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End-Permian conodont fauna from Dongpan section: Correlation between the deep- and shallow-water facies

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This paper systematically investigated the conodonts from the uppermost Permian to the Lower Triassic at the Dongpan Section, Southern Guangxi, South China, and obtained abundant Late Permian conodonts from the syndepositional limestone lenses of beds 3 and 5-2 at this section. One genus and eight species of conodont P1 element including one new species, *Neogondolella dongpanensis* sp. nov., have been identified. The feature of conodont fauna indicates that conodonts collected from beds 3 and 5 at the Dongpan Section belong to the *Neogondolella yini* conodont zone, and correspond to bed 24 at the Meishan Section. Based on these conodont data, we suggest that the *Neoalbaillella optima* radiolarian zone at the Dongpan Section at least extended to the upper part of the *N. yini* conodont zone.

Dongpan Section, end-Permian, conodont fauna, biostratigraphic correlation

The end-Permian biotic crisis was the largest mass extinction in the fossil record. It eliminated over 90% of species in the oceans[1,2] and about 70% of vertebrate families on land[3−5]. The cause and process of this largest mass extinction and the biotic recovery have attracted attention from many geologists. The Global Stratotype Section and Point of the Permian-Triassic Boundary, which was defined by the first appearance of conodont *Hindeodus parvus*[6], was founded at the Section D in Meishan, Changxing county, Zhejiang Province in 2001[7]. The establishment of the GSSP provided a perfect chronostratigraphic framework for research on this event[7,8]. Although the understanding about this event has greatly improved (see review refs. [9−13]), many aspects about this event remain unknown.

The research on biotic and environmental crisis at different sedimentary environments or facies, such as terrestrial, transitional environments from terrestrial to marine, shallow water and deep water facies, is essential for evaluating the process and causes of this extinction event[14,15]. As an important deep-water section during the Permian-Triassic transition, the Dongpan Section, which is located in southwestern Guangxi Zhuang Autonomous Region, has received intensive research in recent years. It is a continuous section from the latest Permian to the Early Triassic, and provides unique materials for study of biotic and environmental changes in deep-water facies during the Permian-Triassic transition. The end-Permian fossils at this section are abundant, including radiolarians[16−20], brachiopods[21,22], bivalves[23], cephalopods[24], foraminiferas[25] and ostra-

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cods[26]. Meng et al.[27] reported the Upper Permian Changhsingian bivalves including *Claraia liuqiaoensis*, *Euchondria jingxianensis*, *Posidonia* sp., *Nuculopsis* sp. and *N*. cf. *yangtzeensis*, and the end-Permian ammonoids, namely *Huananoceras* cf. *perornatum*, *Laibinoceras* cf. *compressum* and *Qianjiangoceras* sp., at bed 12. However, the Early Triassic bivalves including *Claraia dieneri*, *Palaeoneilo* sp., *Bakevellia* sp., *Posidonia* sp. and *Eumorphotis* sp. were not found until bed 13. The typical Early Triassic ammonoids *Ophiceras tingi* and *Ophiceras* sp. were found at the bottom of bed 13 and beds 13-6, 13-7, respectively[27]. So, the Permian-Triassic boundary at the Dongpan Section was placed between beds 12 and 13[27]. Feng et al.[28] proposed that the end-Permian radiolarians underwent two extinction episodes based on high-resolution radiolarian data from this section. He et al.[29] investigated the size of the end-Permian brachiopods and showed that the brachiopods underwent a distinct size reduction. Zhang et al. [30] showed a distinct negative excursion of the organic carbon isotope at bed 10. However, the correlation among this section and other well-studied shallow water sections, especially the global stratotype section and point (GSSP Section) of Permian-Triassic Boundary at Meishan Section, Changxing, Zhejiang Province, is difficult because of the absence of reported conodonts from this section. It is therefore difficult to know whether these biotic crises were global or not. If these crises were global, how did it correlate with the crises happening at other sections? This has hampered the study of coevolution between biota and environment in this deep-water sedimentary environment.

Conodont, as the standard marine microfossil for biostratigraphic correlation during the Permian-Triassic interval, failed to be obtained in the previous investigations at this section. Although other fossil taxa have been used to provide approximate correlation of Dongpan with other sections, the high-resolution correlation among the Dongpan Section and other sections during the Permian-Triassic transition has not been resolved. This study has recovered conodonts from the limestone and silicious limestone interbeds of beds 3 and 5, including some important latest Permian zonal fossils, which provide information for resolving the correlation between this section and other sections.

1 Geological setting

The Dongpan Section is situated about 4 km northeast of Liuqiao Town, Fusui County, Guangxi (Figure 1), and belongs to the Youjiang stratigraphy sub-area of southeast stratigraphy area in the South China stratigraphy area[31]. Palaeogeographically, the Dongpan Section was located in the Liuqiao rift, which was a part of the Youjiang palaeobasin or connected to the ocean in western Guangxi[32]. The strata of the PTB in this section contained the upper part of the Dalong Formation and the base of the Luolou Formation. The Dalong Formation, beds 2 to 12 at this section, was divided into two lithological parts[28]. The lower part (beds 2—5) consists of gray-black, thin siliceous cherts, muddy siliceous rocks, mudstones, interbedded with pale claystone and lense-like limestone. These lenses change laterally into muddy limestone. Based on regional geology study, Gu et al.[25] suggested that these limestone interbeds were formed through the deposition of calcareous turbidites which came from the carbonate platform, and it was synchronous with the sedimentary silicious rocks. Brachiopods, bivalves, ammonoids, foraminiferas, thin-shell ostracods and abundant radiolarians were found in this part. The main radiolarians were *Albaillellaria* and *Latentifistularia*, which lived in deep water. He et al.[21] suggested that the water depth of this member was about 200—500 m. Bed 6 is claystones with thin-bedded siliceous rock interbeds bearing few radiolarians. Bed 7 is mainly composed of siliceous mudstones. The upper part (beds 8—12) is mudstones with intercalations of claystones, yielding bivalves and cephalopods. The Early Triassic Luolou Formation (beds 13—14) is yellow mudstone and silty mudstones containing bivalves and ammonoids.

2 Materials and methods

In order to improve the correlation of the Permian-Triassic stratigraphy between deep-water facies and shallow-sea carbonate facies, this work collected 19 conodont samples near the Permian-Triassic boundary (beds 3—14) at the Dongpan Section. Each sample weighed 15 kg. The mudstone and claystone samples were dealt first with 10% acetic acid, and then dissolved by water directly. The siliceous rocks and siliceous mudstones were dissolved by 5% hydrofluoric acid, and washed every 24 hours. The carbonate rocks were dissolved in 10% acetic acid. After dissolving, the samples were washed by 20 and 160 mesh sieve, and the grains

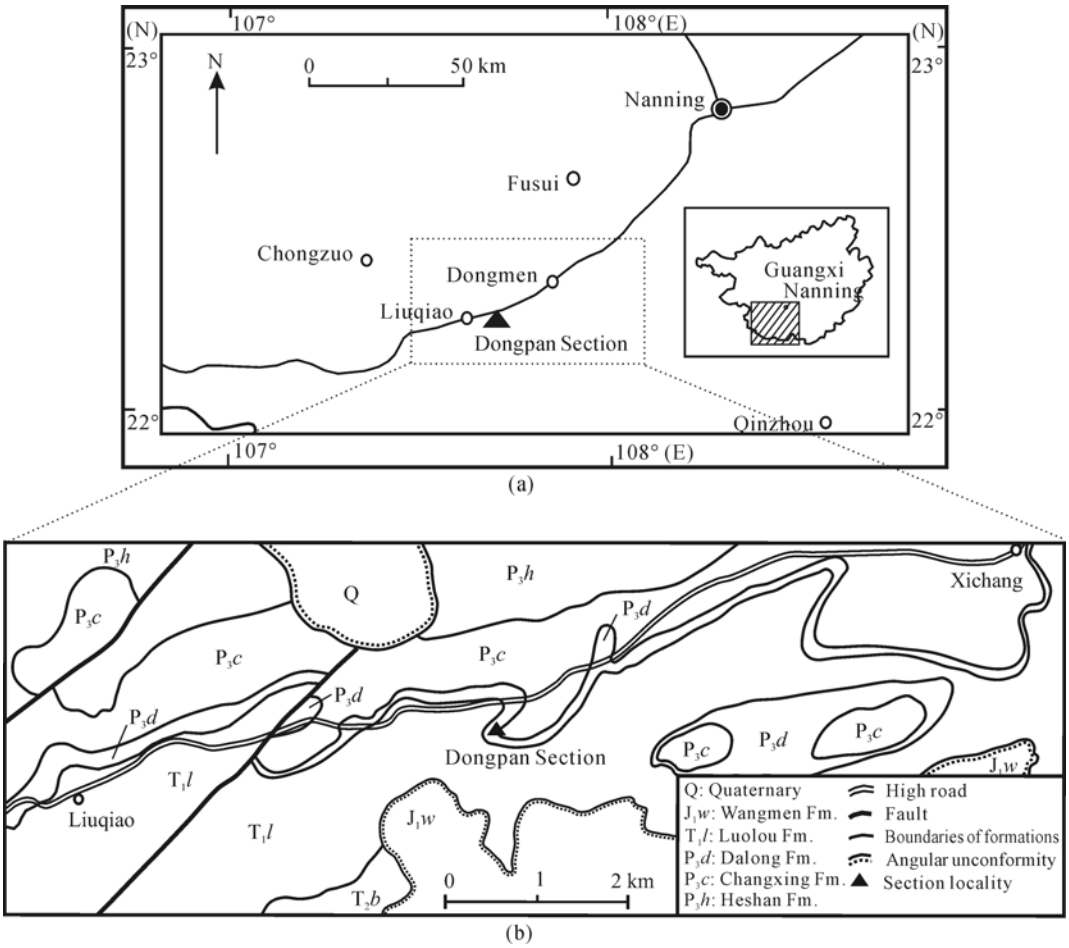

Figure 1 Location map (a) and geologic map (b) of the Dongpan Section, Fusui, Guangxi, China (after ref. [28]).

between these two sizes were collected and dried. A 2.80 −2.81 g/mL gravity liquid made of bromoform (2.89 g/mL) and acetone (0.79 g/mL) was used in conodont separation for all the samples. The conodont elements were picked out under the binocular stereoscope. Because that dissolving rate of the mudstones and siliceous rocks was very slow, only 1/4−1/3 of these samples was dissolved. However, the carbonate lenses from bed 3 and the siliceous carbonate from bed 5-2 have been dissolved completely, and lots of conodont elements were obtained from these two beds. This paper focuses on the conodonts from these two beds. Additionally, a fish teeth and a ramiform conodont were also found in bed 6-1.

3 Characters of the conodont fauna at the Dongpan Section

The conodont fauna at the Dongpan Section was discovered from carbonate lenses within bed 3 and bed 5. To ensure that the conodont fauna from the carbonate lenses are reliable chronological data, it must be proved that the carbonate interbeds are syndepositional. There are two lines of evidence for the syndepositional origin of these carbonates lenses. Gu et al.[25] undertook a detailed sedimentological investigation and concluded that the limestone interbeds and carbonate lenses were deposited from calcicolous turbidite currents derived from a carbonate platform. Chronologically, if the conodont fauna was from a re-worked limestone, the age of the conodont fauna would be much older than that of the present one, and would contradict the fossil records of other taxa. Hence, we think that the conodont-based timing at the Dongpan Section is reliable.

The major conodonts collected at the Dongpan Section are the platform elements of *Neogondolella*, with a few ramiform elements. *Hindeodus* P1 element has not been found. This accords with the characteristics of deep-water conodont fauna proposed by the previous scholars[33,34].

The conodont fauna in bed 3 is abundant. P1 elements of 8 species of the genus *Neogondolella* have been recognized at bed 3 (Figure 2). The ramiform element (P2 and S1 element) in this bed is also abundant. The conodont assemblage in this bed was typical Late Permian elements, many of which are *Neogondolella changxingensis*, *N. dongpanensis* sp. nov., *N. yini*, *N. postwangi*, *N. deflecta*, associated with a few *N. carinata*, *N. subcarinata*, *N.* cf. *zhejiangensis*. *N. yini* was a typical conodont zonal species of the uppermost Changhsingian. At the Meishan Section, the upper limit of the *N. yini* zone was located at the top of bed 24, which was defined by the first appearance of the conodont *N. meishanensis*[35,36]. *N. changxingensis* and *N. deflecta* were typical Changhsingian species[35−39]. However, both species extended to the lowermost Triassic[36]. Mei et al.[35] suggested that the *N. yini* evolved into *N. zhejiangensis* at the bottom of bed 25 at the Meishan Section, the same horizon of the lower limit of the *N. meishanensis* conodont zone. The *N. postwangi* species evolved from *N. wangi,* the first zonal species of the Changhsingian[40], was abundant in the upper Changhsingian[35]. The platform of the conodont *N.* sp. A is similar to that of the *N. yini*. However, there is a distinct brim behind the cusp (an important character of the conodont element during the Permian/Triassic transition) similar to that of *N. taylorae* P1 element, the zonal species of the end-Permian *N. taylorae* zone. Based on these two points, we suggest that this species was a transitional form from *N. yini* to *N. taylorae*.

The conodont fauna in bed 5 is relatively simple. Both the abundance and diversity are lower in bed 5 than in bed 3. The dominated conodont species in this bed are the Late Permian *N. changxingensis* and *N. dongpanen- sis*. Because most elements in this bed are broken, it is hard to identify these elements precisely. So,

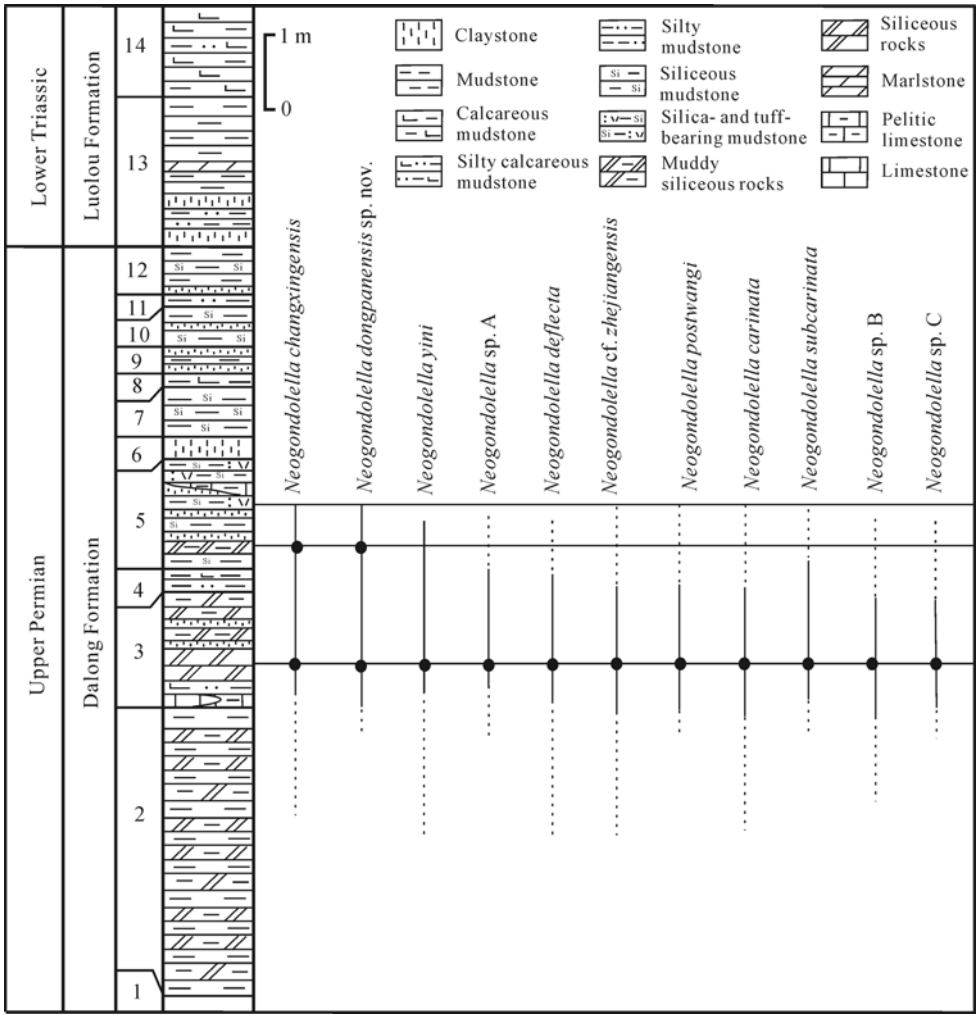

Figure 2 Distribution of the conodont element species obtained at the Dongpan Section.

those elements are named as non-nomenclative species.

4 Biostratigraphy and age discussion of the Dongpan Section

As mentioned above, previously the biostratigraphic study of the Dongpan Section was mainly focused on radiolarians[16−20,28], brachiopods[21,29], bivalves[23] and cephalopods[24]. Jin et al.[20] and Zhang et al.[30] proposed that the radiolarian fauna from beds 2 to 5 belongs to *Neoalbaillella optima* zone, and discovered *Albaillella yaoi* in these beds, which indicated their Late Permian age. Only one Albaillellidae radiolarian was found in bed 6, and it is rarely found above this level. The main radiolarians in beds 6 to 12 were Entactinaria. No radiolarians were reported from bed 13 and above. Because ammonoid fossils of the Changhsingian *Pseudotirolites-Rotodiscoceras* zone were found in beds 2 to 12-2, and the typical Early Triassic ammonites *Ophiceras* and *Lytophiceras* were found in beds 13-1A to 16, the Permian-Triassic boundary was placed between beds 12 and 13 [24,27]. Although the biostratigraphy of above taxa are useful for recognizing the subdivision of the strata during the Permian-Triassic transition at the Dongpan Section, it is still difficult to carry out high-resolution correlation with other sections if only based solely on these data.

The conodonts collected from the Dongpan section, including *Neogondolella yin*i, *N. changxingensis*, *N. deflecta*, *N. carinata*, *N. subcarinata*, *N. postwangi*, are the typical Late Permian species. *Neogondolella yini* is the zonal fossil of the late Changhsingian *N. yini* zone at the Meishan section. Furthermore, *N.* sp. A, a conodont element that is transitional between *N. yini* to *N. taylorae,* was also discovered at bed 3 at the Dongpan section. At the Meishan, *N. taylorae* is the zonal fossil of the *N. taylorae* zone which range from end-Permian to the Early Triassic[36]. Thus, we consider that conodonts from the lens-like limestone at beds 3−5 at the Dongpan Section belong to the *N. yini* zone.

As the evolution rate of radiolarians was slow, Kuwahara[41] considered that the *Neoalbaillella optima* assemblage zone was the only radiolarian zone for the whole Changhsingian. Xia et al.[42] suggested that the whole *N. optima* range zone included four lineage zones, namely *N. optima-A. laota* zone, *A. angusta-A. flexa* zone, *A. trangularis* zone and *A. yaoi* zone in ascending order. The correlation between conodont and radiolarian zones is difficult due to the rare occurrence of conodonts in deep-water facies. Yao et al.[34] investigated the radiolarians and conodonts from the Gujo-hachiman section in southwestern Japan and suggested that the *Neoalbaillella optima* radiolarian zone is equal to the *Neogondolella zhangi* conodont zone, and it may also extend to the *N. meishanensis* zone. However, Xia et al.[42] suggested that the *Albaillella yaoi* zone, the uppermost assemblage zone of the *Neoalbaillella optima* range zone, corresponds to the *Neogondolella changxingensis-N. deflecta* assemblage zone at the Huangshi section, Hubei, China, or the *N. changxingensis-N. postsubcarinata-N. postwangi-N. deflecta* assemblage zone at the Meishan Section. The problem with this correlation was that both the conodont and radiolarian materials were obtained from different sections. The conodont materials from this section, combined with the radiolarian data from the former researchers, indicate that the *Neoalbaillella optima* radiolarian zone at least extended to the upper part of the *N. yini* conodont zone at least (Figure 3).

5 Correlation between the Dongpan section and the Meishan section

5.1 Comparison with the conodont fauna between the Dongpan section and the Meishan section

Compared with the Meishan Section, the conodont fauna at the Dongpan Section also contains common Late Permian conodonts, namely *Neogondolella changxingensis, N. yini, N. postwangi, N. deflecta, N. carinata* and *N. subcarinata.* However, the conodont fauna at the Dongpan Section also has its own characteristics. First, the conodont species, like *N. dongpanensis* sp. nov. with fused carina, are much more common in the Dongpan Section than at the Meishan Section. Secondly, many species from the Dongpan Section have a brim behind the cusp, the typical elements of which are *N.* sp. A, N. sp. B and *N.* sp C. described in this paper.

At the Dongpan Section, most of the conodont elements in bed 3 are adult and complete. The body of the conodont specimen is thick and the denticle is robust (see Figure 4). The size of the P1 elements ranges about 0.6−0.9 mm, and the mean size is about 0.7 mm. In contrast with bed 3, however, most of the conodont specimens from bed 5 are juvenile or broken. The body of the conodont specimen from bed 5 is thin and weak, and colored in translucent amber. The denticle is fragile (see P1 element in Figure 5). Because most of the

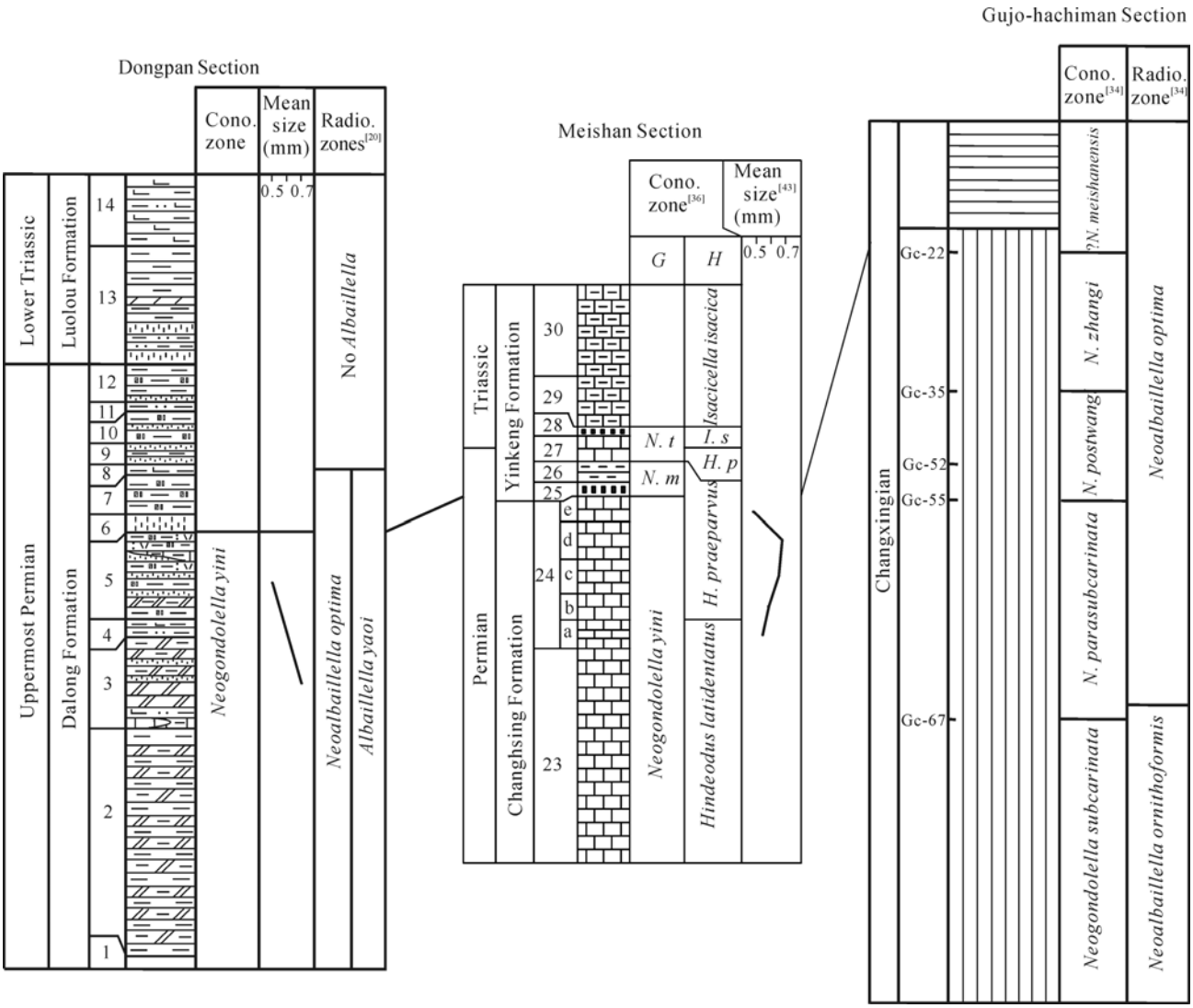

Figure 3 Correlation between Dongpan Section, Meishan Section in South China and Gujo-hachiman Section in Southwest Japan, and between conodont zones and radiolarian zones. *N.m*, *Neogondolella meishanensis*; *N.t*, *Neogondolella taylorae*; *H.p*, *Hindeodus parvus*; *I.s*, *Isarcicella staeschei*; *G*, *Gondolellid*; *H, hindeodid*; Cono. zones, conodont zone; Mean size, curve of conodont mean size variation; Radio. zone, radiolarian zone.

conodont specimens from bed 5 are broken, the precise size measurement cannot be carried out. The estimated value of the size of P1 elements from this bed is about 0.4－0.7 mm, and the mean size was about 0.5 mm. So, the conodont species underwent a distinct size reduction during the transition from beds 3 to 5. Furthermore, at the Meishan section, the conodonts *Neogondolella*, *Hindeodus-Isarcicella* and fish teeth (unpublished data) underwent a distinct size reduction during the transition between bed 24d/24e (uppermost *N. yini* conodont zone)[43,44]. At the Meishan section, the size of the conodont *Neogondolella* and *Hindeodus* P1 elements decreased from 0.688 mm to 0.490 mm and from 0.534 mm to 0.436 mm, respectively.

The size reduction of conodont at the Dongpan Section indicates that the conodont size reduction event was at least a regional one. During the Permian-Triassic transition, this phenomenon took place at different facies, such as the upper-slope facies at the Meishan Section, the lower-slope facies at the Shangsi section and the deep-basinal facies at the Dongpan Section. As proposed by Luo et al.[43], the distinct size reduction of conodont was contributed by the environmental crisis and supported an existing mass extinction; the distinct size reduction occurred at the Dongpan Section would also indicate a deterioration of the environment, which may also induce the extinction of other organisms.

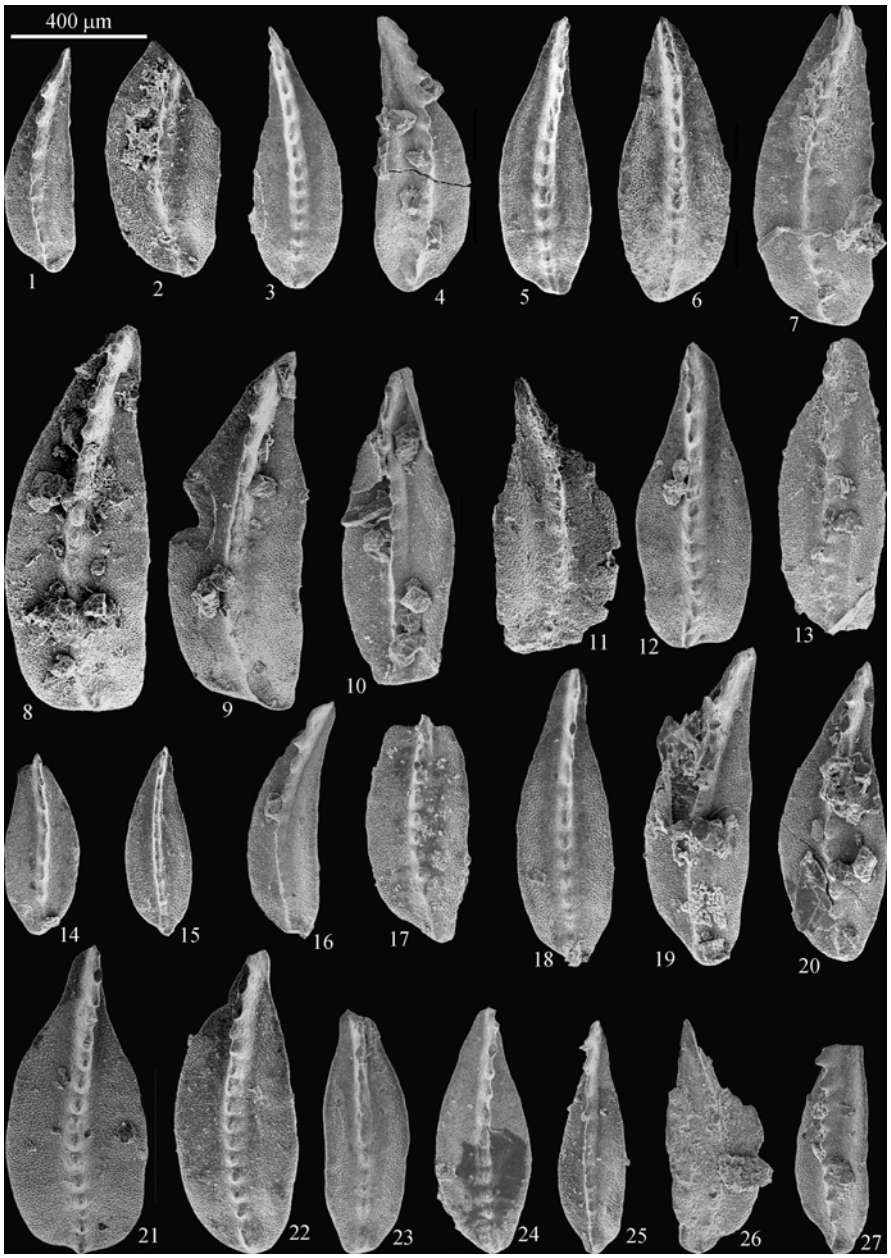

Figure 4 Conodont elements collected from bed 3 at the Dongpan Section, Guangxi Zhuang Autonomous Region. All the specimens are preserved in the Micropaleontology Laboratory, Faculty of Earth Science, China University of Geosciences, Wuhan, China. 1, 3, 15, *Neogondolella yini* P1 element, Mei, Zhang and Wardlaw, 1998 (All the specimens were upper view. 1, Juvenile, register No. lgm_2_019; 3, adult, register No. lgm_2_027; 15, youth, register No. lgm_2_037). 2, *Neogondolella* sp. P1 element, upper view, adult, register No. lgm_2_038. 4, *Neogondolella* sp. A, P1 element. Upper view. adult, register No. lgm_2_022. 5, 6, 13－14, 18, 27, *Neogondolella changxingensis* P1 element, Wang and Wang, 1981 (5, upper view, adult, register No. lgm_2_017; 6, upper view, adult, register No. lgm_2_016; 13, oblique upper view, adult, register No. lgm_2_028; 14, upper view, adult, register No. lgm_2_020; 18, upper view, adult, register No. lgm_2_025; 27, oblique upper view, adult, register No. lgm_2_035). 7, *Neogondolella* cf. *zhejiangensis* P1 element, upper view, adult, register No. lgm_2_032. 8－9, 11－12, *Neogondelella deflecta* P1 element, Wang and Wang, 1981 (All the specimens were upper view. 8, adult, register No. lgm_2_021; 9, adult, register No. lgm_2_018; 11, youth, register No. lgm_2_013; 12, adult, register No. lgm_2_015). 10, *Neogondolella* sp. B. P1 element, upper view, adult, register No. lgm_2_024. 16,19,25, *Neogondolella dongpanensis* sp. nov. P1 element (16, oblique upper view, youth, register No. lgm_2_031; 19, oblique upper view, youth, register No. lgm_2_029; 25, oblique upper view, juvenile, register No. lgm_2_033). 17, *Neogondolella* sp. P1 element, upper view, adult, register No. lgm_2_036. 20, 24, *Neogondolella postwangi* P1 element, Tian, 1993 (Both specimens upper view. 20, adult, register No. lgm_2_030; 24, adult, register No. lgm_2_023). 21, *Neogondolella subcarinata* P1 element, Sweet, 1973. upper view, adult, register No. lgm_2_014. 22, *Neogondolella* sp. C P1 element, upper view, adult, register No. lgm_2_012. 23, *Neogondolella* sp. P1 element, upper view, adult, register No. lgm_2_026. 26, *Neogondolella carinata* P1 element, Clark, 1959. upper view, adult, register No. lgm_2_034.

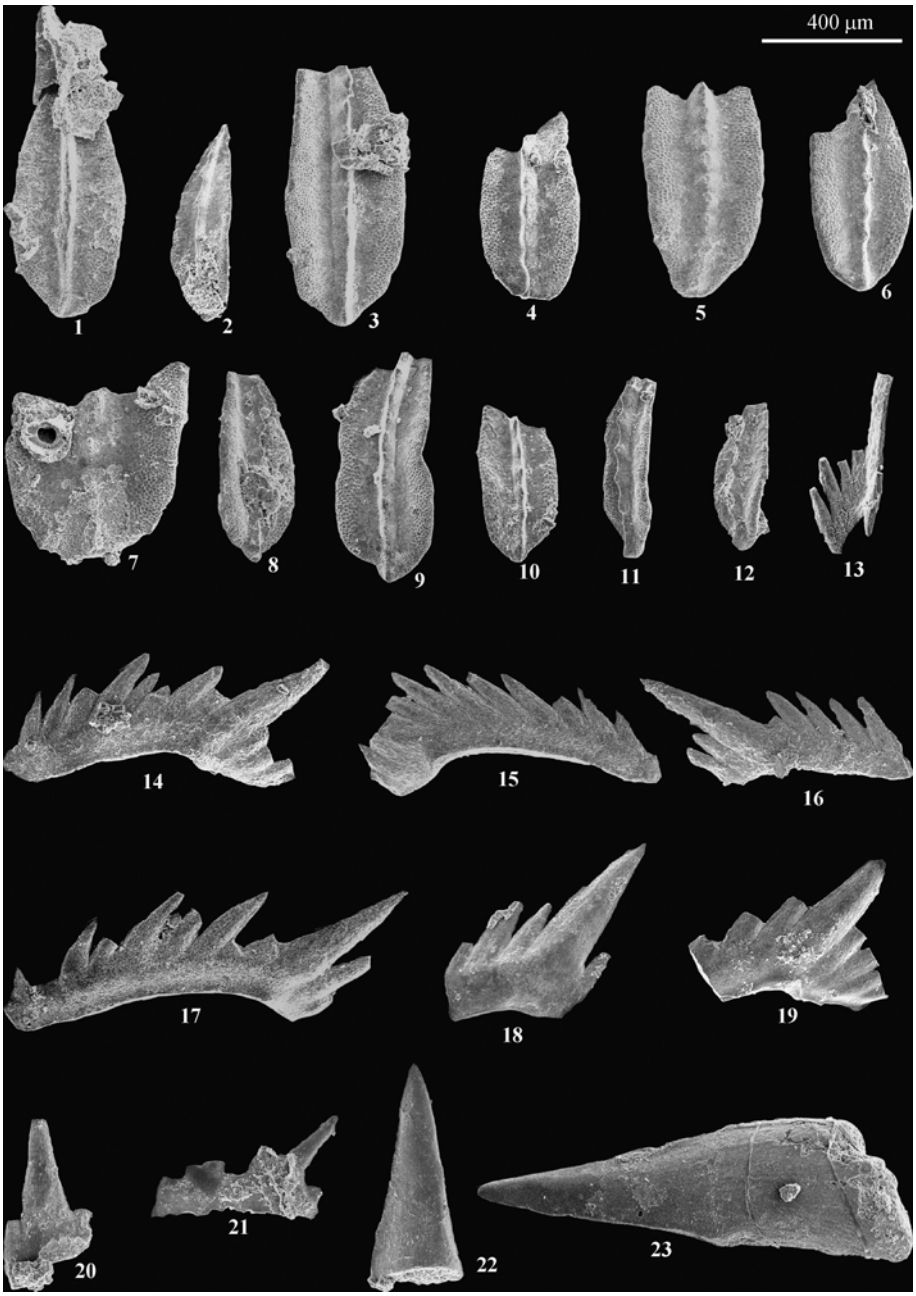

Figure 5 Conodont elements and fish teethes collected from bed 5-2 at the Dongpan Section except for special illustration, Guangxi Zhuang Autonomous Region. All the specimens are preserved in the Micropaleontology Laboratory, Faculty of Earth Science, China University of Geosciences, Wuhan, China. 1－2, *Neogondolella dongpanensis* P1 element (1, upper view, youth, register No. lgm_1_004; 2, oblique upper view, juvenile, register No. lgm_1_003). 3－5, 10, *Neogondolella* sp. P1 element (3, upper view, adult, register No. lgm_1_005; 4, *Neogondolella* sp. P1 element, upper view, youth, register No. lgm_1_006; 5, *Neogondolella* sp. P1 element, upper view, adult, register No. lgm_1_007; 10, upper view, youth, register No. lgm_1_012). 6, 8, 11 and 12, *Neogondolella changxingensis* P1 element, Wang and Wang, 1981 (6, upper view, youth, register No. lgm_1_008; 8, oblique upper view, juvenile, register No. lgm_1_010; 11, lateral view, juvenile, register No. lgm_1_013; 12, oblique upper view, juvenile, register No. lgm_1_014). 7, *Neogondolella* sp. P1 element, upper view, adult, register No. lgm_1_009. 9, *Neogondolella* sp. P1 element, upper view, youth, register No. lgm_1_011. 13, *Neogondolella* S2 element, lateral view, register No. lgm_2_042, appearing in bed 3 at Dongpan Section. 14, 16, *Neogondolella* P2 element (14, lateral view, register No. lgm_2_040; 16, lateral view, register No. lgm_2_043; appearing in bed 3 at Dongpan Section). 15, *Neogondolella* P2 element, lateral view, register No. lgm_2_041, appearing in bed 3 at Dongpan Section, Guangxi. 17, *Neogondolella* P2 element, lateral view, register No. lgm_2_039, appearing in bed 3 at Dongpan Section. 18 and 19, *Neogondolella* P2 element (18, lateral view, register No. lgm_1_016; 19, lateral view, register No. lgm_1_017). 20 and 21, *Neogondolella* P2 element (20, lateral view, register No. lgm_1_018; 21, lateral view, register No. lgm_1_019). 22 and 23, fish teeth.

5.2 Stratigraphical correlation between the Dongpan Section and the Meishan Section

A high-resolution biostratigraphy correlation between the Dongpan Section and the Meishan Section has not been carried out because the previous works have not found conodonts from the former section. Some scholars tried to carry out this correlation based on chemical stratigraphy and lithostratigraphy[30]. Zhang et al.[30] investigated the lithostratigraphy and chemical stratigraphy of the Dongpan Section and suggested that bed 10 at the Dongpan Section corresponds to bed 26 at the Meishan Section. However, the lithology structure during the Permian-Triassic transition at the Dongpan Section, which had several interbeds of claystones and mudstones (a sandwich structure)[27], was more complicated than that of the Meishan Section with only one "sandwich structure" in the Uppermost Permian. This difference made the correlation between these two sections difficult, especially the high-resolution correlation during the P/T transition based on the lithology.

The conodont from beds 3 and 5 at the Dongpan Section belongs to the *N. yini* zone which corresponds to bed 24 at the Meishan Section. During the transition from beds 3 to 5 at the Dongpan Section, the conodont *Neogondolella* underwent a distinct size reduction, which also took place during the transition from beds 24d to 24e at the Meishan Section (Figure 3). This phenomenon indicates that bed 5 at the Dongpan Section would correspond to bed 24e at the Meishan Section. *N.* sp. A, the transition species from *N. yini* to *N. taylorae,* also supported this biostratigraphy correlation between these two sections.

Feng et al.[28] investigated the detailed evolutionary characteristics of the radiolarians and showed they underwent two episodes of extinction, which took place at the top of bed 5 and bed 7, respectively. Furthermore, they suggested that these two episodes of radiolarian extinction corresponded to the top of bed 24d and 24e at Meishan Section, respectively. It means that the correlating results of conodonts and radiolarians have minor differences. It could be interpreted by the fact that these different taxa had different living habits, and therefore they responded at different times to an environmental crisis. However, conodont is a commonly accepted standard taxon for subdivision of the marine strata, and the correlation of conodont should be more reliable than that of radiolarians.

The conodont materials indicated that the thickness of the "event bed" (from the first biotic crisis to the PTB) at the Dongpan Section was about 5 m thick. However, the corresponding thickness at the Meishan Section was only 28 cm. This supports the view that the Meishan Section is very condensed. Furthermore, it also implies that the deep-water Dongpan Section may record much more abundant and complete information about the biggest mass extinction in the Phanerozoic, which provides perfect materials for the study of the co-evolution of biota and environment during the Permian-Triassic transition.

6 Systematic palaeontology

***Neogondolella dongpanensis* sp. nov. Luo, Lai & Jiang**

(Figure 4-16, 19, 25; Figure 5-1, 2)

Holotype: Figure 4-16.

Paratype: Figure 5-1.

Etymology: Named for its first discovery at Dongpan Section.

Diagnosis: *Neogondolella dongpanensis* sp. nov. P1 element is diagnosed by the distinct fused carina. The fused carina becomes gradually lower toward the posterior end. The drop-like platform is composed of rounded, narrowly rounded or slightly pointed posterior end, widest in end 1/4 part and gradually tapering toward the anterior end. The carina of most of the species always deflected innerward. Free blade is not distinct. The adcarinal furrows are shallow. The cusp is not distinct and is located at the end of the platform.

Remarks: This new species is similar to *Neogondolella changxingensis* Wang and Wang, 1981[45]. However, the carina of the new species is fused, while that of the latter is discrete.

Occurrence: Bed 3 and bed 5 of the Dalong Formation

***Neogondolella* sp. A**

(Figure 4-4)

Diagnosis: *Neogondolella* sp. A P1 element has a segminiploanate element. It charactered by the drop-like platform and the distinct brim behind the cusp. The posterior end of the platform is wide and flat. The widest point is located at the posterior end. The adcarinal furrows are wide and shallow. There is no free blade. The anterior part of the carina is composed of 4−5 semi-fused denticles. The denticles of the carina decrease

gradually in size and height toward the posterior until the cusp, which is erect to slightly recline. There is a distinct brim behind the cusp.

Remarks: The new species is similar to *Neogondolella praetaylorae* Kozur, 2004[39]. The differences between them are that the platform of the new species is drop-like, and the widest part is located at the end, and the denticle of the posterior carina is slightly fused with a distinct and erect cusp located at the posterior end. However, the widest part of the latter species with suboval platform is located in the middle or a little behind it. The denticles of the posterior carina of the latter species are discrete, and the cusp is erect but not distinct. The distinct brim behind the cusp of the new species differentiates it from *Neogondolella yini* P1 element Mei, Zhang and Wardlaw, 1998 which has the same platform shape. There is a distinct brim behind the cusp like *Neogondolella taylorae* Orchard, 1998. This is a transitional species from *Neogondolella yini* to *Neogondolella taylorae*. The age of this species may be the same as that of *Neogondolella praetaylorae* Kozur, 2004.

Occurrence: Bed 3 of the Dalong Formation at Dongpan.

***Neogondolella* sp. B**

(Figure 4-10)

Diagnosis: *Neogondolella* sp. B P1 element is segminiploanate element. The platform is oval shape, and the widest part is located at the middle and gradually narrows toward anterior and posterior. Near the end of the platform, the margins of the platform shrink distinctively and then extend to the end of the platform. The end margin is straight and without free blade. The anterior carina of the fused carina is high and composed of 4－5 semi-fused denticles. The carina turns low toward posterior. The cusp is small and erect, and lies a little in front of the posterior margin. There is a narrow brim behind the cusp. The posterior part of the carina deflected to the inner side. The keel is low, and occupied 1/3－1/2 of the attachment surface. The pit under the cusp is small.

Remarks: The new species differentiates from other species with its special platform shape. The fused carina of this species is the same as the *Neogondolella dongpanensis* sp. nov. However, the blunt and straight end platform margin, wide posterior platform and the brim behind the cusp are different from *Neogondolella dongpanensis* sp. nov.

Occurrence: Bed 3 of the Dalong Formation at the Dongpan Section.

***Neogondolella* sp. C**

(Figure 4-22)

Diagnosis: *Neogondolella* sp. C P1 element is segminiploanate element. The platform is a wide ellipse. The adcarina is wide and shallow. The platform margins at middle are sub-parallel, and narrow gradually toward anterior and posterior. The widest part is at middle. At 1/5－1/6 of the anterior platform, it turns narrow sharply. The anterior carina is high, and composed of 3－4 semi-fused denticles, and turn small and low discrete denticles towards posterior. Without free blade. The cusp is distinct, and fused with the last denticle. There is a large gap between the last and second last denticle. Behind the cusp, there is a brim. The keel is low, and occupied 1/3 of the attachment surface. The pit is small.

Remarks: This species is similar to *Neogondolella taylorae* Orchard, 1994 and *N. zhejiangensis* Mei, 1996. The difference between the new species and *N. taylorae* Orchard, 1994 is the wide ellipse platform shape, low and wide adcarina, the sharp narrowed anterior platform and the cusp fused with the first denticle of the new species. The difference between the new species and *N. zhejiangensis* is the platform shape and the brim behind the cusp.

Occurrence: Bed 3 of the Dalong Formation at the Dongpan Section.

7 Conclusions

This paper reports a study of conodont-based correlation between deep water facies (Dongpan Section) and shallower water facies (Meishan Section). Abundant conodonts were found in the limestone lenses at beds 3 and 5 at deep-water Dongpan Section, including 8 species of the genus *Neogondolella*. The conodont fauna from the Dongpan Section belongs to the upper *Neogondolella yini* zone. Based on the conodont zonation and regulation of conodont size reduction at bed 5, we propose that beds 3 to 5 at Dongpan Section corresponds to bed 24 at Meishan Section. And the crisis of the radiolarian would lag behind that of other organisms. At the same time, the conodont data from the Dongpan Section also indicate that the *Neoalbaillella optima* ra-

diolarian zone at least extended to the upper part of *Neogondolella yini* conodont zone.

The conodont correlation revealed that the thickness of the Permian/Triassic "event bed" at the Dongpan Section is much thicker than that at the Meishan Section and indicates that the deep-water facies may record more information about Permian-Triassic mass extinction than shallow-water faices.

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