

# Conodont succession in the Guadalupian-Lopingian boundary interval (upper Permian) of the Maoershan section, Hubei Province, China

Zhang Lili<sup>1,2</sup>, Zhang Ning<sup>1</sup> and Xia Wenchen<sup>1</sup>

<sup>1</sup>Faculty of Earth Science, China University of Geosciences, Wuhan, 430074, China

<sup>2</sup>South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou, 510301, China  
email: zll1115@126.com; zhangn@cug.edu.cn; xiawch@cug.edu.cn

**Abstract:** Middle-Upper Permian conodont biostratigraphy was examined in a major carbonate section and two auxilliary carbonate sections at Maoershan, Hubei, South China. We recognized ten conodont zones across the Guadalupian-Lopingian boundary (GLB) in these sections consisting of the *Jinogondolella shannoni* Zone, *J. altudaensis* Zone, *J. xuanhanensis* Zone, *J. granti* Zone, *Clarkina postbitteri hongshuiensis* Zone, *C. postbitteri postbitteri* Zone, *C. dukouensis* Zone, *C. asymmetrica* Zone, *C. guangyuanensis* Zone, and *C. transcaucasica* Zone in ascending order. This succession corresponds well with the Global Stratotype Section and Point (GSSP) of the GLB at Penglaitan Section, Guangxi, South China. The present biostratigraphic work on Maoershan sections certainly confirmed the conodont zonations through the GLB at the GSSP and also testified the correctness of the GLB demarcation in Maoershan sections. The transition from *Jinogondolella*-dominated faunas in Guadalupian to *Clarkina*-dominated faunas in the Lopingian is recognized in *Clarkina postbitteri hongshuiensis* zone where there is an overlap of *Clarkina* and *Jinogondolella* species.

## INTRODUCTION

Many geologists have been attracted by the study of the Guadalupian – Lopingian boundary (GLB) and conodonts for the past decade (Mei et al. 1994a, 1994b, 1994c, 1998; Henderson 2000, 2001; Henderson et al. 2001, 2002a; Jin et al. 1994, 2001a, 2001b; Jin 2000; Kozur 1992; Kozur and Lucas 1996; Lambert et al. 2002; Mei and Henderson 2002; Mei et al. 2002; Wang et al. 1998; Wang 2000, 2001a, 2001b; Wardlaw and Mei 1998; Wardlaw et al. 1999, 2001; Sun and Xia 2005). Several sections have been identified precisely according to conodont biostratigraphy from bathyal carbonate and chert sequences across the GLB, such as Penglaitan section (Mei et al. 1994c 1998; Henderson 2000, 2001; Henderson et al. 2001, 2002a; Jin et al. 1994; Jin 2000; Wang et al. 1998; Wang 2000, 2001a, 2001b; Wardlaw and Lambert et al. 1999), Dukou section (Mei et al. 1994a, 1994b), and West Texas (Kozur 1992; Kozur and Lucas 1996; Lambert et al. 2002; Wardlaw 2000; Wardlaw et al. 1999, 2001). After discussing carefully (Jin 1999; Henderson and Mei 2002; Kozur et al. 2001; Kozur and Wang 2002; Wardlaw and Henderson 2002), the Penglaitan section in Guangxi, China, among those studied sections, was finally ratified as the Global Stratotype Section and Point (GSSP) of the GLB by the International Union of Geological Sciences (IUGS) in 2004.

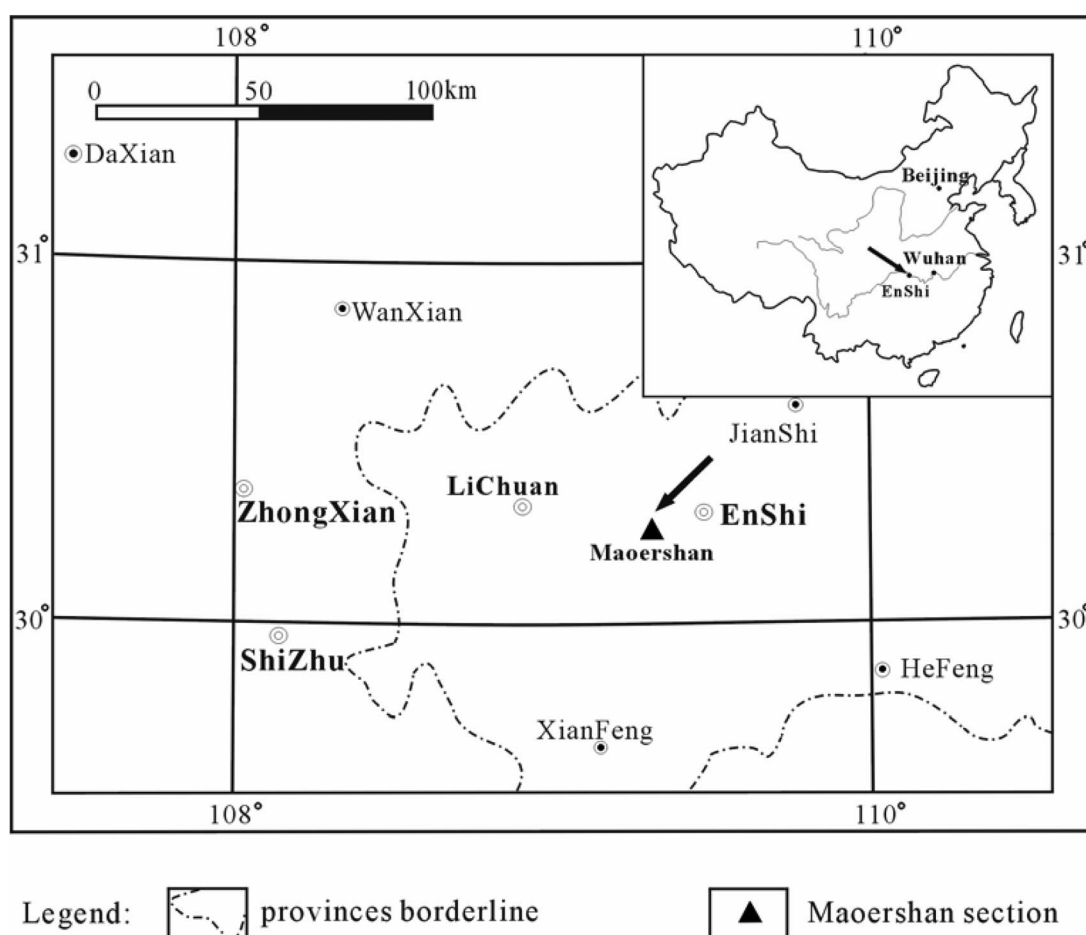
In order to substantiate the correctness of this GSSP and its global importance, we selected a major section and two auxilliary sections for studying correlative conodont zonations at Maoershan, western Hubei, South China, which was deposited in the slope environment of a continental margin basin.

## GEOLOGIC SETTING AND LITHOLOGY

The major section (IIIB section, N 30°18.314'E 109°18.416') is situated at Maoershan, Enshi, Hubei Province, China (text-fig.

1). Also two auxilliary sections (IIIBII and XII) were taken. One is the IIIBII section, about 500 meters west of the major section. The other is the XII section (N 30°20.306'E 109°18.938'), about 2 kilometers northwest of the major section. Tectonically, these sections were situated at the north margin of the Yangtze paleo-block, which drifted in the Paleo-Tethys Ocean during the Late Paleozoic (Yin et al. 1999).

The strata of the Wuchiapian-Changhsingian boundary interval were deposited in a transition zone from a carbonate platform to a rifted continental margin (Feng et al. 1997). The Maokou Limestone consists of packstones and grainstones, widely distributing in the northern Yangtze block and represents the Guadalupian epoch (Feng et al. 1997). The conodonts *J. shannoni* Wardlaw, *J. altudaensis* (Kozur), *J. xuanhanensis* Mei and Wardlaw, *J. granti* Mei and Wardlaw, and *J. posterrata* (Behnken 1975) were recovered from that unit. At the base of the uppermost Guadalupian Series, a black muddy chert named the “Kufeng Chert” (Feng et al. 1997) overlies the Maokou Limestone and contains a mixed conodont assemblage of *Jinogondolella* and *Clarkina*. At the top of the cherty succession is a third-order sequence boundary, which is overlain by a gray claystone with coal partings. This claystone succession is named the Wangpo Beds (Feng et al. 1997). Overlying the Wangpo Beds is a series of mudstones and wackestones that produce Early Lopingian species of *Clarkina* (Mei et al. 1994b; 1998). These lithologies are named the Xiayao Limestone which occurs widely in the north margin of the Yangtze block (Feng et al. 1997). Finally, a black cherty succession named the Dalong Formation overlies the Xiayao Limestone (Feng et al. 1997). The Dalong Formation contains conodonts consisting of *C. orientalis* Barskov and Koroleva, *C. liangshanensis* Wang and *C. leveni* Kozur, Pjatakova and Mostler. The GLB interval consists of the upper Maokou Limestone, “Kufeng Chert”, Wangpo Beds and Xiayao Limestone.



TEXT-FIGURE 1

The location of Maoershan section, which is on the road from Enshi city to Lichuan city, Hubei province, China.

## MATERIALS AND METHODS

The thickness of the Maoershan sections (IIIB, IIIBII and XII) is respectively 64m, 24m and 12m (text-fig. 2). The Maoershan sections are composed mainly of light gray or gray limestone, black chert, and gray claystone with coal partings. A total of 140 samples with sampling intervals of ~ 0.2m was analyzed. We found 18 conodont species belonging to 3 genera.

All of the samples of limestone were crushed into 2cm diameter, and treated in 10% formic acid for 10-12 hours per time for 15-25 times at a temperature of 25°.

Chert was processed in a solution of 5% hydrofluoric acid, for about 8 hours. Claystone was processed in a solution of 5% hydrogen peroxide for 12 hours. The remanent after sieved and dried was studied under a binocular microscope, picking out all the well-preserved or cracked conodont elements with preserved taxonomic features. All the conodont specimens were examined with Scanning Electron Microscopy (JSM-35CF, JEOL LTD) at China University of Geosciences (Wuhan).

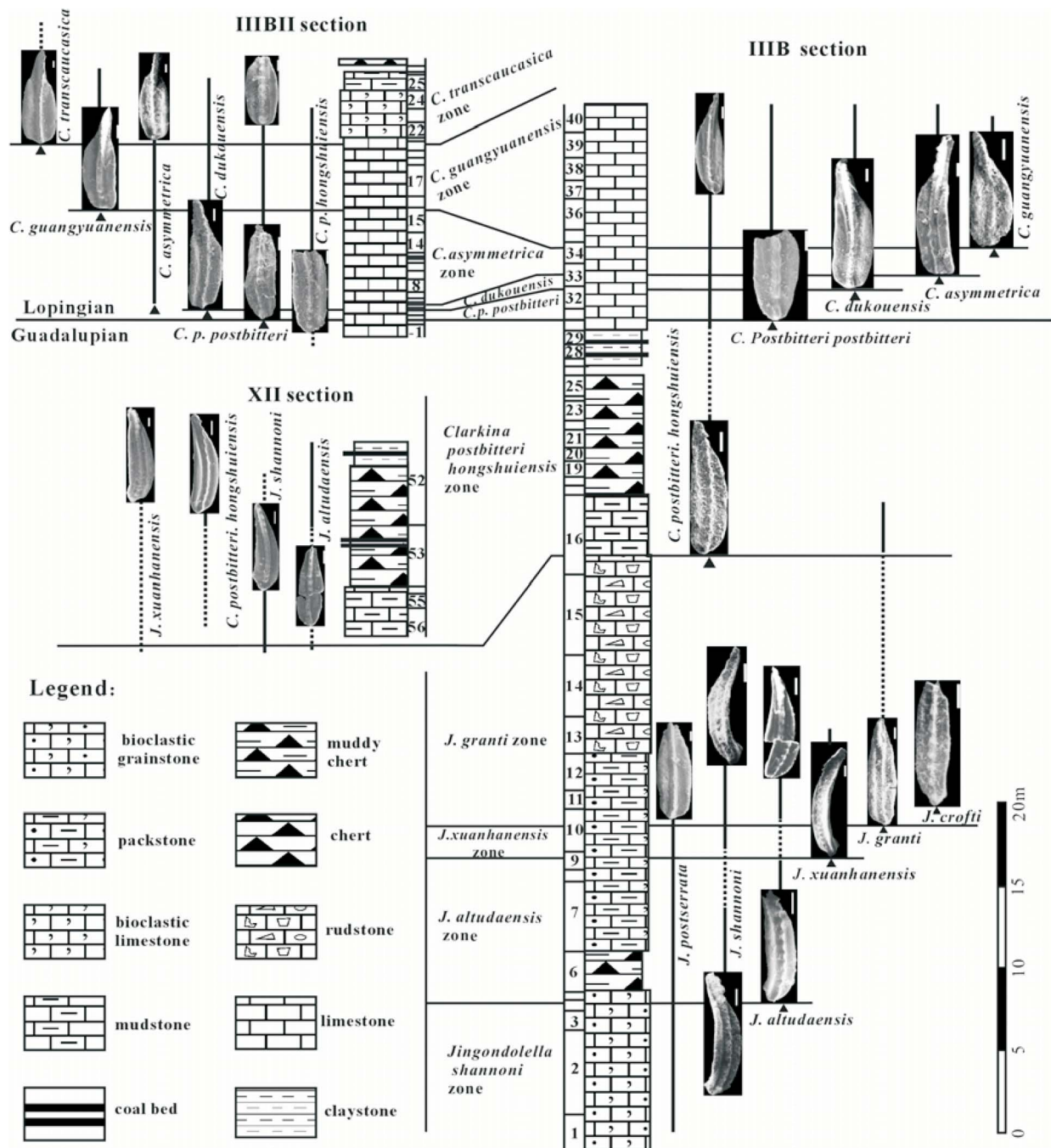
## CONODONT BIOSTRATIGRAPHY

Six species of *Jinogondolella*, ten species of *Clarkina* and two species of *Hindeodus* were identified among 396 specimens recovered from the G-L boundary interval. Stratigraphic ranges

in these three sections confirm ten conodont interval zones using the first occurrence (FO) of guide-species, i.e. *Jinogondolella shannoni* Wardlaw, *Jinogondolella altudaensis* (Kozur), *Jinogondolella xuanhanensis* Mei and Wardlaw, *Jinogondolella granti* Mei and Wardlaw, *Clarkina postbitteri hongshuiensis* Henderson, Mei and Wardlaw, *Clarkina postbitteri postbitteri* Mei and Wardlaw, *Clarkina dukouensis* Mei and Wardlaw, *Clarkina asymmetrica* Mei and Wardlaw, *Clarkina guangyuanensis* Dai and Zhang, and *Clarkina transcaucasica* Gullo and Kozur (text-fig. 2). Among ten conodont zones identified, the upper six (from *J. granti* Zone to *C. guangyuanensis* zone) are described below.

### *Jinogondolella granti* Zone

The *Jinogondolella granti* Zone is diverse, containing the most of *Jinogondolella* species, e.g. *J. crofti* (pl. 1, fig. 16), *J. granti* (pl.1 figs. 7-9, pl. 3, figs. 24-26), *J. shannoni* (pl. 1, fig. 10), *J. altudaensis* (pl. 1, figs. 11-13, pl. 3, fig. 30), *J. xuanhanensis* (pl. 1, figs. 14-15), and *J. postserrata* (pl. 1, figs. 17-18, pl. 3, figs. 27-29). In the major section, the lower limit of this zone is marked by the first appearance of *J. granti* at the base of bed IIIB 10-3, and for the upper limit by the entry of *Clarkina postbitteri hongshuiensis* Henderson, Mei and Wardlaw at the base of bed IIIB 16-6. Every species of *Jinogondolella* represented abundantly in the interval from the base of bed IIIB 10-3



TEXT-FIGURE 2

Columnar section of IIB section, IIBII section and section, conodont biozonation and distribution in Maoershan section, and zonal correlation between these three sections.

to bed IIB 12-3, which may represent a hemera of *Jinogondolella*. Some specimens of *Hindeodus* were also recovered from this zone (pl. 3, fig. 23). However, the abundance and diversity of conodont specimens decreased upward. Passing over the bed IIB 13, only a few poorly-preserved specimens of *Jinogondolella* and some specimens of *Hindeodus* were found.

#### *Clarkina postbitteri hongshuiensis* Zone

The *Clarkina postbitteri hongshuiensis* Zone is a mixed zone with species of *Jinogondolella* and *Clarkina*, *J. shannoni* (pl. 1, fig. 22), *J. altudaensis* (pl. 1, figs. 24-25), *J. granti* (pl. 1, figs. 27-28), and *C. postbitteri hongshuiensis* (pl. 1, figs. 19-21, 23, 26, 29-30) were moderately recovered. The morphology of *J. altudaensis* in this zone is characterized by an elevated anterior



carina and reduced serrations on the margins of the anterior platform. Evolution of *J. altudaensis* and the first appearance of *C. postbitteri hongshuiensis* in this zone may support an evolutionary transition from the genus *Jinogondolella* to *Clarkina*, as proposed by Lambert et al. (2002). This zone extends from the base of bed IIIB 16-6, where *C. postbitteri hongshuiensis* (pl. 1, figs. 19-20) first occurs, to the base of bed IIIB 31, which marks the FO of *Clarkina postbitteri postbitteri* Mei and Wardlaw.

### ***Clarkina postbitteri postbitteri* Zone**

The *Clarkina postbitteri postbitteri* Zone is a *Clarkina*-dominated zone that begins with the first appearance of *Clarkina postbitteri postbitteri* Mei and Wardlaw (pl. 2, figs. 3-4), and ends with the entry of *C. dukouensis* Mei and Wardlaw. In the major section the boundary-index fossil for defining the G-L boundary, *C. postbitteri postbitteri*, is first recovered from bed IIIB31 (text-fig. 2), only along with *C. postbitteri hongshuiensis* (pl. 2, figs. 5-6) from the same sample. In section IIIBII, *C. postbitteri postbitteri* first appears in bed IIIBII 1-1, where only one specimen was found.

### ***Clarkina dukouensis* Zone**

The *Clarkina dukouensis* Zone is widespread in the northern Yangtze Block (Mei et al. 1994a, 1994b). The lower limit is the FO of *C. dukouensis* Mei and Wardlaw (pl. 2, figs. 7-8) at bed IIIB 32-2 in major section, and bed IIIBII 3 in IIIBII section. The upper limit is identified by the first appearance of *C. asymmetrica* Mei and Wardlaw. In addition, *C. postbitteri hongshuiensis* and *C. postbitteri postbitteri* (pl. 2, fig. 11) range this zone. This zone ranges from the bed IIIB 32-2 to the bed IIIB 33-2 in the major section, and from the bed IIIBII 3 to the bed IIIBII 5 (text-fig. 2) in section IIIBII.

### ***Clarkina asymmetrica* Zone**

The *Clarkina asymmetrica* Zone is a diverse zone includes *C. asymmetrica* (pl. 2, figs. 12-13, 15), *C. dukouensis* (pl. 2, fig. 16), *C. postbitteri hongshuiensis*, *C. postbitteri postbitteri*. This zone spans from bed IIIB 33-2 to bed IIIB 34-2 in the major section, and from bed IIIBII 5 to bed IIIBII 15-4 in section IIIBII.

### ***Clarkina guangyuanensis* Zone**

The *Clarkina guangyuanensis* Zone is an epibole of *Clarkina* that begins with the first occurrence of *C. guangyuanensis* Dai and Zhang (pl. 2, figs. 18-19) at bed IIIB 34-2 in the major section, and at bed IIIBII 15-4 in section IIIBII. The top is marked by the entry of *C. transcaucasica* Gullo and Kozur (pl. 3, fig. 5). *C. postbitteri hongshuiensis* (pl. 2, fig. 21), *C. postbitteri postbitteri* (pl. 2, figs. 15, 22-26), *C. dukouensis* (pl. 2, fig. 9, 27-29) and *C. asymmetrica* (pl. 2, fig. 30; pl. 3, fig. 1) also appeared in this zone. In addition to *C. guangyuanensis*, *C. levini* Kozur, Mostler and Pjatakova (pl. 3, figs. 2-3) first appears near the upper limit of this zone and *C. longicuspidata* Mei and Wardlaw (pl. 3, fig. 4) were abundantly recovered from both the major and auxilliary sections.

### ***Clarkina transcaucasica* Zone**

The *Clarkina transcaucasica* Zone is another epibole zone of *Clarkina*, which begins with the FO of *C. transcaucasica* Gullo and Kozur (pl. 3, fig. 5). Moreover, all of the earlier-derived species of *Clarkina* extend into this zone, e. g. *C. postbitteri hongshuiensis*, *C. postbitteri postbitteri* (pl. 3, figs. 9-10), *C. dukouensis* (pl. 3, fig. 11), *C. asymmetrica* (pl. 3, figs. 12-13), *C. guangyuanensis*, *C. levini* (pl. 3, fig. 14), *C. longicuspidata*

(pl. 3, figs. 18-19). Several species, e. g. *C. liangshanensis* (Wang) (pl. 3, fig. 20) and *C. bazarrensis* Mei and Wardlaw 1994 (pl. 3, figs. 15-17) first appear in this zone.

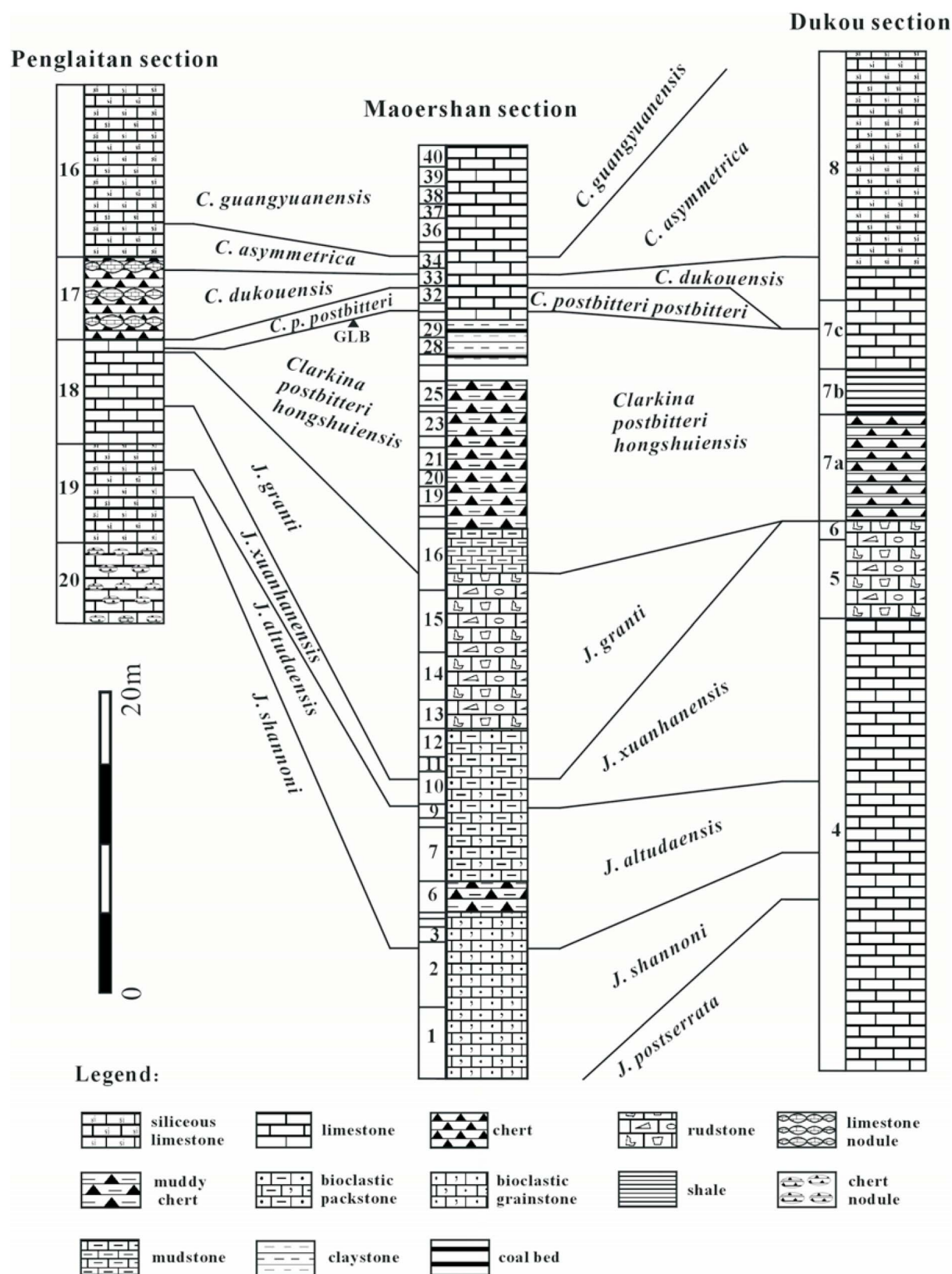
Mei et al. (1998) established a *C. levini* Zone between the *C. asymmetrica* Zone and the *C. guangyuanensis* Zone. Because *C. levini* Kozur, Mostler and Pjatakova is a long-ranging species in the Wuchiapingian, and its first appearance can not be reliably found at the same biolevel, it is abandoned here.

## **DISCUSSION**

Based on our biostratigraphic work, a conodont biozonation sequence of Guadalupian - Lopingian boundary (GLB) interval is divided into ten interval zones, i.e. *Jinogondolella shannoni* Zone, *J. altudaensis* Zone, *J. xuanhanensis* Zone, *J. granti* Zone, *Clarkina postbitteri hongshuiensis* Zone, *C. postbitteri postbitteri* Zone, *C. dukouensis* Zone, *C. asymmetrica* Zone, *C. guangyuanensis* Zone and *C. transcaucasica* Zone in ascending order. These biozones can be well contrasted with the Penlitan Section (text-fig. 3), and demonstrate the scientific significance of Penlitan Section as the GSSP. Correlating with the GSSP of G-L boundary at Penglitan, Guangxi, the GLB could be defined at the base of *C. postbitteri postbitteri* Zone, i.e. at the base of the bed IIIB 31 in the major section and the base of bed IIIBII 1-1 in IIIBII section. The former five zones were derived from the *Jinogondolella* evolutionary lineage, and the later five from the *Clarkina* evolutionary lineage.

The *Clarkina postbitteri hongshuiensis* zone could be distinguished into four stages (I-IV) by the changes of conodont abundance and diversity in Maoershan Section (text-fig. 4). Stage I, the lowest part of *C. postbitteri hongshuiensis* zone, was a relatively abundant and diverse interval (the bed IIIB 16-6 in the major section and the beds XII 56 - XII 54 in XII section) in which the species of *Jinogondolella* are dominant, for example *Jinogondolella shannoni* (pl. 1, fig. 22) and *Jinogondolella altudaensis* (pl. 1, figs. 24-25), but *Clarkina postbitteri hongshuiensis* (pl. 1, figs. 19-20) as the ancestor of *Clarkina* evolutionary lineage is present. Entering Stage II (the bed IIIB 16-7 in the major section and the bed XII 53 in XII section), conodont specimen abundance reduced sharply, only several conodonts were found, like *J. granti* (pl. 1, fig. 28) and *C. postbitteri hongshuiensis* (pl. 2, fig. 1), and the diversity of conodonts was very low. Extending upward to Stage III, a middle conodont-bearing interval (the bed IIIB 16-8 and the bed XII 52), saw the return of some abundance with *J. granti* (pl. 1, fig. 27) and *C. postbitteri hongshuiensis* (pl. 1, figs. 21, 23, 26, 30; pl. 2, fig. 2), but specimens of *Clarkina* dominate. At the uppermost part Stage IV, in a conodont barren interval, the *Jinogondolella* lineage ends here, and only *C. postbitteri hongshuiensis* crosses this interval. This barren interval is composed of claystone with coal partings and pyrite nodules in the mid-lower parts and calcic shale in the upper part. It may be defined as the Pre-Lopingian catastrophic event of marine faunas (Jin et al. 1995).

The G-L boundary-index species, *Clarkina postbitteri postbitteri* Mei and Wardlaw, appeared firstly exactly over the uppermost barren interval. Therefore, our results would support the decision of the GSSP that the GLB is defined by the first appearance datum (FAD) of *Clarkina postbitteri postbitteri* at Penglitan Section. But contrasting Penglitan Section (The Global Stratotype Section and Point of the GLB) (Mei et al. 1994; 1998; Jin et al. 2001; Henderson et al. 2002) with Maoershan Section and Dukou Section (Mei et al. 1994; 1998)



TEXT-FIGURE 3

Interpretative correlation of the conodont biozonation between Maoershan major section, Dukou section (Mei et al. 1994b; 1998) and Penglaitan section (The Global Stratotype Section and Point of GLB ) (Mei et al. 1994c; 1998; Jin et al. 2001; Henderson et al. 2002).

(text-fig. 3), we find easily that (1) the zones except the *C. postbitteri hongshuiensis* Zone of the Maoershan Section are perfectly comparable with those of the GSSP; (2) *C. postbitteri hongshuiensis* Zone below the GLB is very longer-ranged in Maoershan and Dukou Sections than Penglaitan Section, and (3) there is no overlap between *Jinogondolella* and *C. postbitteri hongshuiensis* at Penglaitan Section. Hence, we guess that the *C. postbitteri hongshuiensis* Zone of Penglaitan section may only equal to Stage I of the *C. postbitteri hongshuiensis* Zone of Maoershan section. The four stages of *C. postbitteri hongshuiensis* Zone in Maoershan Section indicate a conodont evolutionary process from Guadalupian *Jinogondolella* dominated to Lopingian *Clarkina* dominated faunas, which may supplement the barren interval from *Jinogondolella* to *Clarkina* at the GSSP of the GLB. Herein the end-Guadalupian event horizon may be recognized well in the Maoershan Section.

## SYSTEMATIC PALEONTOLOGY

Genus *Jinogondolella* Mei, Jin, and Wardlaw 1998

*Jinogondolella shannoni* Wardlaw 1998

Plate 1, figures 1-3, 10, 22

*Jinogondolella shannoni* Wardlaw in WARDLAW and MEI 1998, p. 38-39, pl. 4.1. MEI, JIN, and WARDLAW 1998, pl. 6, figs. 11, 14-17. LAMBERT, WARDLAW, NESTELL, and NESTELL 2002, p. 361, pl. 6, figs. 11-18.

*Mesogondolella shannoni* Wardlaw in MEI, JIN, and WARDLAW 1994a, p. 228, pl. 1.21. WARDLAW 2000, p. 46, pl. 3-4, figs. 26, 27, 29, 30, pl. 3-6, figs. 8-15, pl. 3-7, figs. 12-25, pl. 3-9, figs. 1-27, pl. 3-11, figs. 5-14.

**Description:** A species of *Jinogondolella* characterized by a Pa element with a long, arched and slightly bowed platform, that is widest in the posterior third and from there ahead narrowing gradually; a broadly rounded posterior end with a well developed brim in old specimens; lateral platform margins with a few serrations on anterior fourth; usually the cusp fused with the small denticle in the posterior; generally furrows developed.

*Jinogondolella altudaensis* (Kozur 1992)

Plate 1, figures 4-5, 11-13, 24-25; plate 3, fig. 30

*Clarkina altudaensis* Kozur 1992, p. 103-106, figs. 9-12, 14-17.

*Jinogondolella altudaensis* (Kozur). WARDLAW and MEI 1998, p. 39-40, pl. 5, figs. 1-6, 8-24.

*Mesogondolella altudaensis* (Kozur). WARDLAW 2000, p. 46, pl. 3-5, figs. 8-12, pl. 3-11, figs. 15-17.

**Description:** A Pa element characterized by the width of the platform moderate, the widest in the posterior third, from here pinching gradually backwards and sharply but evenly forwards; the posterior margin bluntly rounded, but in large specimens usually narrowly rounded; the platform upturned slightly; the furrow moderately developed; faint to absent serrations on anterior platform; the carina composed of 12-17 denticles, usually the middle and posterior denticles fused and with the same height, the anterior denticles higher and more separated; the cusp small and inconspicuous in adult specimens.

*Jinogondolella xuanhanensis* Mei and Wardlaw 1998

Plate 1, figures 6, 14-15

*Mesogondolella xuanhanensis* MEI et al. 1994a, p. 33, pl. 3, figs. 2 - 10, 14.- MEI, JIN, and WARDLAW 1994b, pl. 1, figs. 13, 18-20; pl. II, figs. 17-23

*Jinogondolella xuanhanensis* (Mei and Wardlaw). - MEI, JIN, and WARDLAW 1998, pl. 7 figs. 3 - 5, 10, 11, 13, 14. - LAMBERT,

WARDLAW, NESTELL and NESTELL 2002, pl. 1, figs. 5-7, 10-13, 17-18; pl. 2, figs. 12, 13; pl. 3, figs. 14, 15; pl. 5, figs. 1, 2

**Description:** A species of *Jinogondolella* characterized by a long, narrow and moderately arched platform; the widest in the 1/3 of its posterior; on the carina about 20 almost fused denticles, more than *J. prexuanhanensis*; the transverse ridge undeveloped; cusp obvious, located terminally; sometimes fused with the most posterior denticle; posterior end of carina slightly deflecting towards inner side; denticles on the middle carina often entirely fused. Adcarinal furrows shallow; usually lower surface slightly concave.

**Remarks:** This species is compared with *J. altudaensis*: the cusp is bigger, the denticles on the carina are more than *J. altudaensis* and almost entirely fused; the anterior denticles are higher and more fused.

*Jinogondolella granti* Mei and Wardlaw 1994

Plate 1, figures 7-9, 27-28; plate 3, figures 24-26

*Mesogondolella granti* Mei and Wardlaw in MEI, JIN, and WARDLAW 1994b, p. 229, pl. 1, figs. 8-12

*Jinogondolella granti* (Mei and Wardlaw). - MEI, JIN, and WARDLAW 1998, p. 63, pl. 3, figs. 1-4, 10-14; pl. 7, figs. 8, 9, 12, 15-24. - WANG 2000, pl. V, figs. 1-7, pl. VII, figs. 8-12. - HENDERSON, MEI, and WARDLAW 2002, pl. 1, figs. 12-16. - HENDERSON, MEI, and WARDLAW 2001, p. 733, figs. 12-16. - LAMBERT, WARDLAW, NESTELL, and NESTELL 2002, p. 356, pl. 1, figs. 1-3, 8-9, 14-15

*Mesogondolella laibinensis* WANG 2000, p. 10-11, pl. VI, figs. 5-12

**Description:** A Pa element, a species of *Jinogondolella* characterized by a blunt rounded posterior margin, a narrow, arched and long platform; the two sides of posterior are parallel, the cusp high and large; the middle denticles on the carina are fused, but some are separated in the young specimens; a narrow constriction of the furrow near the anterior end of the fused middle carina; at the anterior narrowing and lowering of the platform.

**Remarks:** This species is important in the late Guadalupian Series. There is some difference between *J. granti* and its predecessor *J. xuanhanensis*: *J. granti* bears a blunt rounded posterior margin, a smooth carina and has parallel posterior sides.

*Jinogondolella crofti* (Kozur and Lucas 1996)

Plate 1, figure 16

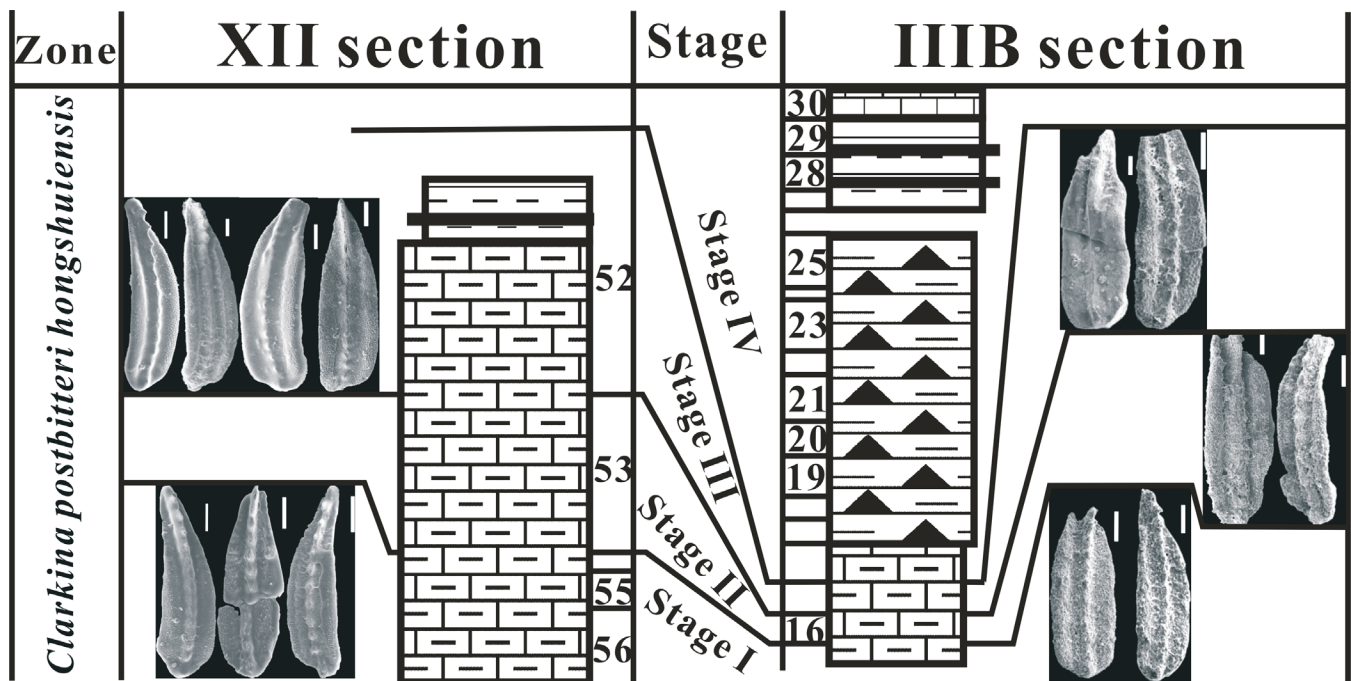
*Clarkina crofti* KOZUR and LUCAS 1996, p. 96-101, figs. 1

*ProtoClarkina crofti* (Kozur and Lucas). - WARDLAW and MEI 1998, p. 40-41, pl. 6, figs. 7, pl. 7, figs. 1-4, 7-21

*Jinogondolella crofti* (Kozur and Lucas). - MEI, JIN, and WARDLAW 1998 (part), pl. 1, figs. 1-3, 5-6. - LAMBERT, WARDLAW, NESTELL, and NESTELL 2002, p. 352-361, pl. 2, figs. 1-11, pl. 4.6, pl. 6, figs. 6-8, 10

**Description:** Wardlaw and Mei (1998) adequately described Pa elements of this species. This species characterized by the very small individual and a very narrow platform; the widest in the half of the posterior; with a high and separated denticles on the carina, a deep and smooth adcarina furrow, a long fixed blade, and a rudimentary free blade with one to two denticles; the denticles increasing in size from posterior to anterior; the posterior denticles smaller in size from the first one to the third one; the posterior margin of platform narrower from the foreside of cusp to the cusp; from the widest to 1/5 in anterior, the platform narrowing gradually, the posterior platform upturned; the cusp is in the terminal posterior and fused with the platform margins.





TEXT-FIGURE 4

Four stages of *Claikina postbitteri hongshuiensis* Zone, and conodonts assemblage in each stage at IIIB Section and XII Section.

#### Genus *Clarkina* Kozur 1989

Type species: *Gondolella leveni* Kozur, Mostler and Pjatkova 1976

*Clarkina postbitteri hongshuiensis* Henderson, Mei and Wardlaw 2002

Plate 1, figs. 19-21, 23, 26, 29-30; plate 2, figures 1-2, 5-6, 10, 21

*Clarkina postbitteri hongshuiensis* HENDERSON, MEI, and WARDLAW 2002, p. 733-735, pl. 1, figs. 1-11, pl. 2, figs. 9-10, 12-13. – JIN et al. 2001, p. 40, pl. 1, figs. 1, 6-10, 13-16

**Description:** A subspecies of *C. postbitteri*, characterized by a narrow brim and high, fused anterior denticles forming a blade, smooth anterior margins; some specimens show rounded posterior terminations whereas others are more blunt or square with rounded corners; in some specimens, the platform narrows abruptly in the anterior or in others, the platform narrows more gradually; the posterior and middle denticles sometimes discrete, sometimes fused; usually there is a gap between the posterior denticle and the cusp.

*Clarkina postbitteri postbitteri* Mei and Wardlaw 1994

Plate 2, figures 3-4, 11, 15, 22-26; plate 3, figures 9-10

*Clarkina postbitteri* Mei and Wardlaw. – MEI et al. 1994b, pl. 1, figs. 3-6, pl. 2, figs. 7-11. – MEI et al. 1998, pl. 4, figs. 1-3, 9-11, pl. 8, figs. 1-9. – WANG 2000, pl. 1, figs. 1-18

*Clarkina postbitteri postbitteri* Mei and Wardlaw. – JIN et al. 2001, pl. 1, figs. 2-5. – HENDERSON, MEI and WARDLAW 2002, p. 735, pl. 2, figs. 1-7. – WANG and XIA 2004, p. 33.3, A-C

**Description:** A subspecies of *Clarkina* characterized by a Pa element with a rounded posterior termination, a small brim, a long and narrow platform that is widest in the anterior half just posterior to the anterior narrowing where the platform is mildly

upturned; the middle denticles on the carina are spaced, from middle to anterior the denticles are fused; the space between the cusp and the first posterior denticle is obvious and larger than any other on carina; the denticles in the anterior are higher and more fused than the others.

*Clarkina dukouensis* Mei and Wardlaw 1994

Plate 2, figures 7-9, 16, 27-29; plate 3, figure 11

*Clarkina dukouensis* Mei and Wardlaw. – MEI et al. 1994b, pl. 1, figs. 18-19. – MEI et al. 1994c, pl. 1, figs. 1-2, pl. 2, figs. 1-6, 12, 13. – MEI et al. 1998, pl. 5, figs. 8, 9, pl. 8, figs. 10-19, pl. 10, figs. 1-4, 6. – WANG 2000, pl. 2, figs. 1-15. – WANG and XIA 2004, p. 33.3, H-I, Q

**Description:** A species of *Clarkina* characterized by a Pa element with a blunt rounded posterior platform, a high and erect cusp, a developed and smooth adcarinal groove; it is widest in the middle, where the platform is upturned and shrinks suddenly ahead till the forefront; The cusp higher than the denticles on the posterior carina; the denticles near the posterior small and separated, but the denticles become larger and more fused ahead.

*Clarkina asymmetrica* Mei and Wardlaw 1994

Plate 2, figures 12-13, 17, 30; plate 3, figures 1, 12-13

*Clarkina asymmetrica* Mei and Wardlaw. – MEI et al. 1994c, pl. 1, figs. 12, 15, 16

**Description:** A species of *Clarkina* characterized by a Pa element with a short platform, squared posterior platform termination, a moderate cusp and upturned platform margin; the carina composed of several denticles, and the middle denticles fused, posterior three denticles much less fused than middle denticles; the denticles increasing in size from posterior to anterior, a small gap between the first posterior denticle and the cusp or the second posterior denticle or both; the inner platform flat and the outer platform slightly convex; the platform narrowing earlier

on the inner side than the outer side, so the conodont is dissymmetric.

***Clarkina guangyuanensis* Dai and Zhang 1989**

Plate 2, figures 18-19

*Neogondolella guangyuanensis* DAI and ZHANG 1989, p. 42, figs. 8-10. – ZHANG, DAI, and TIAN 1984, pl. 2, figs. 12-13. – WANG and DONG 1991 (part), p. 48, pl. 2, figs. 4, 10, 11. – WANG 1993, pl. 52, fig. 7. – TIAN 1993, pl. 20, figs. 13-15

*Clarkina guangyuanensis* (Dai and Zhang). – MEI et al. 1994c, pl. 1, figs. 1, 10. – WANG and XIA 2004, p. 33, figs. R-S

**Description:** A species of *Clarkina* characterized by a Pa element with a short and wide, symmetrical platform; a prominent gap in the posterior denticulation that occurs either between the cusp and the posterior denticle or between the posterior-most and second denticles; this species is shaped like a guitar; the posterior wider and the posterior margin more narrow; the carina lower but arrived the posterior margin and composed of

low denticles; the cusp isn't obvious; the adcarinal groove wide but shallow.

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**PLATE 1**

Each caption is given in the following order: angle of view, sample number, and scanning electron microscopy-negative number.

Scale bar = 100µm. All these conodonts are preserved in the

Fission Tracking Dating Laboratory, China University of Geosciences, Wuhan, China.

Figs. 1-3, 10, 22. *Jinogondolella shannoni* Wardlaw 1998

- 1 oblique lateral view, IIIB 2-2, 1218;
- 2 oblique lateral view, IIIB 2-5, 1213;
- 3 oblique lateral view, IIIB 2-5, 1215;
- 10 oblique lateral view, IIIB 12-5, 1226;
- 22 oblique lateral view, 54, 6131.

Figs. 4-5, 11-13, 24-25. *Jinogondolella altudaensis* (Kozur 1992)

- 4 oblique lateral view, IIIB 4-2, 2495;
- 5 oblique lateral view, IIIB 8-2, 2512;
- 11 oblique lateral view, IIIB 10-6, 2516;
- 12 upper view, IIIB 11-1, 1200
- 13 oblique lateral view, IIIB 12-5, 2504;
- 24 oblique lateral view, 56-2, 6138;
- 25 upper view, 54, 6130.

Figs. 6, 14-15. *Jinogondolella xuanhanensis* Mei and Wardlaw 1998

- 6 oblique lateral view, IIIB 9-3, 1224
- 14 oblique lateral view, IIIB 11-1, 1208;
- 15 oblique lateral view, IIIB 12-1, 1217.

Figs. 7-9, 27-28. *Jinogondolella granti* Mei and Wardlaw 1998

- 7 upper view, IIIB 10-3, 2951;
- 8 upper view, IIIB 10-6, 2965;
- 9 upper view, IIIB 11-2, 2977;
- 27 oblique lateral view, 52-1, 6128;
- 28 upper view, IIIB 16-7, ZHL76-013.

Fig. 16. *Jinogondolella crofti* (Mei and Wardlaw 1998)

- 16 oblique lateral view, IIIB 10-5, 2957.

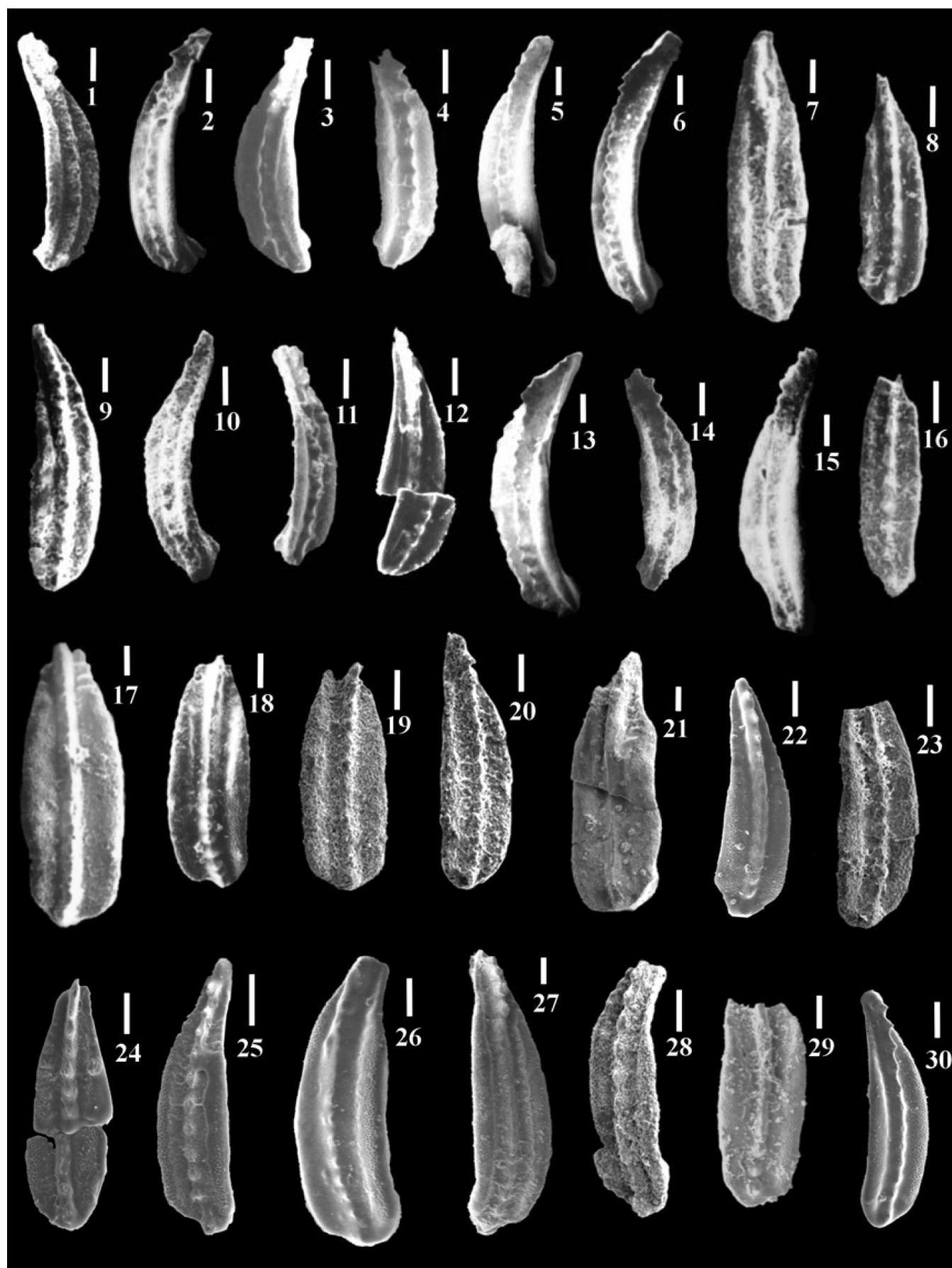
Figs. 17-18. *Jinogondolella postserata* (Behnken 1975)

- 17 upper view, IIIB 10-5, 2956
- 18 upper view, IIIB 11-2, 2962.

Figs. 19-21, 23, 26, 29-30. *Clarkina postbitteri hongshuiensis* Henderson, Mei and Wardlaw 2002

- 19 upper view, IIIB 16-6, ZHL76-012;
- 20 oblique lateral view, IIIB 16-6, ZHL76-011;
- 21 upper view, IIIB 16-8, ZHL76-015;
- 23 oblique lateral view, IIIB 16-8, ZHL76-016;
- 26 oblique lateral view, 52-1, 6127;
- 29 upper view, IIIB(-1)-2, 6143;
- 30 oblique lateral view, 52-1, 6126.





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## PLATE 2

Each caption is given in the following order: angle of view, sample number, and scanning electron microscopy-negative number.

Scale bar = 100µm. All these conodonts are preserved in the

Fission Tracking Dating Laboratory, China University of Geosciences, Wuhan, China.

Figs. 1-2, 5-6, 10, 21. *Clarkina postbitteri hongshuiensis* Henderson, Mei and Wardlaw 2002

- 1 oblique lateral view, IIIB 16-7, ZHL 76-014;
- 2 upper view, XII 52-1, ZHL-002.
- 5 oblique lateral view, IIIB 31, ZHL76-018;
- 6 oblique lateral view, IIIB 31, ZHL76-017;
- 10 oblique lateral view, IIIBII 3, 6146;
- 21 upper view, IIIB 36-1, ZHL76-027.

Figs. 3-4, 11, 15, 22-26. *Clarkina postbitteri postbitteri* Mei and Wardlaw 1994

- 3 upper view, IIIB 31, ZHL76-019;
- 4 upper view, IIIBII 1-1, 6144;
- 11 upper view, IIIB 32-2, ZHL76-022;
- 15 upper view, IIIBII 19-1, 4169;
- 22 upper view, IIIB 36-1, ZHL76-031;
- 23 upper view, IIIB 36-1, ZHL76-029;
- 24 upper view, IIIB 36-1, ZHL76-030;
- 25 upper view, IIIB 40-a, ZHL76-036;
- 26 upper view, IIIB 40-a, ZHL76-037.

Figs. 7-9, 16, 27-29. *Clarkina dukouensis* Mei and Wardlaw 1994

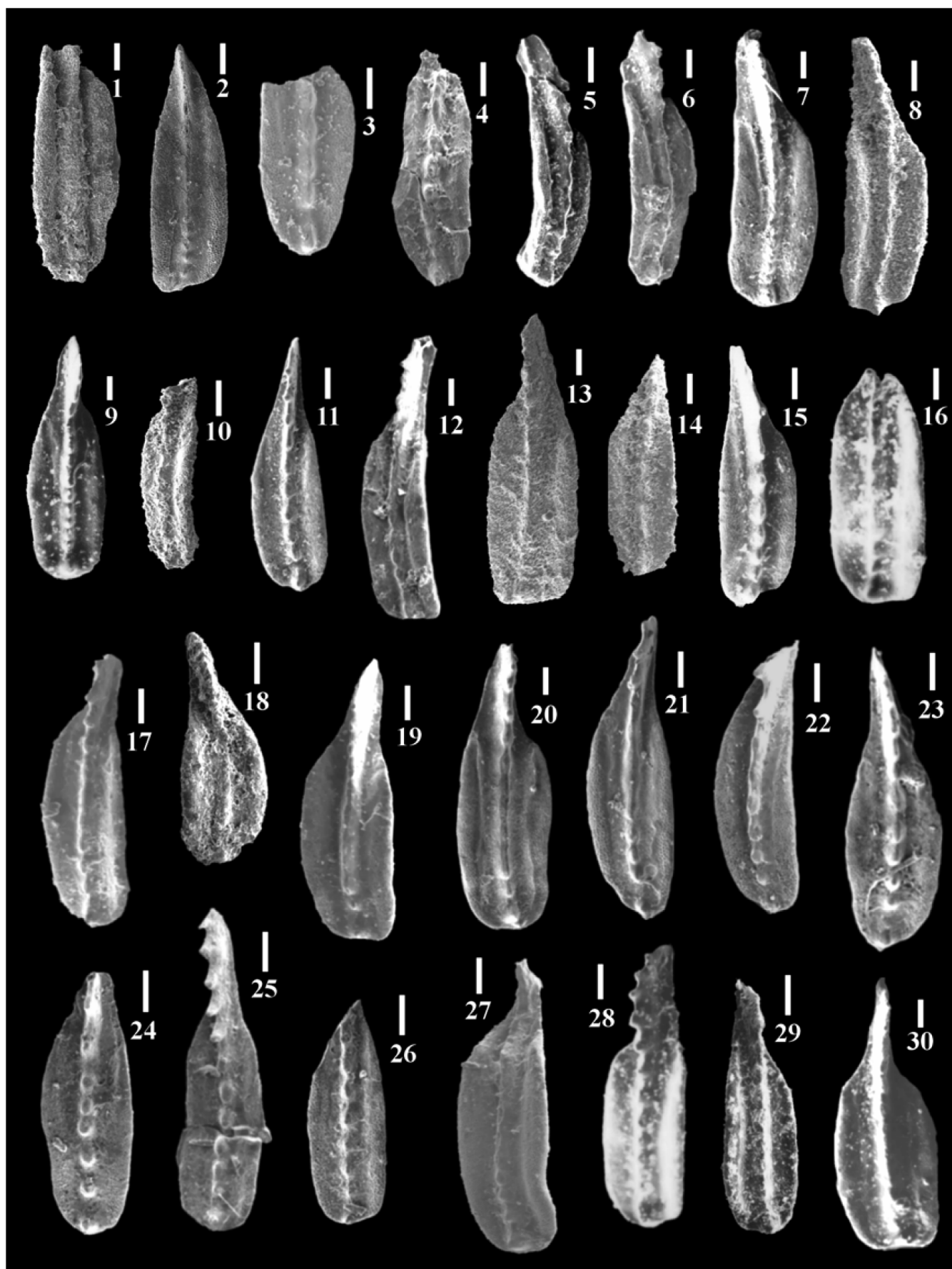
- 7 upper view, ZSJIIIB 32 - 2, ZHL76 - 021;
- 8 upper view, IIIBII 3, 6145;
- 9 upper view, IIIBII 19-1, 4171;
- 16 upper view, ZSJIIIBII 10-1, 4184;
- 27 oblique lateral view, IIIBII 15-4, 5240;
- 28 upper view, IIIBII 17-1, 4177;
- 29 oblique lateral view, IIIBII 19-1, 4172.

Figs. 12-13, 17, 30. *Clarkina asymmetrica* Mei and Wardlaw 1994

- 12 oblique lateral view, IIIB 33-2, ZHL76-024;
- 13 upper view, IIIBII 5, 5226;
- 17 oblique lateral view, IIIBII 14-2, 5233;
- 30 upper view, IIIBII 17-1, 4175.

Figs. 18-20. *Clarkina guangyuanensis* Dai and zhang 1989

- 18 upper view, IIIB 34-2, ZHL76-025;
- 19 upper view, IIIBII 15-4, 5241;
- 20 upper view, IIIB 38-b, ZHL76-033.



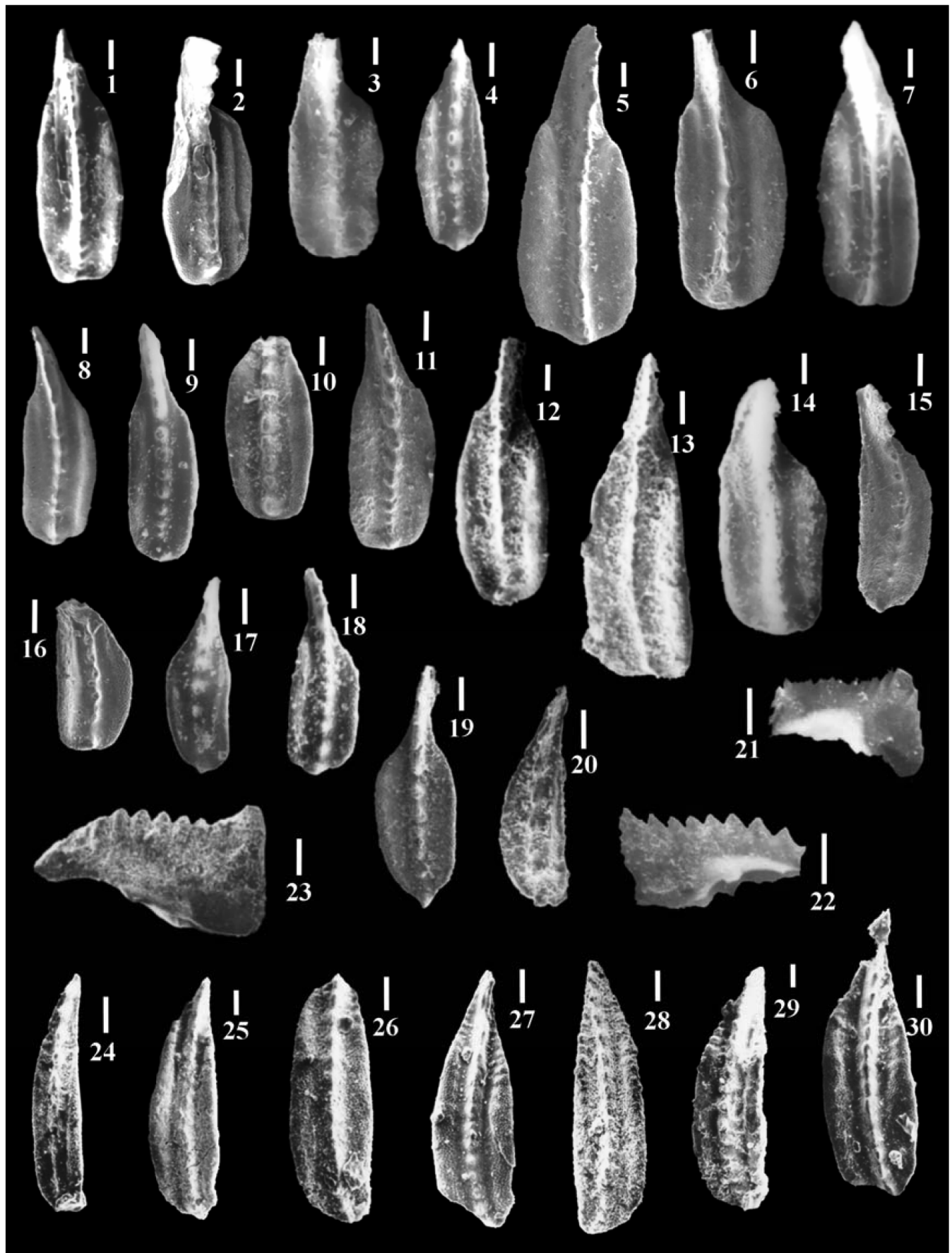


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### PLATE 3

Each caption is given in the following order: angle of view, sample number, and scanning electron microscopy-negative number.  
Scale bar = 100µm. All these conodonts are preserved in the  
Fission Tracing Dating Laboratory, China University of Geosciences, Wuhan, China.

- Figs. 1, 12-13. *Clarkina asymmetrica* Mei and Wardlaw 1994  
1 upper view, IIIBII 20-1, 4168;  
12 upper view, IIIBII 21, 4156;  
13 upper view, IIIBII 21, 4157.
- Figs. 2-3, 14. *Clarkina levini* (Kozur, Mostler and Pjatkova 1975)  
2 oblique lateral view, IIIB 38-b, ZHL76-032;  
3 upper view, IIIBII 19-1, 4170;  
14 upper view, IIIBII 24-3, 4164.
- Figs. 4, 18-19. *Clarkina longicuspidata* Mei et Wardlaw 1994  
4 upper view, IIIBII 20-1, 4167;  
18 upper view, IIIBII 24-3, 4160;  
19 upper view, IIIBII 25-5, 5258.
- Figs. 5-8. *Clarkina transcaucasica* Gullo and Kozur 1992  
5 upper view, IIIBII 20-3, 5248;  
6 upper view, IIIBII 22-4, 5251;  
7 upper view, IIIBII 24-3, 4162;  
8 upper view, IIIBII 24-4, 5256.
- Figs. 9-10. *Clarkina postbitteri postbitteri* Mei and Wardlaw 1994  
9 upper view, IIIBII 25-2, 4159;  
10 upper view, IIIBII 22-4, 4142.
- Fig. 11. *Clarkina dukouensis* Mei and Wardlaw 1994  
11 upper view, IIIBII 25-5, 5259.
- Figs. 15-17. *Clarkina bizarrensis* Mei and Wardlaw 1994  
15 oblique lateral view, IIIBII 23-1, 2135;  
16 oblique lateral view, IIIBII 24-1, 5252;  
17 upper view, IIIBII 24-1, 4166.
- Fig. 20 *Clarkina liangshanensis* (Wang 1978); oblique lateral view, IIIBII 22-1, 4150.
- Fig. 21 *Hindeodus typicalis* (Sweet 1970) lateral view, IIIB 2-5, 1214.
- Figs. 22-23 *Hindeodus minutus* (Ellison 1941)  
22 lateral view, IIIB 4-2, 249
- Figs. 24 -26 *Jinogondolella granti* Mei and Wardlaw 1998  
24 lateral view, IIIB 10-5, 2959;  
25 upper view, IIIB 10-5, 2953;  
26 upper view, IIIB 10-5, 2955.
- Figs. 27 - 29 *Jinogondolella postserata* (Behnken 1975)  
27 upper view, IIIB 10-4, 2946;  
28 upper view, IIIB 11-1, 3000;  
29 lateral view, IIIB 11-2, 2979.
- Fig. 30 *Jinogondolella altudaensis* (Kozur 1992); upper view, IIIB 10-1, 2944.



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