

## SERPUKHOVIAN CONODONT SEQUENCE AND THE VISEAN-SERPUKHOVIAN BOUNDARY IN SOUTH CHINA

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**Key words:** South China, Serpukhovian, Visean-Serpukhovian boundary, conodont sequence.

**Abstract.** This paper describes in detail the conodont sequence of Upper Visean (equivalent to Tatangian of China), Serpukhovian (equivalent to Duwuan of China) and the base of Bashkirian (equivalent to Luosuan of China) in South China. The following conodont zones can be recognized in descending order: *Declinognathodus noduliferus*, *Gnathodus bilineatus bollandensis*, *Lochriea cruciformis*, *L. ziegleri* and *L. nodosa* zones. The first occurrences of *Lochriea ziegleri* and *D. noduliferus* (or *D. lateralis*) are considered as the bases of Serpukhovian and Bashkirian, respectively. The correlation of the conodont sequence from Upper Visean to the base of Bashkirian between South China and the Moscow Basin, South Urals, Great Britain, Ireland and North America is discussed.

**Riassunto.** Questo articolo descrive in dettaglio la successione a conodonti del Viseano superiore (equivalente al Tatangian della Cina), del Serpukhoviano (equivalente al Duwuan della Cina) e la base del Bashkiriano (equivalente al Luosuan della Cina) in Cina meridionale. In ordine discendente sono distinte le seguenti zone a conodonti: *Declinognathodus noduliferus*, *Gnathodus bilineatus bollandensis*, *Lochriea cruciformis*, *L. ziegleri* e *L. nodosa*. Il primo ritrovamento di *Lochriea ziegleri* e *D. noduliferus* (o *D. lateralis*) sono considerati indicativi rispettivamente della base del Serpukhoviano e del Bashkiriano. Sono discusse le correlazioni di questa successione a conodonti dal Viseano superiore alla base del Bashkiriano, tra Cina meridionale e Bacino di Mosca, Urali meridionali, Gran Bretagna, Irlanda e Nord America.

### Introduction

Upper Visean and Serpukhovian marine sediments are widely distributed and well developed in South China, especially in Guizhou and Guangxi. In many places, such as at the Nashui section near Luodian of Guizhou and Baping section near Nandan of Guang-

xi, they form a continuous sequence of limestone containing conodonts and foraminifers, providing an excellent opportunity to study the Visean-Serpukhovian and mid-Carboniferous boundaries and the conodonts of this interval.

Only a few papers, such as Xiong & Zhai (1985), Wang et al. (1987), Dong et al. (1987), Wang & Higgins (1989), Wang (1990) and Zhang (2000) roughly reported on the conodont zonation of this interval in South China. The conodont zonation can be summarized in the descending order as follows: *Gnathodus bilineatus bollandensis* and *Lochriea nodosa* zones. Last year, the present authors collected conodont samples systematically and abundantly again from Upper Visean to the base of Pennsylvanian (Luosuan) at the Nashui section near Luodian of Guizhou. The purpose of this study is to investigate the Upper Visean and Serpukhovian conodont zones, Visean-Serpukhovian boundary and to correlate them with the rest of the world. The development of the conodont zonation in the Nashui section of Luodian, Guizhou can be shown in the Tab. 1. In China, the *Lochriea cruciformis* and *L. ziegleri* zones are first reported in this paper.

### Conodont distribution at the Nashui section

The representative section of the Upper Visean and Serpukhovian in South China is the Nashui section, located at latitude 25°15'03.9"N and longitude 106°29'06.9"E, exposed on the side of the Wangmo-Luodian highway, about 45 km southwest of Luodian town (Fig. 1). The strata in the Nashui section are

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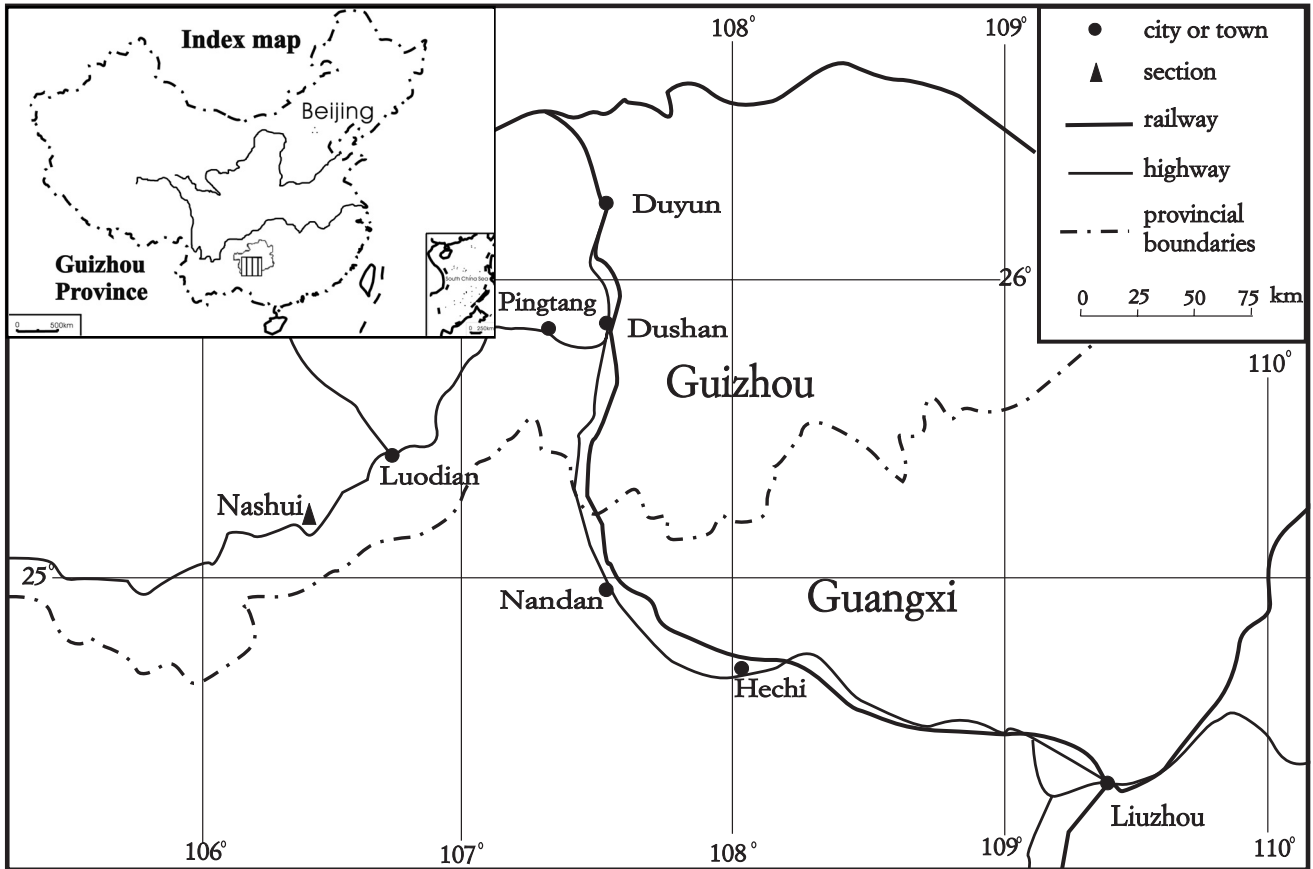


Fig. 1 - Locality map of the Nashui section of Luodian, Guizhou.

This paper		Xiong and Zhai, 1985		Wang et al., 1987; Wang and Higgins, 1989		Zhang, 2000	
Stages	Conodont Zone	Formation	Conodont Zone	Stages	Conodont Zone	Stages	Conodont Zone
Bashkirian Luosuan	<i>Declinognathodus noduliferus</i>	Huashiban	<i>D. lateralis</i>	Luosuan	<i>D. noduliferus</i>	Luosuan	<i>D. noduliferus</i>
Serpukhovian Duwuan	<i>Gnathodus bilineatus bollandensis</i> <i>Lochriea cruciformis</i> <i>L. ziegleri</i>	Shangruiya (part)	<i>G. bilineatus bilineatus</i>	Tatangian (part)	<i>G. bilineatus bollandensis</i>	Duwuan	<i>Adetognathus lautus</i> <i>G. bilineatus bollandensis</i> <i>A. unicornis</i>
Visean Tatangian	<i>L. nodosa</i>		<i>G. bilineatus</i>				Tatangian

Tab. 1 - The course of change and development in conodont zonation from Upper Visean to the base of Bashkirian at the Nashui section of Luodian, Guizhou.

mainly composed of black, dark-grey and grey thin- to medium-bedded wackestone and chert, with normal graded bedding and massive bedding, representing basin-marginal, gentle-slope deposits. The biota is characterized by planktonic and benthic faunas, which have been found in association. The benthic fauna is composed of fusuline and non-fusuline foraminifers; however the nekton fauna is very rich in conodonts. This section was described by Xiong & Zhai (1985) and Wang Zhi-hao & Higgins (1989). Some conodont specimens, which were referred to *Gnathodus bilineatus bollandensis* in Wang & Higgins' paper (1989), are referred to *Gnathodus prebilineatus* in this paper. For example, the specimen (pl.12, fig. 9), which was referred

to *G. bilineatus bollandensis*, is *Gnathodus praebilineatus*. *Gnathodus praebilineatus* is very similar to *G. bilineatus bollandensis*, but can be distinguished from the latter by its not completely developed inner parapet. After restudy, the description of the Nashui section is as follows:

6. Dark grey thick-bedded wackestone and thin-bedded chert in alternate layers, 25.28 m

N25 *Declinognathodus lateralis*, *D. noduliferus*, *Cavusgnathus naviculus*, *C. unicornis*, *Gnathodus bilineatus bilineatus*, *G. bilineatus bollandensis*, *Lochriea commutata*, *L. mononodosa*, *L. multinodosa*, *L. nodosa*, *L. zieglerei*

N23 *Gnathodus bilineatus bilineatus*, *G. bilineatus bollandensis*, *Lochriea commutata*, *L. nodosa*, *L. zieglerei*

N22 *Gnathodus bilineatus bilineatus*, *G. bilineatus bollandensis*, *Lochriea commutata*, *L. nodosa*, *L. zieglerei*

N21 *Lochriea commutata*, *L. mononodosa*, *L. nodosa*

N20 *Gnathodus bilineatus bilineatus*, *G. bilineatus bollandensis*, *Lochriea commutata*, *L. cruciformis*

N19 *Gnathodus bilineatus bilineatus*, *G. bilineatus bollandensis*, *Lochriea commutata*

N18 *Gnathodus bilineatus bollandensis*, *Lochriea commutata*, *L. nodosa*

5. Alternating of dark-grey medium-bedded wackestone and chert, 23.15 m

N17 *Gnathodus bilineatus bollandensis*, *Lochriea commutata*, *L. nodosa*, *L. zieglerei*, *Mestognathus bipluti*, *Pseudognathodus homopunctatus*

N16 *Gnathodus bilineatus bilineatus*, *Lochriea commutata*

N15 *Gnathodus bilineatus bilineatus*, *Lochriea commutata*, *L. nodosa*, *Mestognathus bipluti*

N14 *Gnathodus bilineatus bilineatus*, *Lochriea commutata*, *L. nodosa*, *L. senckenbergica*

N13 *Gnathodus bilineatus bilineatus*, *Lochriea commutata*, *L. nodosa*

N12 *Gnathodus bilineatus bilineatus*, *Lochriea commutata*, *L. nodosa*

N11 *Gnathodus bilineatus bilineatus*, *Lochriea commutata*

4. Dark-grey massive wackestone, 2.4 m

N10 *Gnathodus bilineatus bilineatus*, *Lochriea commutata*

3. Grey to dark-grey thin to medium-bedded wackestone (3-30 cm thick for a layer) containing chert layers, 25.15 m

N9 *Gnathodus bilineatus bilineatus*, *G. praebilineatus*, *Lochriea commutata*

N8 *Cavusgnathus naviculus*, *Gnathodus bilineatus bilineatus*, *Lochriea commutata*, *L. cruciformis*, *L.*

*nodosa*, *L. zieglerei*, *Mestognathus bipluti*, *Pseudognathodus homopunctatus*

N7 *Cavusgnathus naviculus*, *Gnathodus bilineatus bilineatus*, *Lochriea commutata*, *L. zieglerei*, *Mestognathus bipluti*, *Pseudognathodus homopunctatus*

N6 *Gnathodus bilineatus bilineatus*, *Lochriea commutata*, *L. mononodosa*, *L. nodosa*, *L. zieglerei*, *Mestognathus bipluti*, *Pseudognathodus homopunctatus*

N5 *Gnathodus bilineatus bilineatus*, *Lochriea commutata*, *L. mononodosa*, *L. zieglerei*

N4 *Gnathodus bilineatus bilineatus*, *G. praebilineatus*, *Lochriea commutata*, *L. mononodosa*, *L. nodosa*, *L. zieglerei*, *Mestognathus bipluti*, *Pseudognathodus homopunctatus*

N3 *Gnathodus bilineatus bilineatus*, *G. praebilineatus*, *Lochriea commutata*, *L. mononodosa*, *L. nodosa*, *Pseudognathodus homopunctatus*

2. Dark-grey thick-bedded wackestone, 0.84 m

N2 *Gnathodus bilineatus bilineatus*, *Lochriea commutata*, *L. nodosa*, *Mestognathus bipluti*

1. Grey medium-bedded wackestone (14-23 cm thick for a layer) intercalated with chert layers, 2.00 m

N1 *Gnathodus bilineatus bilineatus*, *G. praebilineatus*, *Lochriea commutata*, *L. mononodosa*, *L. nodosa*, *Mestognathus bipluti*, *Pseudognathodus homopunctatus*

The vertical distribution of conodonts is shown in the Fig. 2.

### Conodont zonation

Based on the vertical distribution of conodonts at the Nashui section the following conodont zonation in the descending order can be recognized:

Bashkirian (Luosuan of China)

*Declinognathodus noduliferus* Zone

Serpukhovian (Duwuwan of China)

*Gnathodus bilineatus bollandensis* Zone

*Lochriea cruciformis* Zone

*L. zieglerei* Zone

Upper Visean (Tatangian of China)

*L. nodosa* Zone

*Declinognathodus noduliferus* Zone

The base of this zone coincides with that of Luosuan at the Nashui section, beginning from sample N25. It is marked by the first occurrence of *Declinognathodus noduliferus* or *D. lateralis*, associated with *Cavusgnathus naviculus*, *C. unicornis*, *Gnathodus bilineatus bollandensis*, *G. bilineatus bilineatus*, *Lochriea commutata*, *L. multinodosa*, *L. nodosa*, *L. senckenbergica*. This level is very close to the base of the foraminifer *Millerella marblensis-Eostaffella postmosquensis* Zone (N26) and is considered to be the base of the Bashkirian (Luo-

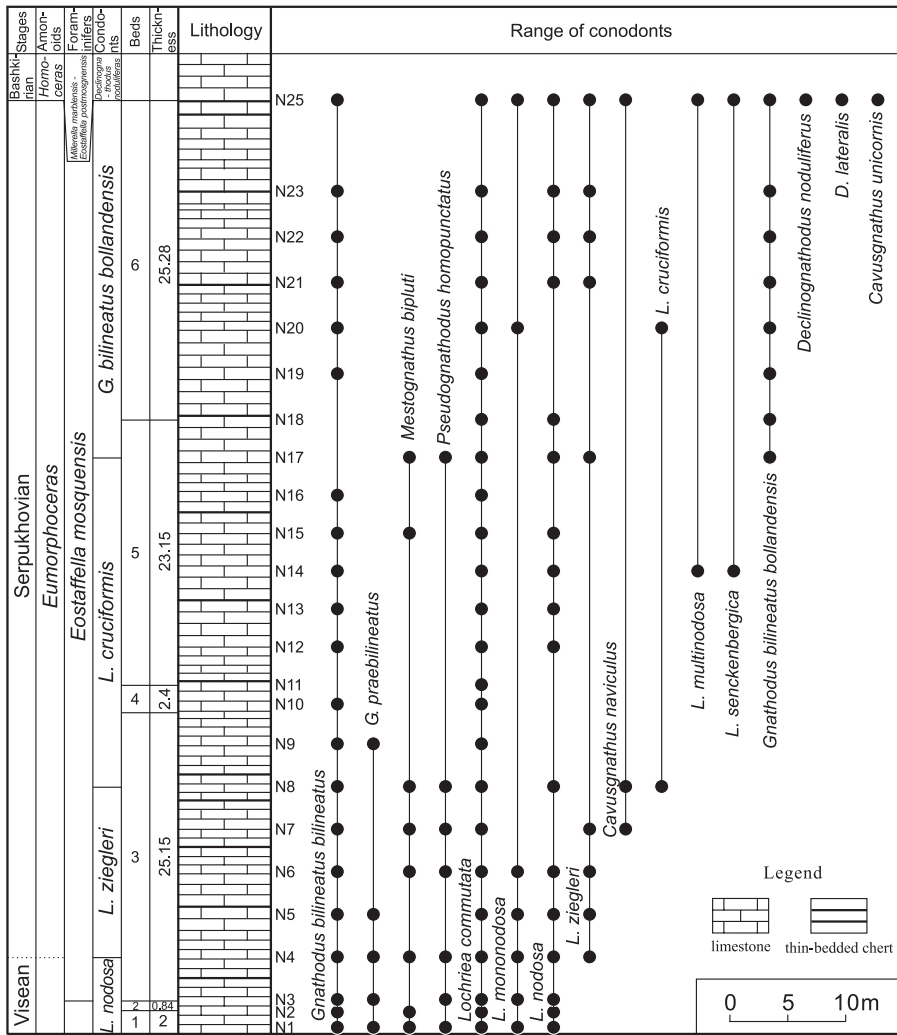


Fig. 2 - Vertical distribution of conodont species and conodont zones from the Upper Visean to the base of Bashkirian in the Nashui section of Luo-dian, Guizhou.

*mononodosa*, *L. nodosa*, *L. senckenbergica*, *Mestognathus bipluti* and *Pseudognathodus homopunctatus*.

#### *Lochriea ziegleri* Zone

This zone, covers an interval of about 15 m, corresponding to samples N4-7. Its lower and upper boundaries are marked by the first occurrences of *Lochriea ziegleri* and *L. cruciformis*, respectively. In addition to the zonal species, other main species include *Cavusgnathus naviculus*, *Gnathodus bilineatus bilineatus*, *G. praebilineatus*, *Lochriea commutata*, *L. mononodosa*, *L. nodosa*, *Mestognathus bipluti* and *Pseudognathodus homopunctatus*.

#### *Lochriea nodosa* Zone

This zone occurs at the base of the section. The first occurrences of *Lochriea nodosa* and *L. ziegleri* indicate its lower and upper boundaries respectively. In addition to the zonal species, other main species include *Gnathodus bilineatus bilineatus*, *G. praebilineatus*, *Lochriea commutata*, *L. mononodosa*, *Mestognathus bipluti* and *Pseudognathodus homopunctatus*.

#### Correlation

1. Correlation with the Moscow Basin and South Urals

According to Nikolaeva et al. (2002), in the Upper Visean and Serpukhovian of Moscow Basin and South Urals, the following conodont sequence in ascending order can be recognized: *Gnathodus bilineatus bilineatus*, *Lochriea mononodosa*, *L. nodosa*, *L. ziegleri* (beds), *L. cruciformis*, *Gnathodus bilineatus bollandensis* zones. Based on the first occurrences of the zonal species, such as *Lochriea nodosa*, *L. ziegleri*, *L. cruciformis* and *Gnathodus bilineatus bollandensis*, the cono-

suans of China). So it is also the mid-Carboniferous boundary here.

#### *Gnathodus bilineatus bollandensis* Zone

This zone, represented by samples N17-24, covers an interval of about 25 m. Its base and top are marked by the first occurrences of *Gnathodus bilineatus bollandensis* and *Declinognathodus noduliferus* or *D. lateralis*, respectively. In addition to the zonal species the other common species include *Gnathodus bilineatus bilineatus*, *Lochriea commutata*, *L. mononodosa*, *L. nodosa*, *L. ziegleri*, *Mestognathus bipluti* and *Pseudognathodus homopunctatus*.

#### *Lochriea cruciformis* Zone

This zone represented by the samples N8-16, covers an interval of about 29 m. Its base and top are marked by the first occurrences of *Lochriea cruciformis* and *Gnathodus bilineatus bollandensis*, respectively. In addition to the zonal species, the common species include *Cavusgnathus naviculus*, *Gnathodus bilineatus bilineatus*, *G. praebilineatus*, *Lochriea commutata*, *L.*

South China This paper				Moscow Basin and South Urals Nikolaeva et al. (2002)		Great Britain and Ireland Higgins (1975,1985)		North America Lane & Straka (1974); Lane & Brenckle (2001)	
Stages	Conodont Zone	Foraminifer Zone	Ammonoid Zone	Stages	Conodont Zone	Stages	Conodont Zone	Stages	Conodont Zone
Bashkirian Lucasian	<i>Declinognathodus noduliferus</i>	<i>Millerella marblensis</i> - <i>Eostaffella postmosquensis</i>	<i>Homoceras</i>	Serpukhovian	<i>Declinognathodus noduliferus</i>		<i>Declinognathodus noduliferus</i>	Morrowan	<i>Declinognathodus noduliferus</i> - <i>Rhachistognathus primus</i>
Serpukhovian Duwuan	<i>Gnathodus bilineatus bollandensis</i>	<i>Eostaffella mosquensis</i>	<i>Eumorphoceras</i>	Serpukhovian	<i>Gnathodus bilineatus bollandensis</i>	Namurian	<i>Gnathodus bilineatus bollandensis</i>	Chesterian (part)	<i>R. muricatus</i>
	<i>L. cruciformis</i>				<i>L. cruciformis</i>		<i>Gnathodus girtyi simplex</i> - <i>Kladognathus</i>		<i>Adetognathus unicornis</i>
	<i>L. ziegleri</i>				<i>L. ziegleri</i> beds				<i>Cavusgnathus naviculus</i>
Visean Tatangian	<i>Lochriea nodosa</i>			Visean	<i>L. nodosa</i>	Visean	<i>Gnathodus girtyi collinsoni</i>		<i>Gnathodus bilineatus (upper part)</i>

Tab. 2 - International correlation of conodont zones from Upper Visean to the base of Bashkirian.

dont sequence of the Moscow Basin and South Urals can be directly correlated with that of South China (Tab. 2).

### 2. Correlation with Great Britain and Ireland

According to Higgins (1975, 1985), the following conodont sequence of Upper Visean and Lower Namurian in Great Britain and Ireland in the descending order has been established: *Gnathodus bilineatus bollandensis*, *G. girtyi simplex* and *G. girtyi collinsoni* zones. Based on the characteristic species *Lochriea nodosa* in both areas, the interval from *Gnathodus girtyi collinsoni* Zone to *G. girtyi simplex* Zone of Great Britain and Ireland can be correlated with that from *Lochriea nodosa* Zone to *L. cruciformis* Zone of South China. The *Gnathodus bilineatus bollandensis* Zone in the both areas can be correlated directly (Tab. 2).

### 3. Correlation with North America

According to Lane & Straka (1974), Lane et al. (1999) and Lane & Brenckle (2001), the following conodont sequence of Chesterian (part) to the base of Morrowan in North America in the descending order can be recognized: *Declinognathodus noduliferus*-*Rhachistognathus primus*, *R. muricatus*, *Adetognathus unicornis*, *Cavusgnathus naviculus* and *Gnathodus bilineatus* zones. Based on the first occurrence of *Declinognathodus noduliferus*, the base of the *Declinognathodus noduliferus* Zone of South China can be correlated with the *D. noduliferus*-*Rhachistognathus primus* Zone of North America. Based on the occurrences of *Cavusgnathus naviculus* in both areas, the base of the *Cavusgnathus naviculus* Zone of North America is within the upper part of the *Lochriea ziegleri* Zone of South China. According to Higgins (1975), Wang Zhi-hao & Higgins (1989), and Nemyrovska (1999), the *Gnathodus bilineatus bollandensis* Zone of Europe can be correlated with *Rhachistognathus muricatus* and *Adetognathus unicornis* zones of North America. So present

*Gnathodus bilineatus bollandensis* Zone of South China can be correlated with the *Rhachistognathus muricatus* and *Adetognathus unicornis* zones of North America too (Tab. 2).

### About the Visean-Serpukhovian boundary

As mentioned by Nikolaeva et al. (2002), the closest level to the ammonoid-based Visean-Serpukhovian boundary is the base of the *Lochriea cruciformis* Zone. So the base of the *Lochriea cruciformis* Zone is recommended as the base of Serpukhovian. But at the Nashui section, the first occurrence of *Lochriea ziegleri* (N4) is very close to the base of the foraminifer *Eostaffella postmosquensis* Zone (N3), which is the index zone of Duwuan in China. In China Duwuan only has one foraminifer *Eostaffella postmosquensis* Zone, which is equivalent to the ammonoid *Eumorphoceras* Zone (Zhang 2000). So the present authors suggested that the first occurrence of *Lochriea ziegleri* be a good marker for the base of Serpukhovian or Duwuan of China. As pointed by Nikolaeva et al. (2002), *Lochriea cruciformis* is rare in the South Urals and its representatives are morphologically different from the type specimen and are somewhat similar to *L. costata* and *L. ziegleri*. They also pointed that the species *Lochriea ziegleri* is more frequent, and it is probably a better choice as a boundary marker in the South Urals. In the evolutionary lineage *Lochriea nodosa*-*L. ziegleri*-*L. cruciformis*, the changes from *L. nodosa* to *L. ziegleri* is much obvious than that from *L. ziegleri* to *L. cruciformis*. In the Nashui section of Luodian, *Lochriea ziegleri* is much more abundant and characteristic and can be distinguished very easily. So it is the reason that *Lochriea ziegleri* is the index species for the base of Serpukhovian or Duwuan of China.

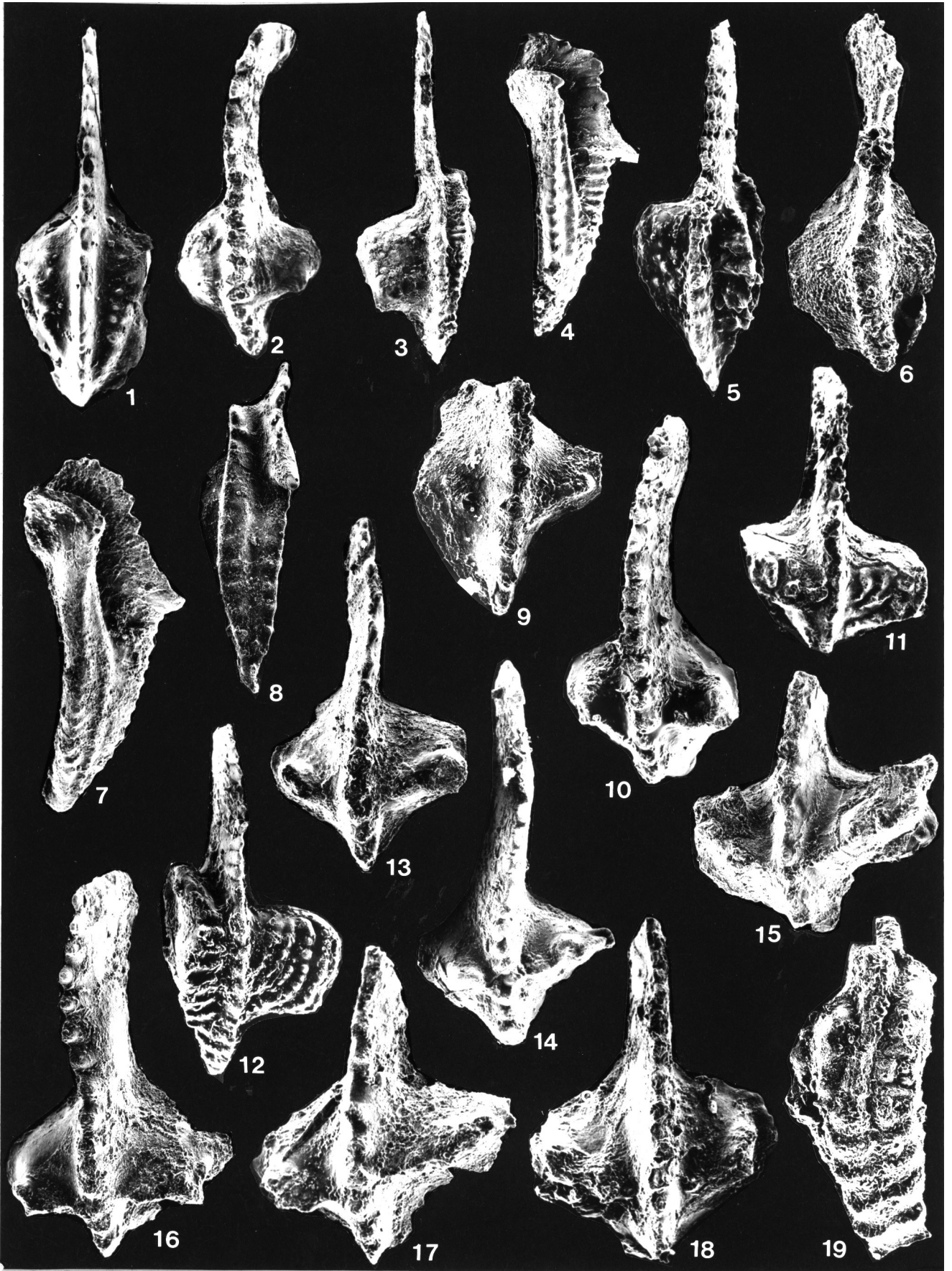
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PLATE 1

(Note: All of the specimens figured in the plate are from the Carboniferous strata in the Nashui section, Luodian of Guizhou. They are deposited in Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences)

- |            |  |                 |   |
|------------|--|-----------------|---|
| Fig. 1     | - <i>Pseudognathodus homopunctatus</i> Ziegler: Oral view, x80, Col. no. N1, Cat. no. 99005.                 | Fig. 8          | - <i>Cavusgnathus naviculus</i> (Hinde): Oral view, x66, Sample N8, Cat. no. 136030.  |
| Fig. 2, 10 | - <i>Lochriea nodosa</i> (Bischoff): Oral views, x90, 70, Samples N4, 2, Cat. nos. 136027, 99095.            | Fig. 9          | - <i>Lochriea mononodosa</i> (Rhodes, Austin & Druce): Oral view, x133, Sample N5, Cat. no. 136031.   |
| Fig. 3     | - <i>Gnathodus bilineatus bollandensis</i> Higgins & Bouckaert: Oral view, x40, Sample N17, Cat. no. 136028. | Fig. 11         | - <i>Lochriea multinodosa</i> (Wirth): Oral view, x60, Sample N14, Cat. no. 136032.   |
| Fig. 4, 7  | - <i>Mestognathus bipluti</i> Higgins: Lateral views, x50, Sample N2, Cat. nos. 99033, 99037                 | Fig. 12         | - <i>Gnathodus bilineatus bilineatus</i> (Roundy): Oral view, x60, Sample N2, Cat. no. 99077.   |
| Fig. 5     | - <i>Gnathodus praebilineatus</i> Belka: Oral view, x80, Sample N9, Cat. no. 99145.                          | Fig. 13, 16     | - <i>Lochriea cruciformis</i> (Clarke): Oral views, x80, Sample N8, Cat. nos. 136033, 136034.   |
| Fig. 6     | - <i>Lochriea commutata</i> (Branson & Mehl): Oral view, x80, Sample N25, Cat. no. 136029.                   | Fig. 14, 17, 18 | - <i>Lochriea zieglerei</i> Nemirovskaya, Perret & Meischner: Oral views, x53, 100, 100, Samples N8, 4, 8, Cat. nos. 99096, 136035, 136036. |
|            |  | Fig. 15         | - <i>Lochriea senckenbergica</i> Nemirovskaya, Perret & Meischner: Oral view, x80, Sample N25, Cat. no. 136037.                             |
|            |  | Fig. 19         | - <i>Declinognathodus lateralis</i> (Higgins & Bouckaert): Oral view, x100, Sample N25, Cat. no. 136038.                                    |



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