| Rivista Italiana di Paleontologia e Stratigrafia | volume 109 | no. 3 | 4 pls. | pp. 379-397 | November 2003 |
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# UPPER CARBONIFEROUS (PENNSYLVANIAN) CONODONTS FROM SOUTH GUIZHOU OF CHINA

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*Received February 13, 2002; accepted April 22, 2003*

*Key-words*: Upper Carboniferous (Pennsylvanian), conodonts, Guizhou, China.

*Abstract.* This paper describes in detail the conodont sequence of the Upper Carboniferous (Pennsylvanian) and the upper and lower boundaries in this interval at the Nashui section in Luodian, South Guizhou. The following 23 conodont zones, in descending order, can be recognized: *Streptognathodus isolatus, S. wabaunsensis, S. tenuialveus, S. firmus, S. nashuiensis, S. simulator, S. guizhouensis, S. gracilis-S. excelsus, S. cancellosus, S. clavatulus, S. nodocarinatus, Idiognathodus podolskensis, Mesogondolella clarki-Idiognathodus robustus, Diplognathodus orphanus-D. ellesmerensis, Idiognathoides ouachitensis, Streptognathodus expansus, Idiognathoides sulcatus parvus, Neognathodus bassleri-Idiognathodus primulus, N. symmetricus-Idiognathodus primulus, N. symmetricus, Idiognathoides corrugatus-I. pacificus, I. sinuatus, I. sulcatus sulcatus* and *Declinognathodus noduliferus* zones. The first occurrences of *Streptognathodus isolatus* and *Declinognathodus nodulirerus* are recognized at the bases of the Permian and the Upper Carboniferous (Pennsylvanian), respectively. The Upper Carboniferous (Pennsylvanian) conodont sequences are discussed and based on these conodont sequences, correlations between Upper Carboniferous (Pennsylvanian) Stages in Chinese and Russian sections, as well as North America are discussed. Additionally, eight new conodont species are also described in this paper.

*Riassunto.* L'articolo descrive in dettaglio la successione a conodonti del Carbonifero superiore ed i suoi limiti inferiore e superiore nella sezione di Nashui nel Guizhou meridionale, Cina. Sono state distinte in ordine discendente, le seguenti 23 zone a conodonti: *Streptognathodus isolatus, S. wabaunsensis, S. tenuialveus, S. firmus, S. nashuiensis, S. simulator, S. guizhouensis, S. gracilis-S. excelsus, S. cancellosus, S. clavatulus, S. nodocarinatus, Idiognathodus podolskensis, Mesogondolella clarki-Idiognathodus robustus, Diplognathodus orphanus-D. ellesmerensis, Idiognathoides ouachitensis, Streptognathodus expansus, Idiognathoides sulcatus parvus, Neognathodus bassleri-Idiognathodus primulus, N. symmetricus-Idiognathodus primulus, N. symmetricus, Idiognathoides corrugatus-I. pacificus, I. sinuatus, I. sulcatus sulcatus* e *Declinognathodus noduliferus*. La prima presenza di *Streptognathodus isolatus* e di *Declinognathodus nodulirerus* sono utilizzate rispettivamente per definire la base del Permiano e del Carbonifero superiore. In base a questa sequenza vengono discusse le zonazioni a conodonti del Carbonifero superiore e successivamente sono esaminate le correlazioni tra i piani del Carbonifero superiore di Cina, Russia e Nord America. Infine vengono descritte 8 nuove specie di conodonti.

## Introduction

The Carboniferous and Permian marine rocks are widely distributed and well developed in South China, especially in Guizhou. In many places, such as at the Nashui section, a continuous sequence of limestone is exposed, and contains conodonts, fusulinids, other foraminifers, ammonoids, corals and brachiopods; thus providing an excellent opportunity to study the Upper Carboniferous (Pennsylvanian) and its boundaries, and the conodonts of this interval.

During the last two decades, our knowledge of the upper part of the Lower Carboniferous, Upper Carboniferous (Pennsylvanian) and Carboniferous-Permian conodont biostratigraphy in South China, particularly at the Nashui section, has been rapidly advanced. Many papers describing the conodont biostratigraphy of this interval in South China have been published. Based on the references presented by Xiong & Zhai (1985), Dong et al. (1987), Kang et al. (1987), Rui et al. (1987), Wang & Rui (1987), Wang et al. (1987a, 1987b), Zhang et al. (1988), Wang & Higgins (1989), Wang (1991, 1996) and Zhang (2000), the Upper Carboniferous conodont zonation (12 zones) in South China can be summarized. They are, in descending order, the: *Streptognathodus wabaunsensis, S. elongatus, S. elegantulus, S. oppletus, S. parvus, Mesogondolella (= Gondolella) clarki, Idiognathoides sulcatus parvus, Idiognathodus primulus, Neognathodus symmetricus, Idiognathoides sinuatus, I. sulcatus* and *Declinognathodus noduliferus* zones. From 1991 to 2001, the present authors systematically collected numerous conodonts from the uppermost part of the Lower Carboniferous to the Lower Permian at the Nashui section, in Luodian, Guizhou. The purpose of these studies was to investigate and describe the Upper Carboniferous (Pennsylvanian) conodont sequence from the Nashui section in more detail, and to refine correlation with Russia and North America.

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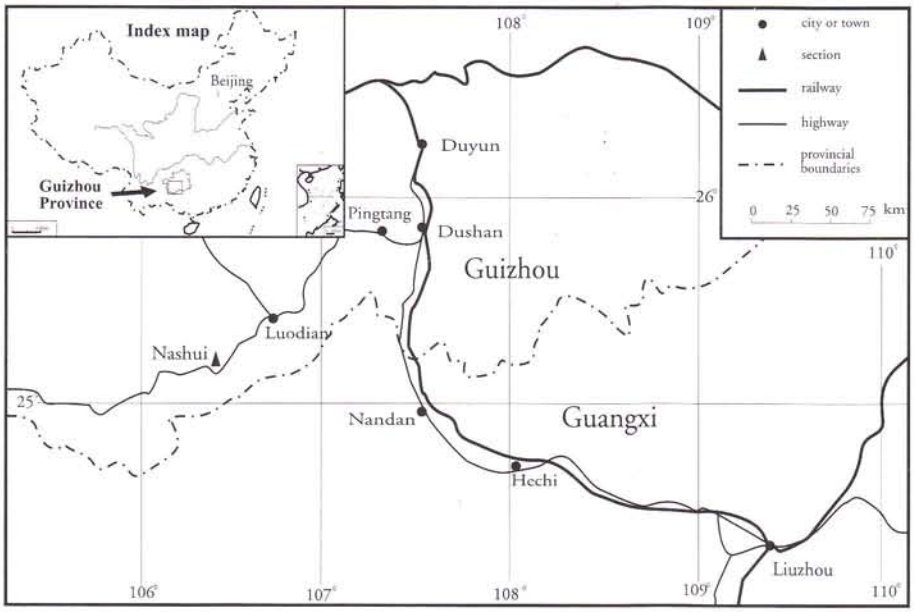



Fig. 1 - Locality map of the studied section.

## Conodont distribution at the Nashui Section

The Upper Carboniferous (Pennsylvanian) section at Nashui, located along the Wangmo-Luodian highway, about 44 km southwest of Luodian town, is easily accessible by car from Guiyang, the capital of Guizhou Province shown in the schematic map (Fig. 1). A continuous sequence of Carboniferous and Lower Permian rocks are well exposed along the east limb of the Nashui brachyanticline. This section was discovered in the 1970s by the Yunnan Institute of Petroleum Geology, Headquarters of Petroleum Prospecting and Exploration. Since then, many geologists have studied this area. References to these previous investigations are contained in: Xiong & Zhai (1985), Rui et al. (1987), Wang et al. (1987a, 1987b), Wang & Rui (1987), Wang & Higgins (1989), and Wang (1991, 1996). During the Upper Carboniferous (Pennsylvanian) this area was situated near the slope of the platform margin, where carbonate deposition by gravity flow occurred. Upper Carboniferous (Pennsylvanian) strata (unnamed formation) at the Nashui section are mainly black, dark-grey and grey thin to medium-bedded wackestone, packstone, grainstone, mudstone and chert beds, with normal grading bedding, and massive bedding. These rocks represent the gentle slope deposits of the basin margin. The biota is characterized by pelagic and benthic forms, which occur in association. The benthic fauna is composed of fusuline and non-fusuline foraminifers, calcareous algae and corals (very rare); however, the pelagic fauna is very rich in conodont. The vertical distribution of the conodonts at the Nashui section is shown in the Fig. 2.

## Conodont zonation

Initial studies of the conodonts at Nashui were by Xiong & Zhai (1985), Wang et al. (1987a), and Wang & Higgins (1989). A conodont zonation for this section was presented in each of these three papers, but with additional samples and restudy of existing samples a more detail conodont zonation is possible. This new zonation, from youngest to oldest rocks, is as follows (Fig. 2).

**Permian**
**Asselian**
25. *Streptognathodus isolatus* Zone

This zone is near the top of the exposure, beginning with the sample N125. The lower limit of the zone is the first occurrence of *Streptognathodus isolatus*, which is associated with *S. longilatus*, *S. tenuialveus*, *S. bellus*, *S. elongatus* and *S. simplex*. The base of the zone corresponds with the base of the fusulinid *Pseudoschwagerina* ex gr. *fusiformis* and *P.* ex gr. *beedei* fauna.

**Upper Carboniferous (Pennsylvanian)**
**Mapingian**
24. *Streptognathodus wabaunsensis* Zone

The N123-124 contain representatives of this zone and occupies about a 3 m interval in the section. The lower and upper limits are marked by the first occurrence of *Streptognathodus wabaunsensis* and *S. isolatus*, respectively.

Fig. 2 - Vertical distribution of conodont species and conodont zones in the Nashui section of Luodian, Guizhou.

Ranges of conodont species
Legend
limestone
siliceous limestone
thin-bedded chert
mudstone
Miss.
Pennsylvanian
Perm.
Duw.
Luosuan
Huashiban
Dalaan
Mapingian
Zis.
Stage
Bed No.
Lithology
Coll. No.
Conodont zones
1 Gnathodus bilineatus bollandensis
2 G. b. bilineatus
3 Lochreia commutata
4 L. nodosa
5 Hindeodus minutus
6 G. girtyi intermedius
7 L. mononodosa
8 Declinognathodus lateralis
9 D. noduliferus noduliferus
10 Cavusgnathus unicornis
11 L. multinodosa
12 D. noduliferus japonicus
13 Idiognathoides sulcatus sulcatus
14 Rhachistognathus prolixus
15 I. sulcatus
16 I. sinuatus
17 D. inaequalis
18 I. pacificus
19 I. corrugatus
20 Neognathodus symmetricus
21 Idiognathodus primulus
22 I. paraprimulus
23 I. subdelicatus
24 Neognathodus bassleri
25 Streptognathodus subsimplex
26 S. parvus
27 Idiognathoides sulcatus parva
28 Idiognathodus nodosus
29 Neolochriea koikei
30 Idiognathodus delicatus
31 S. expansus
32 S. suberectus
33 Idiognathoides tuberculatus
34 Idiognathodus simulosus
35 Idiognathoides ouachitensis
36 Diplognathodus coloradoensis
37 Neognathodus aff. bothrops
38 N. atokaensis
39 N. medadultimus
40 Diplognathodus orphanus
41 D. ellesmerensis
42 Idiognathoides lanei
43 Idiognathodus nemyrovskae
44 Mesogondolella clarki
45 M. subclarki
46 Idiognathodus robustus
47 S. cf. dissectus
48 Idiognathoides tuberculatus
49 Idiognathodus incurvus
50 I. podolskensis
51 S. nodocarinatus
52 S. clavatulus
53 Gondolella donbassica
54 Neognathodus mededultimus
55 Idiognathodus magnificus
56 S. cancellosus
57 S. oppletus
58 Gondolella elegantula
59 S. gracilis
60 S. excelsus
61 Idiognathodus magnificus
62 S. guizhouensis
63 S. elegantulus
64 S. simulator
65 S. luosuensis
66 Adetognathus paralautus
67 I. nashuiensis
68 S. Firmus
69 S. pawhuskaensis
70 S. simplex
71 S. tenuialveus
72 S. bellus
73 S. elongatus
74 S. wabaunsensis
75 S. nodulinearis
76 S. longilatus
77 S. isolatus
Streptognathodus isolatus
Streptognathodus wabaunsensis
Streptognathodus tenuialveus
Streptognathodus firmus
Streptognathodus nashuiensis
Streptognathodus simulator
Streptognathodus guizhouensis
Streptognathodus gracilis-S. excelsus
Streptognathodus cancellosus
Streptognathodus clavatulus
Streptognathodus nodocarinatus
Idiognathodus podolskensis
Mesogondolella clarki-Idiognathodus robustus
Diplognathodus orphanus-D. ellesmerensis
Idiognathoides ouachitensis
Streptognathodus expansus
Idiognathoides sulcatus parva
Idiognathodus primulus-Neognathodus bassleri
Neognathodus symmetricus
Idiognathoides corrugatus - I. pacificus
Idiognathoides sinuatus
Idiognathoides sulcatus sulcatus
Declinognathodus noduliferus
Gnathodus bilineatus bollandensis
0 10 20 30m

In addition to zonal species, other common species in this zone are *Streptognathodus nodulinearis, S. tenuialveus, S. bellus* and *S. elongatus.*

23. *Streptognathodus tenuialveus* Zone

This zone, occupying about a 10 m interval in the section, is represented by the N116-122. The characteristic species are *Streptognathodus tenuialveus* and *S. bellus.* Other common species include *S. firmus, S. elegantulus, S. elongatus* and *S. simplex.* The base and top of this zone are marked by the first occurrence of *S. tenuialveus* and *S. wabaunsensis*, respectively.

22. *Streptognathodus firmus* Zone

This zone extends over about a 6.5 m interval, represented by the N111-115. The base and top of this zone are marked by the first occurrence of *Streptognathodus firmus* and *S. tenuialveus*, respectively. The characteristic species include *Streptognathodus firmus, S. pawhuskaensis* and *S. elegantulus.*

21. *Idiognathodus nashuiensis* Zone

This zone, occupying about a 1m interval between the sample of N110 and N111, represented by the sample N110. The base and top are marked by the first occurrence of *Idiognathodus nashuiensis* and *Streptognathodus firmus* respectively. Another important species is *Adetognathus paralautus.*

**Dalaan**

20. *Streptognathodus simulator* Zone

Approximately a 5.5 m interval contains representatives of this zone and include three (N107-109). The lower and upper limits, respectively, are marked by the first occurrence of *Streptognathodus simulator* or *S. luosuensis* and *Idiognathodus nashuiensis.* The characteristic species are *Streptognathodus simulator* and *S. luosuensis.* Other common species include *Streptognathodus guizhouensis, S. oppletus* and *Adetognathus paralautus.*

19. *Streptognathodus guizhouensis* Zone

This zone occupies about a 12 m interval of the section, represented by the N97-106. In addition to zonal species, other common species include *S. elegantulus, S. oppletus, S. parvus, Idiognathodus delicatus, I. magnificus* and *I. sinuosus.* The first occurrence of *Streptognathodus guizhouensis* and *S. simulator*, respectively, denote the base and top of this zone.

18. *Streptognathodus gracilis-S. excelsus* Zone

This zone, extending about a 12 m interval, represented by the N90-N96, contains the characteristic species *Streptognathodus gracilis* and *S. excelsus.* Other common species include *S. oppletus, S. parvus, S. cancellosus, Idiognathodus delicatus, I. magnificus,* and *I. sinuosus.* The base and top are marked by the first occurrence of *Streptognathodus gracilis* and *S. guizhouensis,* respectively.

17. *Streptognathodus cancellosus* Zone

This zone is represented by the N87- N89, occupying about a 9 m interval, characterized by the occurrence of *Streptognathodus cancellosus.* Other common species are *S. clavatulus, S. parvus, Gondolella elegantula, Idiognathodus delicatus, I. magnificus,* and *I. sinuosus.* The base and top of this zone are marked by the first occurrence of *Streptognathodus cancellosus* and *S. gracilis* or *S. excelsus*, respectively.

16. *Streptognathodus clavatulus* Zone

This zone occupies about a 14 m interval, represented by the N82-86. Its lower and upper limits are marked by the first occurrence of *Streptognathodus clavatulus* and *S. cancellosus*, respectively. In addition to the zonal species, other species of this zone include *Streptognathodus parvus, Idiognathodus delicatus, I. incurvus, Gondolella donbassica, Neognathodus* cf. *bothrops* and *N. medexultimus.*

15. *Streptognathodus nodocarinatus* Zone

This zone, extending about a 16 m interval of the section, is represented by the N75-81. Its base and top are marked by the first occurrence of *Streptognathodus nodocarinatus* and *S. clavatulus*, respectively. In addition to the zonal species, other common species include *S. luodianensis, S. parvus, Idiognathodus incurvus, I. delicatus, I. sinuosus,* and *Mesogondolella clarki.*

14. *Idiognathodus podolskensis* Zone

This zone is represented by the N69-74, occupying about a 10 m interval of the section. The base and top of this zone can be recognized by the first occurrence of *Idiognathodus podolskensis* and *Streptognathodus nodocarinatus*, respectively. In addition to the zonal species, other common species include *I. incurvus, I. delicatus, I. sinuosus, Streptognathodus parvus, Mesogondolella clarki* and *M. subclarki.*

13. *Mesogondolella clarki-Idiognathodus robustus* Zone

This zone extending about a 6.5 m interval of the section is represented by the N64-68. The base and top of this zone are marked by the first occurrence of *Mesogondolella clarki* and *I. podolskensis*, respectively. In addition to the zonal species, other common species include *Mesogondolella subclarki, Diplognathodus coloradoensis, D. orphanus, D. ellesmerensis, Idiognathoides ouachitensis, I. corrugatus, I. sinuatus, I. sulcatus, I. tuburculatus, Idiognathodus delicatus, I. sinuosus, Neognathodus medadultimus* and *Streptognathodus parvus.*

**Huashiban**

12. *Diplognathodus orphanus -D. ellesmerensis* Zone

This zone, occupying about a 10 m interval of the section, represented by the N55-63. Its characteristic species include *Diplognathodus coloradoensis, D. orphanus,* and *D. ellesmerensis.* Other common species are *Idiognathoides lenei, I. ouachitensis, I. pacificus, I. sinuatus, I. corrugatus, I. sulcatus parva, I. sulcatus sulcatus, Idiognathodus delicatus, I. nemyrovskae, I. nodosus, I. subdelicatus, I. sinuosus, Streptognathodus expansus, S. suberectus, S. parvus, Declinognathodus doduliferus noduliferus, Neognathodus atokaensis* and *N.* aff. *bothrops.* The base and top are marked by the first

occurrence of *Diplognathodus orphanus* or *D. ellesmerensis* and *Mesogondolella clarki*, respectively.

11. *Idiognathoides ouachitensis* Zone

This zone, extending through about a 3 m interval, is represented by the N52-54. Its base and top are marked by the first occurrence of *Idiognathoides ouachitensis* and *Diplognathodus ellesmerensis* or *D. orphanus*, respectively. In addition to the zonal species, other common species include *Idiognathoides sinuatus, I. sulcatus sulcatus, Idiognathodus nodosus, Streptognathodus expansus, S. suberectus,* and *Declinognathodus noduliferus noduliferus*.

**Luosuan**

10. *Streptognathodus expansus* Zone

This zone, represented by the N50-51, occupies about a 2 m interval in the section. The base and top are marked by the first occurrence of *Streptognathodus expansus* and *Idiognathoides ouachitensis*, respectively. In addition to the zonal species, other common species include *Streptognathodus suberectus, S. parvus, Idiognathoides pacificus, I. corrugatus, I. sulcatus parva, I. sulcatus sulcatus, I. sinuatus, Declinognathodus noduliferus noduliferus* and *Idiognathodus subdelicatus*.

9. *Idiognathoides sulcatus parva* Zone

This zone, represented by N48-49, occupies about a 2 m interval. The base and top are marked by the first occurrence of *Idiognathoides sulcatus parva* and *Streptognathodus expansus*, respectively. The main species of this zone are *Idiognathoides sulcatus parva, I. sulcatus sulcatus, I. corrugatus, I. sinuatus, Declinognathodus noduliferus noduliferus, Neolochriea koikei* and *Idiognathodus nodosus.*

8. *Idiognathodus primulus- Neognathodus bassleri* Zone

This zone, represented by the N44-47, occupies about a 5 m interval of the section. Its base and top are marked by the first occurrence of *Neognathodus bassleri* and *Idiognathoides sulcatus parva*, respectively. In addition to the zonal species, other main species include *Idiognathodus paraprimulus, Neognathodus symmetricus, Idiognathoides corrugatus, I. pacificus, I. sinuatus, I. sulcatus sulcatus, Declinognathodus noduliferus noduliferus* and *Hindeodus minutus*.

7. *Idiognathodus primulus-Neognathodus symmetricus* Zone

This zone, occupying about a 1.5 m interval from the sample of N43 to N44, is represented by the sample N43. Its base and top are marked by the first occurrence of *Idiognathodus primulus* and *Neognathodus bassleri*, respectively. In addition to the zonal species, other main species include *Idiognathodus paraprimulus, Idiognathoides pacificus, I. sinuatus, I. sulcatus sulcatus, Hindeodus minutus, Declinognathodus noduliferus noduliferus*, and *D. lateralis.*

6. *Neognathodus symmetricus* Zone

This zone, extending about a 5 m interval in the section, is represented by the N39-42. The lower and upper limits of this zone are marked by the first occurrence of *Neognathodus symmetricus* and *Idiognathodus primulus*, respectively. In addition to the zonal species, other main species include *Idiognathoides pacificus, I. corrugatus, I. sinuatus, I. sulcatus sulcatus, Declinognathodus noduliferus noduliferus, Gnathodus bilineatus bilineatus, G. bilineatus bollandensis*, and *Lochreia commutata.*

5. *Idiognathoides corrugatus-I. pacificus* Zone

This zone, occupying a 2 m interval between the sample N38 and N39, is represented by the sample N38. The base and top of this zone are marked by the first occurrence of *Idiognathoides pacificus* or *I. corrugatus* and *Neognathodus symmetricus*, respectively. In addition to the zonal species, other common species of this zone include *Idiognathoides sinuatus, I. sulcatus sulcatus,* and *Declinognathodus noduliferus noduliferus.*

4. *Idiognathoides sinuatus* Zone

Three samples (N35-37), over a 5 m interval, contain conodonts of this zone. It is characterized by the occurrence of *Idiognathoides sinuatus*. Other common species include *Idiognathoides sulcatus sulcatus, Declinognathodus noduliferus noduliferus* and *D. inaequalis*. The base and top of this zone are marked by the first occurrence of *Idiognathoides sinuatus* and *I. pacificus* or *I. corrugatus,* respectively.

3. *Idiognathoides sulcatus sulcatus* Zone

This zone, occupying about a 5 m interval of the section, is represented by 3 samples (N32-34). Its base and top are marked by the first occurrence of *Idiognathoides sulcatus sulcatus* and *I. sinuatus*, respectively. In addition to the zonal species, other main species include *Rhachistognathus prolixus* and *Declinognathodus noduliferus noduliferus.*

2. *Declinognathodus noduliferus* Zone

This zone, represented by the samples from N25 to N31, occupies about a 16 m interval of the section. It is characterized by the occurrence of *Declinognathodus noduliferus noduliferus* and *D. lateralis*. Other common species include *Gnathodus bilineatus bollandensis, G. bilineatus bilineatus, G. girtyi intermedius, Lochreia commutata, L. nodosa, L. mononodosa,* and *L. multinodosa*. The lower and upper limits of this zone are marked by the first occurrence of *Declinognathodus noduliferus* and *Idiognathoides sulcatus sulcatus*, respectively.

**Lower Carboniferous (Mississippian)**

**Duwuan**

1. *Gnathodus bilineatus bollandensis* Zone

This zone occurs at the base of the section, from N18 to N24, an interval of more than 12 m. The first occurrence of *Gnathodus bilineatus bollandensis* and *Declinognathodus noduliferus*, respectively, indicate the lower and upper boundaries of the zone. *Gnathodus bilineatus bollandensis, G. bilineatus bilineatus, G. homopunctatus, Mestognathus bipluti, Lochreia commutata, L. nodosa, L. multinodosa* and *L. mononodosa* are the main species found in this zone.

| This paper | | | | Xiong et Zhai 1985 | | Wang, Rui et Zhang 1987 | | Wang et Higgins 1989 | | Wang 1991 | | Wang 1996 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P$_1$ | Asselian | Zisongian | *S. isolatus* | | *S. elongatus* | | | | | Permian | *S. barskovi* | | |
| Pennsylvanian | Gzhelian | Mapingian | *S. wabaunsensis* | "Maping Formation" | *S. wabaunsensis* | Mapingian | | | | U. Carboniferous (part) | *S. wabaunsensis* | | |
| | | | *S. tenuialveus* | | | | *S. elongatus* | | *S. elongatus* | | *S. elongatus* | | |
| | | | *S. firmus* | | *S. elegantulus* | | *S. elegantulus* | Mapingian | *S. elegantulus* | | *S. elegantulus* | | |
| | | | *I. nashuiensis* | | | | | | | | | | |
| | Kasimovian | Dalaan | *S. simulator* | | *S. suberectus* | | | | | | | | |
| | | | *S. guizhouensis* | "Dala Formation" | | | *S. oppletus* | | *S. oppletus* | | | | |
| | | | *S. gracilis-S. excelsus* | | | | | | | | | | |
| | | | *S. cancellosus* | | *I. delicatus* | | | | | | | | |
| | | | *S. clavatulus* | | *S. oppletus* | | *S. parvus* | | *S. parvus* | | | | |
| | | | *S. nodocarinatus* | | | | | | | | | | |
| | | | *I. podolskensis* | | | | | | | | | | |
| | Moscovian | | *M. clarki-I. robustus* | | *G. qiannanensis* | | *N. clarki* | | *N. clarki* | | | | |
| | | Huashibanian | *D. orphanus-D. ellesmerensis* | | | | | | | | | | |
| | | | *I. ouachitensis* | | | | | | | | | | |
| | Bashkirian | Luosuan | *S. expansus* | "Huashiban Formation" | | | | Weiningian | | | | | |
| | | | *I. sulcatus parva* | | | Weiningian | *I. s. parva* | | *I. s. parva* | | | | |
| | | | *I. primulus-N. bassleri* | | | | | | | | | | |
| | | | *I. primulus-N. symmetricus* | | | | *I. primulus* | | *I. primulus* | | | | |
| | | | *N. symmetricus* | | | Luosuan | *N. symmetricus* | | *I. sinuatus* | | | Upper Carboniferous (part) | *N. symmetricus* |
| | | | *I. corrugatus-I. pacificus* | | | | | | | | | | |
| | | | *I. sinuatus* | | *I. corrugatus* | | *I. sulcatus-I. corrugatus-I. sinuatus* | | *I. sulcatus-I. corrugatus* | | | | *I. sinuatus* |
| | | | *I. sulcatus sulcatus* | | | | | | | | | | *I. sulcatus* |
| | | | *D. noduliferus* | | *D. lateralis* | | *D. noduliferus* | | *D. noduliferus* | | | | *D. noduliferus* |
| Mississippian | Serpukhovian | Duwuan | *G. bilineatus bollandensis* | "Ruya Form." | *G. bilineatus bilineatus* | Tatangian | *G. bilineatus bollandensis* | Tatangian | *G. bilineatus bollandensis* | | | L. Carbonif. | *G. bilineatus bollandensis* |

Tab. 1 - Comparison between some conodont zonations of the Pennsylvanian in the Nashui section of Luodian, Guizhou.

## Correlation

Over the years the conodont zonation of the Nashui section of Luodian, Guizhou has been refined. First, Xiong & Zhai (1985) discovered the *Streptognathodus elongatus, S. wabaunsensis, S. elegantulus, S. suberectus, Idiognathodus delicatus, Streptognathodus oppletus, Gondolella qiannanensis, Idiognathoides corrugatus* and *Declinognathodus lateralis* zones in the Upper Carboniferous strata at the site. Later, Wang et al. (1987a), Wang & Higgins (1989), who studied the same sequence at this site, erected the following conodont zones, from top to bottom: the *Streptognathodus elongatus, S. elegantulus, S. oppletus, S. parvus, Mesogondolella* (=*Neogondolella*) *clarki, Idiognathoides sulcatus parva, Idiognathodus primulus, Neognathodus symmetricus, Idiognathoides sulcatus-I. sinuatus-I. corrugatus, Declinognathodus noduliferus* and *Gnathodus bilineatus bollandensis* zones. Most recently, Wang (1991, 1996) described the *Streptognathodus barskovi* and *S. wabaunsensis* zones across the Carboniferous-Permian boundary, and the *Idiognathoides sinuatus, I. sulcatus* and *Declinognathodus noduliferus* zones at the base of the Upper Carboniferous strata of this section. Specimens from the Nashui section described as "*Streptognathodus barskovi*" by Wang (1991) are referred to *Streptognathodus longilatus* (Chernykh & Ritter, 1997). Because *Streptognathodus isolatus* occurs in the sample N125, the *Streptognathodus barskovi* Zone in Wang's (1991) paper corresponds to the *Streptognathodus isolatus* Zone of this paper. Based on the same collection number and the same zonal species, a comparison between conodont zonations, presented by Xiong & Zhai (1985), Wang et al. (1987a), Wang & Higgins (1989), and Wang (1991) and this paper, can be made (Tab. 1).

| | | Nashui, Guizhou China (This paper) | | USA (Lane et Straka 1974; Winkler 1990; Lambert et al. 2001; Davidorv 2001; Barrick et Heckel 2000) | | Russia (Winkler 1990; Nemyrovska 1999; Nikolaeva et al. 2001; Isakova et al. 2001; Davidov 2001) | | England (Higgins 1975, 1985) | Yunnan, China (Dong et al. 1987) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Permian | Zisong. | *S. isolatus* | Wolf. | *S. isolatus* | Asseli. | *S. isolatus* | | | | |
| Pennsylvanian | Mapingian | *S. wabaunsensis* | Virgilian | *S. wabaunsensis* | Gzhelian | *S. wabaunsensis* | | | Upper Carboniferous | *S. wabaunsensis* |
| | | *S. tenuialveus* | | *S. brownrillensis* | | *S. tenuialveus* | | | | *-S. elongatus* |
| | | *S. firmus* | | *S. vigilicus* | | *S. vigilicus* | | | | *S. elegantulus* |
| | | *I. nashuiensis* | | *S. p. deflectus* | | *S. firmus* | | | | |
| | Dalaan | *S. simulator* | Missourian | *S. zethus* | Kasimovian | *S. zethus* | | | | |
| | | *S. guizhouensis* | | *S. simulator* | | *S. simulator* | | | | |
| | | *S. gracilis-S. excelsus* | | | | | | | | *S. gracilis-S. excelsus S. oppletus* |
| | | *S. cancellosus* | | *S. gracilis* | | *S. gracilis* | | | | *S. cancellosus* |
| | | *S. clavatulus* | | *S. cancellosus* | | *S. cancellosus* | | | | |
| | | *S. nodocarinatus* | | *I. eccentricus* | | *I. eccentricus* | | | | |
| | | *I. podolskensis* | Desm. | *S. nodocarinatus* | | *S. nodocarinatus* | | | | |
| | | *M. clarki-I. robustus* | | *S. subexcelsus N. roundyi N. asymmetricus N. caudatus N. bothrops* | | *S. makhlinea S. subexcelsus N. roundyi N. inaequalis I. podolskensis S. concinus-I. robustus N. medadultimus N. bothrops* | | | | *N. clarki* |
| | Huashibanian | *D.orphanus-D. ellesmerensis* | Atok. | *N. atokaensis* | Moscovian | *N. atokaensis S. transtivus* | | | | |
| | | *I. ouachitensis* | | *D. ophenus* | | *D. donetzianus* | | No conodont zones erected | | |
| | Luosuan | *S. expansus* | Morrowan | *I. ouachitensis* | Bashkirian | *I. ouachitensis* | | | | |
| | | *I. sulcatus parva* | | *I. convexus I. klapperi I. sinuosus* | | *S. expansus* | Westphalian (part) | | | |
| | | *I. primulus-N. bassleri* | | *I. sinuosus* | | *I. sinuosus* | | *I. sulcatus parva* | | *I. sinuosus* |
| | | *I. primulus-N. symmetricus* | | *N. bassleri* | | *N. askynensis* | | *I. primulus-I. sinuatus* | | *N. symmetricus-I. corrugatus* |
| | | *N. symmetricus* | | *N. symmetricus* | | *N. symmetricus* | | | | |
| | | *I. corrugatus-I. pacificus* | | | | *I. corrugatus* | Namurian | *I. sulcatus-I. corrugatus* | | *I. corrugatus* |
| | | *I. sinuatus* | | *I. sinuatus* | | | | | | |
| | | *I. sulcatus sulcatus* | | | | | | | | |
| | | *D. noduliferus* | | *D. noduliferus* | | *D. noduliferus* | | *D. noduliferus* | | *D. noduliferus* |
| Miss. | Duw. | *G. bilineatus bollandensis* | Chest. | *Rh. muricatus-A. unicornis* | Serp. | *G. bilineatus bollandensis* | | *G. bilineatus bollandensis* | L. Carb. | *G. bilineatus bollandensis* |

Tab. 2 - Conodont zones of the Pennsylvanian in Nashui section of Luodian, Guizhou compared with those employed in some other regions.

### 1. Correlation with northwestern Yunnan

According to Dong et al. (1987) the following conodont sequence, in descending order, can be recognized in the Upper Carboniferous of northwestern Yunnan: *Streptognathodus wabaunsensis-S. elongatus, S. elongatus, S. gracilis-S. excelsus, S. oppletus-S. elegantulus, S. cancellosus, Mesogondolella clarki, Idiognathodus sinuosus, Neognathodus symmetricus-Idiognathoides corrugatus* and *Declinognathodus lateralis-D. noduliferus* zones. This conodont sequence is similar to the conodont sequence at Nashui section in Luodian, Guizhou. Based on the first occurrence of characteristic species, such as *Streptognathodus wabaunsensis, S. gracilis, S. excelsus, S. cancellosus, Mesogondolella clarki, Neognathodus symmetricus, Idiognathodus corrugatus* and *Declinognathodus noduliferus* in the two areas, the conodont correlation between them is shown in Table 2.

### 2. Correlation with Great Britain and Ireland

According to Higgins (1975, 1985), the following conodont sequence of Great Britain and Ireland has been established: *Idiognathoides sulcatus parva, Idiognathoides sinuatus-Idiognathodus primulus, Idiognathoides corrugatus-I. sulcatus* and *Declinognathodus noduliferus* zones. Based on the first occurrence of characteristic species, such as *Declinognathodus noduliferus, Idiognathoides sul-*

*catus*, *Idiognathodus primulus* and *Idiognathoides sulcatus parva*, correlation of the Nashui sequence with Great Britain and Ireland is possible. The *Declinognathodus noduliferus*, *Idiognathoides corrugatus- I. sulcatus*, *I. sinuatus-Idiognathodus primulus* and *Idiognathoides sulcatus parvus* zones of Great Britain and Ireland can be correlated with the *Declinognathodus noduliferus* Zone, the interval of the *Idiognathoides sulcatus sulcatus* Zone to the *Neognathodus symmetricus* Zone, the interval of the *Idiognathodus primulus-Neognathodus symmetricus* Zone to the *Idiognathodus primulus-Neognathodus bassleri* Zone, and the *Idiognathoides sulcatus parva* Zone of the Nashui section, respectively (Tab. 2).

### 3. Correlation with North America

Based on studies by Lane & Straka (1974), Winkler (1990), Ritter (1995), Lane et al. (1999), Barrick & Heckel (2000), Lambert et al. (2001), Davydov (2001) in North America, the following Pennsylvanian conodont sequence, in the descending order, can be summarized: the *Streptognathodus wabaunsensis*, Upper *S. virgilicus*, Lower *S. virgilicus*, *S. pawhuskaensis deflectus*, *S. zethus*, *S. simulator*, *S. gracilis*, *S. cancellosus*, *Idiognathodus eccentricus*, *Streptognathodus nodocarinatus*, *S. subexcelsus*, *Neognathodus roundyi*, *N. medexultimus*, *N. medadultimus*, *N. bothrops*, *N. atokaensis*, *Diplognathodus ophenus*, *Idiognathoides ouachitensis*, *Idiognathoides convexus*, *I. klapperi*, *I. sinuosus*, *Neognathodus bassleri*, *N. symmetricus*, *Idiognathoides sinuatus* and *Declinognathodus noduliferus* zones. Some index species are common to both areas, and the correlation of some of the conodont zones between the Nashui and North America can be made as shown in Table 2. Based on the first occurrences of *Declinognathodus noduliferus*, *Idiognathoides sinuatus*, *Neognathodus symmetricus*, *N. bassleri*, *I. ouachitensis*, *Diplognathodus orphanus*, *Streptognathodus nodocarinatus*, *S. cancellosus*, *S. gracilis*, *S. simulator* and *S. wabaunsensis*, the *Declinognathodus noduliferus*, *Idiognathoides sinuatus*, *Neognathodus symmetricus* (including *Idiognathodus primulus-Neognathodus symmetricus*), *N. bassleri* or *N. bassleri-Idiognathodus primulus*, *Idiognathoides ouachitensis*, *Diplognathodus orphanus*, *Streptognathodus nodocarinatus*, *S. cancellosus*, *S. gracilis*, *S. simulator* and *S. wabaunsensis* zones in the both areas can be correlated directly with each other. The *Streptognathodus clavatulus* Zone at the Nashui section can be roughly correlated with the *Idiognathodus eccentricus* Zone based on the presence of the *Streptognathodus clavatulus* in the *I. eccentricus* Zone of North America. Other zones in the both areas cannot be correlated directly because of the provincialism. So other conodont zones in the both areas can only be correlated based on their places in the conodont sequences, and the presence of other common and important species in the both areas (Table 2). For example, the interval from the *Mesogondolella clarki-Idiognathodus robustus* Zone to the *I. podolskensis* Zone at the Nashui section can be correlated with the interval from the *Neognathodus atokaensis* Zone to the *N. roundyi* Zone of the North America based on the first occurrences of *Diplognathodus orphanus* and *Streptognathodus nodocarinatus*, respectively in the two areas. In the *Neognathodus atokaensis* Zone of the North America, *Mesogondolella clarki* is a common species. So the lower part of the *Mesogondolella clarki-Idiognathodus robustus* of the Nashui section may be correlated with the *Neognathodus atokaensis* Zone of the North America. The interval from the *Idiognathodus nashuiensis* Zone to the *Streptognathodus tenuialveus* Zone at the Nashui section is equivalent to the interval from the *S. zethus* Zone to the *S. brownvillensis* Zone of the North America based on the first occurrences of *S. simulator* and *S. wabaunsensis*, respectively, in both areas.

### 4. Correlation with Russia

Based on studies by Goreva (1984), Barskov (1987), Winkler (1990), Chernykh & Ritter (1997), Davydov et al. (1998), Groves et al. (1999), Nemyrovska (1999), Isakova (2001), Davydov (2001) in Russia, the following conodont zones, in the descending order, are summarized: *Streptognathodus wabaunsensis*, *S. tenuialveus*, *S. vigilicus*, *S. firmus*, *S. zethus*, *S. simulator*, *S. gracilis*, *S. cancellosus*, *Idiognathodus eccentricus*, *Streptognathodus makhlinea*, *S. subexcelsus*, *Neognathodus roundyi*, *N. inaequalis*, *Idiognathodus podolkensis-Neognathodus medexultimus*, *Streptognathodus concinnus-Idiognathodus robustus*, *Neognathodus medadultimus*, *N. bothrops*, *Streptognathodus transitivus*, *Idiognathoides ouachitensis*, *Declinognathodus donrtzianus*, *Streptognathodus expansus*, *Idiognathodus sinuosus*, *Neognathodus askynensis*, *N. symmetricus*, *Idiognathoides corrugatus* and *Declinognathodus noduliferus* zones. Based on the first occurrence of the characteristic species, such as *Streptognathodus wabaunsensis*, *S. tenuialveus*, *S. firmus* (=*S. alekseevi*), *S. simulator*, *S. gracilis*, *S. excelsus*, *S. cancellosus*, *Idiognathodus podolskensis*, *Idiognathoides ouachitensis*, *Streptognathodus expansus*, *Neognathodus symmetricus*, *Idiognathoides corrugatus* and *Declinognathodus noduliferus*, the *Streptognathodus wabaunsensis*, *S. tenuialveus*, *S. firmus*, *S. simulator*, *S. gracilis*, *S. cancellosus*, *Idiognathodus podolskensis*, *Idiognathoides ouachitensis*, *Streptognathodus expansus*, *Neognathodus symmetricus*, *Idiognathoides corrugatus* and *Declinognathodus noduliferus* zones in the two areas can be correlated directly with each other (Table 2). The upper part of the *Mesogondolella clarki-Idiognathodus robustus* Zone at Nashui contains the characteristic species *Idiognathodus robustus*. It approximately corresponds to the *Streptognathodus concinnus-Idiognathodus robustus* Zone of Russia. As mentioned above, the *Streptognathodus clavatulus* at Nashui can be correlated with the *Idiognathodus eccentricus* Zone of North America, so the *Streptognathodus clavatulus* at Nashui can be correlated with the *Idiognathodus eccentricus* Zone of Russia too. In the same reason as above, the lower part of the *Mesogondolella clarki-Idiognathodus robustus* Zone at Nashui can be correlated with the *Neognathodus atokaen-*

*sis* Zone of Russia. Other forms, with different names in the two areas can be correlated only based on their places in the conodont sequences, and the occurrence of common species in both areas (Table 2).

### Subdivision and boundaries

In China, the Upper Carboniferous can be subdivided in the descending order into Mapingian (or Xiaoyaoan), Dalaan, Huashibanian and Luosuan regional stages mainly based on the fusulinid zones. Their bases are marked by those of the fusulinid *Montiparus*, *Profusulinella*, *Pseudostaffella antiqua* and *Millerella marblensis-Eostaffella postmosquensis* zones, respectively. So the Upper Carboniferous in China can be summarized in the descending order as follows:

Mapingian (or Xiaoyaoan) *Triticites* Zone
*Montiparus* Zone
Dalaan *Fusulinella-Fusulina* Zone
*Profusulinella* Zone
Huashibanian *Pseudostaffella antiqua* Zone
Luosuan *Millerella marblensis-Eostaffella postmosquensis* Zone

At Nashui, the rocks described in this paper can be subdivided (in descending order) into the: Maping, Dalaan, Huashibanian and Luosuan stages, and contains both the mid-Carboniferous and Carboniferous-Permian boundaries. This section can also be subdivided into the following fusulinid zone: the *Millerella marblensis-Eostafella postmosquensis* Zone (samples N25-45), *Pseudostaffella* Zone (samples N51-58), *Profusulinella* Zone (samples N59-68), *Fusulinella-Beedeina* Zone (samples N71-109), *Montiparus-Triticites* Zone (samples N112-124) (Wang et al. 1987a; Wang & Higgins 1989). In China, the *Millerella marblensis-Eostafella postmosquensis* Zone, *Pseudostaffella* Zone, *Profusulinella* and *Fusulinella-Fusulina* or *Fusulinella-Beedeina* zones, and *Triticites-Montiparus* Zone are referred to the Luosuan, Huashibanian, Dalaan and Maping stages, respectively (Zhang 2000). So based on the fusulinid zones at the Nashui section, the intervals, from the *Declinognathodus noduliferus* Zone to the *Streptognathodus expansus* Zone (samples N25-51), from the *Idiognathoides ouachitensis* Zone to the *Diplognathodus orphanus-D. ellesmerensis* Zone (samples N52-63), from the *Mesogondolella clarki-Idiognathodus robustus* Zone to the *Streptognathodus simulator* Zone (samples N64-109), and from the *S. nashuiensis* Zone to the *S. wabaunsensis* Zone (samples N110-124), are referred to the Luosuan, Huashibanian, Dalaan and Maping stages, respectively.

The first occurrence of *Declinognathodus noduliferus* marks the base of the Pennsylvanian Subsystem, "Mid-Carboniferous boundary" and the base of the Bashkirian or Morrowan Stage (Lane & Manger 1985). The Arrow Canyon, in Nevada (USA) is accepted as GSSP of the Mid-Carboniferous boundary, the base of the Pennsylvanian Subsystem and of the Bashkirian Stage (Lane et al. 1999). In the basal part of the Nashui section (sample N25), the first occurrence of *Declinognathodus noduliferus*, corresponds with the base of the fusulinid *Millerella marblensis-Eostaffella postmosquensis* Zone, and represents the base of the Pennsylvanian Subsystem (Bashkirian or Morrowan Stage). The base of the Permian System, the Asselian Stage, is marked by the first occurrence of *Streptognathodus isolatus* and the GSSP is at Aidaralash Creek, Kazakhstan (Davydov et al. 1998). In the upper part of the Nashui section, the first occurrence of *Streptognathodus isolatus* (sample N125), corresponds approximately with the first occurrence of the fusulinids *Pseudoschwagerina* ex gr. *fusiformis* and *P.* ex gr. *beedei*, marking the Carboniferous-Permian boundary, the base of the Permian System, the Asselian Stage. According to Winkler (1990), Chernykh & Ritter (1997), Nemyrovska (1999), Davydov (2001) and Isakova et al. (2001), the bases of *Declinognathodus donetzianus* Zone and *Streptognathodus zethus* Zone represent the bases of the Moscovian and Gzhelian or Virgilian stages, respectively. The base of the *Declinognathodus donetzianus* Zone is easily recognized by the occurrence of *Diplognathodus ellesmerensis* (Nemyrovska, 1999). In this case the base of the *Diplognathodus orphanus-D. ellesmerensis* Zone (sample N55) at the Nashui section can be correlated with the base of the Moscovian. As mentioned in the correlation with North America, the *Streptognathodus nashuiensis* Zone at the Nashui section is correlated with the *S. zethus* Zone of North America. So in this case the base of the *Streptognathodus nashuiensis* Zone (sample N110) marks the base of the Gzhelian or Vigilian Stage. The base of the Desmoinesian or Kasimovian is at the base of the *Streptognathodus subexcelsus* Zone in North America and Russia (Davydov 2001). It is very close to a horizon in the top part of the *Idiognathodus podolskensis* (lower than sample N75) at the Nashui section. The base of the Missourian of North America is at the base of the *Idiognathodus eccentricus* Zone (Winkler 1990; Barrick & Heckel 2000). So at the Nashui section it is at the base of the *Streptognathodus clavatulus* Zone (sample N82). But in another opinion, the base of the Missourian is near the top part of the *Idiognathodus eccentricus* Zone (Davydov 2001). In this case the base of the Missourian is at the top part of the *Streptognathodus clavatulus* Zone (sample N87) at the Nashui section. The base of the Atokan may be marked by that of the *Idiognathoides ouachitensis* Zone (Nemyrovska 1999). At the Nashui section it is at the point of sample N52. But in another opinion, the base of the Atokan is at the base of the *Diplognathodus orphanus-D. coloradoensis* Zone of North America (Winkler 1990). So in this case the base of the Atokan is corresponding to that of the *Diplognathodus orphanus-D. ellesmerensis* Zone at the Nashui section (sample N55). The tentative correlation of these regional biostratigraphic subdivisions of the Pennsylvanian Subsystem is shown in the Table 2.

## Description of new species

Genus *Idiognathodus* Gunnell, 1931

Type species: *Idiognathodus claviformis* Gunnell, 1931

### **Idiognathodus nemyrovskae** n. sp.

Pl.1, fig. 26

1999 *Idiognathodus primulus* Higgins - Nemyrovska, p.64, pl. 8, fig. 1 only.

**Diagnosis.** Platform of Pa element subsymmetrical, long, and narrow, lanceolate with pointed posterior, widest in length anterior. Irregular nodes or ridges distributed on two sides of carina, remainder of platform covered by irregular, discontinuous transverse ridges.

**Description.** Pa element consisting of blade and platform. Blade extends onto platform as a short ridged carina, occupying one-fourth platform length. Irregular nodes or ridges distributed on both sides of carina, separated by sulci. Platform subsymmetrical, long, narrow, lanceolate, with pointed posterior, widest in anteriorly. Middle and anterior part of platform covered by irregular, discontinuous transverse ridges. Aboral basal cavity deep and wide.

**Comparison.** This new species is similar to *Idiognathodus primulus*, but can be distinguished from the latter by its irregular nodes and ridges, distributed on both sides of the carina.

**Occurrence.** *Diplognathodus orphanus-D. ellesmerensis* and *Mesogondolella clarki-Idiognathodus robustus* zones.

### **Idiognathodus nashuiensis** n. sp.

Pl. 2, figs. 21, 22

**Diagnosis.** Pa element with narrow, long triangular platform, ornamented with parallel transverse ridges without medium furrow. Carina short.

**Description.** Pa element consisting of blade and platform. Blade extending onto platform as a short ridged carina at the anterior of the platform. Platform long, narrow triangular, with wide anterior, posterior pointed, ornamented with parallel transverse ridges on oral surface. Basal cavity wide and deep.

**Comparison.** This species is similar to *I. primulus*, but can be distinguished from the latter by its narrow triangular platform, which is covered by numerous parallel continuous transverse ridges.

**Occurrence.** *Idiognathodus nashuiensis* Zone.

PLATE 1

(Note: All of the specimens are deposited in Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences)

Fig. 1 - *Gnathodus bilineatus hollandensis* Higgins & Bouckaert, 1968: oral view, X50, sample N20, Cat. no. 133198.

Fig. 2 - *Streptognathodus expansus* Igo & Koike, 1964: oral view, X60, sample N53, Cat. no. 99042.

Fig. 3 - *Idiognathoides sulcatus sulcatus* Higgins & Bouckaert,1968: oral view, X60, sample N38, Cat. no. 133199.

Fig. 4 - *Gnathodus bilineatus bilineatus* (Roundy, 1926): oral view, X50, sample N18, Cat. no. 133200.

Fig. 5, 17, 21 - *Declinognathodus lateralis* (Higgins & Bouckaert, 1968): oral views, X40, X60, X50, samples N30, 30, 25, Cat. nos. 133201, 133202, 99013.

Fig. 6, 11 - *Streptognathodus parvus* Dunn, 1966: oral views, X100, X66, samples N88, 66, Cat. nos. 133203, 133204.

Fig. 7 - *Lochriea mononodosa* (Rhodes, Austin & Druce, 1969): oral view, X50, sample N25, Cat. no. 99176.

Fig. 8, 14 - *Neognathodus symmetricus* Lane, 1967: oral views, X60, X86, sample N40, Cat. nos. 99019, 99021.

Fig. 9 - *Idiognathoides corrugatus-I. pacificus* transitional specimen: oral view, X66, sample N38, Cat. no. 133205.

Fig. 10 - *Streptognathodus elongatus* Gunnell, 1933: oral view, X100, sample N125, Cat. no. 133206.

Fig. 12 - *Idiognathodus nodosus* (Ellison et Graves, 1941): oral view, X80, sampleN53, Cat. no. 133207.

Fig. 13, 18 - *Idiognathoides sulcatus parva* Higgins & Bouckaert, 1968: oral views, X66, X80, sampleN50, Cat. nos. 133208, 133209.

Fig. 15 - *Gnathodus girtyi intermedius* Globensky, 1957: oral view, X60, sample N20, Cat. no. 99031.

Fig.16, 20 - *Streptognathodus suberectus* Dunn, 1966: oral views, X80, X60, samples N53, 51, Cat. nos. 133210, 133211.

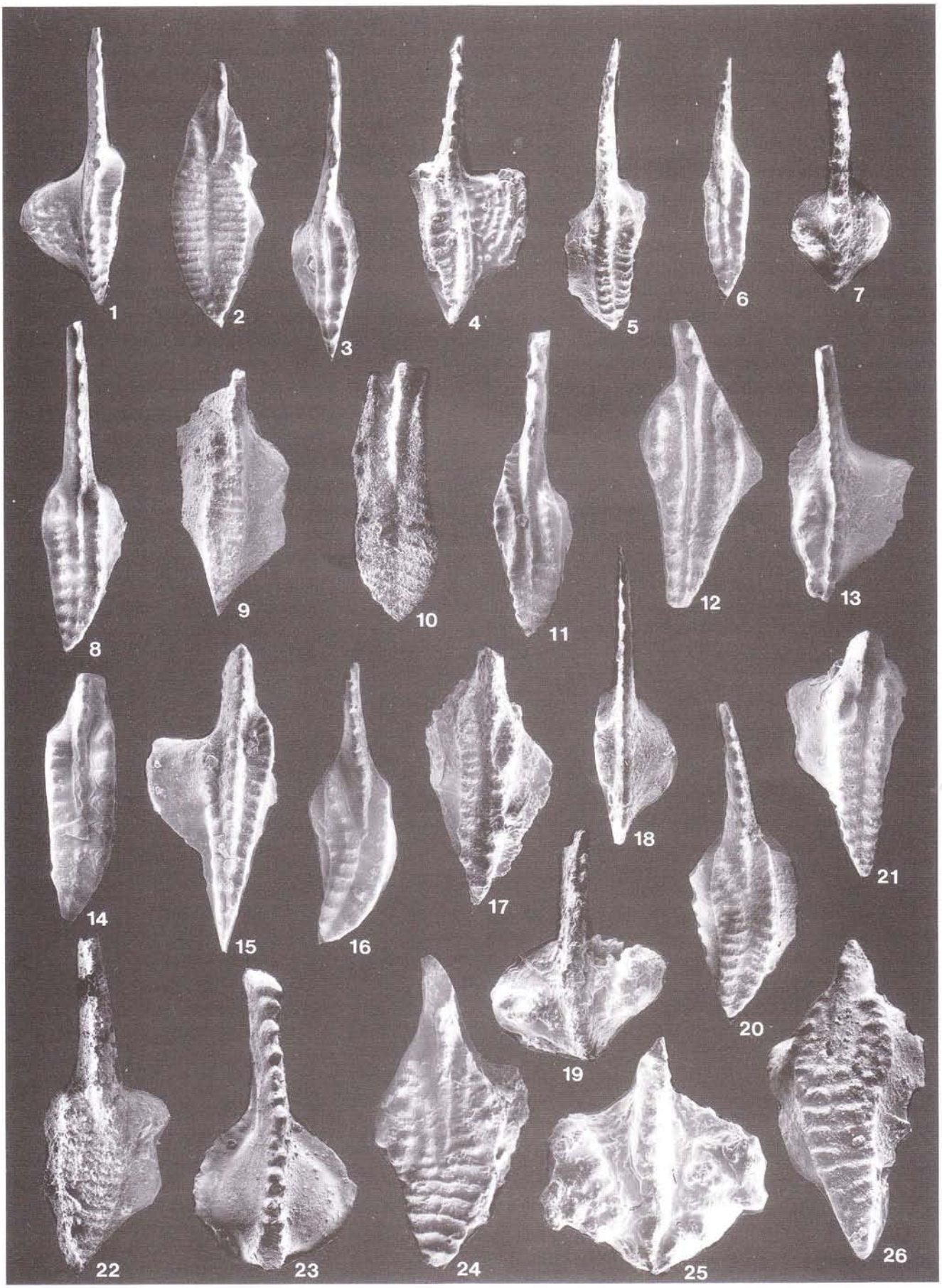
Fig.19, 25 - *Lochriea multinodosus* (Wirth, 1967): oral views, X60, sample N25, Cat. nos. 99167, 99168.

Fig. 22 - *Idiognathoides corrugatus* Harris & Hollingsworth,1933: oral view, X60, sample N41, Cat. no.133212.

Fig. 23 - *Lochriea commutata* (Branson & Mehl,1941): oral view, X60, sample N20, Cat. no.99094.

Fig. 24 - *Idiognathodus robustus* Kossenko & Kozitskaya,1978: oral view, X60, sample N65, Cat. no. 133213.

Fig.26 - *Idiognathodus nemyrovskae* sp. nov.: oral view of holotype, X60, sample N61, Cat. no.133214.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**Idiognathodus paraprimulus** n. sp.

Pl. 2, figs. 11, 12

**Diagnosis.** Pa element with shallow V-shaped trough, continuous transverse ridges, anterior part of platform smooth except for two edged ridges which parallel carina.

**Description.** Unit of Pa element consisting of blade and platform. Blade same length as, or slightly longer than, the platform, continues onto platform as short carina, occupying anterior one-fourth to one-third of the platform. Platform subsymmetrical, long, pointed posteriorly with subparallel and slightly convex sides. Anterior part of the platform smooth except for two ridges, which parallel carina, but separated from it by sulci. There may be one or two nodes on the outer sides of the ridges. Most of platform ornamented with continuous transverse ridges and a shallow, longitudinal, V-shaped trough. Aboral surface of the platform strongly excavated. Cup asymmetrical, outer side wider than inner.

**Comparison.** This species is similar to *Idiognathodus primulus*, but can be distinguished by the shallow, longitudinal V-shaped trough.

**Occurrence.** *Idiognathodus primulus-Neognathodus symmetricus* Zone and *Idiognathodus primulus-Neognathodus bassleri* Zone.

**Idiognathodus subdelicatus** n. sp.

Pl. 2, figs. 6, 8

**Diagnosis.** Continuously transverse ridged platform bearing a shallow but distinct median trough.

**Description.** Unit of Pa element consisting of blade and platform. Blade long, slender, extending onto platform as long ridged carina, occupying half length of platform. Platform slender, lanceolate, posteriorly pointed, greatest width near anterior one-third. Accessory lobes on both sides of platform ornamented with several nodes in aligned along side rims. Posterior part of the continuously transverse ridged platform bearing a shallow median trough. Basal cavity wide and deep.

**Comparison.** This new species is similar to *Idiognathodus delicatus*, but can be distinguished from the latter by the median trough, which cuts the continuous transverse ridges into outer and inner platform parts.

**Occurrence.** *Idiognathodus primulus-Neognathodus bassleri* Zone to *Mesogondolella clarki -Idiognathodus robustus* Zone.

PLATE 2

Fig.1, 2 - *Rhachistognathus prolixus* Baesemann & Lane, 1985: oral views, X60, X66, sample N30, Cat. nos. 99008, 99007.

Fig.3 - *Declinognathodus noduliferus noduliferus* (Ellison & Graves, 1941): oral view, X80, sample N33, Cat. no. 99026.

Fig.4 - *Declinognathodus inaequalis* (Higgins, 1975): oral view, X80, sample N35, Cat. no. 99153.

Fig.5 - *Idiognathodus nodosus* (Ellison & Graves, 1941): oral view, X50, sample N48, Cat. no. 133215.

Fig. 6, 8 - *Idiognathodus subdelicatus* sp. nov.: 6) Latero-oral view, X40, sample N40, Cat. no. 133216; 8) oral view of holotype, X80, sampleN53, Cat. no. 133217.

Fig. 7 - *Streptognathodus elongatus* Gunnell, 1933: oral view, X60, sample N125, Cat. no. 133218.

Fig. 9 - *Declinognathodus noduliferus japonicus* (Igo & Koike, 1964): oral view, X50, sample N32, Cat. no. 99012.

Fig. 10 - *Idiognathodus delicatus* Gunnell, 1931: oral view, X100, sample N66, Cat. no.133219.

Fig.11, 12 - *Idiognathodus paraprimulus* sp. nov.: 11) oral view of holotype, X50, sampleN43, Cat. no. 133220; 12) oral view, X60, sample N43, Cat. no. 99163.

Fig.13 - *Idiognathoides ouachitensis* (Harlton, 1933): oral view, X60, sample N56, Cat. no. 133221.

Fig.14, 20 - *Adetognathus paralautus* Orchard, 1984: oral views, X60, samples N109, 125, Cat. nos. 133222, 99049.

Fig.15 - *Streptognathodus simplex* Gunnell, 1933: oral view, X66, sample N117, Cat. no. 133223.

Fig.16 - *Idiognathodus primulus* Higgins, 1975: oral view, X40, sample N43, Cat. no. 99160.

Fig.17 - *Idiognathoides sinuatus* Harris & Hollingsworth,1933: oral view, X60, sample N35, Cat. no. 99178.

Fig.18 - *Neognathodus* aff. *atokaensis* Grayson, 1984: oral view, X80, sample N53, Cat. no. 133224.

Fig.19 - *Neognathodus medadultimus* Merrill, 1972: oral view, X53, sample N66, Cat. No. 99109.

Fig.21, 22 - *Streptognathodus nashuiensis* sp. nov.: 21) oral view, X80, sample N110, Cat. no. 133225; 22) oral view of holotype, X66, sample N110, Cat. no. 133226.

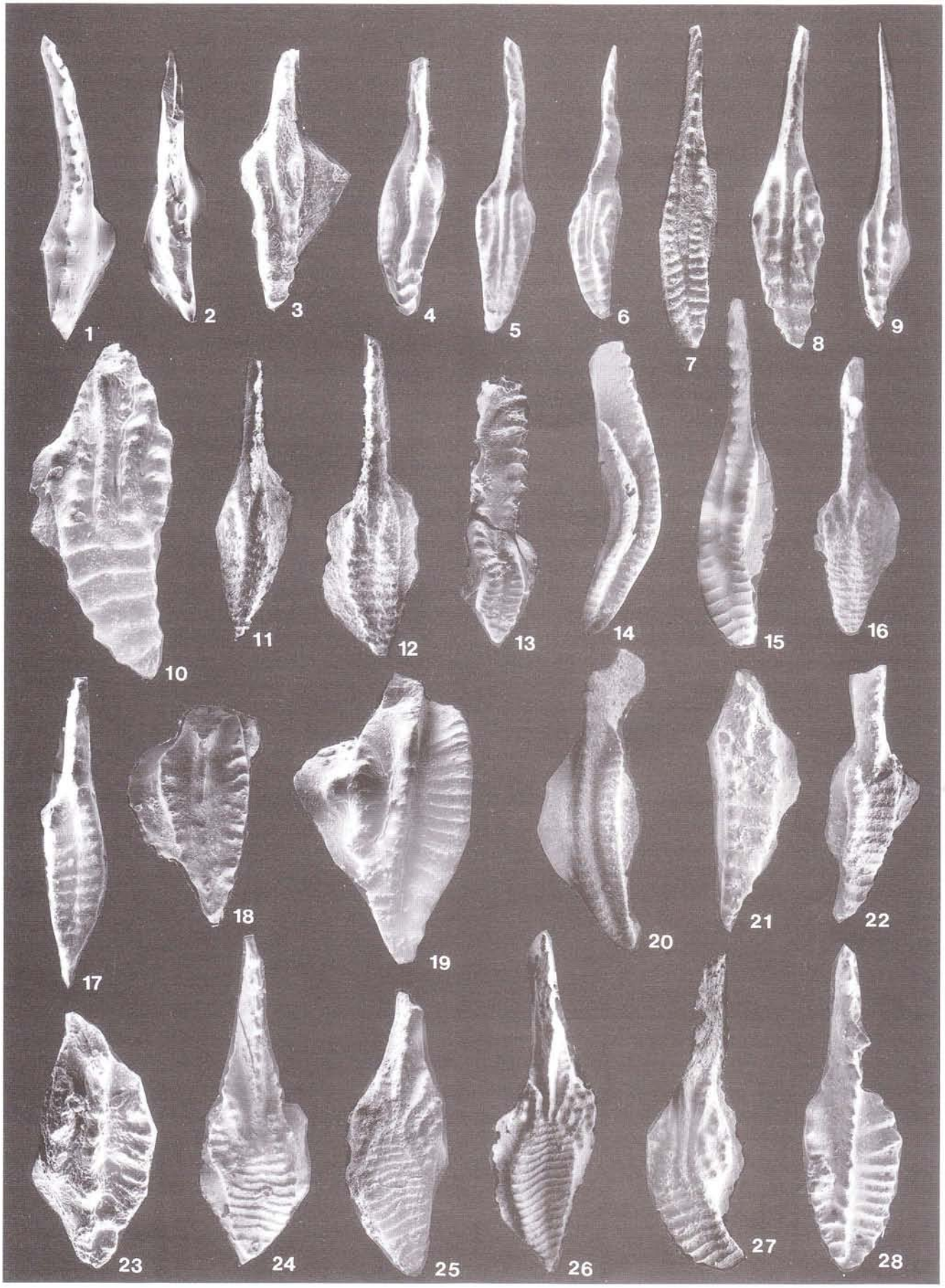
Fig.23 - *Neognathodus bassleri* (Harris & Hollingsworth, 1933): oral view, X80, Sample N44, Cat. no. 99134.

Fig.24 - *Idiognathodus incurvus* Dunn, 1966: oral view, X53, sample N75, Cat. no. 133227.

Fig. 25, 26 - *Idiognathodus podolskensis* Goreva, 1984: oral views, X50, samples N69, 75, Cat. nos. 133228, 133229.

Fig. 27 - *Idiognathodus sinuosus* Ellison & Graves, 1941: oral view, X50, sample N65, Cat. no. 133230.

Fig. 28 - *Neognathodus* aff. *bothrops* Merrill, 1972: oral view, X80, sample N82, Cat. no. 133231.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Genus *Mesogondolella* Kozur, 1988

Type species: *Gondolella bisselli* Clark & Behnken, 1971

**Mesogondolella subclarki** n. sp.

Pl. 3, figs. 22, 23

**Diagnosis.** Broad smooth platform with rounded posterior edge, and a wide posterior brim between the cusp and posterior edge of platform. Carina lower, ridged at anteriorly, composed of lower separated nodes at middle and posterior part.

**Description.** Platform flat, smooth, broad, with broad rounded posterior edge, subparallel lateral edges and narrow rounded anterior. Outer and inner platforms broad, separated from carina by the shallow furrows, which extending along carina. Carina lower, ridged anteriorly, composed of lower separated nodes at middle and posterior part. Posterior cusp, slightly distinctive as a lower isolated node. Broad brim situated between cusp and posterior edge.

**Comparison.** This new species is similar to *Mesogondolella clarki*, but can be distinguished from the latter by its broad brim from posterior edge to cusp.

**Occurrence.** *Mesogondolella clarki-Idiognathodus robustus* and *Idiognathodus podolskensis* zones.

Genus *Streptognathodus* Stauffer & Plummer, 1932

Type species: *Streptognathodus excelsus* Stauffer & Plummer, 1932

**Streptognathodus guizhouensis** n. sp.

Pl. 3, figs. 2, 3

**Diagnosis.** Pa element elongate, with shallow trough and continuous transverse ridges. Carina may extend half the length of platform as a row of small nodes.

**Description.** Unit of Pa element consisting of blade and platform. Platform incurved, elongate and lanceolate. Ridged carina short, but extending the middle of platform as a row of small nodes. Oral surface of platform ornamented with transverse ridges, anterior part cut by the shallow median furrow. Posteriorly transverse ridges relative long, continue across median shallow furrow. Basal cavity wide and deep.

**Comparison.** This species is similar to *S. elegantu-*

PLATE 3

Fig. 1 - *Streptognathodus excelsus* (Stauffer & Plummer, 1932): oral view, X40, sample N90, Cat. no. 133232.

Fig. 2, 3 - *Streptognathodu guizhouensis* sp. nov.: 2) oral view, X50, Sample N97, Cat. nos. 133233, 133234; 3) oral view of holotype, X66, sample N97, Cat. no.

Fig. 4, 5 - *Streptognathodus luosuensis* sp. nov.: 4) oral view of holotype, X40, sample N107, Cat. no. 99106; 5) oral view, X50, sample N108, Cat. no. 99105.

Fig. 6 - *Streptognathodus elegantulus* Stauffer & Plummer, 1932: oral view, X50, sample N101, Cat. no. 133235.

Fig. 7 - *Streptognathodus pawhuskaensis* (Harris & Hollingsworth, 1933): oral view, X50, sample N101, Cat. no. 133236.

Fig. 8 - *Streptognathodus simplex* Gunnell, 1933: oral view, X50, sample N125, Cat. no. 111574.

Fig. 9 - *Streptognathodus* cf. *dissectus* Kossenko, 1975: oral view, X60, sample N65, Cat. no. 133237.

Fig. 10, 11 - *Streptognathodus* cf. *subexcelsus* Alekseev & Goreva, 1994: oral views, X60, X50, sample N94, Cat. nos. 133238, 133239.

Fig. 12 - *Streptognathodus nodocarinatus* Jones, 1941: oral view, X80, sample N76, Cat. no. 133240.

Fig. 13, 14 - *Idiognathoides pacificus* Savage & Barkeley, 1985: oral views, X60, sample N40, Cat. nos. 99131, 133241.

Fig.15, 21 - *Streptognathodus subsimplex* sp. nov.: 15) oral view of holotype, X100, sample N53, Cat. no. 133242; 21) oral view, X80, sample N54, Cat. no. 133243.

Fig. 16, 17 - *Neognathodus* aff. *bothrops* Merrill, 1972: oral views, X80, sample N53, Cat. nos. 99128, 133244.

Fig. 18 - *Idiognathoides tuburculatus* Nemirovska, 1978: oral view, X60, sample N57, Cat. no. 133245.

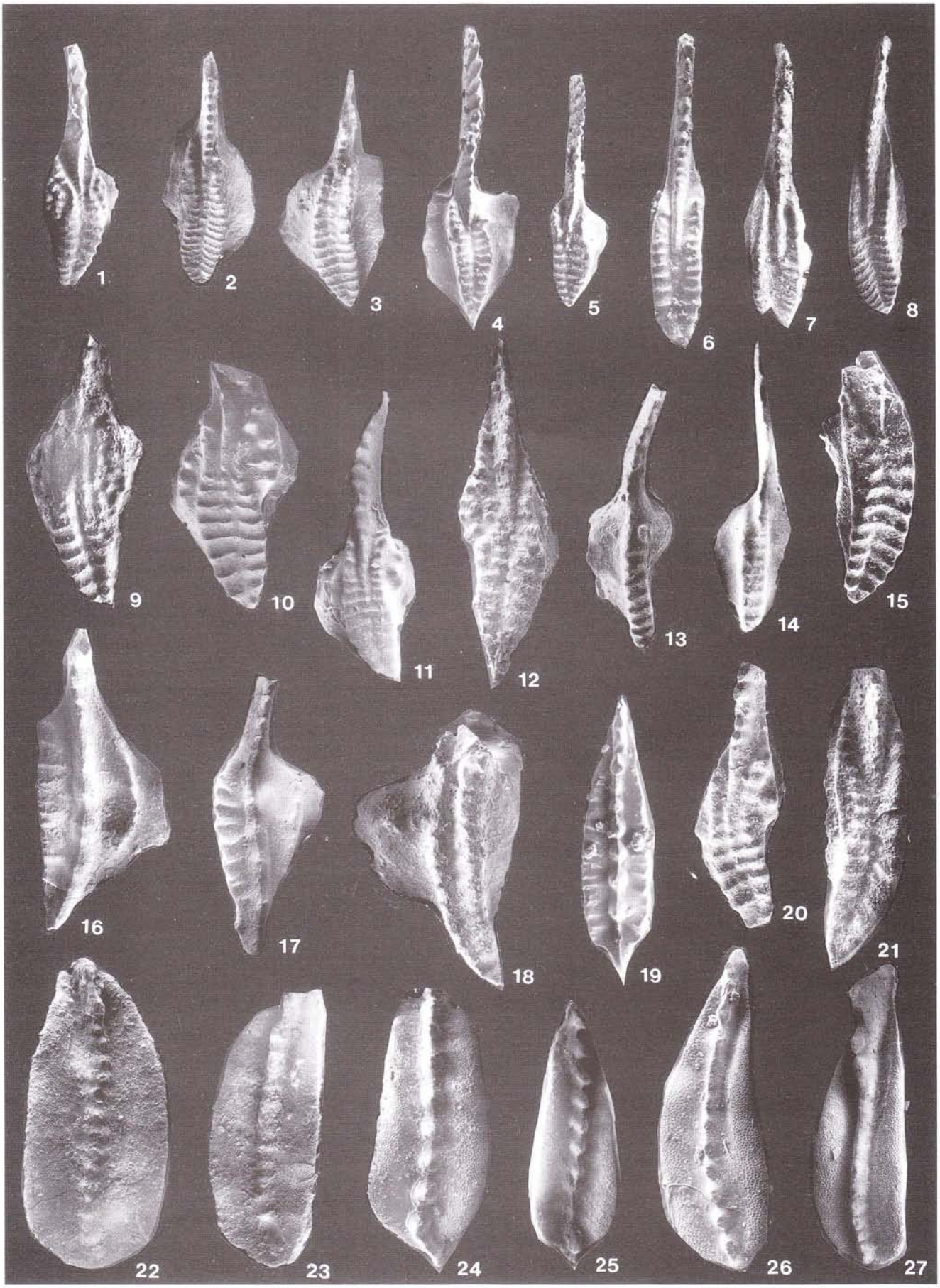
Fig. 19 - *Gondolella elegantula* Stauffer & Plummer, 1932: oral view, X50, sample N87, Cat. no. 99038.

Fig. 20 - *Streptognathodus oppletus* Ellison, 1941: latero-oral view, X66, sample N92, Cat. no. 133246.

Fig. 22, 23 - *Mesogondolella subaclarki* sp. nov.: oral views of holotype and paratype, X40, sample N69, Cat. nos. 99089, 99088.

Fig. 24-26 - *Mesogondolella clarki* (Koike, 1967): oral views, X60, X50, X60, samples N64, 65,82, Cat. nos. 133247-133249.

Fig. 27 - *Gondolella donbassica* Kossenko, 1978: latero-oral view, X50, sample N82, Cat. no. 133250.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*lus*, but can be distinguished by the very shallow trough at midlength.

**Occurrence.** *Streptognathodus guizhouensis* Zone.

### **Streptognathodus luosuensis** n. sp.

Pl. 3, figs. 4, 5

**Diagnosis.** The most diagnostic feature of this species is the short and deflected carina.

**Description.** Short ridged carina deflected to inner side, occupying anterior one-sixth of platform length. Platform small, subsymmetrical, slightly incurved, widest at midlength, with convex outer platform margin and pointed posterior termination. Numerous transverse ridges on inner and outer platform interrupted by a narrow and shallow trough at midlength.

**Comparison.** This species is similar to *S. simplex*, but can be distinguished by the short and deflected carina.

**Occurrence.** *Streptognathodus simulator* Zone.

### **Streptognathodus subsimplex** n. sp.

Pl. 3, figs. 15, 21

**Diagnosis.** Platform of Pa element narrow, elongate, asymmetrical, with short ridged carina, short outer and inner transverse ridges. Median trough shallow, V-shaped.

**Description.** Unit of Pa element consisting of blade and platform. Blade extending onto platform as short ridged carina, occupying one-fourth of platform. Platform narrow, elongate, asymmetrical, slightly incurved. Ridged nodes separated from carina by lateral furrows occur on both sides of the anterior fourth of platform. Remainder of platform ornamented with short inner and outer parallel transverse ridges. Median trough V-shaped, shallow. Basal cavity wide and deep.

**Comparison.** This new species is similar to *S. simplex*, but can be distinguished from the latter by the short carina and shallow trough.

**Occurrence.** *Idiognathoides ouachitensis* Zone and *Diplognathodus orphanus-D. ellesmerensis* Zone.

*Acknowledgements.* Subsidized by the Ministry of Science & Technology China, Basic Research Project (G99-A-05), Chinese Academy of Sciences (Grant KZCX2-SW-129), Natural Science Foundation of China (Grant 40272003), the Innovation Fund of Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences (Grant 000410). We are deeply grateful to Dr. A.C. Higgins (University of Sheffield,UK), Dr. R. R. West (Kansas State University, USA) and prof. M. Gaetani (the editor of the RIPS) for considerably improving the manuscript and Dr. Xiangdong Wang (Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences) for his extremely helpful comments.

PLATE 4

Fig.1, 2 - *Diplognathodus orphanus* (Merrill, 1973): lateral views, X100, X80, sample N55, Cat. nos.133251, 133252.

Fig.3-5 - *Diplognathodus coloradoensis* Murray et Chronic, 1965: Lateral views, X80, X80, X53, samples N67, 53, 53, Cat. nos. 1332253-133255.

Fig.6, 7 - *Diplognathodus ellesmerensis* Bender, 1980: lateral views, X120, samples N58, 60, Cat. nos. 133256, 133257.

Fig.8, 10 - *Streptognathodus clavatulus* Gunnell, 1933: oral views, X53, X46, samples N82, 83, Cat. nos. 133258, 133259.

Fig.9 - *Streptognathodus simulator* Ellison, 1941: oral view, X60, samples N107, Cat. no. 133260.

Fig.11, 13 - *Streptognathodus tenuialveus* Chernykh & Ritter, 1997: oral views, X60, X50, samples N116, 113, Cat. nos. 133261, 133262.

Fig.12, 14 - *Streptognathodus elegantulus* Stauffer & Plammer, 1932: oral views, X40, sample N111, Cat. nos. 99059, 133263.

Fig. 15 - *Cavusgnathus unicornis* Youngquist & Miller, 1949: oral view, X40, sample N125, Cat. no. 99151.

Fig. 16 - *Streptognathodus bellus* Chernykh & Ritter, 1997: oral view, X66, sample N125, Cat. no. 133264.

Fig. 17 - *Streptognathodus gracilis* Stauffer & Plummer, 1932: oral view, X80, sample N90, Cat. no. 133265.

Fig. 18, 19 - *Streptognathodus firmus* Kozitskaya, 1978: oral views, X46, X80, sample N111, Cat. nos. 133266, 133267.

Fig. 20-22 - *Streptognathodus cancellosus* (Gunnell, 1933): oral views, X66, X30, X50, samples N87, 94, 90, Cat. nos. 133268-133270.

Fig. 23 - *Idiognathodus magnificus* Stauffer & Plummer, 1932: oral view, X40, sample N99, Cat. no. 133271.

Fig. 24 - *Streptognathodus nodulinearis* Chernikh & Reshetkova, 1987: oral view, X60, sample N124, Cat. no. 99120.

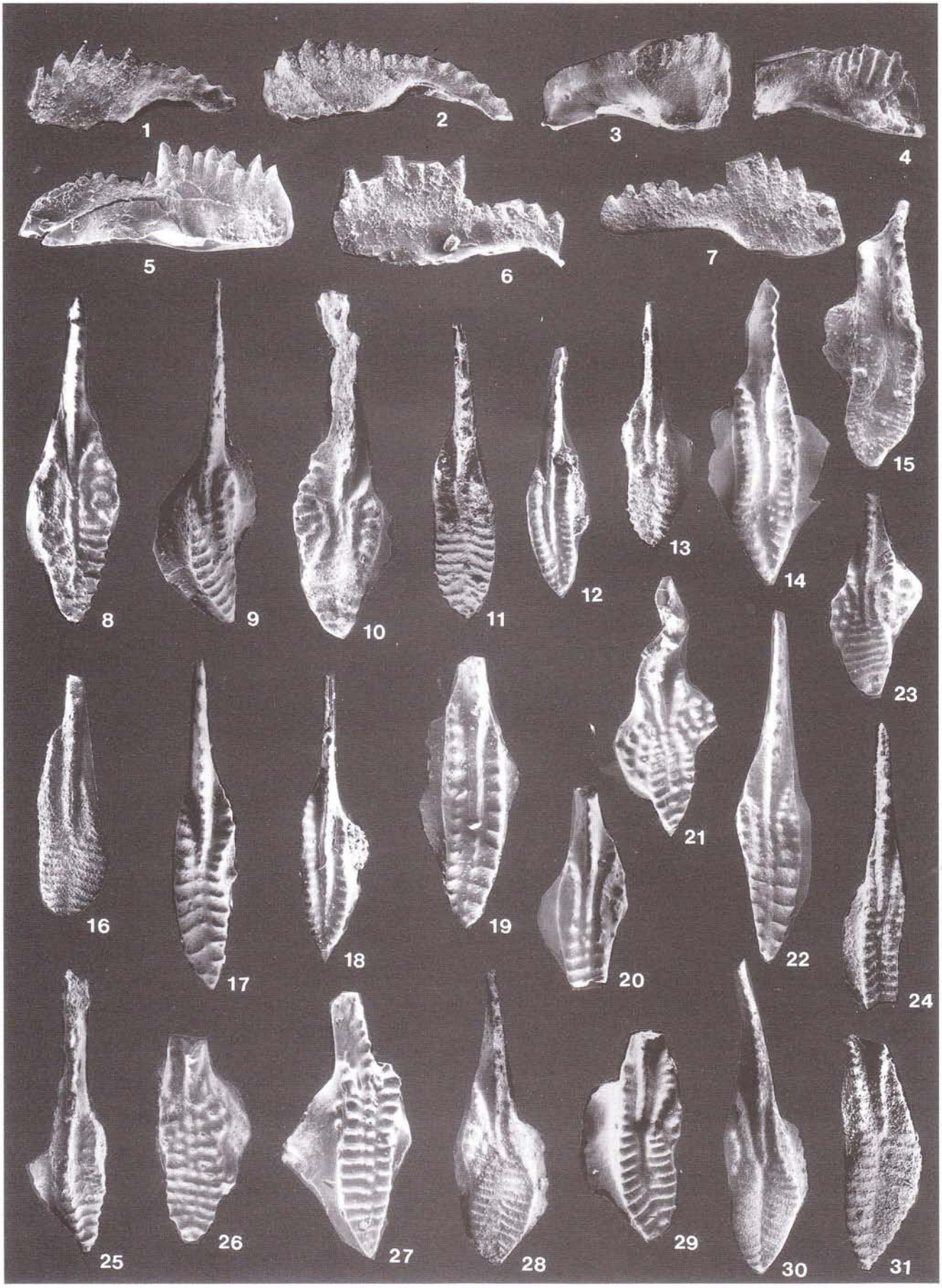
Fig. 25 - *Idiognathoides ouachitensis* (Harlton, 1933): oral view, X60, sample N56, Cat. no. 133272.

Fig. 26, 27 - *Streptognathodus oppletus* Ellison, 1941: oral views, X60, sample N96, Cat. nos. 99108, 99107.

Fig. 28 - *Streptognathodus wabaunsensis* Gunnell, 1933: oral view, X40, sample N123, Cat. no. 99101.

Fig. 29, 30 - *Streptognathodus isolatus* Chenykh, Ritter & Wardlaw, 1996: oral views, X60, X40, sample N125, Cat. nos. 133273, 99100.

Fig. 31 - *Streptognathodus longilatus* Chenykh & Ritter,1997: oral view, X80, sample N125, Cat. no. 133274.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