

江西二叠-三叠系界线层的牙形刺及 *Hindeodus-Isarcicella* 的演化谱系

王 成 源 王 尚 启

(中国科学院南京地质古生物研究所, 南京 210008)

提 要 对江西修水清水岩乡东岭剖面 and 乐平沿沟剖面的再研究表明, *Hindeodus parvus* Morphotype 1 在东岭剖面首现于大冶组的最低层位, 生物地层界线与岩石地层界线一致, 仅比事件地层界线高 5—6cm。沿沟剖面 *Hindeodus parvus* 带厚仅 36cm, 其首现与岩石地层界线也一致。

张克信等提出的 $H. latidentatus \rightarrow H. parvus \rightarrow H. turgidus \rightarrow I. isarcica$ 的演化谱系需作进一步修正。依据华南的资料, 本文第一作者提出新的演化谱系: $H. latidentatus \rightarrow H. parvus \rightarrow I. staeschei \rightarrow I. isarcica$ 。 *H. turgidus* 并不在此演化系列中, 它属 *Hindeodus* 的另一分枝。

二叠-三叠系界线层的牙形刺应区分出浮游相与浅水相。在浮游相, 牙形刺序列为: (1) *Clarkina changxingensis*-*C. deflecta* 带, (2) *C. carinata* 带, (3) *C. planata* 带。在浅水相, 牙形刺序列为: (1) *H. latidentatus* 带, (2) *H. parvus* 带, (3) *I. staeschei* 带, (4) *I. isarcica* 带, (5) *H. postparvus* 带。*I. staeschei* 应为一独立的种, 并应独立建带。

介形类 *Langdaia suboblonga*-*Hollinella tingi* 带在华南广泛分布, 并与 *H. parvus* 同层, 同样是三叠系底界和早三叠世早期的标志化石。

关键词 二叠-三叠系界线 *H. parvus* 带 *I. staeschei* 带 演化谱系 浮游相 浅水相 江西

CONODONTS FROM PERMIAN-TRIASSIC BOUNDARY BEDS IN JIANGXI, CHINA AND EVOLUTIONARY LINEAGE OF *HINDEODUS-ISARCICELLA* *

Wang Cheng-yuan and Wang Shang-qi

(Nanjing Institute of Geology and Palaeontology, Academia Sinica, Nanjing 210008)

Key words P/T boundary, *H. parvus* Zone, *I. staeschei* Zone, evolutionary lineage, conodont zones, pelagic, shallow water, ostracodes, Jiangxi

Abstract

Zhu *et al.* (1994) have reported the conodonts from the Permian-Triassic boundary beds of the Dongling section at Qinshuiwan Township of Xiushui County, and the Yangou section at Rongshan Town

of Leping City. The present authors have made a fresh collection from the two sections centimetre by centimetre with the discovery of many conodont specimens of *Hindeodus parvus* Morphotype 1 and *Isarcicella staeschei*, and one of *I. isarcica*. The exact horizon from which *Hindeodus parvus* Morphotype 1 first appears could be precisely defined. The boundary beds of the Dongling section consist of clay-bed (5–6cm) and Dayie Limestone; *Hindeodus parvus* Morphotype 1 just began to appear at the lowest horizon of the Dayie Limestone, indicating that the biostratigraphic boundary of the Permian-Triassic is coincided with the lithostratigraphic boundary (between the clay-bed and limestone, or between JD⁶ and JD⁷), and only 5–6cm higher than the eventostratigraphic boundary (between JD⁵ and JD⁶). The Yangou section of Leping also consists of limestone. *Hindeodus parvus* Zone is only 36cm in thickness, and *Isarcicella isarcica* Zone is first found in this section. The conodont faunas from the two sections are very simple, with no any neogondolellid elements, indicating a shallow water facies, which is quite different from the Changxing section at Meishan. Dongling section represents a typical shallow water facies at the beginning of the Triassic.

An evolutionary lineage of *H. latidentatus* → *H. parvus* → *H. turgidus* → *I. isarcica* has been proposed (Zhang *et al.*, 1995), but this evolutionary lineage is doubtful. Based on data from South China, the present first author proposes a new evolutionary lineage; *Hindeodus latidentatus* → *H. parvus* → *I. staeschei* → *I. isarcica*. *Hindeodus turgidus* is not in this evolutionary lineage, but belongs to another branch of *Hindeodus*. *I. isarcica* Zone should be subdivided into two conodont zones; *I. staeschei* Zone and *I. isarcica* Zone. Conodont zonation for P/T boundary beds should be distinguished into pelagic facies and shallow water facies; in the pelagic facies the sequence is *Clarkina changxingensis*-*C. deflecta* Zone-*C. carinata* Zone and *C. planata* Zone, while in the shallow water facies the sequence is *H. latidentatus* Zone-*H. parvus* Zone-*I. staeschei* Zone-*I. isarcica* Zone and *H. postparvus* Zone.

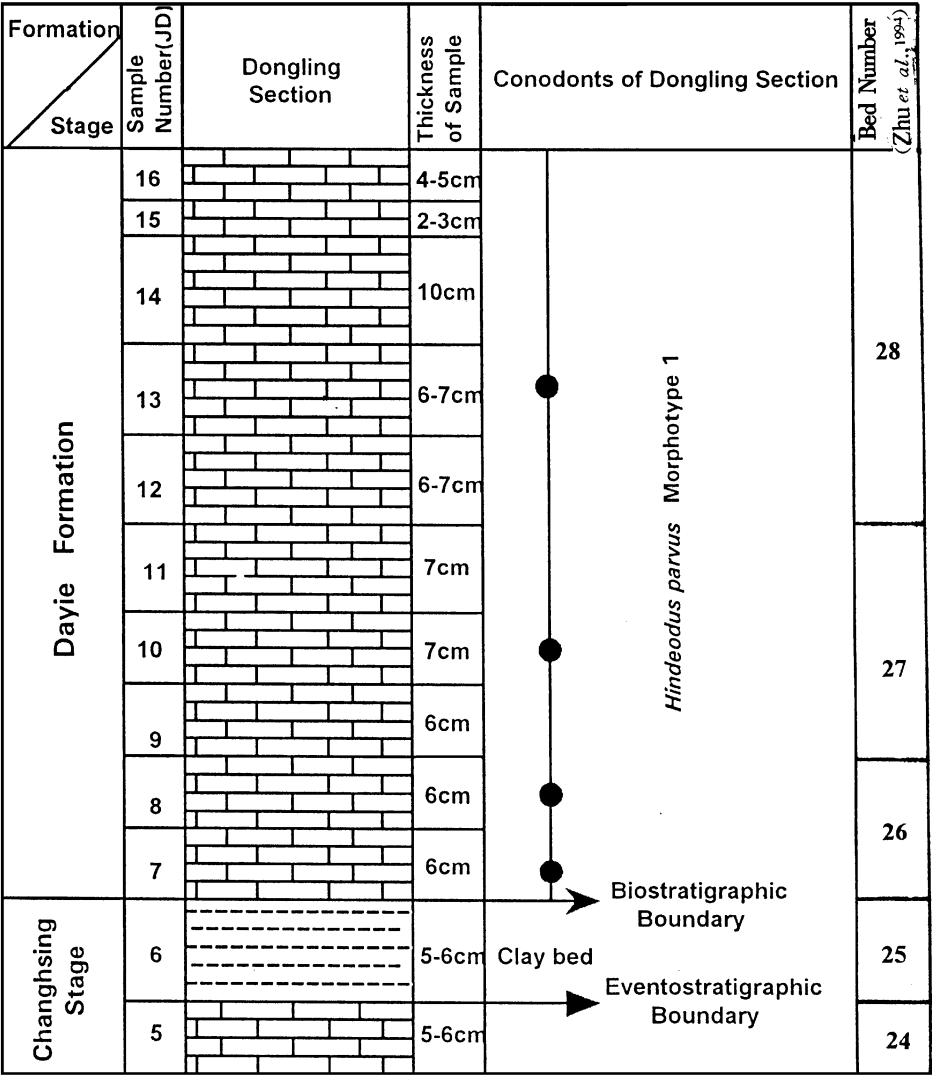
The ostracode *Langdaia suboblonga* - *Hollinella tingi* Zone, which are widely distributed in South China, are in coexistence with *Hindeodus parvus* at Yangou section, and also very good markers for the base of Triassic.

1 RESTUDY OF THE TWO PERMIAN-TRIASSIC BOUNDARY SECTIONS IN JIANGXI

Zhu *et al.* (1995, in Chinese) described the three sections across the Permian-Triassic boundary beds in the northern, central, and southern parts of Jiangxi Province and clearly distinguished the eventostratigraphic and biostratigraphic boundaries. The basal limit of the "boundary clay" bed, which is a good marker for the eventostratigraphic boundary, is not identical with the biostratigraphic boundary. In terms of definition, Wang (1994) proposed that the best P/T biostratigraphic boundary should be defined by the first appearance of *Hindeodus parvus* Morphotype 1. The supplementary criteria for the Permian-Triassic biostratigraphic boundary are the extinction of *Clarkina changxingensis*, *C. deflecta*, *C. dicerocarinata*, *C. meishanensis*, *H. latidentatus* and *H. julfensis*; and the first appearances of *H. parvus* M. 2, *H. turgidus*, *Ophiceras*, *Claraia wangi* and *Hollinella tingi*-*Langdaia suboblonga* Zone. This biostratigraphic boundary falls within the monofacies strata.

But in Zhu *et al.*'s paper, the study of the Permian-Triassic boundary beds is not very pre-

cise. In 1994, Wang , C. Y. and Zhu, X. S. re-collected conodont samples from the Yangou and Xiushui sections, and some new conclusions based on new data have been made. To compare the study degree of the two sections, we have to cite the original description of the two sections in Zhu *et al*'s paper.



Text-fig. 1 Range of *Hindeodus parvus* and biostratigraphic boundary position at Dongling section, Xiushui County, Jiangxi

1.1 Original description of Dongling section at Qinshuiyan Township, Xiushui County

Lower Triassic

Dayie Formation(lowermost part)

30. Gray-yellowish medium-bedded bioclastic limestone bearing conodonts: (JNW81, 79) *Hindeodus minutus* (Ellison), (JNW81) *Ellisonia* sp., (JNW80) *Hindeodella triassica* (Muller) 3.66m

- | | |
|---|-------|
| 29. Gray-purple massive limestone and mudstone | 2.50m |
| 28. Gray-yellowish-purple thin-bedded to medium-bedded limestone | 1.99m |
| 27. Gray yellowish thin-bedded limestone intercalated with purple thin laminar stripes and irregular lamination, bearing conodonts; (JNW ⁷⁴) <i>Hindeodus parvus</i> Morphotype 1 | 0.20m |
| 26. Gray-yellowish and purplish thin-bedded calcarenite | 0.13m |
| 25. Dark yellow claystone, bearing ostracodes; (JNW ⁷²) <i>Cavellina</i> sp. | 0.07m |

—— conformity ——

Upper Permian

Changhsing Formation (The uppermost part)

- | | |
|--|-------|
| 24. Gray, gray-green, purple thin to medium-bedded argillaceous limestone, bearing fragments of hydrozoans and sponges | 3.11m |
| 23. Gray, grayish medium to massive bedded grainstone, yielding foraminifera; (JNW ⁶⁸⁻⁶⁶) <i>Colaniella</i> sp., <i>Neodiscus</i> sp., <i>Agathammina</i> sp., <i>Dagmarita</i> sp., <i>Pachyphoois</i> sp., <i>Septoglobivalvolina</i> sp., <i>Pseudoglandulina</i> sp., <i>Geinitzina</i> sp., <i>Paraglobivalvolina spumida</i> , <i>Cribrogenerina</i> sp.; fusulinids; <i>Palaeofusulina</i> sp., <i>Nankinella</i> sp.; Algae: <i>Gymnocodium bellerophonis</i> , <i>G.</i> sp., <i>Per-mocalculus fragilis</i> , <i>P.</i> sp., <i>Pseudovermiporella</i> sp., and fragments of sponges | 7.69m |

In Zhu *et al*'s paper (1994), the biostratigraphic boundary was delineated at Bed 27, over 13cm higher than the upper limit of the boundary clay bed. In March 1994, the present first author made a fresh and more detailed collection from the same section; after the samples prepared, *Hindeodus parvus* Morphotype 1 was found in the lowermost Dayie Formation (the base of Bed 26, in sample JD7). The biostratigraphic boundary at the base of the Triassic is coincident with the lithostratigraphic boundary of the Dayie Formation in northern Jiangxi, and it is only 5–6cm higher than the eventostratigraphic boundary (Text fig. 1).

This section displays the upper Changhsingian and basal Triassic shallow-water conodont facies. All pelagic elements (ammonoids, pelagic conodonts) are missing, but *Hindeodus* is especially common. This section can be used as an auxiliary boundary section for shallow-water facies across the P/T boundary in South China.

1.2 Original description of Yangou section near Leping City

Lower Triassic

Dayie Formation (lowermost part)

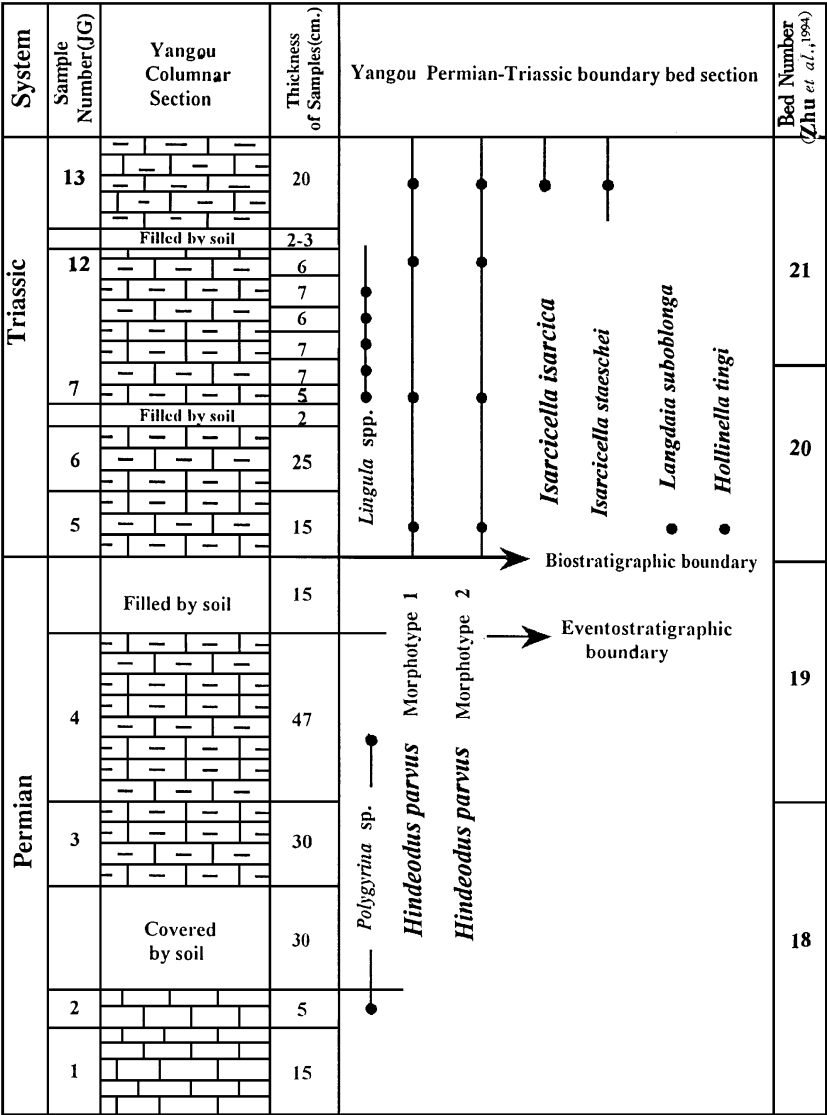
- | | |
|---|-------|
| 22. Gray claystone | 0.03m |
| 21. Gray, yellowish thin-bedded dolomitic grainstone, yielding conodonts; (JNEC ^{46, 45}) <i>Hindeodus minutus</i> , <i>Hindeodella</i> sp.; brachiopods; (JNEC ⁴⁵) <i>Crurithyrus pusilla</i> | 0.30m |
| 20. Gray, yellowish medium-bedded dolomitic grainstone, bearing conodonts (JNEC ⁴⁴) <i>Hindeodus parvus</i> Morphotype 1, <i>Hindeodus parvus</i> Morphotype 2, <i>H. turgidus</i> , <i>H. minutus</i> ; brachiopods; (JNEC ^{44, 43}) <i>Lingula tenuissima</i> | 0.51m |

—— conformity ——

Upper Permian

Changhsing Formation (uppermost part)

19. Gray, yellowish midium-bedded argillaceous dolomitite, bearing conodonts: (JNEC42, 41), *Hindeo-*
dus minutus, *Hindeodus* sp., *Ellisonia* sp. 0.54m
18. Gray to dark gray thin to medium-bedded dolomite, dolomitic grainstone, bearing conodonts:
(JNEC39, 38) *Clarkina deflecta*, *Hindeodus minutus* 0.54m



t-fig. 2 Columnar section and range charts of some important species at Yangou section, Leping, Jiangxi

In Zhu *et al*'s paper, the biostratigraphic boundary falls within Bed 20, 16cm higher than the lower limit of the Dayie Formation; they considered that there was no boundary clay at the Leping section. A restudy of this section shows that the biostratigraphic boundary at the base of Triassic is also coincident with the lithostratigraphic boundary of the Dayie Formation. The biostratigraphic boundary is about 15cm higher than the eventostratigraphic boundary, but the

claystone can not be seen because it is covered by soil (Text-fig. 2).

All pelagic elements (ammonoids, pelagic conodonts) are missing in the Yangou section. It also can be used as an auxiliary boundary stratotype section for shallow-water facies across the P/T boundary in South China (Text-fig. 2).

2 TWO IMPORTANT POINTS OF THIS SECTION

2.1 *Isarcicella staeschei* representing a valid species and zonal fossil

One very primitive specimen of *Isarcicella isarcica* was found with more than twenty advanced specimens of *Isarcicella staeschei* also present in Sample 15. This horizon should belong to the *Isarcicella isarcica* Zone. Below this horizon, *Isarcicella staeschei* would be found, because it appears earlier than *Isarcicella isarcica* in many places. For instance:

a. At the Changxing section, *Isarcicella staeschei* first appears at Bed 28 (Zhang *et al.*, 1995, who identified this specimen as *Isarcicella isarcica*).

b. At the Heping section, Luodian County, Guizhou Province, the first author of this paper has found 8 specimens of *Isarcicella staeschei* but none of *Isarcicella isarcica*.

c. At the Selong Xishan section of Tibet, the so-called *Isarcicella isarcica* corresponds to Morphotype 2 of Sweet (Orchard *et al.*, 1995, p. 832), about 10–30 cm higher than *Hindeodus parvus* in the section, and should belong to *Isarcicella staeschei*.

d. The conodonts from the Werfen Formation, Southern Alps, Italy, show that *Isarcicella staeschei* and *Isarcicella isarcica* have different stratigraphic positions. Especially in the Tesero section, *Isarcicella isarcica* (TS26) is about 10 m higher than the first occurrence of *Isarcicella staeschei* (TS19) (Perri, M. C., 1991, p. 27, Tab. 2). Even the three species, *H. parvus*, *I. staeschei* and *I. isarcica* co-occur in the same sample (TS26, BU27); this does not mean an intraspecific variability but an evolutionary lineage, because these three species have different stratigraphic ranges and their first occurrence horizons are different.

e. Five specimens of *Isarcicella* are found by Matsuda (1981) in samples from two horizons (Beds 61 and 63) of Guryul Ravine section in Kashmir. All of them are referred by Sweet to *Isarcicella isarcica* Morphotype 2 which bears one or two denticles on one side of carina; here we assigned it to *Isarcicella staeschei*. Real *Isarcicella isarcica* (Morphotype 3 by Sweet) has not been found in Kashmir samples, which bears one or two denticles on both sides of carina.

f. At the Xiaoba section of the Anxian County, Sichuan Province, *Isarcicella staeschei* first appears at Bed 21, 4.80 m higher than the P/T boundary, while *Isarcicella isarcica* first appears at Bed 26, about 40 m higher than the P/T boundary, also indicating that *Isarcicella staeschei* appears earlier than *Isarcicella isarcica* (Li *et al.*, 1989, p. 20–22).

g. The Tongkou section in the Beichuan County and the Shangsi section in the Guangyuan City also show the *H. parvus*-*I. staeschei*-*I. isarcica* sequence (Li *et al.*, 1989, p. 10–20).

In brief, *Isarcicella staeschei* is a valid species, and differs from *Isarcicella isarcica* both in morphology and in stratigraphic levels.

2.2 Ostracode *H. tingi*-*L. suboblonga* Zone as good marker for the base of Triassic

Wang (second author of this paper) reported ostracodes from Late Permian and Early Triassic of western Guizhou and northeastern Yunnan as early as in 1978, which showed that most of the Late Paleozoic ostracode genera and species became extinct at the end of the Permian with a few of them, for example, *Hollinella tingi* (Patte) (pl. 3, figs. 1-3), extending upward into the lower part of the Early Triassic Feih sienkuan Formation, and that some genera and species, such as *Langdaia suboblonga* Wang (1978) (pl. 3, figs. 4-7), originated at the beginning of the Feih sienkuan Formation. Wang (1978) pointed out that a concurrent range between *H. tingi* and *L. suboblonga*, which is proposed here as the *H. tingi*-*L. suboblonga* Zone, was identical with the *Claraia wangi* Assemblage, and a marker indicating the Permian-Triassic boundary. The ostracode *Carinaknightina carinata* established by Sohn (1970) from the lower Mittwali Member of the Early Triassic Mianwali Formation in the Salt Range of Pakistan was discovered by Hao (1992) in the *H. tingi*-*L. suboblonga* Zone in Guizhou, providing a further evidence for the early Early Triassic *H. tingi*-*L. suboblonga* Zone. The Chaitou Formation conformably overlying the Late Permian Hsuanwei Formation in western Guizhou and northeastern Yunnan had been disputed in age until 1978. Wang (1978) first proposed the formation as of the early Early Triassic age based on the presence of the *H. tingi*-*L. suboblonga* Zone, the basal limit of which could be also identical with the boundary between the Hsuanwei and Chaitou Formations or Permian-Triassic boundary. However, Yao *et al.* (1980) claimed to place the boundary between the Hsuanwei and Chaitou Formations or the Permian and Triassic at the basal limit of the *Pteria ussurica variabilis* Assemblage (bivalves), which is about 5-10m lower than the basal limit of the *H. tingi*-*L. suboblonga* Zone. Now we have known that the *H. tingi*-*L. suboblonga* Zone and the conodont *Hindeodus parvus* coexist in and begin with JG⁵ from the basal lower member of the Early Triassic Dayie Formation at the Yangou section of Leping, Jiangxi. The basal limit of the *H. tingi*-*L. suboblonga* Zone is proved by *H. parvus* to be identical with the Permian-Triassic boundary (Text fig. 2).

L. suboblonga is different from the species of *Knoxiella* (pl. 3, figs. 8, 9) yielded at the top of the Upper Permian in the absence of median node (L²) and median sulcus (S²), and *H. tingi* mainly inhabited a nearshore shallow-water environment; both are extremely abundant in littoral elastic facies. They are also widely distributed in the Early Triassic strata of South China, including Sichuan, Yunnan, Guizhou, Jiangxi, Zhejiang, and Jiangsu. Consequently, the *H. tingi*-*L. suboblonga* Zone is quite important for indicating the early Early Triassic age and the Permian-Triassic boundary in South China in case of no conodonts.

3 AGREEMENTS AND DISCREPANCIES IN THE STUDY OF CONODONTS FROM MEISHAN SECTION

The conodonts of the Permian-Triassic boundary beds at the Meishan section have been intensively studied in very recently years by different authors (Wang, 1994a, 1994b, 1995; Lai *et al.*, 1995; Zhang *et al.*, 1995). Results of the study have come to some agreements as follows:

1) *Clarkina subcarinata* became extinct at the top of the Changsing Limestone (Wang, 1994a,b, 1995; Wang *et al.*, 1996; Zhang *et al.*, 1995).

2) *Clarkina deflecta* and *C. xiangxiensis* became extinct within boundary Bed 26 (Wang, 1994a,b, 1995; Wang *et al.*, 1996; Zhang *et al.*, 1995).

3) The range of *Clarkina meishanensis* is only restricted to boundary Bed 1 or Beds 25–26 (Zhang *et al.*, 1995; Kozur *et al.*, 1996).

4) *Clarkina carinata* appears earlier than *Hindeodus parvus* (Wang, 1994b, 1995; Wang *et al.*, 1996; Zhang *et al.*, 1995).

5) The range of *Hindeodus changxingensis* is restricted within boundary Beds 1–2 or beds 25–27 (Wang, 1995; Wang *et al.*, 1996).

6) *Hindeodus typicalis* has a long range across the P/T boundary beds (Wang, 1994a,b, 1995; Wang *et al.*, 1996; Zhang *et al.*, 1995).

7) *Hindeodus parvus* first occurs within boundary Bed 2 (base of AEL882-3, Wang, 1994a,b, 1995) or Bed 27 (base of Bed 27c, Yin *et al.*, 1994), indicating the base of the Triassic. i. e., the Permian-Triassic biostratigraphic boundary. This species evolved from *Hindeodus latidentatus*.

8) The P/T biostratigraphic boundary is somewhat higher than the eventostratigraphic boundary, and thus abandons the opinion that "The Permian-Triassic boundary presents an excellent case for integration of biostratigraphic and eventostratigraphic criteria." (Yin, 1994).

9) *Isarcicella staeschei* first occurs at Bed 28, only 8cm higher than the base of the *Hindeodus parvus* Zone, also indicating that the P/T boundary section at Meishan has a low sedimentation rate. But there is no stratigraphic condensation; all conodont index species follow in their phylomorphogenetic succession. Based on study of bioturbation, Bottjer *et al.* have pointed out as early as in 1988 that "The transitional bed is truly primary in nature. Thus, studies of precise evolutionary lineage of fossils, such as conodonts, from these strata most likely reflect biological reality. These results further indicate that the Changxing section may be a desirable stratotype for the Permian-Triassic boundary."

10) All Chinese conodont workers and almost all foreign conodont workers and stratigraphers (e.g. B. F. Glenister, Kotlyar, H. Kozur, Ramovs, B. Wardlaw, Zakharov) support that the Meishan section should be GSSP for the base of Triassic.

But there are still some discrepancies in researches on the Meishan section among the conodont workers:

1) Wang (1994, 1995) reported that the *Clarkina changxingensis* extended up to the upper part of boundary Bed 2 (or Bed 27) passing through the P/T boundary. Lai *et al.* (1995) and Zhang *et al.* (1995) reported that this species became extinct at the top of Bed 26, just below the P/T boundary.

2) Zhang *et al.* (1995, fig. 1) documented that *Clarkina carinata* has a very long range even in the Changsing Limestone, but Kozur (1975, 1978, 1995a,b), Orchard *et al.* (1995),

Wang(1994,1995), Wang *et al.* (1996)documented that most of the so-called *Clarkina carinata* specimens in the upper Changhsing Limestone should be *Clarkina cf. carinata*; the real *Clarkina carinata* first occurs at boundary Bed 1, which is a little below the *Hindeodus parvus* Zone. *Clarkina carinata* is from *Clarkina cf. carinata* (Wang, 1996), which was first reported from the Meishan sections by Clark *et al.* (1986).

3)Wang (1994a, 1994b, 1995, 1996)placed the eventostratigraphic boundary at the base of boundary Bed 1(Claystone bed), 15cm below the biostratigraphic boundary, because the biostratigraphic events began within Bed 24(stepwise mass extinction began earlier)and became stronger at the base of Bed 25; the base of boundary Bed 1(=Beds 25, 26)is marked by a widespread tuffitic horizon that also marks the drastic lithostratigraphic change. Lai *et al.* (1995),Zhang *et al.* (1995)and Ding *et al.* (1995)placed the eventostratigraphic boundary at the base of Bed 27, 8cm below the biostratigraphic boundary, but they did not explain the reason in their papers.

4)One of the great discrepancies is about the conodont sequence across the P/T boundary beds. Lai *et al.* (1995),Zhang *et al.*, (1995)formally proposed a conodont lineage, i.e., the *H. latidentatus*-*H. parvus*-*I. turgida*-*I. isarcica* lineage based on the study of the Meishan section. This evolutionary lineage is not reliable, and has to be partly revised.

Firstly, Lai *et al.* (1995),Zhang *et al.* (1995)did not document that they had found the *I. turgida* between the *H. parvus* Zone and the *I. isarcica* Zone(= *I. staeschei* Zone) at the Meishan sections. How can we recognise this lineage? In fact, there is only an 8cm interval for the *H. parvus* Zone at the Meishan section; it is hard to believe that there is an intermediate link between the *H. parvus* Zone and the *I. isarcica* Zone(= *I. staeschei* Zone here), in addition, the unique specimen of *Isarcicella isarcica* (= *I. staescheri*) that Lai *et al.* (1995)found at Bed 28 has two denticles on one side of the basal cavity, which is a more advanced specimen of this species, indicating this is not the earliest horizon of the species. Later, forms with one denticle will surely be found in the upper 8cm of boundary Bed 2(=Bed 27).

According to identification of Wang (1994, 1995), Kozur et Wang (1995, unpublished data), since *Hindeodus turgidus* first occurs at Bed 29, all the so-called *H. turgidus* specimens with small cusp and very expanded basal cavity should be assigned to *H. cf. turgidus*, which Kozur considers as his new species *I. ? priscus*, implying that *H. turgidus* is not on the lineage from *H. parvus* to *I. staeschei*. This is confirmed by the data of Kozur (1995b)that *I. ? turgida* appears later than *I. staeschei*. According to Kozur (1995b) *I. ? turgida* has evolved from *I. ? prisca* Kozur, but he did not quite exclude the possibility that the thickening of the inner cup (one of the typical features of *Isarcicella*) in these two species is ecologically controlled. In the latter case, *I. ? prisca* would be *H. latidentatus* with thickened inner cup and *I. ? turgida* is *H. parvus* with thickened inner cup. The present authors prefer to use *Hindeodus turgidus* instead of *I. ? turgida*.

Secondly, the so-called *I. isarcica* at Bed 28 should belong to *I. staeschei*. This specimen

has two denticles on one side of the carina; it is far from the holotype of *I. isarcica*, which has one or two denticles on both sides of the carina. The present first author considers that these are two independent species, and they mostly confirm the conodont lineage proposed by Kozur (1995b, 1996), that is, the *H. latidentatus*-*H. parvus*-*I. staeschei*-*I. isarcica* lineage (Text-figs. 1, 2) against the independent *I. ? priscus*-*I. ? turgida* lineage.

5) Opinions on the conodont zonation for the P/T boundary beds are also different among the Chinese conodont workers. In ascending order, Zhang *et al.* (1995) recognised: (1) the *Clarkina changxingensis*-*C. deflecta* Zone for the Changhsingian Stage, including Fauna 1 to Fauna 3 at the latest Changhsingian; (2) *H. parvus* Zone; (3) *I. isarcica* Zone (= *I. staeschei* Zone); and (4) *Clarkina carinata*-*C. planata* Zone.

Based on study of the present first author, in agreement with Kozur (1994, 1995a), the conodont zonation for the P/T boundary beds should be distinguished into the shallow water facies (or *Hindeodus* biofacies) and the pelagic facies (or gondolellid biofacies). One of the greatest advantages of the Meishan section is the co-occurring conodonts both in shallow water facies and in pelagic facies, providing an excellent case for correlation of the conodont zones in different facies.

In shallow water facies have been established *H. latidentatus* Zone-*H. parvus* Zone-*I. staeschei* Zone-*I. isarcica* Zone-*H. postparvus* Zone (Text-figs. 2, 3).

In pelagic facies have been established *Clarkina changxingensis*-*C. deflecta* Zone-*C. carinata* Zone-*C. planata* Zone (Text-figs. 2, 3).

6) Jin *et al.* (1994) and Sheng *et al.* (1994) pointed out: "The so-called boundary clay at the top of the Changhsingian is in fact a residual bed on the nondepositional surface", that is to say, the P/T boundary beds at Meishan section are not continuous deposits. Wang (1994a, 1994b,), Wang *et al.* (1996) pointed out that the boundary clay was continuous deposits below the storm wave base.

7) Yin (1994) and Yang *et al.* (1995) have proposed "subdivisions" for the Permian-Triassic boundary beds, and they "suggest delineation of the P/T boundary between subdivisions 4 and 5, that is at the base of the *H. parvus* Zone". But the concept of the "subdivision" is very obscure. Some "subdivisions" are different biostratigraphic units ("Subdivision" 1 or 5 is a Zone, "Subdivision" 2 is an Assemblage Zone and "Subdivision" 6 is an Acme Zone); whereas "subdivision" 3 is a lithostratigraphic unit (boundary claystone). It is impossible to make a correlation based on such obscure conception. In addition, the base of "Subdivision" 5 (= Mixed Bed 2) and the base of the *H. parvus* Zone (= the base of AEL882-3 or Base 27c) are not at the same level (Wang, 1994a, 1994b, Yin *et al.*, 1994, 1995; Zhang *et al.*, 1995). Despite the fact that both the present authors and Yin as well as Yang *et al.*, agree that the base of the Triassic should be placed at the base of the *H. parvus* Zone, the base of the *H. parvus* Zone in Meishan section for lithostratigraphic reasons should be placed at the base of Bed 27, in the middle part of which appears *H. parvus*. A biostratigraphic boundary, however, must be defined by the bioevent in-

stead of the lithostratigraphic lower boundary of a bed in which this bioevent occurs. In his latest publication Yin(1995) has corrected his previous view and placed the base of the *H. parvus* Zone exactly in the middle part of Bed 27, which is the same as Wang(1994a, b, 1995) proposed.

4 REVISED EARLIEST TRIASSIC CONODONT ZONES

The earliest Triassic conodont zones should be revised, because the conodont sequences are quite different (Text figs. 2, 3) in pelagic facies and shallow water facies.

4.1 Shallow water facies

4.1.1 *H. parvus* Zone

Lower limit defined by first occurrence of *Hindeodus parvus* (Kozur et Pjatakova, 1976) Morphotype 1.

Upper limit defined by first occurrence of *Isarcicella staeschei* Dai et Zhang, 1989.

Remarks *Clarkina deflecta*, *C. subcarinata* and *C. meishanensis* became extinct approximately at the start of the *H. parvus* Zone, but *Clarkina changxingensis*, *Hindeodus changxingensis* and *H. julfensis* finally became extinct within this zone, only *Clarkina carinata*, *Hindeodus laidentatus* M. 1., *H. parvus* M. 1, *H. parvus* M. 2. and *Hindeodus cf. turgidus* could survive through this zone.

4.1.2 *Isarcicella staeschei* Zone

Lower limit defined by the first occurrence of *Isarcicella staeschei* Dai et Zhang, 1989.

Upper limit defined by the first occurrence of *Isarcicella isarcica* (Huckriede, 1958).

Remarks *Clarkina changxingensis*, *Hindeodus changxingensis* and *H. julfensis* became extinct approximately at the start of the *Isarcicella staeschei* Zone, while *Clarkina carinata*, *Hindeodus turgidus*, *H. parvus* M. 1, *H. parvus* M. 2, and *H. typicalis* are present in this zone. Kozur(1995a, b) took *Isarcicella staeschei* as an independent subspecies of *Isarcicella isarcica*, but according to modern biological conception, subspecies is a kind of geographical barrier within one species. At the same layer of the same locality can not appear two subspecies which belong to one species. The holotype of *Isarcicella staeschei* is a form with two denticles on one side; Kozur has found a form with one denticle on one side and he will name it as a new species (personal communication). In this case, *Isarcicella staeschei* should be restricted only to the form with two denticles on one side.

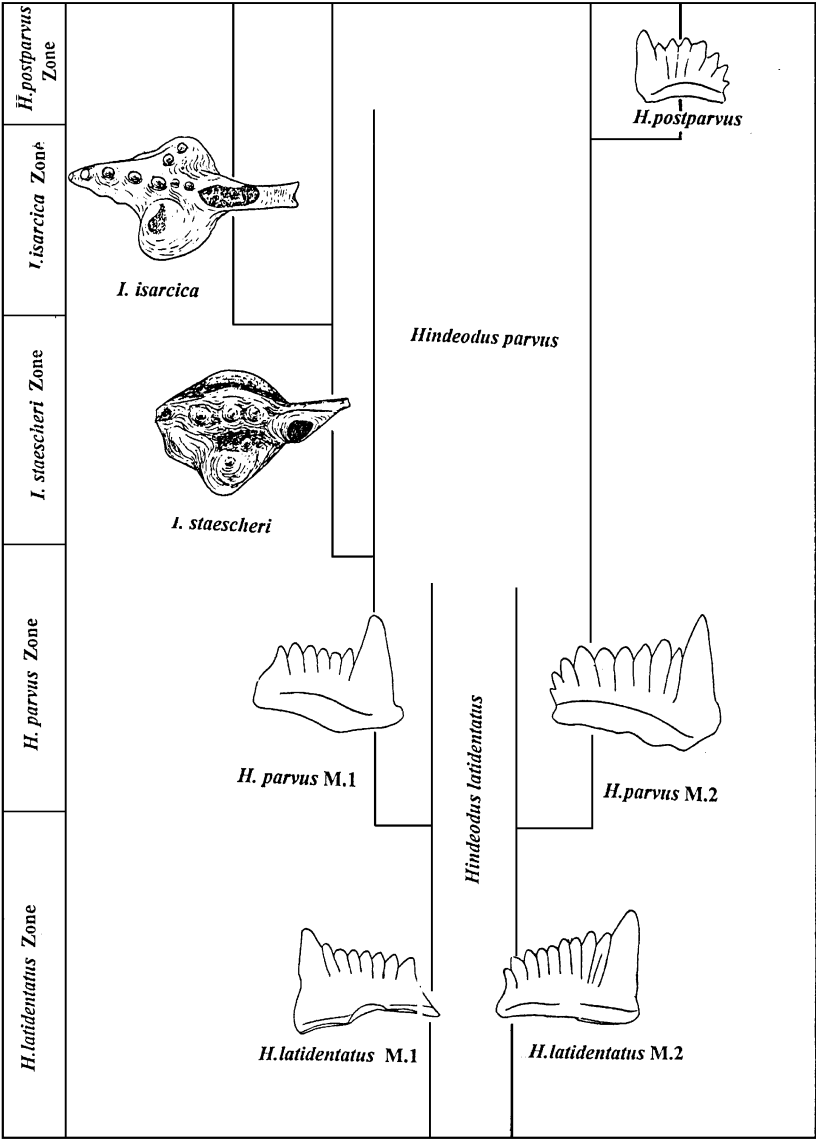
4.1.3 *Isarcicella isarcica* Zone

Lower limit defined by the first occurrence of *Isarcicella isarcica* (Huckriede, 1958).

Upper limit defined by the first occurrence of *Hindeodus postparvus* Kozur, 1989.

Remarks *Clarkina carinata*, *Clarkina planata*, *Hindeodus parvus*, *Hindeodus turgidus* and *Isarcicella staeschei* are present in this zone, but *Isarcicella isarcica* has not been found at the Meishan section by the authors.

4.1.4 *Hindeodus postparvus* Zone



Text-fig. 3 Evolutionary lineage of the conodont *Hindeodus-Isarcicella* at Permian-Triassic boundary beds

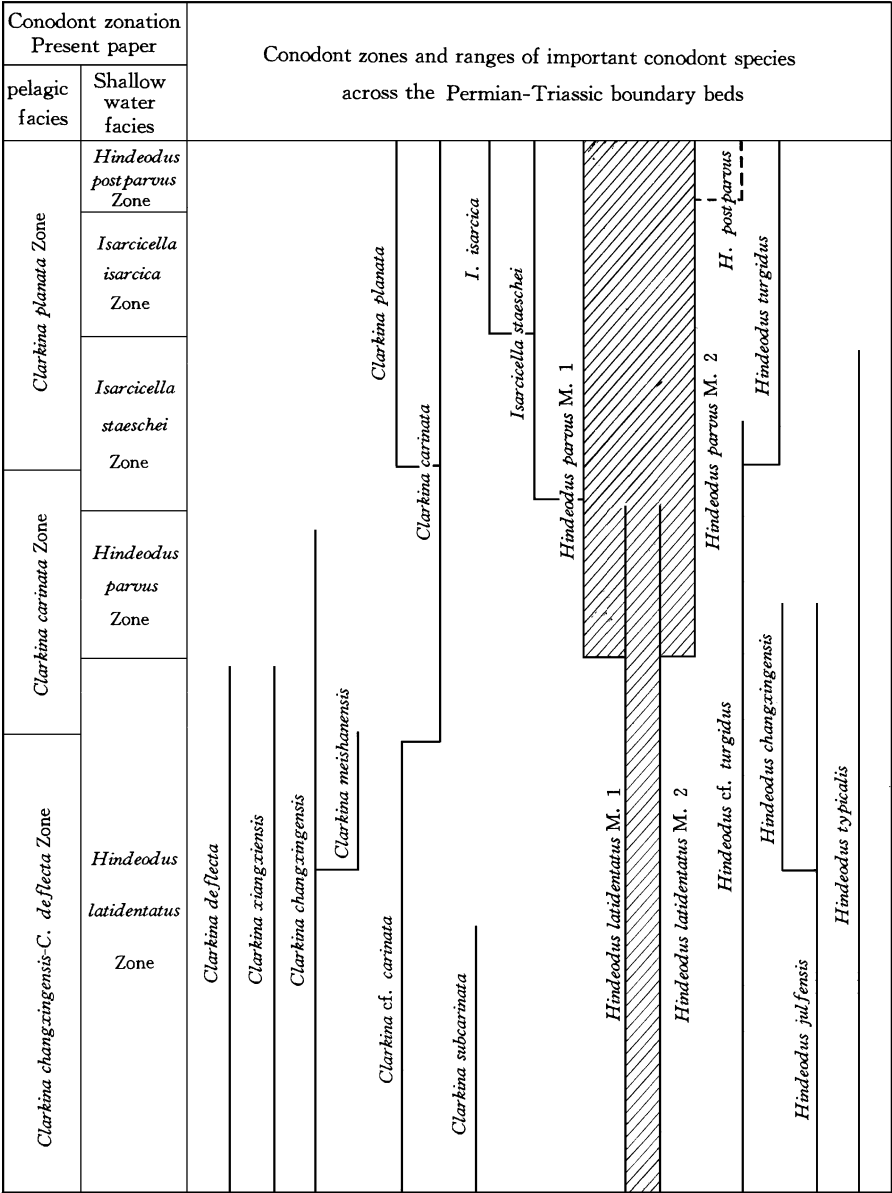
Lower limit defined by the first occurrence of *H. postparvus* Kozur, 1989.

Upper limit defined by the first occurrence of *Neospathodus kummeli* Sweet, 1970.

Remarks *Clarkina carinata*, *I. isarcica*, *Hindeodus parvus* are still present in this zone. The *H. postparvus* Zone corresponds to the ammonoid *Ophiceras commune* Zone (Kozur, 1989). This species so far has not been found in South China by the authors.

4.2 Pelagic facies

4.2.1 *Clarkina carinata* Zone



Text-fig. 4 Charts showing range of some important conodont species in P/T boundary beds of the Meishan section, Changxing, Zhejiang

Lower limit defined by the first occurrence of *Clarkina carinata* (Clark, 1959).

Upper limit defined by the first occurrence of *Clarkina planata* (Clark, 1959).

Remarks Zhang *et al.* (1995) reported the species *Clarkina carinata* with a very long range just across the P/T boundary beds (Zhang *et al.*, 1995, p. 671, fig. 1), while Wang documented the earliest occurrence of this species from boundary Bed 2(=Bed 27). All forms of the

| System | Stage | Formation | Conodont zonation (Present paper) | | Conodont zonation (Zhang et al.,1995) | | Important boundary and surface (This paper) | |
|----------------|---------------|----------------------|--|-----------------------------|--|-----|--|--|
| | | | pelagic facies | shallow Water facies | Conodont Zone | bed | | |
| LOWER TRIASSIC | STAGE | Formation | Clarkina planata Zone. | Hindeodus postparvus Zone ? | Clarkina carinata--Clarkina planata Zone ? | 30 | | |
| | | | | Isarcicella isarcica Zone ? | Isarcicella | | | |
| | | | | | isarcica | 29 | | |
| | | | | | Zone | 28 | | |
| | INDUAN | Yinkeng | Clarkina carinata Zone | Hindeodus parvus Zone | Isarcicella parva Zone | 27 | | |
| | | | | | Fauna 3 | 26 | | |
| | | | | | Fauna 2 | 25 | | |
| | | | Clarkina changxingensis-C. deflecta Zone | Hindeodus latidentatus Zone | | 24 | | |
| | | | | | Fauna 1 | | | |
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| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| UPPER PERMIAN | CHANGHSINGIAN | Formation | Clarkina changxingensis-C. deflecta Zone | Hindeodus latidentatus Zone | | | PTB CS TS EB & LB SB | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | STAGE | Changhsing Formation | | | | | | |
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Text-fig. 5 Conodont zones in pelagic facies and shallow water facies, tentatively correlated with those of the Meishan section, Changxing County

PTB: P/T biostratigraphic boundary; CS: δC^{13} minimum surface; TS: Transgressive surface; EB: Eventostratigraphic boundary; LB: Lithostratigraphic boundary; SB: Sequence stratigraphic boundary

so-called *Clarkina carinata* identified by Zhang *et al.* (1995) at the uppermost Changhsing Limestone were assigned to *Clarkina cf. carinata* by Wang (1995) and Wang *et al.* (1996). The lower limit of this species is a little earlier than that of *H. parvus*. This species evolved

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from *Clarkina cf. carinata*.

This Zone corresponds to the *H. parvus* Zone and the lower part of the *I. staeschei* Zone (Text-figs. 4, 5).

4.2.2 *Clarkina planata* Zone

Lower limit defined by the first occurrence of *Clarkina planata* (Clark, 1959).

Upper limit defined by the first occurrence of *Neospathodus kummeli* Sweet, 1970.

Remarks *Clarkina planata* which evolved from *Clarkina carinata*, first occurs at Bed 29 of the Meishan section (Zhang *et al.*, 1995, fig. 1), somewhat higher than the first occurrence of *Isarcicella isarcica*. It is equivalent to the interval from the upper *I. staeschei* Zone to the *H. postparvus* Zone in the shallow water facies (Text-figs. 4, 5).

5 DESCRIPTION

Genus *Isarcicella* Kozur, 1975

Type species *Spathognathodus isarcicus* Huckriede, 1958

Isarcicella isarcica (Huckriede)

(Pl. II, fig. 1)

1958 *Spathognathodus isarcica* Huckriede, p. 162, pl. 10, figs. 6, 7.

1977 *Isarcicella isarcica*, Sweet in Ziegler, p. 225. Morphotype 3.

1989 *Isarcicella isarcica*, Dai et Zhang (in Li *et al.*, 1989), p. 224, pl. 46, figs. 16, 17, 20.

1991 *Isarcicella isarcica* (Huckriede) Morphotype 3, Perri, pl. 6, figs. 1-3 (only).

Diagnosis A species of *Isarcicella* having one or two nodes or denticles on both sides of basal cavity which is asymmetrically expanded.

Description Unit small, high and short, strongly asymmetrical. Cusp high and robust, located at the anterior, posteriorly followed by several small denticles; ending abruptly posteriorly. Basal cavity strongly expanded, occupying entire underside of the unit, but very narrow under the cusp; bearing one or two nodes or long denticles on both sides of its upper surface.

This species shows a great variation in morphology. The earliest specimen bears one rudimentary node on one side, and one or two long denticles on the other side, but the advanced specimen bears long denticles on both sides.

Remarks The holotype of *Isarcicella isarcica* has one or two denticles on each side of the carina. This species can be easily distinguished from *Isarcicella staeschei* by having denticles on both sides. Sweet (1977) placed the three species, *H. parvus*, *H. typicalis* and *Isarcicella isarcica* in one species, *Isarcicella isarcica*, and he considered those three species as occurring at the same horizon. But *H. parvus* and *I. isarcica* are quite different both in morphology and in stratigraphic levels; *H. parvus* as an independent species has been accepted by conodont workers. *I. staeschei* and *I. isarcica* are also different both in morphology and in stratigraphic levels, the former appearing much earlier than the latter. Most conodont workers assigned *I. staeschei* to *I. isarcica*. In fact, in most documents, the so-called *I. isarcica* should be *I. staeschei*, which really has a wide distribution. This species obviously evolved from *I. staeschei*.

Isarcicella staeschei Dai et Zhang

(Pl. II, figs. 2—5)

- 1964 *Spathognathodus isarcicus* Staesche, pp. 288—289, Abb. 62—63.
- 1973 *Anchignathodus isarcicus*, Sweet (in Teichert *et al.*), pl. 11.
- ? 1977 *Isarcicella isarcica*, Kozur, pl. 1121, pl. 1, figs. 18a—c.
- 1977 *Isarcicella isarcica*, Sweet in Ziegler, p. 225, Morphotype 2.
- 1981 *Isarcicella isarcica*, Matsuda, pp. 93—94, pl. 5, figs. 4—7.
- 1983 *Isarcicella isarcica*, Tian *et al.*, p. 362, pl. 79, figs. 1a—c, 2.
- 1989 *Isarcicella staeschei* n. sp., Dai et Zhang, pp. 224—225, pl. 45, figs. 16, 17; pl. 46, figs. 4—7, 11—13, 18, 19; pl. 53, figs. 13, 14.
- 1989 *Isarcicella triangulata* n. sp., Dai et Zhang, pl. 225, pl. 46, figs. 8—10, 21.
- 1991 *Isarcicella isarcica* (Huckriede) Morphotype 2, Perri, pl. 5, figs. 1—4; pl. 6, figs. 4, 5.
- 1995 *Isarcicella isarcica staeschei* Dai et Zhang, Kozur, pl. 6, fig. 18.
- 1995 *Isarcicella isarcica*, Orchard, Nassichuk et Lin, pp. 832—833, pl. 2, figs. 13, 14.
- 1995 *Isarcicella isarcica*, Lai *et al.*, pl. 1, figs. 1a, b.
- 1995 *Isarcicella isarcica*, Zhang *et al.*, pl. 2, figs. 13a, b.

Diagnosis A species of *Isarcicella* having one or two denticles on one side of basal cavity which is asymmetrically expanded.

Description Unit very small, high and short, strongly asymmetrical. Cusp high, robust, located at the anterior, posteriorly followed by 3—7 small denticles; ending abruptly posteriorly. Basal cavity strongly expanded, occupying entire underside of the unit, but very narrow under the cusp; bearing one or two nodes or long denticles, whereas other side smooth, lacking nodes or denticles.

This species also shows a wide interspecific variability. The earliest element bears a very small rudimentary node on one side; the advanced specimen has two nodes or long denticles on one side. The relative horizon within this zone could be recognized from the sculpture on the surface of the basal cavity.

Remarks According to Sweet and Clark (1981), the apparatus is unimembrate with variable P element scaphate. Sweet (1977), in agreement with Staesche (1964), included the laterally adenticulate elements (= *Hindeodus parvus*) in *Isarcicella isarcica* as Morphotype 1. Morphotypes 2 and 3 include the laterally denticulate elements with one denticle or a denticle series respectively on either or both sides. Now *Hindeodus parvus* which was considered as Morphotype 1 of *Isarcicella isarcica*, has been accepted by most conodont workers as an independent species and a marker for the base of Triassic. Logically, Morphotypes 2 and 3 also should be considered as different independent species. *Isarcicella staeschei* differs from *Isarcicella isarcica* in having one or two denticles on one side of the upper surface of the basal cavity, whereas the latter has denticles on both sides of the basal cavity. This species corresponds to Sweet's *Isarcicella isarcica* Morphotype 2 or to Kozur's subspecies *Isarcicella isarcica staeschei*. *I. staeschei* and *I. isarcica* are different both in morphology and in stratigraphy, the former appearing earlier

than the latter; all these indicate a very clear evolutionary lineage of *Hindeodus latidentatus* → *H. parvus* → *Isarcicella staeschei* → *I. isarcica*.

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Explanation of Plates

All specimens illustrated in plates are housed at Nanjing Institute of Geology and Palaeontology, Academia Sinica, with catalogue numbers 126083—126097.

Plate I

- 1—12. *Hindeodus parvus* (Kozur et Pjatakova)
1. Lateral view of JD 7/126083, $\times 120$, Pa element, Morphotype 1, Dongling section, Dayie Formation. 2, 3. Upper and lateral views of JG5/126084, $\times 120$, $\times 120$, Pa element, Yangou section, Dayie Formation. 4. Pb element, lateral view of JD13/126085, $\times 120$, Donglin section, Dayie Formation. 5. Sa (?) or Sd (?) element, posterior view of JD10/126086, $\times 150$, Dongling section, Dayie Formation. 6. Sb element, lateral view of JD13/126087, $\times 150$, Dongling section, Dayie Formation. 7. M element, lateral view of JD10/126088, $\times 120$, Dongling section, Dayie Formation. 8. Sc element, lateral view of JD13/126089, $\times 120$, Dongling section, Dayie formation. 9—10. Upper and lateral views of JD13/126090, $\times 120$, $\times 120$, Pa element, Morphotype 1. 11, 12. Upper and lateral views of JD/10/126091, $\times 120$, $\times 120$, Pa element, Morphotype 1, Dongling section, Dayie Formation.

Plate II

1. *Icaricella isarcica* (Huckriede)
- Upper view of JG13/126092, $\times 80$, Yangou section, Dayie Formation.
- 2—5. *Isarcicella staeschei* Dai et Zhang
- 2, 3. Upper and lateral views of JD13/126073, $\times 120$, Yangou section, Dayie Formation. 4, 5. Upper and lateral views of JG13/126094, $\times 120$, Yangou section, Dayie Formation.
- 6—11. *Hindeodus parvus* Morphotype 1
- 6, 7. Upper and lateral views of JG12/126095, $\times 100$, Yangou section, Dayie Formation. 8, 9. Upper and lateral views of JG5/126096, $\times 120$, $\times 250$; Yangou section, Dayie Formation. 10, 11. upper and lateral views of JG13/126097, $\times 120$, Yangou Formation, Dayie Formation.

Plate III

- 1—3. *Hollinella tingi* (Patte)
- 1—3. Plesiotype. 1. Lateral view of internal mould of right valve, $\times 40$, NIGP31320. 2. Lateral view of internal mould of left valve, $\times 40$, NIGP31317. 3a, b. Left and dorsal views of steinkern, $\times 40$, NIGP31318. All from the early Early Triassic Chiaitou Formation of western Guizhou.
- 4—7. *Langdaia suboblonga* Wang
- 4a, b. Left and dorsal views of steinkern, paratype (tecnomorph), $\times 40$, NIGP31361. 5a, b. Left and dorsal views of steinkern, paratype (heteromorph), $\times 40$, NIGP31362. 6a, b. Left and dorsal views of steinkern, holotype (heteromorph), $\times 40$, NIGP31359. 7a, b. Left and dorsal views of steinkern, paratype (tecnomorph), $\times 40$, NIGP31360. All from the lower part of Early Triassic Feisienkuan Formation of western Guizhou.
8. *Knoxiella langdaiensis* Wang
- Right, left and dorsal views of steinkern, holotype, $\times 40$, NIGP31343, from the Late Permian Hsuanwei Formation of western Guizhou.
9. *Knoxiella oblonga* Wang
- Right, left and dorsal views of holotype (Heteromorph), $\times 40$, NIGP31355, from the Late Permian Hsuanwei Formation of western Guizhou.