

Middle Cambrian through lowermost Ordovician conodonts from Hunan, South China

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Abstract.—Since 1986, samples with a total mass of more than 14,000 kg, mainly from three key sections in western Hunan, South China, have been processed for conodonts. Previous work mainly focused on biostratigraphy, but the taxonomy has been performed only on the faunas of the middle Cambrian. Described herein are conodonts of the upper Cambrian (Furongian Series) through lowermost Ordovician from Hunan, South China. Conodonts of the middle Cambrian are redescribed, based on material that has been recovered for more than three decades. The fauna consists of 82 species belonging to 36 genera. Newly established genera are *Lugnathus* n. gen., *Miaognathus* n. gen., *Millerodontus* n. gen., *Tujiagnathus* n. gen., *Wangcunella* n. gen. and *Wangcunognathus* n. gen. New species are *Coelocerodontus hunanensis* n. sp., *Furnishina wangcunensis* n. sp., *Laiwugnathus hunanensis* n. sp., *Laiwugnathus transitans* n. sp., *Lugnathus hunanensis* n. gen. n. sp., *Miaognathus multicostatus* n. gen. n. sp., *Millerodontus intermedius* n. gen. n. sp., *Prosgittodontus compressus* n. sp., *Tujiagnathus gracilis* n. gen. n. sp., *Wangcunella conicus* n. gen. n. sp., *Wangcunognathus elegans* n. gen. n. sp., *Westergaardodina dimorpha* n. sp., *Westergaardodina gigantea* n. sp., and *Westergaardodina sola* n. sp. The taxonomy of some conodont genera is revised. In the light of histological investigation, genera are assigned to euconodonts, paraconodonts, or protoconodonts. The 13 conodont zones previously proposed in the middle Cambrian through lowermost Ordovician remain the same, but taxa within these conodont zones are documented more clearly because of the revised taxonomy proposed herein.

Introduction

Nogami (1966, 1967) published the first studies on Cambrian conodonts recovered from North China. An (1981, 1982) and An et al. (1983) greatly expanded systematic studies on Cambrian conodonts of northern and northeastern China. Wang (1985) and Chen and Gong (1986) focused on conodonts across the Cambrian–Ordovician boundary in northern and northeastern China. Wang and Luo (1984), An and Zheng (1990), and Zhao et al. (2000) found only sporadic Cambrian conodonts in northwestern China.

An (1982) used a more biostratigraphic approach. He made good use of the favorable geological conditions in northern and northeastern China, mainly in four key sections in Liaoning, Hebei, and Shandong. There, he founded conodont zones of the Zhangxia Formation (middle Cambrian) through the Fengshan Formation (upper Cambrian). Paraconodont zones below the Fengshan Formation were the first to be proposed for this interval anywhere in the world.

An et al. (1981) also initiated studies of Cambrian conodonts in South China, although they focused on conodonts across the Cambrian–Ordovician boundary. They found *Cordylodus proavus* Müller, 1959 and other important elements, such as *Monocostodus sevierensis* (Miller, 1969), in the dolostone in the top part of the Sanyoudong Formation in Yichang, Hubei. An et al. (1981) first proposed that the Cambrian–Ordovician boundary

should be drawn at ~10 m below the top of the Sanyoudong Formation, which previously had been considered to be entirely upper Cambrian. Dong (1983, 1985) restudied conodonts in the interval across the Cambrian–Ordovician boundary in Yichang, where he found *Cordylodus intermedius* Furnish, 1938 and *Cordylodus angulatus* Pander, 1856. Dong founded three conodont assemblage zones in these Yichang strata and proposed that the Cambrian–Ordovician boundary there should be drawn at the base of the *Monocostodus sevierensis*–*Cordylodus intermedius* Assemblage Zone, which is 14 m below the top of the Sanyoudong Formation in Yichang. Dong (1987) recognized the *Proconodontus* Zone, *Cordylodus proavus* Zone, and *C. intermedius* Zone in Chuxian, Anhui, South China. Based on conodonts from western Zhejiang and Chuxian, Anhui in South China, Ding et al. (1993a, b) distinguished the *Proconodontus* Zone and the *C. proavus* Zone. Western Hunan has a favorable geological setting for systematic studies of Cambrian conodonts in South China because of relatively continuous carbonate deposition, but conodont research there was in a pioneer state before the late 1980s. Xi-ping Dong began studying Cambrian through lowermost Ordovician conodont biostratigraphy and taxonomy in western Hunan in 1985. An and Hu (1985) and An (1987) studied two sections, namely at Luoyixi in Guzhang County and Likouzui in Fenghuang County. Because they recovered only a few Cambrian conodonts, it was not possible to propose

conodont zones. Recently, Bagnoli and colleagues did excellent work on the Cambrian conodonts of South China (Qi et al., 2006; Bagnoli et al., 2008; Bagnoli and Qi, 2011).

One difficulty in biostratigraphic study of Cambrian conodonts has been the lack of a detailed zonation based on paraconodonts below the upper upper Cambrian. A regionally applicable zonation based on earliest euconodonts, which first appear in the upper upper Cambrian, was largely established in North America in the 1980s and has been improved subsequently (Miller et al., 2003). This zonation based on early euconodonts played an important role in delimiting the Cambrian–Ordovician boundary and should prove to be useful in defining the terminal stage of the Cambrian (Miller, 1980, 1981, 1987, 1988; Miller et al., 1982, 2006, 2011, 2014a; Forty et al., 1982; Taylor and Landing, 1982; Nowlan, 1985; Bagnoli et al., 1987; Barnes, 1988; Fåhræus and Roy, 1993; Landing, 1979, 1993; Landing and Westrop, 2006; Landing et al., 1986, 2003, 2007, 2011; Ji and Barnes, 1994; Taylor and Repetski, 1995; Nicoll et al., 1999; Parsons and Clark, 1999; Cooper et al., 2001; Pyle et al., 2007). Since 1982, several of these zones and subzones have been successively recognized in North China (An, 1982; An et al., 1983; Wang, 1985; Chen and Gong, 1986; Nowlan and Nicoll, 1995), South China (Dong, 1985, 1987; Dong et al., 2004c), Australia (Nicoll, 1990, 1991; Nicoll and Shergold, 1991), Kazakhstan (Dubinina, 2000), Mexico (Landing et al., 2007), New Zealand (Wright and Cooper, 1994), Turkey (Göncüoğlu and Kozur, 2000), and South Korea (Lee, 2001, 2002a, b, 2004, 2008a, b; Lee et al., 2009).

Despite all of this published work, conodonts in the middle Cambrian and most of the upper Cambrian have not been recognized worldwide as useful index fossils. There are several reasons for this. First, trilobites have been, and remain, the key fossils for biostratigraphic subdivision and correlation of Cambrian rocks, and most biostratigraphic studies have been centered on this group. Other groups, including conodonts, were largely neglected until the late 1960s. Second, the routine technique of etching samples with acetic acid for conodonts is suitable for processing only carbonate rocks. Conodonts are generally rare or absent in many dolostones, so only limestones are suitable in most cases for large-scale processing. However, continuously deposited and well-exposed middle Cambrian to Lower Ordovician limestone successions occur only in a few countries, such as China. Third, there has been a tendency among many conodont workers to consider the Cambrian paraconodont taxa to be stratigraphically long ranging and hence of limited use for stratigraphic subdivision and correlation.

In Europe, the well-studied middle to upper Cambrian sections in Scandinavia are stratigraphically very condensed, and the trilobite biostratigraphy has been well studied. These strata have particularly great potential for study of paraconodonts. Conodont faunas in these successions were described in a magnificent monograph by Müller and Hinz (1991). However, because the aim of their study was taxonomic rather than biostratigraphic, they focused their sampling on fossiliferous limestone nodules in the black shale succession. The age of each sample was subsequently established based on the trilobite taxa present. As a result, ranges of conodont species are known only in terms of trilobite zones, and the range of each conodont taxon

within a specific trilobite zone is currently unknown unless it is present in the overlying and underlying zones. Müller and Hinz (1991) established no conodont zones, but their study suggests that many taxa are long ranging, although some of their species have restricted stratigraphic ranges (Müller and Hinz, 1991, table 2). It seems likely that their classic monograph has contributed to the belief that many paraconodonts are stratigraphically long ranging and hence of limited biostratigraphic use. In addition, several other studies in Europe and elsewhere have been mainly general or taxonomic in nature, with relatively little attention paid to the potential use of especially paraconodonts as guide fossils (Müller, 1959).

The fourth factor contributing to the lack of established Cambrian paraconodont biostratigraphy in most regions of the world is the lack of detailed research. Outside of China, there has been relatively little conodont research in strata older than the late late Cambrian, especially compared with the extensive work on euconodonts from younger rocks. For instance, many promising Cambrian sections in eastern and western North America remain unexplored for conodonts (Dong et al., 2004a). For the past 25 years, the middle and lower upper Cambrian conodont biostratigraphic work in the world has largely been centered in China, and especially in South China.

The purpose of this paper is to describe conodonts of the upper Cambrian (Furongian Series) through lowermost Ordovician from Hunan, South China and to redescribe conodonts of the middle Cambrian, based on the material that has been accumulated for the past quarter century. The taxonomy of some conodont genera is revised. In light of histological investigation, some genera can now be assigned to euconodonts, paraconodonts, or protoconodonts.

Geological setting

In terms of the paleogeography of China, the Southeast Stratigraphic Region is characterized by flyschoid sediments. In the Yangtze Stratigraphic Region, the middle and upper Cambrian succession mainly is composed of dolostone. Only in the Langyashan Subregion does the middle and upper Cambrian consist mainly of dolomitic limestone. The upper part of the middle Cambrian through the lowermost Ordovician is made up chiefly of limestone in the Danzai-Baojing-Qinyang Subregion of the Jiangnan Stratigraphic Region. Within that area, mainly in western Hunan, are well-developed and continuously deposited stratigraphic successions. Accordingly, western Hunan is an ideal area for the study of Cambrian conodonts in South China.

Three sections in Hunan were selected as key sections. These are the Paibi section in Huayuan County, the Wangcun section in Yongshun County, and Wa'ergang section in Taoyuan County. Three other sections in Hunan were selected as auxiliary sections, including the Xiaoxi section in Jishou County, the Xiaoxiqiao section in Qianzhou, and the Yangjiazhai section in Jishou. Two additional sections in Hunan were selected as reference sections; these are the Tieqiao to Liangshuijing section in Fenghuang County and the Huaqiao section in Baojing County (Fig. 1). Some of the data gathered from these investigations have been published (Dong, 1990a, b, 1991, 1992, 1993, 1997, 1999a, b, 2000, 2001; Dong and Bergström, 2000a, b, 2001a, b; Dong et al., 2001, 2004a, c). The present

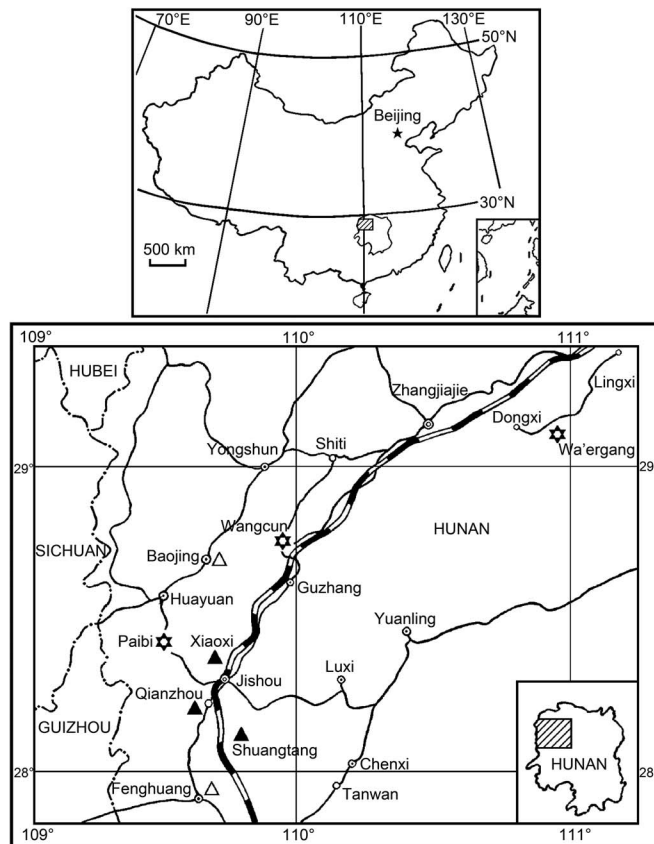


Figure 1. Location of the studied sections: ☆ Location of the key sections, ▲ location of the auxiliary sections, △ location of the reference sections.

study is the continuation of these previous studies and includes the first systematical description of the conodonts of upper Cambrian through lowermost Ordovician from Hunan, South China, taxonomic revision of some Cambrian conodonts, review of the problems in the zonation of paraconodonts recovered from western Hunan, South China, and assignment of some genera to euconodonts, paraconodonts, or protoconodonts in light of histological investigation.

Conodont samples were collected from the three key sections on 15 occasions from 1986 to 2008 and from the three auxiliary sections from 1986 to 1995. The two reference sections were collected only sporadically, in 1986 and 1987. The average sampling interval is 2.5 m and the average sample mass is 4.6 kg. A total of 3,100 conodont samples have been collected, including re-sampled ones and 388 conodont-barren samples, with a total mass of more than 14,000 kg.

In the study area, there are mainly five types of lithology in the interval from the middle Cambrian Huaqiao Formation to the lower part of the lowermost Ordovician Panjiazui Formation.

1. Dark-gray, thin-bedded to medium- to thin-bedded, laminated, argillaceous, very fine to finely crystalline limy dolostone. Protoconodonts, but almost no other fossils, occur in this lithology.
2. Alternating layers of dark-gray, medium-bedded, laminated, argillaceous dolostone, and dark gray, medium-bedded micrite and biomicrite. The argillaceous dolostone does not yield

fossils, whereas the limestones yield abundant conodonts, fossil embryos (Dong, 2007a, 2009a, b; Dong et al., 2004b, 2005a, 2010; Peng and Dong, 2008; Cheng et al., 2011), fossils of typical Orsten-type preservation (Dong et al., 2005b; Liu and Dong, 2007, 2009, 2010; Zhang and Dong, 2009; Zhang et al., 2011a, b, 2012; Duan et al., 2012), highly modified sponge spicules (Dong and Knoll, 1996; Chen and Dong, 2008), radiolarians (Dong et al., 1997), small shelly fossils (Zhu et al., 2003, 2004; Zhu and Dong, 2004), as well as trilobites and brachiopods.

3. Dark-gray, thin- to medium-bedded biomicrosparite that yields abundant conodonts as well as some trilobites, brachiopods, and bradoriids.
4. Gray, thick-bedded calcirudite. Fragmentary trilobites have been found occasionally in this lithology. No conodont samples have been collected from this lithology.
5. Dark-gray, thin-bedded micrite intercalated with dark-gray, thin-bedded to laminated, dolomitic calcisiltite, containing organic matter and scattered pyrite. Burrows and bioturbation may occur. The micrite yields abundant conodonts, as well as trilobites, brachiopods, small shelly fossils, sponge spicules, and radiolarians.

Except for type 4, the calcirudites, the other four types of lithology were collected with specific sampling intervals from the key sections and auxiliary sections on the first sampling round. Mainly type 2, type 3, and type 5 were collected from the key sections during the second and third sampling rounds. Mainly type 3 and type 5 were collected during the fourth to the twelfth sampling rounds. The purpose of the fourth to the fifteenth sampling rounds was to recover, in addition to conodonts, sponge spicules, radiolarians, and soft-bodied fossils, such as embryos, and typical Orsten-type fossils, especially arthropods.

Materials and methods

The samples were processed by routine etching with ~10% technical acetic acid in plastic pails with a capacity of 10 L. The cycle of sieving and changing acid required 7–10 days. The samples (including duplicate samples) generally needed to be processed in three to four cycles for complete dissolution. During processing, the reaction time and the pH value of the solution were adjusted according to the lab temperature (~20°C in winter and up to 35°C in July and August). Some samples were processed in plastic pails with two-layered screens to recover better specimens for histologic studies as well as for recovery of phosphatized soft-bodied fossils. Results using the two-layered screens were very good.

For histological study, protoconodont-like elements were examined by double-polished thin sections and by etching both the thin sections and artificially fractured specimens with 0.5% orthophosphoric acid for 10 minutes, and then their images were taken by scanning electron microscope. Because of the small size and thin-walled nature of these paraconodonts and earliest euconodonts, the oil immersion technique is used for those elements (Dong et al., 2005c). Clove oil was used as the immersion medium, and specimens were examined using a Zeiss Axiophot or Olympus microscope fitted with differential interference contrast (Nomarski) optics. Photomicrographs were obtained using a Nikon Coolpix

990 or Olympus BH2 BHS UMA camera fitted via a c-mount and interchange lens to the microscope.

Repository and institutional abbreviation.—All the figured specimens are deposited at the Geological Museum, Peking University (GMPKU).

Chronostratigraphy

The Ordovician is divided into Lower, Middle, and Upper Ordovician series. The current classification of Cambrian is divided into four series; Series 2 and Series 3 have not been formally named. The Terreneuvian and Series 2 are sometimes informally referred to as lower Cambrian, Series 3 is sometimes informally referred to as middle Cambrian, and the fourth series, the Furongian Series, is sometimes referred to as upper Cambrian. Therefore, we use the term Lower Ordovician formally, but also use the terms middle Cambrian and upper Cambrian informally.

Conodont biostratigraphy

Based on the stratigraphic ranges of conodont species, the middle Cambrian through lowermost Ordovician succession at Wangcun, Wa'ergang, and Paibi, South China, is subdivided into 13 conodont zones (Figs. 2–4; see also Dong and Bergström, 2001a).

Gapparodus bisulcatus-*Westergaardodina brevidens* Zone.—This zone is recognized in the lower part of the middle Cambrian Huaqiao Formation in the Paibi section, Huayuan and in the Wangcun section, Yongshun. Its lower limit is marked by the First Appearance Datum (FAD) of *Gapparodus bisulcatus* (Müller, 1959), and its upper limit is defined by the FAD of *Shandongodus priscus* An, 1982. The entire zone is characterized the dominance of protoconodonts and the first occurrence and high diversity of the genus *Westergaardodina* Müller, 1959. The main taxa of the zone are *Furnishina bigeminata* Dong, 1993, *F. kleithria* Müller and Hinz, 1991, *G. bisulcatus*, *Gumella cuneata* Müller and Hinz, 1991, *Huayuanodontus tricornis* (Dong, 1993), *Laiwugnathus hunanensis* n. sp., *Muellerodus? oelandicus* (Müller, 1959), *Paibiconus proarcuratus* Dong, 1993, *Phakelodus tenuis* (Müller, 1959), *Westergaardodina brevidens* Dong, 1993, *W. horizontalis* Dong, 1993, and *Yongshunella polymorpha* Dong and Bergström, 2001a.

Shandongodus priscus-*Hunanognathus tricuspидatus* Zone.—This zone is recognized in the upper part of the middle Cambrian Huaqiao Formation in the Paibi and Wangcun sections. Its lower limit is defined by the FAD of *Shandongodus priscus* and its upper limit by the FAD of *Westergaardodina quadrata* (An, 1982). It is characterized by the extreme diversity of paraconodonts and the maximum numbers of protoconodonts. Its main taxa are *Coelocerodontus bicostatus* van Wamel, 1974, *Furnishina cf. alata* Szaniawski, 1971, *F. cf. gladiata* Müller and Hinz, 1991, *F. cf. kranzae* Müller and Hinz, 1991, *F. longibasis* Bednarczyk, 1979, *F. pernica* An, 1982, *F. cf. quadrata* Müller, 1959, *Hunanognathus tricuspидatus* Dong, 1993, *Muellerodus? obliquus* (An, 1982), *M. pomeranensis* (Szaniawski, 1971), *Nogamiconus sinensis* (Nogami, 1966), *S. priscus*, *Westergaardodina elegans* Dong and Bergström, 2001a, *W. tetragonia* Dong, 1993, and

Westergaardodina sp. D. In addition, there are taxa ranging upward from the underlying zone, including *F. bigeminata*, *Gapparodus bisulcatus*, *Gumella cuneata*, *Huayuanodontus tricornis*, *M.? oelandicus*, *Paibiconus proarcuratus*, *Phakelodus tenuis*, *W. brevidens*, and *Yongshunella polymorpha*.

Westergaardodina quadrata Zone.—This zone can be recognized in the lower part of the middle Cambrian Chefu Formation in the Paibi and Wangcun sections. Its lower limit is defined by the FAD of *Westergaardodina quadrata* and its upper limit by the FAD of *W. matsushitai* Nogami, 1966. It is characterized by the great abundance of *W. quadrata*. Its main taxa are *Furnishina quadrata* Müller, 1959, *Prosagittodontus compressus* n. sp., *W. cf. behrae* Müller and Hinz, 1991, *W. quadrata*, *W. cf. quadrata* and *W. sola* n. sp. In addition, there are taxa ranging into this zone from the underlying zone, such as *Furnishina cf. alata*, *F. bigeminata*, *F. kleithria*, *F. longibasis*, *F. pernica*, *F. cf. quadrata*, *Gapparodus bisulcatus*, *Gumella cuneata*, *Huayuanodontus tricornis*, *Hunanognathus tricuspидatus*, *Nogamiconus sinensis*, *Muellerodus? obliquus*, *M.? oelandicus*, *M. pomeranensis*, *Paibiconus proarcuratus*, *Phakelodus tenuis*, *W. elegans*, *W. tetragonia*, and *Yongshunella polymorpha*.

Westergaardodina matsushitai-*Westergaardodina grandidens* Zone.—This zone can be recognized in the upper part of the middle Cambrian Chefu Formation in the Paibi, Wangcun, and Wa'ergang sections. Its base is marked by the FAD of *Westergaardodina matsushitai*, and its top is defined by the FAD of *Westergaardodina lui* Dong, Repetski, and Bergström, 2004c. It is characterized by a notable reduction in the number of protoconodonts and by the occurrence of morphologically unusual species of *Westergaardodina*. Its main elements are *Laiwugnathus transitans* n. sp., *L. cf. kouzhenensis* An, 1982, *Prosagittodontus dahlmani* (Müller, 1959), *Westergaardodina cf. horizontalis* Dong, 1993, *W. gigantea* n. sp., *W. grandidens* Dong, 1993, and *W. matsushitai*. In addition, there are taxa ranging from the underlying zone, such as *Coelocerodontus bicostatus*, *Furnishina cf. alata*, *F. bigeminata*, *F. cf. kranzae*, *F. longibasis*, *F. quadrata*, *F. cf. quadrata*, *Gapparodus bisulcatus*, *Gumella cuneata*, *Huayuanodontus tricornis*, *Muellerodus? obliquus*, *M.? oelandicus*, *M. pomeranensis*, *Nogamiconus sinensis*, *Paibiconus proarcuratus*, *Phakelodus tenuis*, *Prosagittodontus compressus* n. sp., *W. elegans*, *W. cf. quadrata*, *W. sola* n. sp., *W. quadrata* and *Yongshunella polymorpha*.

Westergaardodina lui-*Westergaardodina ani* Zone.—This zone occurs in the lower part of the upper Cambrian Bitiao Formation in the Wangcun and Wa'ergang sections. This zone supersedes the *Westergaardodina prolifera* Zone as used in Dong and Bergström (2001a). Its lower boundary is defined by the FAD of *W. lui*, and its top by the FAD of *W. cf. calix* Müller and Hinz, 1991. It is characterized by a notable reduction of the diversity of species of *Westergaardodina* compared with strata below. Its main taxa are *Furnishina dayangchaensis* Chen and Gong, 1986, *F. furnishi* Müller, 1959, *F. cf. furnishi* Müller, 1959, *F. gladiata* Müller and Hinz, 1991, *F. kranzae* Müller and Hinz, 1991, *F. primitiva* Müller, 1959, *F. tortilis* (Müller, 1959), *F. cf. ovata* Müller and Hinz, 1991, *Muellerodus cambricus* (Müller, 1959), *M. guttulus* Müller and Hinz, 1991, *Proacodus obliquus* Müller, 1959, *P. pulcherus* (An, 1982), *Prooneotodus gallatini* (Müller, 1959), *P. terashimai*

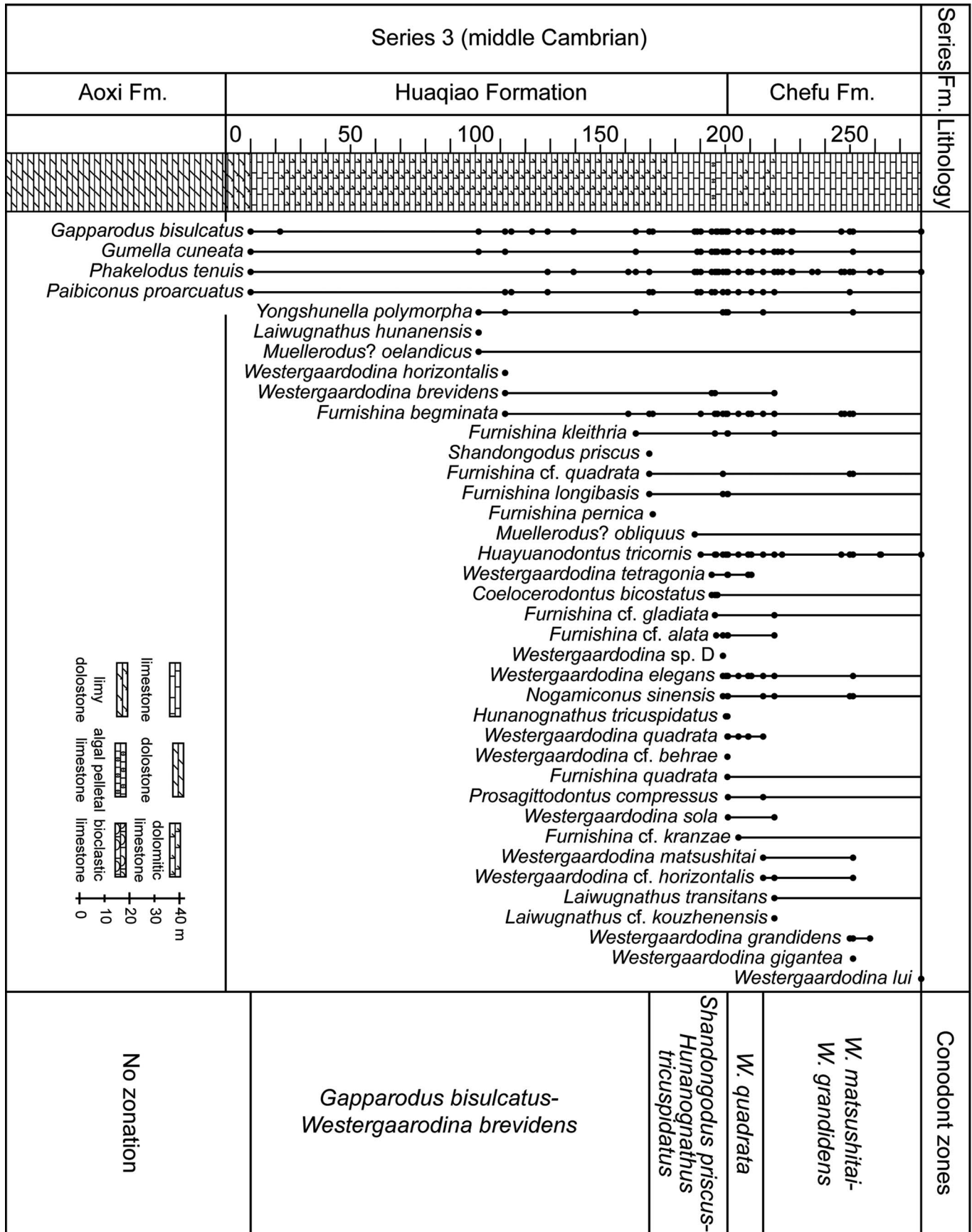


Figure 2. (Continued)

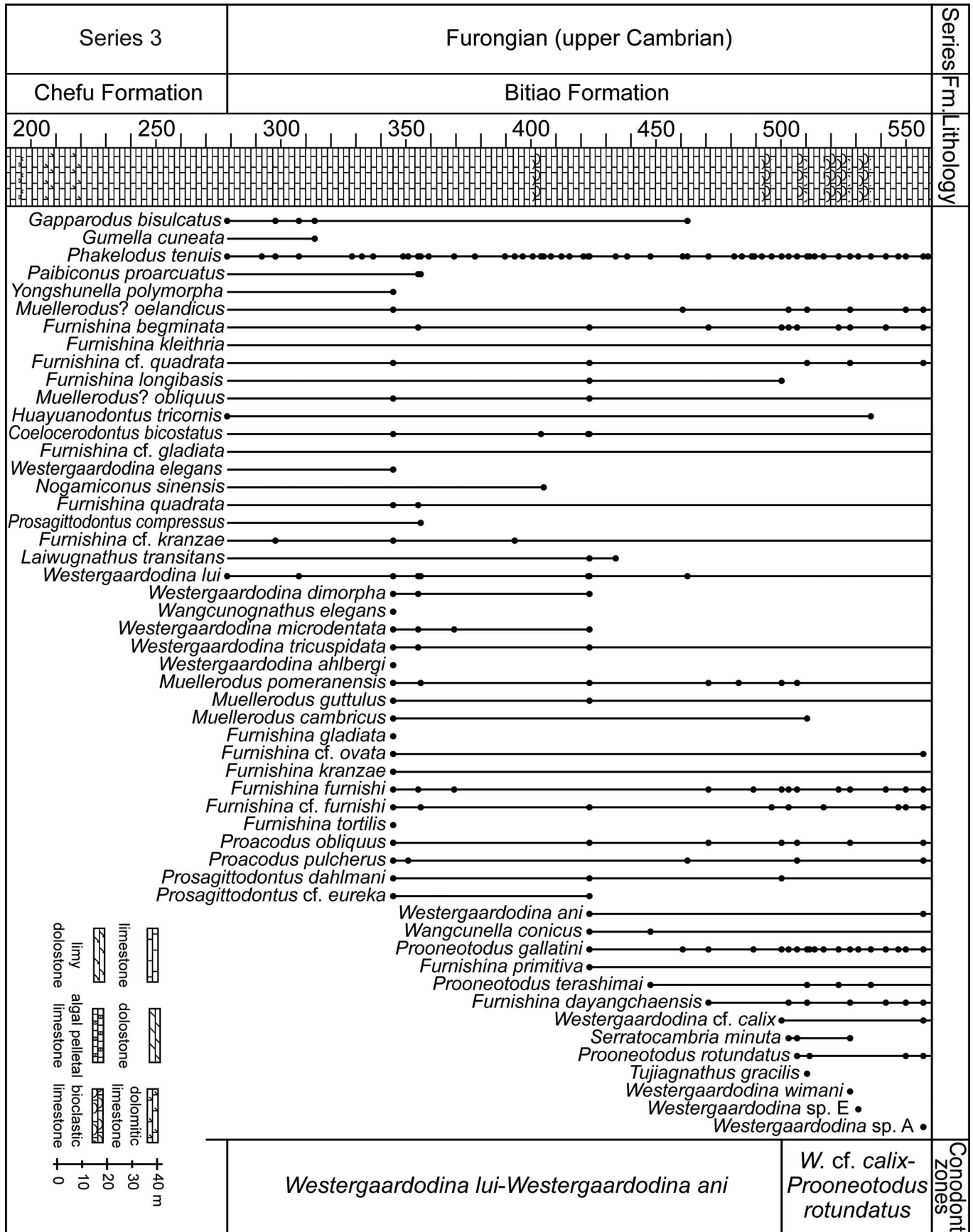


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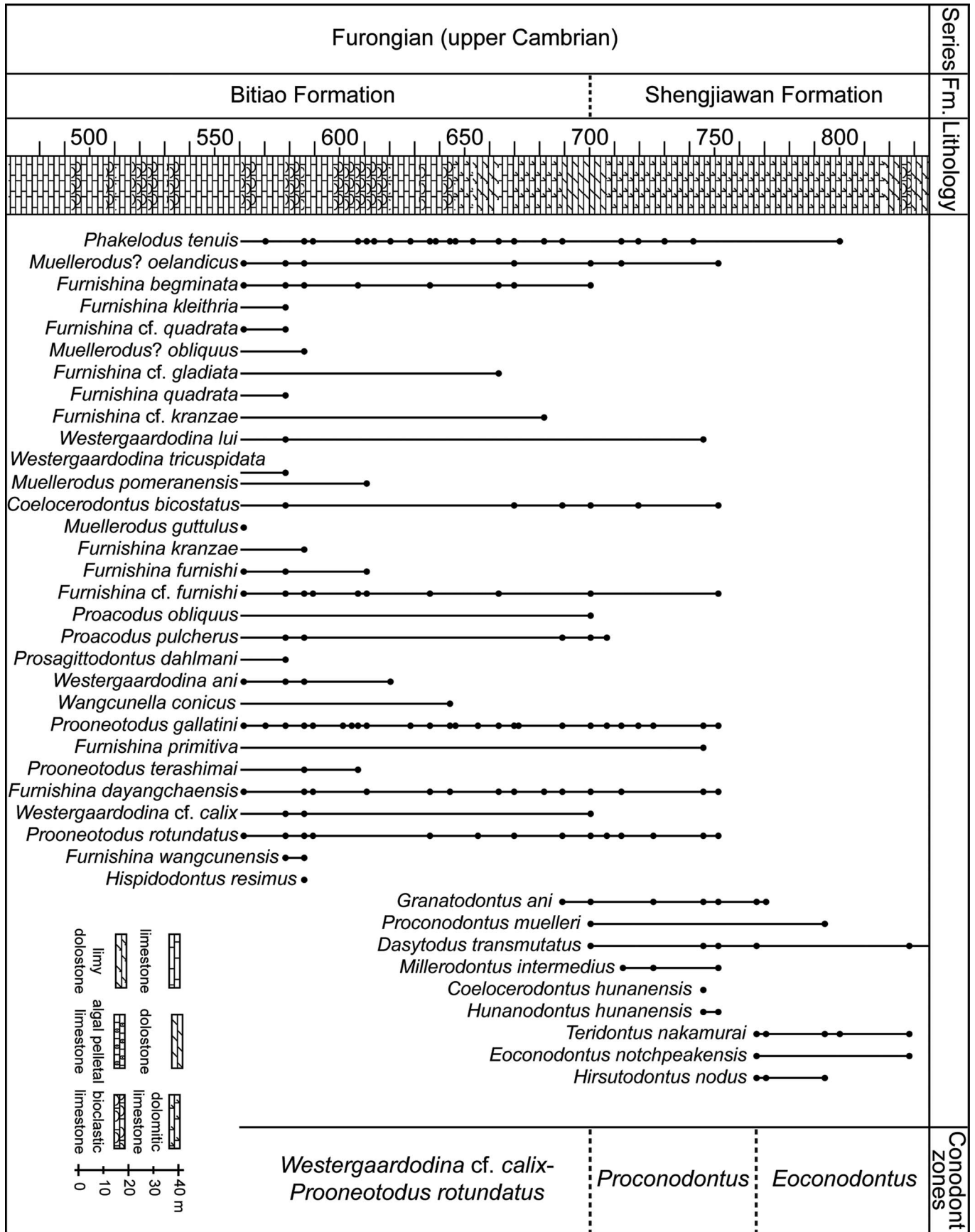


Figure 2. Chart showing the stratigraphic ranges of the upper middle Cambrian through upper Cambrian (Furongian) conodonts and conodont zones in the Wangcun section in Hunan, China.

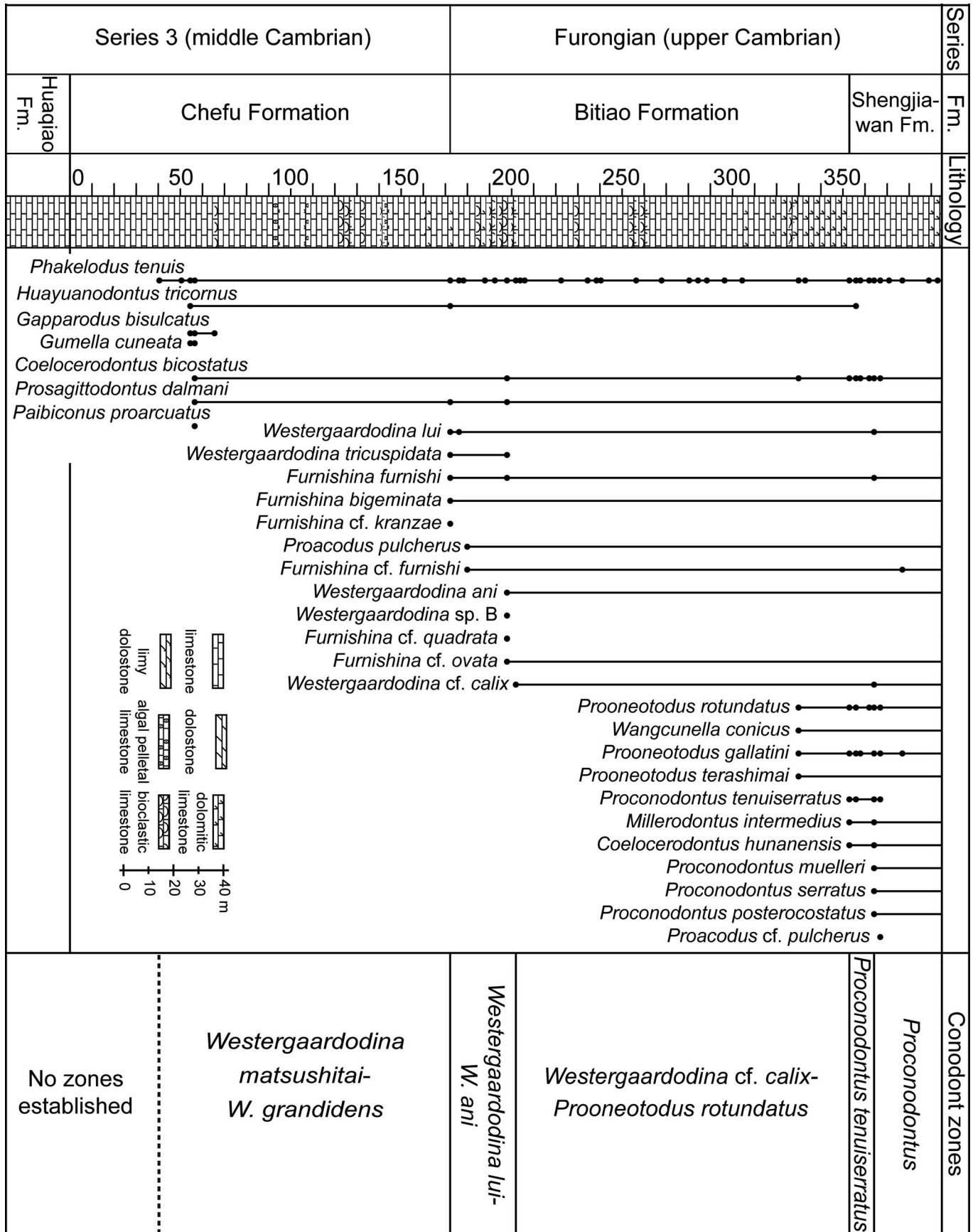


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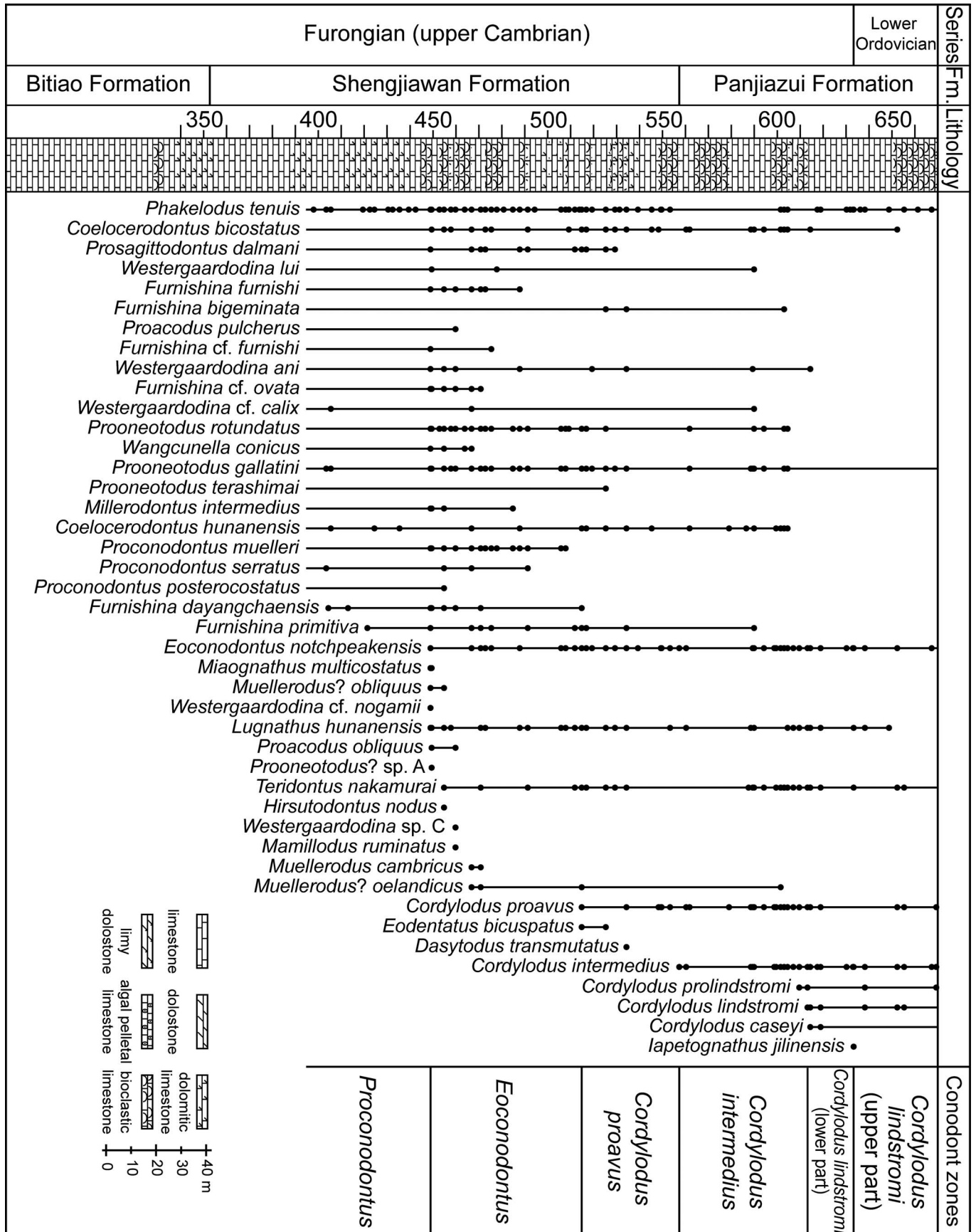


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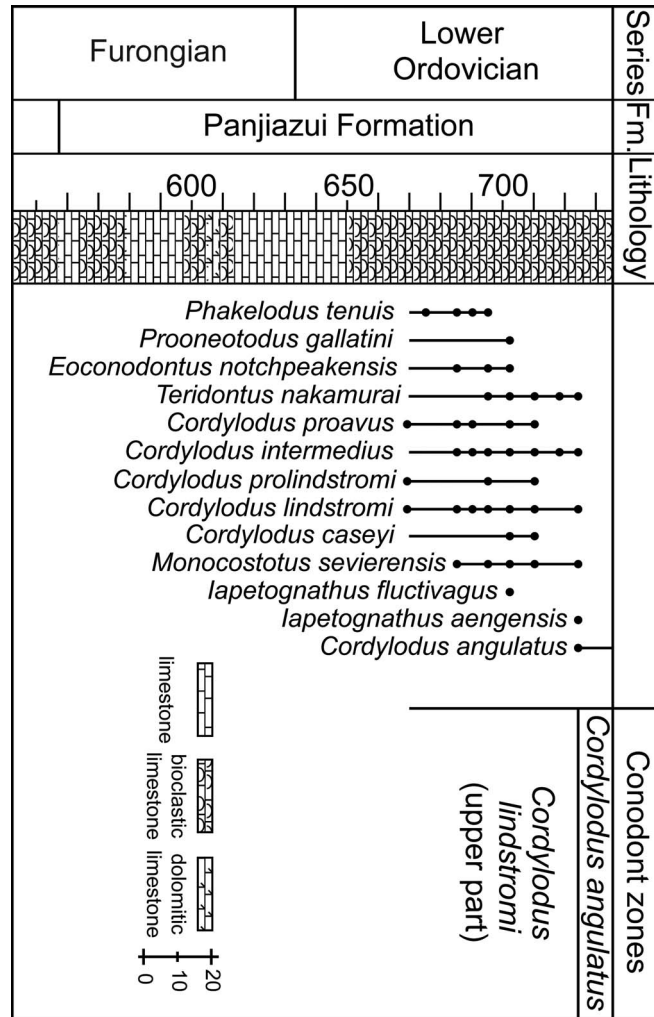


Figure 3. Chart showing the stratigraphic ranges of the upper middle Cambrian through lowermost Ordovician conodonts and conodont zones in the Wa'ergang section in Hunan, China.

(Nogami, 1967), *Prosagittodontus cf. eureka* Müller, 1959, *Wangcunella conicus* n. gen. n. sp., *Wangcunognathus elegans* n. gen. n. sp., *Westergaardodina ahlbergi* Müller and Hinz, 1991, *W. ani* Dong et al., 2004c, *W. dimorpha* n. sp., *W. lui*, *W. microdentata* Zhang in An et al., 1983, *W. tricuspidata* Müller, 1959, and *Westergaardodina* sp. B. In addition, there are taxa that continue from the underlying zone, such as *Coelocerodontus bicostatus*, *F. bigeminata*, *F. cf. kranzae*, *F. cf. gladiata*, *F. longibasis*, *F. quadrata*, *F. cf. quadrata*, *Gapparodus bisulcatus*, *Gumella cuneata*, *Huayuanodontus tricornis*, *Laiwugnathus transitans* n. sp., *M.? obliquus*, *M.? oelandicus*, *M. pomeranensis*, *Nogamiconus sinensis*, *Phakelodus tenuis*, *Prosagittodontus compressus* n. sp., *P. dahlmani*, *W. elegans*, and *Yongshunella polymorpha*.

Westergaardodina cf. calix-*Prooneotodus rotundatus* Zone.—This zone is recognized in the upper part of the upper Cambrian Bitiao Formation in the Wangcun and Wa'ergang sections. This zone supercedes the *Westergaardodina cf. behrae*-*Prooneotodus rotundatus* Zone as used in Dong and Bergström (2001a). Its base is marked by the FAD of *Westergaardodina cf. calix* and its upper limit by the FAD of *Proconodontus tenuiserratus* Miller, 1980. It is characterized by the maximum number of species of *Prooneotodus*

observed in the various zones. Its main taxa are *Furnishina wangcunensis* n. sp., *Granatodontus ani* (Wang, 1985), *Hispidodontus resimus* Nicoll and Shergold, 1991, *Prooneotodus rotundatus* (Druce and Jones, 1971), *Serratocambria minuta* Müller and Hinz, 1991, *Tujiagnathus gracilis* n. gen. n. sp., *W. cf. calix*, *W. wimani* Szaniawski, 1971, *Westergaardodina* sp. A., and *Westergaardodina* sp. E. In addition, there are taxa ranging from the underlying zone, such as *Coelocerodontus bicostatus*, *F. bigeminata*, *F. dayangchaensis*, *F. furnishi*, *F. cf. furnishi*, *F. kleithria*, *F. cf. kranzae*, *F. cf. gladiata*, *F. longibasis*, *F. cf. ovata*, *F. cf. quadrata*, *Huayuanodontus tricornis*, *Muellerodus cambricus*, *M.? oelandicus*, *M. pomeranensis*, *M.? obliquus*, *Phakelodus tenuis*, *Proacodus obliquus*, *P. pulcherus*, *Prooneotodus terashimai*, *Prosagittodontus dahlmani*, *Wangcunella conicus* n. gen. n. sp., *Westergaardodina ani*, *W. lui*, and *W. tricuspidata*.

Proconodontus tenuiserratus Zone.—This zone can be recognized in the lower part of the upper Cambrian Shengjiawan Formation in the Wa'ergang section. Its lower boundary is defined by the FAD of *Proconodontus tenuiserratus* and its upper boundary by the FAD of *Proconodontus muelleri* Miller, 1969. Its main taxa are *Coelocerodontus hunanensis* n. sp.,

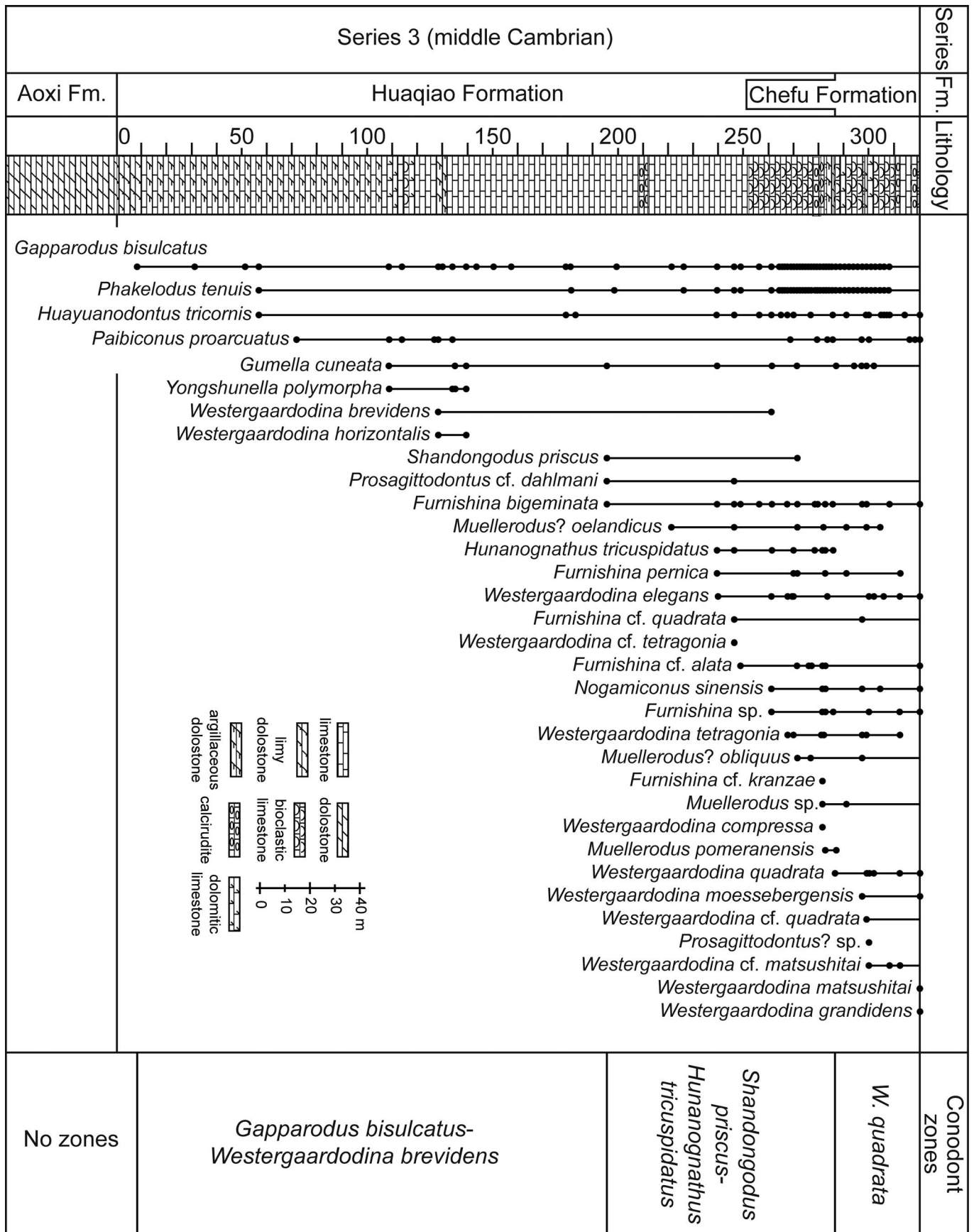


Figure 4. (Continued)

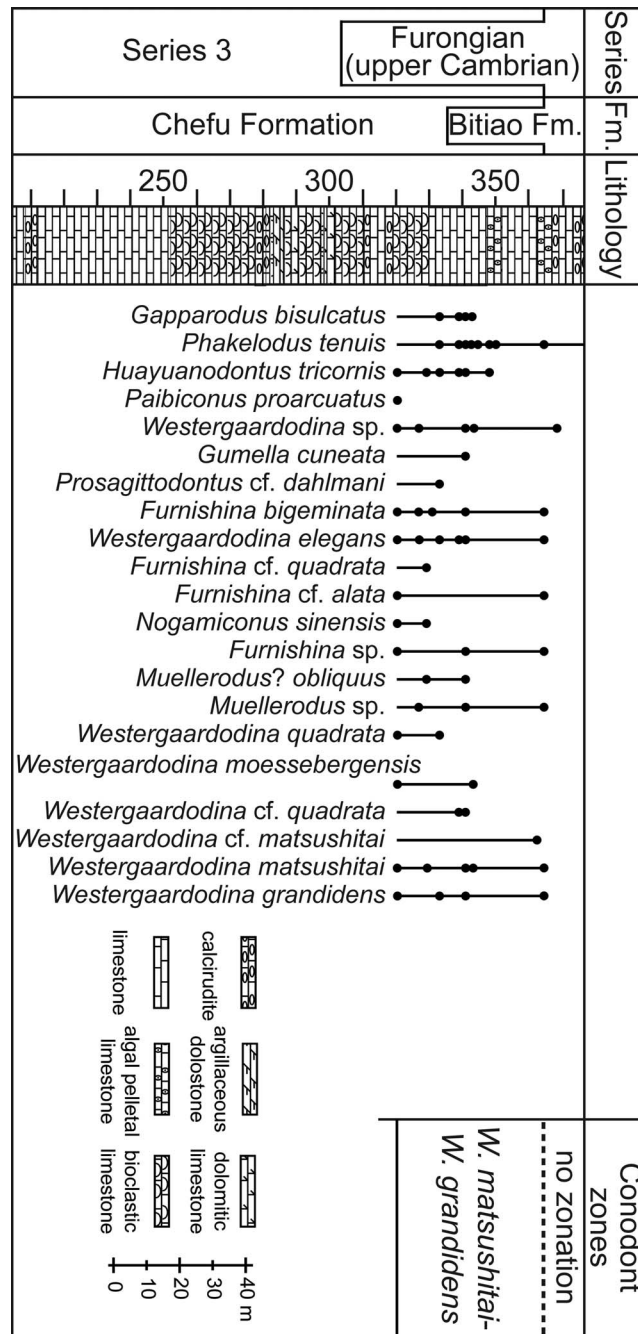


Figure 4. Chart showing the stratigraphic ranges of the upper middle Cambrian conodonts and conodont zones in the Paibi section in Hunan, China (modified after Dong and Bergström, 2001a).

Millerodontus intermedius n. gen. n. sp., and *P. tenuiserratus*. In addition, there are taxa ranging from the underlying zone upward into this zone, such as *Coelocerodontus bicostatus*, *Furnishina bigeminata*, *F. dayangchaensis*, *F. furnishi*, *Granatodontus ani*, *Huayuanodontus tricornis*, *Muellerodus cambricus*, *M.? oelandicus*, *Phakelodus tenuis*, *Proacodus obliquus*, *Prooneotodus gallatini*, *P. terashimai*, *P. rotundatus*, *Wangcunella conicus* n. gen. n. sp., *Westergaardodina ani*, *W. lui*, and *W. cf. calix*.

Proconodontus Zone.—This zone is recognized in the lower part of the upper Cambrian Shengjiawan Formation in the Wangcun and Wa’ergang sections. In addition, this zone can be

identified in the upper Cambrian Cheshuitong Formation in Chuxian, Anhui (Dong, 1987). Its lower and upper limits are defined by the FAD of *Proconodontus muelleri* and *Eoconodontus notchpeakensis* (Miller, 1969), respectively. Its main taxa are *Dasyodus transmutatus* (Xu and Xiang in An et al., 1983), *P. muelleri*, *P. posterocostatus* Miller, 1980, *P. serratus* Miller, 1980, and *Proacodus cf. pulcherus* (An, 1982). In addition, there are taxa that range from the underlying zone into this zone, such as *Coelocerodontus bicostatus*, *C. hunanensis* n. sp., *Furnishina bigeminata*, *F. furnishi*, *F. cf. furnishi*, *F. dayangchaensis*, *F. cf. ovata*, *Granatodontus ani*, *Millerodontus intermedius* n. gen. n. sp.,

Muellerodus cambricus, *M.?* *obliquus*, *M.?* *oelandicus*, *Phakelodus tenuis*, *Proacodus obliquus*, *P. pulcherus*, *Proconodontus tenuiserratus*, *Prooneotodus gallatini*, *P. terashimai*, *P. rotundatus*, *Prosagittodontus dahlmani*, *Wangcunella conicus* n. gen. n. sp., *Westergaardodina ani*, *W. lui*, and *W. cf. calix*.

***Eoconodontus* Zone.**—This zone can be recognized in the upper part of the upper Cambrian Shengjiawan Formation in the Wa'ergang section. Its lower and upper boundaries are defined by the FAD of *Eoconodontus notchpeakensis* and *Cordylodus proavus*, respectively. Its main taxa are *E. notchpeakensis*, *Lugnathus humanensis* n. gen. n. sp., *Hirsutodontus nodus* (Zhang and Xiang, 1983), *Mamillodus ruminates* Dubinina, 2000, *Miaognathus multicostatus* n. gen. n. sp., *Prooneotodus?* sp. A, *Teridontus nakamurai* (Nogami, 1967), *Westergaardodina cf. nogamii* Müller Hinz, 1991, and *Westergaardodina* sp. C. In addition, there are taxa ranging from the underlying zone into this zone, such as *Coelocerodontus bicostatus*, *C. hunanensis* n. sp., *Furnishina bigeminata*, *F. dayangchaensis*, *F. furnishi*, *F. cf. furnishi*, *F. primitiva*, *F. cf. ovata*, *Dasytodus transmutatus*, *Granatodontus ani*, *Millerodontus intermedius* n. gen. n. sp., *Muellerodus cambricus*, *M.?* *oelandicus*, *Phakelodus tenuis*, *Proacodus obliquus*, *Prooneotodus gallatini*, *P. terashimai*, *P. rotundatus*, *Proconodontus muelleri*, *P. posterocostatus*, *P. serratus*, *Prosagittodontus dahlmani*, *Wangcunella conicus* n. gen. n. sp., *Westergaardodina cf. calix*, *W. ani*, and *W. lui*.

***Cordylodus proavus* Zone.**—This zone is recognized in the upper part of the upper Cambrian Shengjiawan Formation in the Wa'ergang section. Moreover, this zone can be recognized in the upper Cambrian Cheshuitong Formation at Chuxian, Anhui (Dong, 1987). Its lower and upper boundaries are defined by the FAD of *Cordylodus proavus* and *C. intermedius* Furnish, 1938, respectively. Its main taxa are *C. proavus* and *Eodontatus bicuspatatus* Nicoll and Shergold, 1991. In addition, there are taxa ranging from the underlying zone, such as *Coelocerodontus bicostatus*, *C. hunanensis* n. sp., *Dasytodus transmutatus*, *Eoconodontus notchpeakensis*, *Furnishina bigeminata*, *F. furnishi*, *F. dayangchaensis*, *F. primitiva*, *Lugnathus humanensis* n. gen. n. sp., *Muellerodus?* *oelandicus*, *Phakelodus tenuis*, *Prooneotodus gallatini*, *P. rotundatus*, *P. terashimai*, *Prosagittodontus dahlmani*, *Teridontus nakamurai*, *Westergaardodina cf. calix*, *W. ani*, and *W. lui*.

***Cordylodus intermedius* Zone.**—This zone is recognized in the lowermost part of the Panjiazui Formation in the Wa'ergang section. It can also be recognized in the lowermost part of the Cheshuitong Formation in Chuxian, Anhui (Dong, 1987); that formation originally was assigned to the Lower Ordovician. Its lower boundary is marked by the FAD of *Cordylodus intermedius*, and its upper boundary by the FAD of *C. lindstromi* Druce and Jones, 1971. Its main taxa are *C. intermedius* and *C. prolindstromi* Nicoll, 1991. In addition, there are taxa ranging from the underlying zone, such as *Coelocerodontus bicostatus*, *C. hunanensis* n. sp., *Cordylodus proavus*, *Eoconodontus notchpeakensis*, *Furnishina primitiva*, *Lugnathus humanensis* n. gen. n. sp., *Muellerodus?* *oelandicus*, *Phakelodus tenuis*,

Prooneotodus gallatini, *P. rotundatus*, *Teridontus nakamurai*, *Westergaardodina ani*, *W. cf. calix*, and *W. lui*.

***Cordylodus lindstromi* Zone.**—This zone is recognized in the lower part of the Panjiazui Formation in the Wa'ergang section. Its lower and upper boundaries are defined by the FAD of *Cordylodus lindstromi* and *C. angulatus*, respectively. Its main taxa are *C. caseyi* Druce and Jones, 1971, *C. lindstromi*, *Iapetognathus fluctivagus* Nicoll, Miller, Nowlan, Repetski, and Ethington, 1999, *I. jilinensis* Nicoll, Miller, Nowlan, Repetski, and Ethington, 1999, and *Monocostodus sevierensis*. Taxa that continue from the underlying zone include *Coelocerodontus bicostatus*, *Cordylodus intermedius*, *C. proavus*, *C. prolindstromi*, *Eoconodontus notchpeakensis*, *Lugnathus humanensis* n. gen. n. sp., *Phakelodus tenuis*, *Teridontus nakamurai*, and *Westergaardodina ani*.

***Cordylodus angulatus* Zone (lower part).**—This zone is recognized in the lower part of the Panjiazui Formation in the Wa'ergang section. Its lower limit is defined by the FAD of *Cordylodus angulatus*, but its upper limit is not delimited herein because the upper portion of this zone is beyond the scope of the present study. Its main taxa are *C. angulatus* and *Iapetognathus aengensis* (Lindström, 1955). In addition, there are taxa that range from the underlying zone, such as *C. intermedius*, *C. lindstromi*, *Monocostodus sevierensis*, and *Teridontus nakamurai*.

Correlation of conodont zones

The formal conodont zonation older than the Fengshan Formation in North China and the Shengjiawan Formation in South China (Furongian, upper Cambrian) has been mainly established in China (Figs. 5, 6). Outside China, the middle Cambrian conodont zone *Gapparodus bisulcatus*-*Westergaardodina mossebergensis* is erected in the lower part of the Machari Formation, Yeongweol area, Gangweon Province, in South Korea (Lee et al., 2009).

At present, the paraconodont zones below the Shengjiawan Formation in Hunan can be correlated only with those in North China (An, 1982; Chen and Gong, 1986). In contrast, euconodont zones in Hunan can be correlated widely with related zones in North China and elsewhere (Fig. 5).

***Gapparodus bisulcatus*-*Westergaardodina brevidens* Zone.**—In terms of species, this zone shares only a few elements with the *Laiwugnathus laiwuensis* Zone of North China (An, 1982). The upper boundary of the Hunan zone and the *L. laiwuensis* Zone are both marked by the FAD of *Shandongodus priscus*, so the top of both zones may be correlated. In Hunan, the lowest occurrence of *Gapparodus bisulcatus* is in the lowermost part of the middle Cambrian Huaqiao Formation, and this level is equivalent to the lowest occurrence of the trilobite *Ptychagnostus atavus* (Tullberg, 1880). The lowest occurrence of *P. atavus* in Hunan corresponds to that of *Crepicephalina* Resser and Endo in Kobayashi, 1935 in North China (Peng, 2009a). Accordingly, it is inferred that the lower part of the *G. bisulcatus*-*Westergaardodina brevidens* Zone correlates with the lower part of the Zhangxia Formation in North China (Fig. 6).

Series	Formation	Hunan South China (Dong et al., 2004)	North China (An, 1982; Wang, 1985; Chen and Gong, 1986)	Western U. S. A. (Miller, 1980, 1988; Nicoll et al., 1999)	W. Newfoundland, Canada (Barnes, 1988; Cooper et al., 2001)
Lower Ordovician (part)	Panjiazui Fm.	Above study interval	<i>Cordylodus angulatus</i> - <i>Chosonodina herfurthi</i>	<i>Cordylodus angulatus</i>	<i>Cordylodus angulatus</i> (<i>angulatus</i> Fauna)
		<i>Cordylodus angulatus</i> (lower part)			
Furongian (upper Cambrian)	Panjiazui Fm.	<i>Cordylodus lindstromi</i> (upper part)	<i>Cordylodus lindstromi</i> (upper part)	<i>lapetognathus</i>	<i>lapetognathus fluctivagus</i> (<i>lindstromi</i> - <i>prion-lapetognathus</i> Fauna)
		<i>Cordylodus lindstromi</i> (lower part)	<i>Cordylodus lindstromi</i> (lower part)	<i>Cordylodus lindstromi sensu lato</i>	<i>Cordylodus intermedius</i> (<i>intermedius</i> Fauna)
	<i>Cordylodus intermedius</i>	<i>Cordylodus intermedius</i>	<i>Cordylodus intermedius</i>		
	Shengjiawan Fm.	<i>Cordylodus proavus</i>	<i>Cordylodus proavus</i>	<i>Cordylodus proavus</i>	<i>Cordylodus proavus</i> (<i>proavus</i> Fauna)
		<i>Eoconodontus</i>	<i>Cambrooistodus</i>	<i>Eoconodontus</i>	<i>Eoconodontus notchpeakensis</i>
		<i>Proconodontus</i>	<i>Proconodontus</i>	<i>Proconodontus muelleri</i>	No zonation established
<i>Proconodontus posterocostatus</i>					
<i>Proconodontus tenuiserratus</i>	<i>Proconodontus tenuiserratus</i>	<i>Proconodontus tenuiserratus</i>			
Bitiao Fm.	<i>Westergaardodina cf. calix</i> - <i>Prooneotodus rotundatus</i>	<i>Westergaardodina aff. fossa</i> - <i>Prooneotodus rotundatus</i>	No zonation established		
	<i>Westergaardodina lui</i> - <i>W. ani</i>	<i>Muellerodus? erectus</i>			
Chefu Fm.	<i>W. matsushitai</i> - <i>W. grandidens</i>	<i>Westergaardodina matsushitai</i>			
	<i>Westergaardodina quadrata</i>	<i>Westergaardodina orygma</i>			
Huaqiao Fm.	<i>Shandongodus priscus</i> - <i>Hunanognathus tricuspoidatus</i>	<i>Shandongodus priscus</i>			
	<i>Gapparodus bisulcatus</i> - <i>Westergaardodina brevidens</i>	<i>Laiwugnathus laiwuensis</i>			

Figure 5. Correlation of the upper middle Cambrian through lowermost Ordovician conodont zones in Hunan, South China, and those in North China, western USA, and Newfoundland, Canada.

Series	Stage	Formation		Conodont Zones (Dong et al., 2004)	Trilobite Zones (Peng, 2009a, b; Peng et al., 2012)	
		N.China	Hunan			
Furongian (upper Cambrian)	Tremadoc	Yeli Fm. (part)	Panjiazui Fm.	<i>C. angulatus</i> (lower part)	<i>Hysteroleonus</i> (part)	
				<i>C. lindstromi</i> (upper part)		
				<i>C. lindstromi</i> (lower part)		
				<i>Cordylodus intermedius</i>		
	Stage 10	Fengshan Fm.	Shenjiawan Fm.	<i>Cordylodus proavus</i>	<i>Leiostegium constrictum</i> - <i>Shenjiawania brevis</i>	
				<i>Eoconodontus</i>	<i>Mictosaukia striata</i> - <i>Fatocephalus</i>	
				<i>Proconodontus</i>	<i>Leiagnostus</i> cf. <i>bexelli</i> - <i>Archaeuloma taoyuanense</i>	
				<i>Proconodontus tenuiserratus</i>	<i>Lotagnostus americanus</i>	
		Jiangshanian	Changshan Fm.	Bitiao Fm.	<i>Westergaardodina</i> cf. <i>calix</i> - <i>Prooneotodus rotundatus</i>	<i>Eolotagnostus decorus</i> - <i>Kaolishaniella</i>
					<i>Westergaardodina lui</i> - <i>W. ani</i>	<i>Rhaptagnostus ciliensis</i> - <i>Oncholotellus</i> cf. <i>kuruktagnensis</i>
						<i>Agnostotes orientalis</i>
						<i>Tomagnostella orientalis</i> - <i>Corynexochus plumula</i>
	Paibian				<i>Agnostus inexpectans</i> - <i>Proceratopyge protracta</i>	
					<i>Glyptagnostus reticulatus</i>	
Series 3 (middle Cambrian)	Guzhangian	Gushan Fm.	Chefu Fm.	<i>Westergaardodina matsushitai</i> - <i>W. grandidens</i>	<i>Glyptagnostus stolidotus</i>	
				<i>Westergaardodina quadrata</i>	<i>Linguagnostus reconditus</i>	
	Drumian	Zhangxia Fm.	Huaqiao Fm.	<i>Shandongodus priscus</i> - <i>Hunanognathus tricuspидatus</i>	<i>Proagnostus bulbosus</i>	
				<i>Gapparodus bisulcatus</i> - <i>Westergaardodina brevidens</i>	<i>Lejopyge laevigata</i>	
					<i>Lejopyge armata</i>	
					<i>Goniagnostus nathorsti</i>	
					<i>Ptychagnostus punctuosus</i>	
					<i>Ptychagnostus atavus</i>	

Figure 6. Correlation between the conodont zones and trilobite zones of the upper middle Cambrian through lowermost Ordovician in Hunan, South China.

Shandongodus priscus-*Hunanognathus tricuspoidatus* Zone.—This zone shares the zonal index species *Shandongodus priscus* with the *S. priscus* Zone in North China, so the two zones can be easily correlated with each other. The bases of the two zones are marked by the FAD of *S. priscus*, so the bases of these zones may be correlated. The top of the *S. priscus*-*Hunanognathus tricuspoidatus* Zone in Hunan is marked by the FAD of *Westergaardodina quadrata*. *W. quadrata* and *Westergaardodina orygmata* are associated in North China, and their FAD is at the same horizon. Accordingly, the top of the *S. priscus*-*H. tricuspoidatus* Zone in Hunan appears to be identical to that of the *S. priscus* Zone in North China.

Westergaardodina quadrata Zone.—*Westergaardodina quadrata* and *W. orygmata* occur together and basically have the same range in the *W. orygmata* Zone in North China. The base of both these zones precisely corresponds with each other. Because the tops of both zones are defined by the FAD of *W. matsushitai*, these zones represent the same stratigraphic interval, and the *W. quadrata* Zone in South China is equivalent to the *W. orygmata* Zone in North China.

Westergaardodina matsushitai-*Westergaardodina grandidens* Zone.—*Westergaardodina matsushitai* occurs in the *W. matsushitai* Zone in Hunan and in North China (An, 1982). As mentioned above, the bases of both zones are defined in the same way and hence represent the same stratigraphic level. The top of the Hunan zone is defined by the FAD of *W. lui*, which is only a few meters higher than the last occurrence of *W. grandidens* and *W. matsushitai*, so it is nearly identical to the top of the latter zone. Therefore, the Hunan zone is correlated with the *W. matsushitai* Zone in North China.

Westergaardodina lui-*Westergaardodina ani* Zone.—In Hunan, this zone shares only *Proacodus pulcherus* with the fauna of the *Muellerodus? erectus* Zone in North China (An, 1982; Dong and Bergström, 2001a; Dong et al., 2004c). The base of the Hunan zone is defined by the FAD of *Westergaardodina lui*, and the base of the North China zone is defined by the last occurrence of *W. matsushitai*. In Hunan, the FAD of *W. lui* is only a few meters higher than the last occurrence of *W. matsushitai* and *W. grandidens*. Accordingly, the bases of both zones are roughly coeval. The top of the Hunan zone is marked by the FAD of *W. cf. calix*, whereas the top of the North China zone is defined as the level of the last appearance of *M.? erectus*. Precise correlation of the tops of these zones is difficult, and these zones are only approximately equivalent to each other.

Westergaardodina cf. calix-*Prooneotodus rotundatus* Zone.—This zone shares *Prooneotodus terashimai*, and abundant *P. gallatini* with the *Westergaardodina* aff. *fossa*-*P. rotundatus* Zone in North China (An, 1982; Dong and Bergström, 2001a; Dong et al., 2004c). The bases of both zones are broadly equivalent. The tops of both these zones are marked by the FAD of *Proconodontus tenuiserratus*, so these zones appear to represent the same stratigraphic interval.

Proconodontus tenuiserratus Zone.—*Proconodontus tenuiserratus* occurs in the *P. tenuiserratus* Zone in Hunan, in the *P. tenuiserratus* Zone in North China (An, 1982; Chen and Gong, 1986), and in the western United States of America (Miller, 1988; Miller et al., 2003). Because of the rather short stratigraphic range of this species, this zone in these three regions can be approximately correlated with one another.

Proconodontus Zone.—*Proconodontus muelleri* and *Terodontus nakamurai* occur in the *Proconodontus* Zone in Hunan and in North China (An, 1982; Chen and Gong, 1986), and both taxa are also present in western USA (Miller, 1988; Nicoll et al., 1999; Miller et al., 2003). Because *P. posterocostatus* has been found only in two horizons in Hunan, the *P. posterocostatus* Subzone and the *P. muelleri* Subzone recognized in North China cannot be distinguished in Hunan. However, the *Proconodontus* Zone in Hunan roughly corresponds to the *Proconodontus* Zone in North China (An, 1982; Chen and Gong, 1986). The Hunan zone corresponds to the interval of both the *P. posterocostatus* Zone and the *P. muelleri* Zone recognized in the western USA (Miller, 1988; Miller et al., 2003).

Eoconodontus Zone.—*Eoconodontus notchpeakensis* occurs in the *Eoconodontus* Zone in Hunan and in the *Cambrooistodus* Zone of North China (Chen and Gong, 1986) and in the *Eoconodontus* Zone in the western USA (Miller, 1988; Miller et al., 2003, 2014a). In the western United States, the *Eoconodontus* Zone is subdivided into the *E. notchpeakensis* Subzone and the *Cambrooistodus minutus* Subzone. The correlation between these subzones and the *Cambrooistodus* Zone in North China (Chen and Gong, 1986) is not clear because in North China the lowest part of the range of *E. notchpeakensis* is within the *Proconodontus* Zone (Chen and Gong, 1986, text-fig. 26), and a separate *Eoconodontus* Zone is not recognized there. *Cambrooistodus* is not found in Hunan, and the *Cambrooistodus* Zone is only recognized at Dayangcha, North China in the warm (shallow) water realm (Miller, 1988, fig. 3). The *Eoconodontus* Zone in Hunan is interpreted as broadly equivalent with the *Eoconodontus* Zone in the western United States (Miller, 1988) and with the *Cambrooistodus* Zone of North China (Chen and Gong, 1986). The *Eoconodontus* Zone in Hunan also roughly corresponds with the *E. notchpeakensis* Zone in western Newfoundland, Canada (Barnes, 1988), and with the *Eoconodontus* Zone in Black Mountain, western Queensland, Australia (Shergold et al., 1991).

Cordylodus proavus Zone.—*Cordylodus proavus* occurs in the *C. proavus* Zone in Hunan and in the *C. proavus* Zone in North China (An, 1982; Chen and Gong, 1986), and the two zones can be correlated with each other. The base of the zone is marked by the FAD of *C. proavus* and the top by the FAD of *C. intermedius*. The *C. proavus* Zone in Hunan is also correlated with the *C. proavus* Zone in the western USA (Miller, 1980, 1988; Nicoll et al., 1999; Miller et al., 2003), and with the interval containing the *proavus* Fauna in western Newfoundland (Barnes, 1988; Cooper et al., 2001).

Cordylodus intermedius Zone.—This zone is recognized worldwide. In the western United States, according to Miller (1988), “the base of the *Cordylodus intermedius* Zone is at the

lowest occurrence of several euconodonts (*Hirsutodontus simplex*, *Monocostodus sevierensis*, *Semiacontiodus lavadomensis*, *Utahconus utahensis*, and *C. intermedius*), and the paraconodont *Albiconus postcostatus* Miller, 1980. In some sections, all of these species begin at the same level or if one occurs below the others, it is often *H. simplex*.” The *C. intermedius* Zone is divided into the *H. simplex* and *Clavohamulus hintzei* Subzones in the western United States. In the Dayangcha sections in northeastern China, the first appearance of *C. intermedius*, *H. simplex*, *U. utahensis*, *S. lavadomensis*, *M. sevierensis*, and *A. postcostatus* is at the same, or nearly the same, horizon, so the base of the *C. intermedius* Zone there correlates with the base of the *H. simplex* Subzone of the North American zonal scheme (Chen and Gong, 1986). However, *H. simplex* and *C. hintzei* have not yet been found in Hunan, probably because these two species were shallow water taxa. Rare specimens of these species have been found at the Green Point section, Newfoundland, but these specimens may be reworked from shallow water platform strata (Cooper et al., 2001). The precise correlation of the *C. intermedius* Zone in Hunan with the *C. intermedius* Zone in other regions is somewhat unclear. This is particularly the case with correlation of the top of the *C. intermedius* Zone in Hunan with that of the *C. intermedius* zones in other regions. Therefore, we interpret the *C. intermedius* Zone in Hunan as only roughly equivalent to the *C. intermedius* Zone in North China (Chen and Gong, 1986), the *C. intermedius* Zone in the western United States (Miller, 1988; Nicoll et al., 1999; Miller et al., 2003), and the interval of the *intermedius* Fauna in western Newfoundland (Cooper et al., 2001).

Cordylodus lindstromi Zone.—This zone is recognized widely in the world. We tentatively consider the *Cordylodus lindstromi* Zone in Hunan as broadly corresponding to the *C. lindstromi* Zone in North China (Chen and Gong, 1986). The Hunan zone corresponds to the combined *Iapetognathus* Zone and the *Cordylodus lindstromi* Zone in the western USA (Ross et al., 1997; Nicoll et al., 1999; Miller et al., 2003), and roughly to the *Iapetognathus fluctivagus* Zone (*lindstromi-prion-Iapetognathus* Fauna) in western Newfoundland (Cooper et al., 2001). Terfelt et al. (2012) restudied the Global boundary Stratotype Section and Point (GSSP) for the base of the Ordovician System in the Green Point section, Newfoundland, Canada. They found *I. fluctivagus* is not present at the boundary interval. As a result, the identification of the Cambrian–Ordovician boundary level outside the GSSP section has proven to be problematic. Miller et al. (2003, 2014b) suggested the base of *Iapetognathus* Zone should be the Cambrian–Ordovician boundary level, i.e., the FAD of lowest species of *Iapetognathus*. In Hunan, *I. jilinsensis* Nicoll et al., 1999 is the lowest species of *Iapetognathus*. Consequently, the FAD of *I. jilinsensis* is the base of the upper part of the *C. lindstromi* Zone and the Cambrian–Ordovician boundary level. Unfortunately, *I. jilinsensis* has been found at only one level in Hunan, so this correlation is only approximate.

Cordylodus angulatus Zone (lower part).—*Cordylodus angulatus* occurs in the *C. angulatus* Zone in Hunan and in the *C. angulatus-Chosonodina herfurthi* Zone in North China

(Chen and Gong, 1986), in the *C. angulatus* Zone in the western United States (Miller, 1980, 1988; Ross et al., 1997; Nicoll et al., 1999; Miller et al., 2003), and in the interval of the *angulatus* Fauna in western Newfoundland (Barnes, 1988; Cooper et al., 2001). It appears that the *C. angulatus* Zone in Hunan corresponds to the lower part of the zone in the regions mentioned, and the top of this zone is above the stratigraphic interval studied herein.

Correlation of conodont zones with trilobite zones

Many workers have investigated the trilobite biostratigraphy of Cambrian sections in Hunan, e.g., Lu (1956), Jegorova et al. (1963), Lin et al. (1966), Yang (1978, 1981, 1984), Lin (1991), Dong (1990a, b, 1991), Peng (1987, 1992), Peng and Robison (2000), Peng et al. (2004), Peng (2009a, b) and Peng et al. (2012). Peng (2009a, b) and Peng et al. (2012) presented a comprehensive summary with much new information that allows detailed correlation with the Cambrian conodont zones in Hunan (Fig. 6).

Conodont histology

Although histological study on conodonts can be traced back to the 1930s (Branson and Mehl, 1933), systematic histological investigations on conodonts began in the 1970s (Müller and Nogami, 1971) and since then has been carried out by many authors (Bengtson, 1976, 1983; Szaniawski, 1982, 1983, 1987; Andres, 1988; Szaniawski and Bengtson, 1993, 1998; Müller and Hinz, 1998, etc.). The discovery of the entire conodont animal (Briggs et al., 1983; Aldridge, 1987; Aldridge et al., 1993; Gabbott et al., 1995) greatly stimulated the comparative histological study on euconodonts so as to verify their biological affinity, and many papers were involved in the “conodont controversies” (Purnell et al., 1995; Aldridge and Purnell, 1996; Donoghue et al., 2000). In contrast to the debate, Szaniawski did refined work on the affinity of protoconodonts based on their hard tissues and the fossils of chaetognaths recognized in the Burgess Shale (Szaniawski, 2002, 2005). Philip C. J. Donoghue and Xi-ping Dong investigated well-preserved elements of protoconodonts, paraconodonts, and the earliest euconodonts from the middle and late Cambrian in the Paibi, Wangcun, and Wa’ergang sections in western Hunan. They found that conodont elements recovered from western Hunan are of great significance in terms of histology. Our comparative histological study on the earliest euconodonts has been published (Dong et al., 2005c; Guo et al., 2005a, b), and the study on paraconodonts will be published in a separate paper.

Assignment of taxa to either protoconodonts, paraconodonts, or euconodonts is vitally important in the study of Cambrian conodonts. The present paper is only involved in the histological study as it relates to assigning taxa to one of those three groups. Bengtson (1976) proposed a model showing an evolutionary sequence from protoconodonts through paraconodonts to euconodonts. A direct evolutionary relationship between protoconodonts and paraconodonts remains unproved and is much more hypothetical than that between paraconodonts and euconodonts (Szaniawski and Bengtson, 1993; Donoghue et al., 2000; Murdock et al., 2013). At present, protoconodonts are

assigned to phylum Chaetognatha Leuckart, 1854, whereas paraconodonts and euconodonts are assigned to different classes of phylum Chordata Bateson, 1886 (Lee et al., 2009).

Histological investigations by Philip C. J. Donoghue and Xi-ping Dong (unpublished data) indicate that it is not always possible to distinguish reliably among the elements of these three taxonomic groups based only on study of their external morphology, even by experienced observers, and histological study is often required to determine the correct taxonomy. *Paibiconus* Dong, 1993 and *Huayuanodontus* Dong and Bergström, 2001a were both considered originally to be protoconodonts (An and Mei, 1994; Dong and Bergström, 2001a). Histological investigation by Philip C. J. Donoghue and Xi-ping Dong verified that *Paibiconus* is a protoconodont (Dong, 2004). However, longitudinal cross sectioning of elements of *Huayuanodontus* showed a two-layered structure that is different from that of protoconodonts, paraconodonts, or euconodonts. Therefore, further histological work is needed to determine the taxonomic assignment of *Huayuanodontus* (cf. Dong, 2007b). *Coelocerodontus* Ethington, 1959 has thin-walled coniform elements with large basal cavities. The cross section is extremely narrow. Clusters are very common. It has been referred to as a protoconodont, paraconodont, or euconodont by different authors (Müller and Hinz, 1991, p. 53). Müller and Hinz (1991) considered it to be a euconodont, although they did not elucidate their histological evidence in 1991 or later (Müller and Hinz, 1998). Philip C. J. Donoghue and Xi-ping Dong tested many specimens of this genus recovered from Hunan by means of immersion in clove oil (unpublished data). Unequivocal crown material was found in all the tested specimens, so this genus should be considered as a euconodont.

Prooneotodus rotundatus is a cosmopolitan paraconodont species. Miller (1980) recognized a new genus and species that resembles *P. rotundatus*. He stated that the new genus and species differs from *P. rotundatus* in possessing a thin layer of apatite (crown material) that covers a massive white basal cone (Miller, 1980, p. 32). Unfortunately, he has not performed any histological investigations that he mentioned would be needed to confirm his interpretation (personal communication, J.F. Miller, 2007). We investigated well-preserved elements that appear to be *P. rotundatus* from upper Cambrian strata in Hunan, South China by means of the oil immersion technique (Dong et al., 2005c). Some of the investigated elements show typical paraconodont structure. However, some investigated elements have crown tissues, in which we found crystals of apatite perpendicular to the conodont grown axis, and regeneration could be observed at the apical portion of the elements. Both features are typical of euconodonts, and these elements are considered euconodonts rather than paraconodonts. Herein, they are assigned to *Millerodontus intermedius* n. gen. n. sp., and the species is interpreted as a transition between the paraconodont *Prooneotodus* and the primitive euconodont genus *Proconodontus*. Regenerated tips of elements are found also in *Proconodontus*, which occurs with *Millerodontus*. This is the first report to establish a new conodont genus in the light of histological study.

Post-Tremadocian conodonts are all euconodonts, but protoconodonts, paraconodonts, and euconodonts co-occur in

Cambrian through Tremadocian strata. Therefore, histological investigation of Cambrian conodonts is of great importance not only in the differentiation of protoconodonts, paraconodonts, and euconodonts, but this information is the foundation on which to explore the taxonomy and the early evolution of conodonts.

Systematic paleontology

Recently, Lee et al. (2009) separated the Cambrian and Tremadocian conodonts into three groups: paraconodonts, euconodonts, and protoconodonts in their Systematic Paleontology and proposed an updated classification of conodont faunas in terms of phylum, class, and order. We follow their taxonomic treatment herein.

Euconodonts

Phylum Chordata Bateson, 1886
Superclass Conodonta Pander, 1856
Class Conodonti Branson, 1938

Genus *Coelocerodontus* Ethington, 1959

Type species.—*Coelocerodontus trigonius* Ethington, 1959.

Remarks.—This genus consists of thin-walled coniform elements with large basal cavities. The cross section is extremely narrow. Clusters are very common. As mentioned above, histological investigation indicates that it is a euconodont. It is probably the oldest known euconodont.

Coelocerodontus bicostatus van Wamel, 1974
Figures 7.1–7.12, 7.16–7.18, 8.1–8.4

- 1974 *Coelocerodontus bicostatus* van Wamel, p. 55, pl. 3, fig. 2.
1974 *Coelocerodontus latus* van Wamel, p. 56, pl. 1, fig. 2.
1983 “*Coelocerodontus*” *bicostatus* van Wamel; Landing, p. 1172, fig. 10A, B.
1986 *Stenodontus compressus* Chen and Gong, p. 186, pl. 24, figs. 11, 16, pl. 25, figs. 2–5, 7–13, 16, text-fig. 76.
1986 *Stenodontus jilinensis* Chen and Gong, p. 187, pl. 18, figs. 2, 4–7, 9, 17, 18, pl. 19, figs. 3, 7, pl. 24, figs. 1, 9, 18, pl. 34, figs. 9, 14, 15, 19, text-fig. 77.
1987 *Coelocerodontus bicostatus* van Wamel; An, p. 104, pl. 1, fig. 11.
1987 *Diaphanodus latus* (van Wamel); Bagnoli et al., p. 155, pl. 2, figs. 11, 12.
1988 *Coelocerodontus cambricus* (Nogami); Heredia and Bordonaro, p. 190, pl. 2, figs. 2, 3.
1988 *Rotundoconus mendozanus* Heredia and Bordonaro, p. 194, pl. 3, fig. 5, pl. 4, fig. 3.
1988 *Coelocerodontus cambricus* (Nogami); Lee and Lee, pl. 1, fig. 27.
1988 *Coelocerodontus apparatus*, Andres, pl. 9, figs. 3–8, text-fig. 19.

- 1991 *Coelocerodontus bicostatus* van Wamel; Müller and Hinz, p. 53, pl. 41, figs. 1–21, text-figs. 20A–D.
- 2000 “*Proacontiodus*” *latus entis* Dubinina, p. 175, pl. 3, figs. 15, 16, 20, 21 (not figs. 1, 1a, 7, 8).
- 2000 “*Proacontiodus*” *latus* Dubinina, p. 174, pl. 3, figs. 30, 31.
- 2001 *Coelocerodontus cambricus* (Nogami); Lee, p. 449, figs. 6, 11.
- 2002a *Coelocerodontus cambricus* (Nogami); Lee, p. 165, pl. 2, fig. 16.
- 2002b *Coelocerodontus cambricus* (Nogami); Lee, p. 25, pl. 1, figs. 16, 17.
- ? 2006 *Coelocerodontus bicostatus* van Wamel; Qi et al., p. 187, pl. 3, fig. 17.
- 2007 *Coelocerodontus bicostatus* van Wamel; Landing et al., p. 922, fig. 9a, b.
- 2009 *Coelocerodontus bicostatus* van Wamel; Lee et al., p. 423, figs. 7, 18.
- 2011 *Coelocerodontus bicostatus* van Wamel; Bagnoli and Qi, p. 12 (G, H, I).
- 2014 *Stenodontus compressus* Chen and Gong; Bagnoli and Stouge, p. 20, fig. 11, N–R.

Description.—Bimembrate apparatus of asymmetrical and subsymmetrical elements. The asymmetrical element is thin-walled and coniform. It is laterally compressed, with keeled anterior and posterior edges. Its cross section is extremely narrow. Both lateral sides have a costa that extends up to the apex. The pointed apex extends far beyond the posterior basal margin, leading to a recurved triangular outline in lateral view. The basal cavity is very deep. The subsymmetrical element differs from the asymmetrical element in the hook-like apical portion and the inconspicuous carinae instead of costae on both lateral sides.

Materials.—469 specimens.

Occurrence.—Known from the Wangcun and Wa’ergang sections, where it ranges from the *Shandongodus priscus-Hunanognathus tricuspoidatus* Zone through the *Cordylodus intermedius* Zone.

Remarks.—Müller and Hinz (1991) described Morphotype alpha and Morphotype beta of this species. Of the material at hand, the asymmetrical element and subsymmetrical element correspond, respectively, with Morphotype alpha and Morphotype beta in terms of overall morphology.

Coelocerodontus hunanensis new species
Figures 7.13–7.15, 7.19–7.25, 9.1–9.14, 9.18, 9.19

Diagnosis.—Elongate proclined, thin-walled coniform elements with very deep basal cavities, laterally compressed, with keeled anterior and posterior edges. Both lateral sides are characterized by costae or only one lateral side is characterized by a costa. The outline is extremely slender, with a high length/maximum width ratio.

Description.—Elongate, thin-walled coniform elements, proclined, asymmetrical, laterally compressed, with keeled anterior and posterior edges. The cross section is extremely narrow. Both lateral

sides are characterized by costae or only one lateral side is characterized by a costa, each of which extends up to the apex; position of these costae is highly variable. The outline of the element is extremely slender. The length/maximum width ratio is more than 3.5. The tip of the cusp is usually not preserved. The basal cavity is very deep.

Etymology.—Named for its provenance in Hunan Province.

Types.—Holotype: GMPKU2432, from the *Cordylodus intermedius* Zone, Furongian (upper Cambrian), Panjiazui Formation, Wa’ergang section, Wa’ergang village, Taoyuan County, Hunan Province.

Materials.—368 specimens.

Occurrence.—Known from Wangcun and Wa’ergang sections, where it ranges from the *Proconodontus tenuiserratus* Zone through the *Cordylodus intermedius* Zone.

Remarks.—It differs from *Coelocerodontus bicostatus* in its much more slender outline and much higher length/maximum width ratio.

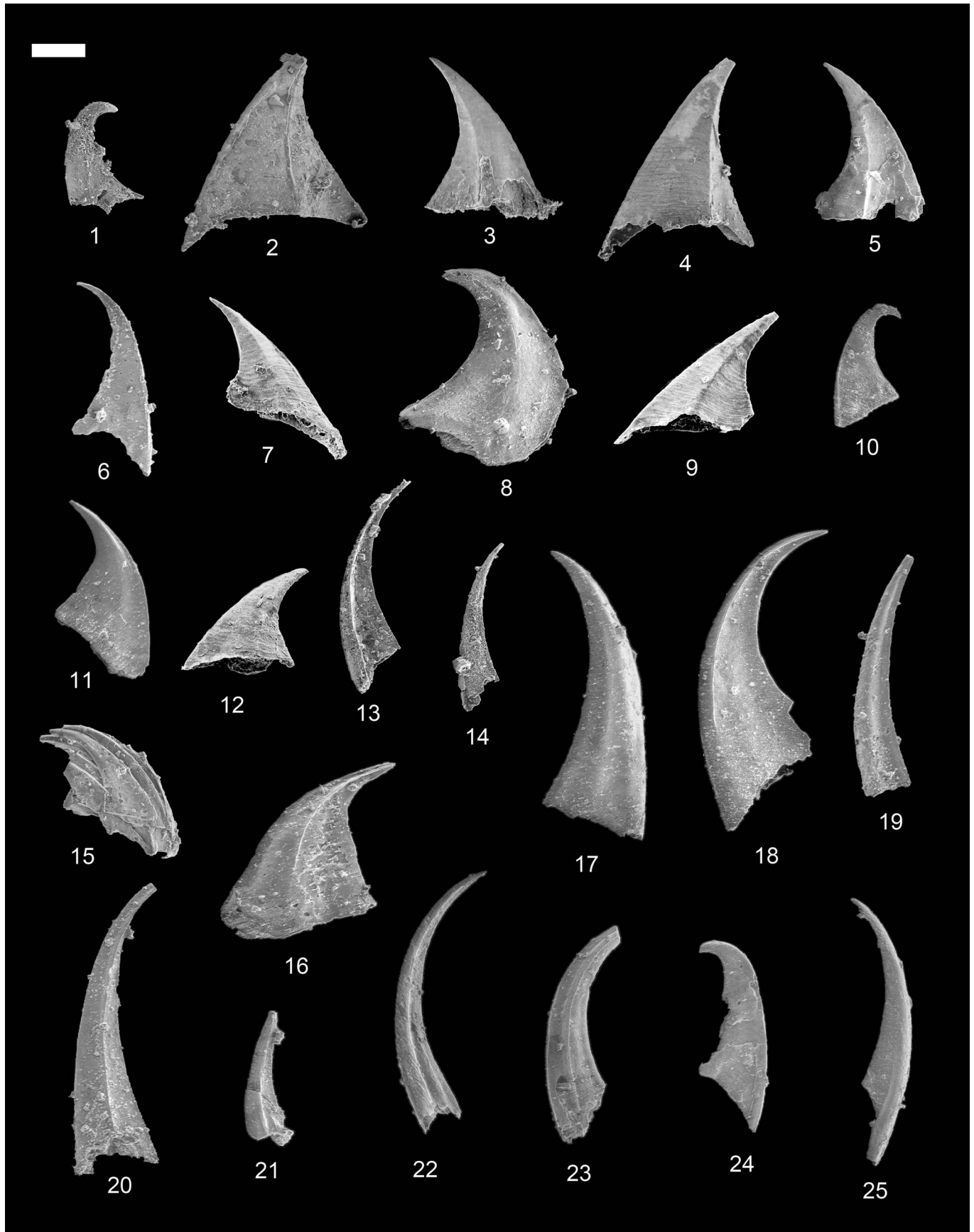
Genus *Cordylodus* Pander, 1856

Type species.—*Cordylodus angulatus* Pander, 1856.

Remarks.—Most species of this genus are cosmopolitan in distribution and are of great significance in biostratigraphy and the evolution of early euconodonts. There has never been a consensus on their apparatus reconstruction. Miller (1980) established a two-element apparatus of this genus, and he identified them as rounded and compressed elements based on the cross section of the cusp. This interpretation was accepted by some authors based on their own collections, e.g., An et al. (1983), Chen and Gong (1986), and Dong (1987) (only *Cordylodus proavus*). Viira et al. (1987) recognized three element types of *C. proavus*, whereas Barnes (1988) suggested four element types. Nicoll (1990) reinterpreted the apparatus reconstruction of this genus as a septimembrate apparatus containing M, S, and P elements. We still use the apparatus reconstruction by Miller (1980). Although this two-element model does not seem to be refined and updated, it is more practical than more complex models. Miller’s rounded element includes Nicoll’s S elements and probably Nicoll’s P elements, and Miller’s compressed elements correspond to Nicoll’s M elements.

Cordylodus angulatus Pander, 1856
Figures 9.15, 9.17, 9.20, 9.22–9.24, 10.1, 10.2

- 1856 *Cordylodus angulatus* Pander, p. 33, pl. 2, figs. 28–31, pl. 3, fig. 10.
- 1856 *Cordylodus rotundatus* Pander, p. 33, pl. 2, figs. 32, 33.
- 1938 *Cordylodus subangulatus* Furnish, p. 338, text-fig. 2D, pl. 42, fig. 3.
- 1955 *Cordylodus angulatus* Pander; Lindström, p. 551, pl. 5, fig. 9, text-fig. 3 (G).



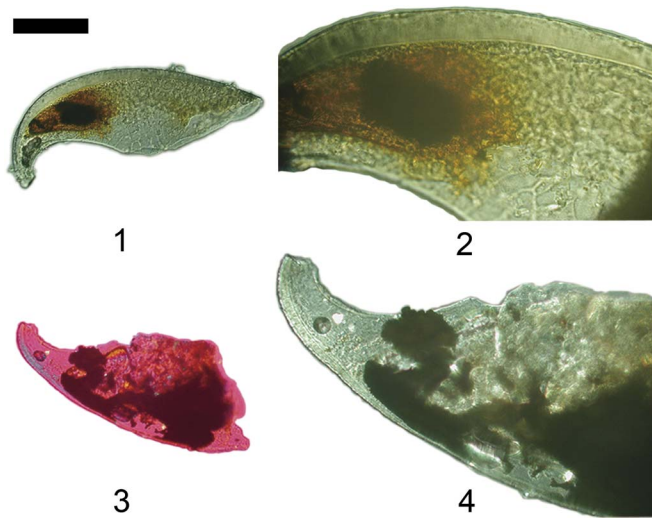


Figure 8. Conodont images using oil immersion techniques (Dong et al., 2005c) with Differential Interference Contrast (Nomarski) illumination. (1–4) *Coelocerosodontus bicostatus* van Wamel, 1974; (1) overview, GMPKU2254, showing the crown structure of euconodont; (2) close-up of (1); (3) overview, GMPKU2255, showing the crown structure of euconodont; (4) close-up of (3). Relative scale bar represents 109 μm (1, 3), 38 μm (2, 4).

- 1955 *Cordylodus rotundatus* Pander; Lindström, p. 553, pl. 5, figs. 17–20, text-fig. 3 (F).
- 1971 *Cordylodus angulatus* Pander; Druce and Jones, p. 66, pl. 3, figs. 4–6, text-figs. 23a, b.
- 1971 *Cordylodus rotundatus* Pander; Druce and Jones, p. 71, text-figs. 23t, pl. 3, figs. 8–10.
- 1971 *Cordylodus* sp. A Druce and Jones, p. 72, text-fig. 23u, pl. 8, fig. 10a, b.
- 1971 *Cordylodus rotundatus* Pander; Ethington and Clark, pl. 1, fig. 17.
- 1971 *Cordylodus angulatus* Pander; Ethington and Clark, pl. 1, 15, 16, 20.
- 1973 *Cordylodus angulatus* Pander; Müller, p. 27, pl. 11, figs. 1–7, text-fig. 2G.
- 1973 *Cordylodus rotundatus* Pander; Müller, p. 36, text-figs. 2H, 10a, b, pl. 11, figs. 8–10.
- 1974 *Cordylodus rotundatus* Pander; van Wamel, pl. 1, fig. 14.
- 1980 *Cordylodus angulatus* Pander; Miller, p. 13, pl. 1, figs. 22, text-fig. 4Q.
- 1980 *Cordylodus rotundatus* Pander; Miller, p. 20–21, pl. 1, fig. 24, text-fig. 4p.
- 1981 *Cordylodus angulatus* Pander; An, pl. 2, fig. 17.
- 1981 *Cordylodus rotundatus* Pander; An, pl. 1, figs. 18–19.
- 1982 *Cordylodus angulatus* Pander; Repetski, p. 16, pl. 4, fig. 9, text-fig. 4 (L).
- 1982 *Cordylodus rotundatus* Pander; Repetski, p. 18, pl. 5, fig. 3, text-fig. 4 (N).
- 1983 *Cordylodus angulatus* Pander; An et al., p. 84, pl. 8, figs. 1, 2.
- 1983 *Cordylodus rotundatus* Pander; An et al., p. 88–89, pl. 8, figs. 3–7.
- 1985 *Cordylodus rotundatus* Pander; Nowlan, p. 111, text-fig. 4 (3).
- 1985 *Cordylodus angulatus* Pander; Wang, p. 215, pl. 1, figs. 1–3, pl. 7, figs. 11–14, pl. 10, figs. 17 (not 15), pl. 11, figs. 17, 18 (?), pl. 12, figs. 18 (?), 19, 20 (?), pl. 14, fig. 7 (not 8) (part).
- 1985 *Cordylodus rotundatus* Pander; Wang, p. 219, pl. 1, fig. 5, pl. 7, figs. 25, 26; pl. 11, fig. 22.
- 1985 *Cordylodus angulatus* Pander; Dong, p. 394, pl. 1, fig. 6, pl. 3, fig. 5, text-fig. 1 (J).
- 1985 *Cordylodus rotundatus* Pander; Dong, p. 396, pl. 2, fig. 8, pl. 3, fig. 9, text-fig. 1L.
- 1986 *Cordylodus angulatus* Pander; Chen and Gong, p. 125, pl. 34, figs. 2–4, text-fig. 36.
- 1986 *Cordylodus rotundatus* Pander; Chen and Gong, p. 133, pl. 37, figs. 3, 8, 18, text-fig. 41.
- 1987 *Cordylodus angulatus* Pander; Dong, p. 153, pl. 1, figs. 17, 18, 22, text-figs. 3H, J, 4F.
- 1987 *Cordylodus rotundatus* Pander; Dong, p. 155, pl. 1, fig. 20 only (not 23), text-fig. 3I only (not K).
- 1990 *Cordylodus angulatus* Pander; Nicoll, figs. 3 (4b–c only), 5 (3a–4c only), 12.
- 1994 *Cordylodus angulatus* Pander; Ji and Barnes, p. 31, pl. 5, figs. 1–9.
- 1994 *Cordylodus angulatus* Pander; Wright and Cooper, p. 471, fig. 17B.
- 1996 *Cordylodus angulatus* Pander; Lee et al., p. 99, pl. 2, fig. 1.
- 1998 *Cordylodus angulatus* Pander; Rao and Tortello, p. 43, pl. 1, figs. 1, 2, 3, 6.
- 2000 *Cordylodus angulatus* Pander; Zhao et al., p. 194, pl. 37, figs. 13, 14, 16, 17.
- 2000 *Cordylodus rotundatus* Pander; Zhao et al., p. 194, pl. 37, figs. 7–12.
- 2001 *Cordylodus angulatus* Pander; Pyle and Barnes, p. 1397, pl. 1, figs. 3, 4.

Figure 7. (1–12, 16–18) *Coelocerosodontus bicostatus* van Wamel, 1974; (1) Shenjiawan Formation, Wangcun section, GMPKU2399, lateral view; (2) Bitiao Formation, Wangcun section, GMPKU2400, lateral view; (3) Bitiao Formation, Wangcun section, GMPKU2401, lateral view; (4) Bitiao Formation, Wangcun section, GMPKU2402, lateral view; (5) Bitiao Formation, Wangcun section, GMPKU2403, lateral view; (6) Shenjiawan Formation, Wa'ergang section, GMPKU2404, lateral view; (7) Bitiao Formation, Wa'ergang section, GMPKU2405, lateral view; (8) Huaqiao Formation, Wangcun section, GMPKU2413, (9) Bitiao Formation, Wa'ergang section, GMPKU2406, lateral view; (10) Shenjiawan Formation, Wa'ergang section, GMPKU2407, lateral view; (11) Panjiazui Formation, Wa'ergang section, GMPKU2408, lateral view; (12) Bitiao Formation, Wa'ergang section, GMPKU2409, lateral view; (16) Panjiazui Formation, Wa'ergang section, GMPKU2410, lateral view; (17) Panjiazui Formation, Wa'ergang section, GMPKU2411, lateral view; (18) Panjiazui Formation, Wa'ergang section, GMPKU2412, lateral view; (13–15, 19–25) *Coelocerosodontus hunanensis* n. sp.; (13) Shenjiawan Formation, Wangcun section, GMPKU2414, lateral view; (14) Shenjiawan Formation, Wangcun section, GMPKU2415, lateral view; (15) Shenjiawan Formation, Wa'ergang section, GMPKU2416, cluster; (19) Shenjiawan Formation, Wa'ergang section, GMPKU2417, lateral view; (20) Shenjiawan Formation, Wa'ergang section, GMPKU2418, lateral view; (21) Shenjiawan Formation, Wa'ergang section, GMPKU2419, lateral view; (22) Shenjiawan Formation, Wa'ergang section, GMPKU2420, lateral view; (23) Shenjiawan Formation, Wa'ergang section, GMPKU2421, lateral view; (24) Shenjiawan Formation, Wa'ergang section, GMPKU2422, lateral view; (25) Shenjiawan Formation, Wa'ergang section, GMPKU2423, lateral view. Relative scale bar represents 147 μm (1–11, 14, 16–25), 135 μm (12, 13, 15).



- 2002 *Cordylodus angulatus* Pander; Pyle and Barnes, p. 177, pl. 4, figs. 1–3.
- 2003 *Cordylodus angulatus* Pander; Heinsalu et al., p. 147, text-fig. 5, 24 (only).
- 2004c *Cordylodus angulatus* Pander; Dong et al., p. 1201, pl. 2, figs. 17, 28, 30, pl. 4, figs. 4, 6, 12, 14.
- 2005 *Cordylodus angulatus* Pander; Ortega and Albanesi, p. 365, fig. 5 (14).
- 2007 *Cordylodus angulatus* Pander; Pyle et al., p. 1735, fig. 11.8, 11.9.
- 1993 *Cordylodus caseyi* Druce and Jones; Landing, p. 14, fig. 8, 3–13, p. 15, fig. 9, 1–11.
- 2001 *Cordylodus caseyi* Druce and Jones; Pyle and Barnes, p. 1397, pl. 1, fig. 6.
- 2002 *Cordylodus caseyi* Druce and Jones; Pyle and Barnes, p. 177, pl. 4, figs. 4–7.
- 2003 *Cordylodus caseyi* Druce and Jones; Landing et al., p. 86, fig. 7, 16 (only).

Description.—Bimembrate apparatus of rounded and compressed elements. Rounded element with cusp and denticles rounded or oval in cross section and composed mostly of white matter. Basal cavity shallow to moderately deep, usually extending not higher than top of posterior denticulate process. Anterior edge of basal cavity strongly concave and tip recurved. Anterobasal margin slightly rounded to well rounded. Posterior process without carina or with a carina on one side. Compressed element symmetrical or subsymmetrical, with long posterior denticulate process. Cusp and denticles compressed laterally with sharp edges. Basal cavity shallow to moderately deep. Anterior edge of basal cavity slightly concave.

Materials.—12 specimens.

Occurrence.—Known from the Wa'ergang section, where it occurs in the *Cordylodus angulatus* Zone (lower part).

Remarks.—Miller (1980) suggested that the two form-species *Cordylodus angulatus* and *Cordylodus rotundatus* belong to two multielement species mainly based on the minor differences between them. However, many conodont workers considered the two form-species to be a single apparatus, because the two form-species commonly occur together. Based on the common association of the two form-species recovered from Hunan, we follow the opinion of the majority.

Cordylodus caseyi Druce and Jones, 1971
Figures 9.21, 9.25, 9.26, 11.4

- 1971 *Cordylodus caseyi* Druce and Jones, p. 67, pl. 2, figs. 9–12, text-figs. 23d, e.
- 1990 *Cordylodus caseyi* Druce and Jones; Nicoll, p. 543, figs. 3 (3b), 13 (4a–5c), 14 (1–2) only.
- 1938 *Cordylodus intermedius* Furnish, p. 338, pl. 42, fig. 31, text-fig. 2c.
- 1955 *Cordylodus prion* Lindström, p. 552, pl. 5, figs. 14–16.
- 1971 *Cordylodus intermedius* Furnish; Druce and Jones, p. 68, pl. 3, figs. 1–3, text-figs. 23f, g.
- 1971 *Cordylodus oklahomensis* Müller; Druce and Jones, p. 69, pl. 5, figs. 6–7, text-fig. 23j.
- 1971 *Cordylodus prion* Lindström; Lindström, pl. 2, figs. 1–7, text-figs. 23i, k–o.
- 1971 *Cordylodus proavus* Müller; Druce and Jones, p. 70, text-fig. 23p, pl. 1, fig. 1 only (not figs. 2–6). (part)
- 1973 *Cordylodus intermedius* Furnish; Müller, p. 30, pl. 10, figs. 1–3, text-figs. 2c, 4a, b.

Description.—The element is asymmetrical. The long cusp is reclined, oval in cross-section. The base is greatly expanded to give a triangular cross section in the basal view. The basal cavity is moderately large with anterior edge concave or straight. A conspicuous keel is developed on the lateral margin of the cusp and base.

Materials.—26 specimens.

Occurrence.—Known from the Wa'ergang section, where it occurs in the *Cordylodus lindstromi* Zone.

Remarks.—This species is characterized by its expanded base with a triangular cross-section and the keel developed on the lateral margin of the cusp and base. Only rounded elements have been found for this species.

Cordylodus intermedius Furnish, 1938

Figures 10.3–10.6, 11.1–11.3, 11.5–11.27, 12.1–12.4, 12.7

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Figure 9. (1–14, 18, 19) *Coelocerosodontus hunanensis* n. sp.; (1) Shenjiawan Formation, Wa'ergang section, GMPKU2424, lateral view; (2) Shenjiawan Formation, Wa'ergang section, GMPKU2425, lateral view; (3) Shenjiawan Formation, Wa'ergang section, GMPKU2426, cluster, lateral view; (4) Shenjiawan Formation, Wa'ergang section, GMPKU2427, lateral view; (5) Shenjiawan Formation, Wa'ergang section, GMPKU2428, lateral view; (6) Shenjiawan Formation, Wa'ergang section, GMPKU2429, cluster, lateral view; (7) Panjiazui Formation, Wa'ergang section, GMPKU2430, cluster, lateral view; (8) Panjiazui Formation, Wa'ergang section, GMPKU2431, lateral view; (9) Panjiazui Formation, Wa'ergang section, holotype, GMPKU2432, lateral view; (10) Panjiazui Formation, Wa'ergang section, GMPKU2433, lateral view; (11) Panjiazui Formation, Wa'ergang section, GMPKU2434, cluster, lateral view; (12) Panjiazui Formation, Wa'ergang section, GMPKU2435, lateral view; (13) Panjiazui Formation, Wa'ergang section, GMPKU2436, cluster, lateral view; (14) Panjiazui Formation, Wa'ergang section, GMPKU2437, cluster, lateral view; (18) Panjiazui Formation, Wa'ergang section, GMPKU2438, lateral view; (19) Panjiazui Formation, Wa'ergang section, GMPKU2439, lateral view; (15, 17, 20, 22–24) *Cordylodus angulatus* Pander, 1856; (15) Panjiazui Formation, Wa'ergang section, GMPKU2440, lateral view; (17) Panjiazui Formation, Wa'ergang section, GMPKU2441, lateral view; (20) Panjiazui Formation, Wa'ergang section, GMPKU2442, lateral view; (22) Panjiazui Formation, Wa'ergang section, GMPKU2169, lateral view; (23) Panjiazui Formation, Wa'ergang section, GMPKU2170, lateral view; (24) Panjiazui Formation, Wa'ergang section, GMPKU2171, lateral view; (16) *Cordylodus proavus* Müller, 1959, Panjiazui Formation, Wa'ergang section, GMPKU2443, lateral view; (21, 25, 26) *Cordylodus caseyi* Druce and Jones, 1971; (21) Panjiazui Formation, Wa'ergang section, GMPKU2444, lateral view; (25) Panjiazui Formation, Wa'ergang section, GMPKU2446, lateral view; (26) Panjiazui Formation, Wa'ergang section, GMPKU2447, posterior view. Relative scale bar represents 158 µm (1, 2, 4–19, 22), 150 µm (3, 20, 21, 23–26).

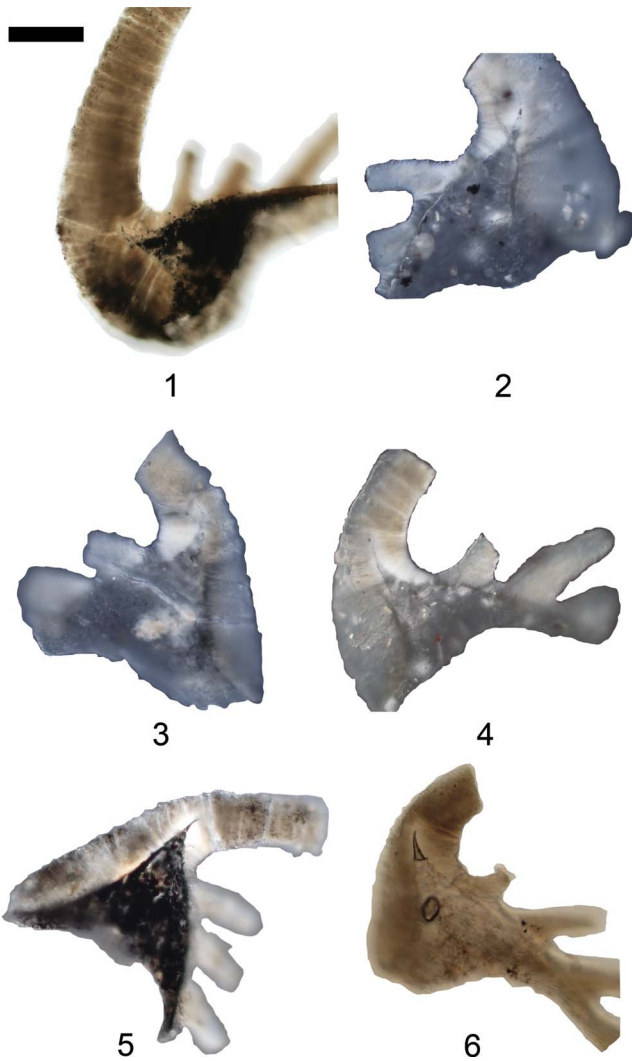


Figure 10. Conodont images using oil immersion techniques (Dong et al., 2005c) with Differential Interference Contrast (Nomarski) illumination, showing the shapes of basal cavities. (1, 2) *Cordylodus angulatus* Pander, 1856; (1) the same specimen as Figure 9.17; (2) the same specimen as Figure 9.20; (3–6) *Cordylodus intermedius* Furnish, 1938; (3) the same specimen as Figure 12.1; (4) the same specimen as Figure 12.2; (5) the same specimen as Figure 12.3; (6) the same specimen as Figure 12.7. Relative scale bar represents 167 μm (1), 109 μm (2, 5), 103 μm (3, 4, 6).

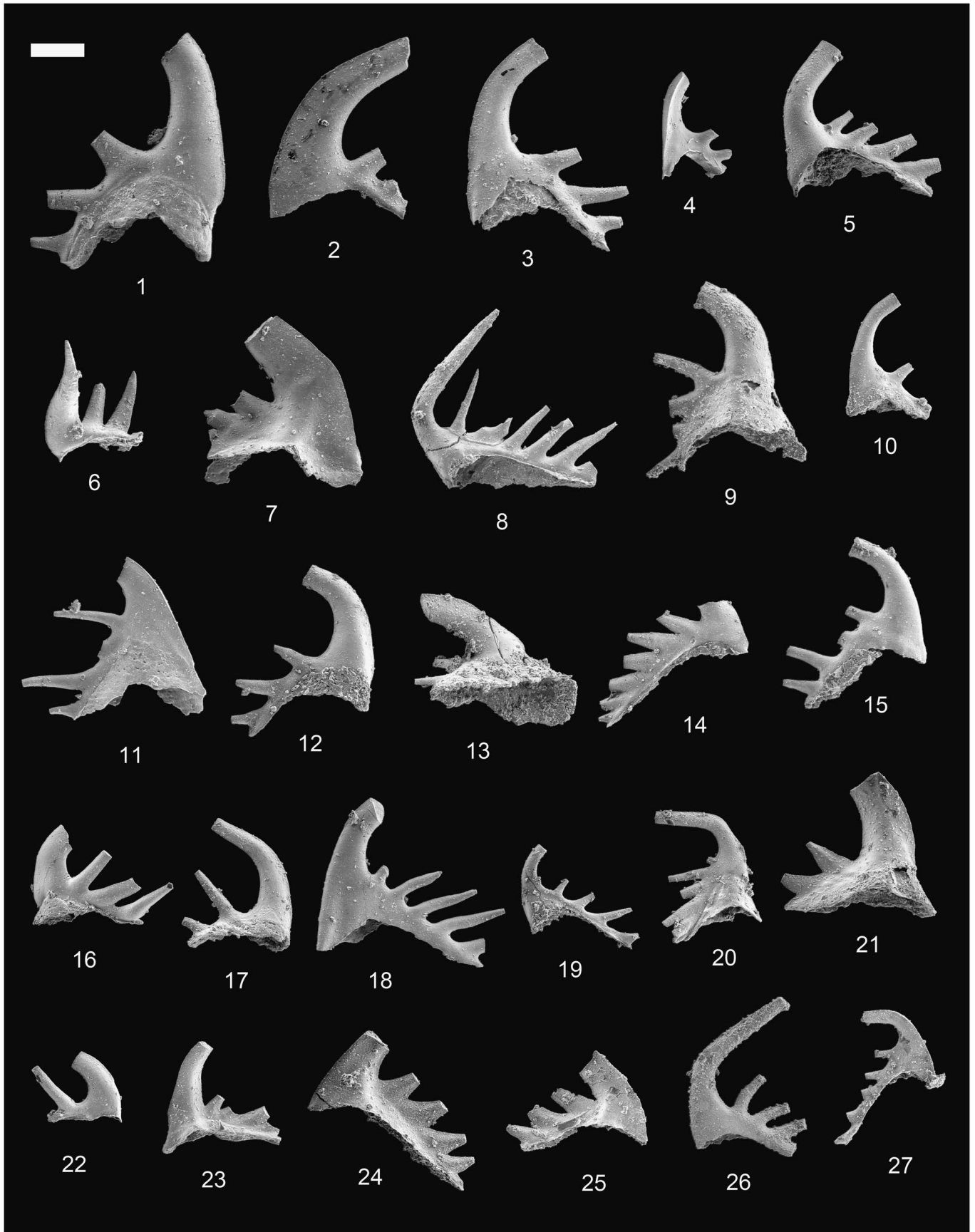
1973 *Cordylodus prion* Lindström; Müller, p. 33, text-figs. 2E, 8, pl. 10, fig. 4.
 1974 *Cordylodus prion* Lindström; van Wamel, p. 59, pl. 1, figs. 8–9.

1980 *Cordylodus intermedius* Furnish; Miller, p. 17, pl. 1, fig. 16, text-fig. 4L.
 1980 *Cordylodus intermedius* Furnish; Landing et al., p. 19, figs. 5E, 6A, B.
 1982 *Cordylodus intermedius* Furnish; s.f. Repetski, p. 17, pl. 5, fig. 2, text-fig. 4 (M).
 1983 *Cordylodus intermedius* Furnish; An et al., p. 85, pl. 7, fig. 16.
 1985 *Cordylodus intermedius* Furnish; Wang, p. 215, pl. 1, figs. 12, 13, 15, 14 (?), pl. 7, figs. 22–24, pl. 9, figs. 5–7, pl. 11, figs. 5–7; pl. 13, figs. 22, 23 (not pl. 14, fig. 4). (part)
 1985 *Cordylodus intermedius* Furnish; Dong, p. 394, pl. 2, fig. 6, pl. 3, fig. 10, text-fig. 1k.
 1986 *Cordylodus intermedius* Furnish; Chen and Gong, p. 127, pl. 35, figs. 2, 3, 6, 9, pl. 36, fig. 7, pl. 37, figs. 1, 2, 4–7, 10–11, 13, 15–17, pl. 38, figs. 2, 3, 7–8, 13, 15, text-fig. 38.
 1987 *Cordylodus intermedius* Furnish; Dong, p. 154, pl. 1, figs. 14, 15, 19, 25, text-figs. 3E, F, L, 4C.
 1987 *Cordylodus intermedius* Furnish; Bagnoli et al., p. 153, pl. 1, figs. 15–18.
 1994 *Cordylodus intermedius* Furnish; Ji and Barnes, p. 32, pl. 5, figs. 10–18.
 1998 *Cordylodus intermedius* Furnish; Rao and Tortello, p. 43, pl. 1, fig. 7.
 2000 *Cordylodus intermedius* Furnish; Zhao et al., p. 195, pl. 37, figs. 15, 21.
 2000 “*Cordylodus*” *intermedius* Furnish; Dubinina, p. 188, pl. 9, fig. 25.
 ? 2000 “*Cordylodus*” *lenzi* Müller; Dubinina, p. 188, pl. 9, fig. 21.
 2002 *Cordylodus intermedius* Furnish; Pyle and Barnes, p. 47, pl. 4, figs. 15–17.
 2004c *Cordylodus intermedius* Furnish; Dong et al., pl. 2, figs. 8, 9, 19, 21, 24, pl. 4, figs. 5, 13.

Description.—Bimembrate apparatus of rounded and compressed elements. Rounded element symmetrical or subsymmetrical, possessing a distinctive basal cavity with anterior edge concave or straight. Compressed element may be symmetrical or asymmetrical due to lateral bending of cusp and presence of the slight carina on inner side of basal margin. Cusp and denticles laterally compressed and sharp edges, denticles fused at base.

Materials.—260 specimens.

Figure 11. (1–3, 5–27) *Cordylodus intermedius* Furnish, 1938; (1) Panjiazui Formation, Wa’ergang section, GMPKU2452, lateral view; (2) Panjiazui Formation, Wa’ergang section, GMPKU2453, lateral view; (3) Panjiazui Formation, Wa’ergang section, GMPKU2454, lateral view; (5) Panjiazui Formation, Wa’ergang section, GMPKU2455, lateral view; (6) Panjiazui Formation, Wa’ergang section, GMPKU2456, lateral view; (7) Panjiazui Formation, Wa’ergang section, GMPKU2457, lateral view; (8) Panjiazui Formation, Wa’ergang section, GMPKU2458, lateral view; (9) Panjiazui Formation, Wa’ergang section, GMPKU2459, lateral view; (10) Panjiazui Formation, Wa’ergang section, GMPKU2460, lateral view; (11) Panjiazui Formation, Wa’ergang section, GMPKU2461, lateral view; (12) Panjiazui Formation, Wa’ergang section, GMPKU2462, lateral view; (13) Panjiazui Formation, Wa’ergang section, GMPKU2463, lateral view; (14) Panjiazui Formation, Wa’ergang section, GMPKU2464, lateral view; (15) Panjiazui Formation, Wa’ergang section, GMPKU2465, lateral view; (16) Panjiazui Formation, Wa’ergang section, GMPKU2466, lateral view; (17) Panjiazui Formation, Wa’ergang section, GMPKU2467, lateral view; (18) Panjiazui Formation, Wa’ergang section, GMPKU2468, lateral view; (19) Panjiazui Formation, Wa’ergang section, GMPKU2469, lateral view; (20) Panjiazui Formation, Wa’ergang section, GMPKU2470, lateral view; (21) Panjiazui Formation, Wa’ergang section, GMPKU2471, lateral view; (22) Panjiazui Formation, Wa’ergang section, GMPKU2472, lateral view; (23) Panjiazui Formation, Wa’ergang section, GMPKU2473, lateral view; (24) Panjiazui Formation, Wa’ergang section, GMPKU2474, lateral view; (25) Panjiazui Formation, Wa’ergang section, GMPKU2475, lateral view; (26) Panjiazui Formation, Wa’ergang section, GMPKU2476, lateral view; (27) Panjiazui Formation, Wa’ergang section, GMPKU2477, lateral view; (4) *Cordylodus caseyi* Druce and Jones, 1971; Panjiazui Formation, Wa’ergang section, GMPKU2451, lateral view. Relative scale bar represents 180 μm (1–21, 24–27), 145 μm (22), 154 μm (23).



Occurrence.—Known from the Wa'ergang section, where it ranges from the *Cordylodus intermedius* Zone through the *Cordylodus lindstromi* Zone (upper part).

Remarks.—The overwhelming majority of conodont workers believed that *Cordylodus intermedius* is the evolutionary intermediate between *Cordylodus proavus* and *Cordylodus angulatus*. Nevertheless, Nicoll (1990) proposed that *C. intermedius* is an invalid species, and that much of the material previously assigned to *C. intermedius* should be reassigned to *C. angulatus* and that some of the stratigraphically older specimens probably should be assigned to *C. proavus*. He also replaced the *C. intermedius* Zone by a lower *Hirsutodontus simplex* Zone and an upper *Clavohamamulus hintzei* Zone. However, in terms of stratigraphical range, the FAD of *C. intermedius* is just between that of *C. proavus* and that of *C. angulatus*. In terms of morphology, the anterior edge of basal cavity is concave or straight in *C. intermedius*, whereas it is convex in *C. proavus*. Therefore, the reassignment of the stratigraphically older specimens of *C. intermedius* to *C. proavus* is absolutely inconsistent with the original definition of the two form-species, even if the reassignment of some specimens of *C. intermedius* to *C. angulatus* sounds plausible. So far as it goes, Nicoll's (1990) proposal has never been accepted, and *C. intermedius* is unequivocally a valid species, while *C. intermedius* Zone is valid and useful for the work on Cambrian–Ordovician boundary (Cooper et al., 2001; Terfelt et al., 2012)

Cordylodus lindstromi Druce and Jones, 1971
Figures 12.5, 12.6, 12.8–12.26, 13.1–13.15

- 1971 *Cordylodus lindstromi* Druce and Jones, p. 68, pl. 1, figs. 7–9, text-fig. 23h, pl. 2, fig. 8.
1973 *Cordylodus lindstromi* Druce and Jones; Müller, p. 22, text-figs. 2d, 6a, b, pl. 9, figs. 10, 11.
1982 *Cordylodus lindstromi* Druce and Jones; s.f. Repetski, p. 17, pl. 5, figs. 4–5, text-fig. 4 (O).
1983 *Cordylodus lindstromi* Druce and Jones; An et al., p. 86, pl. 7, figs. 17–19.
1985 *Cordylodus lindstromi* Druce and Jones; Wang, p. 216, pl. 1, fig. 6, pl. 13, fig. 24.
1986 *Cordylodus lindstromi* Druce and Jones; Chen and Gong, p. 129, pl. 34, figs. 1, 5–8, text-fig. 39.
1987 *Cordylodus lindstromi* Druce and Jones; Dong, p. 154, pl. 1, fig. 30, text-fig. 3, G.
1990 *Cordylodus lindstromi* Druce and Jones; Nicoll, p. 545, fig. 3, (2b only), fig. 16, (7–14 only), fig. 17 (not fig. 18).

- 1991 *Cordylodus lindstromi* Druce and Jones; Nicoll, p. 231, figs. 2.3, 2.4, fig. 4. (part)
1994 *Cordylodus lindstromi* Druce and Jones; Ji and Barnes, p. 32, pl. 5, figs. 19–22.
? 1999 *Cordylodus lindstromi* Druce and Jones; Parsons and Clark, p. 7, figs. 26–27.
2000 *Cordylodus lindstromi* Druce and Jones; Göncüoğlu and Kozur, p. 599, fig. 4, g, p. 601, fig. 5, a, g.
2000 “*Cordylodus*” *lindstromi* Druce and Jones; Dubinina, p. 188, pl. 9, figs. 15, ?16–17.
2001 *Cordylodus lindstromi* Druce and Jones; Pyle and Barnes, p. 1397, pl. 1, fig. 7.
2002 *Cordylodus lindstromi* Druce and Jones; Pyle and Barnes, p. 48, pl. 4, figs. 18–21.
2003 *Cordylodus lindstromi* Druce and Jones; Heinsalu et al., p. 147, text-fig. 5, 13–14 (only, not 15–20). (part)
2004c *Cordylodus lindstromi* Druce and Jones; Dong et al., pl. 2, figs. 14, 16, 22, 23, pl. 4, figs. 7, 15.
2007 *Cordylodus lindstromi* Druce and Jones; Pyle et al., p. 1733, fig. 10, 3–4.

Description.—Bimembrate apparatus of rounded and compressed elements. Rounded elements and compressed elements symmetrical, with distinctive basal cavities. Secondary apex of basal cavity extends into the first, and rarely the second, denticle. The anterior edge of basal cavity is convex.

Materials.—200 specimens.

Occurrence.—Known from the Wa'ergang section, where it where it occurs in the *Cordylodus lindstromi* Zone.

Remarks.—The specimens at hand agree well with *Cordylodus lindstromi*.

Cordylodus proavus Müller, 1959
Figures 9.16, 14.1–14.23

- 1959 *Cordylodus proavus* Müller, p. 448, pl. 15, figs. 11, 12, 18, text-fig. 3B.
1959 *Cordylodus oklahomensis* Müller, p. 447, text-fig. 3A, pl. 15, figs. 15, 16.
1969 *Cordylodus proavus* Müller; Miller, p. 424, pl. 65, figs. 37–45, text-fig. 3D.

Figure 12. (1–4, 7) *Cordylodus intermedius* Furnish, 1938; (1) Panjiazui Formation, Wa'ergang section, GMPKU2478, lateral view; (2) Panjiazui Formation, Wa'ergang section, GMPKU2479, lateral view; (3) Panjiazui Formation, Wa'ergang section, GMPKU2480, lateral view; (4) Panjiazui Formation, Wa'ergang section, GMPKU2481, lateral view; (7) Panjiazui Formation, Wa'ergang section, GMPKU2482, lateral view; (5, 6, 8–26) *Cordylodus lindstromi* Druce and Jones, 1971; (5) Panjiazui Formation, Wa'ergang section, GMPKU2483, lateral view; (6) Panjiazui Formation, Wa'ergang section, GMPKU2484, lateral view; (8) Panjiazui Formation, Wa'ergang section, GMPKU2485, lateral view; (9) Panjiazui Formation, Wa'ergang section, GMPKU2486, lateral view; (10) Panjiazui Formation, Wa'ergang section, GMPKU2487, lateral view; (11) Panjiazui Formation, Wa'ergang section, GMPKU2488, lateral view; (12) Panjiazui Formation, Wa'ergang section, GMPKU2489, lateral view; (13) Panjiazui Formation, Wa'ergang section, GMPKU2490, lateral view; (14) Panjiazui Formation, Wa'ergang section, GMPKU2491, lateral view; (15) Panjiazui Formation, Wa'ergang section, GMPKU2492, lateral view; (16) Panjiazui Formation, Wa'ergang section, GMPKU2493, lateral view; (17) Panjiazui Formation, Wa'ergang section, GMPKU2494, lateral view; (18) Panjiazui Formation, Wa'ergang section, GMPKU2496, lateral view; (19) Panjiazui Formation, Wa'ergang section, GMPKU2497, lateral view; (20) Panjiazui Formation, Wa'ergang section, GMPKU2498, lateral view; (21) Panjiazui Formation, Wa'ergang section, GMPKU2499, lateral view; (22) Panjiazui Formation, Wa'ergang section, GMPKU2500, lateral view; (23) Panjiazui Formation, Wa'ergang section, GMPKU2501, lateral view; (24) Panjiazui Formation, Wa'ergang section, GMPKU2502, lateral view; (25) Panjiazui Formation, Wa'ergang section, GMPKU2503, lateral view; (26) Panjiazui Formation, Wa'ergang section, GMPKU2504, lateral view. Relative scale bar represents 128 µm (1–7, 11–20, 22, 24–26), 114 µm (8–10, 21, 23).

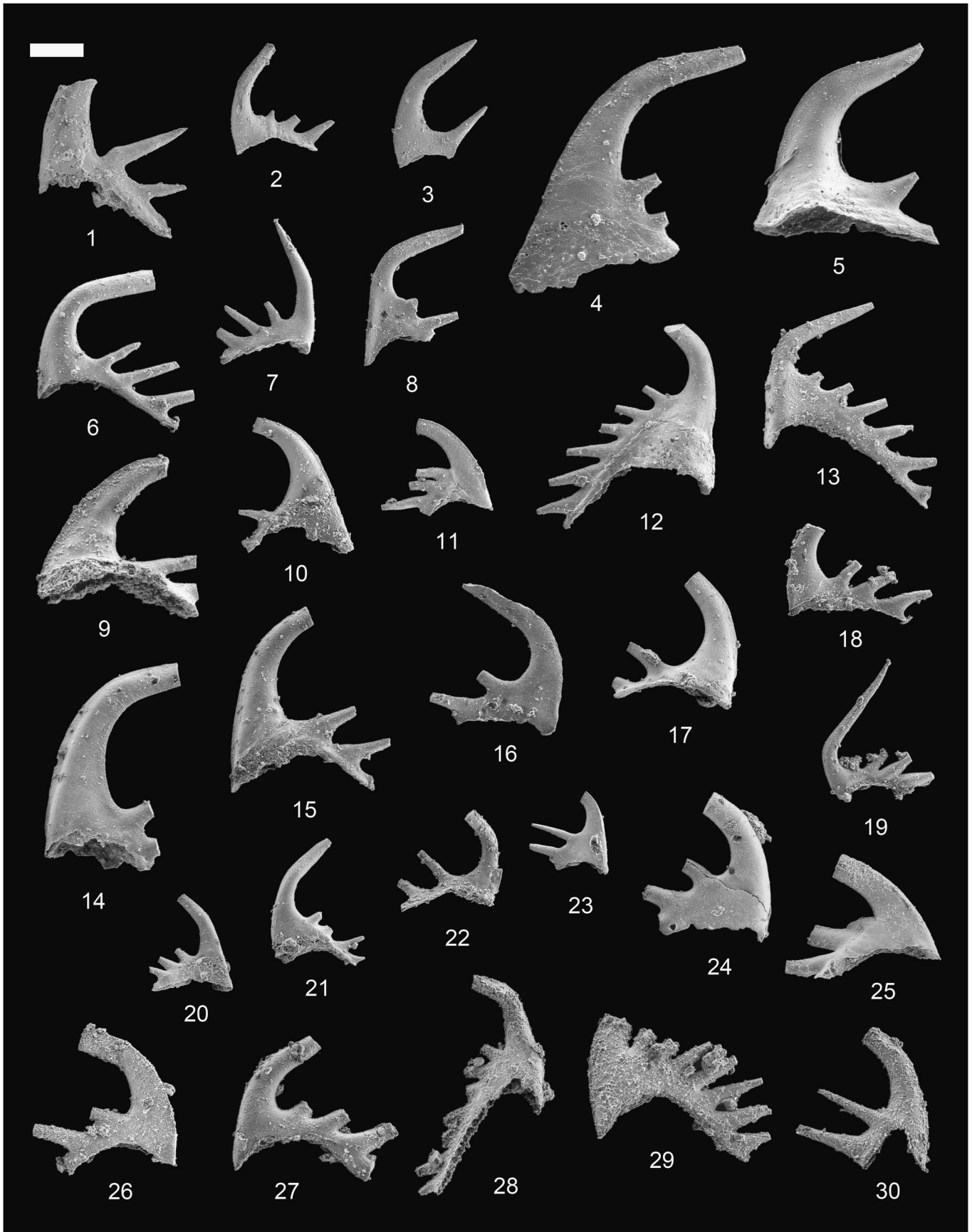




- 1969 *Cordylodus oklahomensis* Müller; Miller, p. 423, text-fig. 3, I, pl. 65, figs. 46–53.
- 1971 *Cordylodus proavus* Müller; Druce and Jones, p. 70, pl. 1, figs. 2–6 (not 1), text-fig. 23q, r (not p). (part)
- 1971 *Cordylodus* cf. *C. proavus* Müller; Druce and Jones, p. 71, pl. 1, figs. 10, 11 (?), 12, text-fig. 23s.
- 1971 *Cordylodus proavus* Müller; Ethington and Clark, pl. 1, fig. 19.
- 1971 *Cordylodus oklahomensis* Müller; Ethington and Clark, pl. 1, fig. 24.
- 1973 *Cordylodus proavus* Müller; Müller, p. 35, text-figs. 2A, 9, pl. 9, figs. 1–9.
- 1973 *Cordylodus oklahomensis* Müller; Müller, p. 33, text-figs. 2b, 7a, b, pl. 9, figs. 12, 13.
- 1974 *Cordylodus angulatus* Pander; van Wamel, pl. 1, fig. 5 (not figs. 6, 7). (part)
- 1980 *Cordylodus proavus* Müller; Müller, p. 19–20, text-figs. 4G, H, pl. 1, figs. 14, 15.
- 1983 *Cordylodus proavus* Müller; An et al., p. 87–88, pl. 7, figs. 1–5, 8, 11.
- 1983 *Cordylodus* aff. *C. proavus* Müller; An et al., p. 88, pl. 7, figs. 6, 7, 9, 10, text-fig. 10 (3).
- 1985 *Cordylodus proavus* Müller; Dong, p. 395–396, pl. 1, figs. 1, 2, text-figs. 1 (A, B).
- 1985 *Cordylodus proavus* Müller; Wang, p. 217, pl. 1, figs. 10, 18–23, pl. 7, figs. 15–20, pl. 9, figs. 9–12, pl. 11, figs. 2–4, 19–21, figs. 2–4, 19–21, pl. 13, figs. 26, 31, pl. 14, figs. 11–16.
- 1986 *Cordylodus proavus* Müller; Chen and Gong, p. 130, pl. 35, figs. 1, 4–5, 7–8, 10–14, pl. 36, figs. 1–6, 8–24, pl. 37, figs. 9, 12, 14, pl. 38, figs. 1, 4, 6, 9, 11–12, 14, 16–18, text-fig. 40.
- 1987 *Cordylodus proavus* Müller; Dong, p. 155, pl. 1, figs. 7–10, text-fig. 3D.
- 1990 *Cordylodus proavus* Müller; Nicoll, p. 550, figs. 3 (1b–d only, not 1a), 19 (2–4 only, not 1), 20–22. (part)
- 1993 *Cordylodus proavus* Müller; Landing, p. 14, figs. 8, 16, figs. 9, 14.
- 1996 *Cordylodus proavus* Müller; Lee et al., p. 97, pl. 1, figs. 4–5, 9–10.
- ? 1999 *Cordylodus proavus* Müller; Parsons and Clark, p. 7, fig. 5 (24–25).
- 2000 *Cordylodus proavus* Müller; Dubinina, p. 190, pl. 9, figs. 1–4, 6, 8–10, 14, 19, 20.
- 2000 *Cordylodus proavus* Müller; Zhao et al., p. 195, pl. 37, figs. 18–20.
- 2001 *Cordylodus proavus* Müller; Lee, p. 451, fig. 7 (20–23).
- 2002a *Cordylodus proavus* Müller; Lee, p. 165, pl. 2, figs. 31, 32.
- 2002b *Cordylodus proavus* Müller; Lee, p. 27, pl. 2, figs. 5, 6.
- 2002 *Cordylodus proavus* Müller; Pyle and Barnes, p. 49, pl. 5, figs. 4–6.
- 2003 *Cordylodus proavus* Müller; Landing et al., p. 86, figs. 7, 11–13.
- 2003 *Cordylodus proavus* Müller; Heinsalu et al., p. 147, text-fig. 5 (1–4).
- 2004 *Cordylodus proavus* Müller; Lee, p. 60, fig. 5, BB–CC.
- 2004c *Cordylodus proavus* Müller; Dong et al., pl. 2, figs. 11, 12, 15, 20, 29, pl. 4, figs. 3, 11.
- 2006 *Cordylodus proavus* Müller; Miller et al., p. 394, fig. 9 A, B.
- 2007 *Cordylodus proavus* Müller; Landing et al., p. 917, fig. 5 (h–l).
- 2007 *Cordylodus proavus* Müller; Pyle et al., p. 1733, fig. 10 (1–2).
- Description.*—Bimembrate apparatus of rounded and compressed elements, possessing deep basal cavities, the anterior edge of basal cavities is convex, with the tips of basal cavities extending higher than the base of most posterior denticles up to near the apex of the element. Rounded element symmetrical or subsymmetrical. Cusp and denticles round or oval in cross section, composed of white matter. Denticles separated from one another at base. Compressed element asymmetrical due to lateral bending of cusp and due to a carina near the base of inner side. Cusp and denticles composed of white matter, compressed laterally, with keeled anterior and posterior edges. Denticles fused at bases.
- Materials.*—600 specimens.
- Occurrence.*—Known from the Wa'ergang section, where it ranges from the *Cordylodus proavus* Zone through the *Cordylodus lindstromi* Zone (upper part).
- Cordylodus prolindstromi* Nicoll, 1991
Figures 14.24–14.30, 15.1–15.35, 16.1–16.26
- 1991 *Cordylodus prolindstromi* Nicoll, p. 233, figs. 2 (4), 13 (3–4 only, not 1–2), 14–16.
- Materials.*—250 specimens.
- Occurrence.*—Known from Wa'ergang section where it ranges from the *Cordylodus intermedius* Zone through the *Cordylodus lindstromi* Zone.
- Remarks.*—Nicoll (1991) erected *Cordylodus prolindstromi* and suggested it is the ancestor of *Cordylodus lindstromi*. The main difference between them is the shape of the second apex of basal cavity. According to Nicoll (1991), in *C. lindstromi* the

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Figure 13. Conodont images using oil immersion techniques (Dong et al., 2005c) with Differential Interference Contrast (Nomarski) illumination, showing the shapes of the biapical basal cavities. (1–15) *Cordylodus lindstromi* Druce and Jones, 1971; (1) the same specimen as Figure 12.10; (2) the same specimen as Figure 12.8; (3) the same specimen as Figure 12.11; (4), the same specimen as Figure 12.13; (5) the same specimen as Figure 12.12; (6) the same specimen as Figure 12.14; (7) the same specimen as Figure 12.23; (8) the same specimen as Figure 12.15; (9) the same specimen as Figure 12.16; (10) the same specimen as Figure 12.17; (11) the same specimen as Figure 12.19; (12) the same specimen as Figure 12.18; (13) the same specimen as Figure 12.20; (14) the same specimen as Figure 12.24; (15) the same specimen as Figure 12.25. Relative scale bar represents 80 µm (1, 5–7, 11, 13), 67 µm (2), 121 µm (3, 9, 10, 12, 15), 92 µm (4), 58 µm (8), 103 µm (14).



secondary apex of the basal cavity is pointed, whereas in *C. prolindstromi*, it is truncated by a flat top. In many specimens of *C. prolindstromi*, the tip of the secondary apex of the basal cavity appears to be truncated by a flat top when observed under the ordinary binocular microscope. However, specimens from Hunan have been examined using the oil immersion technique (Dong et al., 2005c). Photomicrographs of these specimens taken with a differential interference contrast (Nomarski) microscope indicate that the shape of the secondary apex is irregular, i.e. it is neither pointed nor truncated by a flat top (Fig. 15). So, the truncated, flat-top shape of the secondary apex may be a preservational artifact. In light of this, *C. prolindstromi* may be a junior synonym of *C. lindstromi*. Nevertheless, because the type specimens of *C. prolindstromi* from Australia have not been examined using the oil immersion technique, we provisionally retain the name of this species.

Genus *Dasytodus* Chen and Gong, 1986

Type species.—*Proconodontus transmutatus* Xu and Xiang in An et al., 1983.

Dasytodus transmutatus (Xu and Xiang in An et al., 1983)
Figure 17.1, 17.2

- 1983 *Proconodontus transmutatus* Xu and Xiang in An et al., p. 128, pl. 3, figs. 14–16, pl. 33, fig. 3, text-fig. 9 (22).
1986 *Dasytodus transmutatus* (Xu and Xiang); Chen and Gong, p. 135, pl. 28, figs. 1, 3–8, 11, text-fig. 43.
2000 *Hirsutodontus transmutatus* (Xu and Xiang); Duninina, p. 187, pl. 6, figs. 3, 3a, not 6. (part)
2001 *Teridontus transmutatus* (Xu and Xiang); Lee, p. 449, fig. 6.27, 6.28.
2002a *Dasytodus transmutatus* (Xu and Xiang); Lee, p. 165, pl. 2, fig. 17.
2002b *Teridontus transmutatus* (Xu and Xiang); Lee, p. 27, pl. 2, fig. 2.3.
2008a *Dasytodus transmutatus* (Xu and Xiang); Lee, p. 228, fig. 1 (6).

Description.—Coniform elements, proclined and asymmetrical. Cusp short with rounded cross section. Base long and flaring downwards. Small spines scattered mainly on the base but also on the cusp. Basal cavity deep, with the apex extending up to slightly below the point of flexure of the cusp.

Comparison.—*Dasytodus transmutatus* differs from *Granatodontus ani* mainly in the spiny surface ornamentation in the former rather than tiny nodular surface ornamentation in the latter.

Materials.—Six specimens.

Occurrence.—Known from the Wangcun and Wa'ergang sections, where it ranges from the *Proconodontus* Zone through the *Cordylodus proavus* Zone.

Remarks.—The specimens at hand agree closely with those illustrated and described by Chen and Gong (1986), except that spines are scattered also on the cusp in the Hunan material. This difference is considered here to represent intraspecific variation.

Genus *Eoconodontus* Miller, 1980

Type species.—*Proconodontus notchpeakensis* Miller, 1969.

Eoconodontus notchpeakensis (Miller, 1969)
Figure 17.3–17.17

- 1967 *Oneotodus nakamurai* Nogami, p. 216, text-fig. 3D, E (not text-fig. 3A–C), pl. 1, figs. 10, 11 (not figs. 9, 12, 13). (part)
1969 *Proconodontus notchpeakensis* Miller, p. 438, text-fig. 5G, pl. 66, figs. 21–29.
1969 *Proconodontus carinatus* Miller, p. 437, text-fig. 5I, pl. 66, figs. 15–20 (not figs. 13, 14). (part)
1971 *Oneotodus nakamurai* Nogami; Druce and Jones, p. 82, text-fig. 26j, pl. 10, figs. 1, 2, 5, 6 (not figs. 3, 4, 7, 8). (part)
1973 *Proconodontus notchpeakensis* Miller; Müller, p. 43, pl. 4, fig. 6.
1975 *Oneotodus nakamurai* Nogami; Lee, p. 81, text-figs. 2E, G, pl. 1, figs. 6, 9, 10.
1977 *Oneotodus nakamurai* Nogami; Abaimova and Markov, p. 92, pl. 14, figs. 12–14, 16.
1980 *Eoconodontus notchpeakensis* (Miller); Miller, p. 22, pl. 1, figs. 10–12, text-figs. 3D, E.
1982 *Proconodontus notchpeakensis* Miller; An, p. 142, pl. 8, fig. 2, pl. 13, figs. 1–11.
1983 *Proconodontus notchpeakensis* Miller; An et al., p. 127, pl. 5, figs. 10–12 (not figs. 19, 20). (part)

Figure 14. (1–23) *Cordylodus proavus* Müller, 1959; (1) Shenjiawan Formation, Wa'ergang section, GMPKU2505, lateral view; (2) Shenjiawan Formation, Wa'ergang section, GMPKU2506, lateral view; (3) Shenjiawan Formation, Wa'ergang section, GMPKU2507, lateral view; (4) Panjiazui Formation, Wa'ergang section, GMPKU2508, lateral view; (5) Panjiazui Formation, Wa'ergang section, GMPKU2509, lateral view; (6) Panjiazui Formation, Wa'ergang section, GMPKU2510, lateral view; (7) Panjiazui Formation, Wa'ergang section, GMPKU2511, lateral view; (8) Panjiazui Formation, Wa'ergang section, GMPKU2512, lateral view; (9) Panjiazui Formation, Wa'ergang section, GMPKU2513, lateral view; (10) Panjiazui Formation, Wa'ergang section, GMPKU2514, lateral view; (11) Panjiazui Formation, Wa'ergang section, GMPKU2515, lateral view; (12) Panjiazui Formation, Wa'ergang section, GMPKU2516, lateral view; (13) Panjiazui Formation, Wa'ergang section, GMPKU2517, lateral view; (14) Panjiazui Formation, Wa'ergang section, GMPKU2518, lateral view; (15) Panjiazui Formation, Wa'ergang section, GMPKU2519, lateral view; (16) Panjiazui Formation, Wa'ergang section, GMPKU2520, lateral view; (17) Panjiazui Formation, Wa'ergang section, GMPKU2521, lateral view; (18) Panjiazui Formation, Wa'ergang section, GMPKU2522, lateral view; (19) Panjiazui Formation, Wa'ergang section, GMPKU2523, lateral view; (20) Panjiazui Formation, Wa'ergang section, GMPKU2524, lateral view; (21) Panjiazui Formation, Wa'ergang section, GMPKU2525, lateral view; (22) Panjiazui Formation, Wa'ergang section, GMPKU2526, lateral view; (23) Panjiazui Formation, Wa'ergang section, GMPKU2527, lateral view; (24–30) *Cordylodus prolindstromi* Nicoll, 1991; (24) Panjiazui Formation, Wa'ergang section, GMPKU2528, lateral view; (25) Panjiazui Formation, Wa'ergang section, GMPKU2529, lateral view; (26) Panjiazui Formation, Wa'ergang section, GMPKU2530, lateral view; (27) Panjiazui Formation, Wa'ergang section, GMPKU2531, lateral view; (28) Panjiazui Formation, Wa'ergang section, GMPKU2532, lateral view; (29) Panjiazui Formation, Wa'ergang section, GMPKU2533, lateral view; (30) Panjiazui Formation, Wa'ergang section, GMPKU2534, lateral view. Relative scale bar represents 145 µm (1, 3–10, 12–16, 19, 21, 22, 24, 27, 29), 136 µm (2, 11, 17, 18, 20, 23, 25, 26, 28, 30).

←



- 1985 *Eoconodontus notchpeakensis* (Miller); Wang, p. 223, pl. 3, figs. 8–10, pl. 4, figs. 10, 11, pl. 7, figs. 1–3, pl. 13, figs. 4, 13, 14, pl. 14, fig. 18.
- 1985 *Eoconodontus notchpeakensis* (Miller); Dong, p. 399, pl. 1, figs. 3, 4, text-figs. 1C–D.
- 1986 *Eoconodontus notchpeakensis* (Miller); Chen and Gong, p. 140, pl. 19, fig. 13, pl. 31, figs. 2, 6, 8, pl. 32, figs. 2, 4, 6–7, 9, 11, pl. 33, figs. 2, 8, text-fig. 48.
- 1987 *Eoconodontus notchpeakensis* (Miller); Dong, p. 163, pl. 1, figs. 1, 2, pl. 3, figs. 20, 21.
- 1993 *Eoconodontus notchpeakensis* (Miller); Landing, p. 6, fig. 4 (4, 6, 9).
- 1996 *Eoconodontus notchpeakensis* (Miller); Lee et al., p. 97, pl. 1, figs. 6–7.
- 2000 *Eoconodontus notchpeakensis* (Miller); Dubinina, p. 192, pl. 7, figs. 8–12, 16–20, ?figs. 14–15, pl. 8, figs. 2–7, 14, ?fig. 1, pl. 9, figs. 11–13.
- 2001 *Eoconodontus notchpeakensis* (Miller); Lee, p. 451, fig. 7 (17, 19, 24).
- 2002 *Eoconodontus notchpeakensis* (Miller); Lee, p. 165, pl. 2, figs. 28, 29.
- 2002 *Eoconodontus notchpeakensis* (Miller); Lee, p. 27, pl. 2, figs. 17, 19.
- 2003 *Eoconodontus notchpeakensis* (Miller); Heinsalu et al., p. 147, text-figs. 9, 10.
- 2004c *Eoconodontus notchpeakensis* (Miller); Dong et al., p. 1204, pl. 2, figs. 1, 3.
- 2004 *Eoconodontus notchpeakensis* (Miller); Lee, p. 60, fig. 5 (V–W).
- 2006 *Eoconodontus notchpeakensis* (Miller); Miller et al., p. 394, fig. 9 (O, P).
- 2007 *Eoconodontus notchpeakensis* (Miller); Landing et al., p. 918, fig. 6 (q, r).
- 2011 *Eoconodontus notchpeakensis* (Miller); Miller et al., p. 604, fig. 7, K–N.

Description.—Bimembrate apparatus of rounded and compressed elements. Both elements proclined to erect; basal cavity variable, from moderately large to very deep; cusp short to long, composed of white matter; surface smooth. Rounded element symmetrical or subsymmetrical, oval in cross section, possessing or lacking anterior and posterior keels. Compressed element asymmetrical due to lateral bending of the cusp and to the

presence of carina on inner side of the base; cusp strongly compressed laterally, with prominent anterior and posterior keels.

Materials.—226 specimens.

Occurrence.—Known from the Wa'ergang section, where it ranges from the *Eoconodontus* Zone through the *Cordylodus lindstromi* Zone (upper part).

Genus *Eodentatus* Nicoll, 1991

Type species.—*Eodentatus bicuspatatus* Nicoll and Shergold, 1991.

Eodentatus bicuspatatus Nicoll and Shergold, 1991
Figure 17.18, 17.19

1991 *Eodentatus bicuspatatus* Nicoll and Shergold, p. 99, fig. 3.

Materials.—Two specimens.

Occurrence.—Known from the Wa'ergang section, where it occurs in the *Cordylodus proavus* Zone.

Remarks.—The present specimens agree in all respects with those described and illustrated by Nicoll and Shergold (1991). This species is characterized by ramiform elements with two denticles and an elongated ovate base.

Genus *Granatodontus* Chen and Gong, 1986

Type species.—*Granatodontus ani* (Wang, 1985).

Granatodontus ani (Wang, 1985)
Figure 18.1–18.29

1983 *Hirsutodontus* sp. aff. *Hirsutodontus primitivus* An et al., p. 104, pl. 4, figs. 22–23.

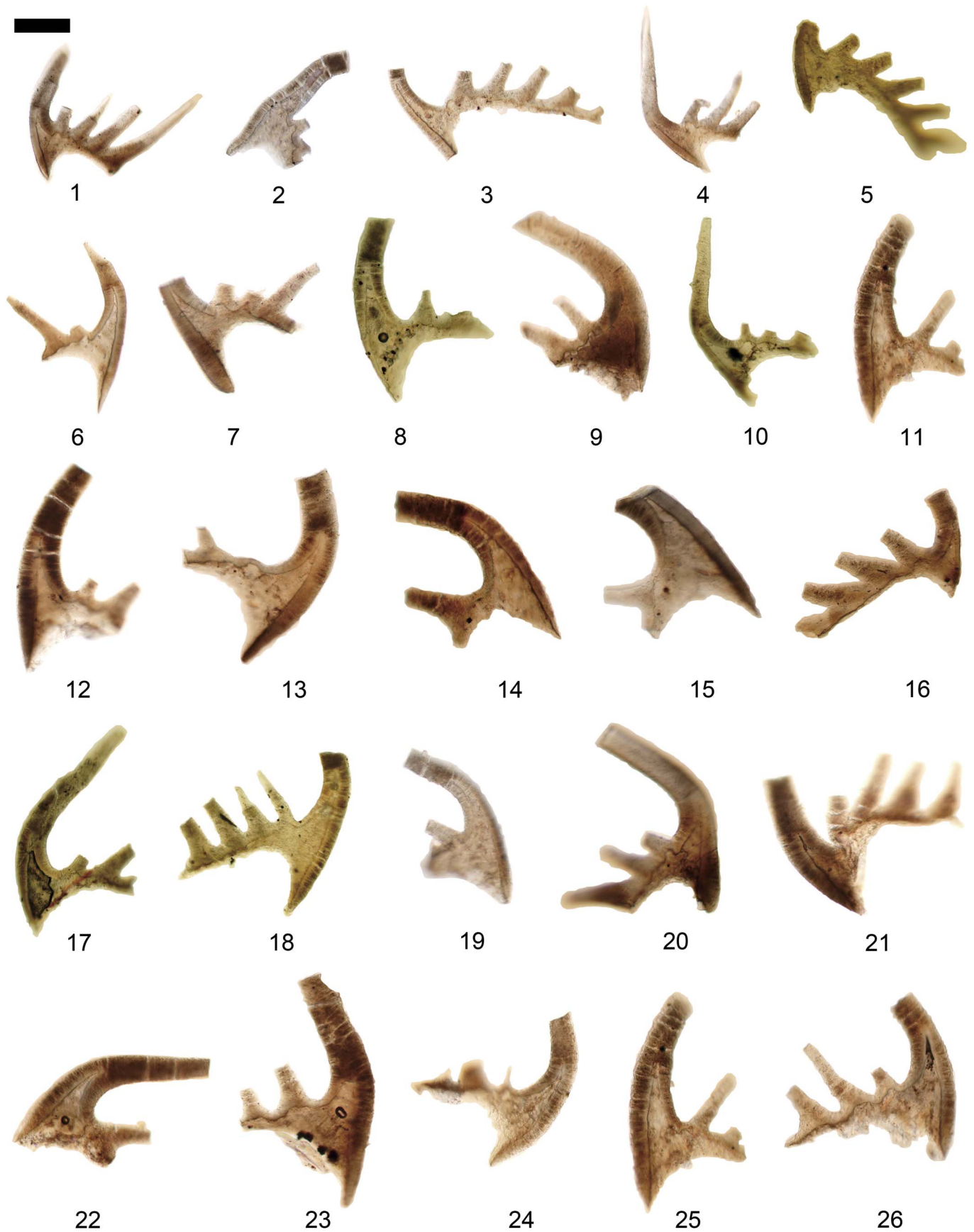
1985 *Hirsutodontus primitivus* An et al., pl. 1, figs. 1–2.

1985 *Hirsutodontus? ani* Wang in Chen et al., 1985, p. 92, pl. 26, figs. 4–6.

1986 *Granatodontus ani* (Wang); Chen and Gong, p. 149, pl. 26, fig. 8, pl. 27, figs. 1–5, 8–10, pl. 28, figs. 13, 14, pl. 31, fig. 10, text-fig. 53.

Figure 15. (1–35) *Cordylodus prolindstromi* Nicoll, 1991; (1) Panjiazui Formation, Wa'ergang section, GMPKU2535, lateral view; (2) Panjiazui Formation, Wa'ergang section, GMPKU2536, lateral view; (3) Panjiazui Formation, Wa'ergang section, GMPKU2537, lateral view; (4) Panjiazui Formation, Wa'ergang section, GMPKU2538, lateral view; (5) Panjiazui Formation, Wa'ergang section, GMPKU2539, lateral view; (6) Panjiazui Formation, Wa'ergang section, GMPKU2540, lateral view; (7) Panjiazui Formation, Wa'ergang section, GMPKU2541, lateral view; (8) Panjiazui Formation, Wa'ergang section, GMPKU2542, lateral view; (9) Panjiazui Formation, Wa'ergang section, GMPKU2543, lateral view; (10) Panjiazui Formation, Wa'ergang section, GMPKU2544, lateral view; (11) Panjiazui Formation, Wa'ergang section, GMPKU2545, lateral view; (12) Panjiazui Formation, Wa'ergang section, GMPKU2546, lateral view; (13) Panjiazui Formation, Wa'ergang section, GMPKU2547, lateral view; (14) Panjiazui Formation, Wa'ergang section, GMPKU2548, lateral view; (15) Panjiazui Formation, Wa'ergang section, GMPKU2549, lateral view; (16) Panjiazui Formation, Wa'ergang section, GMPKU2550, lateral view; (17) Panjiazui Formation, Wa'ergang section, GMPKU2551, lateral view; (18) Panjiazui Formation, Wa'ergang section, GMPKU2552, lateral view; (19) Panjiazui Formation, Wa'ergang section, GMPKU2553, lateral view; (20) Panjiazui Formation, Wa'ergang section, GMPKU2554, lateral view; (21) Panjiazui Formation, Wa'ergang section, GMPKU2555, lateral view; (22) Panjiazui Formation, Wa'ergang section, GMPKU2556, lateral view; (23) Panjiazui Formation, Wa'ergang section, GMPKU2557, lateral view; (24) Panjiazui Formation, Wa'ergang section, GMPKU2558, lateral view; (25) Panjiazui Formation, Wa'ergang section, GMPKU2559, lateral view; (26) Panjiazui Formation, Wa'ergang section, GMPKU2560, lateral view; (27) Panjiazui Formation, Wa'ergang section, GMPKU2561, lateral view; (28) Panjiazui Formation, Wa'ergang section, GMPKU2562, lateral view; (29) Panjiazui Formation, Wa'ergang section, GMPKU2563, lateral view; (30) Panjiazui Formation, Wa'ergang section, GMPKU2564, lateral view; (31) Panjiazui Formation, Wa'ergang section, GMPKU2565, lateral view; (32) Panjiazui Formation, Wa'ergang section, GMPKU2566, lateral view; (33) Panjiazui Formation, Wa'ergang section, GMPKU2567, lateral view; (34) Panjiazui Formation, Wa'ergang section, GMPKU2568, lateral view; (35) Panjiazui Formation, Wa'ergang section, GMPKU2569, lateral view; Relative scale bar represents 150 µm (1–3, 5–23, 25–27, 30–35), 137 µm (4, 24, 28), 120 µm (29).

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- 2000 *Hirsutodontus ani* Wang; Dubinina, p. 186, pl. 6, fig. 1a.
 2002 *Granatodontus ani* (Wang); Lee, p. 165, pl. 2, fig. 13.
 2004 *Granatodontus ani* (Wang); Lee, p. 60, fig. 5 (P).
 2004 *Granatodontus ani* (Wang); Wu and Dong, p. 230, pl. 1, figs. 1–4.
 2008 *Granatodontus ani* (Wang); Lee, p. 228, fig. 1 (3–4), p. 229, pl. 1, fig. 1.
 2008 *Granatodontus asymmetrica* Lee, p. 229, pl. 1, figs. 2, 3.
 2008 *Granatodontus multicorrugata* Lee, p. 229, pl. 1, figs. 4–6.
 2009 *Granatodontus ani* (Wang); Lee et al., p. 423, fig. 7 (19), p. 425, fig. 8 (2).
- 1991 *Hirsutodontus nodus* (Zhang and Xiang); Nicoll and Shergold, figs. 4, 5 (1).
 2001 *Hirsutodontus nodus* (Zhang and Xiang); Lee, p. 449, fig. 6 (19, 26), p. 451, fig. 7 (3).
 2002 *Teridontus nodus* (Zhang and Xiang); Lee, p. 27, pl. 2, fig. 20.
 2002 *Hirsutodontus nodus* (Zhang and Xiang); Lee, p. 165, pl. 2, fig. 14.
 2004 *Hirsutodontus nodus* (Zhang and Xiang); Lee, p. 60, fig. 5 (S, X).

Materials.—20 specimens.

Description.—Coniform elements, erect to proclined and symmetrical, oval in cross section. Base large. Basal cavity large and deep, with apex extending beyond the point of flexure of cusp. The surface of the whole element is ornamented with numerous tiny nodes, rarely with a few tiny spines, except for the apex.

Materials.—80 specimens.

Occurrence.—Known from Wangcun section where it ranges from the *Westergaardodina* cf. *calix-Prooneotodus rotundatus* Zone through the *Eoconodontus* Zone.

Remarks.—Chen and Gong (1986) suggested that *Granatodontus ani* (Wang, 1985) is a paraconodont, based on its large basal cavity and lack of white matter. However, histological investigation verifies *G. ani* is a euconodont (Wu and Dong, 2004; Murdock et al., 2013). Conodont elements with conspicuous surface ornamentation, such as spines or nodes, should all be considered to be euconodonts rather than paraconodonts. This generalization can be made without histological study, based on a hypothesis proposed by Bengtson (1976).

Genus *Hirsutodontus* Miller, 1969

Type species.—*Hirsutodontus hirsutus* Miller, 1969.

Hirsutodontus nodus (Zhang and Xiang in An et al., 1983)
 Figure 19.4–19.13

- 1983 *Teridontus nakamurai nodus* Zhang and Xiang in An et al., p. 157, pl. 6, figs. 7, 8, text-fig. 14 (19).
 1986 *Dasytodus nodus* (Zhang and Xiang); Chen and Gong, p. 135, pl. 28, fig. 10, pl. 31, fig. 9, text-fig. 42.

Occurrence.—Known from the Wangcun and Wa'ergang sections, where it occurs in the *Eoconodontus* Zone.

Remarks.—An et al. (1983) erected a new subspecies *Teridontus nakamurai nodus* Zhang and Xiang. Chen and Gong (1986) assigned this subspecies to *Dasytodus*. Having examined the published material and the new material from Hunan, we agree with Nicoll and Shergold (1991) that *T. nakamurai nodus* should be assigned to *Hirsutodontus* rather than *Dasytodus*. The morphological difference between *Dasytodus transmutatus* and *Hirsutodontus nodus* has been fully elucidated by Nicoll and Shergold (1991). The surface of the element of *H. nodus* is ornamented with only a few tiny nodes, so it differs from *Hirsutodontus hirsutus* Miller.

Genus *Hispidodontus* Nicoll and Shergold, 1991

Type species.—*Hispidodontus discretus* Nicoll and Shergold, 1991.

Hispidodontus resimus Nicoll and Shergold, 1991
 Figure 19.17–19.19

- 1991 *Hispidodontus resimus* Nicoll and Shergold, p. 107, figs. 14, 15, 16 (1–2).

Materials.—Three specimens.

Occurrence.—Known from the Wangcun section, where it occurs in the *Westergaardodina* cf. *calix-Prooneotodus rotundatus* Zone.

Remarks.—The specimens at hand agree well with *Hispidodontus resimus* described and figured by Nicoll and Shergold (1991). They are all S elements.

Figure 16. Conodont images using oil immersion techniques (Dong et al., 2005c) with Differential Interference Contrast (Nomarski) illumination, showing the shapes of the biapical basal cavities. (1–26) *Cordylodus prolindstromi* Nicoll, 1991; (1) the same specimen as Figure 15.10; (2) the same specimen as Figure 15.4; (3) the same specimen as Figure 15.5; (4) the same specimen as Figure 15.6; (5) the same specimen as Figure 15.11; (6) the same specimen as Figure 15.13; (7) the same specimen as Figure 15.14; (8) the same specimen as Figure 15.15; (9) the same specimen as Figure 15.16; (10) the same specimen as Figure 15.17; (11) the same specimen as Figure 15.19; (12) the same specimen as Figure 15.20; (13) the same specimen as Figure 15.21; (14) the same specimen as Figure 15.22; (15) the same specimen as Figure 15.23; (16) the same specimen as Figure 15.25; (17) the same specimen as Figure 15.26; (18) the same specimen as Figure 15.27; (19) the same specimen as Figure 15.28; (20) the same specimen as Figure 15.29; (21) the same specimen as Figure 15.30; (22) the same specimen as Figure 15.31; (23) the same specimen as Figure 15.32; (24) the same specimen as Figure 15.33; (25) the same specimen as Figure 15.34; (26) the same specimen as Figure 15.35. Relative scale bar represents 168 µm (1, 4), 149 µm (2, 3, 6, 10, 12, 17, 18, 21, 22, 24), 121 µm (5, 8, 13, 16, 26), 109 µm (7, 14, 19), 134 µm (9, 11, 23, 25), 98 µm (15), 101 µm (20).

←



Genus *Iapetognathus* Landing, 1982

Type species.—*Pravognathus aengensis* Lindström, 1955.

Iapetognathus aengensis (Lindström 1955)

Figure 20.11–20.17

- 1955 *Pravognathus aengensis* Lindström, p. 585, pl. 5, figs. 10–13.
- 1982 *Iapetognathus preaengensis* Landing in Fortey et al., p. 124–126, text-figs. 6 (B, C), 8 (B, C, H).
- 1986 *Iapetognathus preaengensis* Landing; Landing, Barnes, and Stevens, p. 1934, pl. 1, fig. 8.
- 1986 *Iapetognathus* sp. Kaljo et al., pl. 3, fig. 13.
- 1987 *Iapetognathus aengensis* (Lindström); Olgun, p. 60, fig. 30.
- 1988 *Iapetognathus preaengensis* Landing; Barnes, fig. 13cc only (not fig. 13 y, z, aa, bb, dd, ee). (part)
- 1988 *Iapetognathus preaengensis* Landing; Kaljo et al., figs. 4f, 5f.
- 1988 *Iapetognathus* sp. Kaljo et al., figs. 4bb, 5bb only.
- 1993 *Iapetognathus preaengensis* Landing; Landing, p. 11, fig. 8 (1, ?2).
- 1993 *Iapetognathus* sp. aff. *I. preaengensis* Landing; Fähræus and Roy, pl. 2, fig. 26 only.
- 1996 *Iapetognathus aengensis* (Lindström); Löfgren, p. 173, fig. 8 (G, K).
- 1999 *Iapetognathus aengensis* (Lindström); Nicoll et al., p. 44, pl. 1, figs. 1–5, pl. 2, figs. 1–4, pl. 3, figs. 1–4, pl. 4, figs. 1–3, pl. 5, figs. 1–3.
- 2003 *Iapetognathus aengensis* (Lindström); Heinsalu et al., p. 147, text-fig. 5 (26–30).
- 2012 *Iapetognathus aengensis* (Lindström); Terfelt et al., p. 230, fig. 2, A–E.

Materials.—Five specimens.

Occurrence.—Known only from the Wa'ergang section, where it occurs in the *Cordylodus angulatus* Zone (lower part).

Remarks.—Nicoll et al. (1999) diagnosed multimembrate apparatus in which six element types have been identified, i.e., Sc, Sb, Sd, Xb, Pb, and Pa elements. However, only five elements of *Iapetognathus aengensis* have been recovered from Hunan, and all are S elements.

Iapetognathus fluctivagus Nicoll et al., 1999

Figure 20.18–20.24

- 1970 New Genus A Miller, p. 110, pl. 1, figs. 32–34, text-fig. 11E.
- 1982 New Genus 2 (cordylodid) Miller et al., text-figs. 5, 6.
- 1987 *Iapetognathus preaengensis* Landing; Miller, fig. 3.
- 1988 *Iapetognathus preaengensis* Landing; Barnes, fig. 13z, aa only.
- 1995 *Iapetognathus* n. sp. Taylor and Repetski, p. 135.
- 1995 *Iapetognathus* n. sp. 1 Miller and Stitt, p. 108.
- 1995 *Iapetognathus* n. sp. 1 Miller and Taylor, p. 111.
- 1999 *Iapetognathus fluctivagus* Nicoll et al., p. 46, pl. 6, figs. 1–5, pl. 7, figs. 1–4, pl. 8, figs. 1–2, pl. 9, figs. 1–7, pl. 10, figs. 1–6, pl. 11, figs. 1–6.
- 2004c *Iapetognathus fluctivagus* Nicoll et al.; Dong et al., p. 1205, pl. 3, figs. 1–3.
- non 2007 *Iapetognathus fluctivagus* Nicoll et al.; Pyle et al., 1656, p. 1733, fig. 10 (8, 9).
- 2012 *Iapetognathus?* *fluctivagus* Nicoll et al.; Terfelt et al., p. 230, fig. 2, F–G, H–K.

Materials.—Three specimens.

Occurrence.—Known only from the Wa'ergang section, where it occurs in the upper part of the *Cordylodus lindstromi* Zone.

Remarks.—Although *Iapetognathus fluctivagus* is widespread in North America, specimens of it are very rare in China. So far, only three specimens belonging to P elements have been recovered in western Hunan, South China, by means of sampling and processing on an extremely large scale. Cooper et al. (2001) established a stratotype for the base of the Ordovician based on the FAD of this species at Green Point in Newfoundland, Canada.

Iapetognathus jilinensis Nicoll et al., 1999

Figure 20.25–20.28

- 1995 *Iapetognathus* n. sp. A Nowlan and Nicoll, p. 115–116.
- 1999 *Iapetognathus jilinensis* Nicoll et al., p. 48, pl. 12, figs. 1a–4f, pl. 13, figs. 1a–3f, pl. 14, figs. 1a–4b.

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Figure 17. (1, 2) *Dasytodus transmutatus* (Xu and Xiang, 1983); (1) Shenjiawan Formation, Wangcun section, GMPKU2570, lateral view; (2) Shenjiawan Formation, Wa'ergang section, GMPKU2571, lateral view; (3–17) *Eoconodontus notchpeakensis* Miller, 1980; (3) Shenjiawan Formation, Wangcun section, GMPKU2572, lateral view; (4) Shenjiawan Formation, Wangcun section, GMPKU2573, lateral view; (5) Shenjiawan Formation, Wa'ergang section, GMPKU2574, lateral view; (6) Shenjiawan Formation, Wa'ergang section, GMPKU2575, lateral view; (7) Shenjiawan Formation, Wa'ergang section, GMPKU2576, lateral view; (8) Shenjiawan Formation, Wa'ergang section, GMPKU2577, lateral view; (9) Shenjiawan Formation, Wa'ergang section, GMPKU2578, lateral view; (10) Shenjiawan Formation, Wa'ergang section, GMPKU2579, lateral view; (11) Shenjiawan Formation, Wa'ergang section, GMPKU2580, lateral view; (12) Shenjiawan Formation, Wa'ergang section, GMPKU2581, lateral view; (13) Shenjiawan Formation, Wa'ergang section, GMPKU2582, lateral view; (14) Shenjiawan Formation, Wa'ergang section, GMPKU2583, lateral view; (15) Shenjiawan Formation, Wa'ergang section, GMPKU2584, lateral view; (16) Shenjiawan Formation, Wa'ergang section, GMPKU2585, lateral view; (17) Shenjiawan Formation, Wa'ergang section, GMPKU2586, lateral view; (18, 19) *Eodentatus bicuspatatus* Nicoll and Shergold, 1991; (18) Shenjiawan Formation, Wa'ergang section, GMPKU2587, ramiform element, lateral view; (19) Shenjiawan Formation, Wa'ergang section, GMPKU2588, ramiform element, lateral view; (20–25) *Furnishina bigeminata* Dong, 1993; (20) Huaqiao Formation, Wangcun section, GMPKU2589, outer lateral view; (21) Huaqiao Formation, Wangcun section, GMPKU2590, inner lateral view; (22) Huaqiao Formation, Wangcun section, GMPKU2591, outer lateral view; (23) Chefu Formation, Wangcun section, GMPKU2592, outer lateral view; (24) Chefu Formation, Wangcun section, GMPKU2593, outer lateral view; (25) Bitiao Formation, Wangcun section, GMPKU2594, lateral view; (26–31) *Furnishina dayangchaensis* Chen and Gong, 1986; (26) Bitiao Formation, Wangcun section, GMPKU2595, posterior view; (27) Bitiao Formation, Wangcun section, GMPKU2596, cluster; (28) Bitiao Formation, Wangcun section, GMPKU2597, posterior view; (29) Bitiao Formation, Wangcun section, GMPKU2598, oblique posterior view; (30) Shenjiawan Formation, Wa'ergang section, GMPKU2599, posterior view; (31) Shenjiawan Formation, Wa'ergang section, GMPKU2600, oblique posterior view. Relative scale bar represents 126 µm (1, 23), 135 µm (2–22, 24–31).



Materials.—Only one specimen.

Occurrence.—Known only from the Wa'ergang section, where it occurs in the *Cordylodus lindstromi* Zone (Upper Part).

Remarks.—Only a single specimen belonging to S element has been recovered from western Hunan.

Genus *Mamillodus* Abaimova, 1983

Type species.—*Mamillodus tubularis* Abaimova, 1983.

Mamillodus ruminatus Dubinina, 2000
Figure 21.7

2000 *Mamillodus ruminatus* Dubinina, p. 171, pl. 7, figs. 1–6.

Materials.—Only one specimen.

Occurrence.—Known from the Wa'ergang section, where it occurs in the *Eoconodontus* Zone.

Remarks.—The specimens at hand agree closely with *Mamillodus ruminatus*. Dubinina indicated it is a paraconodont. Based on its surface ornamentation, however, it is probably a euconodont (Bengtson, 1976).

Genus *Millerodontus* new genus

Type species.—*Millerodontus intermedius* n. gen. n. sp.

Diagnosis.—Coniform euconodont elements, proclined, symmetrical, with rounded cross section. Keels or costae are lacking. Basal cavity is very deep.

Etymology.—In honor of James F. Miller, Missouri State University, USA, the name is composed from Miller and a derivative of Greek, *odon*, tooth.

Millerodontus intermedius new genus new species
Figures 21.13, 21.14, 21.17–21.19, 22.1–22.8

Diagnosis.—As for genus.

Description.—Moderate to small coniform elements, proclined, and symmetrical. The apex is pointed. Both anterior and

posterior sides are rounded, without keels or costae. Basal cavity is very deep, the apex of which extends nearly to the tip of the element. The cross section is circular. Crown tissues and the phenomenon of regeneration could be observed at the apical portion of element.

Etymology.—*intermedius*, Latin, intermediate.

Types.—Holotype: GMPKU2252 from the *Proconodontus tenuiserratus* Zone, Shenjiawan Formation, Wa'ergang section, Wa'ergang village, Taoyuan county, Hunan Province.

Materials.—10 specimens.

Occurrence.—Known from the Wa'ergang and Wangcun sections, where it ranges from the *Proconodontus tenuiserratus* Zone through the *Cordylodus proavus* Zone.

Comparision.—In gross morphology, *Millerodontus intermedius* n. gen. n. sp. resembles *Prooneotodus rotundatus*, but it is recognized as euconodont in the light of histological investigation. *M. intermedius* is a representative of the model of early evolution of euconodonts proposed by Bengtson (1976), according to which euconodont elements originated from paraconodonts through acquisition of a crown. *M. intermedius* is probably the transitional form between *P. rotundatus* and *Proconodontus tenuiserratus*.

Remarks.—The majority of the specimens which resemble *Prooneotodus rotundatus* have thick sheaths, just like Miller's interpretation that a thin layer of apatite covers a massive white basal cone (Miller, 1980, p. 31–32). Not all specimens could be investigated by means of the oil immersion technique, and thin sectioning would ruin the specimens. Therefore, the number of specimens of *Millerodontus intermedius* n. gen. n. sp. is probably much more than ten.

Genus *Monocostodus* Miller, 1980

Type species.—*Aodus sevierensis* Miller, 1969.

Monocostodus sevierensis (Miller, 1969)
Figure 21.20–21.23

Figure 18. (1–29) *Granatodontus ani* (Wang, 1985); (1) Bitiao Formation, Wangcun section, GMPKU2652, lateral view; (2) Bitiao Formation, Wangcun section, GMPKU2653, lateral view; (3) Shenjiawan Formation, Wangcun section, GMPKU2654, lateral view; (4) Shenjiawan Formation, Wangcun section, GMPKU2655, lateral view; (5) Shenjiawan Formation, Wangcun section, GMPKU2656, lateral view; (6) Shenjiawan Formation, Wangcun section, GMPKU2657, posterior view; (7) Shenjiawan Formation, Wangcun section, GMPKU2658, lateral view; (8) Shenjiawan Formation, Wangcun section, GMPKU2659, lateral view; (9) Shenjiawan Formation, Wangcun section, GMPKU2660, lateral view; (10) Shenjiawan Formation, Wangcun section, GMPKU2661, lateral view; (11) Shenjiawan Formation, Wangcun section, GMPKU2662, lateral view; (12) Shenjiawan Formation, Wangcun section, GMPKU2663, lateral view; (13) Shenjiawan Formation, Wangcun section, GMPKU2664, lateral view; (14) Shenjiawan Formation, Wangcun section, GMPKU2665, lateral view; (15) Shenjiawan Formation, Wangcun section, GMPKU2666, lateral view; (16) Shenjiawan Formation, Wangcun section, GMPKU2667, lateral view; (17) Shenjiawan Formation, Wangcun section, GMPKU2668, lateral view; (18) Shenjiawan Formation, Wangcun section, GMPKU2669, lateral view; (19) Shenjiawan Formation, Wangcun section, GMPKU2670, lateral view; (20) Shenjiawan Formation, Wangcun section, GMPKU2671, lateral view; (21) Shenjiawan Formation, Wangcun section, GMPKU2672, lateral view; (22) Shenjiawan Formation, Wangcun section, GMPKU2673, lateral view; (23) Shenjiawan Formation, Wangcun section, GMPKU2674, lateral view; (24) Shenjiawan Formation, Wangcun section, GMPKU2675, lateral view; (25) Shenjiawan Formation, Wangcun section, GMPKU2676, lateral view; (26) Shenjiawan Formation, Wangcun section, GMPKU2677, lateral view; (27) Shenjiawan Formation, Wangcun section, GMPKU2678, lateral view; (28) Shenjiawan Formation, Wangcun section, GMPKU2679, lateral view; (29) Shenjiawan Formation, Wangcun section, GMPKU2680, lateral view. Relative scale bar represents 154 µm (1, 2, 5–24, 26, 28, 29), 144 µm (3, 4, 25), 164 µm (27).

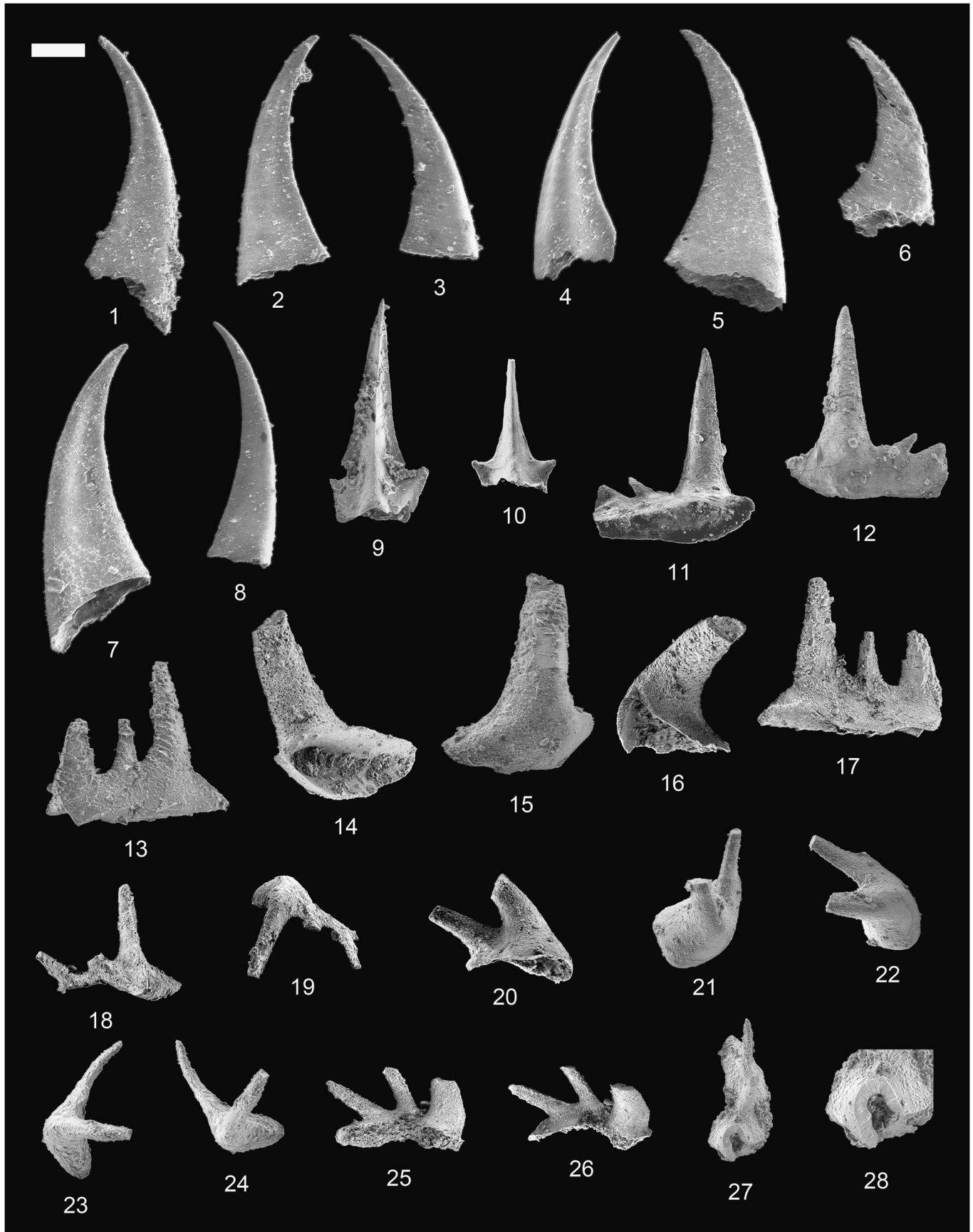


- 1969 *Acodus sevierensis* Miller, p. 418, pl. 63, figs. 25–31 (not figs. 21–24, 32). (part)
- 1969 *Acontiodus (Semiacontiodus) unicastatus* Miller, p. 421, pl. 64, figs. 19–54 (not figs. 46–48). (part)
- 1971 *Drepanodus simplex* Branson and Mehl; Druce and Jones, p. 74, text-fig. 24b, pl. 13, figs. 1–4.
- 1973 *Semiacontiodus sevierensis* (Miller), Lindström, p. 442–445.
- 1980 *Monocostodus sevierensis* (Miller); Miller, p. 27, pl. 2, figs. 8–9, text-fig. 4U.
- 1982 *Monocostodus sevierensis* (Miller); Landing in Fortey et al., p. 123, text-fig. 8 (Q, R).
- 1983 *Monocostodus sevierensis* (Miller); An et al., p. 108, pl. 6, figs. 19–23.
- 1985 *Monocostodus sevierensis* (Miller); Dong, p. 400, pl. 3, figs. 8, 11.
- ? 1985 *Monocostodus sevierensis* (Miller); Wang in Chen et al., p. 93, pl. 25, figs. 9–11, text-fig. 14 (7).
- 1987 *Monocostodus sevierensis* (Miller); Dong, p. 163, pl. 1, figs. 26, 32, pl. 2, figs. 1, 2.
- 1993 *Monocostodus sevierensis* (Miller); Landing, p. 6, fig. 4 (10, 18, 19).
- 1996 *Drepanodus simplex* Branson and Mehl; Lee et al., p. 97, pl. 1, fig. 17.
- 1998 *Monocostodus sevierensis* (Miller); Rao and Tortello, p. 43, pl. 1, figs. 13–18.
- 2000 *Drepanodus simplex* Branson and Mehl; Zhao et al., p. 198, pl. 9, figs. 1–9.
- 2000 *Monocostodus sevierensis* (Miller); Zhao et al., p. 206, pl. 8, figs. 1–7.
- 2003 *Monocostodus sevierensis* (Miller); Landing et al., p. 86, fig. 7 (14, 18).
- Occurrence.*—Known from the Wa'ergang section, where it ranges from the *Cordylodus lindstromi* Zone (upper part) through the *Cordylodus angulatus* Zone.
- Genus *Proconodontus* Miller, 1969
- Type species.*—*Proconodontus muelleri* Miller, 1969.
- Proconodontus muelleri* Miller, 1969
Figure 23.8–23.32
- 1969 *Proconodontus mülleri mülleri* Miller, p. 437, text-fig. 5H, pl. 66, figs. 30–40.
- 1970 *Proconodontus mülleri mülleri* Miller; Miller, pl. 2, fig. 18.
- 1971 *Proconodontus mulleri mulleri* Miller; Ethington and Clark, pl. 1, fig. 25.
- 1971 *Coelocerodontus burkei* Druce and Jones, p. 61, text-fig. 22a (not text-fig. 22e), pl. 11, figs. 9–11 (not figs. 5–8, 12). (part)
- ? 1973 *Proconodontus muelleri* Miller; Müller, p. 42, pl. 3, figs. 4–7, ?10 (not fig. 8). (part)
- 1976 *Proconodontus muelleri* Miller; Miller and Paden, p. 595, pl. 1, figs. 4, 5.
- 1978 *Proconodontus muelleri muelleri* Miller; Tipnis et al., pl. 1, figs. 13, 17.
- 1980 *Proconodontus muelleri* Miller; Miller, p. 29, text-fig. 4C, pl. 1, fig. 7.
- 1981 *Proconodontus muelleri* Miller; Miller in Robison, p. W146, fig. 95 (2a, b).
- 1982 *Proconodontus muelleri muelleri* Miller; Fortey et al., p. 125, text-fig. 9 (K).
- 1982 *Proconodontus muelleri* Miller; An, p. 141, pl. 12, figs. 8, 9, 11–13, pl. 16, figs. 10, 12.
- 1983 *Proconodontus muelleri* Miller; An et al., p. 126, pl. 5, fig. 21 only (not figs. 15, 16, 23, 24). (part)
- 1985 *Proconodontus muelleri* Miller; Nowlan, p. 114, fig. 5.1.
- 1985 *Proconodontus muelleri* Miller; Wang, p. 231, pl. 2, figs. 16–20 (not fig. 21), pl. 6, figs. 17–19, pl. 7, figs. 10, 27, pl. 8, figs. 17, 18, pl. 12, fig. 7, pl. 13, figs. 1, 6. (part)
- ? 1985 *Proconodontus muelleri* Miller; Wang, p. 231, pl. 9, figs. 16–18, pl. 13, fig. 25.
- 1986 *Proconodontus muelleri* Miller; Chen and Gong, p. 159, pl. 32, figs. 1, 3, 10, 12–14, 17, pl. 33,

Description.—Slender coniform elements, erect to reclined, with short base and long cusp. Cross section is circular through base and the aboral half of the cusp, but it becomes extremely laterally compressed through the oral half of cusp. The anterior and posterior sides of the oral half of cusp are keeled. Basal cavity is shallow. The slender cusp is composed entirely of white matter.

Materials.—12 specimens.

Figure 19. (1–3) *Gumella cuneata* Müller and Hinz, 1991; (1) Huaqiao Formation, Wangcun section, GMPKU2681, lateral view; (2) Huaqiao Formation, Wangcun section, GMPKU2682, lateral view; (3) Chefu Formation, Wangcun section, GMPKU2683, lateral view; (4–13) *Hirsutodontus nodus* (Zhang and Xiang, 1983); (4) Shenjiawan Formation, Wangcun section, GMPKU2684, lateral view; (5) Shenjiawan Formation, Wangcun section, GMPKU2685, lateral view; (6) Shenjiawan Formation, Wangcun section, GMPKU2686, lateral view; (7) Shenjiawan Formation, Wangcun section, GMPKU2687, lateral view; (8) Shenjiawan Formation, Wangcun section, GMPKU2688, lateral view; (9) Shenjiawan Formation, Wa'ergang section, GMPKU2689, lateral view; (10) Shenjiawan Formation, Wa'ergang section, GMPKU2690, lateral view; (11) Shenjiawan Formation, Wa'ergang section, GMPKU2691, lateral view; (12) Panjiazui Formation, Wa'ergang section, GMPKU2692, lateral view; (13) Panjiazui Formation, Wa'ergang section, GMPKU2693, lateral view; (14–16, 22–24) *Huayuanodontus tricornis* (Dong, 1993); (14) Chefu Formation, Wangcun section, GMPKU2242, posterior view; (15) Chefu Formation, Wangcun section, GMPKU2694, posterior view; (16) Chefu Formation, Wangcun section, GMPKU2695, posterior view; (22) Chefu Formation, Paibi section, GMPKU2696, posterior view; (23) Chefu Formation, Paibi section, GMPKU2245, posterior view; (24) close-up of (23) posterior view; (17–19) *Hispidodontus resimus* Nicoll and Shergold, 1991; (17) Bitiao Formation, Wangcun section, GMPKU2697, posterolateral view; (18) Bitiao Formation, Wangcun section, GMPKU2698, broken specimen, outer lateral view; (19) Bitiao Formation, Wangcun section, GMPKU2699, anterolateral view; (20, 21, 25, 26) *Lugnathus hunanensis* n. gen. n. sp.; (20) Panjiazui Formation, Wa'ergang section, GMPKU2700, lateral view; (21) Panjiazui Formation, Wa'ergang section, GMPKU2701, lateral view; (25) Panjiazui Formation, Wa'ergang section, holotype, GMPKU2702, lateral view; (26) Panjiazui Formation, Wa'ergang section, GMPKU2703, lateral view. Relative scale bar represents 502 µm (1), 269 µm (2), 270 µm (3), 164 µm (4–8, 10–13, 17, 18, 20, 21, 25, 26), 157 µm (9, 14, 19, 23), 146 µm (15, 16), 147 µm (22), 111 µm (24).



- figs. 3–5, 11 (not pl. 19, fig. 6), text-fig. 60 (1–2; 4–6; not 3). (part)
- 1987 *Proconodontus muelleri* Miller; Dong, p. 169, pl. 1, figs. 3–5, text-figs. 3B, C, 4D.
- 1987 *Proconodontus muelleri* Miller; An, p. 109, pl. 2, figs. 4, 17.
- 1987 *Proconodontus* aff. *muelleri* Miller; An, p. 110, pl. 2, figs. 19–21.
- 1988 *Proconodontus muelleri* Miller; Andres, p. 125, pl. 10, figs. 1–8, pl. 11, figs. 1–8, pl. 12, figs. 1–4, text-figs. 20–25.
- 1988 *Proconodontus muelleri* Miller; Lee and Lee, pl. 2, figs. 27–29.
- 1991 *Proconodontus muelleri* Miller; Müller and Hinz, p. 56, pl. 42, figs. 1–16, text-figs. 22B, C.
- 1993 *Proconodontus muelleri* Miller; Landing, p. 6, fig. 4 (5).
- 1996 *Proconodontus muelleri* Miller; Lee et al., p. 97, pl. 1, fig. 3.
- ? 2000 *Proconodontus muelleri* Miller; Dubinina, p. 194, pl. 7, fig. 7.
- 2001 *Proconodontus muelleri* Miller; Lee, p. 451, fig. 7.15.
- 2002 *Proconodontus muelleri* Miller; Lee, p. 165, pl. 2, fig. 26.
- 2002 *Proconodontus muelleri* Miller; Lee, p. 27, pl. 2, fig. 15.
- 2004 *Proconodontus muelleri* Miller; Lee, p. 60, fig. 5 (H).
- 2006 *Proconodontus muelleri* Miller; Miller et al., p. 394, fig. 9 (S).
- 2007 *Proconodontus muelleri* Miller; Landing et al., p. 918, fig. 6 (n, o).
- 2009 *Proconodontus muelleri* Miller; Lee et al., p. 423, fig. 7 (8).
- 2011 *Proconodontus muelleri* Miller; Miller et al., p. 604, fig. 7, I, J.

Description.—Coniform elements, moderate to large, proclined and symmetrical or nearly so. The cross section is circular at the apical portion and it changes into an oval to moderately compressed outline toward the base. Basal cavity is very large and deep, with the apex extending nearly to the tip of it. Both anterior and posterior edges are characterized by sharp keels of variable extent. Usually, the posterior keel is more conspicuous and extends from the tip to the base, while the anterior keel

extends from the tip to variable distances down toward the base of the element. Regeneration of the tip is often observed at the apical portion of the element.

Materials.—200 specimens.

Occurrence.—Known from the Wangcun and Wa'ergang sections, where it ranges from the *Proconodontus* Zone through the *Eoconodontus* Zone.

Remarks.—Miller (1980) believed white matter is lacking in *Proconodontus*. However, Müller and Hinz (1991) found white matter in the keel and in the regenerated part of the tip. Later, they verified this observation by histological investigation (Müller and Hinz, 1998, p. 108–110, fig. 18.3). Indeed, our histological study on many specimens of *Proconodontus muelleri* recovered from Hunan, South China also verified this conclusion (Xi-ping Dong and Philip C. J. Donoghue, unpublished data).

Proconodontus posterocostatus Miller, 1980
Figure 24.1, 24.2

- 1971 *Coelocerodontus burkei* Druce and Jones, p. 61, pl. 11, figs. 7, 8 (not figs. 5, 6, 9–12). (part)
- 1980 *Proconodontus posterocostatus* Miller, p. 30, text-fig. 4B, pl. 1, figs. 4–6.
- non 1982 *Proconodontus posterocostatus* Miller; An, p. 142, pl. 12, figs. 3, 4, 6, 7, 10.
- 1986 *Proconodontus posterocostatus* Miller; Chen and Gong, p. 161, pl. 25, figs. 1, 6, pl. 30, figs. 1, 3–4, 8–13, pl. 32, fig. 8, pl. 33, figs. 7, 9 (not pl. 19, fig. 16), text-fig. 61 (1, 3–8, not 2). (part)
- 2002 *Proconodontus posterocostatus* Miller; Lee, p. 165, pl. 2, fig. 25.
- 2002 *Proconodontus posterocostatus* Miller; Lee, p. 27, pl. 2, fig. 12.
- 2004c *Proconodontus posterocostatus* Miller; Dong et al., pl. 1, fig. 3.
- 2004c *Proconodontus serratus* Miller; Dong et al., pl. 1, fig. 11.
- ? 2009 *Proconodontus posterocostatus* Miller; Lee et al., p. 423, fig. 7 (7, 9).

Figure 20. (1–8) *Lugnathus hunanensis* n. gen. n. sp.; (1) Panjiazui Formation, Wa'ergang section, GMPKU2704, lateral view; (2) Panjiazui Formation, Wa'ergang section, GMPKU2705, lateral view; (3) Panjiazui Formation, Wa'ergang section, GMPKU2706, lateral view; (4) Panjiazui Formation, Wa'ergang section, GMPKU2707, lateral view; (5) Panjiazui Formation, Wa'ergang section, GMPKU2708, lateral view; (6) Panjiazui Formation, Wa'ergang section, GMPKU2709, lateral view; (7) Panjiazui Formation, Wa'ergang section, GMPKU2710, lateral view; (8) Panjiazui Formation, Wa'ergang section, GMPKU2711, lateral view; (9, 10) *Hunanognathus tricuspoidatus* Dong, 1993; (9) Huaqiao Formation, Wangcun section, GMPKU2712, posterior view; (10) Huaqiao Formation, Wangcun section, GMPKU2141, posterior view; (11–17) *Iapetognathus aengesis* (Lindström, 1955); (11) Panjiazui Formation, Wa'ergang section, GMPKU2713, S element, aboral view; (12) The same specimen, anterior view; (13) Panjiazui Formation, Wa'ergang section, GMPKU2714, S element, anterior view; (14) Panjiazui Formation, Wa'ergang section, GMPKU2715, S element, aboral view; (15) The same specimen, anterior view; (16) Panjiazui Formation, Wa'ergang section, GMPKU2716, S element, oblique aboral-posterior view; (17) Panjiazui Formation, Wa'ergang section, GMPKU2717, S element, anterior view; (18–24) *Iapetognathus fluctivagus* Nicoll, Miller, Nowlan, Repetski and Ethington, 1999; (18) Panjiazui Formation, Wa'ergang section, GMPKU2718, P element, anterior view; (19) the same specimen, oral view; (20) Panjiazui Formation, Wa'ergang section, GMPKU2719, P element, oblique aboral-posterior view; (21) the same specimen, oblique lateral view; (22) the same specimen, oblique lateral view; (23) Panjiazui Formation, Wa'ergang section, GMPKU2720, P element, outer lateral view; (24) the same specimen, oblique anterior view; (25–28) *Iapetognathus jilinensis* Nicoll, Miller, Nowlan, Repetski and Ethington, 1999; (25) Panjiazui Formation, Wa'ergang section, GMPKU2721, S element, oblique aboral-posterior view; (26) the same specimen, posterior view; (27) the same specimen, oblique oral-lateral view; (28) close-up of (27) showing cusp cross-section. Relative scale bar represents 139 µm (1–9, 11, 27), 123 µm (10), 72 µm (28).

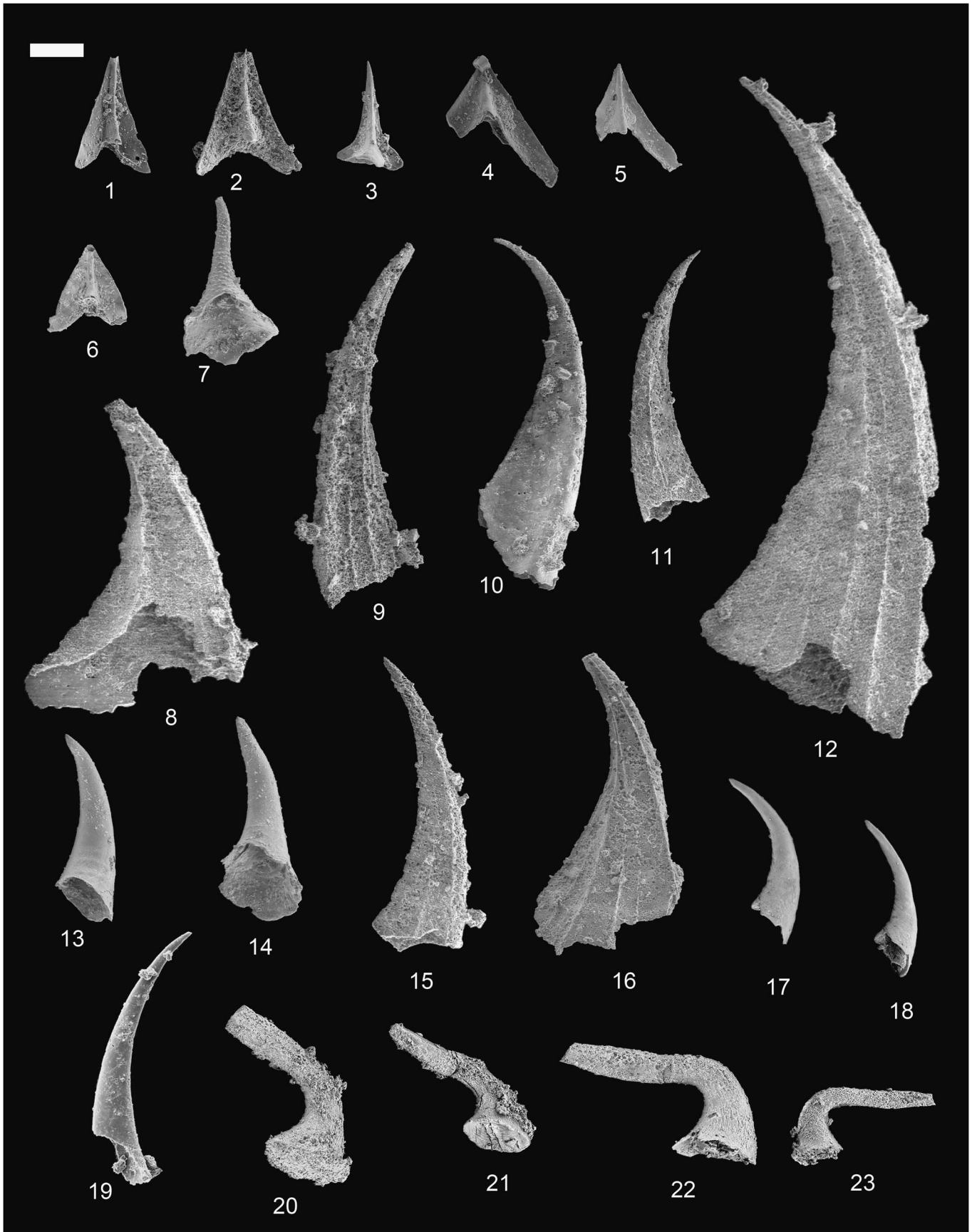




Figure 22. Conodont images using oil immersion techniques (Dong et al., 2005c) with Differential Interference Contrast (Nomarski) illumination, showing euconodont structure. (1–8) *Millerodontus intermedius* n. gen. n. sp.; (1–4) The same specimen as Figure 21.17; (1) overview, showing the crown structure of euconodont; (2) close-up of the cusp of (1); (3) close-up of the tip of (2), showing the regeneration phenomena of euconodont; (4) close-up of (3), showing the tiny phosphate crystals perpendicular to growth axis (shown by arrow); (5) the same specimen as Figure 21.14 overview, showing the crown structure of euconodont; (6–8) the same specimen as Figure 21.13; (6) overview; (7) close-up of (6); (8) close-up of the tip of (7), showing the crown structure of euconodont. Relative scale bar represents 55 μm (1), 19 μm (2), 14 μm (3), 12 μm (4), 71 μm (5), 75 μm (6), 62 μm (7), 24 μm (8).

Description.—Moderate to large coniform elements, erect to proclined and symmetrical or nearly so. The cross section is circular at the apical portion and changes to an oval outline toward the base. Basal cavity is very large and deep, the apex extends nearly to the tip of the element; posterior edges are characterized by a sharp keel that extends from apex to a variable distance down the posterior edge of the element and may be one-third of the total length of the element; anterior keel is lacking.

Materials.—Five specimens.

Occurrence.—Known from the Wa'ergang sections, where it ranges from the *Proconodontus* Zone through the *Eoconodontus* Zone.

Proconodontus serratus Miller, 1969

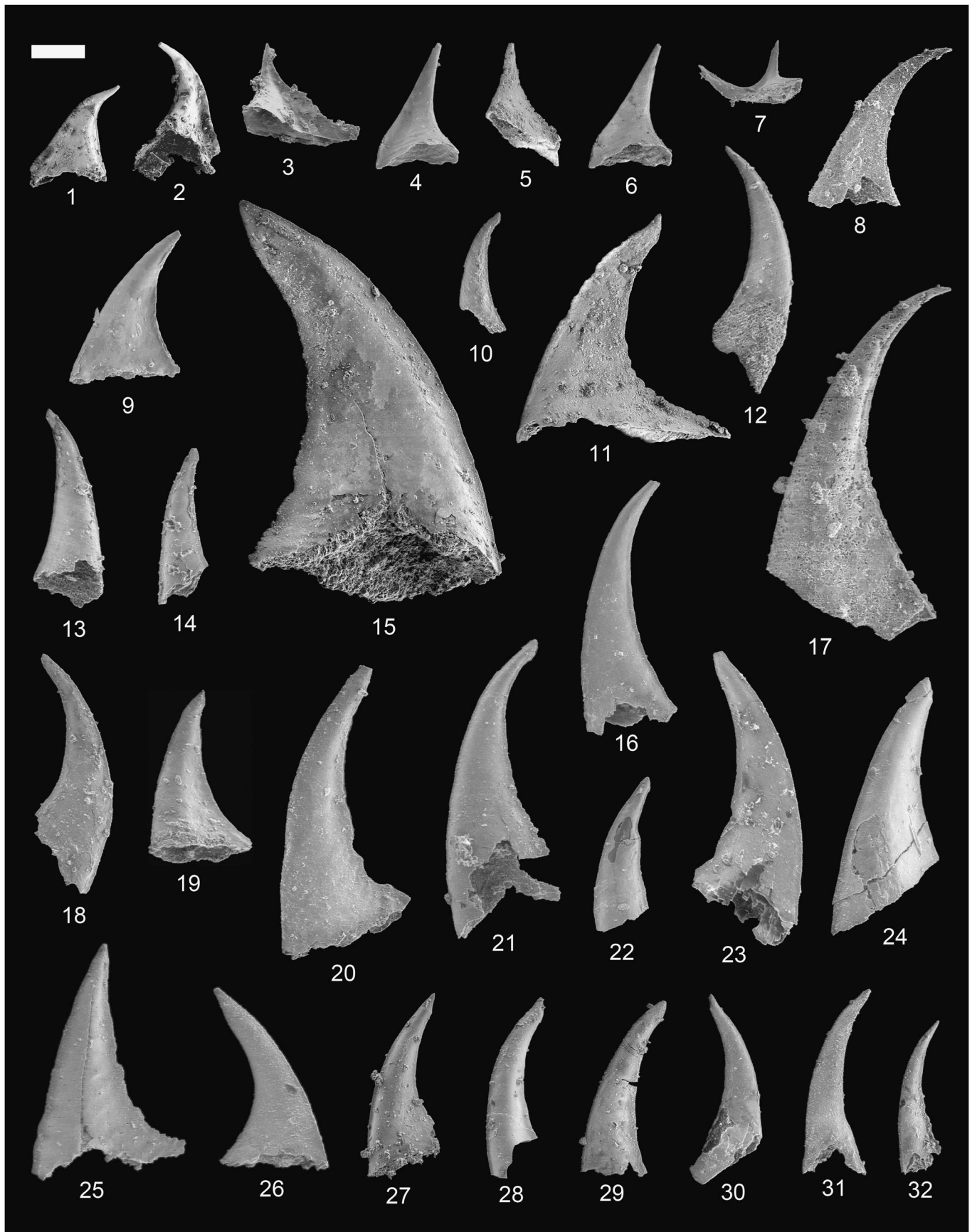
Figure 24.3–24.6

- 1969 *Proconodontus muelleri serratus* Miller, p. 438, pl. 66, figs. 41–44.
 1971 *Coelocerodontus burkei* Druce and Jones, p. 61, pl. 11, fig. 12 (not figs. 5–11). (part)
 1973 *Proconodontus muelleri serratus* Miller; Lindström, p. 409, pl. 1, fig. 6.
 1973 *Proconodontus serratus* Miller; Müller, p. 44, pl. 4, figs. 1, 2.
 1980 *Proconodontus serratus* Miller; Miller, p. 31, pl. 1, fig. 13, text-fig. 4D.
 1980 *Proconodontus serratus* Miller; Landing et al., p. 33, fig. 8I–L.
 1982 *Proconodontus muelleri serratus* Miller; Fortey et al., p. 124, fig. 9 (L).
 1983 *Proconodontus muelleri* Miller; An et al., p. 126, pl. 5, fig. 24a, b. (part)
 1985 *Proconodontus serratus* Miller; Wang, p. 233, pl. 6, fig. 26.
 1986 *Proconodontus serratus* Miller; Chen and Gong, p. 162, pl. 33, figs. 1, 6, 10, text-fig. 62.
 1988 *Proconodontus serratus* Miller; Lee and Lee, pl. 2, figs. 30, 31.
 1991 *Proconodontus serratus* Miller; Müller and Hinz, p. 56, pl. 42, figs. 17–21, pl. 43, figs. 1–3, 6, 7, text-fig. 22A.
 2000 *Proconodontus serratus* Miller; Dubinina, p. 195, pl. 6, figs. 21, 21a.
 2006 *Proconodontus serratus* Miller; Miller et al., p. 394, fig. 9 (Q, R).
 2007 *Proconodontus serratus* Miller; Landing et al., p. 918, fig. 6 (t).
 2011 *Proconodontus serratus* Miller; Miller et al., p. 604, fig. 7C, D.

Description.—Moderate to large coniform elements, proclined and symmetrical. The cross section is laterally compressed. Basal cavity is very large and deep, with the apex extending nearly to the tip of the element. Anterior and posterior edges are characterized by prominent keels. The posterior keel is serrated except for the apical portion.

Materials.—Six specimens.

Figure 21. (1, 2) *Laiwugnathus humanensis* n. sp.; (1) Huaqiao Formation, Wangcun section, holotype, GMPKU2722, posterior view; (2) Huaqiao Formation, Wangcun section, GMPKU2723, posterior view; (3) *Laiwugnathus* cf. *kouzhensis* An, 1982, Chefu Formation, Wangcun section, GMPKU2724, posterior view; (4–6) *Laiwugnathus transitans* n. sp.; (4) Chefu Formation, Wangcun section, GMPKU2725, posterior view; (5) Chefu Formation, Wangcun section, holotype, GMPKU2726, posterior view; (6) Bitiao Formation, Wangcun section, GMPKU2727, lateral view; (7) *Mamillodus ruminatus* Dubinina, 2000, Shenjiawan Formation, Wa'ergang section, GMPKU2728, posterior view; (8–12, 15, 16) *Miaognathus multicostatus* n. gen. n. sp.; (8) Shenjiawan Formation, Wa'ergang section, GMPKU2729, lateral view; (9) Shenjiawan Formation, Wa'ergang section, GMPKU2730, lateral view; (10) Shenjiawan Formation, Wa'ergang section, GMPKU2731, lateral view; (11) Shenjiawan Formation, Wa'ergang section, GMPKU2732, lateral view; (12) Shenjiawan Formation, Wa'ergang section, holotype, GMPKU2733, lateral view; (15) Shenjiawan Formation, Wa'ergang section, GMPKU2734, lateral view; (16) Shenjiawan Formation, Wa'ergang section, GMPKU2735, lateral view; (13, 14, 17–19) *Millerodontus intermedius* n. gen. n. sp.; (13) Shenjiawan Formation, Wa'ergang section, GMPKU2736, lateral view; (14) Shenjiawan Formation, Wa'ergang section, GMPKU2737, lateral view; (17) Shenjiawan Formation, Wa'ergang section, holotype, GMPKU2252, lateral view; (18) the same specimen, posterior-lateral view; (19) Shenjiawan Formation, Wa'ergang section, GMPKU2167, lateral view; (20–23) *Monocostodus severiensis* Miller, 1980; (20) Panjiazui Formation, Wa'ergang section, GMPKU2738, lateral view; (21) Panjiazui Formation, Wa'ergang section, GMPKU2739, lateral view; (22) Panjiazui Formation, Wa'ergang section, GMPKU2740, lateral view; (23) Panjiazui Formation, Wa'ergang section, GMPKU2741, lateral view; Relative scale bar represents 146 μm (1, 17, 23), 156 μm (2–16, 18, 20–22), 103 μm (19).



Occurrence.—Known from the Wa'ergang sections, where it ranges from the *Proconodontus* Zone through the *Eoconodontus* Zone.

Proconodontus tenuiserratus Miller, 1980
Figure 24.7, 24.8, 24.11

- 1971 *Coelcerodontus burkei* Druce and Jones, p. 61, text-fig. 22e, pl. 11, figs. 5, 6 (not figs. 7–12). (part)
1980 *Proconodontus tenuiserratus* Miller, p. 31, text-fig. 4A, pl. 1, figs. 1–3.
1982 *Proconodontus tenuiserratus* Miller; An, p. 143, pl. 12, figs. 1, 2, 5.
1985 *Proconodontus tenuiserratus* Miller; Wang, p. 233, pl. 8, fig. 7, ?pl. 12, fig. 8.
1986 *Proconodontus tenuiserratus* Miller; Chen and Gong, pl. 29, figs. 1–16, pl. 30, figs. 2, 5–7, text-fig. 63.
2000 *Proconodontus tenuiserratus* Miller; Dubinina, p. 195, pl. 6, fig. 22.
2002a *Proconodontus tenuiserratus* Miller; Lee, p. 165, pl. 2, fig. 24.
2002b *Proconodontus tenuiserratus* Miller; Lee, p. 27, pl. 2, figs. 10, 11.
2004 *Proconodontus tenuiserratus* Miller; Lee, p. 60, fig. 5 (Y).
2004c *Proconodontus tenuiserratus* Miller; Dong et al., pl. 1, figs. 7, 12, pl. 2, fig. 26.

Description.—Moderate to small coniform elements, erect to proclined and symmetrical. The cross section is usually circular, rarely compressed laterally near the base. Basal cavity is very deep, with the apex extending nearly to the tip of the element. The posterior side is characterized by a keel that is small, finely serrated, and extends from tip about halfway to the base, but it extends from the tip nearly to the base in some advanced forms. Anterior keel is lacking.

Materials.—12 specimens.

Occurrence.—Known from the Wa'ergang section, where it ranges from the *Proconodontus tenuiserratus* Zone through the *Proconodontus* Zone.

Genus *Teridontus* Miller, 1980

Type species.—*Oneotodus nakamurai* Nogami, 1967.

Teridontus nakamurai (Nogami, 1967)
Figure 25.4, 25.5, 25.8–25.15, 25.17–25.22

- 1959 *Oneotodus* sp. A Müller, p. 458, pl. 13, fig. 17.
1967 *Oneotodus nakamurai* Nogami, p. 216, text-figs. 3A, B, C, ?D, ?E, pl. 1, figs. 9–13.
1969 *Oneotodus nakamurai* Nogami; Miller, p. 435, text-fig. 5E, pl. 63, figs. 1–10.
1971 *Oneotodus nakamurai* Nogami; Druce and Jones, p. 82, text-fig. 26i, pl. 10, figs. 3, 4, 7, 8. (part)
1973 *Oneotodus nakamurai* Nogami; Müller, p. 41, pl. 5, fig. 4.
1971 *Oneotodus datsonensis* Druce and Jones, p. 80, text-fig. 26c, pl. 14, figs. 1–3. (part)
1980 *Teridontus nakamurai* (Nogami); Miller, p. 34, pl. 2, figs. 15, 16, text-fig. 4 (O).
1982 *Teridontus nakamurai* (Nogami); An, p. 150, pl. 14, figs. 1–11, pl. 15, fig. 11.
1983 *Teridontus nakamurai* (Nogami); An et al., p. 156, pl. 6, figs. 1–6.
1985 *Teridontus nakamurai* (Nogami); Wang, p. 241, pl. 3, figs. 1, 2, 4, pl. 6, figs. 9–12, pl. 8, figs. 1–3, pl. 10, figs. 1–3, pl. 13, figs. 5, 11, 12.
1985 *Teridontus nakamurai* (Nogami); Dong, p. 405, pl. 1, figs. 5, 18, text-fig. 1 (H).
1986 *Teridontus nakamurai* (Nogami); Chen and Gong, p. 192, pl. 34, fig. 12, pl. 39, figs. 1, 3, 9, 11–13, pl. 40, figs. 1, 3, 5, 7, 9, 12–13, pl. 47, figs. 7, 8, pl. 48, fig. 16, text-fig. 79 (1–12, 15, 16).
1987 *Teridontus nakamurai* (Nogami); Dong, p. 175, pl. 1, figs. 27–28.
1996 *Teridontus nakamurai* (Nogami); Lee et al., p. 97, pl. 1, figs. 2, 8.
1999 *Teridontus nakamurai* (Nogami); Parsons and Clark, p. 7, fig. 5 (17–18, ?23).
2000 *Teridontus nakamurai* (Nogami); Dubinina, p. 196, pl. 6, figs. 2, 4, 5, 7, 8, 8a.
2000 *Teridontus nakamurai* (Nogami); Zhao et al., p. 227, pl. 9, figs. 19–26.
2001 *Teridontus nakamurai* (Nogami); Lee, p. 450, fig. 7 (1, 2, 4–8, 10–13).

Figure 23. (1–6) *Proacodus pulcherus* (An, 1982); (1) Bitiao Formation, Wangcun section, GMPKU2793, anterior view; (2) Bitiao Formation, Wangcun section, GMPKU2794, posterior view; (3) Bitiao Formation, Wangcun section, GMPKU2795, posterior view; (4) Shenjiawan Formation, Wa'ergang section, GMPKU2796, posterior view; (5) Bitiao Formation, Wangcun section, GMPKU2797, posterior view; (6) Shenjiawan Formation, Wa'ergang section, GMPKU2798, posterior view; (7) *Proacodus* cf. *pulcherus* (An, 1982) Bitiao Formation, Wangcun section, GMPKU2799, posterior view; (8–32) *Proconodontus muelleri* Miller, 1969; (8) Shenjiawan Formation, Wangcun section, GMPKU2800, lateral view; (9) Shenjiawan Formation, Wa'ergang section, GMPKU2801, lateral view; (10) Shenjiawan Formation, Wa'ergang section, GMPKU2802, lateral view; (11) Shenjiawan Formation, Wangcun section, GMPKU2803, lateral view; (12) Shenjiawan Formation, Wa'ergang section, GMPKU2804, lateral view; (13) Shenjiawan Formation, Wa'ergang section, GMPKU2805, lateral view; (14) Shenjiawan Formation, Wa'ergang section, GMPKU2806, lateral view; (15) Shenjiawan Formation, Wangcun section, GMPKU2807, lateral view; (16) Shenjiawan Formation, Wa'ergang section, GMPKU2808, lateral view; (17) Shenjiawan Formation, Wa'ergang section, GMPKU2809, lateral view; (18) Shenjiawan Formation, Wa'ergang section, GMPKU2810, lateral view; (19) Shenjiawan Formation, Wa'ergang section, GMPKU2811, lateral view; (20) Shenjiawan Formation, Wa'ergang section, GMPKU2812, lateral view; (21) Shenjiawan Formation, Wa'ergang section, GMPKU2813, lateral view; (22) Shenjiawan Formation, Wa'ergang section, GMPKU2814, lateral view; (23) Shenjiawan Formation, Wa'ergang section, GMPKU2815, lateral view; (24) Shenjiawan Formation, Wa'ergang section, GMPKU2816, lateral view; (25) Shenjiawan Formation, Wa'ergang section, GMPKU2817, lateral view; (26) Shenjiawan Formation, Wa'ergang section, GMPKU2818, lateral view; (27) Shenjiawan Formation, Wa'ergang section, GMPKU2819, lateral view; (28) Shenjiawan Formation, Wa'ergang section, GMPKU2820, lateral view; (29) Shenjiawan Formation, Wa'ergang section, GMPKU2821, lateral view; (30) Shenjiawan Formation, Wa'ergang section, GMPKU2822, lateral view; (31) Shenjiawan Formation, Wa'ergang section; GMPKU2823, lateral view; (32) Shenjiawan Formation, Wa'ergang section, GMPKU2824, lateral view. Relative scale bar represents 165 µm (1–6, 8–21, 23, 24, 28), 156 µm (7, 27), 173 µm (22, 25, 26, 29–32).

←



- 2002 *Teridontus nakamurai* (Nogami); Lee, p. 165, pl. 2, fig. 15.
- 2002 *Teridontus nakamurai* (Nogami); Lee, p. 27, pl. 2, fig. 21.
- 2003 *Teridontus nakamurai* (Nogami); Landing et al., p. 86, fig. 7 (3).
- 2005 *Teridontus nakamurai* (Nogami); Ortega and Albanesi, p. 365, figs. 17–18.
- 2007 *Teridontus nakamurai* (Nogami); Landing et al., p. 918, fig. 6 (i–l).
- 2007 *Teridontus nakamurai* (Nogami); Pyle et al., p. 1733, fig. 10 (6, 7).
- 2009 *Teridontus nakamurai* (Nogami); Lee et al., p. 423, fig. 7 (2).

Description.—Simple coniform elements with much morphological variation. Base is usually long but is short in advanced forms. Cusp is erect to reclined and is almost entirely composed of white matter that terminates in sharp boundary that is transverse to the cusp at a point slightly above the tip of basal cavity. Cross section is circular to oval. Fine lengthwise striae are usually preserved on the surface of the whole element.

Materials.—100 specimens.

Occurrence.—Known from the Wangcun and Wa'ergang sections, where it ranges from the *Proconodontus* Zone through the *Cordylodus angulatus* Zone.

Genus *Tujiagnathus* new genus

Type species.—*Tujiagnathus gracilis* n. gen. n. sp.

Diagnosis.—Slender, cylindrical coniform elements with a minute hook-like cusps. The posterior side is ornamented by numerous tiny nodes. Basal cavity is very deep.

Etymology.—Tujia, ethnic minority group in western Hunan, South China; *gnathus*, Greek, jaw.

Tujiagnathus gracilis new genus new species Figure 25.16, 25.23

Diagnosis.—As for the genus.

Description.—Coniform elements, moderate to small, and symmetrical. The cusp is small and hook-like. The base is slender and cylindrical. Both anterior and posterior sides are rounded. The posterior side is ornamented by numerous tiny nodes. Basal cavity is very deep, with the apex extending above the point of flexure of the element.

Etymology.—*gracilis*, Latin, gracile or slender.

Types.—Holotype: GMPKU2934 from the *Westergaardodina* cf. *calix-Prooneotodus rotundatus* Zone, Bitiao Formation, Wangcun section, Wangcun village, Yongshun county, Hunan Province.

Materials.—Nine specimens.

Occurrence.—Known from Wangcun section, where it occurs in the *Westergaardodina* cf. *calix-Prooneotodus rotundatus* Zone.

Comparison.—In gross morphology, the present species looks like *Prooneotodus terashimai*, but *Tujiagnathus gracilis* has conspicuous surface ornamentation, so it is a euconodont (Bengtson, 1976), whereas *P. terashimai* is a paraconodont.

Genus *Wangcunella* new genus

Type species.—*Wangcunella conicus* n. gen. n. sp.

Diagnosis.—Coniform elements without differentiation between cusp and base. Basal cavity is shallow. Cross section is circular.

Etymology.—Named for the Wangcun section in Hunan Province.

Wangcunella conicus new genus new species Figure 25.24–25.28

Diagnosis.—As for the genus.

Description.—Elements with conical gross morphology. There is no differentiation between cusp and base. The large base tapers rapidly toward the tip. Basal cavity is shallow. Cross section is circular from the apex through the base.

←
Figure 24. (1, 2) *Proconodontus posterocostatus* Miller, 1980; (1) Shenjiawan Formation, Wa'ergang section, GMPKU2825, lateral view; (2) Shenjiawan Formation, Wa'ergang section, GMPKU2826, lateral view; (3–6) *Proconodontus serratus* Miller, 1969; (3) Shenjiawan Formation, Wa'ergang section, GMPKU2827, lateral view; (4) Shenjiawan Formation, Wa'ergang section, GMPKU2828, lateral view; (5) Shenjiawan Formation, Wa'ergang section, GMPKU2829, lateral view; (6) Shenjiawan Formation, Wa'ergang section, GMPKU2830, lateral view; (7, 8, 11) *Proconodontus tenuiserratus* Miller, 1980; (7) Shenjiawan Formation, Wa'ergang section, GMPKU2831, lateral view; (8) Shenjiawan Formation, Wa'ergang section, GMPKU2832, lateral view; (11) Shengjiawan Formation, Wangcun section, GMPKU2168, lateral view; (9, 10, 12–32) *Prooneotodus gallatini* Müller, 1959; (9) Bitiao Formation, Wangcun section, GMPKU2833, lateral view; (10) Bitiao Formation, Wangcun section, GMPKU2834, lateral view; (12) Bitiao Formation, Wangcun section, GMPKU2835, lateral view; (13) Bitiao Formation, Wangcun section, GMPKU2836, lateral view; (14) Bitiao Formation, Wangcun section, GMPKU2837, lateral view; (15) Bitiao Formation, Wangcun section, GMPKU2838, lateral view; (16) Bitiao Formation, Wangcun section, GMPKU2839, lateral view; (17) Bitiao Formation, Wangcun section, GMPKU2840, lateral view; (18) Bitiao Formation, Wangcun section, GMPKU2841, lateral view; (19) Bitiao Formation, Wangcun section, GMPKU2842, lateral view; (20) Bitiao Formation, Wangcun section, GMPKU2843, lateral view; (21) Bitiao Formation, Wangcun section, GMPKU2844, lateral view; (22) Bitiao Formation, Wangcun section, GMPKU2845, lateral view; (23) Bitiao Formation, Wangcun section, GMPKU2846, lateral view; (24) Bitiao Formation, Wangcun section, GMPKU2847, lateral view; (25) Bitiao Formation, Wangcun section, GMPKU2848, lateral view; (26) Bitiao Formation, Wangcun section, GMPKU2849, lateral view; (27) Bitiao Formation, Wangcun section, GMPKU2850, lateral view; (28) Bitiao Formation, Wangcun section, GMPKU2851, lateral view; (29) Bitiao Formation, Wangcun section, GMPKU2852, lateral view; (30) Bitiao Formation, Wa'ergang section, GMPKU2853, lateral view; (31) Bitiao Formation, Wa'ergang section, GMPKU2854, lateral view; (32) Shenjiawan Formation, Wa'ergang section, GMPKU2855, lateral view. Scale bar represents 138 µm (1–32).



Etymology.—*conicus*, Latin, conical, referring to the gross morphology of the element.

Types.—Holotype: GMPKU2936, from the *Westergaardodina* cf. *calix-Prooneotodus rotundatus* Zone, Bitiao Formation, Wangcun section, Wangcun village, Yongshun county, Hunan Province.

Materials.—18 specimens.

Occurrence.—Known from the Wangcun and Wa'ergang sections, where it ranges from the *Westergaardodina lui*-*Westergaardodina ani* Zone through the *Eoconodontus* Zone.

Paraconodonts

Class Paraconodontida Müller, 1962

[*nomen translatum* (pro Order Paraconodontida Müller, 1962), emended Landing, 1995]

Genus *Furnishina* Müller, 1959

Type species.—*Furnishina furnishi* Müller, 1959.

Furnishina cf. *alata* Szaniawski, 1971

Figure 26.29, 26.30

cf. 1971 *Furnishina alata* Szaniawski, p. 406, pl. 1, figs. 3, 4, pl. 3, figs. 3–5.

1987 *Furnishina* aff. *furnishi* Müller; An, pl. 3, fig. 8.

1991 *Furnishina* cf. *alata* Szaniawski; Müller and Hinz, p. 16, pl. 7, figs. 18, 20.

1993 *Furnishina* cf. *alata* Szaniawski; Dong, p. 350, pl. 2, figs. 11, 13, 15.

2001a *Furnishina* cf. *alata* Szaniawski; Dong and Bergström, p. 960, pl. 1, figs. 1, 3, 10.

2006 *Furnishina* cf. *F. alata* Szaniawski; Qi et al., p. 182, pl. 2, fig. 15.

2008 *Furnishina* cf. *alata* Szaniawski; Bagnoli et al., p. 112, fig. 3 (A).

Materials.—48 specimens.

Occurrence.—Present in the Paibi and Wangcun sections from the *Shandongodus priscus*-*Hunanognathus tricuspis* Zone through the *Westergaardodina matsushita*-*Westergaardodina grandidens* Zone.

Remarks.—The specimens at hand agree in gross morphology with *Furnishina alata* but differ in the posterior keel, which is not developed or present only along the cusp.

Furnishina bigeminata Dong, 1993

Figure 17.20–17.25

1993 *Furnishina bigeminata* Dong, p. 350, pl. 4, figs. 3, 4, 6, 14.

2001a *Furnishina bigeminata* Dong; Dong and Bergström, p. 960, pl. 3, fig. 17, pl. 5, fig. 14.

2006 *Furnishina bigeminata* Dong; Qi et al., p. 186, pl. 2, fig. 6.

2008 *Furnishina bigeminata* Dong; Bagnoli et al., p. 112, fig. 3 (B).

Materials.—688 specimens.

Occurrence.—Present in the Paibi, Wangcun, and Wa'ergang sections, where it ranges from the *Gapparodus bisulcatus*-*Westergaardodina brevidens* Zone through the *Cordylodus proavus* Zone.

Remarks.—The present specimens agree well with *Furnishina bigeminata* as described and figured by Dong and Bergström (2001a).

Furnishina dayangchaensis Chen and Gong, 1986

Figure 17.26–17.31

1986 *Furnishina dayangchaensis* Chen and Gong, p. 144, pl. 17, figs. 2, 3, 6, 8, 9, 14, pl. 19, fig. 11, text-fig. 50 (2).

2000 *Furnishina furnishi* Müller; Dubinina, p. 168, pl. 2, fig. 17. (part)

Materials.—78 specimens.

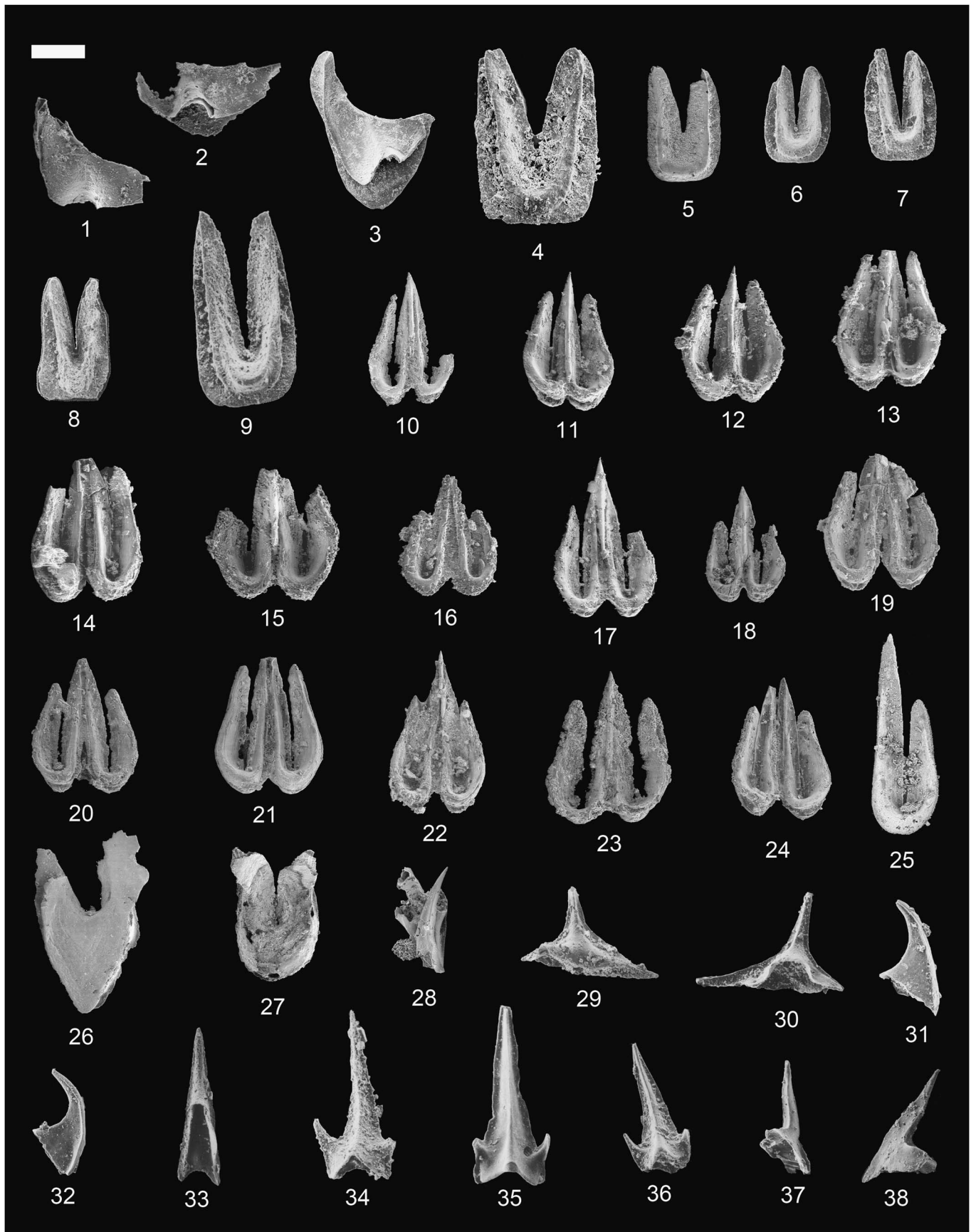
Occurrence.—Present in the Wangcun and Wa'ergang sections, where it ranges from the *Westergaardodina lui*-*Westergaardodina ani* Zone through the *Cordylodus proavus* Zone.

Remarks.—The present specimens agree well with *Furnishina dayangchaensis* as described and figured by Chen and Gong (1986).

Furnishina furnishi Müller, 1959

Figure 27.1–27.9

←
Figure 25. (1, 2) *Prosagittodontus* cf. *eureka* (Müller, 1959); (1) Bitiao Formation, Wangcun section, GMPKU2913, posterior view; (2) Shenjiawan Formation, Wa'ergang section, GMPKU2914, posterior view; (3, 6, 7) *Serratocambria minuta* Müller and Hinz, 1991; (3) Bitiao Formation, Wangcun section, GMPKU2915, posterior view; (6) Bitiao Formation, Wangcun section, broken specimen, GMPKU2916, posterior view; (7) Bitiao Formation, Wangcun section, GMPKU2917, anterior view; (4, 5, 8–15, 17–22) *Teridontus nakamurai* (Nogami, 1967); (4) Shenjiawan Formation, Wangcun section, GMPKU2918, lateral view; (5) Shenjiawan Formation, Wangcun section, GMPKU2919, lateral view; (8) Shenjiawan Formation, Wangcun section, GMPKU2920, lateral view; (9) Shenjiawan Formation, Wangcun section, GMPKU2921, lateral view; (10) Shenjiawan Formation, Wangcun section, GMPKU2922, lateral view; (11) Shenjiawan Formation, Wangcun section, GMPKU2923, lateral view; (12) Shenjiawan Formation, Wa'ergang section, GMPKU2924, lateral view; (13) Shenjiawan Formation, Wa'ergang section, GMPKU2925, lateral view; (14) Shenjiawan Formation, Wa'ergang section, GMPKU2926, lateral view; (15) Shenjiawan Formation, Wa'ergang section, GMPKU2927, lateral view; (17) Shenjiawan Formation, Wa'ergang section, GMPKU2928, lateral view; (18) Shenjiawan Formation, Wa'ergang section, GMPKU2929, lateral view; (19) Shenjiawan Formation, Wa'ergang section, GMPKU2930, lateral view; (20) Shenjiawan Formation, Wa'ergang section, GMPKU2931, lateral view; (21) Shenjiawan Formation, Wa'ergang section, GMPKU2932, lateral view; (22) Shenjiawan Formation, Wa'ergang section, GMPKU2933, lateral view; (16, 23) *Tujiagnathus gracilis* n. gen. n. sp.; (16) Bitiao Formation, Wangcun section, GMPKU2934, holotype, lateral view; (23) Bitiao Formation, Wangcun section, GMPKU2935, lateral view; (24–28) *Wangcunella conicus* n. gen. n. sp.; (24) Bitiao Formation, Wangcun section, GMPKU2936, lateral view; (25) Bitiao Formation, Wangcun section, GMPKU2937, lateral view; (26) Bitiao Formation, Wangcun section, GMPKU2938, lateral view; (27) Bitiao Formation, Wa'ergang section, GMPKU2939, lateral view; (28) Bitiao Formation, Wa'ergang section, GMPKU2940, holotype, lateral view. Scale bar represents 130 µm (1–28).



- 1959 *Furnishina furnishi* Müller, p. 452, pl. 11, figs. 5, 6, 9, 11–13, 15, text-fig. 6D.
- 1971 *Furnishina asymmetrica* Müller; Müller, p. 8, pl. 1, figs. 9, 12, 14–16.
- 1971 *Furnishina furnishi* Müller; Müller and Nogami, p. 14, pl. 1, fig. 5.
- 1972 *Furnishina furnishi* Müller; Müller and Nogami, fig. 1A.
- 1973 *Furnishina asymmetrica* Müller; Müller, p. 39, pl. 1, figs. 6, 8.
- ? 1976 *Furnishina furnishi* Müller; Abaimova and Ergaliev, p. 391, pl. 14, figs. 1, 2.
- ? 1976 *Furnishina furnishi* Müller; Miller et al., p. 595, pl. 1, figs. 8–12.
- 1979 *Furnishina furnishi* Müller; Bednarczyk, p. 427, pl. 1, figs. 1–3, 5–9, 12, pl. 3, figs. 14, 20, 21.
- 1981 *Furnishina furnishi* Müller; Miller in Robison, p. W112, fig. 64, 7a, b.
- 1986 *Furnishina furnishi* Müller; Chen et al., p. 367, pl. 1, fig. 17.
- 1988 *Furnishina furnishi* Müller; Lee and Lee, pl. 1, figs. 16, 17.
- 1991 *Furnishina furnishi* Müller; Müller and Hinz, p. 17, pl. 13, figs. 1–7, 11, 12, text-fig. 8 (A).
- ? 2000 *Furnishina furnishi* Müller; Göncüoğlu and Kozur, p. 599, fig. 4 (h).
- ? 2000 *Furnishina furnishi* Müller; Dubinina, p. 168, pl. 3, figs. 9–10 (not pl. 1, figs. 8, 9, 26, pl. 3, figs. 2, 3, 12, 23, 25). (part)
- 2009 *Furnishina furnishi* Müller; Lee et al., p. 421, fig. 6 (17).
- included a variety of forms that could not be assigned properly to another species. The new diagnosis restricted the occurrence of *F. furnishi*, so that it ranges from the trilobite zone 3 through zone 5 in the upper Cambrian of Sweden. Accordingly, many elements previously referred to *F. furnishi* by different authors, especially Chinese authors, should be excluded from this species based on their characters and occurrences.
- Furnishina cf. furnishi* Müller, 1959
Figure 27.10–27.16
- cf. 1959 *Furnishina furnishi* Müller, p. 452, pl. 11, figs. 5, 6, 9, 11–13, 15, text-fig. 6D.
- cf. 1991 *Furnishina furnishi* Müller; Müller and Hinz, p. 17, pl. 13, figs. 1–7, 11, 12; text-fig. 8 (A).
- 2000 *Furnishina furnishi* Müller; Dubinina, p. 168, pl. 3, fig. 11. (part)
- 2007 *Furnishina furnishi* Müller; Landing et al., p. 922, fig. 9 (c).
- 2009 *Furnishina furnishi* Müller; Lee et al., p. 423, fig. 7 (16), p. 425, fig. 8 (10).

Materials.—16 specimens.

Occurrence.—Known from the Wangcun and Wa'ergang sections, where it ranges from the *Westergaardodina lui-Westergaardodina ani* Zone through the *Eoconodontus* Zone.

Remarks.—Similar to *Furnishina furnishi* but differs in the posterior side, which is not convexly domed, and the median keel is indistinct.

Materials.—30 specimens.

Occurrence.—Known from the Wangcun and Wa'ergang sections, where it ranges from the *Westergaardodina lui-Westergaardodina ani* Zone through the *Cordylodus proavus* Zone.

Remarks.—Müller and Hinz (1991) emended the diagnosis of *Furnishina furnishi*. Previously, it was defined very broadly and

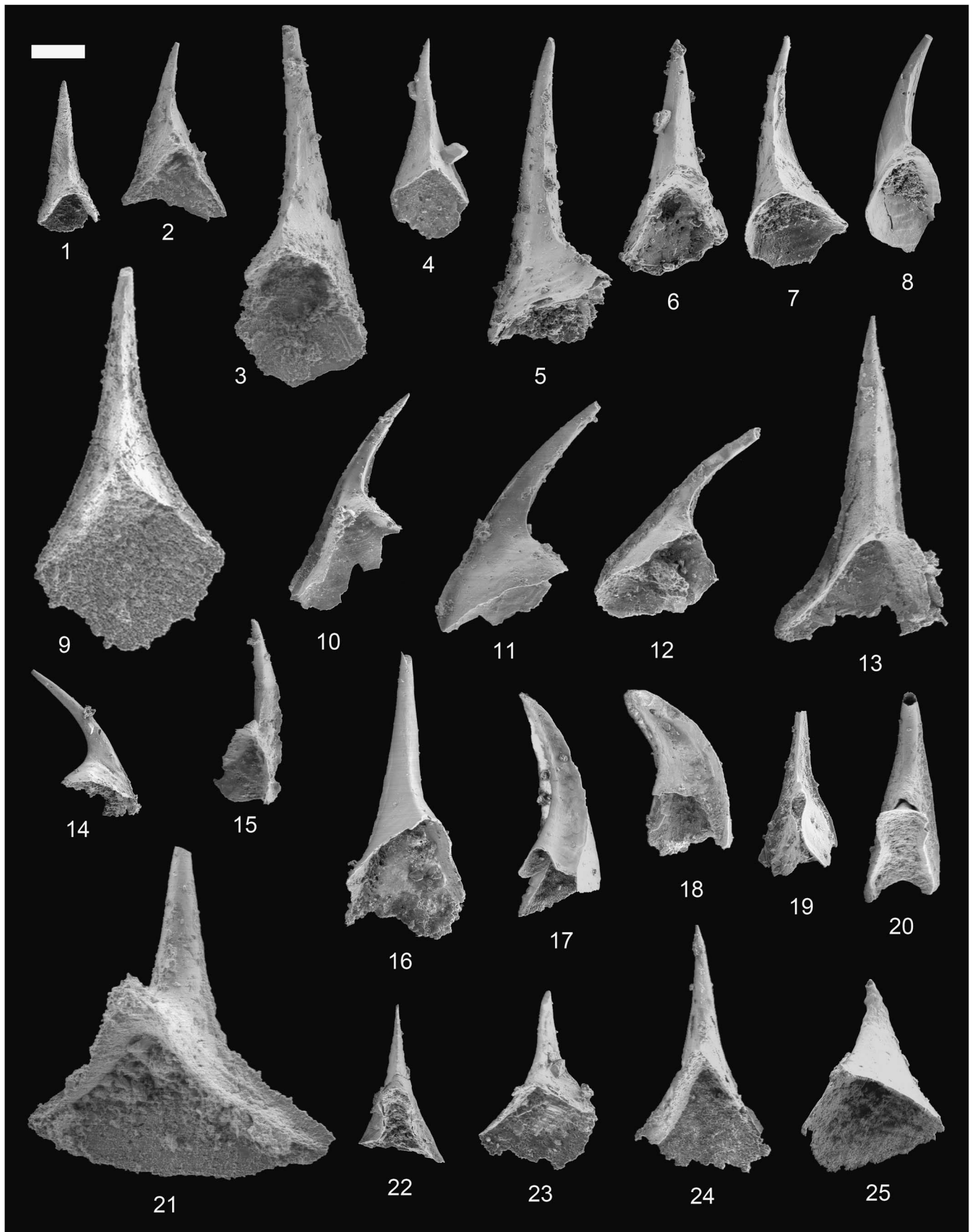
Furnishina gladiata Müller and Hinz, 1991
Figure 27.17

- 1959 *Scandodus* n. sp. b Müller, p. 464, pl. 12, fig. 5.
- 1991 *Furnishina gladiata* Müller and Hinz, p. 29, pl. 16, figs. 1–13, 15, text-fig. 8 (S).

Materials.—Three specimens.

←

Figure 26. (1–3) *Westergaardodina sola* n. sp.: (1) Chefu Formation, Wangcun section, GMPKU3031, posterior view; (2) Chefu Formation, Wangcun section, GMPKU3032, posterior view; (3) Chefu Formation, Paibi section, holotype, GMPKU3033, posterior view; (4–9) *Westergaardodina tetragonia* Dong, 1993: (4) Chefu Formation, Wangcun section, GMPKU3034, posterior view; (5) Chefu Formation, Wangcun section, GMPKU3035, posterior view; (6) Chefu Formation, Paibi section, GMPKU3036, posterior view; (7) Chefu Formation, Paibi section, GMPKU3037, posterior view; (8) Chefu Formation, Paibi section, GMPKU3038, posterior view; (9) Chefu Formation, Paibi section, GMPKU3039, posterior view; (10–24) *Westergaardodina tricuspидata* Müller, 1959: (10) Bitiao Formation, Wangcun section, GMPKU3040, posterior view; (11) Bitiao Formation, Wangcun section, GMPKU3041, posterior view; (12) Bitiao Formation, Wangcun section, GMPKU3042, posterior view; (13) Bitiao Formation, Wangcun section, GMPKU3043, posterior view; (14) Bitiao Formation, Wangcun section, GMPKU3044, posterior view; (15) Bitiao Formation, Wangcun section, GMPKU3045, posterior view; (16) Bitiao Formation, Wangcun section, GMPKU3046, posterior view; (17) Bitiao Formation, Wangcun section, GMPKU3047, posterior view; (18) Bitiao Formation, Wangcun section, GMPKU3048, posterior view; (19) Bitiao Formation, Wangcun section, GMPKU3049, posterior view; (20) Bitiao Formation, Wangcun section, GMPKU3050, posterior view; (21) Bitiao Formation, Wangcun section, GMPKU3051, posterior view; (22) Bitiao Formation, Wangcun section, GMPKU3052, posterior view; (23) Bitiao Formation, Wangcun section, GMPKU3053, posterior view; (24) Bitiao Formation, Wangcun section, GMPKU3054, posterior view; (25) *Westergaardodina wimani* Szaniawski, 1971, Bitiao Formation, Wangcun section, GMPKU2200, posterior view; (26) *Westergaardodina* sp. A, Bitiao Formation, Wangcun section, GMPKU3055, posterior view; (27) *Westergaardodina* sp. B, Bitiao Formation, Wa'ergang section, GMPKU3056, posterior view; (28) *Yongshunella polymorpha* Dong and Bergström, 2001a, Huaqiao Formation, Wangcun section, GMPKU3057, cluster; (29, 30) *Furnishina cf. alata* Szaniawski, 1971; (29) Huaqiao Formation, Paibi section, GMPKU3058, posterior view; (30) Huaqiao Formation, Paibi section, GMPKU3059, posterior view; (31–33) *Furnishina pernica* An, 1982: (31) Huaqiao Formation, Paibi section, GMPKU3060, lateral view; (32) Chefu Formation, Paibi section, GMPKU3061, lateral view; (33) Huaqiao Formation, Paibi section, GMPKU3062, posterior view; (34–36) *Hunanognathus tricuspидatus* Dong, 1993: (34) Huaqiao Formation, Paibi section, GMPKU3063, posterior view; (35) Huaqiao Formation, Paibi section, GMPKU3064, posterior view; (36) Huaqiao Formation, Paibi section, GMPKU3065, posterior view; (37, 38) *Shandongodus priscus* An, 1982; (37) Huaqiao Formation, Paibi section, GMPKU3066, posterolateral view; (38) Huaqiao Formation, Paibi section, GMPKU3067, lateral view. Relative scale bar represents 183 µm (1, 2, 5, 10–24, 28, 34), 323 µm (3), 172 µm (4, 6, 7, 9, 25, 29, 32, 33, 35, 36), 238 µm (8), 373 µm (26), 472 µm (27), 157 µm (30, 31), 139 µm (37, 38).



Occurrence.—Known from the Wangcun sections, where it occurs in the *Westergaardodina lui*–*Westergaardodina ani* Zone.

Remarks.—The specimens at hand agree in all respects with Müller and Hinz's (1991) species.

Furnishina cf. *gladiata* Müller and Hinz, 1991
Figure 27.18

cf. 1959 *Scandodus* n. sp. b Müller, p. 464, pl. 12, fig. 5.

cf. 1991 *Furnishina gladiata* Müller and Hinz, p. 29, pl. 16, figs. 1–13, 15, text-fig. 8 (S).

Materials.—Two specimens.

Occurrence.—Known from the Wangcun section, where it ranges from *Shandongodus priscus*–*Humanognathus tricuspis* Zone through the *Westergaardodina* cf. *calix*–*Prooneotodus rotundatus* Zone.

Remarks.—Similar to *Furnishina gladiata*, but it differs in its anterolateral costae that do not appear as large laminae.

Furnishina kleithria Müller and Hinz, 1991
Figure 27.19, 27.20, 27.22

1991 *Furnishina kleithria* Müller and Hinz, p. 21, pl. 15, figs. 1–5, 7–10, 16, text-fig. 8 (P, Q).

2006 *Furnishina kleithria* Müller and Hinz; Qi et al., p. 186, pl. 2, fig. 7.

2008 *Furnishina kleithria* Müller and Hinz; Bagnoli et al., p. 112, fig. 3 (R).

Materials.—10 specimens.

Occurrence.—Known from the Wangcun section, where it ranges from the *Gapparodus bisulcatus*–*Westergaardodina brevidens* Zone through the *Westergaardodina* cf. *calix*–*Prooneotodus rotundatus* Zone.

Remarks.—The present specimens at hand agree with *Furnishina kleithria* as described and illustrated by Müller and Hinz (1991).

Furnishina kranzae Müller and Hinz, 1991
Figure 27.21, 27.23–27.25

1991 *Furnishina kranzae* Müller and Hinz, pl. 12, figs. 1, 2, 6, 8, 12–14, 18, fig. 8 (B).

Materials.—Nine specimens.

Occurrence.—Known from the Paibi and Wangcun sections, where it ranges from *Westergaardodina lui*–*Westergaardodina ani* Zone through the *Westergaardodina* cf. *calix*–*Prooneotodus rotundatus* Zone.

Remarks.—The specimens at hand agree with *Furnishina kranzae* as described and figured by Müller and Hinz (1991).

Furnishina cf. *kranzae* Müller and Hinz, 1991
Figure 28.1

cf. 1991 *Furnishina kranzae* Müller and Hinz, pl. 12, figs. 1, 2, 6, 8, 12–14, 18, fig. 8 (B).

1993 *Furnishina* cf. *kranzae* Müller and Hinz; Dong, p. 350, pl. 4, figs. 1, 2, 5.

2001a *Furnishina* cf. *kranzae* Müller and Hinz; Dong and Bergström, p. 961, pl. 5, fig. 9.

Materials.—18 specimens.

Occurrence.—Known from the Paibi, Wangcun and Wa'ergang sections, where it ranges from the *Westergaardodina quadrata* Zone through the *Westergaardodina* cf. *calix*–*Prooneotodus rotundatus* Zone.

Remarks.—Differs from the typical *Furnishina kranzae* in having indistinctly laterally deflected cusps and in the weakly developed posterior keels. Our specimens also occur in stratigraphically older strata than *F. kranzae*.

Furnishina longibasis Bednarczyk, 1979
Figure 28.2, 28.3

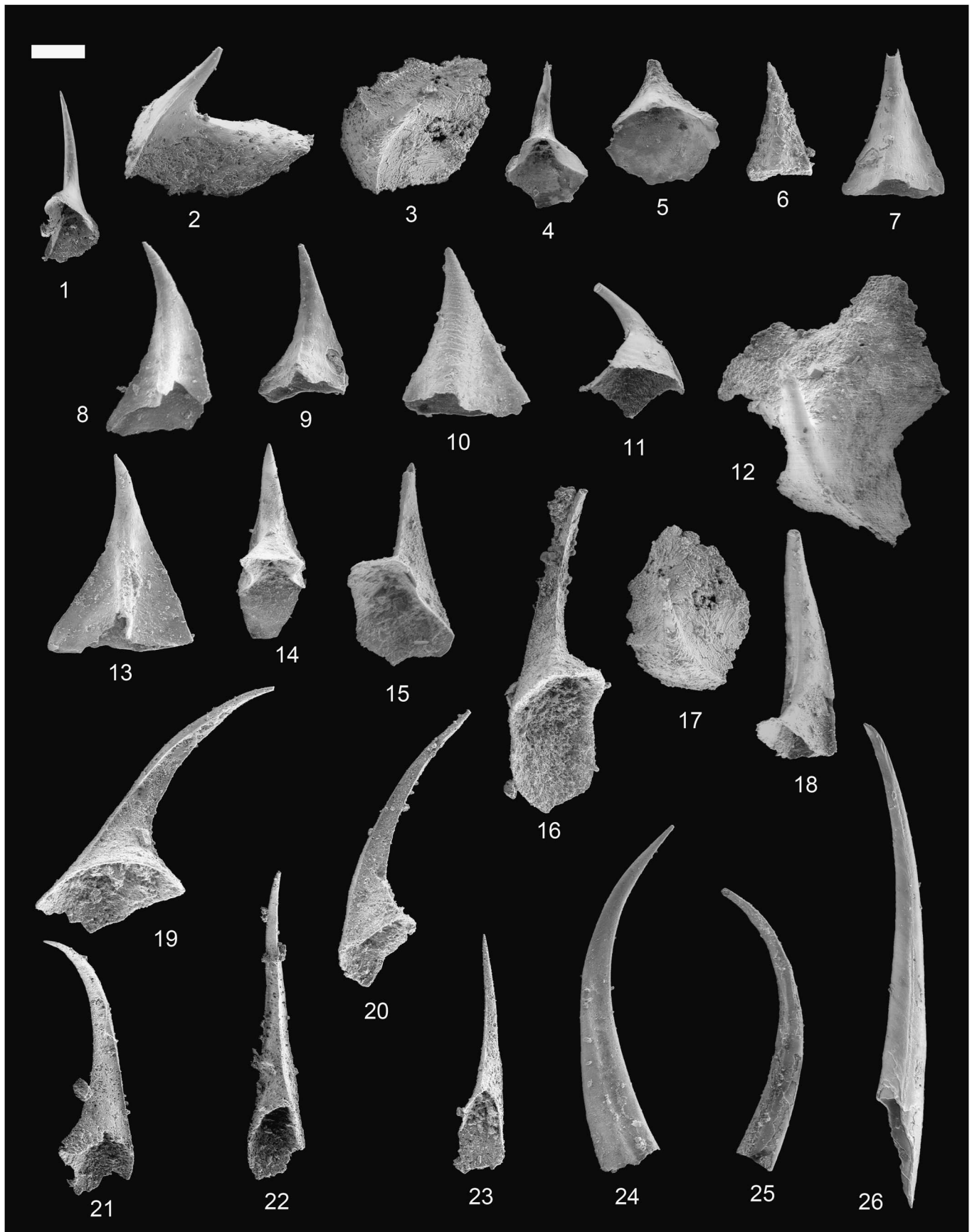
1979 *Furnishina longibasis* Bednarczyk, p. 427, pl. 1, figs. 1, 4.

1991 *Furnishina longibasis* Bednarczyk; Müller and Hinz, p. 21, pl. 11, figs. 10, 12.

2006 *Furnishina longibasis* Bednarczyk; Qi et al., p. 186, pl. 2, figs. 2, 4 (not 1, 3). (part)

2009 *Furnishina longibasis* Bednarczyk; Lee et al., p. 420, fig. 6 (3).

←
Figure 27. (1–9) *Furnishina furnishi* Müller, 1959; (1) Bitiao Formation, Wangcun section, GMPKU2601, posterior view; (2) Bitiao Formation, Wangcun section, GMPKU2602, posterior view; (3) Bitiao Formation, Wangcun section, GMPKU2603, posterior view; (4) Bitiao Formation, Wangcun section, GMPKU2604, posterior view; (5) Bitiao Formation, Wangcun section, GMPKU2605, posterior view; (6) Bitiao Formation, Wangcun section, GMPKU2606, posterior view; (7) Bitiao Formation, Wangcun section, GMPKU2607, posterior view; (8) Bitiao Formation, Wangcun section, GMPKU2608, posterior view; (9) Shenjiawan Formation, Wa'ergang section, GMPKU2609, posterior view; (10–16) *Furnishina* cf. *furnishi* Müller, 1959; (10) Bitiao Formation, Wangcun section, GMPKU2610, oblique posterior view; (11) Bitiao Formation, Wangcun section, GMPKU2611, lateral view; (12) Bitiao Formation, Wangcun section, GMPKU2612, lateral-posterior view; (13) Bitiao Formation, Wangcun section, GMPKU2613, posterior view; (14) Bitiao Formation, Wangcun section, GMPKU2614, lateral view; (15) Bitiao Formation, Wangcun section, GMPKU2615, posterior view; (16) Bitiao Formation, Wangcun section, GMPKU2616, posterior view; (17) *Furnishina gladiata* Müller and Hinz, 1991, Bitiao Formation, Wangcun section, GMPKU2617, oblique posterior view; (18) *Furnishina* cf. *gladiata* Müller and Hinz, 1991, Huaqiao Formation, Wangcun section, GMPKU2618, lateral-posterior view; (19, 20, 22) *Furnishina kleithria* Müller and Hinz, 1991; (19) Chefu Formation, Wangcun section, GMPKU2619, posterior view; (20) Chefu Formation, Wangcun section, GMPKU2620, posterior view; (22) Chefu Formation, Wangcun section, GMPKU2621, posterior view; (21) (23–25) *Furnishina kranzae* Müller and Hinz, 1991; (21) Bitiao Formation, Wangcun section, GMPKU2622, posterior view; (23) Bitiao Formation, Wangcun section, GMPKU2623, posterior view; (24) Bitiao Formation, Wangcun section, GMPKU2624, posterior view; (25) Bitiao Formation, Wangcun section, GMPKU2625, posterior view. Scale bar represents 132 µm (1–25).



- Materials*.—Six specimens.
- Occurrence*.—Known from the Wangcun section, where it ranges from the *Shandongodus priscus-Hunanognathus tricuspidatus* Zone through the *Westergaardodina cf. calix-Prooneotodus rotundatus* Zone.
- Remarks*.—The specimens at hand agree in all respects with *Furnishina longibasis*.
- Furnishina cf. ovata* Müller and Hinz, 1991
Figure 28.4, 28.5
- cf. 1991 *Furnishina ovata* Müller and Hinz, p. 22, pl. 8, figs. 7, 8, 10–22, text-fig. 8 (T).
- Materials*.—Four specimens.
- Occurrence*.—Known from the Wangcun and Wa'ergang sections, where it ranges from *Westergaardodina lui-Westergaardodina ani* Zone through the *Eoconodontus* Zone.
- Remarks*.—Similar to *Furnishina ovata* but differs in its anterolateral costae, which are not restricted to the base but extend to the cusp and are more pronounced.
- Furnishina pernica* An, 1982
Figure 26.31–26.33
- 1982 *Furnishina pernica* An, p. 133, pl. 4, figs. 1–4, pl. 8, fig. 4.
- 1993 *Furnishina pernica* An; Dong, pl. 5, figs. 4, 5, 9.
- 2001a *Furnishina pernica* An; Dong and Bergström, p. 961, pl. 5, figs. 1, 13.
- ? 2009 *Furnishina pernica* An; Lee et al., p. 425, fig. 8 (4).
- Materials*.—26 specimens.
- Occurrence*.—Known from the Paibi and Wangcun sections, where it ranges from the *Shandongodus priscus-Hunanognathus tricuspidatus* Zone through the *Westergaardodina quadrata* Zone.
- Remarks*.—The specimens at hand agree well with *Furnishina pernica*.
- Furnishina primitiva* Müller, 1959
Figure 28.6–28.10, 28.13
- 1959 *Furnishina primitiva* Müller, p. 453, pl. 11, figs. 1 (?), 2–4.
- 1971 *Furnishina primitiva* Müller; Müller, pl. 1, fig. 11.
- 1976 *Furnishina primitiva* Müller; Abaimova and Ergaliev, pl. 14, fig. 8.
- 1986 *Furnishina primitiva* Müller; Chen and Gong, p. 146, pl. 17, figs. 7, 11, 18, pl. 18, fig. 11 (not pl. 20, fig. 8), text-fig. 51 (1–3, not 4). (part)
- 1987 *Furnishina primitiva* Müller; An, p. 106, pl. 3, fig. 10.
- 1988 *Furnishina primitiva* Müller; Lee and Lee, pl. 1, figs. 14, 15.
- 1991 *Furnishina primitiva* Müller; Müller and Hinz, p. 23, pl. 12, figs. 3, 4, 7, 9, 10, 15–17, 19, text-fig. 8 (C, D).
- non. 1993 *Furnishina primitiva* Müller; Landing, p. 6, fig. 4 (3).
- 2009 *Furnishina primitiva* Müller; Lee et al., p. 421, fig. 6 (2, 4, not 7). (part)
- Materials*.—18 specimens.
- Occurrence*.—Known from the Wangcun and Wa'ergang sections, where it ranges from *Westergaardodina lui-Westergaardodina ani* Zone through the *Cordylodus intermedius* Zone.
- Remarks*.—The specimens at hand agree in all respects with Müller's species.
- Furnishina quadrata* Müller, 1959
Figure 28.12
- 1959 *Furnishina quadrata* Müller, p. 453, pl. 12, figs. 2, 4, 9, fig. 6C.
- 1966 *Furnishina quadrata* Müller; Nogami, p. 355, pl. 9, figs. 3, 4.
- 1976 *Furnishina quadrata* Müller; Abaimova and Ergaliev, p. 392, pl. 14, figs. 3, 4, 6, 7.
- 1979 *Furnishina quadrata* Müller; Bednarczyk, p. 428, pl. 1, figs. 15, 16.
- 1981 *Furnishina quadrata* Müller; Miller et al., fig. 4 (E).
- ? 1985 *Furnishina quadrata* Müller; Wang, p. 226, pl. 3, fig. 14, pl. 8, fig. 14.

←

Figure 28. (1) *Furnishina cf. kranzae* Müller and Hinz, 1991, Bitiao Formation, Wangcun section, GMPKU2626, posterior view; (2, 3) *Furnishina longibasis* Bednarczyk, 1979; (2) Bitiao Formation, Wangcun section, GMPKU2627, lateral view; (3) Bitiao Formation, Wangcun section, GMPKU2628, lateral-anterior view; (4, 5) *Furnishina cf. ovata* Müller and Hinz, 1991; (4) Bitiao Formation, Wangcun section, GMPKU2629, posterior view; (5) Bitiao Formation, Wangcun section, GMPKU2630, posterior view; (6–10, 13) *Furnishina primitiva* Müller, 1959; (6) Bitiao Formation, Wangcun section, GMPKU2631, posterior view; (7), Shenjiawan Formation, Wa'ergang section, GMPKU2632, posterior view; (8) Shenjiawan Formation, Wa'ergang section, GMPKU2633, posterior view; (9) Shenjiawan Formation, Wa'ergang section, GMPKU2634, posterior view; (10) Shenjiawan Formation, Wa'ergang section, GMPKU2635, posterior view; (13) Shenjiawan Formation, Wa'ergang section, GMPKU2636, posterior view; (11, 14–17) *Furnishina cf. quadrata* Müller, 1959; (11) Bitiao Formation, Wangcun section, GMPKU2637, oblique posterior view; (14) Chefu Formation, Wangcun section, GMPKU2638, posterior view; (15) Bitiao Formation, Wangcun section, GMPKU2639, posterior view; (16) Bitiao Formation, Wangcun section, GMPKU2640, posterior view; (17) Bitiao Formation, Wangcun section, GMPKU2641, top view; (12) *Furnishina quadrata* Müller, 1959, Bitiao Formation, Wangcun section, GMPKU2642, top view; (18) *Furnishina tortilis* (Müller, 1959) Bitiao Formation, Wangcun section, GMPKU2643, posterior view; (19–23) *Furnishina wangcunensis* n. sp.; (19) Bitiao Formation, Wangcun section, GMPKU2644, lateral view; (20) Bitiao Formation, Wangcun section, GMPKU2645, lateral view; (21) Bitiao Formation, Wangcun section, GMPKU2646, lateral view; (22) Bitiao Formation, Wangcun section, holotype, GMPKU2647, lateral view; (23) Bitiao Formation, Wangcun section, GMPKU2648, posterior view; (24–26) *Gapparodus bisulcatus* (Müller, 1959); (24) Huaqiao Formation, Wangcun section, GMPKU2649, lateral view; (25) Huaqiao Formation, Wangcun section, GMPKU2650, lateral view; (26) Huaqiao Formation, Wangcun section, GMPKU2651, lateral view. Relative scale bar represents 154 µm (1–26).

- ? 1986 *Furnishina quadrata* Müller; Chen and Gong, p. 147, pl. 17, fig. 17, text-fig. 52 (2).
 1991 *Furnishina quadrata* Müller; Müller and Hinz, p. 23, pl. 9, figs. 1–13.
 2001a *Furnishina quadrata* Müller; Dong and Bergström, p. 961, pl. 3, fig. 16.
 ? 2006 *Furnishina quadrata* Müller; Qi et al., p. 185, pl. 1, figs. 13–14.

Materials.—Five specimens.

Occurrence.—Known only from the Wangcun section, where it occurs from the *Westergaardodina quadrata* Zone through the *Westergaardodina lui-Westergaardodina ani* Zone.

Remarks.—The specimens at hand agree closely with Müller's description.

Furnishina cf. quadrata Müller, 1959
 Figure 28.11, 28.14–28.17

- cf. 1959 *Furnishina quadrata* Müller, pl. 12, figs. 2, 4, 9, fig. 6C.
 cf. 1991 *Furnishina quadrata* Müller; Müller and Hinz, pl. 9, figs. 1–13.
 1993 *Furnishina cf. quadrata* Müller; Dong, p. 351, pl. 5, figs. 7, 8, 10, 18.
 2001a *Furnishina cf. quadrata* Müller; Dong and Bergström, p. 962, pl. 3, fig. 13.

Materials.—36 specimens.

Occurrence.—Known from the Paibi and Wangcun sections, where it is present in the *Shandongodus priscus-Hunanognathus tricuspoidatus* Zone through the *Westergaardodina cf. calix-Prooneotodus rotundatus* Zone.

Remarks.—Differs from the type specimen of *Furnishina quadrata* in that the anterior sides of the element are not concave but slightly convex. Its first appearance also occurs stratigraphically lower than typical *F. quadrata*.

Furnishina tortilis (Müller, 1959)
 Figure 28.18

- 1959 *Scandodus tortilis* Müller, p. 464, pl. 12, figs. 7, 8, 10, text-fig. 9.
 1971 *Scandodus tortilis* Müller; Müller, pl. 2, fig. 1.
 1979 *Scandodus tortilis* Müller; Bednarczyk, p. 434, pl. 4, fig. 15.
 1981 *Proscandodus tortilis* (Müller); Miller in Robison, p. 113, fig. 64 (5).
 1991 *Furnishina tortilis* (Müller); Müller and Hinz, p. 24, pl. 14, figs. 2–19, text-fig. 8 (N, O).
 ? 2006 *Furnishina tortilis* (Müller); Qi et al., p. 185, pl. 1, figs. 5–9.
 2009 *Furnishina tortilis* (Müller); Lee et al., p. 425, fig. 8 (1, ?13).

Materials.—Three specimens.

Occurrence.—Known only from the Wangcun section, where it occurs in the *Westergaardodina lui-Westergaardodina ani* Zone.

Remarks.—The specimens at hand agree well with *Furnishina tortilis*.

Furnishina wangcunensis new species
 Figure 28.19–28.23

Diagnosis.—Slender coniform elements. Cusp is distinctively recurved. The posterior costa and two anterolateral costae are sharp. Basal cavity is very deep.

Description.—Slender coniform elements with the cusp distinctively recurved toward the posterior side. Elements usually subsymmetrical but rarely asymmetrical due to lateral bending. Anterior side is convex, whereas the two posterolateral sides are concave. The posterior costa and two anterolateral costae are sharp, extending from the base up to a point that is above the recurved part of the cusp. The cross section is rounded apically and passes into subtriangular along the rest of the entire element, except for the base, where the cross section is subtriangular or irregularly rectangular. The basal cavity is very deep, with the apex above the recurved point of cusp.

Etymology.—Named for the Wangcun section in Hunan Province.

Types.—Holotype: GMPKU2647, from the *Westergaardodina cf. calix-Prooneotodus rotundatus* Zone, Furongian (upper Cambrian), Bitiao Formation, Wangcun section, Wangcun village, Yongshun County, Hunan Province.

Materials.—98 specimens.

Occurrence.—Known from the Wangcun section where it is present in the *Westergaardodina cf. calix-Prooneotodus rotundatus* Zone.

Comparison.—*Furnishina wangcunensis* n. sp. differs from *Furnishina dayangchaensis* in its more slender elements, distinctively recurved cusps, and sharp posterior costae and anterolateral costae.

Genus *Hunanognathus* Dong, 1993

Type species.—*Hunanognathus tricuspoidatus* Dong, 1993.

Hunanognathus tricuspoidatus Dong, 1993
 Figures 20.9, 20.10, 26.34–26.36

- ? 1987 *Westergaardodina amplicava* (Müller); An, pl. 3, fig. 14.
 1993 *Hunanognathus tricuspoidatus* Dong, p. 352, pl. 3, figs. 1–3.
 2001a *Hunanognathus tricuspoidatus* Dong; Dong and Bergström, p. 965, pl. 4, figs. 2–4.

Materials.—60 specimens.

Occurrence.—Known from the Paibi and Wangcun sections, where it ranges from the *Shandongodus priscus*–*Hunanognathus tricuspoidatus* Zone through the *Westergaardodina quadrata* Zone.

Remarks.—The specimens at hand agree well with *Hunanognathus tricuspoidatus* described and figured by Dong and Bergström (2001a). A single specimen referred to as *Furnishina?* sp. indet. by Müller and Hinz (1991, p. 25, pl. 14, fig. 1) was found in Zone 1 at Gum, Sweden, and a similar specimen was recovered in the present study in the lower part of the *Westergaardodina quadrata* Zone of the Chefu Formation. In gross morphology, both these specimens are similar to *H. tricuspoidatus*, but they differ from the latter in having only one small denticle. It is probable that these specimens are closely related to *H. tricuspoidatus*, but additional specimens are needed to assess this possible relationship.

Genus *Laiwugnathus* An, 1982

Type species.—*Laiwugnathus laiwuensis* An, 1982.

Laiwugnathus hunanensis new species
Figure 21.1, 21.2

Diagnosis.—Coniform elements, triangular in outline. The anterior side is convex, whereas the posterior side is concave, with a prominent median keel. Both sides are fused along the upward arched basal margin.

Description.—Coniform elements, triangular in outline, without a clear boundary between cusp and base. Anterior side is slightly convex. Posterior side is concave and is characterized by a slender median keel ending with an opening. The keel tapers gradually upward. Both anterior and posterior sides are fused along the basal margin. No basal cavity could be observed. Lateral edge of element is straight and sharp. Basal margin is sharp and is arched upward. The end of the keel is higher than the highest part of the arched basal margin.

Etymology.—Named for its provenance in the Chinese Province of Hunan.

Types.—Holotype: GMPKU2722, from *Gapparodus bisulcatus*–*Westergaardodina brevidens* Zone, middle Cambrian, Huaqiao Formation, Wangcun section, Wangcun village, Yongshun County, Hunan Province.

Materials.—Nine specimens.

Occurrence.—Present in the Wangcun section, where it occurs in the *Gapparodus bisulcatus*–*Westergaardodina brevidens* Zone.

Comparison.—*Laiwugnathus hunanensis* n. sp. differs from *Laiwugnathus fenghuangensis* An, 1982 in its much more slender median keel and the absence of a basal cavity. It differs from *Laiwugnathus kouzhenensis* An, 1982 in its much shorter median keel and upward-arched basal margin. The median keel of *L. kouzhenensis* is much longer, ending with an opening

shaped like a loudspeaker and extending below the basal margin. *L. hunanensis* differs from *Laiwugnathus graoilentus* An and Mei, 1994 in that the keel of the latter is more slender and solid.

Remarks.—Specimens of various species of *Laiwugnathus* are very common in North China but are relatively rare in Hunan.

Laiwugnathus cf. *kouzhenensis* An, 1982
Figure 21.3

1982 *Laiwugnathus* cf. *kouzhenensis* An, 1982, p. 135, pl. 2, figs. 12–13.

Materials.—Five specimens.

Occurrence.—Present in the Wangcun section, where it occurs in the *Westergaardodina matsushitai*–*Westergaardodina grandidens* Zone.

Remarks.—Similar to *Laiwugnathus kouzhenensis*, but the specimens at hand differ in the longitudinal keel. In *L. kouzhenensis*, the median keel is prominent, ending with an opening shaped like a loudspeaker. In the present specimens, the boundary between the median keel and the posterior side of the upper part of the cusp is not distinct.

Laiwugnathus transitans new species
Figure 21.4–21.6

2001a *Westergaardodina* sp. Dong and Bergström, p. 963, pl. 1, fig. 21.

Diagnosis.—Coniform elements with a large cusp and small base. The anterior side is convex, whereas the posterior side is concave, with a prominent median rounded keel. Both sides are fused along the straight basal margin.

Description.—Coniform elements with a long, narrow cusp. The small base extends laterally, like a very short lateral projection typical of *Westergaardodina*. Anterior side is slightly convex. Posterior side is concave and is characterized by a rounded, median keel that is long and large that ends with cone shaped opening. Both anterior and posterior sides are fused along the basal margin. No basal cavity could be observed. Lateral edge of element is straight and sharp. Basal margin is sharp and almost straight. The end of the keel is near the basal margin.

Etymology.—Latin, *transitans*, transitional.

Types.—Holotype: GMPKU2726, from *Westergaardodina matsushitai*–*Westergaardodina grandidens* Zone, middle Cambrian, Chefu Formation, Wangcun section, Wangcun village, Yongshun County, Hunan Province.

Materials.—Ten specimens.

Occurrence.—Present in the Paibi and Wangcun sections, where it ranges from the *Westergaardodina matsushitai*–*Westergaardodina*

grandidens Zone through the *Westergaardodina lui*-*Westergaardodina ani* Zone.

Comparison.—*Laiwugnathus transitans* n. sp. differs from *Laiwugnathus kouzhenensis* in its base which inclines downwards like two short lateral projections of the genus *Westergaardodina*.

Remarks.—*Laiwugnathus transitans* n. sp. is probably the transitional form between *Laiwugnathus* and tricuspidate *Westergaardodina*.

Genus *Lugnathus* new genus

Type species.—*Lugnathus hunanensis* n. gen. n. sp.

Diagnosis.—Large, simple, coniform elements, proclined, asymmetrical and laterally compressed, with a carina on one lateral side. Anterior and posterior edges lack costae. Basal cavity is very deep, the apex of which extends nearly to the tip of the cusp.

Etymology.—In honor of the late Professor Lu Yan-hao, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences; Academician of Chinese Academy of Sciences, the name is composed from Lu and a derivative of Greek, *gnathus*, jaw.

Remarks.—In gross morphology, *Lugnathus* is somewhat similar to *Proconodontus* but differs from the latter in lacking either an anterior or posterior costa. Also, *Lugnathus* is a paraconodont, which is verified by our histological investigation of specimens recovered from Hunan (Fig. 29).

Lugnathus hunanensis new genus new species

Figures 19.20, 19.21, 19.25, 19.26, 20.1–20.8, 29.1–29.4

Diagnosis.—As for the genus.

Description.—Large, hollow, coniform elements, proclined, asymmetrical, laterally compressed, with carina on one lateral side. The apex is pointed. The cusp is slender, with a pointed tip. Anterior and posterior edges lack costae. The basal cavity is very deep, the apex of which extends nearly to tip of cusp.

Etymology.—Named for Hunan Province.

Types.—Holotype: GMPKU2702, from *Cordylodus intermedius* Zone, Furongian (upper Cambrian), Panjiazui Formation, Wa'ergang section, Wa'ergang village, Taoyuan County, Hunan Province.

Materials.—120 specimens.

Occurrence.—Known from the Wa'ergang and Wangcun sections, where it ranges from the *Eoconodontus* Zone through the *Cordylodus lindstromi* Zone (upper part).

Genus *Miaognathus* new genus

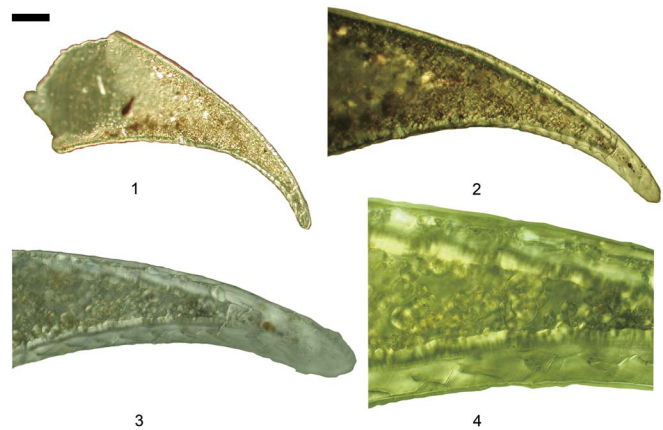


Figure 29. Conodont images using oil immersion techniques (Dong et al., 2005c) with Differential Interference Contrast (Nomarski) illumination, showing pataconodont structure. (1–4) *Lugnathus hunanensis* n. gen. n. sp.; (1) overview, GMPKU3068; (2) close-up of (1), showing the growth lamellae of paraconodont; (3) close-up of the tip, showing the growth lamellae of paraconodont in detail; (4) close-up of (1) showing the structure of the basal tissue which intergrades with the core of calcosphere (dentine). Relative scale bar represents 46 μ m (1), 27 μ m (2), 11 μ m (3), 6 μ m (4).

Type species.—*Miaognathus multicostatus* n. gen. n. sp.

Diagnosis.—Large coniform elements, proclined and asymmetrical. It is strongly laterally compressed. Basal cavity is very large and deep. The posterior edge has a costa, and the anterior edge is without costae. One to four costae are on each of the lateral sides.

Etymology.—Miao, ethnic minority group in western Hunan, South China; *gnathus*, Greek, jaw.

Miaognathus multicostatus new genus new species

Figure 21.8–21.12, 21.15, 21.16

Diagnosis.—As for the genus.

Description.—Large-sized coniform, proclined and asymmetrical. It is strongly laterally compressed. Basal cavity is very large and deep, the apex of which extends nearly to tip. The posterior edge is characterized by a sharp costa, whereas the anterior edge is without costa. One to four costae are on each of the lateral sides. Cross-section is sharp subtriangular except for the apex.

Etymology.—*multicostatus*, Latin, referring to the multiple costae.

Types.—Holotype: GMPKU2733 from the *Eoconodontus* Zone, Furongian (upper Cambrian), Shenjiawan Formation, Wa'ergang section, Wa'ergang village, Taoyuan County, Hunan Province.

Materials.—20 specimens.

Occurrence.—Known from the Wa'ergang section, where it occurs in the *Eoconodontus* Zone.

Comparison.—*Miaognathus multicostatus* n. gen. n. sp. is more or less similar to species of *Coelocerodontus* in gross

morphology, but it differs from the latter in its much larger size, lack of an anterior keel, and the presence of more than one costa on its lateral sides. Also, their stratigraphic ranges are different.

Remarks.—The species of *Coelocerodontus* are euconodonts, whereas *Miaognathus multicostatus* n. gen. n. sp. is probably a paraconodont.

Genus *Muellerodus* Miller, 1980

Type species.—*Distacodus* (?) *cambricus* Müller, 1959.

Remarks.—The name *Muellerodus* Miller, 1980 was proposed to replace *Muellerina* Szaniawski, 1971, which is a homonym of an ostracode genus proposed in 1965.

Muellerodus cambricus (Müller, 1959)
Figure 30.1–30.3, 30.6

- 1959 *Distacodus* (?) *cambricus* Müller, p. 450, pl. 14, figs. 1, 2, text-fig. 4.
1971 *Oneotodus cambricus* (Müller); Müller, pl. 2, fig. 3.
1979 *Muellerina cambricus* (Müller); Bednarczyk, p. 429, pl. 2, fig. 8.
1981 *Muellerodus cambricus* (Müller); Miller in Robison, p. W112, fig. 64, 3a, b.
1982 *Muellerodus pomeranensis* An, p. 138, pl. 9, figs. 6, 8 (not 7).
1991 *Muellerodus cambricus* (Müller); Müller and Hinz, p. 29, pl. 18, figs. 1–4, 6–13, 15, 17, text-fig. 10 (A, B).
2006 *Muellerodus cambricus* (Müller); Qi et al., p. 186, pl. 2, fig. 14.
2009 *Muellerodus cambricus* (Müller); Lee et al., p. 427, fig. 9 (3).
2011 *Muellerodus cambricus* (Müller); Bagnoli and Qi, p. 12, fig. 4 (J).

Materials.—Six specimens.

Occurrence.—Known from the Wangcun and Wa'ergang sections, where it ranges from the *Westergaardodina lui-Westergaardodina ani* Zone through the *Eoconodontus* Zone.

Remarks.—The present specimens agree well with *Muellerodus cambricus* described and figured by Müller and Hinz (1991).

Muellerodus guttulus Müller and Hinz, 1991
Figure 30.4

- 1991 *Muellerodus guttulus* Müller and Hinz, p. 29, pl. 19, figs. 1–9, 11, text-fig. 10 (D).

Materials.—Two specimens.

Occurrence.—Known from the Wangcun section, where it occurs in the *Westergaardodina lui-Westergaardodina ani* Zone.

Remarks.—The specimens at hand agree well with those described and figured by Müller and Hinz (1991).

Muellerodus? obliquus (An, 1982)
Figure 30.5, 30.11, 30.12

- 1982 *Proscandodus obliquus* An, p. 148, pl. 9, figs. 1–5.
1993 *Muellerodus? obliquus* (An); Dong, pl. 5, figs. 3, 11, 17.
2001a *Muellerodus? obliquus* (An); Dong and Bergström, p. 968, pl. 4, fig. 10.
2006 *Muellerodus? obliquus* (An); Qi et al., p. 186, pl. 2, figs. 10–11.

Materials.—48 specimens.

Occurrence.—Known from the Paibi and Wangcun sections, where it ranges from the *Shandongodus priscus-Humanognathus tricuspoidatus* Zone through the *Proconodontus* Zone.

Remarks.—The present specimens are closely similar to An's species. Müller and Hinz (1991) considered *Proscandodus* to be a junior synonym of *Furnishina*. Our specimens are characterized by convex anterior and posterior sides, slender cusps, and one lateral costa that is more prominent than the other. These are features more characteristic of *Muellerodus* than *Furnishina*, and hence we refer this species to the former genus.

Muellerodus? oelandicus (Müller, 1959)
Figure 30.7–30.10

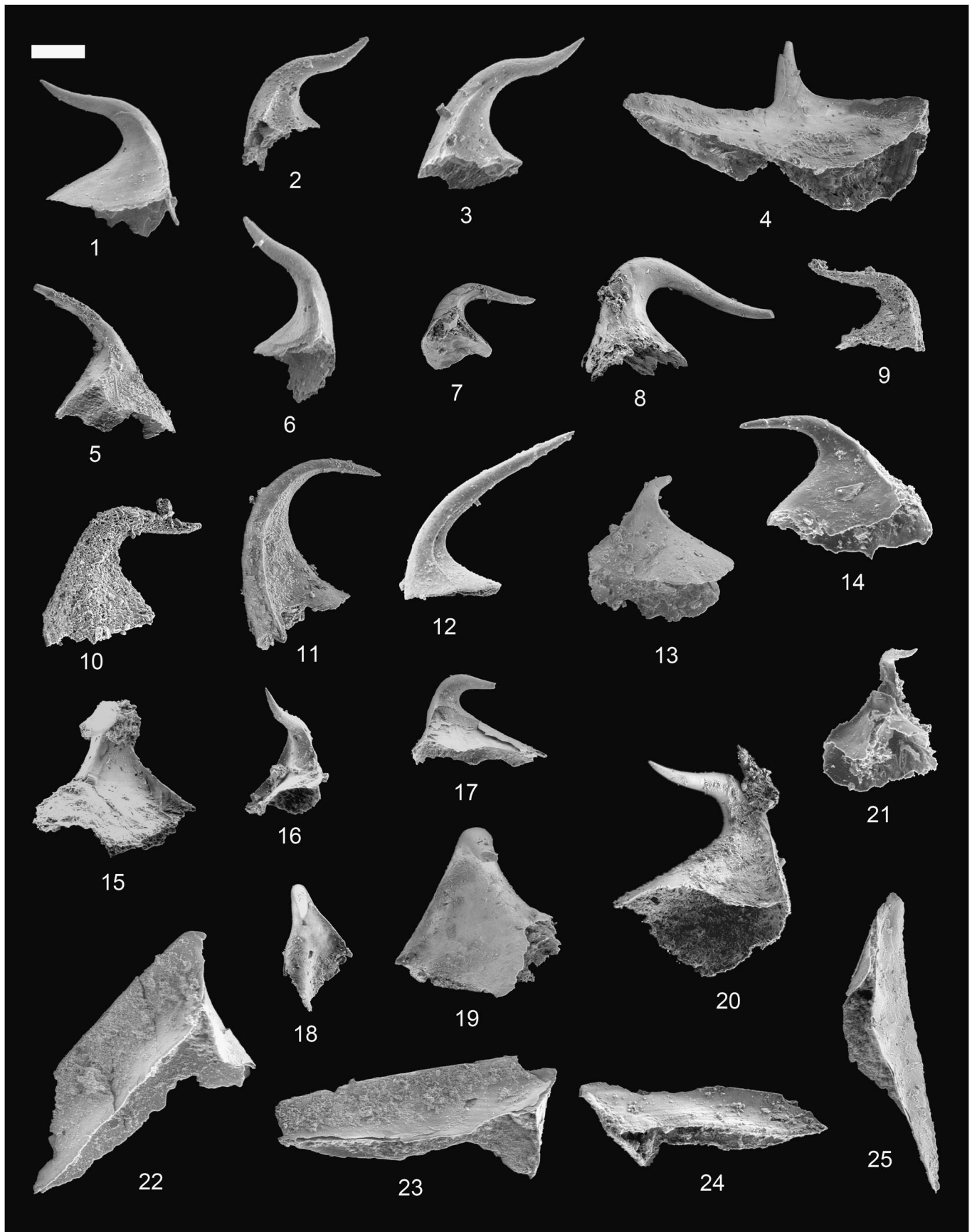
- 1959 *Scandodus oelandicus* Müller, p. 463, pl. 12, fig. 14, 15, text-fig. 10.
1983 *Muellerodus oelandicus* (Müller); An et al., p. 109, pl. 3, fig. 9.
1986 *Proscandodus oelandicus* (Müller); Chen and Gong, p. 171, pl. 34, fig. 13, text-fig. 67 (2).
1991 *Muellerodus? oelandicus* (Müller); Müller and Hinz, p. 29, pl. 20, figs. 1–13, fig. 10 (E, F).
1993 *Muellerodus? oelandicus* (Müller); Dong, pl. 3, figs. 6, 11.
2001a *Muellerodus? oelandicus* (Müller); Dong and Bergström, p. 968, pl. 5, fig. 12, pl. 6, fig. 9.
2006 *Muellerodus? oelandicus* (Müller); Qi et al., p. 186, pl. 2, fig. 12.
2009 *Muellerodus? oelandicus* (Müller); Lee et al., p. 423, fig. 7 (10).
2011 *Muellerodus? oelandicus* (Müller); Bagnoli and Qi, p. 12, fig. 4 (K).

Materials.—32 specimens.

Occurrence.—Known from Paibi, Wa'ergang and Wangcun sections, where it ranges from the *Gapparodus bisulcatus-Westergaardodina brevidens* Zone through the *Cordylodus intermedius* Zone.

Remarks.—The specimens at hand agree closely with Müller's species.

Muellerodus pomeranensis (Szaniawski, 1971)
Figure 30.13–30.21



- 1971 *Muellerina pomeranensis* Szaniawski, p. 408, pl. 1, fig. 2, pl. 2, fig. 3, pl. 4, figs. 1–4.
- 1981 *Muellerodus pomeranensis* (Szaniawski); Miller et al., fig. 4 (I, J).
- 1982 *Muellerodus pomeranensis* (Szaniawski); An, p. 138, pl. 9, fig. 7 only (not figs. 6, 8), pl. 16, fig. 7, pl. 17, figs. 1, 3. (part)
- 1983 *Muellerodus pomeranensis* (Szaniawski); An et al., p. 110, pl. 3, fig. 10.
- 1987 *Muellerodus pomeranensis* (Szaniawski); An, p. 108, pl. 3, figs. 4, 17.
- 1991 *Muellerodus pomeranensis* (Szaniawski); Müller and Hinz, p. 30, pl. 18, figs. 5, 14, 16, 18–21, text-fig. 10 (C).
- 1993 *Muellerodus pomeranensis* (Szaniawski); Dong, pl. 2, fig. 8.
- 2001a *Muellerodus pomeranensis* (Szaniawski); Dong and Bergström, p. 968, pl. 3, fig. 12.
- 2006 *Muellerodus pomeranensis* (Szaniawski); Qi et al., p. 186, pl. 2, fig. 13.
- 2009 *Muellerodus pomeranensis* (Szaniawski); Lee et al., p. 425, fig. 8 (3).
- 1982 Gen et sp. indet. An, p. 156, pl. 8, fig. 7.
- 1983 *Nogamiconus sinensis* (Nogami); An et al., p. 110, pl. 30, fig. 11.
- 1991 *Nogamiconus sinensis* (Nogami); Müller and Hinz, p. 31, pl. 21, figs. 1–6, text-fig. 12 (A, B).
- 1993 *Nogamiconus sinensis* (Nogami); Dong, pl. 4, figs. 7–9.
- 2001a *Nogamiconus sinensis* (Nogami); Dong and Bergström, p. 969, pl. 4, figs. 11–12.

Materials.—178 specimens.

Occurrence.—Known from Paibi and Wangcun sections, where it ranges from the *Shandongodus priscus-Hunanognathus tricuspoidatus* Zone through the *Westergaardodina lui-Westergaardodina ani* Zone.

Remarks.—The present specimens compare well with previous descriptions and illustrations of this species. Our collections includes several clusters containing only one type of element.

Genus *Proacodus* Müller, 1959

Type species.—*Proacodus obliquus* Müller, 1959.

Proacodus obliquus Müller, 1959

Figure 31.11–31.15, 31.17, 31.20–31.22, 31.25

- 1959 *Proacodus obliquus* Müller, p. 458, pl. 13, figs. 1, 4 (not fig. 2). (part)
- 1971 *Proacodus obliquus* Müller; Müller, pl. 2, fig. 2.
- 1979 *Proacodus obliquus* Müller; Bednarczyk, p. 433, pl. 1, figs. 11, 14.
- 1981 *Proacodus obliquus* Müller; Miller in Robison, p. W112, fig. 64 (4a, b).
- 1991 *Proacodus obliquus* Müller; Müller and Hinz, p. 34, pl. 22, figs. 12–23, fig. 13 (C).

Description.—Proclined, asymmetrical elements with a long lateral process. Both anterior and posterior sides are broadly rounded. The lateral process is very long and keeled on its upper side. Basal cavity is large and deep, the apex of which extends past the point of flexure of the element. Cross section is round at the apex and becomes an elongated oval at the base.

Materials.—30 specimens.

Materials.—24 specimens.

Occurrence.—Known from the Paibi and Wangcun sections where it ranges from the upper part of the *Shandongodus priscus-Hunanognathus tricuspoidatus* Zone through the *Westergaardodina cf. calix-Prooneotodus rotundatus* Zone.

Remarks.—The specimens at hand agree closely with previously described elements of this species, except that the flank costae of some specimens are indistinct. We do not feel that this slight difference merits taxonomic separation of our specimens from *Muellerodus pomeranensis*.

Genus *Nogamiconus* Miller, 1980

Type species.—*Proacodus? sinensis* (Nogami, 1966).

Nogamiconus sinensis (Nogami, 1966)

Figure 30.22–30.25

- 1966 *Proacodus? sinensis* Nogami, p. 356, pl. 10, figs. 12–14.
- 1971 *Proacodus sinensis* Nogami; Müller, fig. 1c.
- 1981 *Nogamiconus sinensis* (Nogami); Miller in Robison, p. W112, fig. 64 (6a, b).



Figure 30. (1–3, 6) *Muellerodus cambricus* (Müller, 1959); (1) Shenjiawan Formation, Wa'ergang section, GMPKU2744, lateral view; (2) Shenjiawan Formation, Wa'ergang section, GMPKU2745, lateral view; (3) Shenjiawan Formation, Wa'ergang section, GMPKU2746, lateral view; (6) Shenjiawan Formation, Wa'ergang section, GMPKU2747, lateral view; (4) *Muellerodus guttulus* Müller and Hinz, 1991, Bitiao Formation, Wangcun section, GMPKU2748, posterior view; (5, 11, 12) *Muellerodus? obliquus* (An, 1982); (5) Bitiao Formation, Wangcun section, GMPKU2749, lateral view; (11) Bitiao Formation, Wangcun section, GMPKU2750, lateral view; (12) Huaqiao Formation, Paibi section, GMPKU2751, lateral view; (7–10) *Muellerodus? oelandicus* (Müller, 1959); (7) Huaqiao Formation, Wangcun section, GMPKU2752, lateral view; (8) Bitiao Formation, Wangcun section, GMPKU2753, lateral view; (9) Bitiao Formation, Wangcun section, GMPKU2754, lateral view; (10) Shenjiawan Formation, Wangcun section, GMPKU2755, lateral view; (13–21) *Muellerodus pomeranensis* (Szaniawski, 1971); (13) Bitiao Formation, Wangcun section, GMPKU2756, posterior view; (14) Bitiao Formation, Wangcun section, GMPKU2757, posterolateral view; (15) Bitiao Formation, Wangcun section, GMPKU2758, posterior view; (16) Bitiao Formation, Wangcun section, GMPKU2759, posterior view; (17) Bitiao Formation, Wangcun section, GMPKU2760, posterior view; (18) Bitiao Formation, Wangcun section, GMPKU2761, oblique posterior view; (19) Bitiao Formation, Wangcun section, GMPKU2762, posterior view; (20) Bitiao Formation, Wangcun section, GMPKU2763, posterior view; (21) Bitiao Formation, Wangcun section, GMPKU2764, posterior view; (22–25) *Nogamiconus sinensis* (Nogami, 1966); (22) Huaqiao Formation, Wangcun section, GMPKU2765, posterior view; (23) Chefu Formation, Wangcun section, GMPKU2766, posterior view; (24) Chefu Formation, Wangcun section, GMPKU2767, posterior view; (25) Chefu Formation, Wangcun section, GMPKU2768, posterior view. Relative scale bar represents 123 µm (1, 2, 4, 6, 8, 11, 16, 17, 22, 25), 117 µm (3, 5, 7, 9, 10, 12–15, 18–21), 159 µm (23, 24).



Occurrence.—Known from the Wangcun and Wa'ergang sections, where it ranges from the *Westergaardodina lui-Westergaardodina ani* Zone through the *Eoconodontus* Zone.

Proacodus pulcherus (An, 1982)

Figures 23.1–23.6, 31.16, 31.18, 31.19, 31.23, 31.24, 31.26

- 1959 *Proacodus obliquus* Müller, p. 458, pl. 13, fig. 2 only. (part)
 1982 *Muellerodus pulcherus* An, p. 139, pl. 9, figs. 13, 15, pl. 10, figs. 12, 14.
 1991 *Proacodus pulcherus* (An); Müller and Hinz, p. 34, pl. 22, figs. 3–5, 7–11, text-fig. 13 (A, B).
 2000 *Proacodus obliquus* Müller; Dubinina, p. 172, pl. 3, figs. 4–6.
 2006 *Proacodus pulcherus* (An); Qi et al., p. 187, pl. 3, fig. 18.
 2011 *Proacodus pulcherus* (An); Bagnoli and Qi, p. 12, fig. 4 (L).

Description.—Coniform elements, proclined, asymmetrical, with a short lateral process. Both anterior and posterior sides are broadly rounded. The lateral process is short and keeled on its upper side. Basal cavity is large and deep, with the apex extending past the point of flexure of the element. Cross section is round at the apex and becomes tear-shaped at the base.

Materials.—40 specimens.

Occurrence.—Known from the Wangcun and Wa'ergang sections, where it ranges from the *Westergaardodina lui-Westergaardodina ani* Zone through the *Proconodontus* Zone.

Proacodus cf. pulcherus (An, 1982)

Figure 23.7

- cf. 1959 *Proacodus obliquus* Müller, p. 458, pl. 13, fig. 2, only. (part)
 cf. 1982 *Muellerodus pulcherus* An, p. 139, pl. 9, figs. 13, 15, pl. 10, figs. 12, 14.
 cf. 1991 *Proacodus pulcherus* (An); Müller and Hinz, p. 34, pl. 22, figs. 3–5, 7–11, text-fig. 13 (A, B).

Description.—Coniform elements, proclined, asymmetrical, with a long lateral process. Both anterior and posterior sides are broadly rounded. The long lateral process extends horizontally

and then upward and has a keel on its upper side. Basal cavity large and deep, with the apex extending past the point of flexure of the element. Cross section is round at the apex and becomes tear-shaped at the base.

Materials.—Three specimens.

Occurrence.—Known from Wa'ergang sections, where it occurs in the *Proconodontus* Zone.

Remarks.—This form is similar to *Proacodus pulcherus*, but it differs in its longer process, which extends upward. Also, the apex of the present species is straight, whereas the apex of *P. pulcherus* is twisted.

Genus *Prooneotodus* Müller and Nogami, 1971

Type species.—*Oneotodus gallatini* Müller, 1959.

Prooneotodus gallatini (Müller, 1959)

Figures 24.9, 24.10, 24.12–24.32, 32.1–32.15, 32.17–32.21

- 1959 *Oneotodus gallatini* Müller, p. 457, pl. 13, figs. 5–10, 12, 18.
 1971 *Oneotodus gallatini* Müller; Druce and Jones, p. 81, pl. 9, figs. 9a–c, pl. 10, figs. 9a–10c, text-figs. 26f, g.
 1973 *Oneotodus gallatini* Müller; Özgül and Gedik, p. 48, pl. 1, figs. 1, 20.
 1980 *Oneotodus gallatini* Müller; Lee, pl. 1, fig. 4.
 1981 *Prooneotodus gallatini* (Müller); Miller in Robison, p. W113, fig. 64 (2a–c).
 1981 *Prooneotodus gallatini* (Müller); Miller et al., fig. 4K–M.
 1982 *Prooneotodus gallatini* (Müller); An, p. 144, pl. 11, figs. 5–6, 9–14, pl. 16, fig. 13.
 1982 *Prooneotodus gallatini* (Müller); Fortey et al., p. 125, text-figs. 9 (H, O).
 1983 *Prooneotodus gallatini* (Müller); An et al., p. 128, pl. 5, fig. 7.
 1983 *Prooneotodus gallatini* (Müller); Azmi, p. 379, pl. 3, figs. 3, 5.
 1985 *Prooneotodus gallatini* (Müller); Wang, p. 235, pl. 3, figs. 23–25, pl. 5, figs. 4, 5, pl. 8, figs. 12, 21, pl. 12, figs. 22, 26, pl. 13, fig. 10, pl. 14, fig. 5.
 1986 “*Prooneotodus*” *gallatini* (Müller); Chen and Gong, p. 166, pl. 22, figs. 13, 17 (not 15, 16), pl. 23, figs. 2–3,

←

Figure 31. (1–4) *Paibiconus proarcuatus* Dong, 1993; (1) Chefu Formation, Wangcun section, GMPKU2769, posterolateral view; (2) Chefu Formation, Wangcun section, GMPKU2770, anterior view; (3) Huaqiao Formation, Wangcun section, GMPKU2002, anterior view; (4) Close-up view of the broken surface of (3), showing protoconodont structure; (5–10) *Phakelodus tenuis* (Müller, 1959); (5) Chefu Formation, Wangcun section, GMPKU2771, cluster; (6) Bitiao Formation, Wangcun section, GMPKU2772, cluster; (7) Bitiao Formation, Wangcun section, GMPKU2773, lateral view; (8) Bitiao Formation, Wangcun section, GMPKU2774, cluster; (9) Shenjiawan Formation, Wa'ergang section, GMPKU2775, lateral view; (10) Shenjiawan Formation, Wa'ergang section, GMPKU2776, cluster; (11–15, 17, 20–22, 25) *Proacodus obliquus* Müller, 1959; (11) Bitiao Formation, Wangcun section, GMPKU2777, top view; (12) Bitiao Formation, Wangcun section, GMPKU2778, posterior view; (13) Bitiao Formation, Wangcun section, GMPKU2779, posterior view; (14) Bitiao Formation, Wangcun section, GMPKU2780, posterior view; (15) Bitiao Formation, Wangcun section, GMPKU2781, posterior view; (17) Bitiao Formation, Wangcun section, GMPKU2782, posterior view; (20) Bitiao Formation, Wangcun section, GMPKU2783, posterior view; (21) Bitiao Formation, Wangcun section, GMPKU2784, top view from anterior side; (22) Bitiao Formation, Wangcun section, GMPKU2785, posterior view; (25) Shenjiawan Formation, Wa'ergang section, GMPKU2786, top view from anterior side; (16, 18, 19, 23, 24, 26) *Proacodus pulcherus* (An, 1982); (16) Bitiao Formation, Wangcun section, GMPKU2787, posterior view; (18) Bitiao Formation, Wangcun section, GMPKU2788, posterior view; (19) Bitiao Formation, Wangcun section, GMPKU2789, posterior view; (23) Bitiao Formation, Wangcun section, GMPKU2790, posterior view; (24) Bitiao Formation, Wangcun section, GMPKU2791, posterior view; (26) Bitiao Formation, Wangcun section, GMPKU2792, posterior view. Relative scale bar represents 311 µm (1), 362 µm (2), 227 µm (3), 71 µm (4), 130 µm (5, 8, 9, 12–26), 188 µm (6), 160 µm (7), 119 µm (10), 100 µm (11).

- 7, 10, 16–19, pl. 24, fig. 12, text-figs. 64 (2, 5, not 3). (part)
- 1987 *Prooneotodus gallatini* (Müller); An, p. 112, pl. 2, figs. 1, 2, 5, 6, 11, 15.
- 1987 *Prooneotodus gallatini* (Müller); Buggisch and Repetski, p. 159, pl. 8, fig. 2.
- 1991 *Prooneotodus gallatini* (Müller); Müller and Hinz, p. 37, pl. 24, figs. 1–28, 29.
- 2000 *Prooneotodus gallatini* (Müller); Dubinina, p. 178, pl. 4, figs. 22, 29, 30.
- 2000 “*Prooneotodus*” *mitriformis* Dubinina, p. 178, pl. 4, fig. 28.
- 2000 *Prooneotodus rotundatus* (Druce et Jones); Zhao et al., p. 216, pl. 23, figs. 25, 28.
- 2002a *Prooneotodus gallatini* (Müller); Lee, p. 165, pl. 2, fig. 10.
- 2002b *Prooneotodus gallatini* (Müller); Lee, p. 27, pl. 2, fig. 7.
- 2004 *Prooneotodus gallatini* (Müller); Lee, p. 60, fig. 5 (N).
- 2007 *Prooneotodus gallatini* (Müller); Landing et al., p. 922, fig. 9 (d, e).
- 2009 *Prooneotodus gallatini* (Müller); Lee et al., p. 423, fig. 7 (12, 15), p. 425, fig. 8 (16), p. 427, fig. 9 (2).
- 2011 *Prooneotodus gallatini* (Müller); Bagnoli and Qi, p. 12, fig. 4 (C).
- 1976 *Prooneotodus rotundatus* (Druce and Jones); Miller and Paden, p. 596, pl. 1, figs. 24, 25.
- 1982 *Prooneotodus rotundatus* (Druce and Jones); An, p. 144, pl. 4, fig. 12, pl. 11, figs. 1–4, 7, 8.
- 1982 *Prooneotodus rotundatus* (Druce and Jones); Fortey et al., p. 125, text-fig. 9 (J, M).
- 1983 *Prooneotodus rotundatus* (Druce and Jones); An et al., p. 129, pl. 5, fig. 6.
- 1985 *Prooneotodus rotundatus* (Druce and Jones); Wang, p. 236, pl. 3, figs. 5–7, pl. 6, fig. 13, pl. 7, figs. 7, 8, pl. 8, fig. 6, pl. 9, fig. 2, pl. 10, fig. 9, pl. 12, fig. 6, pl. 13, figs. 8, ?32.
- 1986 “*Prooneotodus*” *rotundatus* (Druce and Jones); Chen and Gong, p. 167, pl. 22, figs. 1–4 (not 5), 6, 9–11, 18, 20, pl. 23, figs. 1, 9, 12, 14, 20 (not pl. 26, fig. 9), text-fig. 64 (1). (part)
- 1987 *Prooneotodus rotundatus* (Druce and Jones); s.f. Dong, p. 170, pl. 1, fig. 29, text-fig. 3M.
- 2000 *Prooneotodus rotundatus* (Druce and Jones); Dubinina, p. 179, pl. 4, figs. 26, 27.
- 2001 *Prooneotodus rotundatus* (Druce and Jones); Lee, p. 449, fig. 6 (5).
- 2002 *Prooneotodus rotundatus* (Druce and Jones); Lee, p. 165, pl. 2, fig. 8.
- 2002 *Prooneotodus rotundatus* (Druce and Jones); Lee, p. 27, pl. 2, fig. 8.
- 2004 *Prooneotodus rotundatus* (Druce and Jones); Lee, p. 60, fig. 5 (I).
- 2009 *Prooneotodus rotundatus* (Druce and Jones); Lee et al., p. 427, fig. 9 (1).

Description.—Moderate to small coniform elements, erect to proclined, symmetrical to asymmetrical. The apex is pointed. Both anterior and posterior sides are rounded. No keels or costae are present. Basal cavity is deep, with the apex extending past the point of flexure of the element or even nearly to its tip. The cross section is round at the apex and changes to variably oval at the base.

Materials.—300 specimens.

Occurrence.—Known from the Wangcun and Wa’ergang sections, where it ranges from the *Westergaardodina lui*-*Westergaardodina ani* Zone through the *Cordylodus intermedius* Zone.

Prooneotodus rotundatus (Druce and Jones, 1971)

Figure 32.16, 32.22–32.29

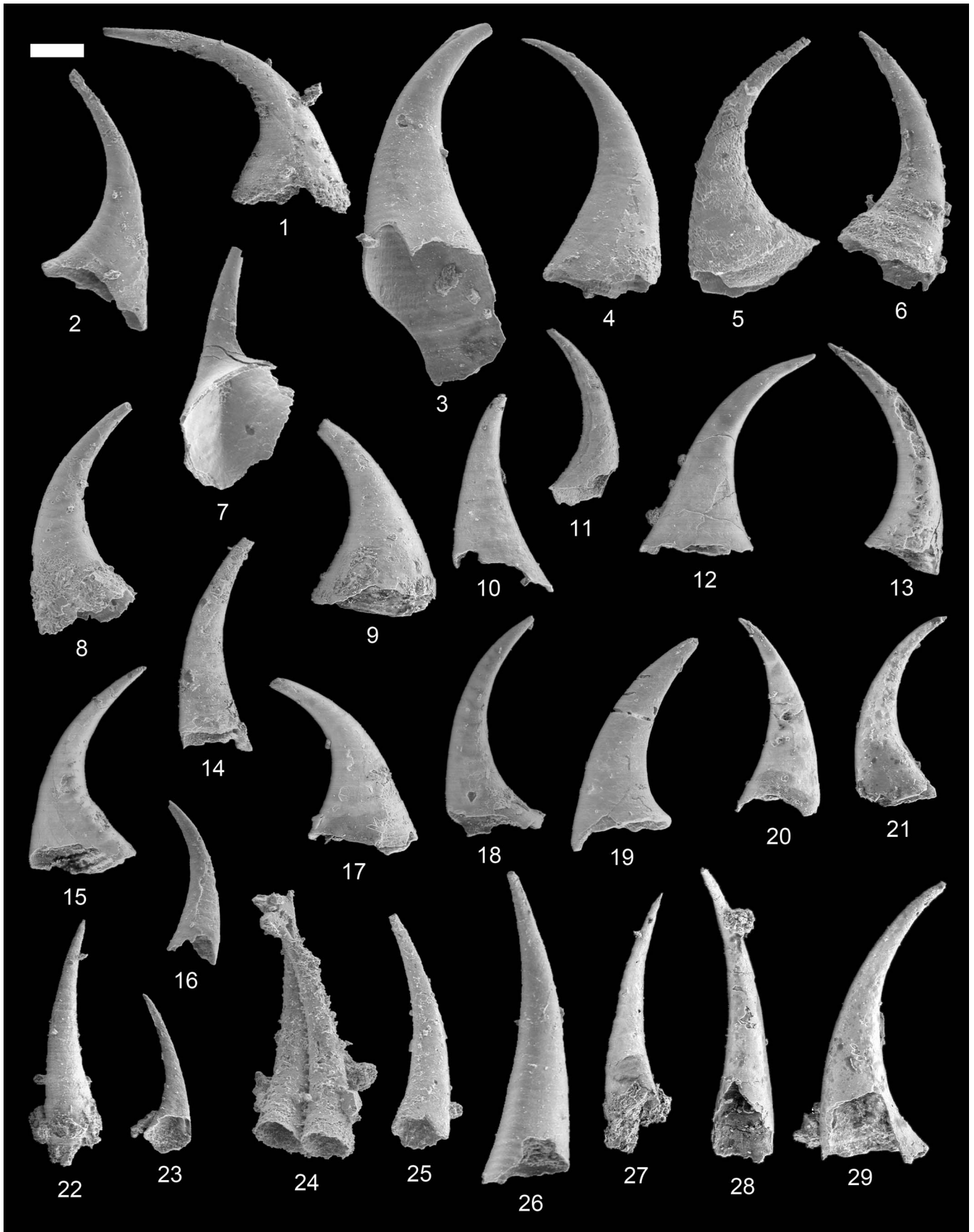
- 1971 *Coelocerodontus rotundatus* Druce and Jones, p. 62, pl. 9, figs. 10–13, text-figs. 22c, d.
- 1973 *Proconodontus* cf. *rotundatus* (Druce and Jones); Müller, p. 43, pl. 3, figs. 1–3.

Description.—Coniform elements, moderate to small, proclined and symmetrical. The apex is pointed. Both anterior and posterior sides are rounded. No keels or costae are present. Basal cavity is very deep, with the apex extending nearly to the tip of the element. The cross section is circular through the small cusp and base.

Materials.—90 specimens.

Occurrence.—Known from the Wangcun and Wa’ergang sections, where it ranges from *Westergaardodina* cf. *calix*-*Prooneotodus rotundatus* Zone through the *Cordylodus intermedius* Zone.

Figure 32. (1–15, 17–21) *Prooneotodus gallatini* Müller, 1959; (1) Shenjiawan Formation, Wa’ergang section, GMPKU2856, lateral view; (2) Shenjiawan Formation, Wa’ergang section, GMPKU2857, lateral view; (3) Shenjiawan Formation, Wa’ergang section, GMPKU2858, lateral view; (4) Shenjiawan Formation, Wa’ergang section, GMPKU2859, lateral view; (5) Shenjiawan Formation, Wa’ergang section, GMPKU2860, lateral view; (6) Shenjiawan Formation, Wa’ergang section, GMPKU2861, lateral view; (7) Shenjiawan Formation, Wa’ergang section, GMPKU2862, oblique posterior view from base; (8) Shenjiawan Formation, Wa’ergang section, GMPKU2863, lateral view; (9) Shenjiawan Formation, Wa’ergang section, GMPKU2864, lateral view; (10) Shenjiawan Formation, Wa’ergang section, GMPKU2865, lateral view; (11) Shenjiawan Formation, Wa’ergang section, GMPKU2866, lateral view; (12) Shenjiawan Formation, Wa’ergang section, GMPKU2867, lateral view; (13) Shenjiawan Formation, Wa’ergang section, GMPKU2868, lateral view; (14) Shenjiawan Formation, Wa’ergang section, GMPKU2869, lateral view; (15) Shenjiawan Formation, Wa’ergang section, GMPKU2870, lateral view; (17) Shenjiawan Formation, Wa’ergang section, GMPKU2871, lateral view; (18) Shenjiawan Formation, Wa’ergang section, GMPKU2872, lateral view; (19) Shenjiawan Formation, Wa’ergang section, GMPKU2873, lateral view; (20) Shenjiawan Formation, Wa’ergang section, GMPKU2874, lateral view; (21) Shenjiawan Formation, Wa’ergang section, GMPKU2875, lateral view; (16, 22–29) *Prooneotodus rotundatus* (Druce and Jones, 1971); (16) Bitiao Formation, Wangcun section, GMPKU2876, lateral view; (22) Shenjiawan Formation, Wa’ergang section, GMPKU2877, lateral view; (23) Shenjiawan Formation, Wa’ergang section, GMPKU2878, lateral view; (24) Shenjiawan Formation, Wa’ergang section, GMPKU2879, cluster, lateral view; (25) Shenjiawan Formation, Wa’ergang section, GMPKU2880, lateral view; (26) Shenjiawan Formation, Wa’ergang section, GMPKU2881, lateral view; (27) Shenjiawan Formation, Wa’ergang section, GMPKU2882, lateral view; (28) Shenjiawan Formation, Wa’ergang section, GMPKU2883, lateral view; (29) Shenjiawan Formation, Wa’ergang section, GMPKU2884, lateral view. Relative scale bar represents 130 μ m (1–13, 16–29), 138 μ m (14, 15).



Remarks.—*Prooneotodus rotundatus* differs from *Prooneotodus gallatini* in its circular cross section and deeper basal cavity. In addition, elements of the former taper gradually, whereas elements of the latter taper relatively rapidly. In gross morphology, *P. rotundatus* resembles *Millerodontus intermedius* n. gen. n. sp., but the latter is recognized as a primitive euconodont in the light of histological investigation. Accordingly, some published specimens previously assigned to *P. rotundatus* probably should be reassigned to *M. intermedius*, but this could only be done by means of histological investigation.

Prooneotodus terashimai (Nogami, 1967)
Figure 33.1–33.8

- 1967 *Oneotodus terashimai* Nogami, p. 217, pl. 1, figs. 14–16.
1985 *Prooneotodus terashimai cylindricum* An and Hu, pl. 1, fig. 1.
1987 *Prooneotodus terashimai cylindricum* An and Hu; AN, p. 113, pl. 1, figs. 1–3.
2000 *Prooneotodus terashimai kazakhstanica* Dubinina, p. 179, pl. 4, figs. 19, 19a, 20, 20a.
2000 *Phakelodus terashimai* (Nogami); Göncüoğlu and Kozur, p. 599, fig. 4 (d).
? 2009 *Prooneotodus terashimai* (Nogami); Lee et al., p. 427, fig. 9 (11).

Description.—Coniform elements, moderate to small, and symmetrical. The cusp is small and hook-like. The base is slender and cylindrical. Both anterior and posterior edges are rounded. No keels or costae are present. Basal cavity is very deep, and the apex extends past the point of flexure of the element.

Materials.—20 specimens.

Occurrence.—Known from the Wangcun and Wa'ergang sections, where it ranges from the *Westergaardodina lui-Westergaardodina ani* Zone through the *Cordylodus proavus* Zone.

Remarks.—*Prooneotodus terashimai* is characterized by the minute and hook-like cusp. An and Hu (1985) erected a new subspecies *Prooneotodus terashimai cylindricum*. The only difference between them is that the latter is much slender in

gross morphology. It is considered as intraspecific variation herein.

Prooneotodus? sp. A
Figure 33.9

Description.—Large coniform element with pointed apex. There is no conspicuous junction between cusp and base. The anterior side is slightly convex, whereas the posterior side is strongly convex. Keels and costae are lacking. The cross-section is circular at the apex and becomes roundly triangular in the rest of the element. Basal cavity is large and extends nearly to tip.

Materials.—Only one specimen.

Occurrence.—Known from the Wa'ergang section, where it occurs in the *Eoconodontus* Zone.

Genus *Prosagittodontus* Müller and Nogami, 1971

Type species.—*Sagittodontus dalmani* Müller, 1959.

Prosagittodontus compressus new species
Figure 33.10, 33.11

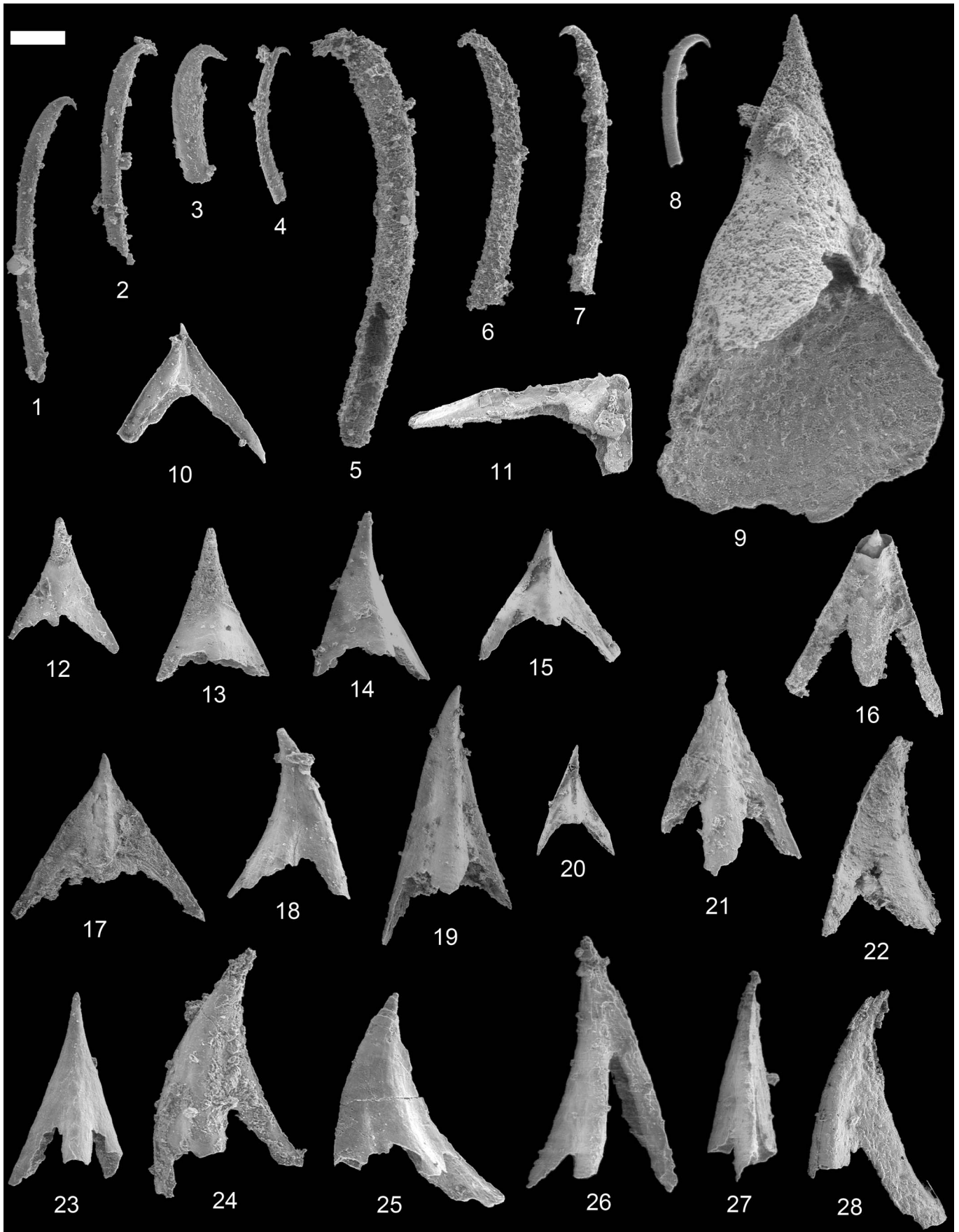
- 1994 *Laiwugnathus sagittatus* An and Mei, p. 537, pl. 1, figs. 28, 29.
2001a *Prosagittodontus?* sp. Dong and Bergström, p. 963, pl. 1, figs. 17, 18.

Diagnosis.—A species of *Prosagittodontus* with two lateral projections inclining downward, with the outer parts strongly compressed. A third projection becomes a rounded median keel or an indistinct bulge. The basal cavity is moderately large and deep.

Description.—Coniform elements shaped like arrowheads in outline. The apical angle is less than 90°. From the pointed tip, the flanks diverge in an almost straight line, separating into two lateral projections that are strongly compressed in the outer parts, with sharp costae on the margins. A third projection becomes a rounded median keel or an indistinct bulge. The anterior side of elements is flattened, whereas the posterior side is concave. The basal cavity is moderately large and deep.

Etymology.—*compressus*, Latin, compressed.

Figure 33. (1–8) *Prooneotodus terashimai* (Nogami, 1967); (1) Bitiao Formation, Wangcun section, GMPKU2885, lateral view; (2) Bitiao Formation, Wangcun section, GMPKU2886, lateral view; (3) Bitiao Formation, Wangcun section, GMPKU2887, lateral view; (4) Bitiao Formation, Wangcun section, GMPKU2888, lateral view; (5) Bitiao Formation, Wangcun section, GMPKU2889, lateral view; (6) Bitiao Formation, Wangcun section, GMPKU2890, lateral view; (7) Bitiao Formation, Wa'ergang section, GMPKU2891, lateral view; (8) Shenjiawan Formation, Wa'ergang section, GMPKU2892, lateral view; (9) *Prooneotodus?* sp. A, Shenjiawan Formation, Wa'ergang section, GMPKU2893, posterior view; (10, 11) *Prosagittodontus compressus* n. sp.; (10) Chefu Formation, Wangcun section, holotype, GMPKU2894, anterior view; (11) Chefu Formation, Wangcun section, GMPKU2895, posterior view; (12–28) *Prosagittodontus dalmani* (Müller, 1959); (12) Bitiao Formation, Wangcun section, GMPKU2896, posterior view; (13) Bitiao Formation, Wangcun section, GMPKU2897, posterior view; (14) Bitiao Formation, Wangcun section, GMPKU2898, posterior view; (15) Bitiao Formation, Wangcun section, GMPKU2899, posterior view; (16) Bitiao Formation, Wangcun section, GMPKU2900, posterior view; (17) Bitiao Formation, section, Wa'ergang GMPKU2901, posterior view; (18) Shenjiawan Formation, Wa'ergang section, GMPKU2902, oblique posterior view; (19) Bitiao Formation, Wangcun section, GMPKU2903, posterior view; (20) Bitiao Formation, Wangcun section, GMPKU2904, posterior view; (21) Bitiao Formation, Wangcun section, GMPKU2905, posterior view; (22) Bitiao Formation, Wangcun section, GMPKU2906, oblique posterior view; (23) Shenjiawan Formation, Wa'ergang section, GMPKU2907, posterior view; (24) Shenjiawan Formation, Wa'ergang section, GMPKU2908, posterior view; (25) Shenjiawan Formation, Wa'ergang section, GMPKU2909, posterior view; (26) Shenjiawan Formation, Wa'ergang section, GMPKU2910, posterior view; (27) Shenjiawan Formation, Wa'ergang section, GMPKU2911, posterior view; (28) Shenjiawan Formation, Wa'ergang section, GMPKU2912, oblique posterior view. Relative scale bar represents 137 µm (1–19, 21–28), 144 µm (20).



Types.—Holotype: GMPKU2894, from the *Westergaardodina matsushitai*-*Westergaardodina grandidens* Zone, Chefu Formation, Wangcun section, Wangcun village, Yongshun county, Hunan Province.

Materials.—Nine specimens.

Occurrence.—Known from the Wangcun and Paibi sections, where it ranges from the *Westergaardodina quadrata* Zone through the *Westergaardodina lui*-*Westergaardodina ani* Zone.

Remarks.—*Prosagittodontus compressus* n. sp. appears to be the transitional form among *Prosagittodontus*, *Laiwugnathus*, and tricuspidate *Westergaardodina*. However, the outline of *Laiwugnathus* is triangular or subtriangular, while tricuspidate *Westergaardodina* has a median projection. Accordingly, this species is assigned to *Prosagittodontus* herein.

Prosagittodontus dalmani (Müller, 1959)
Figure 33.12–33.28

- 1959 *Sagittodontus dalmani* Müller, p. 460, pl. 14, figs. 5, 7, 10.
1971 *Sagittodontus dalmani* Müller; Müller, pl. 1, fig. 8.
1978 *Prosagittodontus dalmani* (Müller); Abaimova, p. 501, pl. 8, figs. 3, 5, 7.
1981 *Prosagittodontus dalmani* (Müller); Miller in Robison, p. W114, fig. 65. 2a, b.
1982 *Prosagittodontus dalmani* (Müller); An, p. 147, pl. 5, fig. 6.
1986 *Prosagittodontus dalmani* (Müller); Chen et al., p. 369, pl. 2, figs. 14, 15.
1987 *Prosagittodontus dalmani* (Müller); An, p. 113, pl. 3, figs. 23, 24.
1991 *Prosagittodontus dalmani* (Müller); Müller and Hinz, p. 37, pl. 25, figs. 1–22, text-fig. 14 (B).
2002 *Prosagittodontus dalmani* (Müller); Lee, p. 25, pl. 1, fig. 15.
2009 *Prosagittodontus dalmani* (Müller); Lee et al., p. 427, fig. 9.6.

Materials.—90 specimens.

Occurrence.—Known from the Wangcun and Paibi sections, where it ranges from the *Westergaardodina matsushitai*-*Westergaardodina grandidens* Zone through the *Cordylodus proavus* Zone.

Remarks.—The specimens at hand agree well with those described and figured by Müller (1959) and Müller and Hinz (1991). The median projection of *Prosagittodontus dalmani* is prominent and extends posteriorly, resulting in a crudely triangular basal cross-section of the element. So, *P. dalmani* differs from *Prosagittodontus compressus*.

Prosagittodontus cf. eureka (Müller, 1959)
Figure 25.1, 25.2

- 1959 cf. *Sagittodontus eureka* Müller, p. 461, pl. 14, fig. 6.
1973 cf. *Prosagittodontus eureka* (Müller); Müller, p. 45, pl. 5, figs. 1–2.

1982 *Prosagittodontus eureka* (Müller); An, p. 147, pl. 5, figs. 1–2.

1982 *Prosagittodontus aff. eureka* (Müller); An, p. 148, pl. 5, figs. 4, 8.

2011 *Prosagittodontus aff. eureka* (Müller); Bagnoli and Qi, p. 12, fig. 4 (D, E).

Materials.—Four specimens.

Occurrence.—Known from Wangcun section, where it occurs *Westergaardodina lui*-*Westergaardodina ani* Zone.

Remarks.—The specimens at hand are similar to those described and figured by Müller (1959, 1973), but the median keel on the posterior side of the present specimens is much less distinct than that of *Prosagittodontus eureka* s. s. An (1982) described and figured four specimens assigned to *P. eureka* or *Prosagittodontus aff. eureka*. Those specimens should be all assigned to *Prosagittodontus cf. eureka*.

Genus *Serratocambria* Müller and Hinz, 1991

Type species.—*Serratocambria minuta* Müller and Hinz, 1991.

Serratocambria minuta Müller and Hinz, 1991
Figure 25.3, 25.6, 25.7

- 1991 *Serratocambria minuta* Müller and Hinz, p. 38, pl. 27, figs. 1–17, text-fig. 15 (A, B).
1994 *Serratocambria dacryoidea* An and Mei, p. 538, pl. 2, figs. 25–26.

Description.—Ramiform elements, small and asymmetrical, with a long serrated lateral process. The small cusp is strongly recurved and spine-like. Both anterior and posterior sides are broadly rounded. The lateral process is long, compressed, and serrated on its upper edge. Basal cavity is moderate in size, with the apex extending nearly up to the point of flexure of the element. Cross section is round at the apex and changes into a variable outline at the base.

Materials.—12 specimens.

Occurrence.—Known only from the Wangcun section, where it occurs in the *Westergaardodina cf. calix*-*Prooneotodus rotundatus* Zone.

Remarks.—An and Mei (1994) erected a new species, *Serratocambria dacryoidea*. It differs from *Serratocambria minuta* in its short lateral process and the erect, serrated tiny denticles. The short lateral process is broken, and the shape of the denticles is considered to represent intraspecific variation. Thus, the two species are considered synonyms herein.

Genus *Shandongodus* An, 1982

Type species.—*Shandongodus priscus* An, 1982.

Shandongodus priscus An, 1982
Figure 26.37, 26.38

- 1982 *Shandongodus priscus* An, p. 149, pl. 4, figs. 5–8, pl. 5, fig. 10.
 1990 *Shandongodus priscus* An; Dong, pl. 1, figs. 10, 12, 13.
 1993 *Shandongodus priscus* An; Dong, pl. 3, fig. 4.
 1994 *Shandongodus priscus* An; An and Mei, pl. 2, figs. 17, 24.
 2001a *Shandongodus priscus* An; Dong and Bergström, p. 972, pl. 3, fig. 14.
 2008 *Shandongodus priscus* An; Bagnoli et al., p. 112, fig. 3 (F, G).

Materials.—Eight specimens.

Occurrence.—Known from Paibi and Wangcun sections, where it occurs in the *Shandongodus priscus*-*Hunanognathus tricuspidatus* Zone.

Remarks.—The specimens at hand agree in all respects with those described and illustrated by An (1982).

Genus *Wangcunognathus* new genus

Type species.—*Wangcunognathus elegans* n. gen. n. sp.

Diagnosis.—Reclined coniform elements, with a short, adenticulate, posterior process which possesses a sharp oral costa with a conspicuous indentation. Anterior side of elements possess two sharp antero-lateral costae extending from apex to base. Posterior side of cusp possesses a sharp costa. Basal cavity deep, with a tip that ends higher than the top of posterior process.

Etymology.—Named for the Wangcun section in Hunan Province and *gnathus*, Greek, jaw.

Wangcunognathus elegans new genus new species
 Figure 34.1–34.26

Diagnosis.—As for the genus.

Description.—Reclined coniform elements with a short adenticulate, posterior process. It is asymmetrical due to lateral bending. The anterior sides of elements are slightly convex with two sharp anterolateral costae extending from apex to base. The posterior sides of cusps possess a sharp costa, which leads to the subtriangular cross-section of the cusp. The base is slightly either compressed or expanded laterally to a variable extent, so the cross-section of the base is variable in shape. The oral margin is characterized by a sharp costa with a conspicuous indentation. Basal cavity deep, with a tip that ends above the top of the posterior process.

Etymology.—*elegans*, Latin, elegant.

Types.—Holotype: GMPKU2950 from the *Westergaardodina lui*-*Westergaardodina ani* Zone, Bitiao Formation, Wangcun section, Wangcun village, Yongshun county, Hunan Province.

Materials.—300 specimens.

Occurrence.—Known from the Wangcun section, where it occurs in the *Westergaardodina lui*-*Westergaardodina ani* Zone.

Remarks.—*Wangcunognathus elegans* n. gen. n. sp. probably is a paraconodont.

Genus *Westergaardodina* Müller, 1959

Type species.—*Westergaardodina bicuspidata* Müller, 1959.

Remarks.—The morphology of *Westergaardodina* is so different from that of other conodonts that some completely different morphological terms are used to describe these species. For example, there are two groups of species of *Westergaardodina*, those with two cusp-like features (bicuspidate) and those with three (tricuspidate). These cusp-like features are referred to as projections, two of which are lateral projections and the third (if present) is a median projection. The lateral projections may have a basal cavity or not. There may be a depression or groove around part or all of the outer perimeter of the lateral projections, referred to as a lateral cavity. In some species the projections are directed upward from the lower part of the element but then bend outward in the upper part; the turning point is where the bending begins. The morphology of elements described herein is based on the terms introduced or modified by Müller and Hinz (1991, p. 14–15).

Westergaardodina ahlbergi Müller and Hinz, 1991
 Figure 35.3

- ? 1973 *Westergaardodina muelleri* (Nogami); Müller, p. 48, pl. 2, fig. 9.
 1982 *Westergaardodina* cf. *muelleri* (Nogami); An, p. 153, pl. 6, fig. 11.
 1991 *Westergaardodina ahlbergi* Müller and Hinz, p. 41, pl. 38, figs. 1–11.

Materials.—Four specimens.

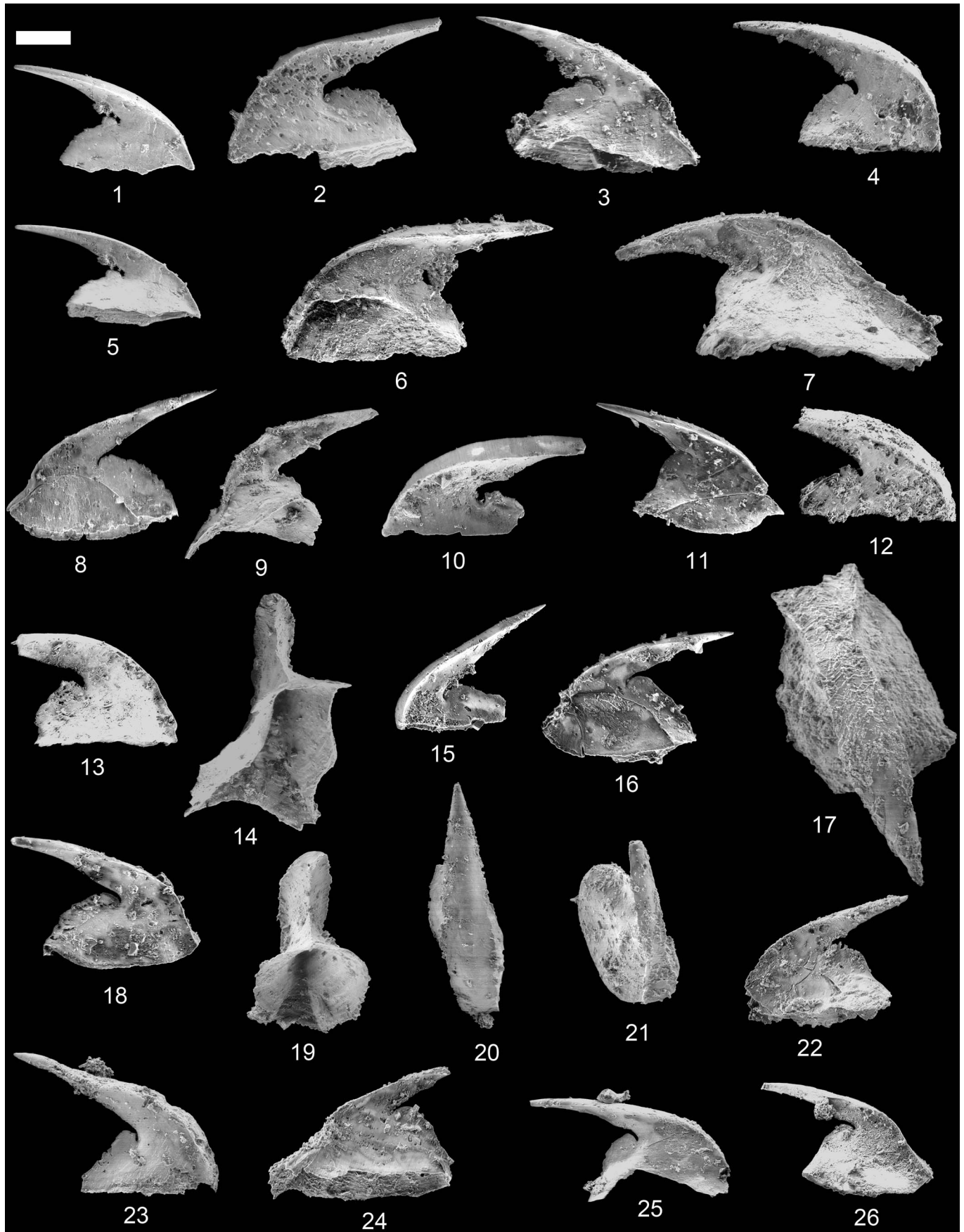
Occurrence.—Known from the Wangcun section, where it occurs in the *Westergaardodina lui*-*Westergaardodina ani* Zone.

Remarks.—The specimens at hand agree in all aspects with the species described and figured by Müller and Hinz (1991).

Westergaardodina ani Dong, Repetski, and Bergström, 2004c
 Figure 35.2, 35.4–35.6

- 2004c *Westergaardodina ani* Dong, Repetski, and Bergström, p. 1197, pl. 3, figs. 11–13, 16, 21.

Description.—Small, bicuspidate *Westergaardodina*. The anterior side is convex and characterized by deeply incised turning points, which may be indistinct due to the tiny, spine-like median projection. The median projection is absent in larger specimens. The posterior side is deeply concave. The two lateral projections are nearly of the same length, and the interspace between them is generally extremely narrow. The length/width ratio is nearly three to one. The gross morphology of the unit looks like a slender spoon. Lateral cavities are absent or indistinctly developed along the upper four-fifths of the



lateral projection. A basal cavity is absent, but a shallow furrow can be observed in some specimens.

Materials.—86 specimens.

Occurrence.—Known from Wangcun and Wa'ergang sections, where it ranges from the *Westergaardodina lui-Westergaardodina ani* Zone through the *Cordylodus lindstromi* Zone (lower part).

Comparison.—The present species differs from *Westergaardodina ligula* in its slender appearance and the different lateral cavities. Moreover, it appears considerably lower stratigraphically than *W. ligula*.

Remarks.—The present species *Westergaardodina ani* was previously called *Westergaardodina proligula*, which is a *nomen nudum* (Dong, 1999, 2000).

Westergaardodina cf. behrae Müller and Hinz, 1991
Figure 35.9

1991 cf. *Westergaardodina behrae* Müller and Hinz, p. 42, pl. 37, figs. 1–6, 9, 10, 12, 13.

Materials.—12 specimens.

Occurrence.—Known from the Wangcun section, where it occurs in the *Westergaardodina quadrata* Zone.

Remarks.—The specimens at hand agree in gross morphology with *Westergaardodina behrae* but differ in its much larger size and the converging, shorter lateral projections.

Westergaardodina brevidens Dong, 1993
Figure 35.7, 35.8

1993 *Westergaardodina brevidens* Dong, p. 353, pl. 1, figs. 6, 7.

2001a *Westergaardodina brevidens* Dong; Dong and Bergström, p. 973, pl. 1, fig. 8, pl. 2, fig. 8, pl. 6, fig. 6.

Materials.—28 specimens.

Occurrence.—Known from Paibi and Wangcun sections, where it ranges from the *Gapparodus bisulcatus-Westergaardodina*

brevidens Zone through the *Shandongodus priscus-Hunanognathus tricuspis* Zone.

Remarks.—The present specimens agree well with those described and figured by Dong and Bergström (2001a).

Westergaardodina cf. calix Müller and Hinz, 1991
Figure 35.10–35.20

1991 cf. *Westergaardodina cf. calix* Müller and Hinz, p. 43, pl. 37, figs. 7, 8, 11, 14–16.

2004c *Westergaardodina cf. calix* Müller and Hinz; Dong et al., p. 1197, pl. 1, figs. 15–20, 22–25, 28.

Description.—Small- to medium-size, bilaterally symmetrical, tricuspidate elements. The profile is rather flat. The median projection is narrower and longer than the lateral ones. In relation to the total length, the turning points are fairly high. The anterior side is smooth, with a wide central depression. The posterior side is a little smaller than the anterior one, especially along the lateral margin. The median projection bears a distinct rod-like keel, which extends above the turning points but does not reach the basal margin. Lateral cavities are developed in most specimens along the upper part of the lateral projections. Basal cavity is absent.

Materials.—78 specimens.

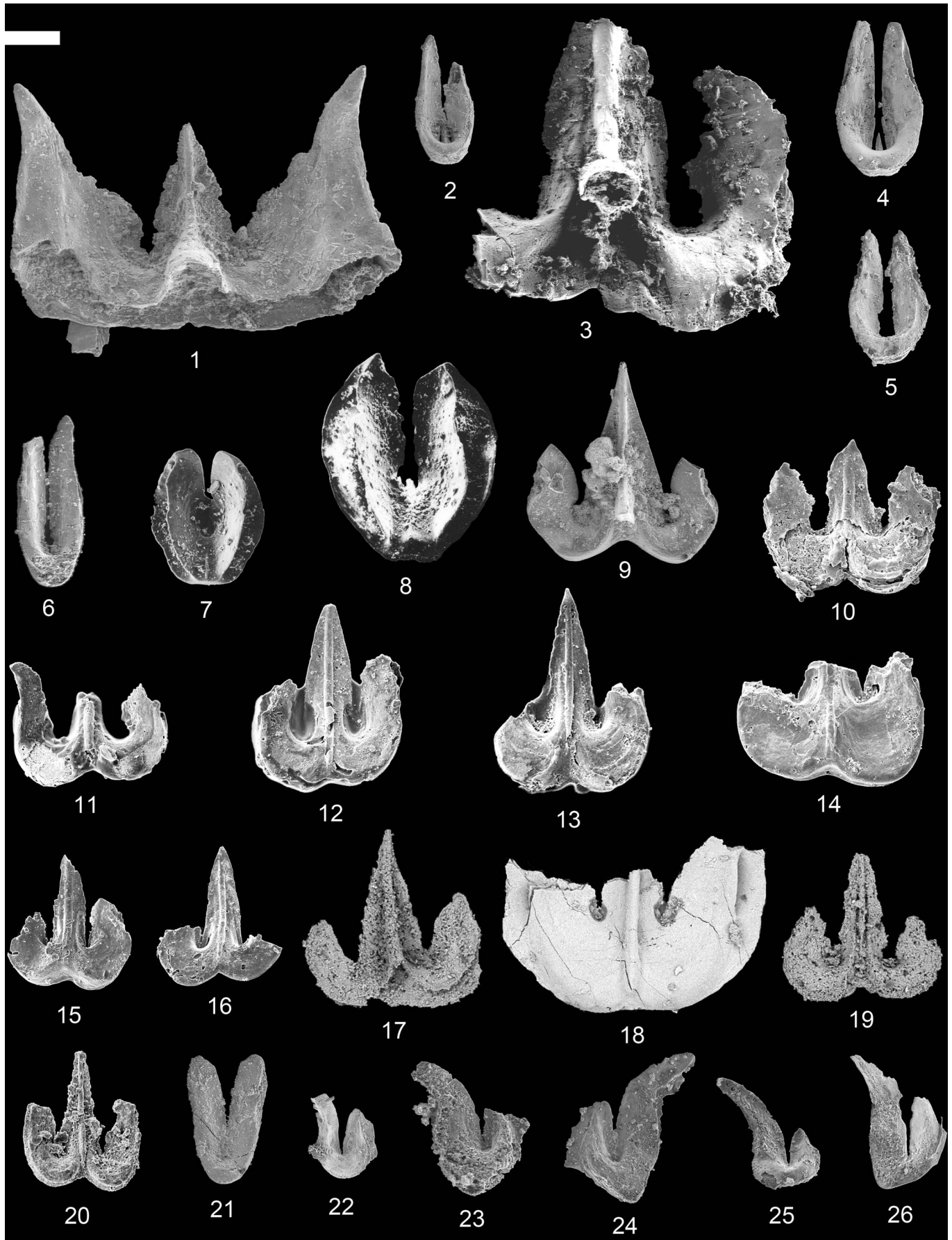
Occurrence.—Known from the Wangcun and Wa'ergang sections, where it ranges from the *Westergaardodina cf. calix-Prooneotodus rotundatus* Zone through the *Cordylodus intermedius* Zone.

Remarks.—This species includes specimens which are not well preserved and previously were included in *Westergaardodina cf. behrae*. The present form resembles *Westergaardodina calix* in gross morphology, but it differs in its narrower and longer median projection, and in being thicker. Moreover, it appears lower stratigraphically than *W. calix*. Because the majority of the specimens of *Westergaardodina cf. calix* are not completely preserved in that one, two, or three of the upper parts of the three projections are missing, we do not propose it as a new species. The main difference between *Westergaardodina behrae* and *W. cf. calix* is in the height of the turning points, the width of the median projection, and the relative lengths of the elements (Müller and Hinz, 1991, p. 42).

Westergaardodina dimorpha new species
Figures 35.22–35.26, 36.1–36.4

←

Figure 34. (1–26) *Wangcunognathus elegans* n. gen. n. sp.; (1) Bitiao Formation, Wangcun section, GMPKU2941, lateral view; (2) Bitiao Formation, Wangcun section, GMPKU2942, lateral view; (3) Bitiao Formation, Wangcun section, GMPKU2943, lateral view; (4) Bitiao Formation, Wangcun section, GMPKU2944, lateral view; (5) Bitiao Formation, Wangcun section, GMPKU2945, lateral view; (6) Bitiao Formation, Wangcun section, GMPKU2946, lateral view; (7) Bitiao Formation, Wangcun section, GMPKU2947, lateral view; (8) Bitiao Formation, Wangcun section, GMPKU2948, lateral view; (9) Bitiao Formation, Wangcun section, GMPKU2949, lateral view; (10) Bitiao Formation, Wangcun section, holotype, GMPKU2950, lateral view; (11) Bitiao Formation, Wangcun section, GMPKU2951, lateral view; (12) Bitiao Formation, Wangcun section, GMPKU2952, lateral view; (13) Bitiao Formation, Wangcun section, GMPKU2953, lateral view; (14) Bitiao Formation, Wangcun section, GMPKU2954, posterior view; (15) Bitiao Formation, Wangcun section, GMPKU2955, lateral view; (16) Bitiao Formation, Wangcun section, GMPKU2956, lateral view; (17) Bitiao Formation, Wangcun section, GMPKU2957, oblique anterior view; (18) Bitiao Formation, Wangcun section, GMPKU2958, lateral view; (19) Bitiao Formation, Wangcun section, GMPKU2959, posterior view; (20) Bitiao Formation, Wangcun section, GMPKU2960, oblique anterior view; (21) Bitiao Formation, Wangcun section, GMPKU2961, lateral-anterior view; (22) Bitiao Formation, Wangcun section, GMPKU2962, lateral view; (23) Bitiao Formation, Wangcun section, GMPKU2963, lateral view; (24) Bitiao Formation, Wangcun section, GMPKU2964, lateral view; (25) Bitiao Formation, Wangcun section, GMPKU2965, lateral view; (26) Bitiao Formation, Wangcun section, GMPKU2966, lateral view. Scale bar represents 127 µm (1–26).



Diagnosis.—Small, asymmetrical, bicuspidate elements comprising left and right forms. One projection is much longer than the other. No basal cavity. The lateral cavities are very small or there are no lateral cavities.

Description.—Small-sized, asymmetrical, bicuspidate elements comprising left and right forms. The lateral projections are not of equal size; one is much longer than the other. They are sub-circular in the lower part of elements and diverge at a very small angle at first, but the angle increases upward and the projections are recurved outward. The anterior side is flat or a little convex, whereas the posterior side is concave. Both projections are fused up to a level that is much higher than the turning points or are fused up to the tips of the projections, so there are no basal cavities. The very small lateral cavities are restricted only to the upper parts of the projections or there are no lateral cavities. A broad bulge may be developed in the basal region. Sometimes, the longer projection is broken and the recurved upper part is not preserved. Left and right forms occur in about equal numbers.

Etymology.—*dimorpha*, Latin, dimorphic.

Types.—Holotype: GMPKU2980 from the *Westergaardodina lui-Westergaardodina ani* Zone, Bitiao Formation, Wangcun section, Wangcun village, Yongshun county, Hunan Province.

Materials.—200 specimens

Occurrence.—Known from the Wangcun section, where it occurs in the *Westergaardodina lui-Westergaardodina ani* Zone.

Westergaardodina elegans Dong and Bergström, 2001a
Figure 36.5–36.9, 36.13

- 1993 *Westergaardodina* sp. A. Dong, p. 355, pl. 2, figs. 1–4.
2001a *Westergaardodina elegans* Dong and Bergström, p. 973, pl. 3, fig. 18, pl. 4, figs. 9, 15, pl. 6, fig. 7.
2006 *Westergaardodina elegans* Dong and Bergström; Qi et al., p. 187, pl. 3, figs. 5, 7.

Materials.—266 specimens.

Occurrence.—Known from Paibi and Wangcun sections, where it ranges from the *Shandongodus priscus-Hunanognathus tricuspoidatus* Zone through the *Westergaardodina lui-Westergaardodina ani* Zone.

Remarks.—The present specimens agree well with those described and figured by Dong and Bergström (2001a).

Westergaardodina gigantea new species
Figure 36.10–36.12

Diagnosis.—Large, symmetrical, bicuspidate elements. The posterior side is much smaller than the anterior side. The turning point is located very high.

Description.—Large-sized, symmetrical, bicuspidate elements. The anterior side is convex, whereas the posterior side is concave. The posterior side is much smaller than the anterior side. Both projections are fused at the bases. The turning points are located very high. The lateral projections are of equal size. Tips of projections are directed slightly outward, beginning near the tops of the projections. The large lateral openings wrap around the base and are exposed on the anterior sides of the base.

Etymology.—*gigantea*, Latin, gigantic.

Types.—Holotype: GMPKU2994 from the *Westergaardodina matsushitai-Westergaardodina grandidens* Zone, Chefu Formation, Wangcun section, Wangcun village, Yongshun county, Hunan Province.

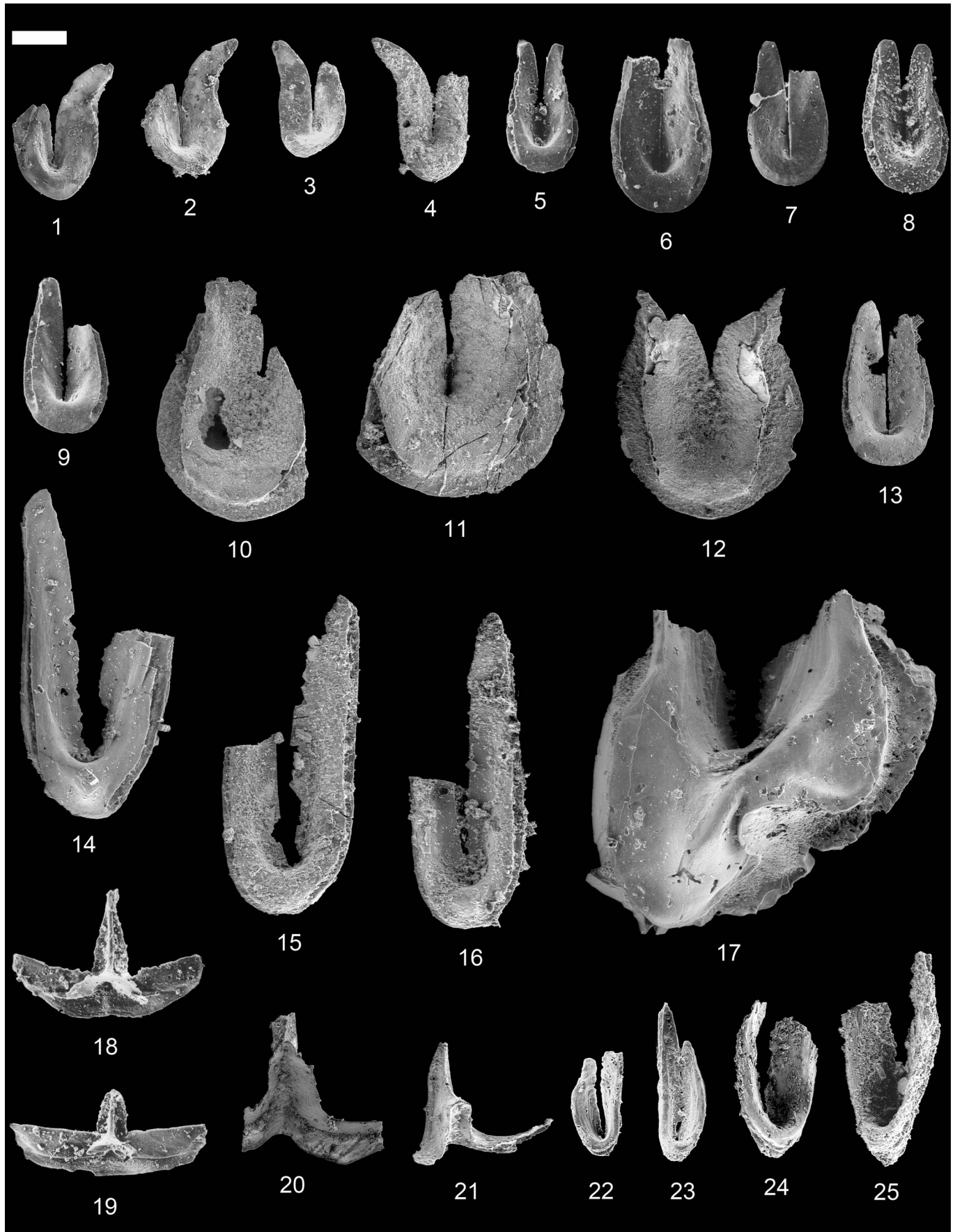
Materials.—12 specimens.

Occurrence.—Known only from Wangcun section, where it occurs in the *Westergaardodina matsushitai-Westergaardodina grandidens* Zone.

Remarks.—*Westergaardodina gigantea* n. sp. is distinguished by its large size and by the turning points being located very high.

Westergaardodina grandidens Dong, 1993
Figure 36.14–36.17

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Figure 35. (1) *Westergaardodina* sp. C, Shenjiawan Formation, Wa'ergang section, GMPKU2967, posterior view; (2, 4–6) *Westergaardodina ani* Dong, Repetski and Bergström, 2004c; (2) Bitiao Formation, Wangcun section, GMPKU2968, posterior view; (4) Bitiao Formation, Wangcun section, GMPKU2969, posterior view; (5) Bitiao Formation, Wangcun section, GMPKU2970, posterior view; (6) Panjiazui Formation, Wa'ergang section, GMPKU2971, posterior view; (3) *Westergaardodina ahlbergi* Müller and Hinz, 1991, Bitiao Formation, Wangcun section, GMPKU2972, posterior view; (7, 8) *Westergaardodina brevidens* Dong, 1993; (7) Huaqiao Formation, Paibi section, GMPKU2973, posterior view; (8) Huaqiao Formation, Paibi section, GMPKU2974, posterior view; (9) *Westergaardodina cf. behrae* Müller and Hinz, 1991, Bitiao Formation, Wangcun section, GMPKU2975, posterior view; (10–20) *Westergaardodina cf. calix* Müller and Hinz, 1991; (10) Bitiao Formation, Wangcun section, GMPKU2136, posterior view; (11) Bitiao Formation, Wangcun section, GMPKU2135, posterior view; (12) Bitiao Formation, Wangcun section, GMPKU2137, posterior view; (13) Bitiao Formation, Wangcun section, GMPKU2130, posterior view; (14) Bitiao Formation, Wangcun section, GMPKU2134, posterior view; (15) Bitiao Formation, Wangcun section, GMPKU2128, posterior view; (16) Bitiao Formation, Wangcun section, GMPKU2127, posterior view; (17) Bitiao Formation, Wangcun section, GMPKU2129, posterior view; (18) Shenjiawan Formation, Wa'ergang section, GMPKU2133, posterior view; (19) Bitiao Formation, Wangcun section, GMPKU2131, posterior view; (20) Bitiao Formation, Wangcun section, GMPKU2132, posterior view; (21) *Westergaardodina* sp. D, Huaqiao Formation, Wangcun section, GMPKU2976, posterior view; (22–26) *Westergaardodina dimorpha* n. sp.; (22) Bitiao Formation, Wangcun section, GMPKU2977, posterior view; (23) Bitiao Formation, Wangcun section, GMPKU2978, posterior view; (24) Bitiao Formation, Wangcun section, GMPKU2979, posterior view; (25) Bitiao Formation, Wangcun section, holotype, GMPKU2980, posterior view; (26) Bitiao Formation, Wangcun section, GMPKU2981, anterior view. Relative scale bar represents 171 µm (1, 3, 6, 25, 26), 165 µm (2, 4, 5, 8–13, 15, 18, 20, 21, 23, 24), 156 µm (7, 14, 16, 17, 19), 264 µm (22).



- 1978 *Westergaardodina moessebergensis* (Müller); Abaimova, p. 503, pl. 8, figs. 8, 10, ?11.
- 1991 *Westergaardodina matsushita* (Nogami); Müller and Hinz, pl. 28, fig. 17 only (not figs. 15–16, 18–20). (part)
- 1993 *Westergaardodina grandidens* Dong, p. 354, pl. 3, figs. 5, 8, 9.
- 2001a *Westergaardodina grandidens* Dong; Dong and Bergström, p. 973, pl. 4, figs. 1, 5, 7.
- 2013 *Westergaardodina grandidens* Dong; Lee, p. 169, pl. 2, figs. 10, 23–27.
- cf. 1993 *Westergaardodina horizontalis* Dong, p. 354, pl. 1, figs. 13–14.
- 2001a *Westergaardodina* cf. *horizontalis* Dong; Dong and Bergström, p. 976, pl. 2, fig. 21.

Materials.—Six specimens.

Occurrence.—Known from the Wangcun section, where it occurs in the *Westergaardodina matsushitai*–*Westergaardodina grandidens* Zone.

Remarks.—This form is similar to *Westergaardodina horizontalis* in having two horizontally extending, wing-like lateral projections, but the keel on the median projection is much shorter than in *W. horizontalis* s. s., and it is solid rather than hollow. The keel extends from the tip to a point approximately one-third of the length of the median projection, where the posterior side of the element is nearly perpendicular to the flat anterior side, forming deep and broad basal and lateral cavities.

Westergaardodina lui Dong, Repetski, and Bergström, 2004c
Figures 36.22–36.25, 37.1–37.3, 37.7–37.9

2004c *Westergaardodina lui* Dong, Repetski, and Bergström, p. 1197, pl. 3, figs. 4–10, 18–20, 22–24, 27.

Description.—A small, bilaterally asymmetrical bicuspidate *Westergaardodina*. One lateral projection is longer than another, and there are right and left forms. The anterior side is strongly convex and is characterized by a deeply incised turning point. The posterior side is deeply concave, with the maximum depth at the turning point. Along the longer lateral projection, the posterior side is smaller than the anterior one, resulting in a shallow lateral cavity extending along most of the projection. The lateral cavity is missing or weakly developed within the upper one-third of the shorter lateral projection. The base is rather narrow.

Materials.—98 specimens.

Occurrence.—Known from the Wangcun and Wa'ergang sections, where it ranges from the *Westergaardodina lui*–*Westergaardodina ani* Zone through the *Cordylodus intermedius* Zone.

Materials.—66 specimens.

Occurrence.—Known from the Paibi and Wangcun sections, where it occurs in the *Westergaardodina matsushitai*–*Westergaardodina grandidens* Zone.

Remarks.—The present specimens agree well with those described and figured by Dong and Bergström (2001a).

Westergaardodina horizontalis Dong, 1993
Figure 36.18, 36.19

- 1993 *Westergaardodina horizontalis* Dong, p. 354, pl. 1, figs. 13–14.
- 2001a *Westergaardodina horizontalis* Dong; Dong and Bergström, p. 974, pl. 6, figs. 13–14.
- ? 2008 *Westergaardodina horizontalis* Dong; Bagnoli et al., p. 112, fig. 3 (M).

Materials.—12 specimens.

Occurrence.—Known from the Paibi and Wangcun sections, where it occurs in the *Gapparodus bisulcatus*–*Westergaardodina brevidens* Zone.

Remarks.—The present specimens agree well with those described and figured by Dong and Bergström (2001a).

Westergaardodina cf. *horizontalis* Dong, 1993
Figure 36.20, 36.21

←
Figure 36. (1–4) *Westergaardodina dimorpha* n. sp.; (1) Bitiao Formation, Wangcun section, GMPKU2982, posterior view; (2) Bitiao Formation, Wangcun section, GMPKU2983, posterior view; (3) Bitiao Formation, Wangcun section, GMPKU2984, anterior view; (4) Bitiao Formation, Wangcun section, GMPKU2985, posterior view; (5–9, 13) *Westergaardodina elegans* Dong and Bergström, 2001a; (5) Chefu Formation, Paibi section, GMPKU2986, posterior view; (6) Chefu Formation, Paibi section, GMPKU2987, posterior view; (7) Chefu Formation, Paibi section, GMPKU2988, anterior view; (8) Chefu Formation, Paibi section, GMPKU2989, posterior view; (9) Chefu Formation, Paibi section, GMPKU2990, posterior view; (13) Chefu Formation, Paibi section, GMPKU2991, posterior view; (10–12) *Westergaardodina gigantea* n. sp.; (10) Chefu Formation, Wangcun section, GMPKU2992, posterior view; (11) Chefu Formation, Wangcun section, GMPKU2993, posterior view; (12) Chefu Formation, Wangcun section, holotype, GMPKU2994, posterior view; (14–17) *Westergaardodina grandidens* Dong, 1993; (14) Chefu Formation, Paibi section, GMPKU2995, posterior view; (15) Chefu Formation, Wangcun section, GMPKU2996, posterior view; (16) Chefu Formation, Wangcun section, GMPKU2997, posterior view; (17) Chefu Formation, Paibi section, large broken basal part, GMPKU2998, posterior view; (18, 19) *Westergaardodina horizontalis* Dong, 1993; (18) Huaqiao Formation, Paibi section, GMPKU2999, posterior view; (19) Huaqiao Formation, Paibi section, GMPKU3000, posterior view; (20, 21) *Westergaardodina* cf. *horizontalis* Dong, 1993; (20) Chefu Formation, Wangcun section, GMPKU3001, oblique posterior view; (21) Chefu Formation, Wangcun section, GMPKU3002, oblique posterior view; (22–25) *Westergaardodina lui* Dong, Repetski and Bergström, 2004c; (22) Bitiao Formation, Wangcun section, GMPKU2182, posterior view; (23) Bitiao Formation, Wangcun section, GMPKU2183, posterior view; (24) Shenjiawan Formation, Wangcun section, GMPKU3003, posterior view; (25) Shenjiawan Formation, Wangcun section, GMPKU3004, posterior view. Relative scale bar represents 156 µm (1, 2, 4, 7, 13–17, 19, 20, 24, 25), 145 µm (3, 5, 9, 18, 22, 23), 136 µm (6, 8), 218 µm (10–12), 199 µm (21).

Comparison.—The present species differs from *Westergaardodina ligula* in its narrow base and asymmetrical bicuspidate elements. It differs from *Westergaardodina wimani* in its narrow base, strongly convex anterior side, and deeply concave posterior side. Also, the lateral projections of *W. wimani* differ considerably in length.

Westergaardodina matsushitai Nogami, 1966
Figure 37.4–37.6, 37.10–37.12

- 1966 *Westergaardodina matsushitai* Nogami, p. 360, pl. 10, figs. 6–8.
1971 *Westergaardodina matsushitai* Nogami; Müller, fig. 1d.
1978 *Westergaardodina matsushitai* Nogami; Abaimova, p. 502, pl. 8, fig. 6.
1981 *Westergaardodina matsushitai* Nogami; An, p. 219, pl. 1, fig. 4.
1982 *Westergaardodina matsushitai* Nogami; An, p. 153, pl. 6, figs. 1–4.
1983 *Westergaardodina matsushitai* Nogami; An et al., p. 163, pl. 1, figs. 3, 4, 8.
1991 *Westergaardodina matsushitai* Nogami; Müller and Hinz, p. 46, pl. 28, figs. 15, 16, 18–20 (not fig. 17). (part)
1993 *Westergaardodina matsushitai* Nogami; Dong, p. 354, pl. 1, figs. 4, 5.
2001a *Westergaardodina matsushitai* Nogami; Dong and Bergström, p. 976, pl. 6, figs. 10–12.
? 2002a *Westergaardodina matsushitai* Nogami; Lee, p. 164, pl. 1, fig. 1.
? 2002b *Westergaardodina matsushitai* Nogami; Lee, p. 25, pl. 1, fig. 3.
2006 *Westergaardodina matsushitai* Nogami; Qi et al., p. 187, pl. 3, fig. 4.

Materials.—47 specimens.

Occurrence.—Known from the Paibi and Wangcun sections, where it occurs in the *Westergaardodirna matsushitai*-*Westergaardodirna grandidens* Zone.

Remarks.—The specimens at hand agree well with those described and illustrated by Nogami (1966) and Müller and Hinz (1991), except that their plate 8, figure 7 is assigned herein to *Westergaardodina grandidens*. Some specimens exhibit a smaller than typical angle of divergence between the lateral

projections, but that is considered to represent intraspecific variation. Müller and Hinz's (1998, p. 105) experimented on elements of *Westergaardodina polymorpha* and concluded that the angle of divergence is not of taxonomic value. However, that is not known whether or not this conclusion can be applied to other species of *Westergaardodina*.

Westergaardodina microdentata Zhang in An et al., 1983
Figure 37.13, 37.14, 37.16

- 1983 *Westergaardodina microdentata* Zhang in An et al., p. 164, pl. 1, figs. 15–17; text-fig. 9 (7).
1991 *Westergaardodina microdentata* Zhang; Müller and Hinz, p. 47, pl. 40, figs. 8–15.

Materials.—Nine specimens.

Occurrence.—Known from the Wangcun section, where it occurs from the *Westergaardodina lui*-*Westergaardodina ani* Zone through the *Westergaardodina* cf. *calix*-*Prooneotodus rotundatus* Zone.

Remarks.—The present specimens agree in all aspects with the previous descriptions and illustrations of *Westergaardodina microdentata*.

Westergaardodina cf. *nogamii* Müller and Hinz, 1991
Figure 37.15

- cf. 1991 *Westergaardodina nogamii* Müller and Hinz, p. 47, pl. 39, figs. 1–10.

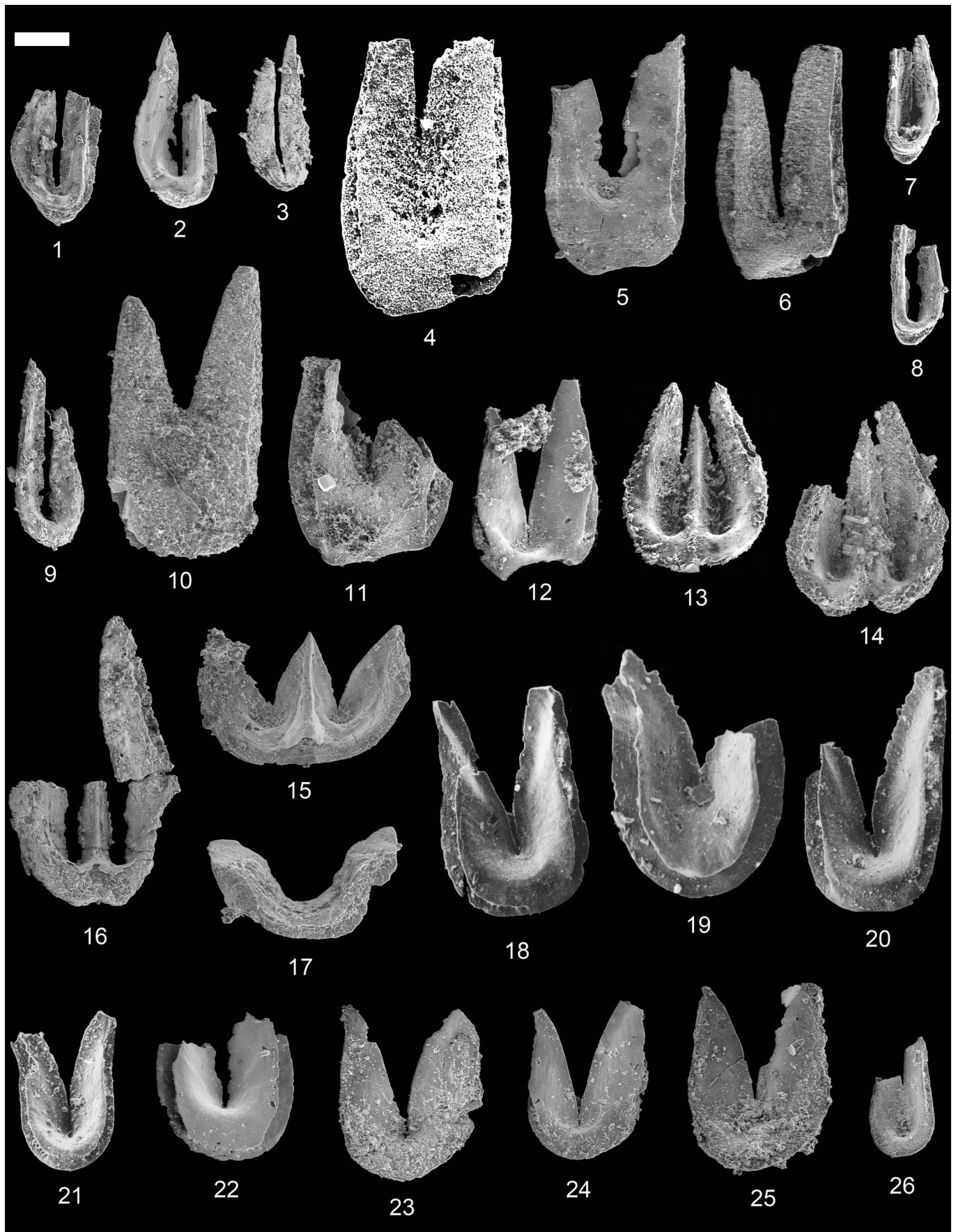
Materials.—Only one specimen.

Occurrence.—Known from the Wa'ergang section, where it occurs in the *Eoconodontus* Zone.

Remarks.—The specimen at hand approximately agrees in gross morphology with *Westergaardodina nogamii*, but it differs in its much smaller size, diverging lateral projections, and shorter median projection. Nevertheless, the present specimen is insufficient to name a new species.

Westergaardodina quadrata (An, 1982)
Figure 37.18–37.26

Figure 37. (1–3, 7–9) *Westergaardodina lui* Dong, Repetski, and Bergström, 2004c; (1) Bitiao Formation, Wangcun section, GMPKU3005, posterior view; (2) Bitiao Formation, Wangcun section, GMPKU3006, posterior view; (3) Bitiao Formation, Wangcun section, GMPKU3007, anterior view; (7) Bitiao Formation, Wangcun section, GMPKU3008, posterior view; (8) Bitiao Formation, Wangcun section, GMPKU3009, posterior view; (9) Bitiao Formation, Wangcun section, GMPKU3010, posterior view; (4–6, 10–12) *Westergaardodina matsushitai* Nogami, 1966; (4) Chefu Formation, Wangcun section, GMPKU3011, posterior view; (5) Chefu Formation, Wangcun section, GMPKU3012, posterior view; (6) Chefu Formation, Wangcun section, GMPKU3013, posterior view; (10) Chefu Formation, Wangcun section, GMPKU3014, posterior view; (11) Chefu Formation, Wangcun section, GMPKU3015, posterior view; (12) Bitiao Formation, Wangcun section, GMPKU3016, posterior view; (13) (14, 16) *Westergaardodina microdentata* Zhang, 1983; (13) Bitiao Formation, Wangcun section, GMPKU3017, posterior view; (14) Bitiao Formation, Wangcun section, GMPKU3018, posterior view; (16) Bitiao Formation, Wangcun section, GMPKU3019, posterior view; (15) *Westergaardodina* cf. *nogamii* Müller and Hinz, 1991, Shenjiawan Formation, Wa'ergang section, GMPKU3020, posterior view; (17) *Westergaardodina* sp. E, Bitiao Formation, Wangcun section, GMPKU3021, posterior view; (18–26) *Westergaardodina quadrata* (An, 1982); (18) Chefu Formation, Paibi section, GMPKU3022, posterior view; (19) Chefu Formation, Paibi section, GMPKU3023, posterior view; (20) Chefu Formation, Paibi section, GMPKU3024, posterior view; (21) Chefu Formation, Paibi section, GMPKU3025, posterior view; (22) Chefu Formation, Paibi section, GMPKU3026, posterior view; (23) Chefu Formation, Wangcun section, GMPKU3027, anterior view; (24) Chefu Formation, Wangcun section, GMPKU3028, posterior view; (25) Chefu Formation, Wangcun section, GMPKU3029, posterior view; (26) Chefu Formation, Wangcun section, GMPKU3030, posterior view. Relative scale bar represents 143 µm (1–3, 5, 6, 9–17, 19, 23–26), 136 µm (4, 7, 8, 18, 20, 21), 219 µm (22).



- 1982 *Westergaardodina moessebergensis quadrata* An, p. 153, pl. 6, figs. 5–8, 10.
- 1983 *Westergaardodina moessebergensis* (An), An et al., p. 164, pl. 1, fig. 6 only.
- 1987 *Westergaardodina bicuspadata* (Müller); An, p. 115, pl. 3, figs. 13, 18.
- 1991 *Westergaardodina quadrata* (An); Müller and Hinz, p. 50, pl. 30, figs. 9, 11–21.
- 1993 *Westergaardodina quadrata* (An); Dong, pl. 2, figs. 6, 7, 9, 10, 12.
- 2001a *Westergaardodina quadrata* (An); Dong and Bergström, p. 978, pl. 1, fig. 14, pl. 3, fig. 15, pl. 6, figs. 4, 8.
- 2006 *Westergaardodina quadrata* (An); Qi et al., p. 187, pl. 3, fig. 1.
- 2009 *Westergaardodina quadrata* (An); Lee et al., p. 425, fig. 8 (19), p. 427, fig. 9 (16).

Materials.—79 specimens.

Occurrence.—Known from the Paibi and Wangcun sections, where it ranges from the *Westergaardodina quadrata* Zone through the *Westergaardodina matsushitai*-*Westergaardodina grandidens* Zone.

Remarks.—The specimens at hand agree well with those described and illustrated by An (1982) and Müller and Hinz (1991).

Westergaardodina sola new species
Figure 26.1–26.3

- 2001a *Westergaardodina* sp. Dong and Bergström, p. 967, pl. 2, fig. 18.

Diagnosis.—Medium-sized elements with unique outline. The posterior side is smaller than the anterior, with a prominent bulge on the posterior side. Both sides are fused along the upper margin, so that there is only one “projection.” Basal cavity is large and connected with the “lateral cavity”.

Description.—Element is medium-sized, with an outline that is unique among all known species of *Westergaardodina*. The anterior side is flat, whereas the posterior side is concave with a prominent bulge. The posterior side is smaller than the anterior. Both sides are fused along the upper margin, which is formed into a sharp costa. Both sides extend upward on the left part of the element, leading to the formation of a structure similar to a projection. Basal cavity is large and connected with the opening of the projection-like structure. The size of the posterior side and the length and shape of the “lateral projection” are variable.

Etymology.—*sola*, Latin, sole, referring to the unique outline of the element.

Types.—Holotype: GMPKU3033 from the *Westergaardodina quadrata* Zone, Chefu Formation, Paibi section, Paibi village, Huayuan county, Hunan Province.

Materials.—Nine specimens.

Occurrence.—Known from the Wangcun and Paibi sections, where it ranges from the *Westergaardodina quadrata* Zone through the *Westergaardodina matsushitai*-*Westergaardodina grandidens* Zone.

Westergaardodina tetragonia Dong, 1993
Figure 26.4–26.9

- 1993 *Westergaardodina tetragonia* Dong, p. 355, pl. 1, figs. 1–3, 9.
- 2001a *Westergaardodina tetragonia* Dong; Dong and Bergström, p. 979, pl. 6, figs. 1, 3.
- non 2006 *Westergaardodina tetragonia* Dong; Qi et al., p. 187, pl. 3, fig. 6.

Materials.—45 specimens.

Occurrence.—Known from the Paibi and Wangcun sections, where it ranges from the *Shandongodus priscus*-*Humanognathus tricuspatus* Zone through the *Westergaardodina quadrata* Zone.

Remarks.—The present specimens agree well with those described and figured by Dong and Bergström (2001a).

Westergaardodina tricuspadata Müller, 1959
Figure 26.10–26.24

- 1959 *Westergaardodina tricuspadata* Müller, p. 470, pl. 15, figs. 5, 6.
- 1965 *Westergaardodina tricuspadata* Müller; Grant, p. 145, pl. 15, fig. 31.
- 1979 *Westergaardodina tricuspadata* Müller; Bednarczyk, p. 436, pl. 2, fig. 5.
- 1991 *Westergaardodina tricuspadata* Müller; Müller and Hinz, p. 50, pl. 36, figs. 1–4, 6.

Materials.—100 specimens.

Occurrence.—Known from the Wangcun and Wa'ergang sections, where it ranges from the *Westergaardodina lui*-*Westergaardodina ani* Zone through the *Westergaardodina* cf. *calix*-*Prooneotodus rotundatus* Zone.

Remarks.—The specimens at hand agree well with those described and illustrated by Müller (1959) and Müller and Hinz (1991).

Westergaardodina wimani Szaniawski, 1971
Figure 26.25

- 1971 *Westergaardodina wimani* Szaniawski, p. 409, pl. 1, fig. 5, pl. 5, figs. 7–9.
- 1982 *Westergaardodina wimani* Szaniawski; An, p. 156, pl. 9, fig. 9 only (not fig. 14). (part)
- 1991 *Westergaardodina wimani* Szaniawski; Müller and Hinz, p. 51, pl. 28, figs. 21–27.
- 2004c *Westergaardodina wimani* Szaniawski; Dong et al., p. 1205, pl. 3, fig. 29.

Materials.—Eight specimens.

Occurrence.—Known from the Wangcun section, where it ranges from the *Westergaardodina* cf. *calix-Prooneotodus rotundatus* Zone through the *Proconodontus* Zone.

Remarks.—The present specimens agree well with those described and illustrated by Szaniawski (1971) and Müller and Hinz (1991). Müller and Hinz (1991) assigned *Westergaardodina semitricuspidata* An, 1982 to *Westergaardodina wimani*. However, An (1982) erected his species based on only two broken specimens. In the light of additional similar specimens recovered from Hunan, the characters of this species are much more evident.

Westergaardodina sp. A
Figure 26.26

Description.—Large-sized, symmetrical, bicuspidate element. The turning point is located very high. The anterior side is flat, whereas the posterior side is slightly concave. The lateral projections extend from the triangular lower part of the element and diverge greatly, leading to an anchor-shaped profile of the element. Large lateral cavities extend from tips to bases of projections and connect with the basal cavity.

Materials.—Only one specimen.

Occurrence.—Known from Wangcun section, where it occurs in the *Westergaardodina* cf. *calix-Prooneotodus rotundatus* Zone.

Remarks.—*Westergaardodina* sp. A is distinguished by its large size, very high turning point, and the anchor-shaped profile. Nevertheless, the present specimen is inadequate to name a new species.

Westergaardodina sp. B
Figure 26.27

Description.—Large-sized, symmetrical, bicuspidate element. The turning point is located relatively high. The anterior side is slightly convex, whereas the posterior side is concave. Both lateral projections are fused up to a level that is above the turning point. The lateral projections extend from the semicircular lower part of element and diverge slightly. Tips of projections directed slightly outward, and lateral openings are only in the upper parts of the projections. The lower part of element is very thick antero-posteriorly.

Materials.—Only one specimen.

Occurrence.—Known from the Wa'ergang sections, where it occurs in the *Westergaardodina lui-Westergaardodina ani* Zone.

Remarks.—*Westergaardodina* sp. B is distinguished by its large size, relatively high turning point, and antero-posteriorly thick, semicircular lower part of element. The present specimen is insufficient to name a new species.

Westergaardodina sp. C
Figure 35.1

Description.—Large subsymmetrical, tricuspidate element. The anterior side is convex, whereas the posterior side is concave. The median projection is smaller than the lateral ones. It is characterized by a long keel which extends from tip to base and ends with a conical opening. The tips of lateral projections are directed outward. The large basal cavity is continuously open near the base.

Materials.—Eight specimens, but only one specimen is well preserved.

Occurrence.—Known from the Wa'ergang sections, where it occurs in the *Eoconodontus* Zone.

Comparison.—The specimen at hand are somewhat similar to *Westergaardodina amplivava* Müller, 1959 in gross morphology. They differ from the latter in having a wider median projection that has a larger funnel-shaped keel. Also, there are no keels on the lateral projections of the present species.

Westergaardodina sp. D
Figure 35.21

Description.—Small-sized, symmetrical, bicuspidate elements. The lateral projections diverge at an acute angle. The turning points are located relatively high. The anterior side is convex, whereas the posterior side is concave. Both vertical projections are fused up to a level that is a little below the turning points. The lateral cavities are small and extend upward to just a little below the turning points. A broad bulge is developed in the basal region.

Materials.—Nine specimens, but only one specimen is well preserved.

Occurrence.—Known from the Wangcun section, where it occurs in the *Shandongodus priscus-Hunanognathus tricuspidatus* Zone.

Westergaardodina sp. E
Figure 37.17

Description.—Medium-sized, subsymmetrical, bicuspidate elements which are distinguished by the broad U-shaped or saddle-shaped profile. There is no conspicuous boundary between the base and the two lateral projections, which extend laterally. The anterior side is convex, whereas the posterior side is concave and smaller than the anterior side. Both sides are fused along the entire upper margin of the element. Basal cavity is shallow and connected with the lateral cavities in some specimens that have deep lateral cavities.

Materials.—Eight specimens, but only one specimen is well preserved.

Occurrence.—Known from Wangcun section, where it occurs in the *Westergaardodina* cf. *calix-Prooneotodus rotundatus* Zone.

Comparison.—*Westergaardodina* sp. E differs from any known species of *Westergaardodina* in its peculiar profile.

Genus *Yongshunella* Dong and Bergström, 2001a

Type species.—*Yongshunella polymorpha* Dong and Bergström, 2001a.

Yongshunella polymorpha Dong and Bergström, 2001a
Figure 26.28

- 1993 *Hertzina?* sp. A. Dong, p. 351, pl. 5, figs. 1, 2, 6.
2001a *Yongshunella polymorpha* Dong and Bergström, p. 980, pl. 1, fig. 20, pl. 2, figs. 1–7, 14, 22, pl. 4, figs. 8, 14.
2006 *Yongshunella polymorpha* Dong and Bergström; Qi et al., p. 187, pl. 3, fig. 16.
2008 *Yongshunella polymorpha* Dong and Bergström; Bagnoli et al., p. 112, Fig. 3 (C–E).

Materials.—120 specimens.

Occurrence.—Known from the Paibi and Wangcun sections, where it ranges from the *Gapparodus bisulcatus*-*Westergaardodina brevidens* Zone through the *Westergaardodina lui*-*Westergaardodina ani* Zone.

Remarks.—The present specimens agree well with described and figured by Dong and Bergström (2001a).

Protoconodonts

Phylum Chaetognatha Leuckart, 1854
Order Protoconodontida Landing, 1995

Genus *Gapparodus* Abaimova, 1978

Type species.—*Hertzina? bisulcatus* Müller, 1959.

Gapparodus bisulcatus (Müller, 1959)
Figure 28.24–28.26

- 1959 *Hertzina? bisulcatus* Müller, p. 456, pl. 13, figs. 22, 23, 27.
1966 *Hertzina? bisulcatus* Müller; Poulsen, p. 8, pl. 1, fig. 9, text-fig. 3.
1969 *Hertzina bisulcatus* Müller; Clark and Robison, p. 1045, fig. 1 (d).
1969 *Hertzina bisulcatus* Müller; Clark and Miller, fig. 1 (2–4).
1971 *Hertzina bisulcatus* Müller; Müller, p. 12, pl. 1, fig. 7.
1973 *Hertzina bisulcatus* Müller; Özgül and Gedik, p. 47, pl. 1, fig. 8.
1974 *Hertzina bokononi* Landing, p. 1246, text-fig. 1 (h, i).
1974 *Hertzina bisulcatus* Müller; Landing, p. 1246, text-fig. 1 (c, d, e, f). (with var. 1 and 2)
1975 *Hertzina bisulcatus* Müller; Lee, p. 80, pl. 1, figs. 2c, 3.
1976 *Hertzina? bisulcatus* Müller; Bengtson, p. 191, figs. 5–9.
1976 *Hertzina? bisulcatus* Müller; Abaimova and Ergaliev, p. 392, pl. 14, figs. 12–15.

- 1978 *Gapparodus heckeri* Abaimova, p. 496, pl. 7, figs. 3, 4, text-fig. 1 (e).
1978 *Gapparodus bellus* Abaimova, p. 497, pl. 7, figs. 6, 7, text-fig. 1 (g).
1978 *Gapparodus bisulcatus* (Müller); Abaimova, p. 497, p. 7, fig. 8, text-fig. 1 (h).
1978 *Gapparodus porrectus* Abaimova, p. 497, p. 7, fig. 5, text-fig. 1 (i).
1987 *Gapparodus bisulcatus* (Müller); An, p. 106, pl. 1, figs. 6, 8–9, 26. (part)
1990 *Gapparodus bisulcatus* (Müller); An and Zheng, p. 159, pl. 2, figs. 2, 8.
1991 *Gapparodus bisulcatus* (Müller); Müller and Hinz, p. 25, pl. 3, figs. 1–42.
1993 *Gapparodus bisulcatus* (Müller); Dong, pl. 6, figs. 1, 3, 9, 12.
1994 *Gapparodus bisulcatus* (Müller); An and Mei, pl. 1, fig. 30.
1998 *Gapparodus bisulcatus* (Müller); Müller and Hinz, p. 96, fig. 2 (1–11).
2001a *Gapparodus bisulcatus* (Müller); Dong and Bergström, p. 964, pl. 3, figs. 1, 3, pl. 5, fig. 11.
2006 *Gapparodus bisulcatus* (Müller); Qi et al., p. 187, pl. 3, fig. 15.
2008 *Gapparodus bisulcatus* (Müller); Bagnoli et al., p. 112, fig. 3 (O).
2009 *Gapparodus bisulcatus* (Müller); Lee et al., p. 420, fig. 6 (1, 11, 15, 22).

Description.—Moderate to large, slender coniform elements, evenly recurved over their entire length, so there is no conspicuous junction between cusp and base. Both anterior and posterior sides are convex. The lateral sides are characterized by distinct furrows, the position of which is variable. Basal cavities are very deep, with the apex extending nearly to the tip of the element. The cross section is circular at the apical portion and changes into a variable outline toward the base.

Materials.—Approximately 1200 specimens.

Occurrence.—Known from the Paibi, Wangcun and Wa'ergang sections, where it ranges from the *Gapparodus bisulcatus*-*Westergaardodina brevidens* Zone through the *Westergaardodina lui*-*Westergaardodina ani* Zone. The species is common in South China, Sweden, Denmark, and Kazakhstan and it has also been found in Ordos, northwestern China and eastern New York State. It is rare in most of North China and in most of North America. Its distribution suggests that it most probably preferred cold-water environments.

Remarks.—The specimens at hand agree in all respects with the elements described by Müller and Hinz (1991).

Genus *Gumella* Müller and Hinz, 1991

Type species.—*Gumella cuneata* Müller and Hinz, 1991.

Gumella cuneata Müller and Hinz, 1991
Figure 19.1–19.3

- 1971 *Hertzina elongata* Müller, pl. 1, fig. 2.
 1987 *Gapparodus bisulcatus* (Müller); An, p. 106, pl. 1, fig. 10. (part)
 1991 *Gumella cuneata* Müller and Hinz, p. 26, pl. 4, figs. 1–25, pl. 5, figs. 1–28.
 1998 *Gumella cuneata* Müller and Hinz; Müller and Hinz p. 97, figs. 3, 4 (1–7), 5 (1–5).
 2001a *Gumella cuneata* Müller and Hinz; Dong and Bergström, p. 964, pl. 1, figs. 5–7, 11, 19.
 2008 *Gumella cuneata* Müller and Hinz; Bagnoli et al., p. 112, fig. 3 (N).
 2009 *Gumella cuneata* Müller and Hinz; Lee et al., p. 421, fig. 6 (19–21), p. 425, fig. 8 (15).

Description.—Coniform elements, moderate to large, proclined, with no conspicuous junction between cusp and base. Anterior sides convex, posterior sides flattened. Lateral sides characterized by symmetrical posterolateral furrows, the posterior sides of which are reinforced by an additional unit. Basal cavity very large and deep, with its apex extending nearly to the tip of the element. The cross section is circular at the apical portion and it changes into a variable outline toward the base.

Materials.—280 specimens.

Occurrence.—Known from the Paibi, Wangcun, and Wa'ergang sections, where it ranges from the *Gapparodus bisulcatus*-*Westergaardodina brevidens* Zone through the *Westergaardodina lui*-*Westergaardodina ani* Zone.

Remarks.—*Gumella cuneata* and *Gapparodus bisulcatus* are similar in gross morphology, but the former species has more distinct and deeper lateral furrows reinforced by an additional unit (Müller and Hinz, 1991, p. 26). Although the internal structure of the two species represents the same type, the structure of *G. cuneata* appears to be somewhat more complex. The fact that elements of *G. cuneata* and *G. bisulcatus* frequently occur together and are quite similar in external and internal morphology may indicate that they represent the same multi-element species.

Genus *Huayuanodontus* Dong and Bergström, 2001a

Type species.—*Albiconus? tricornis* Dong, 1993.

Huayuanodontus tricornis (Dong, 1993)
 Figure 19.14–19.16, 19.22–19.24

- 1993 *Albiconus? tricornis* Dong, p. 349, pl. 6, figs. 4, 5, 11, 15, 20–22.
 2001a *Huayuanodontus tricornis* (Dong); Dong and Bergström, p. 964, pl. 2, figs. 15–16, pl. 3, figs. 2, 4, 8, 11.
 2006 *Huayuanodontus tricornis* (Dong); Qi et al., p. 187, pl. 3, figs. 13–14.
 2008 *Huayuanodontus tricornis* (Dong); Bagnoli et al., p. 112, fig. 3 (I).
 2013 *Huayuanodontus tricornis* (Dong); Lee, p. 168, pl. 1, figs. 24–26.

Materials.—600 specimens.

Occurrence.—Present in the Paibi, Wangcun, and Wa'ergang sections, where it ranges from the *Gapparodus bisulcatus*-*Westergaardodina brevidens* Zone through the *Proconodontus tenuiserratus* Zone.

Remarks.—The specimens at hand agree well with *Huayuanodontus tricornis* described and figured by Dong and Bergström (2001a). The present species differs from *Albiconus postcostatus* Miller in having a triangular, rather than roundly triangular, cross-section, and a more slender shape of the element which is not laterally compressed, as is Miller's species. The present species occurs in significantly older strata than *A. postcostatus*, which is present in strata near the Cambrian–Ordovician boundary. The present form looks like a protoconodont. However, preliminary histological investigation indicates it is neither a protoconodont nor a paraconodont. It is also not a euconodont (Dong, 2007a). Therefore, further detailed histological work is needed to substantiate the nature of the present genus, although it seems beyond the scope of this study.

Genus *Paibiconus* Dong, 1993

Type species.—*Paibiconus proarcuratus* Dong, 1993.

Paibiconus proarcuratus Dong, 1993
 Figure 31.1–31.4

- 1993 *Paibiconus proarcuratus* Dong, p. 353, pl. 5, figs. 12–16.
 2001a *Paibiconus proarcuratus* Dong; Dong and Bergström, p. 969, pl. 1, fig. 4, pl. 2, fig. 11, pl. 3, figs. 5–7.
 2008 *Paibiconus proarcuratus* Dong; Bagnoli et al., p. 112, fig. 3 (Q).

Materials.—660 specimens.

Occurrence.—Known from the Paibi, Wa'ergang and Wangcun sections, where it occurs from the *Gapparodus bisulcatus*-*Westergaardodina brevidens* Zone through the *Westergaardodina matsushitai*-*Westergaardodina grandidens* Zone.

Remarks.—The specimens at hand agree well with those described and figured by Dong and Bergström (2001a). Histological investigation verified that this form is a protoconodont (Dong, 2004).

Genus *Phakelodus* Miller, 1984

Type species.—*Oneotodus tenuis* (Müller, 1959).

Remarks.—Müller and Hinz (1991, p. 32) separated specimens of *Oneotodus tenuis* into two taxa, *Phakelodus tenuis* and *Phakelodus elongatus*, stating “both *P. elongatus* and *P. tenuis* are long-ranging and widespread”. Although they appear in strikingly similar clusters, they were not regarded as morphotypes of a single species. All recognized clusters are unimembrate. Further, the occurrence of these species is indeed overlapping but not

consistent enough (Müller and Hinz, 1991, table 3) for them to represent different morphotypes of a single species.

We have numerous specimens of these taxa from Hunan, where both are long-ranging and co-occurring, and are found unimemberate clusters that contain either the *Phakelodus tenuis* type or the *Phakelodus elongatus* type. However, this fact does not prove that these forms represent different species because it is quite possible that a protoconodont animal could have possessed more than one type of cluster. It is also possible that this could be an example of sexual dimorphism. In this study, we consider both these two types of elements, *P. tenuis* type (morphotype A) and *P. elongatus* type (morphotype B) to represent *P. tenuis*.

No clusters of the stout species *Phakelodus simplex* Müller and Hinz, 1991 have been found anywhere. In gross morphology, that species is more reminiscent of the paraconodont *Prooneotodus gallatini*, except that *P. simplex* has a protoconodont internal structure. It may be that *P. simplex* should not be referred to *Phakelodus*.

Phakelodus tenuis (Müller, 1959)

Figure 31.5–31.10

- 1959 *Oneotodus tenuis* Müller, p. 457, pl. 13, figs. 11, 13, 14, 20.
- 1990 *Prooneotodus tenuis* (Müller); An and Zheng, p. 160, pl. 1, figs. 1, 6, 7.
- 1991 *Phakelodus tenuis* (Müller); Müller and Hinz, p. 33, pl. 1, figs. 6, 10, 11, 15–21, 23, pl. 2, figs. 1–24. (including extensive synonymy to 1988).
- 1991 *Phakelodus elongatus* (An); Müller and Hinz, p. 32, pl. 1, figs. 1–5, 7–9, 12–14, 22. (including extensive synonymy to 1988).
- 1993 *Phakelodus tenuis* (Müller); Dong, pl. 4, figs. 12, 13, pl. 6, figs. 2, 8, 17.
- 1993 *Phakelodus tenuis* (Müller); Landing, p. 6, fig. 4 (1).
- 1993 *Phakelodus elongatus* (An); Dong, pl. 4, figs. 10, 11, pl. 6, figs. 6, 7.
- 1994 *Phakelodus tenuis* (Müller); An and Mei, pl. 1, fig. 23.
- 1998 *Phakelodus elongatus* (An); Rao and Tortello, p. 45, pl. 2, figs. 16, 17.
- 1999 *Phakelodus tenuis* (Müller); Göncüoğlu and Kozur, p. 599, fig. 4 (B).
- 2000 *Phakelodus tenuis* (Müller); Dubinina, p. 166, pl. 1, fig. 7, pl. 2, figs. 10–12, 25.
- 2000 *Phakelodus? cavatua* Dubinina, p. 166, pl. 1, figs. 19, 19a, 27, 27a.
- 2001a *Phakelodus tenuis* (Müller); Dong and Bergström, p. 970, pl. 3, fig. 19, pl. 5, figs. 8, 10, pl. 6, fig. 5.
- 2001 *Phakelodus tenuis* (Müller); Lee, p. 449, fig. 6 (1).
- 2002 *Phakelodus elongatus* (An); Lee, p. 25, pl. 1, fig. 1.
- 2002 *Phakelodus tenuis* (Müller); Lee, p. 25, pl. 1, fig. 2.
- 2002 *Phakelodus tenuis* (Müller); Lee, p. 164, pl. 1, fig. 8.
- 2004 *Phakelodus elongatus* (An); Lee, p. 60, fig. 5 (A).
- 2007 '*Phakelodus elongatus*' (Zhang in An et al., 1983); Landing et al., fig. 6 (u).
- 2007 *Phakelodus tenuis* (Müller); Landing et al., fig. 6 (s).
- 2008 *Phakelodus?* sp. Bagnoli et al., p. 112, fig. 3 (H).
- 2009 *Phakelodus tenuis* (Müller); Lee et al., p. 420, fig. 6 (12, 14).
- 2009 *Phakelodus elongatus* (An); Lee et al., p. 420, fig. 6 (9, 10).

Materials.—Approximately 20,000 specimens.

Occurrence.—*Phakelodus tenuis* is present in the Paibi, Wangcun, and Wa'ergang sections. It ranges from the *Gapparodus bisulcatus*-*Westergaardodina brevidens* Zone through the *Cordylodus lindstromi* Zone (Lower Part).

Remarks.—Our specimens agree well with *Phakelodus tenuis* type (morphotype A) and *Phakelodus elongatus* type (morphotype B), respectively.

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