Middle and Upper Permian Conodont Biostratigraphy in Bedded Cherts of the Mino Terrane, Central Japan

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(With 7 Figures and 3 Plates)

Abstract

Stratigraphic distribution of conodonts and radiolarians in the Middle and Upper Permian bedded cherts of the Mino Terrane was investigated. Two conodont assemblage zones are newly established in the Middle and Upper Permian, namely, the Neogondolella wilcoxi Assemblage Zone and the Neogondolella subcarinata Assemblage Zone. They are assigned to the late Middle to early Late Permian and the middle to late Late Permian. Systematic description of 5 species of Neogondolella is also given.

Key Words: Neogondolella, conodont, radiolaria, Upper Permian, bedded chert.

Introduction

In Japan, Permian conodont biostratigraphy has been based mainly on studying conodonts in calcareous sequences. IGO (1979, 1981) studied the stratigraphic distribution of conodonts in limestones distributed in central Japan, and established two assemblage zones and two faunas in the Lower Permian. The Middle and Upper Permian conodonts, however, were not well investigated for lack of limestones. Recently, the Upper Permian conodont biostratigraphy of limestone facies has progressed in South China. WANG and WANG (1981a) established four conodont assemblage zones in the Upper Permian and correlated them with the conodont zones of the Ali Bashi Formation of northwestern Iran and the Dorashamian Formation of the Transcaucasia. ZHAO et al. (1981) and YANG et al. (1987) correlated these conodont assemblage zones with the Upper Permian fusulinacean zones of South China. DING (1992) redefined the conodont zones of WANG and WANG (1981a) by means of the biohorizons of the characteristic species.

Middle and Upper Permian bedded cherts with well-preserved radiolarians are distributed in the Mino Terrane and they also yield conodonts (e.g., ISHIGA et al., 1982a; WAKITA, 1983). These bedded cherts have stratigraphical continuity and are suited for biostratigraphical research. I examined the stratigraphic distribution of the conodonts and the accompanying radiolarians in the following parts: the Nabejiriyama section of ISHIGA et al. (1982a), the Gujo-hachiman section of KUWAHARA and SAKAMOTO (1992), and the section and the block in the Funabuseyama area (Fig. 1).

Acknowledgments

I wish to express my sincere gratitude to Professor Yao Akira and Dr. Ezaki Yoichi of Osaka City University for their help throughout the course of this work. I also express my thanks to Miss Kuwahara Kiyoko for offering her samples, collaboration and suggestions. Sincere thanks are due to Mr. Funakawa Satoshi and Mr. Ishimoto Hideki of Osaka City University for their help with sampling. Professor Igo Hisaharu of Tokyo Gakugei University kindly advised me on Permian conodonts.

Method

Rock samples were put in 5 percent hydrofluoric acid for 24 hours to separate fossils from matrices. I used 20 and 200 mesh sieves to obtain the residues, including fossils. Residues were dried and conodonts were separated from silica minerals by using heavy liquid, sodium polytungstate and a centrifugal machine. To obtain many conodonts, I repeated the above mentioned treatment. Conodonts were picked under a binocular microscope and identified under a scanning electron microscope.

Geological setting and materials

(1) Ryozensan area: The geology of this area was investigated by Miyamura et al. (1976) and divided into the Ryozensan Formation and the Ikuridani Group. Both group and formation were redefined by Harayama et al. (1989). The Ryozensan Formation consists mainly of greenstone and limestone with small amounts of chert. The limestone yields Early Permian fusulinids, namely, Pseudofusulina vulgaris, Pseudofusulina kraftti, Rugosofusulina alpina, Paraschwagerina endoi, Triticites obai and Triticites simplex (Miyamura et al., 1976). The Ikuridani Group consists mainly of sandstone and
mudstone accompanied by a lot of cherts. It is considered to be a Jurassic accretionary Complex because of the occurrence of Jurassic radiolarians (Harayama et al., 1989).

The bedded chert section as seen in this study is a lenticular body occurring as an allochthonous block in Jurassic mudstone. It is located about three kilometers south of Mt. Ryozensan, along the Shirodani river, in Taga Town, Inukami Country, Shiga Prefecture. This section is composed of interbedded grey to dark grey chert (3 to 8 cm thick) and thin mudstone. I collected 64 samples bed by bed from the bedded chert section, of which the total thickness is about 4.6 m. The Neoalbaillella optima Assemblage Zone and the Neoalbaillella ornithoformis Assemblage Zone of Ishiga (1990) are recognized in this section (Fig. 5).

(2) Gujo-hachiman area: This area was surveyed in detail by Wakita (1983, 1984). According to Wakita (1983), Jurassic strata covered by acidic volcanic Cretaceous rocks are widely distributed in this area. Jurassic strata are composed mainly of allochthonous blocks and submarine slide deposits. Allochthonous blocks are made of cherts, limestones and greenstones. These cherts contain Middle Permian to Early Jurassic radiolarians.

The examined bedded chert section is located five kilometers north of Itadori Village, Mugi Country, Gifu Prefecture. It is the same section as the bedded chert section of
Fig. 3. Geologic map of the Gujo-hachiman area (after Wakita, 1983).

KUWAHARA and SAKAMOTO (1992). This chert block is an olistolith included in the Nabigawa Formation (WAKITA, 1984), accompanied by siliceous mudstone yielding Late Permian radiolarians, with a fault contact (KUWAHARA et al., 1991). The bedded chert is composed of alternating beds of grey chert (2 to 9 cm thick) and thin mudstone. I collected 121 chert samples bed by bed from the bedded chert, of which the total thickness is 7.7 m. In this section I recognized the same radiolarian assemblage zones as in the Ryozensan section (Fig. 6).

(3) Funabuseyama area: The Permian Okumino Group (SANO, 1988a) is widely distributed around the Mt. Funabuseyama, Gifu Prefecture. The Okumino Group is divided into three formations: the Hashikadani, the Amanokawara and the Funabuseyama Formations (SANO, 1988a). They are separated from each other by faults. The Funabuseyama and the Amanokawara Formations are composed mainly of limestone, yielding Early to Middle Permian fusulinids, such as Pseudofusulina ambiguа, Parafusulina kaerimizensis, Parafusulina yabei, Misellina claudiae, Neoschwagerina simplex and Verbeekina
verbeeki (SANO, 1988b). The Hashikadani Formation is composed of greenstone, chert and siliceous mudstone.

I collected rock samples from the cherts belonging to the Hashikadani Formation of the Funabuseyama area (Fig. 4). Conodonts were found from the Hk section (showed as star 1 in Fig. 4) and from the rock samples that were collected near the confluence of the Iwaidani Valley and the Neohigashigawa River (St. Iw, showed as star 2 in Fig. 4). The Hk section is composed of interbedded grey chert (about 5 cm thick) and thin mudstone. The rock samples from the St. Iw is collected from grey to light grey, massive cherts. They contain Follicucullus scholasticus but no specimens of Albaillella and Neoralbaillella, so they are correlated with the Follicucullus scholasticus Assemblage Zone
Figure 5: Stratigraphic distribution of conodonts and radiolarians from the Ryzemian section.

Condons obliques from each section

Kito Kaua

Ryzemian section: Neogondolella wilcoxii Clarke and Berken was recognized

Of Iheia (1999).
in the lowermost part of this section. *Neogondolella* sp. aff. *Ng. orientalis* (BARSakov and KOLOREVA), *Neogondolella subcarinata* SWEET and *Neogondolella* sp. aff. *Ng. changxingensis* WANG and WANG occur from the lower to upper part of this section. *Prioniodella decrescens* TATGE and *Xaniognathus* spp. were also recognized besides the genus *Neogondolella* in this section. *Hindeodus minutus* (ELLISON) was not found in this study, but ISHIGA et al. (1982a) have reported the species from the middle to upper part of this section. Some specimens of *Neogondolella* spp. of ISHIGA et al. (1982a) are the same species as *Neogondolella* sp. aff. *Ng. orientalis* of this study (Fig. 5).

(2) Gujo-hachiman section: *Neogondolella* sp. aff. *Ng. orientalis*, *Neogondolella wilcoxi*, *Hindeodus minutus* and *Prioniodella decrescens* were recognized in the lower part of this section. *Neogondolella subcarinata*, *Neogondolella* sp. aff. *Ng. changxingensis* and *Xaniognathus* spp. occur from the lower to upper part of this section (Fig. 6).

(3) Funabuseyama area: Determinable conodonts were recognized in two samples from the St. Iw. The conodont components of these samples are the same, namely, *Neogondolella wilcoxi*, *Neogondolella* sp. A and *Xaniognathus* sp. cf. *X. sweeti* Igo. Indeterminable hindeodellid-form conodonts were recognized both from the St. Iw and the Hk section.

### Upper Middle and Upper Permian conodont biostratigraphy

In this study, two conodont assemblage zones, namely, the *Neogondolella wilcoxi* Assemblage Zone and the *Neogondolella subcarinata* Assemblage Zone, in ascending order, are established (Fig. 7). The features of these zones are described below. The

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<td>Late Permian</td>
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<td><em>Ng. subcarinata</em></td>
<td><em>Ng. deflecta-Ng. s.changxingensis</em></td>
<td><em>Ng. wilcoxi</em></td>
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<td><em>Na. optima</em></td>
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<td>M. Permian</td>
<td><em>Fo. scholasticus</em></td>
<td><em>Ng. wilcoxi</em></td>
<td><em>Ng. s. subcarinata-Ng. s. elongata</em></td>
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Fig. 7. Correlation of conodont zone with the other zones and the ranges of the stratigraphically important species.
age of each zone is based on the co-existing radiolarians, and on correlation with the assemblages reported from South China by WANG and WANG (1981a, b) and DING (1992), and from North America by CLARK and BEHNKEN (1979). The radiolarian assemblage zones of ISHIGA (1990) are applied in this study.

(1) Neogondolella wilcoxi Assemblage Zone

Definition: The lower limit of this zone is marked by the first appearance of Neogondolella wilcoxi. The upper limit of this zone is marked by the first appearance of Neogondolella orientalis.

Composition of conodont assemblage: This zone is characterized by an assemblage of Neogondolella wilcoxi, Neogondolella sp. A, Xaniognathus sp. cf. X. sweeti and indeterminable hindeodellid-form conodonts.

Age: Neogondolella wilcoxi was reported from the Lamar Limestone, the youngest of the limestone members of the Guadalupian Bell Canyon Formation and the Upper Gerster Formation in the United States (CLARK and BEHNKEN, 1979). In this study, I found Neogondolella wilcoxi from the upper Permian strata. CLARK and BEHNKEN (1979) reported the occurrence of Neogondolella wilcoxi from the upper Middle Permian. Therefore, this zone is assigned to late Middle to early Late Permian.

Correlation: According to CLARK and WANG (1988), Neogondolella wilcoxi was found in the upper Middle Permian, and it corresponds to the Neogondolella serrata - Neogondolella aserrata Assemblage Zone of WANG and WANG (1981b). In this study, Neogondolella wilcoxi occurred in the upper Permian beds. Therefore, the Neogondolella wilcoxi Assemblage Zone corresponds to the upper part of the Neogondolella serrata - Neogondolella aserrata Assemblage Zone and the Neogondolella liangshanensis Assemblage Zone of WANG and WANG (1981b).

Follicucullus scholasticus, occurring in the Lamar Limestone, is characteristic of this zone. Hence, this zone is correlated with the Follicucullus scholasticus Assemblage Zone.

(2) Neogondolella subcarinata Assemblage Zone

Definition: The lower limit of this zone is marked by the first appearance of Neogondolella subcarinata. The upper limit of this zone is unknown from this study.

Composition of conodont assemblage: This zone is characterized by an assemblage of Neogondolella subcarinata, Neogondolella sp. aff. Ng. changxingensis, Neogondolella sp. aff. Ng. orientalis, Prioniodella decrescens, Xaniognathus spp. and indeterminable hindeodellid-form conodonts. Neogondolella wilcoxi occurs in the lower part of this zone.

Age: Neogondolella subcarinata and Neogondolella changxingensis occur in the middle part of the Changxing Formation in South China (WANG and WANG, 1981a). Therefore, this zone is assigned to middle to late Late Permian.

Correlation: WANG and WANG (1981b) established two conodont assemblage zones in the Changxingian, namely, the Neogondolella subcarinata subcarinata (= Ng. subcarinata) - Neogondolella subcarinata elongata (= Ng. wangi) Assemblage Zone and the Neogondolella deflecta - Neogondolella subcarinata changxingensis (= Ng. changxingensis)
Assemblage Zone. Ding (1992) used the first appearance of *Neogondolella changxingensis* for the base of the *Neogondolella changxingensis* zone. On the basis of the composition of the conodont assemblage, the *Neogondolella subcarinata* Assemblage Zone of this study is correlated with the upper part of the *Neogondolella subcarinata - Neogondolella wangi* Assemblage Zone and the *Neogondolella deflecta - Neogondolella changxingensis* Assemblage Zone of Wang and Wang (1981b), and with the *Neogondolella changxingensis* Zone of Ding (1992). Based on the composition of the accompanying radiolarians, the *Neogondolella subcarinata* Assemblage Zone of this study corresponds to the *Neoalbaillella optima* Assemblage Zone and the *Neoalbaillella ornithoformis* Assemblage Zone.

**Discussion**

Late Permian conodonts have been hardly studied in Japan, although Igo (1979) introduced the conodont assemblage of Kuman. The present study establishes two conodont assemblage zones in the bedded chert sections, and correlates them with the radiolarian assemblage zones of Ishiga (1990). Thus, it is possible to correlate between radiolarian zones and fusulinacean zones on the basis of conodont zones, because conodonts occur in both limestones and cherts.

The age of the two newly established assemblage zones in this study is now discussed. The components of the *Neogondolella wilcoxi* Assemblage Zone are *Neogondolella wilcoxi*, *Neogondolella* sp. A and *Xaniognathus* sp. cf. *X. sweeti*. *Neogondolella wilcoxi* has been described from the Guadalupian Lamar Limestones by Clark and Behnken (1979). Clark and Wang (1988) reported that the range of *Neogondolella wilcoxi* is limited to late Middle Permian. *Neogondolella wilcoxi* occurred in the *Neoalbaillella optima* Assemblage Zone. Hence, *Neogondolella wilcoxi* ranges to early late Permian. The range of *Xaniognathus sweeti* is limited to early Middle Permian (Igo, 1981). *Follicucullus scholasticus* occurs in this zone, it is also reported from the Lamar Limestones by Ormiston and Babcock (1979). Ishiga (1990) studied the stratigraphic distribution of Permian radiolarians and established the *Follicucullus scholasticus* Assemblage Zone as being late Middle to early Late Permian. Because of the co-occurrence of *Neogondolella wilcoxi* and *Follicucullus scholasticus* and the occurrence of *Neogondolella wilcoxi* from the *Neoalbaillella optima* Assemblage Zone, the age of this zone should be late Middle to early Late Permian. The reason that the range of *Xaniognathus sweeti* does not extend to late Middle Permian is that the study of Middle and Late Permian conodonts was not well developed in the 1980's because of the lack of Middle and Upper Permian limestones.

The *Neogondolella subcarinata* Assemblage Zone of this study includes *Neogondolella subcarinata*, *Neogondolella* sp. aff. *Ng. orientalis*, *Neogondolella* sp. aff. *Ng. changxingensis*, *Neogondolella wilcoxi* and *Prioniodella decrescens*. This assemblage resembles the Late Permian assemblages reported from South China by Wang and Wang (1981b). This zone also includes Late Permian radiolarians such as *Neoalbaillella optima*, *Neoalbaillella ornithoformis*, *Neoalbaillella grypus*, *Albaillella triangularis*, *Albaillella excelsa* and
Albaillella levis. Therefore, this zone corresponds to the Neoalbaillella optima Assemblage Zone and the Neoalbaillella ornithoformis Assemblage Zone of Ishiga (1990). According to Ishiga (1990), these zones are dated early Late Permian and late Late Permian, respectively. Hence, the Neogondolella subcarinata Assemblage Zone of this study is dated Late Permian. However, the beds that include Neogondolella changxingensis and Neogondolella deflecta characteristically are not found in the sections in this study. Therefore, this zone does not include the uppermost Permian.

Paleontological note

The classification of the genus Neogondolella is based on the morphologic characters of oral and aboral views. The specimens obtained in this study are registered in the Department of Geosciences, Faculty of Science, Osaka City University.

Systematic paleontology

Class CONODONTA Eichenberg, 1930
Superfamily GONDOLELLACEA Lindström, 1970
Family XANIOGATHIDAE Sweet, 1981
Genus NEOGONDOLELLA Bender and Stoppel, 1965

Neogondolella sp. aff. Ng. changxingensis Wang and Wang, 1981

(Plate 2, figs. 5–10)

cf. Gondolella changxingensis (Wang and Wang), Ding, 1986, pl. 1, figs. 4–7.
cf. Neogondolella changxingensis Wang and Wang, Clark and Wang, 1988, fig. 3 (24); Duan, 1987, figs. 13–15; Igo, 1989, p. 280, figs. 5 (7, 8); Dai and Zhang, 1989, in Li et al., p. 227, 228, pl. 43, figs. 16–18; Wang and Dong, 1991, p. 47, 48, pl. 3, fig. 3.


Remarks: Small differences are observed between this species and Neogondolella changxingensis Wang and Wang. This species has a narrower platform than that of Neogondolella changxingensis and the posteriormost denticle of this species is slightly larger than that of Neogondolella changxingensis. So, this species should be divided into some subspecies.

Comparison: This species is distinguished from Neogondolella subcarinata by its
narrow and elongated platform, and from *Neogondolella orientalis* by the position of the cusp.

*Neogondolella* sp. aff. *Ng. orientalis* (Barskov and Koloreva), 1970

(Plate 1, figs. 4–7)

*Neogondolella* sp., Ishiga *et al.*, 1982a, pl. 4, figs. 1–4.

*Gondolella* sp. cf. *G. orientalis* Barskov and Koloreva, Suyari *et al.*, 1983, pl. 1, figs. 6a–c.


Description: Element of the species oval to rhombic in outline. Platform wide, abruptly tapering anteriorly. In oral view, carina not extending to posterior end of platform. Some small nodes existing between end of carina and end of platform. Cusp indistinct, not located at posterior end of platform. Posterior end of platform rounded. Denticles on carina low, fused, occasionally separated. Surface of platform granulated. In aboral view, keel occupying more than one-third of attachment surface, connecting to loop elliptical in outline.

Remarks: *Neogondolella orientalis* was first described by Barskov and Koloreva (1970). According to them, the carina of the species does not extend to the posterior end of the platform. The specimens recognized as *Neogondolella* sp. aff. *Ng. orientalis* in this study are different from that of *Neogondolella orientalis* in the character of the platform end. The carina of *Neogondolella* sp. aff. *Ng. orientalis* also does not extend to the posterior end of the platform. However, some small denticles exist between the end of the carina and the end of the platform. So, this species should be described as a new species.

Comparison: This species is distinguished from the other species of *Neogondolella* by the wide platform brim and the characteristic end of the carina.

*Neogondolella subcarinata* Sweet, 1973

(Plate 2, figs. 1–4)

*Neogondolella subcarinata* Sweet, 1973, In Teichert *et al.*, p. 436, pl. 13, figs. 12, 13, 16, 17; Duan, 1987, pl. 1, fig. 19; Dai and Zhang, 1989, In Li *et al.*, p. 233, 234, pl. 43, figs. 12, 13, pl. 44, figs. 25, 28; Igo, 1989, fig 5 (3–5).

*Gondolella carinata subcarinata* (Sweet), Kozur, 1975, p. 19, pl. 2, figs. 9, 10.


Description: Platform short, teardrop shaped, widest at posterior one fourth of element. Platform abruptly tapering anteriorly from widest point of platform. In oral view, carina straight, composed of 7 to 12 denticles, forming a low ridge with an
indistinct cusp at posterior end of platform. Surface of platform granulated. In aboral view, width of keel less than half of that of element. Keel abruptly tapering anteriorly from widest point in matured specimens, gradually tapering anteriorly in juvenile specimens. Keel connecting to loop at posterior platform. Loop sub-triangular shaped or battered.

Comparison: This species is distinguished from *Neogondolella orientalis* by the position of the cusp, and distinguished from *Neogondolella changxingensis* by the short and wide platform.

*Neogondolella wilcoxi* **Clark and Behnken, 1979**

(Plate 1, figs. 1-3)

*Neogondolella wilcoxi* **Clark and Behnken, 1979,** p. 274, pl. 2, figs. 10, 16, 19–21.

Description: Element of *Neogondolella wilcoxi* symmetrical to subsymmetrical. Platform narrow, triangular shaped at posterior end of platform. In oral view, honeycomb structure observed on both lateral edges of platform. Shallow lateral furrows present on both sides of carina. Surface of furrows smooth. Carina low, straight, extending to posterior end of platform. Nodes on carina low, separated. Small cusp merging with edge of posterior end of platform. In aboral view, narrow keel running longitudinal to element, connecting to small loop. Buttress distinct at posterior end.

Remarks: The specimens of *Neogondolella wilcoxi* are incomplete. But they are distinguishable from the other species of *Neogondolella* by the morphologic character of the posterior end of the platform. Posteriormost denticle of the specimen is slightly shorter than that of *Neogondolella wilcoxi* reported by **Clark and Behnken** (1979). So, this species may be described as a new species.

Comparison: This species is distinguished from *Neogondolella* sp. A by the separated denticles and the triangular shaped posterior end of platform.

*Neogondolella* sp. A

(Plate 1, figs. 9)


Remarks: The specimens of *Neogondolella* sp. A are not well preserved, but they are distinguishable from the other species of *Neogondolella* by the shape of the platform.

Comparison: This species is distinguished from the other species of *Neogondolella* by the fused denticles, the rounded posterior end of platform and the overall shape of the platform. This species is distinguished from *Neogondolella orientalis* and *Neogondolella* sp. aff. *Ng. orientalis* by the narrow platform.
References


WARITA, K., 1983: Allochthonous blocks and submarine slide deposits in the Jurassic formation southwest


Explanation of Plate 1
(Scale bars show 100 μm.)

Figs. 1–3. Neogondolella wilcoxi Clark and Behnken
1. OCU902101, oral view
2, 3. OCU200403, oral and aboral views

Figs. 4–7. Neogondolella sp. aff. Ng. orientalis (Barskov and Koloreva)
4, 5. OCU201801, oral and aboral views
6, 7. OCU203004, oral and aboral views

Fig. 8. Prionodella decrescens Tatge
OCU904007, left lateral view

Fig. 9. Neogondolella sp. A
OCU400103, oral view
Explanation of Plate 2
(Scale bars show 100 μm.)

Figs. 1–4. *Neogondolella subcarinata* Sweet
1, 2. OCU203322, oral and aboral views
3, 4. OCU202002, oral and aboral views

Figs. 5–10. *Neogondolella* sp. aff. *Ng. changxingensis* Wang and Wang
5, 6. OCU203201, oral and aboral views
7, 8. OCU102301, oral and aboral views
9, 10. OCU102501, oral and aboral views

Fig. 11. *Hindeodus minutus* (Ellison)
OCU004155, left lateral view

Fig. 12. *Diplognathodus* sp.
OCU204008, right lateral view

Fig. 13. *Xaniognathus* sp.
OCU202404, right lateral view
Explanation of Plate 3
(Scale bars show 100 μm.)

Fig. 1. Neoalbaillella ornithoformis Takemura and Nakaseko
OCU110604

Fig. 2. Neoalbaillella optima Ishiga, Kito and Imoto
OCU101503

Fig. 3. Follicucullus scholasticus Ormiston and Babcock
OCU203024

Figs. 4, 5. Albaillella triangularis Ishiga, Kito and Imoto
4. OCU101101
5. OCU101527

Fig. 6. Albaillella excelsa Ishiga, Kito and Imoto
OCU203023

Fig. 7. Albaillella levis Ishiga, Kito and Imoto
OCU203804