki. |
| 33  | limestone   | Omama (possibly Upper part) | Neogondolella cf. clarki | yes | Neogondolella sp.? | Carboniferous | Permian? |
| 34  | chert       | Omama (Lower part) | Neogondolella cf. clarki | yes | Neogondolella cf. gujioensis (Iigo) | Carboniferous | Cisuralian (late Artinskian–early Kungurian) | Posterior denticles more closely spaced than M. clarki. Anterior denticles more fused and higher than M. clarki. |
| 35  | limestone   | Omama (Lower part) | Gnathodus sp. | yes | Sweetognathus sp. or Gullodus sp. or Hindodus sp. | Carboniferous | Permian? |
| 36  | limestone   | Omama (Lower part) | Gnathodus sp. | yes | Hindodus sp.? | Carboniferous | ? | Image too small. |
| 37  | limestone   | Omama (Lower part) | Gnathodus sp. | yes | ? | Carboniferous | ? |
| 38  | limestone   | Omama (Lower part) | Gnathodus sp. | yes | Neostreptognathodus sp.? | Carboniferous | Permian? (Kungurian–Roadian?) |
| 39  | limestone   | Omama (Lower part) | Streptognathodus sp. | yes | Neostreptognathodus sp.? | Carboniferous | Permian? (Kungurian–Roadian?) |
| 40  | limestone   | Omama (Lower part) | Cuvagnathus sp. | yes | Neostreptognathodus sp.? | Carboniferous | Permian? (Kungurian–Roadian?) | Connection of blade and carina needs to be visible for confirmation of Cuvagnathus. |
| 41  | limestone   | Omama (Lower part) | Neospathodus sp. | yes | Carminispathodus element? | Carboniferous | Permian? |
| 42  | limestone   | Omama (Lower part) | Neospathodus sp. | yes | Pseudosweetognathus sp.? | Carboniferous | Permian? (Kungurian–Roadian?) | Not segminate Neospathodus. Carinal blade should be present if it is Idospathodus. |
| 43  | limestone   | Omama (Lower part) | Siphonoolithina sp. | yes | ? | Carboniferous |
| No. | Rock facies | Complex | Original identification | Image | Reidentification | Age | Revised age | Notes |
|-----|-------------|---------|-------------------------|-------|------------------|-----|-------------|-------|
| 44  | chert       | Omama (Lower part) | Conodonta gen. & sp. indet | yes | Paragondolella cf. noah (Hayashi) | Early Carboniferous | Late Triassic (Carbionian) | Well developed keel, anteriorly shifted (not terminal) basal pit is different from Palaeozoic species. Possesses posterior node unlike P. polyplacophoris. Lacks nodes on generication points unlike M. praecommunisti. Quadratella according to Orchard (2013, 2014). |
| 45  | chert       | Omama (Lower part) | Conodonta gen. & sp. indet | yes | Carnepigondolella sp.? | Early Carboniferous | Late Triassic? | |
| 46  | chert       | Omama (Lower part) | Conodonta gen. & sp. indet | yes | Modkins sp.? | Early Carboniferous | Late Triassic? | Developed keel. Carina extends to posterior. |
| 47  | chert       | Omama (Lower part) | Conodonta gen. & sp. indet & Gondolella sp. | yes | Paragondolella sp.? & segminiplanate element | Early Carboniferous | Middle-Late Triassic? | Broken segminiplanate element. |
| 48  | chert       | Omama (Lower part) | Conodonta gen. & sp. indet | yes | ? | Early Carboniferous? | |
| 49  | chert       | Omama (Lower part) | Conodonta gen. & sp. indet | yes | evolved Paragondolella | Early Carboniferous | Late Triassic (Carbionian) | Juvenile specimen. Quadratella sp. According to Orchard (2013, 2014). Upturned platform distinguishes it from primitive Paragondolella. |
| 50  | chert       | Omama (Lower part) | Conodonta gen. & sp. indet | yes | Sephardiella sp.? | Early Carboniferous | Triassic | Developed keel is different from Carboniferous and Permain species. |
| 51  | chert       | Omama (Lower part) | Conodonta gen. & sp. indet | yes | Sephardiella modesti? | Early Carboniferous | Triassic | Carina extends to posterior. Posteriormost denticle not thick. |
| 52  | chert       | Omama (Lower part) | Conodonta gen. & sp. indet | yes | Sephardiella sp.? | Early Carboniferous | Triassic | Carina extends to posterior. Posteriormost denticle not thick. |
| 53  | chert       | Omama (Lower part) | Anchigondolella sp. | yes | Carminiscaphate element | Early Carboniferous? | |
| 54  | chert       | Omama (Lower part) | Anchigondolella sp. | yes | Carminiscaphate element | Early Carboniferous? | |
| 55  | chert       | Omama (Lower part) | Gondolella sp. | yes | Segminiplanate element? | Early Carboniferous? | |
| 56  | chert       | Omama (Lower part) | Icriodus sp. | yes | ? | Early Carboniferous? | |
| 57  | chert       | Omama (Lower part) | Icriodus sp. | yes | ? | Early Carboniferous? | |
| 58  | chert       | Omama (Lower part) | Icriodus sp. | yes | ? | Early Carboniferous? | |
| 59  | chert       | Omama (Lower part) | Icriodus sp. | yes | ? | Early Carboniferous? | |

Sashida et al. (1992)

KIS-16 siliceous claystone Kurohonne–Kiryu (Lower part in the Kiryu area) Neospathodus homeri (Bender) yes Triassospathodus ex. gr. homeri Early Triassic Early Triassic (late Olenekian) | Fig. 5.6. Since the form of the basal cavity is unclear, they could be Triassospathodus unialatus (not Neospathodus symmetricus) Orchard; see Taxonomic Notes). |
Table 1 Continued.

| No. | Rock facies | Complex | Original identification | Image | Reidentification | Age | Revised age | Notes |
|-----|-------------|---------|-------------------------|-------|-----------------|-----|-------------|-------|
| BAN-4 | silicic claystone | Kurohime–Kiryu (Lower part in the Kiryu area) | Neohindeodella aequiramosa (Kozar and Mostler) | yes | "Neohindeodella gebzeensis" (Gedik) (part) | Early Triassic | Early–Middle Triassic (late Olenekian–early Anisian) | Figs. 5.9, 5.12. Anterior margin connects smoothly with basal margin in "N. aequiramosa". Fig. 5.11 is "Neohindeodella sp.". |
| BAN-5 | silicic claystone | Kurohime–Kiryu (Lower part in the Kiryu area) | Neospathodus homeri (Bender) | yes | Triassospathodus ex. gr. homeri | Early Triassic | Early Triassic (late Olenekian) | Figs. 5.5, 5.7. Since the form of the basal cavity is unclear, they could be T. unialatus (= Neospathodus symmetricus Orchard). |
| &nbsp; | &nbsp; | &nbsp; | Cypridodella muelleri (Tatge) | yes | ? | &nbsp; | &nbsp; | In "C. muelleri", the base is flared laterally below the cup and denticles on the long process are strongly inclined. |
| &nbsp; | &nbsp; | &nbsp; | Neohindeodella aequiramosa (Kozar and Mostler) | yes | maintained | &nbsp; | &nbsp; | Fig. 5.20. Broken. |
| &nbsp; | &nbsp; | &nbsp; | Neohindeodella triassica (Müller) | yes | "Neohindeodella cf. gebzeensis" (Gedik) (part), "Cypridodella sp." (part) | Early–Middle Triassic (late Olenekian–Anisian) | 5.10. "Neohindeodella sp.". 5.14. "Grodella sp." Denticles recline towards opposite directions in the anterior and posterior processes of "N. triassica", but denticles are all inclined to the left in specimen. 5.15, 5.18. "N. cf. gebzeensis". 5.21, 5.22. "Cypridodella sp.". |
| &nbsp; | &nbsp; | &nbsp; | Neohindeodella benderi (Kozar and Mostler) | yes | maintained | &nbsp; | &nbsp; | &nbsp; |
| &nbsp; | &nbsp; | &nbsp; | Diplododella sp. | yes | &nbsp; | &nbsp; | &nbsp; | &nbsp; |

Motoki and Sashida (2004)

| A-25 | silicic claystone | Kurohime–Kiryu (Lower part in the Kiryu area) | Neospathodus abruptus Orchard, Pa element | no | | Early Triassic | | |
| A-26 | silicic claystone | Kurohime–Kiryu (Lower part in the Kiryu area) | Neospathodus abruptus Orchard, Pa element | yes | Triassospathodus ex. gr. abruptus (part) | Early Triassic | Early Triassic (late Olenekian) | Figs. 5.1, 5.2. Anterior margin connects smoothly with basal margin in "T. abruptus". Fig. 5.11 is "Triassospathodus sp.". |
| A-28 | silicic claystone | Kurohime–Kiryu (Lower part in the Kiryu area) | Neospathodus abruptus Orchard, Pa element | yes | Triassospathodus ex. gr. abruptus (part) | Early Triassic | Early Triassic (late Olenekian) | Figs. 5.1, 5.2. Anterior margin connects smoothly with basal margin in "T. abruptus". Fig. 5.11 is "Triassospathodus sp.". |
| A-30 | silicic claystone | Kurohime–Kiryu (Lower part in the Kiryu area) | Neospathodus abruptus Orchard, Pa element | yes | Triassospathodus ex. gr. abruptus (part) | Early Triassic | Early Triassic (late Olenekian) | Figs. 5.1, 5.2. Anterior margin connects smoothly with basal margin in "T. abruptus". Fig. 5.11 is "Triassospathodus sp.". |
| No. | Rock face | Complex | Original identification | Image | Redescription | Age | Revised age | Notes |
|-----|-----------|---------|------------------------|-------|---------------|-----|-------------|-------|
| 5-24 | silicous claystone | Kurohone-Kiryu (Lower part in the Kiyu area) | Neospathodus sp., Pb element | no | Early Triassic | no | Early Triassic | |
| A-25 | silicous claystone | Kurohone-Kiryu (Lower part in the Kiyu area) | Neospathodus sp., Sc element | yes | Early Triassic | yes | Early Triassic | |
| A-26 | silicous claystone | Kurohone-Kiryu (Lower part in the Kiyu area) | Neospathodus sp., Sc element | yes | Early Triassic | no | Early Triassic | |
| A-27 | silicous claystone | Kurohone-Kiryu (Lower part in the Kiyu area) | Neospathodus sp., Sc element | yes | Early Triassic | no | Early Triassic | |
| A-28 | silicous claystone | Kurohone-Kiryu (Lower part in the Kiyu area) | Neospathodus sp., Sc element | yes | Early Triassic | no | Early Triassic | |
| A-29 | silicous claystone | Kurohone-Kiryu (Lower part in the Kiyu area) | Neospathodus sp., Sc element | yes | Early Triassic | no | Early Triassic | |
| A-30 | silicous claystone | Kurohone-Kiryu (Lower part in the Kiyu area) | Neospathodus sp., Sc element | yes | Early Triassic | no | Early Triassic | |

Fig. 6.14. Dygirate ramiform element.

Fig. 6.17. Dygirate ramiform element.
Table 1 Continued.

| No. | Rock facies      | Complex                                                | Original identification | Image | Reidentification | Age               | Revised age | Notes                                                                 |
|-----|------------------|--------------------------------------------------------|-------------------------|-------|------------------|-------------------|-------------|-----------------------------------------------------------------------|
| A-31| siliceous claystone | Kurohoke–Kiryu (Lower part in the Kiryu area) | Neospathodus abruptus (Orchard, Pb) | yes   | Neospathodus unialatus | Early Triassic | Early Triassic (late) | Fig. 6.3. Denticle height is subequal. |
|     |                  |                                                       | Neospathodus sp., Pb element | no    |                  |                   |             |                                                                                 |
|     |                  |                                                       | Neospathodus sp., Sb2 element | no    |                  |                   |             |                                                                                 |
|     |                  |                                                       | Neospathodus sp., Sc element | no    |                  |                   |             |                                                                                 |
|     |                  |                                                       | Neospathodus sp., M element  | no    |                  |                   |             |                                                                                 |

| Ito (2019) | IT16071201 | chert | Gyodosan | condont fragment | yes |                      |                     |             |                                                                      |
| Ito (2020b) | IT18101408 | chert | Kuzu (Unit 3) | condont fragment | yes |                      |                     |             |                                                                      |
| Ito (2020b) | IT18101409 | chert | Kuzu (Unit 3) | condont fragment | yes |                      |                     |             |                                                                      |
| Ito et al. (2021a) | 164 | chert | Omama (Lower part) | condont fragment | yes |                      |                     |             |                                                                      |
| Ito et al. (2021a) | 234 | chert | Omama (Lower part) | condont fragment | yes |                      |                     |             |                                                                      |
| Ito et al. (2021a) | 257 | chert | Omama (Lower part) | condont fragment | yes |                      |                     |             |                                                                      |
| This study | Ban-yama | siliceous claystone | Kurohoke–Kiryu (Lower part in the Kiryu area) | "Novispathodus benderi (Kozur & Mostler)" | yes | Early-middle Triassic (late Olenekian–early Anisian) | Novispathodus is regarded as a junior synonym of Triassospathodus see Taxonomic notes. |
| K96-2-A | siliceous claystone | Kurohoke–Kiryu (Lower part in the Kiryu area) | Triassospathodus abruptus (Orchard) | yes | Early Triassic (late Olenekian) | Novispathodus is regarded as a junior synonym of Triassospathodus see Taxonomic notes. |
|         |                  |                                                      | Triassospathodus homeri (Bender) | yes | Early Triassic (late Olenekian) |                     |             |                                                                      |
|         |                  |                                                      | Triassospathodus unialatus (Mosher) | yes | Early Triassic (late Olenekian) |                     |             |                                                                      |
|         |                  |                                                      | Triassospathodus sp. | yes | Early Triassic (late Olenekian) |                     |             | Anterobasal margin and posteriormost denticle is not clearly visible. |
| K96-2-B | siliceous claystone | Kurohoke–Kiryu (Lower part in the Kiryu area) | Triassospathodus abruptus (Orchard) | yes | Early Triassic (late Olenekian) |                     |             |                                                                      |
obtained in the present study, the identification of some specimens needs to be reconsidered, as mentioned below.

Sashida et al. (1992) showed conodonts from Ban-yama (see also 4) Newly obtained conodonts and their geological age). The form species “Neohindeodella aequitemasosa Kozur and Mostler” possesses anteriorly reared and projecting denticles at the anterior end, the anterior margin of which connects smoothly with the antero-basal margin. However, the specimens identified as this species in Sashida et al. (1992) have either an anteriormost denticle that connects at a right angle with the antero-basal margin (their Figures 5.9, 5.11, 5.12) or is considerably broken (their Figure 5.20). In fact, the morphology of the anterior process and numerous erect denticles on the posterior process in the specimens in Figures 5.9 and 5.12 match the characters of a different form species “Neohindeodella gebzeensis (Gedik)” (their Figure 5.20). In fact, the morphology of the anterior process and numerous erect denticles on the posterior process in the specimens in Figures 5.9 and 5.12 match the characters of a different form species “Neohindeodella gebzeensis (Gedik)” (their Figure 5.20). In fact, the morphology of the anterior process and numerous erect denticles on the posterior process in the specimens in Figures 5.9 and 5.12 match the characters of a different form species “Neohindeodella gebzeensis (Gedik)” (Figures 5.15 and 5.18), which is a species with a basal margin protruding downwards below the cusp, are comparable to “N. gebzeensis”. The other specimens identified as “N. triassica” are also misidentified: Figure 5.10 is much more bent in lateral view, while Figures 5.14, 5.21 and 5.22 are digyrate elements of the form genus “Cypridodella” and “Cypridodella”.

Motoki and Sashida (2004) reported T. abruptus, which is characterised by abrupt shortening of the denticles in the posterior. While the character can be seen in Figures 6.2 and 6.6, it is not seen in Figures 6.3, 6.4 and 6.5. The sub-equal denticles of the latter three are closer to that of T. unialatus. On the other hand, the specimen identified as Neospathodus symmetricus (= T. unialatus) in their Figure 6.10 has a small denticle at the posterior end, which is not a feature of this species according to the original description (Orchard, 1995). Triassospathodus brevissimus was illustrated in Figure 6.7 of Motoki and Sashida (2004), but this specimen does not possess the sub-quadratate lateral outline formed by small erect denticles of mostly equal height that distinguishes this species (Orchard, 1995; Maekawa et al., 2018; Muto et al., 2019).

6. Conclusions

1) Conodonts were newly found from siliceous claystone near the border of the Tochigi and Gunma prefectures. We obtained the form species “Neohindeodella benderi (Kozur & Mostler)” from Ban-yama and Triassospathodus abruptus (Orchard), Triassospathodus homeri (Bender) and Triassospathodus unialatus (Mosher) (= Neospathodus symmetricus Orchard) from Kaizawa. These conodonts indicate the Spathian (late Olenekian Age).

2) We reinvestigated the illustrations of conodonts provided by previous studies. Many of the conodonts previously identified as Carboniferous conodonts are Permian and Triassic species. In particular, two out of six specimens identified as Mesogondolella clarki (Koike) were reidentified as Mesogondolella cf. gujoensis (Igo) and some specimens identified as early Carboniferous species of unknown genera should be identified as Late Triassic species such as Paragondolella cf. noah (Hayashi).

3) As far as the conodonts are concerned, there is no compelling evidence indicating the presence of Carboniferous limestone and chert, which was reported by previous studies. The oldest age that can be confirmed by conodonts is the late Artinskian to early Kungurian age of the Cisuralian (early Permian) indicated by M. cf. gujoensis from the Kurohone–Kiryu and Omama complexes.

7. Taxonomic notes

Remarks for the conodonts obtained in this study are mentioned here. For detailed synonym lists, the reader is referred to Muto et al. (2019, 2020).

“Neohindeodella benderi (Kozur and Mostler)” (form species) (Figure 3.1)
Remarks: This form species is easily recognised by its anterior process that is conspicuously bent down and bears a long denticle at the anterior end, but otherwise is poorly denticulate.

Triassospathodus abruptus (Orchard) (Figures 3.2, 3.3)
Remarks: A species characterised by segminate elements with denticles that decrease height rapidly at the posterior. This species was defined as the type species of the genus Novispathodus abruptus by Orchard (2005), but the distinguishing features of Novispathodus are seen as intraspecific variations in related neospathodids (Koike, 2004; Muto et al., 2020). Therefore, Novispathodus is regarded as a junior synonym of Triassospathodus.

Triassospathodus homeri (Bender) (Figure 3.4)
Remarks: This species has a short posterior process of up to five denticles above the elongated posterior part of the basal cavity.

Triassospathodus unialatus (Mosher) (Figures 3.5, 3.6)
Remarks: The P1 element of this species is a segminate element with denticles of subequal height and a posteriorly rounded basal cavity. The P1 element was described as Neospathodus symmetricus by Orchard (1995) and was shown to be accompanied by the form species “Cypridodella unialata (Mosher)” as its S2 element (Koike, 2004), which has the priority (Muto et al., 2020).

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5万分の1地質図幅「桐生及足利」地域から産出したコノドント化石：足尾テレーンの“石炭紀”コノドントを中心とした再検討

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要 旨
これまで足尾山地からは多くのコノドント化石の産出が報告されているが、多くの研究は古い分類や生層序の知見に基づいている。本研究では、5万分の1地質図幅「桐生及足利」地域内から報告されているコノドント化石を現在の分類と生層序に基づき再検討した。図示されている標本については必要に応じて同定の修正を試み、図示されていないもののについては現在の分類体系に基づいて分類群名を読み替えた。また、本研究で独自に得た前期三畳紀のコノドントも併せて報告する。特筆すべきは、石炭紀のコノドントとして報告されていた標本の多くがペルム紀または三畳紀のものであり、石炭紀のものだと断定できる標本が無いことである。その結果、同地域で確認できる最も古い岩石の年代はシスウラリアン世（前期ペルム紀）となり、同地域から報告されている最も古い放散虫の年代とほぼ一致した。