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# Lopingian (Late Permian) brachiopods from South China, Part 1: Orthotetida, Orthida and Rhynchonellida

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Contents

**Abstract. For more than half a century, South China has been a classic area for the research of the Upper Permian Lopingian Series. This series contains abundant and biostratigraphically well-zoned brachiopods and other invertebrate fossils unparalleled in any other parts of the world. This two-part monographic study is aimed to (1) document the diverse brachiopod faunas of the Lopingian Series (embracing both Wuchiapingian and Changhsingian Stages) from 12 Lopingian sections in South China, and (2) to provide a comprehensive investigation into the biostratigraphical, palaeoecological and palaeobiogeographical significance of these faunas in relation to the end-Permian and pre-Lopingian (end-Guadalupian) mass extinctions.**

**Thousands of specimens collected from 12 Lopingian sections across South China have been examined and referred to about 200 species, representing the most diverse brachiopod fauna of the Lopingian in the world. The first part of the planed two-part monographic study, 73 brachiopod species in 27 genera of the Orthotetida, Orthida (in part) and Rhynchonellida are described, of which three new genera and nine new species are included. In addition, many existing species are reviewed, revised and re-described in detail in English wherever appropriate in the light of new and better materials examined. The order Orthotetida is the most flourishing group which contains 42 species in 11 genera. The order Rhynchonellida and Orthida are represented by 11 genera and five genera, respectively. The three new genera and nine new species are : *Meekella chenxianensis* n. sp., *Meekellogeyerella meekelloides* n. gen. and n. sp., *Perigeyerella chenxianensis* n. sp., *P. obesa* n. sp., *Camerenteletes enteletoides* n. gen. and n. sp., *Prelissorhynchia plena* n. sp., *Pseudostretorhynchus deflecta* n. gen. and n. sp., *Tropidelasma triangularis* n. sp., and *Uncinunellina exilis* n. sp.**

**In addition to the detailed taxonomic work, this first part of the monographic study has also provided a concise but informative stratigraphical framework in which the 12 Lopingian sections are described with detailed information on horizons where the brachiopods were collected.**

**Key words : brachiopod, Late Permian, Lopingian, South China**

## Introduction

In most recent Permian global palaeogeographical reconstructions, South China and its adjacent Cathaysian continental blocks (*e.g.*, Indo-China, Tarim, North China) have been depicted as isolated terranes located in the eastern Tethyan gape [*e.g.*, Scotese and Langford, 1995; (Scotese, Paleomap project: http://www.scotese.com/); Ziegler *et al.*, 1997, Yin *et al.*, 1999, 2004)]. It is probably due to this unique palaeogeographical position that South China has preserved the most complete Lopingian marine deposits and the best Permian-Triassic boundary sequences. To date, tens of Permian-Triassic sections have been well documented from South China (Zhao *et al.*, 1981; Sheng *et al.*, 1984; Yang *et al.*, 1987; Li *et al.*, 1989; Shen *et al.*, 1995; Yin *et al.*, 1996, 2001). The unique palaeogeographical position of South China has also led some scientists to propose that South China may have acted as the most potential region to unravel the pattern of the great end-Permian mass extinction and the pre-Lopingian biotic crisis (Jin, 1993; Jin *et al.*, 1994a; 2000, Stanley and Yang, 1994; Erwin, 1994, 2006; Shen and Shi, 1996, 2002; Shen *et al.*, 2006a; Hallam and Wignall, 1997, Shi *et al.*, 1999; Shi and Shen, 2000; Wang and Sugiyama, 2000).

Recent studies of the Permian-Triassic strata in South China have increased exponentially, with efforts being mostly concentrated on biostratigraphy and increasing attention being paid to chemostratigraphy, sequence stratigraphy, magnetostratigraphy, geochronology and eventostratigraphy [for a comprehensive and up-to-date review (see Jin *et al.*, 1994b, 1998, 2003; Erwin *et al.*, 2002, Erwin, 2006)]. In the biostratigraphical approach, microfossils, especially conodonts and fusulinids, have been explored extensively due to their relatively short biostratigraphical ranges and locally abundant occurrences (Mei *et al.*, 1994, 1998a, 1998b, 2002; Jin *et al.*, 1998; Mei and Henderson, 2002). Macrofossils, perhaps with the exception of ammonoids, have been generally under-utilized. However, the strong dependence of conodonts and fusulinids on such important ecological factors as temperature, salinity, and substrate has substantially limited their application in the Gondwanan and Boreal Realms. For instance, so far only a few Permian conodonts have been found from northern and southern high latitude regions. In contrast, brachiopods are much more ubiquitous in global distribution and have been proven very useful in correlating most Permian-Triassic sections, especially where conodonts and/or fusulinids are absent or poorly known (*e.g.*, Ding *et al.*, 1985; Shi *et al.*, 1995; Archbold, 1999; Kotlyar *et al.*, 2004; Klets and Budnikov, 2006; Shen *et al.*, 2006b; Shi, 2006).

The Lopingian Series, as a fully developed marine sequence with highly diverse faunas in South China, has been extensively studied by the Chinese working groups (Hou *et al.*, 1979; Liao, 1980a, 1987; Zhao *et al.*, 1981; Sheng and Jin, 1994; Jin *et al.*, 1994b, 1998, 2003) recently, which led to the acceptance as an international standard for the youngest series (Lopingian) of the Permian choronostratigraphic timescale (Jin *et al.*, 1997, 1998; Gradstein *et al.*, 2004) and the definitions of three GSSPs (Permian-Triassic boundary, Lopingian-base and Changhsingian-base) in South China (Yin *et al.*, 2001; Jin *et al.*, 2006a, 2006b). Many Lopingian (Wuchiapingian to Changhsingian) brachiopod faunas have been previously reported from South China (Zhan in Hou *et al.*, 1979; Liao, 1980a, 1987; Shen *et al.*, 1992; Shen and He, 1994a, 1994b; Shen *et al.*, 2004; Chen *et al.*, 2005a), but those with detailed systematic studies are still few. In this monographic paper of systematic studies, we aim to document systematically the Lopingian (Late Permian) brachiopod faunas from 12 Lopingian sections of South China (Text-Figure 1). Thousands of specimens have been examined and referred to about 200 species, representing the most diverse brachiopod fauna of the Lopingian in the world.

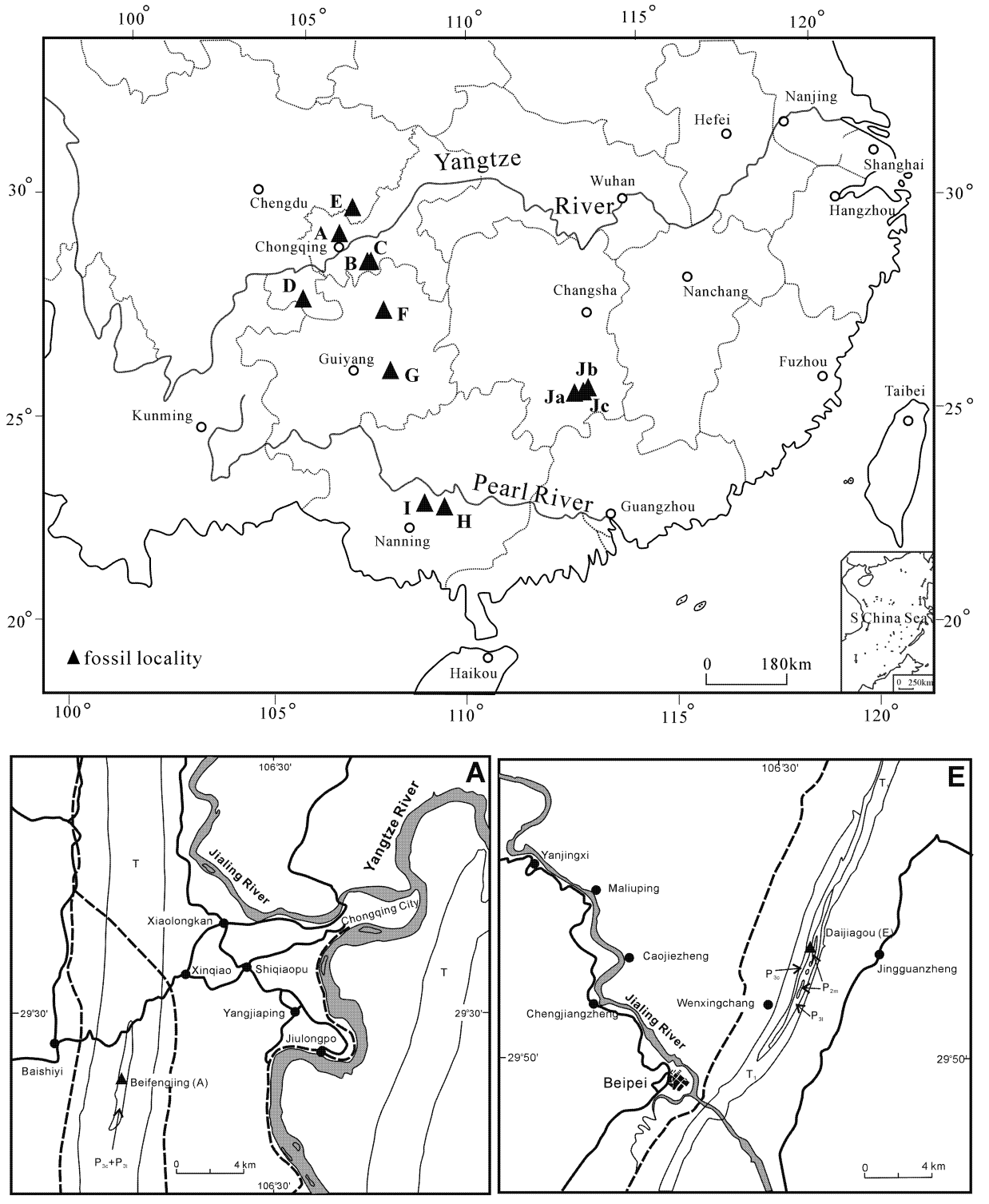
This paper is the first part of two and described Orthotetida, Orthida (in part) and Rhynchonellida (in total, 27 genera and 73 species), with a brief description of the pertinent stratigraphic sections from which the brachiopod materials were collected. A few *Peltichia* species from those sections were described in detail by Shen *et al.* (1999), therefore are not repeated in this paper except for some new occurrences from studied sections. The second part will deal with Productida, Spiriferida, Spiriferinida and Terebratulida, as well discussing the biostratigraphical zonation, correlation, and biogeography of the described Lopingian brachiopods.

In this paper and the following paper, the three-fold Permian timescale of Jin *et al.* (1997) is followed and the usage of the term Lopingian Series follows Jin *et al.* (1997), Sheng and Jin (1994) and Jin *et al.* (1998, 2003). The Lopingian Series includes two stages: the Wuchiapingian followed by the Changhsingian Stage. Its base is defined by the FAD of the conodont *Clarkina postbitteri postbitteri* at the Penglaitan section in Laibin, Guangxi Province (Jin *et al.*, 1998, 2001, 2006b; Henderson *et al.*, 2002) and its top was defined by the FAD of the conodont *Hindeodus parvus* at the Meishan D section in Changxing, Zhejiang Province (Yin *et al.*, 2001).

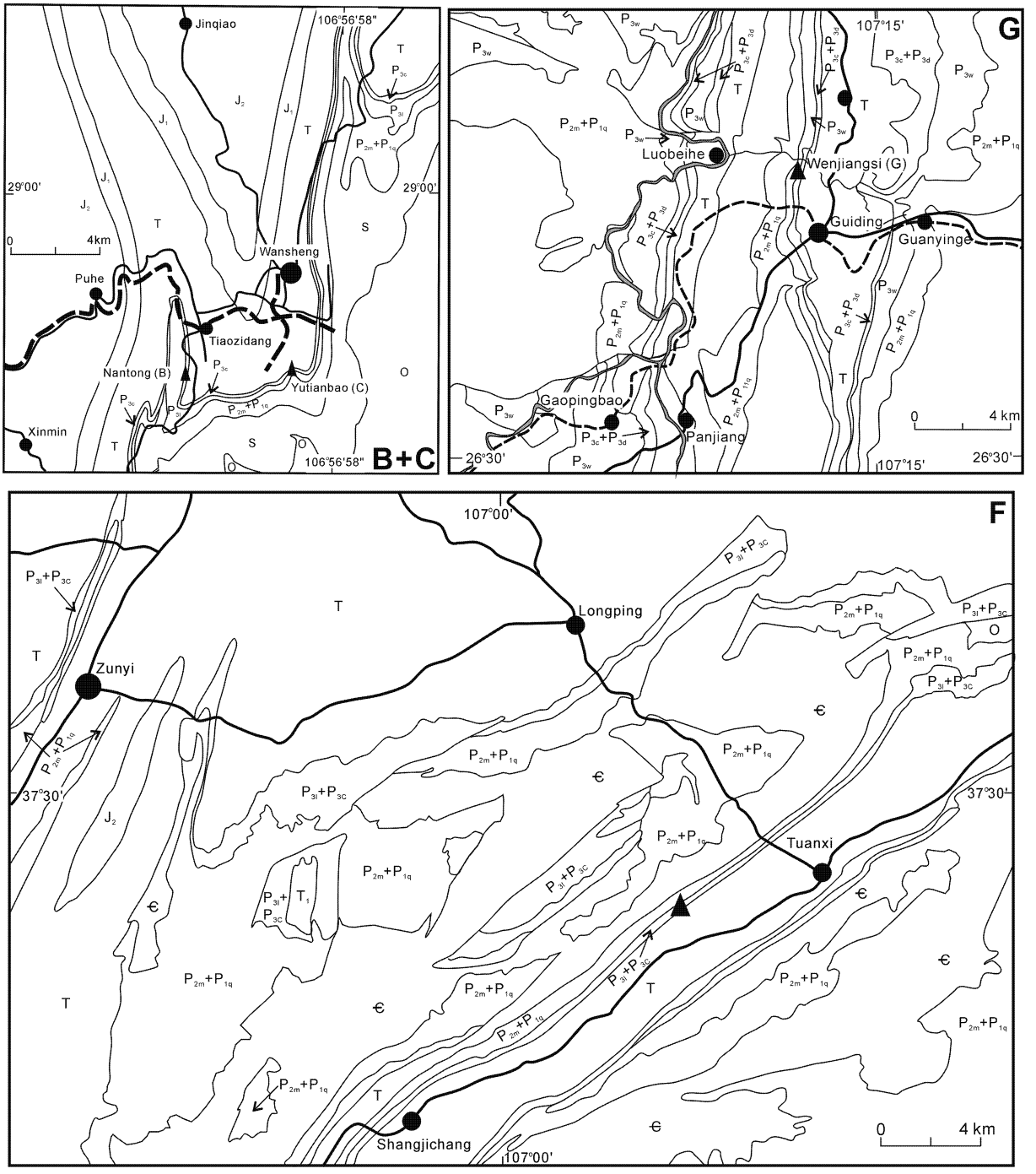
## Previous Work

Lopingian brachiopods of South China have been known for more than eight decades. However, only piecemeal systematic studies have been published on scattered elements of the diverse faunas, with many lacking detailed stratigraphic control (Frech, 1911; Grabau, 1931; Huang, 1932a, 1933; Wang, 1955a; Zhang and Jin, 1961; Wang *et al.*, 1964). According to the data provided in Wang *et al.* (1964), some 87 brachiopod species had been described from the Lopingian of South China before 1962. During the 1970s, several Late Palaeozoic palaeontological atlases of South China were published (Yang *et al.*, 1977; Tong, 1978; Feng and Jiang, 1978; Wang *et al.*, 1982), in which some Lopingian brachiopods were also briefly described and illustrated. However, many of the species reported in these atlases lack detailed stratigraphical and systematic information.

The first systematic description of the Lopingian brachiopods based on detailed stratigraphic data was provided




**Text-Figure 1.** Index Map of South China showing fossil localities from which brachiopods have been described and detailed geological maps of fossil localities. A, Beifengjing ; B, Nantong ; C, Yutianbao ; D, Chuanyan ; E, Daijiagou ; F, Tuanxi ; G, Wenjiangsi ; H, Penglaitan ; I, Heshan ; Ja, Xiaoyuanchong ; Jb, Sanhe ; Jc, Dapaichong.

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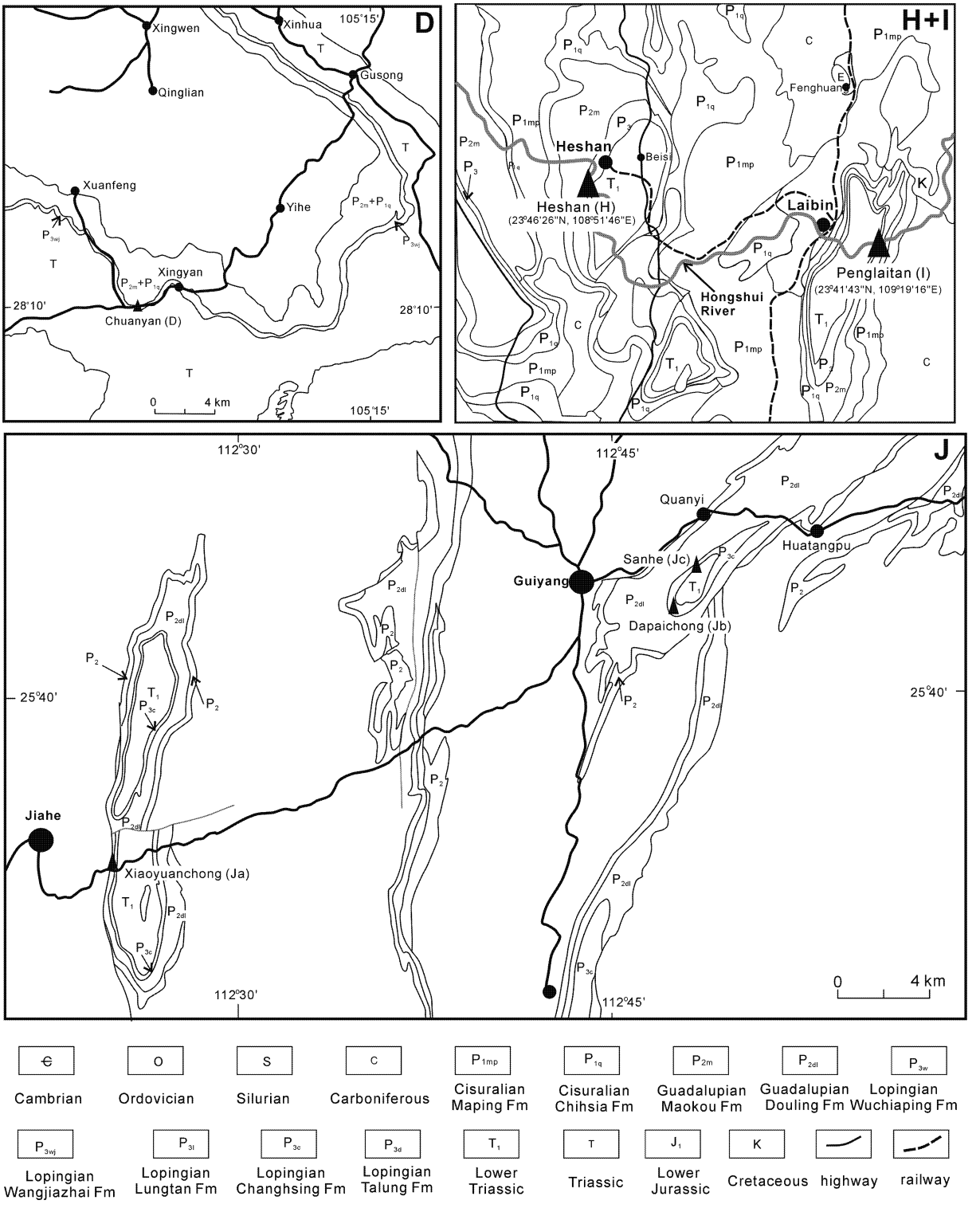



**Text-Figure 1 continued**

by Zhan (in Hou *et al.*, 1979). This study documented 77 brachiopod species from the Lopingian Wangpanli and Shuizhutang Formations in northern Guangdong Province, South China. In the following year, Liao (1980a) published an extensive study on the Lopingian brachiopods from western Guizhou and eastern Yunnan and proposed a succession of three brachiopod assemblage zones ranging from the Wuchiapingian to Changhsingian. In the same paper, Liao (1980a) also recognized two types of Changhsingian brachiopod biofacies: (1) brachiopods associated with limestone, represented by the *Peltichia zigzag–Spinomarginifera chenyaoyenensis* Assemblage, and (2) brachiopods associated with siliceous rocks, represented by the *Paryphella sulcatifera–Paracrurithyris pigmaea* Assemblage.

Several extensive studies of Changhsingian brachiopods of South China have appeared over the last decade in the light of extensive investigations by Chinese scientists on the Permian–Triassic boundary and associated geological problems. These include Liao (1980b) on brachiopods from the Permian–Triassic boundary beds in southeastern China, Liao and Meng (1986) on the brachiopods from southern Hunan Province, Liao (1987) on the silicified brachiopods from Guangxi Province, Shen *et al.* (1992) and Zeng *et al.* (1995) on the brachiopods from Chongqing, Xu and Grant (1994) on the brachiopods from Permian–Triassic boundary beds of South China, Shen and He (1994a, 1994b) from Chongqing City and Guizhou Provinces. In phase with these studies, several review papers on the zonation, palaeoecology and extinction patterns of Changhsingian brachiopods have also appeared (Yang *et al.*, 1987; Shen *et al.*, 1992; Shen and He, 1994a, 1994b; Shen and Shi, 1996, 2002; He and Shi, 1996; Shi and Shen, 2000; Rong and Shen, 2002; Chen *et al.*, 2005a, 2005b, 2005c; Shen *et al.*, 2006a).

Published information of the Lopingian brachiopods has greatly advanced our understanding of the extinction and evolutionary processes of the Late Permian brachiopod faunas. However, our knowledge is still limited as many other stratigraphical sections and brachiopod faunas remain to be described and the palaeoecological and biogeographical aspects of the faunas have only started to draw our attention for carrying potentially important insights into the Permian–Triassic events.

## Stratigraphy of Studied Sections

The Upper Permian of South China has been traditionally grouped under the name Lopingian Series, following the classic work by Huang (1932b) in which the Permian was divided into three series: Chuanshanian, Yangsingian and Lopingian in ascending order. Under this scheme, Huang (1932b) recognized three main subdivisions within the Lopingian; they are in descending order (1) Changhsing Limestone with *Oldhamina*; (2) Choutang Series (a marine facies) without *Oldhamina* and Leibakou Series (a 'non-marine series') with *Gigantopteris* Flora, and (3) the Omeishan Basalt. The Omeishan Basalt and the "Leibakou Series" have since been proved to be of latest Maokouan (Guadalupian) age and have therefore been removed from the Lopingian Series (Sheng and Jin, 1994).

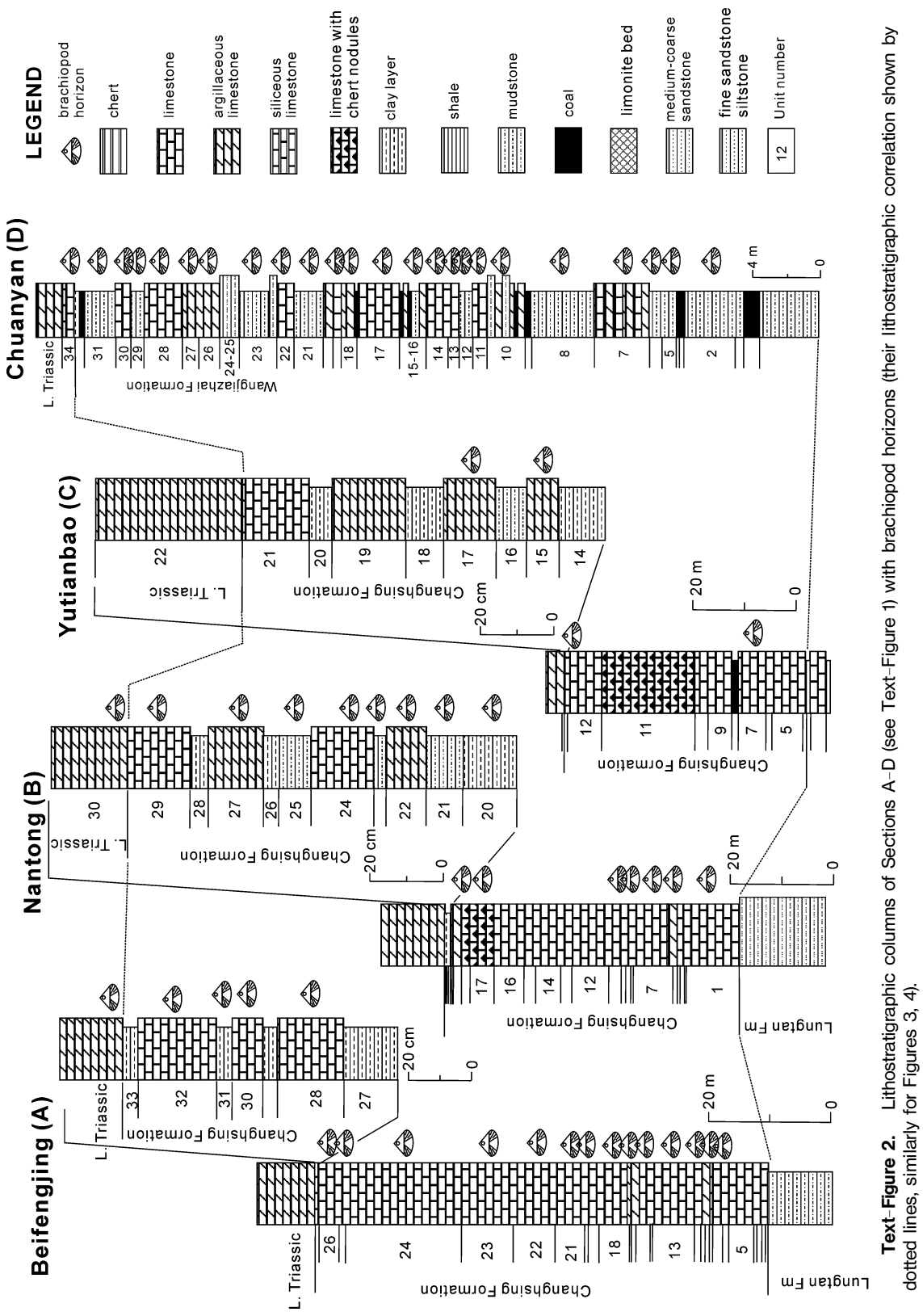
The Lopingian Series as an international chronostratigraphical unit was formalized by Jin *et al.* (1994b, 1997, 1998) and now has been accepted by IUGS in the latest International Stratigraphical Chart formally released by the International Stratigraphical Commission (Gradstein *et al.*, 2004) and includes two stages: the Wuchiapingian followed by the Changhsingian. In South China, both stages are represented by an array of sedimentary facies, most of which have been named differently. For this reason, it is necessary to describe the stratigraphy of the sections we studied in groups or individually.

### Beifengjing (Section A) in the Zhongliang Hill, Nantong (Section B) and Yutianbao (Section C) in the Wansheng area, Daijiagou (Section E) in the Huayingshan area, Chongqing City and Tuanxi (Section F) in the Zunyi area, Guizhou Province

The Lopingian sequences of these seven sections (Text-Figures 1A–C, E, F; 2A–C, 3E–F) are each composed of two parts, the Lungtan Formation in the lower and the Changhsing Formation in the upper. The term Lungtan Formation has been widely used in China for a coal-bearing sequence occurring above the Maokou/Kuhfeng/Lengwu Formations and below the Changhsing Formation (or the Talung Formation). The formation is usually separated from the underlying strata by an unconformity of regional significance (a consequence of the Dongwu Uplift Movement) and characterized by containing the *Gigantopteris* flora, *Clarkina orientalis* and *C. leveni* conodonts, *Sangyangites, Konglingites, Anderssonoceras*, and *Prototoceras* ammonoids, and the *Codonofusiella* fusulinoidean fauna.

Among the above seven sections we studied, only the upper part of the Lungtan Formation and the Changhsing Formation were studied in four sections (Text-Figures 2A–C, 3E). At the Beifengjing Section in Zhongliang Hill in Chongqing City (Text-Figures 1B, 2B), however, the Lungtan Formation is dominated by shale from which no fossils have been found. At Nantong and Yutianbao (Text-Figures 1B, 1C, 2B, 2C) in the Wansheng area, the Lungtan Formation is identified by sandstone with some brachiopods, but largely covered.

At the Daijiagou Section in the Huayinshan area (Text-Figure 1E), both the Lungtan and Changhsing Formations were studied in detail. The coal-bearing Lungtan Formation unconformably overlies the Middle Permian (Guadalupian) Maokou Formation which is distinctly marked by a workable limonite/pyrite unit at the boundary. A total of three members have been recognized within the Lungtan Formation (Text-Figure 3E) at the Daijiagou Section in Chongqing City. There, the lower member is a coal-bearing unit characterized by fine sandstone, siltstone and shale containing coal seams and the *Gigantopteris* flora. The middle member is a marine facies identified by shale and sandy shale with limestone intercalations of varying thickness (Text-Figure 3E). The limestone beds contain abundant brachiopods (Zeng *et al.*, 1995; Chen *et al.*, 2005a). These two members have not been observed from the four sections (Sections A–C) shown in Text-Figure 2. The upper member at the Daijiagou Section is characterized by mudstone containing




**Text-Figure 2.** Lithostratigraphic columns of Sections A–D (see Text-Figure 1) with brachiopod horizons (their lithostratigraphic correlation shown by dotted lines, similarly for Figures 3, 4).

few marine bivalve fragments. The lithological succession of the Daijiagou Section can be broadly correlated with the Lopingian Series at the Tuanxi Section (Text-Figure 3F) in the Zunyi area, Guizhou Province (Text-Figure 1F). The Lopingian at the Tuanxi Section also includes the Lungtan Formation and the Changhsing Formation in ascending order, there the lowest member (Member 1) of the Lungtan Formation mainly consists of shale, mudstone interbedded with coal seams, but no brachiopods. The following two members (Members 2 and 3) of the Lungtan Formation also mainly consist of shale, mudstone and some limestone yielding abundant brachiopods, but without coal seam.

Stratigraphically above the Lungtan Formation at the seven sections discussed above is a succession of light- or dark-coloured, thick-bedded massive packstone, wackestone and grainstone frequently with chert nodules. This succession is the well-known Changhsing Formation and has been interpreted to represent the deposits of a carbonate platform. Invariably across the sections, the Changhsing Formation contains the *Clarkina wangi-C. subcarinata-C. yini-C. meishanensis* conodont succession (Mei *et al.*, 1998b), the *Pseudotirolites-Tapashanites* ammonoid fauna and the *Palaeofusulina* fusulinoidean fauna. Brachiopods occur throughout the formation and are dominated by the species of *Peltichia, Meekella, Prelissorhynchia, Orthothetina, Spinomarginifera, Alphaneospirifer*, etc.

**Chuanyan (Section D), Xingwen, Sichuan Province**

The Chuanyan Section (Text-Figures 1D, 2D) is situated at the southern border of Sichuan Province, where the Lopingian is evidently different from those in the above-mentioned areas. The Lopingian Series is represented by two formations. The Lungtan Formation in the lower mainly consists of a series of non-marine sediments including sandstone, siltstone and mudstone, and contains abundant plant fossils and coal seams. Marine fossils are occasionally found in this formation. Stratigraphically above the Lungtan Formation is a unit named the Wangjiazhai Formation, consisting of fine sandstone, highly organic wackestone, mudstone, claystone with several coal seams. Brachiopods and some other marine fossils occur throughout this formation. Palaeoecological analyses of brachiopods from this section have been briefly presented by Zeng (1986, 1990, 2004).

**Wenjiangsi (Section G), Guiding, Guizhou Province**

The Lopingian Series in this locality (Text-Figure 1G) includes three lithologic units, namely the Wuchiaping Formation, Changhsing Formation and Talung Formation in ascending order (Text-Figure 3G). At this section, the Wuchiaping Formation overlies unconformably the Maokou Formation and is dominated by thick-bedded massive limestone in the lower part, cherty limestone and mudstone with chert nodules in the middle part grading upward into coal-bearing shale and siltstone of the upper part. Brachiopods, fusulinoideans and corals occur throughout the formation although seemingly more abundant in the middle and upper parts. The Wuchiaping Formation is largely equivalent to the Lungtan Formation in age, but lithologically differs from the Lungtan Formation by the dominance of carbonate rather than coal-bearing clastic deposits.

There is no discernable break between the Wuchiaping and the overlying Changhsing Formation. The Changhsing Formation, some 78 meters thick, is dominated by thick-bedded limestone with abundant cherty nodules and brachiopod fossils. The Talung Formation conformably overlying the Changhsing Formation is composed of medium-bedded chert and contains at its base some small, thin-shelled brachiopods and ammonoids. It should be pointed out that the Changhsing Formation and the Talung Formation together largely corresponds to the Changhsingian Stage.

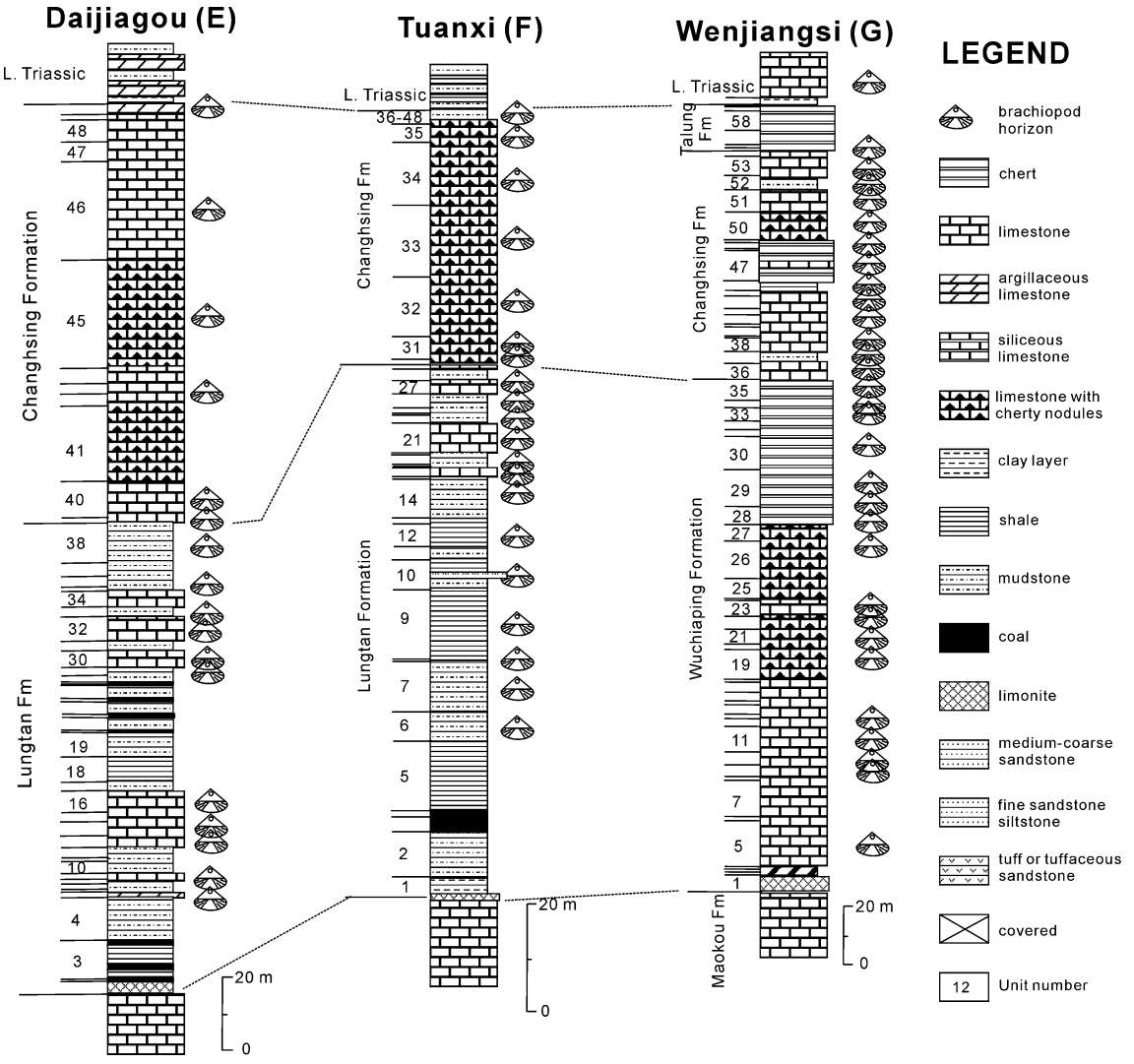
**Penglaitan (Section H) and Heshan (Section I), Laibin, Guangxi Province**

The Penglaitan Section (Text-Figures 1H-I; 4H-I) is situated in a narrow northeast-southwest trending basin believed to have been developed during the Maokouan. There, the Lopingian Series is more than 400 m thick and divided into two formations: the Heshan Formation succeeded by the Talung Formation. Recent biostratigraphical studies have demonstrated that the Penglaitan Section represents a unique continuous Maokouan-Lopingian boundary sequence (Mei *et al.*, 1994, 1998a; Jin *et al.*, 1998; Henderson *et al.*, 2002); it therefore has received considerable attentions from geologists and palaeontologists in the recent decade (Jin *et al.*, 1997, 1998, Wang *et al.*, 2004, Kaiho *et al.*, 2005), culminating with the recent establishment of this section as the Lopingian-base GSSP (Jin *et al.*, 2006b). The same section has also been designated as the standard of the Substage Laibinian (early Wuchiapingian) of the Wuchiapingian Stage (Jin *et al.*, 1994b, 1998). At this section, the Heshan Formation is mainly composed of dark to dark-gray cherty wackestone interpreted to have been deposited in a relatively deep marine environment. The Talung Formation, on the other hand, is much thicker than the underlying Heshan Formation and is characterized by tuffs, tuffaceous sandstone and mudstone, chert and occasional coal seams. Ammonoids dominated by *Pseudotilorites* and brachiopods are abundant but concentrated only within a few horizons of the upper part (Text-Figure 4H).

The Heshan Section (Text-Figure 4I) is located about 40 km west of the Penglaitan Section. Here, the Heshan Formation is composed primarily of thick-bedded massive limestone, interbedded with four coal seams defined by a distinct unconformity at the base of the formation, which is represented by carbonate shoal deposits in the Penglaitan Section. The overlying Talung Formation, which was originally named from this locality, is distinguished by volcanic tuff, clay or ash and chert with abundant ammonoids and some plant fossils.

**Xiaoyuanchong (Section Ja), Sanhe (Section Jb) and Dapaichong (Section Jc) in Chenxian (Chen County), Hunan Province**

The Lopingian sequence of this area is quite variable laterally. Three sections were measured accordingly. In the Xiaoyuanchong locality (Text-Figures 1J, 5Ja), the lower Lopingian is identified by the Douling and Xiaoyuanchong



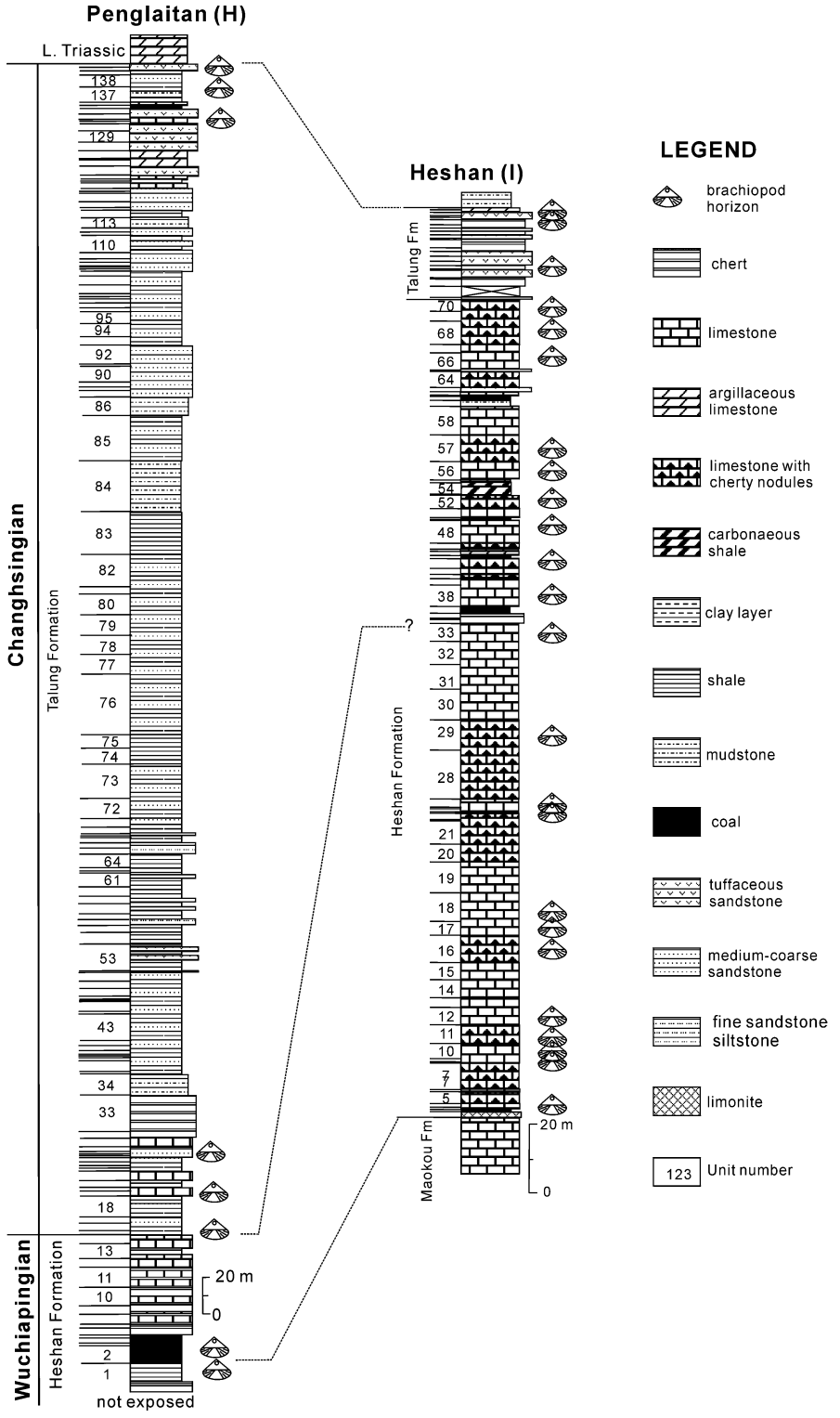

**Text-Figure 3.** Lithostratigraphic columns of Sections E-G with brachiopod horizons.

Formations in ascending order. The Douling Formation contains three members. The lower member is probably of late Maokouan age based on ammonoids and therefore not included in this study. The middle and upper members are both dominated by mudstones, but the upper member contains limestone lenses containing the conodont *Clarkina postbitteri postbitteri* (Mei, pers. comm. 1998) of early Lopingian age and the ammonoids characterized the *Roadoceras-Doulingoceras* Zone (Zhou, 1987; Zhou and Gong, 1994). The overlying Xiaoyuanchong Formation consists of mainly black siliceous mudstone and chert containing small brachiopods and ammonoids. The Talung Formation at this section is argillaceous limestone, mudstone and sandstone, with rare brachiopods.

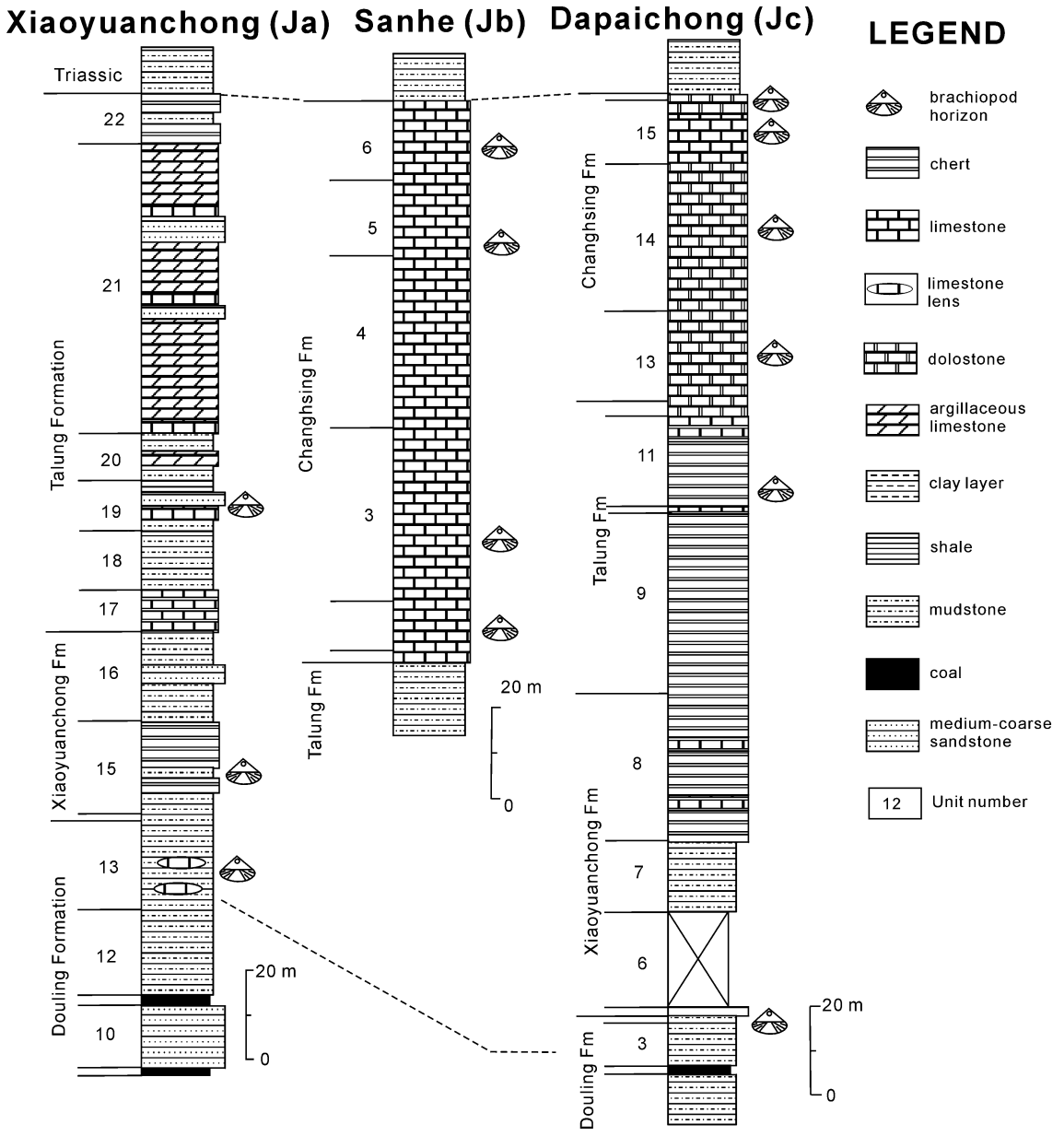
The Sanhe Section and the Dapaichong Section in the Huatang area, Chenxian County of Hunan Province (Text-Figures 5Jb, Jc) are located east of the Xiaoyuanchong Section. At the Dapaichong Section, the Douling and Xiaoyuanchong Formations are comparable to the same formations of the Xiaoyuanchong Section described above, but the upper part of the Huatang Section is clearly different in that the Talung Formation is dominated by chert and the Changhsing Formation by dolomitic limestone. At the Sanhe Section only the topmost Changhsing Formation was measured and the lithology of this section is closely similar to that of the Dapaichong Section.

### Brachiopod Collections and Repository

Most of the specimens described in this paper were collected by SSZ and first studied in his Ph. D. thesis (1989, unpublished). Some specimens obtained for this study from China University of Mining and Technology were collected by then postgraduate students Zhang Zhi-pei, Zhang Chuan and Men Da-gong. Some species were briefly described as new species in Chinese or figured only by Shen *et al.* (1992)




**Text–Figure 4.** Lithostratigraphic columns of Sections H, I with brachiopod horizons.




**Text-Figure 5.** Lithostratigraphic columns of Sections Ja, Jb and Jc with brachiopod horizons.

and Shen and He (1994a). Those species are herein re-described in English along with new materials in light of recent developments in brachiopod taxonomy and Permian biostratigraphy. The specimens registered are referred to by both locality and museum collection numbers. The locality number of a brachiopod specimen is identified by a prefix section letter A, B, or C through to J followed by a horizon (bed/unit) number indicating where exactly the specimen was obtained from. The letters, A, B or C, corresponds to the same letters in the labelled sections of Text-Figures 1 to 5. All the fossil horizons studied and referred to below in the "occurrence" section of the systematic palaeontology are clearly indicated in Text-Figures 2 to 5.

The same specimen, if measured, sectioned and/or illustrated, also carries a museum collection number prefixed with NIGP, standing for Nanjing Institute of Geology and Palaeontology, China where these materials are housed. Some specimens including holotypes were previously figured by Shen *et al.* (1992) and Shen and He (1994a) with registered numbers of China University of Mining and Technology prefixed with CUMT. Since China University of Mining and Technology no longer houses any palaeontological collections, we have shifted the registered numbers to the museum collection numbers of NIGP with the original numbers indicated in the brackets.

## Systematic Description

The classification above the generic levels of Brachiopoda largely follows the latest Treatises by Williams *et al.* (1997, 2000a, 2000b, 2002).

### Order ORTHOTETIDA Waagen, 1884

### Suborder ORTHOTHETIDINA Waagen, 1884
### Superfamily ORTHOTETOIDEA Williams, 1953
### Family MEEKELLIDAE Stehli, 1954
### Genus *Meekella* White and John, 1867

*Type species*.—*Plicatula striatocostata* Cox, 1857, p. 568, pl. 8, fig. 7 from the Moscovian, Iowa, USA.

*Discussion*.—*Meekella* is a long-range genus and characterized by both costellate and plicate ornamentation and distinct subparallel dental plates and strong bilobate cardinal process and erismata. However, it is very difficult to obtain good interiors from the South Chinese specimens. One silicified specimen (NIGP141525) from the Changhsing Formation at Wenjiangsi, Guiding, Guizhou offers an opportunity to compare the South Chinese specimen with those of West Texas. The specimen from Wenjiangsi clearly shows a strong bilobate cardinal process projecting into the ventral valve and strong brachiophore plates (term of Williams *et al.*, 1965 ; erismata of Cooper and Grant, 1974 ; also socket plates of Thomas, 1958).

*Parameekella* He and Zhu (1985), with *Parameekella huayinshanensis* He and Zhu (1985, p. 199, pl. 1, figs. 6–9 ; pl. 2, figs. 7–9) as the type species, is herein considered as a junior synonym of *Meekella*. *Parameekella* was proposed by He and Zhu (1985) based on the characters like *Meekella* but with a strong flabellate muscle platform in each valve, low and triangular interarea and quadrate cardinal extremities. However, specimens from West Texas, USA indicate the muscle scars were seen only in old and very large specimens (Cooper and Grant, 1974, p. 350). Our observation of the South Chinese specimens suggests that the muscle scars in *Meekella* appear quite variable (Huang, 1933, pl. 4, figs. 1–2, 6a–d, 7–9 ; pl. 3, figs. 19, 22 ; He and Zhu, 1985, pl. 1, figs. 6–9 ; pl. 2, figs. 7–9 ; Feng and Jiang, 1978, pl. 86, figs. 6a–d ; Liao, 1980a, pl. 3, figs. 20–23 ; Liang, 1990, pl. 12, figs. 7–13 ; Xu and Grant, 1994, fig. 12–1–12) and the muscle platform usually occur in the adult and large specimens.

*Gegenella* Li and Gu, 1976, with *Gegenella gegenensis* Li and Gu (1976, p. 237, pl. 153, figs. 1–4 ; pl. 154, figs. 2–4, 6) from the Guadalupian Gegenaobao Formation in Inner Mongolia, China as the type species, was briefly described and poorly figured. This genus is questionable over its supposed differences from other orthothetid genera. The strongly divergent dental plates and a median ridge between them appear to readily distinguish it from any other orthothetid genera. However, the nature of the dental plates and the median ridge is not clearly displayed. The so-called dental plates may be the ridges outlining the impressed muscle scars, and the median ridge could be some anklose callus between the dental plates which are very common in *Meekella*. This genus was considered a synonym of *Meekella* by Williams *et al.* (2000b).

*Asiomeekella* Liang, 1990, designated with *Asiomeekella isoconvexa* Liang (1990, p. 121, pl. 12, figs. 1–6, fig. 13) from the Capitanian Lengwu Formation at Tonglu of Zhejiang Province, southeast China as the type species, was poorly defined by Liang (1990) based on a single specimen. The cardinalia of the dorsal valve of *Asiomeekella* is unknown. It is identical with *Meekella* in general appearance but with catacline ventral interarea and a pair of submedial ridges between dental plates. The submedial ridges between dental plates on the floor of the ventral valve may be nothing more than radial striations that are very commonly associated with muscle scars (Williams *et al.*, 2000b). The inclination of ventral cardinal area is highly variable in *Meekella*, a feature that should be best treated as intraspecific or interspecific variations.

### *Meekella kueichowensis* Huang, 1933

Plate 1, Figures 1–11 ; Plate 2, Figures 1–12 ; Plate 26, Figures 10, 12

*Meekella kueichowensis* Huang, 1933, p. 27, pl. 3, figs. 19–21 ; pl. 4, figs. 1–4.
*Meekella* aff. *kueichowensis* Huang, 1933, p. 28, pl. 3, fig. 22.
*Meekella* sp. nov. aff. *Meekella kueichowensis* Huang, 1933, p. 28, pl. 4, figs. 6a–d.
*Meekella kueichowensis* Huang ; Wang, 1955b, p. 151, pl. 86, figs. 3–8.
*Meekella kueichowensis* Huang ; Wang *et al.*, 1964, p. 201, pl. 28, fig. 18.
*Meekella kueichowensis* Huang ; Yang *et al.*, 1977, p. 320, pl. 132, fig. 3.
*Meekella kueichowensis* Huang ; Feng and Jiang, 1978, p. 237, pl. 86, fig. 5.
*Meekella dorsisulcata* Feng in Feng and Jiang, 1978, p. 237, pl. 86, fig. 5.
*Meekella kueichowensis* Huang ; Tong, 1978, p. 213, pl. 78, fig. 1.
*Meekella kueichowensis* Huang ; Zhan in Hou *et al.*, 1979, p. 64, pl. 10, figs. 5–6.
*Meekella kueichowensis* Huang ; Liao, 1980a, pl. 3, fig. 24.
*Meekella langdaiensis* Liao, 1980a, p. 255, pl. 3, figs. 20–23.
*Meekella kueichowensis* Huang ; Waterhouse, 1983, p. 116, pl. 1, fig. 11.
*Parameekella huayinshanensis* He and Zhu, 1985, p. 199, pl. 1, figs. 6–9.
*Meekella kueichowensis* Huang ; Liao, 1987, pl. 3, figs. 19–20.
*Meekella dorsisulcata* Feng ; Zeng *et al.*, 1995, pl. 1, fig. 15.

*Materials*.—Numerous specimens, most of them are internal moulds of disarticulated ventral and dorsal valves from mudstone. Registered specimens : Three conjoined shells (NIGP141516, 141517, 141527), an incomplete conjoined shell (NIGP141519), an incomplete external mould of a dorsal valve (NIGP141520), a nearly complete dorsal valve (NIGP141521), five internal moulds of ventral valve (NIGP141518, 141522–141524, 141526) and a silicified incomplete conjoined shell with cardinal structures (NIGP141525)

*Description*.—Shell large, semicircular to slightly transver-

sely elliptical in outline, unequally biconvex in lateral profile ; hinge wide but shorter than shell width near shell midlength ; lateral flanks strongly rounded, anterior margin broadly rounded ; anterior commissure faintly to moderately sulcate ; both valves finely costellate, costellae increasing by bifurcation and intercalation, numbering about 12–18 per 5 mm near anterior margin ; plication variable, low and with rounded crests, originating from the umbonal region, separated by equally wide intertroughs, usually bifurcating anteriorly, occasionally irregular and wavy, roughly consisting of three orders, primary plicae originating from umbonal region, secondary plicae bifurcating from primary plications just anterior to the umbonal region, tertiary plicae intercalating between main and secondary plicae or bifurcating from secondary plicae, numbering 20–30 in total near anterior margin.

Ventral valve flat to moderately convex in lateral profile ; umbonal region usually strongly convex in posterior profile, but anterior region broadly and moderately convex in profile ; flanks moderately steep ; beak blunt, usually forming an angle more than 120 degree, slightly curved toward dorsal valve ; interarea broadly triangular in shape, moderately concave ; pseudodelthyrium narrow, about quarter of hinge width, forming monticulus at meddle part ; dorsal valve moderately to strongly convex in lateral profile, greatest convexity at umbonal region ; umbonal slopes steep, anterior half somewhat flattened ; flanks gently swollen ; fold nearly absent ; interarea ill-defined ; sulcus wide and weak, only present near anterior margin.

Ventral interior with two strong subparallel dental plates (Plate 26, Figure 10), slightly converging toward valve floor and nearly united at the umbonal cavity, commonly filled with secondary shell, forming pseudospondylium, but rapidly becoming separated anteriorly, extending over about one-third of shell length ; muscle scars in adults flabellate surrounded by low ridges, much longer than dental plates, consisting of anteriorly extending shallow grooves, separated by low radial longitudinal ridges ; dorsal interior with long, divergent brachiophore plates and strong bilobate cardinal process (Plate 26, Figure 12), forming an angle of about 60 degree.

*Measurements (in mm)*.—(L=length, W=width, T=thickness, HW=hinge width, IH=interarea height. Same herein after)

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141516 | 58.6 | 65.9 | 38.7 | 44.6 |
| NIGP141517 | 51.8 | 60.5 | 30.6 | 39.2 |
| NIGP141518 | 50.5 | 68.8 | >20.0 | 59.6 |
| NIGP141519 | 52.4 | 58.4 | 37.7 | >32.0 |
| NIGP141520 | 50.1 | 70.0 | >26.0 | — |
| NIGP141521 | 37.0 | 46.0 | — | 39.2 |
| NIGP141522 | 31.0 | 35.5 | — | 11.0 |
| NIGP141523 | 43.5 | 56.3 | — | 23.5 |
| NIGP141524 | 35.8 | 49.0 | — | 24.5 |
| NIGP141526 | 43.4 | >40 | — | 37.3 |
| NIGP141527 | 28.8 | 35.2 | 17.7 | 20.1 |

*Discussion*.—Although *Meekella kueichowensis* is one of the commonest species in the Lopingian of South China, its general outline and profile are poorly understood because all figured specimens by Huang (1933) are internal moulds and not complete. Its lateral profile and anterior commissure have been seldom figured by previous workers. Our specimens from the Lungtan Formation in Zunyi (Pl. 1, figs. 1–4) are almost identical to the syntypes of the species as originally figured by Huang (1933) both in surface ornamentation and outline. The present material shows a strongly convex, non-sulcate to weakly sulcate dorsal valve and a gently sulcate anterior commissure. The specimen described as *Meekella kueichowensis* by Liang (1990. p. 124, pl. 12, fig. 13) from the Lengwu Formation is very different from those previously described in view of its high interarea and very weak plication. Conjoined shells from limestone with similar characters in South China were subsequently named as *Meekella dorsisulcata* by Feng in Feng and Jiang (1978, p. 237, pl. 86, fig. 6). *M. dorsisulcata* is herein considered to be a synonym of *M. kueichowensis* based on their similar size, outline, weak dorsal sulcus and plication. *Meekella langdaiensis* Liao (1980a, p. 255, pl. 3, figs. 20–23) from the Changhsing Formation in Liuzhi of Guizhou Province is probably another synonym of the present species in terms of their similar size, outline, convexity, sulcate anterior commissure and about 20 plicae. However, specimens figured as *M. langdaiensis* by Xu and Grant (1994, p. 24, fig. 12-1-12) from the Longdongchuan Formation, Zhen'an County of Shaanxi Province in the northern margin of the Yangtze Platform and the Lungtan Formation, Huzhou of Zhejiang Province, South China are evidently different from the specimens described by Liao (1980a). Xu and Grant's (1994) specimens have a much higher interarea and relatively fewer coarser plicae, suggesting a distinct, perhaps new species of *Meekella*. Since *Parameekella* He and Zhu (1985) has been considered to be a synonym of *Meekella* (see discussion above), *Parameekella huayingshanensis* He and Zhu (1985) is also a synonym of the present species in terms of their similar external characters.

*Meekella megala* Grant (1993, p. 9, figs. 8.1–8.7) from the Middle Permian of Hydra Island, Greece resembles the present species in its large size and coarse and distinct plications ; however, further comparisons are hindered because the Greek specimen is incomplete. *Meekella timanica* Tschernyschew from the *Schwagerina* Bed of Timan (Tschernyschew, 1902, p. 585, pl. 25, fig. 4) resembles the present species in outline and lateral profile, but its plication is much weaker. The present species is also similar to *Meekella circularis* Cooper and Grant (1974, p. 360, pl. 101, figs. 1–8) from the Hueco Formation of West Texas, USA in shape and profile, but the latter has fewer and more regular plication. *Meekella occidentalis* (Newberry, 1861, p. 126, pl. 1, figs. 5, 5a ; Cooper and Grant, 1974, p. 367, pl. 117, figs. 1–4, 9–13) from the Cathedral Mountain Formation in West Texas is similar to the present species in terms of its size and plications, but has a much less convex lateral profile. *Meekella enormis* Cooper and Grant (1974, p. 361, pl. 69, figs. 10–12 ; pl. 106, figs. 1–25 ; pl. 107, figs. 1–17) from the Skinner Ranch Formation also attains the size of the present species and possesses similar plications, but has a high and nearly catacline ventral interarea and no sulcus on the dorsal valve. *Meekella grandis* King (1931, p. 54, pl. 6, figs. 5–7) from the

Wolfcamp and Leonard Formations in the Glass Mountains, Texas, USA also differs from the present species by its less convex lateral profile, nearly rectimarginate anterior commissure and coarser plications. *Meekella gigantea* Hayasaka [1933, p. 26, pl. 6, fig. 2; pl. 9, fig. 4; pl. 10–11, pl. 12, fig. 1 (not pl. 9, fig. 3)] from the *Fusulina* limestone in the Nabeyama region, Tochigi Prefecture, Japan is larger and possesses much coarser plicae than the present species.

*Occurrence*.—A–11, 19, 26; B–22; D–5; E–5, 9, 16, 18, 27, 29, 32, 34; F–6, 18, 20, 21, 27, 28, 29, 33; G–5, 32, 35, 36, 37, 45; I–38, I–56, I–57; H–137; I–68; Jc–15.

### *Meekella arakeljani* (Sokolskaja in Ruzhentsev and Sarytcheva, 1965)

Plate 2, Figures 13–26; Plate 26, Figures 5, 6, 11

*Orthotetina arakeljani* Sokolskaja in Ruzhentsev and Sarytcheva, 1965, p. 205, pl. 30, figs. 3a–c.
*Orthotetina arakeljani* Sokolskaja; Yang *et al.*, 1977, p. 320, pl. 133, fig. 5.
*Orthotetina arakeljani* Sokolskaja, Liao, 1980a, p. 256, pl. 3, figs. 5–6.
*Meekella arakeljani* Sokolskaja; Liao, 1980a, pl. 3, figs. 5, 6.
*Meekella* aff. *arakeljani* (Sokolskaja); Yanagida and Nakornsri, 1999, p. 115, pl. 27, fig. 2.

*Material examined*.—1 conjoined shell. Registered specimens: Two complete conjoined shells (NIGP141528, 141531), two incomplete conjoined shells (NIGP141529, 141530), a ventral valve (NIGP141532) and two internal moulds of ventral valve (NIGP141534, 141533).

*Description*.—Small to medium size for genus, nearly equally biconvex in lateral profile, circular or subcircular in outline; hinge straight, about two-thirds of shell width at shell midlength, lateral and anterior margins almost regularly rounded; anterior commissure weakly sulcate; plicae fine to moderate coarse, strong, with well rounded crests, increasing anteriorly by bifurcation or intercalation, numbering in total 20–25 at anterior margin, separated by intertroughs with nearly equal width.

Ventral valve moderately convex in lateral profile, umbonal region commonly with a nearly flat attachment scar and gently arched at anterior profile; flanks moderately steep; beak blunt, nearly erect; interarea broadly triangular in shape, slightly concave in lateral profile, gently apsacline; dorsal valve also moderately convex in lateral profile, maximum convexity at umbonal region; beak and interarea normally not developed; sulcus absent, but slightly flattened at central anterior region.

Ventral interior with two subparallel dental plates, dental plates converging toward valve floor (Plate 26, Figures 5), filled by secondary shell between them (Plate 26, Figure 11), extending about one quarter of valve length; dorsal interior with two strong divergent brachiophore plates and bilobate cardinal process (Plate 26, Figure 6).

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141528 | 34.0 | 38.4 | 20.9 | 17.9 |
| NIGP141529 | 35.8 | 38.0 | 23.0 | 23.0 |
| NIGP141530 | 29.5 | 32.0 | 15.3 | 19.0 |
| NIGP141531 | 33.6 | 38.0 | 20.8 | 18.5 |
| NIGP141532 | 27.2 | 31.5 | — | — |
| NIGP141533 | 31.1 | 32.9 | >12.9 | 20.1 |
| NIGP141534 | 22.1 | 24.5 | — | 19.4 |

*Discussion*.—Sokolskaja (in Ruzhentsev and Sarytcheva, 1965) considered that the present species represented a transitional form between *Orthothetina* and *Meekella* because it possesses *Meekella*-type plication and *Orthothetina*-type dental plates. However, specimens from South China indicate that the extending direction of dental plates in *Meekella* and *Orthothetina* are commonly variable, unlike the presence of plication which is usually regarded as a distinct feature distinguishing *Meekella* from *Orthothetina* (Williams *et al.*, 2000b, p. 663). The present specimens are nearly identical with *M. arakeljana* (Sokolskaja in Ruzhentsev and Sarytcheva, 1965) from the Lopingian of the Transcaucasus in view of outline, size and plications. The Thai specimens described by Yanagida and Nakornsri (1999) are generally comparable with the type specimen, but have weaker plication.

This species differs from *Meekella kueichowensis* Huang by its small size, nearly circular outline and finer plicae.

*Occurrence*.—A–26; B–22; C–17; F–15, 16, 21, 31, 33; G–32, 41; H–137; Jc–15.

### *Meekella* cf. *deltoides* Liao, 1980a

Plate 3, Figures 1–6

*Meekella deltoides* Liao, 1980a, p. 256, pl. 3, figs. 1–4.

*Material examined*.—Three incomplete conjoined shells and an incomplete ventral valve. Registered specimens: Two incomplete conjoined shells (NIGP141535, 141536).

*Description*.—Shell small for genus, one of the specimens measured 25.6 mm long, 34.6 mm wide, 15.7 thick, and 18 mm in hinge width; moderately biconvex, elongately triangular in outline, maximum width at anterior part; lateral sides broadly rounded and anterior sides almost straight; hinge about half of shell width, anterior commissure moderately sulcate; surface costellate and plicate, plicae fine, weak and unequal in size, increasing by bifurcation and intercalation, numbering 5 in 10 mm at median region, shell surface usually with several concentric rugae.

Ventral valve with strongly swollen umbonal region; beak attenuated, blunt, suberect and slightly distorted; interarea high, triangular in shape, suberect, strongly apsacline; pseudodelthyrium narrowly triangular, about one-third of hinge width; umbonal slope strongly declined, but flanks and front slope faintly declined. Dorsal valve moderately convex in lateral profile; umbonal region slightly swollen, flattened anteriorly; sulcus weak, originating from median region, widening anteriorly.

Ventral interior with two nearly parallel dental plates and dorsal interior with two divergent brachiophore plates.

*Discussion*.—The present species differs from any other known forms of the genus in its triangular outline, weak

plication, high suberect and strongly apsacline interarea. The present specimens are comparable with that from the Lungtan Formation in Zhijin of Guizhou described by Liao (1980a) in general characters. But it possesses more elongately triangular outline, higher interarea and smaller umbonal angle.

*Occurrence*.—A-26, 30 ; B-22 ; F-29.

### ***Meekella sichuanensis*** **Shen, He and Zhu, 1992**

Plate 3, Figures 7-17

*Meekella sichuanensis* Shen *et al.*, 1992, p. 176, pl. 1, figs. 13-14 ; pl. 2, figs. 1-2.

*Holotype*.—NIGP141539 (=CUMT8242), a conjoined shell from A-26 (Plate 3, Figures 11-14).

*Other material examined*.—Five complete conjoined shells. Two conjoined shells registered (NIGP141538, 141537).

*Diagnosis*.—Large *Meekella* with transversely elliptical outline and bumpy and braided plication on both valves.

*Description*.—Shell fairly large for genus, transversely elliptical in outline, maximum width at shell midlength, strongly convex in profile ; hinge straight, almost two-thirds of shell width ; sides rounded, anterior margin fairly broadly rounded. Surface costellate and plicate, costae strong and distinct, usually increasing by intercalation, numbering 11 in 5 mm at median region of mature specimens ; plications bumpy, moderately developed with rounded crests, originating anterior to umbonal region, interspaced by narrow troughs, usually regular on posterior valve, but bifurcating and intercalating anteriorly, strongly braided ; anterior commissure generally sulcate.

Ventral valve moderately convex in profile, maximum convexity at midvalve ; beak rapidly contracted, pointed and distorted ; interarea high, asymmetrically triangular, slightly concave ; beak ridges distinct ; pseudodelthyrium fairly narrow and with monticulus ; umbonal slopes strongly declined, flanks moderately steep and flattened anteriorly. Dorsal valve nearly circular in outline, moderately convex in profile, maximum convexity at umbonal region ; flanks faintly steep, sulcus originating from medium region, widening anteriorly.

Ventral interior with two strong dental plates, dental plates converging toward valve floor, sometimes forming pseudospondylium, extending anteriorly to about 1/5 of shell length. Dorsal interior with two strong brachiophore plates.

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141537 | 45.0 | 48.0 | 30.8 | 26.8 |
| NIGP141538 | 50.8 | 55.5 | 35.1 | 33.0 |
| NIGP141539 | 50.2 | 51.3 | 33.2 | 31.5 |

*Discussion*.—The present species is characterized by its bumpy and strongly braided plication on both valves, which easily distinguish it from any other known species of *Meekella*. *Derbyia pannuciella* Xu and Grant (1994, p. 24, figs. 11.1-11.5) from the Changhsing Formation, Huzhou, Zhejiang Province resembles the present species in its bumpy and strongly braided ornament, but the former, as described by Xu and Grant (1994), has a median septum in the ventral valve. However, the specimen shown in their figure 11.2 and 11.4 appears to have two dental plates. Therefore, *D. pannuciella* Xu and Grant could be a synonym of the present species. *Meekella kueichowensis* Huang (1933) differs from the present species by its more transverse outline and simple regular plication.

*Occurrence*.—A-26, 28.

### ***Meekella versiformis*** **Shen, He and Zhu, 1992**

Plate 3, Figures 18-21

*Meekella versiformis* Shen *et al.*, 1992, pl. 1, figs. 9-12.

*Holotype*.—NIGP141540 (=CUMT8241), a complete conjoined shell from A-26.

*Diagnosis*.—Shell small, elongate in outline, ventral interarea high, costellae and plicae on surface fine and distinct, sulcus absent on dorsal valve, anterior commissure rectimarginate.

*Description*.—Shell 44.8 mm long, 44 mm wide, 26 mm thick, interarea 32.5 mm wide and 22 mm high ; moderately biconvex, elongate in outline, length almost equal to width, maximum width anterior to shell midlength ; lateral sides nearly straight in posterior profile, but regularly rounded anteriorly, anterior margin fairly broadly rounded ; anterior commissure usually rectimarginate ; hinge straight, shorter than width ; shell surface with delicate costae and plicae, costae fine and distinct, numbering about 20 in 5 mm, increasing by bifurcation and intercalation ; plicae also fine and distinct, originating anterior to umbonal region, interspaced by intertroughs with equal width, sometimes bifurcating at anterior part, numbering 5-6 in 10 mm ; concentric lines usually developed on both valves.

Ventral valve slightly curved at umbonal region, but flat on anterior valve in lateral profile, slightly domed in anterior profile ; beak high, blunt, usually distorted ; umbonal angle about 90 degree ; interarea quite high, but erect, triangular in shape, strongly apsacline ; pseudodelthyrium narrowly triangular, about one-third of hinge width, with a low and fairly narrow monticulus ; umbonal region of valve moderately swollen ; umbonal slopes strongly steep ; flank regularly declined, flattened anteriorly. Dorsal valve semicircular in outline, moderately rounded in lateral profile and moderately domed in anterior profile, maximum convexity at umbonal region ; sulcus absent.

Ventral interior with two strong dental plates ; dental plates about one quarter of shell length, meeting toward valve floor in umbonal cavity, forming pseudospondylium, but rapidly separated, yet converging anteriorly ; dorsal interior with two strong divergent brachiophore plates.

*Discussion*.—The present species is characterized by its high interarea, fine and distinct costae and plicae, and absence of sulcus on the dorsal valve. *Meekella sichuanensis* Shen *et al.* (1992) differs from the present by its distinct dorsal sulcus and braided plications on both valves. *Meekella heterpfolda* Liang, 1990 can be readily distinguished from the present species by its very weak plication and distinct dorsal sulcus.

*Occurrence*.—A–26.

### ***Meekella heterofolda*** **Liang, 1990**

Plate 4, Figures 1–4

?*Orthotetina peregrina* Sokolskaja in Ruzhentsev and Sarytcheva, 1965, p. 208, pl. 30, figs. 7a–c. (non figs. 6a–c).
*Meekella heterofolda* Liang, 1990, p. 123, pl. 11, figs. 6–10.
*Meekella perigeyerelloides* Shen *et al.*, 1992, p. 17, pl. 2, figs. 3–6.

*Material examined*.—NIGP141541 (=CUMT8251), a complete conjoined shell.

*Diagnosis*.—*Meekella* with outline very similar to *Perigeyerella costellata* Wang, and very weak plication on surface, but with two parallel dental plates and no spondylium; sulcus conspicuous on dorsal valve, hinge about half of shell width.

*Description*.—Shell large in size for genus, 54.3 mm long, 54.8 mm wide, 34 mm thick, hinge 29.8 mm wide, interarea 15.8 mm high, sulcus 27.4 mm wide at anterior margin; equally biconvex, subcircular in outline, maximum width at shell midlength; hinge straight, normally not auriculate; lateral and anterior sides almost equally and evenly rounded; anterior commissure moderately sulcate; plication fairly weak, only developed on midvalve, unequal in size, separated by intertroughs of equal width; costellae conspicuous on posterior and meddle parts of valves, numbering 13 in 5 mm, increasing anteriorly by insertion in intertroughs, becoming fine on anterior part, numbering about 20 on anterior part; growth lines weak on middle part of valves, but gradually becoming stronger anteriorly.

Ventral valve evenly and gently convex in lateral profile; beak blunt and attenuated, forming an umbonal angle of about 90 degree; interarea moderately high, slightly concave longitudinally; beak ridges bluntly angular; pseudodelthyrium narrowly triangular and with monticulus; umbonal slopes steep; flanks evenly declined and flattening anteriorly; front slope on midvalve elevated, forming fold of about half width. Dorsal valve unevenly convex in profile, lidlike, maximum convexity at umbonal region; flanks evenly declined; sulcus originating from umbonal region, widening and deepening anteriorly.

Ventral interior with two strong dental plates, dental plates about 1 cm long, meeting at valve floor at about 1 mm from beak, then gradually separating at about 10 degree, attaining about 5 mm between frontal ends. Dorsal valve with two strong brachiophore plates diverging at about 60 degree.

*Discussion*.—The present specimen seems to represent a transitional form between *Orthothetina* and *Meekella* in view of its ornamentation. The weak plication on both valves may suggest an affinity to *Meekella*, while the slightly divergent dental plates recall *Orthothetina. Meekella perigeyerelloides* Shen *et al.* (1992) is considered to be a junior synonym of the present species in terms of their distinct narrow sulcus on the dorsal valve, weak plication and similar size and outline. The present specimen is rather similar to *Perigeyerella costellata* Wang (1955a, p. 101, pl. 6, figs. 1–10) from the Changhsing Formation, Tongzi of Guizhou both in outline and profile, but may be distinguished from the latter in its divergent dental plates and weak plication on the valves. *M. heterofolda* differs from *M. kuichowensis* Huang (1933) in its subcircular outline, narrow and distinct sulcus and weak plication. The present species also bears some resemblance to *M. sichuanensis* described above, but the latter possesses a transversely elliptical outline and stronger braided plication. One of the two specimens described by Sokolskaja (in Ruzhentsev and Sarytcheva, 1965, pl. 30, figs. 6–7) from the Upper Permian of the Transcaucasus under *Orthotetina peregrina* (Abich, 1878) is also similar to the present specimen in view of similar outline, profile and weak plication.

*Occurrence*.—A–26.

### ***Meekella pusilloplicata*** **Liao, 1980a**

Plate 4, Figures 5–13

*Meekella pusilloplicata* Liao, 1980a, p. 256, pl. 2, figs. 21–22.
?*Meekella pusilloplicata* Liao; Chen *et al.*, 2005a, p. 352, fig. 7l.

*Material examined*.—A complete conjoined shell (NIGP141542), two incomplete internal moulds of ventral valve (NIGP141543, 141544), and an incomplete internal mould of conjoined shell (NIGP141545).

*Description*.—Medium in size for genus, semielliptical in outline, weakly biconvex, greatest width anterior to shell midlength; hinge straight, and long, slightly shorter than shell width; cardinal extremities distinctly auriculate; posterior side nearly straight, converging posteriorly at about 150 degree, lateral sides nearly straight, slightly diverging anteriorly, anterior side broadly rounded; anterior commissure rectimarginate or gently sulcate; shell surface with weak and irregular plicae, plicae beginning at about 1 cm from beak, usually with rounded crests and interspaced by equally wide intertroughs; costellae fine and distinct, numbering about 16 in 5 mm; concentric wrinkles usually irregularly developed, stronger anteriorly.

Ventral valve flat to slightly concave in lateral profile, slightly domed in anterior profile; beak blunt, erect; interarea widely triangular, strongly apsacline, not concave; pseudodelthyrium triangular with convex monticulus, about one quarter of hinge width; beak ridges angular; umbonal region slightly swollen; lateral and front slopes slightly declined or nearly flat; dorsal valve longitudinally moderately convex in lateral profile and moderately domed in anterior profile; beak not conspicuous; interarea linear; sulcus absent, but usually flattened on anterior valve in the median region; umbonal and lateral margins evenly and moderately declined.

Ventral interior with two strong dental plates, converging toward valve floor but not united, parallel or slightly divergent anteriorly, extending about one-third of shell length; muscle scars flabellate, but comparatively weak, surrounded by a low ridge along anterior side.

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141542 | 34.3 | 48.3 | 20.3 | 42.5 |

| | | | | |
|---|---|---|---|---|
| NIGP141543 | 27.0 | 49.6 | — | — |
| NIGP141544 | 39.0 | 42.0 | 20.0 | 36.0 |
| NIGP141545 | — | 55.5 | — | >50 |

*Discussion*.—The transverse semielliptical outline, wide and low interarea, nearly flat or slightly concave ventral valve and low weak plication suggest that the present species can be readily distinguished from any other species of *Meekella*. The present specimens are generally identical with the type specimen of *M. pusilloplicata* Liao (1980a) from the Lungtan Formation, Guizhou Province although it appears slightly more transverse in outline. A dorsal valve from the Lungtan Formation at the Daijiagou section was figured as *M. pusilloplicata* Liao by Chen *et al.* (2005a). Although the dorsal valve basically matches the present species in general outline, straight hinge and weak plication, it is impossible to identify its generic assignment based on a single dorsal valve.

*Occurrence*.—E-29; G-32, F-21, 22.

### *Meekella abnormalis* Huang, 1933

Plate 4, Figures 14-17

*Meekella abnormalis* Huang, 1933, p. 30, pl. 4, fig. 7.
*Meekella* aff. *abnormalis* Huang; Zhan in Li *et al.*, 1989, pl. 27, figs. 7-8.

*Material examined*.—A complete conjoined shell (NIGP141546) and an incomplete internal mould of ventral valve (NIGP141547).

*Description*.—Complete shell 22.3 mm long, 28.7 mm wide, 10.2 mm thick, hinge 20 mm wide, interarea 7.8 mm high; weakly convex; ventral valve equal to dorsal valve in size, semicircular in outline, maximum width at shell midlength; hinge straight, slightly shorter than maximum width; lateral and anterior sides nearly evenly rounded, anterior side broadly rounded; anterior commissure almost rectimarginate; shell surface with delicate costellation and plication; costellae fine but distinct, originating from beak, increasing in number by intercalation, numbering about 10 in 5 mm near frontal margin; plication generally weak, only developed on anterior valve, becoming inconspicuous on lateral and umbonal regions, interspaced by intertroughs as wide as plicae.

Ventral valve nearly flat longitudinally, gently convex transversely; beak blunt, erect; interarea widely triangular, catacline; beak ridges angular; pseudodelthyrium slightly convex, with highly convex monticulus; dorsal valve gently inflated in lateral and anterior profiles; sulcus originating from umbonal region, widening and deepening anteriorly, attaining about one-third of maximum width near anterior margin.

Ventral interior with two parallel dental plates; dental plates short, converging toward valve floor, but not united; dorsal interior with two divergent brachiophore plates.

*Discussion*.—The present species is characterized by its catacline interarea and dorsal valve as large as ventral valve. The specimen figured by Zhan (in Li *et al.*, 1989) from the Changhsingian Longdongchuan Formation in Zhenan of Shaanxi Province is basically identical with the present specimens.

*Occurrence*.—F-6, 16.

### *Meekella beipeiensis* Chen in Chen et al., 2005a

Plate 4, Figures 18-25; Plate 5, Figures 1-14; Plate 26, Figure 8

*Meekella beipeiensis* Chen in Chen *et al.*, 2005a, p. 350, figs. 7D, 7E, 9.
*Meekella kueichowensis* Huang; Chen in Chen *et al.*, 2005a, p. 352, fig. 10A.

*Material examined*.—23 specimens. Registered specimens: Seven complete conjoined shells (NIGP141548-141556) and two incomplete conjoined shells (NIGP141557, 141558).

*Description*.—Shell medium to large in size, moderately and subequally biconvex, outline variable, subcircular, circularly triangular or pentagonal, greatest width slightly anterior to shell midlength; hinge straight, about two-thirds of greatest width; cardinal extremities slightly auriculate; lateral sides regularly rounded and anterior side broadly rounded; anterior commissure strongly sulcate in adults, but weakly sulcate in juveniles; shell surface finely costellate and weakly plicate, costellae increasing mainly by intercalation on posterior part of valves, but increasing by both bifurcation and intercalation on anterior part of valves, numbering about 16-20 in 5 mm; plication fairly faint, originating anterior to umbonal region, usually irregular longitudinally on anterior valve, increasing by bifurcation, growth line only developed on middle and anterior parts of valves.

Ventral valve unevenly convex in profile, maximum convexity at umbo; beak conspicuous, slightly attenuated, pointed and strongly curved toward dorsal valve; umbonal angle about 45 degree; interarea triangular, strongly concave and apsacline; beak ridges distinct, angular, pseudodelthyrium narrowly triangular in shape and with strongly convex monticulus along midline; umbonal slopes steep, lateral slopes evenly and moderately declined and anterior slope faintly declined; fold distinct in adults, but absent in juveniles; dorsal valve lidlike, unevenly convex in lateral profile, greatest width at umbonal region; umbonal and lateral slopes evenly declined; sulcus originating anterior to umbonal region, rapidly widening and deepening anteriorly.

Ventral interior with two strong dental plates, dental plates converging toward valve floor, not united (Plate 26, Figure 8); nearly parallel anteriorly, attaining one-fourth of shell length; dorsal interior with two brachiophore plates, diverging at an angle of about 90 degree.

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141548 | 42.9 | 46.1 | 30.8 | 30.2 |
| NIGP141549 | 48.0 | 50.6 | 31.3 | 27.5 |
| NIGP141550 | 47.3 | 48.0 | 30.0 | 25.0 |
| NIGP141551 | 35.8 | 35.5 | 25.0 | 21.9 |
| NIGP141552 | 46.0 | 44.8 | 31.7 | 27.0 |
| NIGP141553 | 44.3 | 42.9 | 29.5 | 25.3 |

| | | | | |
|---|---|---|---|---|
| NIGP141554 | >53.0 | 50.0 | 36.3 | 28.5 |
| NIGP141555 | 38.5 | 40.8 | 23.0 | 23.1 |
| NIGP141556 | 33.5 | 36.2 | 20.0 | 24.0 |
| NIGP141557 | 42.0 | 54.8 | 33.5 | 35.0 |
| NIGP141558 | 48.2 | >41 | 30.6 | 26.7 |

*Discussion*.—The strongly incurved, slightly attenuated beak and moderately deep sulcus on dorsal valve and distinctive fold on ventral valve at maturity of the present species can distinguish it from any other species in this genus. *Meekella zhejiangensis* Liang (in Wang *et al.*, 1982, p. 192, pl. 100, figs. 10–14; Liang, 1990, p. 124, pl. 12, figs. 7–11) and its synonym, *Asiomeekella isoconvexa* Liang (1990, p. 121, pl. 12, figs. 1–6, fig. 13), from the Capitanian Lengwu Formation at Tonglu, Zhejiang Province, southeast China bears some resemblance to the present species in terms of their outline, size and plication, but differs by its low blunt suberect beak. *Meekella kueichowensis* differs from the present species by its much more transverse outline, low and obtuse beak and weak dorsal sulcus. The specimen figured as *Meekella kueichowensis* by Chen in Chen *et al.* (2005a, p. 352, fig. 10A) is nearly consistent with those of the present species in terms of its acute and attenuated beak and distinct dorsal sulcus.

*Occurrence*.—B–22, 24, 25; C–15, 17.

### *Meekella chenxianensis* new species

Plate 5, Figures 15–21; Plate 6, Figures 1–3; Plate 26, Figures 9, 14

*Meekella langdaiensis* Liao; Xu and Grant, 1994, p. 24, figs. 12, 5–12 (non.1–4).

*Holotype*.—NIGP141559 from Jc–15 (Plate 5, figs. 18–21).

*Other material examined*.—Two conjoined shells (NIGP141560, NIGP141562) and two complete ventral valves (NIGP141561, 141563).

*Diagnosis*.—Large, pauciplicate, acute, suberect beak, flat interarea and distinct sulcus on dorsal valve.

*Description*.—Large in size, subequally biconvex, subcircular to circularly triangular in outline, greatest width at midvalve; hinge straight, half to two thirds of shell width; posterolateral sides slightly concave, lateral sides regularly rounded and anterior side gently rounded; anterior commissure slightly to strongly sulcate. Shell surface costellate and plicate, costellae fairly fine, increasing by intercalation and bifurcation, numbering 7 in 2 mm near margin; plications with rounded crests and interspaced by equally wide intertroughs, plications increasing by bifurcation and intercalation, beginning from beak, totally about 15–25 near anterior margin.

Ventral valve nearly flat in lateral profile, but moderately domed in anterior profile; beak thin, erect, usually slightly distorted; interarea triangular, nearly flat except the slightly convex pseudodelthyrium; beak edges bluntly angular, posterolateral slopes sharply inclined, but gradually flattening anteriorly. Dorsal valve strongly convex in lateral profile, greatest convexity at umbonal region; interarea and beak inconspicuous; lateral slopes steep; sulcus originating anterior to umbo, widening and deepening anteriorly, occupying about two thirds of shell width.

Ventral interior with two well developed dental plates, extending about one-third of valve length, converging toward valve floor, but not united (Plate 26, Figures 9, 14); dorsal interior with two strong diverging brachiophore plates and bilobate cardinal process.

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW | IH |
|---|---|---|---|---|---|
| NIGP141559 | 40.1 | 47.9 | 24.5 | 29.8 | 20.0 |
| NIGP141560 | 39.3 | 42.7 | 19.8 | – | – |
| NIGP141561 | 29.9 | 31.2 | – | 22.5 | 17.9 |
| NIGP141562 | 39.4 | 37.3 | >26.3 | 25.4 | >15.7 |
| NIGP141563 | 21.2 | 26.0 | – | 16.0 | 5.1 |

*Etymology*.—Chenxian, a county name in Hunan Province, China.

*Discussion*.—As noted above in the description of *Meekella kueichowensis* Huang, *M. langdaiensis* Liao is considered to be a junior synonyms of *M. kueichowensis* Huang. Although Xu and Grant (1994) designated their specimens as *M. langdaiensis* (not Liao), the specimens figured are obviously different from the type of *M. kueichowensis* Huang. Xu and Grant's (1994) specimens have a much higher interarea and narrower outline than Liao's specimens. Therefore, we consider that the specimens figured by Xu and Grant (1994) represent a new species of *Meekella*, named herein *M. chenxianensis* new species. This new species is similar to *M. beipeiensis* Chen (in Chen *et al.*, 2005a), but differs in possessing a nearly erect, acute, attenuated beak, weakly biconvex profile and fewer plicae.

This species is similar to *Meekella accidentalis* (Newberry, 1861, p. 126, pl. 1, figs. 5, 5a; Cooper and Grant, 1974, p. 367, pl. 117, figs. 1–4, 9–13) and *Meekella grandis* (King, 1931, p. 54, pl. 6, figs. 5–7) from the Wolfcamp and Leonard Formations in the Glass Mountains, Texas, USA in view of their lateral profile and acute beak, but the North American species possess much distinct plication. *Meekella sanheensis* Liao and Meng (1986, p. 76, pl. 1, figs. 27, 28) differs from the present species by its very high ventral interarea.

*Occurrence*.—Jc–15.

### Genus *Orthothetina* Schellwien, 1900a

*Orthothetina* Schellwien, 1900a, p. 8.
*Hamletella* Hayasaka, 1953, p. 92.
*Lopingia* Zhan in Hou *et al.*, 1979, p. 64.
*Orthothetina* Schellwien; Liao, 1987, p. 98.
*Orthothetina* Schellwien; Williams *et al.*, 2000b, p. 663.

*Type species*.—*Orthotetes persicus* Schellwien, 1900a, p. 8 from the Kazanian, Persia, Iran.

*Discussion*.—This genus was formerly misspelt as *Orthotetina* by most Chinese workers. Zhan (in Hou *et al.*, 1979) proposed a genus *Lopingia* with *Orthotetes ruber* Frech (1911, p. 124) as the type species. As defined by Zhan, *Lopingia* is characterized by a subquadrate or subcircular outline and short and subparallel dental plates. In proposing this genus, Zhan (in Hou *et al.*, 1979) referred *Orthothetina ruber* (Frech)

and *O. regularis* (Huang) to *Lopingia*. However, *Lopingia* has not been accepted by most other brachiopod workers because the diagnostic characteristics for this genus are believed to be intra-generic variations, including variable size, shape and the orientation of dental plates (Williams *et al.*, 2000b). In this paper, we regard *Lopingia* as a junior synonym of *Orthothetina*. Hayasaka (1953), using *Streptorhynchus altus* Hamlet (1928) from the Permian of Timor as the type species, proposed the genus *Hamletella*. *Hamletella* is also a synonym of *Orthothetina* in terms of its two dental plates and finely costellate but non-plicate shell.

*Orthothetina* generally differs from *Meekella* by its non-plicate shell, but the tendency to form plications seems inherent within the Orthetetoidea (Grant, 1995). Some species of *Orthothetina* in the Dzhulfian stage of Iran and Pakistan show some irregular plications (Sokolskaja in Ruzhentsev and Sarytcheva, 1965 ; Grant, 1970). *Orthothetina* differs from *Meekella* by its two thinner and closer dental plates (Liao, 1987). *Orthothetina* differs from *Perigeyerella* Wang, 1955a by the two nearly parallel dental plates which do not converge to a spondylium, but this distinction is also difficult for some species (see discussion below in *Perigeyerella*, Wang, 1955a), and from *Orthotetes* Fischer de Waldheim, 1829 and *Derbyia* Waagen, 1884 by its nearly parallel dental plates instead of median septum. *Schellwienella* Thomas, 1910 also possesses two thin dental plates and finely costellate shell which are similar to *Orthothetina*. But the dental plates of *Schellwienella* are short and distinctly divergent. In addition, *Schellwienella* has a very different cardinalia in the dorsal valve, characterized by widely divergent recurved socket ridges and low cardinal process of the family Pulsiidae Cooper and Grant (1974).

### *Orthothetina ruber* (Frech, 1911)

Plate 6, Figures 4-18

*Orthotetes ruber* Frech, 1911, p. 124, pl. 26, figs. 4a-b.
*Orthotetes ruber* Frech, 1911 ; Hayasaka, 1922, p. 72, pl. 3, figs. 24-25.
*Orthotetes ruber* Frech, 1911 ; Grabau, 1931, p. 351, pl. 24, figs. 6 (non.9).
*Schellwienella ruber* (Frech) ; Huang, 1933, p. 23, pl. 3, figs. 8-9.
*Schellwienella ruber* (Frech) ; Shimizu, 1961, p. 246, pl. 9, figs. 1-5.
*Schellwienella ruber* (Frech) ; Wang *et al.*, 1964, p. 206, pl. 29, figs. 21-22.
*Orthotetina ruber* (Frech) ; Jin *et al.*, 1974, p. 311, pl. 164, figs. 1-2.
*Orthotetina ruber* (Frech) ; Yang *et al.*, 1977, p. 321, pl. 132, fig. 5.
*Orthotetina ruber* (Frech) ; Feng and Jiang, 1978, p. 238, pl. 87, fig. 10 (non 9).
*Orthotetina ruber* (Frech) ; Tong, 1978, p. 214, pl. 78, figs. 3-6.
*Lopingia ruber* (Frech) ; Zhan in Hou *et al.*, 1979, p. 65, pl. 4, figs. 3-4.
*Orthotetina ruber* (Frech) ; Liao, 1980a, pl. 2, figs. 1-3.
*Orthotetina ruber* (Frech) ; Liao and Meng, 1986, pl. 1, figs. 18-19.
*Orthotetina ruber* (Frech) ; Xu in Yang *et al.*, 1987, p. 218, pl. 7, figs. 10-18.
*Orthotetina ruber* (Frech) ; Zhu, 1990, p. 64, pl. 18, figs. 29-32 (non pl. 9, figs. 21-23).
*Orthotetina ruber* (Frech) ; Liang, 1990, p. 109, pl. 15, figs. 9-10.

*Material examined*.—Numerous specimens, most of specimens are disarticulated ventral and dorsal valves. Registered specimens : A complete conjoined shell (NIGP141577), a complete internal mould of conjoined shell (NIGP141565), four internal moulds of ventral valve (NIGP141569, 141572, 141573, 141576) and six internal moulds of dorsal valve (NIGP141564, 141566-141568, 141574, 141575).

*Description*.—Shell medium in size for genus, subquadrate to semicircular in outline, length nearly equal to width, convex-concave or convex-flat in profile, maximum width near shell midlength ; hinge straight, about two-thirds of shell width ; cardinal extremities widely auriculate, cardinal angle about 120 degree ; lateral sides regularly rounded, anterior side gently rounded ; anterior commissure rectimarginate ; surface ornamented with delicate costellae ; costellae fine but distinct, increasing by intercalation, 14 in 5 mm near anterior margin ; interspaces as wide as costellae ; growth lines sparse, increasing in density anteriorly.

Ventral valve nearly flat or slightly concave in lateral profile ; umbonal region slightly swollen, umbonal slopes gently declined ; beak bluntly pointed ; interarea widely triangular, apsacline ; dorsal valve evenly convex in lateral profile, maximum convexity near midvalve ; flanks evenly declined ; sulcus originating from umbonal region, widening and deepening anteriorly.

Ventral interior with two knife-edged dental plates, dental plates short and diverging at different angles between 10-45 degree, extending anteriorly for about one-quarter of shell length ; dorsal interior with two brachiophore plates diverging at about 60 degree.

*Measurements (in mm)*.—(LDP=Length of dental plates)

| Specimen no. | L | W | T | HW | LDP |
|---|---|---|---|---|---|
| NIGP141564 | 24.0 | 30.0 | 5.0 | 20.0 | — |
| NIGP141565 | 16.2 | 18.7 | 2.0 | 10.7 | 4.1 |
| NIGP141566 | 16.7 | 19.3 | — | 10.5 | — |
| NIGP141567 | 16.7 | 19.8 | — | 14.5 | — |
| NIGP141568 | 25.0 | 28.9 | — | 20.5 | — |
| NIGP141569 | 15.3 | 20.0 | — | 16.6 | 4.0 |
| NIGP141570 | 19.7 | 22.9 | — | 17.5 | 3.1 |
| NIGP141571 | 18.0 | 21.3 | — | 10.7 | — |
| NIGP141572 | 18.2 | 20.5 | — | 13.7 | 7.3 |
| NIGP141573 | 20.8 | 25.7 | — | 12.7 | — |
| NIGP141574 | 21.2 | 29.4 | — | 19.1 | — |
| NIGP141575 | 16.8 | 22.7 | — | 14.1 | — |
| NIGP141576 | 17.3 | 18.6 | — | 13.6 | 4.4 |
| NIGP141577 | 12.6 | 16.2 | 6.2 | 10.7 | — |

*Discussion*.—*Orthothetina ruber* is one of the commonest species in the Lopingian of South China. Our specimens match well in all observed respects with Frech's (1911) and Hayasaka's (1922) materials which they referred to as *O.*

*ruber.*

Grabau (1931, pl. 24, figs. 6, 9) described two specimens from the Permian in Jisu Honguer (Zhesi), Inner Mongolia as *O. ruber* (Frech) ; the specimen in his figure 9, however, possesses a high catacline interarea and conspicuous concentric wrinkles, unlike the types of *O. ruber* (Frech) from the Lopingian of Jiangxi Province, South China. The specimen in Grabau's figure 6 is similar to the present species in its outline and size, but its umbonal region, beak and costellae are not preserved, preventing further comparison. Feng (in Feng and Jiang, 1978, pl. 87, figs. 9–10) described two specimens from the Lungtan Formation, Guizhou Province as *O. ruber* (Frech), one of which (fig. 9), however, may be referred to *O. frechi* Huang, described below, by its size and the nearly rounded cardinal extremities.

*Occurrence*.—A–1, 8, 9, 11, 19, 20, 28 ; B–1, 19, 21, 22 ; D–5, 8, 15, 21, 23, 27, 31 ; E–30, 33, 40, 42, 45 ; F–6, 8, 10, 14, 15, 16, 18, 19, 20, 31, 32, 33, 41, 43, 44, 46 ; G–32, 37, 45, 46, 55 ; H–130 ; I–2, 9, 38, 56, 57 ; Jb–4, 5 ; Jc–15.

### *Orthothetina regularis* (Huang, 1933)

Plate 6, Figures 19–24

*Schellwienella regularis* Huang, 1933, p. 25, pl. 3, figs. 10–11.
*Schellwienella regularis* Huang, 1933 ; Shimizu, 1961, p. 247, pl. 9, figs. 6–9.
*Schellwienella regularis* Huang, 1933 ; Wang *et al.*, 1964, p. 207, pl. 29, fig. 19.
*Orthothetina regularis* (Huang) ; Yang *et al.*, 1977, p. 320, pl. 32, fig. 12.
*Lopingia regularis* (Huang) ; Zhan in Hou *et al.*, 1979, p. 66, pl. 4, figs. 22–23.
*Orthothetina regularis* (Huang) ; Liao, 1980a, pl. 1, figs. 39–42.
*Orthothetina regularis* (Huang) ; Liao and Meng, 1986, pl. 1, fig. 16.
*Orthothetina regularis* (Huang) ; Liao, 1987, pl. 3, figs. 1–7.
*Orthothetina regularis* (Huang) ; Xu in Yang *et al.*, 1987, pl. 7, figs. 19–22, 26.
*Orthothetina regularis* (Huang) ; Zhu, 1990, p. 64, pl. 9, figs. 21–23 (non pl. 18, figs. 29–32).

*Material examined*.—Numerous specimens, most of which are disarticulated valves. Registered specimens : A complete conjoined shell (NIGP141582), three internal moulds of ventral valve (NIGP141578, 141580, 141581) and an incomplete dorsal valve (NIGP061).

*Description*.—Shell small for genus, semicircular or subcircular in outline, plano–convex to convex–plane in profile, greatest width at shell midlength ; hinge shorter or nearly equal to greatest width ; cardinal extremities rounded ; lateral sides and anterior side evenly rounded ; anterior commissure rectimarginate ; shell surface with delicate radial costellae, costellae fine and conspicuous, increasing by intercalation, numbering 13 in 5 mm near front margin, interspaced by equal intertroughs.

Ventral valve nearly flat or slightly convex in lateral profile ; umbonal region usually slightly swollen, but flattening anteriorly and laterally ; beak blunt, two posterior sides converging, forming an umbonal angle more than 120 degree ; interarea moderately high, gently apsacline to catacline ; dorsal valve flat to moderately convex in lateral profile, maximum convexity slightly posterior to midvalve ; sulcus almost absent or very weak.

Ventral interior with two rather short dental plates, dental plates generally 1.5–2.5 mm long, diverging at an angle of 10–45 degree ; dorsal interior with two divergent brachiophore plates.

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141578 | 8.0 | 11.6 | — | 11.2 |
| NIGP141579 | 14.5 | 14.0 | — | — |
| NIGP141580 | 11.2 | 12.8 | — | — |
| NIGP141581 | 10.1 | 12.5 | — | — |
| NIGP141582 | 11.8 | 13.6 | 5.4 | 10.5 |

*Discussion*.—The present species is commonly associated with *Orthothetina ruber* (Frech, 1911) in the Lopingian of South China, probably suggesting that some of them may be juveniles of the latter. Nevertheless, our examination of the materials in hand shows that the present species is distinguished from *O. rube*r in its small size, semicircular or subcircular outline and rather short dental plates.

*Occurrence*.—E–40, 49 ; A–4, 11, 20, 26, 31 ; B–1, 11, 19, 21, 23 ; C–17 ; D–8, 23, 26, 29 ; F–27, 42, 46 ; G–28, 32, 37, 45, 56 ; H–130, 137, 140 ; I–56 ; Jc–10.

### *Orthothetina eusarkos* (Abich, 1878)

Plate 6, Figures 25–28

*Streptorhynchus creistria* var. *eusarkos* Abich, 1878, p. 73, pl. 6, fig. 4.
*Streptorhynchus crenistris* var. *incurvus* Abich, 1878, p. 73, pl. 5, fig. 5.
*Perigeyerella costellata subquadrat*a Zhang and Jin, 1961, p. 408, pl. 3, figs. 21–23.
*Orthothetina eusarkos* (Abich) ; Sokolskaja in Ruzhentsev and Sarytcheva, 1965, p. 208, pl. 31, figs. 3–5.
*Schellwienell*a sp. Shimizu, 1981, p. 69, pl. 8, fig. 11.

*Material examined*.—Two ventral valves (NIGP141585, 141586) and three dorsal valves (NIGP141583, 141584, 141587).

*Description*.—Shell large–sized for genus, moderately biconvex, outline subcircular or quadrately circular, greatest width at shell midlength ; hinge straight, more than two–thirds of shell width ; lateral sides evenly rounded, meeting hinge line at about 120 degree, anterior side broadly rounded ; anterior commissure probably slightly sulcate ; shell surface finely costellate, costellae fine but distinct, interspaced by intertroughs of equal width, increasing in number by intercalation, numbering about 14 in 5 mm near front margin, growth lines usually developed around ventral umbonal region and occasionally developed on other regions.

Ventral valve nearly flat except for curved umbonal region in lateral profile, but moderately domed in anterior profile ; umbonal slopes moderately steep ; flanks gently declined ; beak blunt, suberect ; interarea widely triangular in shape, moderately to strongly apsacline ; beak ridges conspicuous ;

pseudodelthyrium narrowly triangular and with a convex monticulus along its midway ; fold absent ; dorsal valve lidlike, more strongly convex in profile than ventral valve, maximum convexity slightly posterior to midvalve ; umbonal and lateral slopes strongly declined ; anterior slope moderately steep ; sulcus weak, originating from midvalve.

Ventral interior with two thin parallel dental plates converging toward valve floor, but not united, extending anteriorly to about one-third of shell length ; dorsal interior with two strong brachiophore plates diverging at about 70 degree ; cardinal process large, bilobed ; shaft slit posteriorly along midline.

*Measurements (in mm).*—

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141583 | 31.2 | 56.0 | 11.0 | 32.0 |
| NIGP141584 | 30.0 | 33.0 | 6.3 | 25.5 |
| NIGP141585 | 36.0 | 38.5 | 4.0 | 32.0 |
| NIGP141586 | >33.5 | 42.5 | 11.0 | 37.0 |
| NIGP141587 | 35.0 | 42.8 | 16.0 | 29.0 |

*Discussion*.—*O. eusarkos* is the largest species in *Orthothetina* so far described in the world. Perhaps with the exception of their suberect beak, the present specimens are otherwise identical to *Orthothetina eusarkos* (Abich, 1878) from Transcaucasia and to those assigned to the same species by Sokolskaja (in Ruzhentsev and Sarytcheva, 1965). Zhang and Jin (1961) described a specimen as *Perigeyerella costellata subquadrata* from the Lopingian, Jinxian County, Anhui Province, China. However, the description of "ventral interior with two thin dental plates" and their figure 23 of plate 3 show that the specimen is referrable to *Orthothetina.* Furthermore, Zhang and Jin's specimen also has a subcircular outline, a large size and an evenly biconvex profile, all matching with those of the present species.

It is worthy mentioning that the ventral valve figured by Shimizu (1981, p. 69, pl. 8, fig. 11) from the Unit $E_1$ of the Khunamuh Formation in Kashmir appears to be conspecific with the present species in terms of its two strong parallel dental plates, a subquadrate outline and its maximum width at midvalve.

*Occurrence*.—A-8, 9, 10 ; G-45.

### ***Orthothetina shuangtangensis*** **Liang, 1990**

Plate 6, Figures 29-34 ; Plate 7, Figures 1-8

? *Perigeyerella costellata* Jin and Ye, 1979, p. 77, pl. 22, figs. 16-18.

*Orthothetina shuangtangensis* Liang in Wang *et al.*, 1982, p. 196, pl. 99, figs. 8-12.

*Material examined*.—Three internal moulds of ventral valve (NIGP141589, 141592, 141593) and three complete conjoined shells (NIGP141588, 141590, 141591).

*Description*.—Shell of medium size for genus, elongate in outline, moderately biconvex, greatest width slightly anterior to shell midlength ; hinge straight and short, about half of shell width ; cardinal extremities slightly auriculate or nearly rounded ; posterior sides converging toward beak at about 60 degree, lateral sides rounded ; anterior commissure slightly sulcate ; shell costellate, costellae fine and dense, increasing anteriorly by intercalation, numbering about 20 in 5 mm at midvalve ; growth lines increasing in density anteriorly.

Ventral valve gently convex longitudinally, but moderately domed transversely ; beak attenuated, nearly erect ; interarea fairly high, slightly distorted, elongately triangular in shape ; beak ridges conspicuous ; pseudodelthyrium narrowly triangular ; monticulus domed along midline of interarea ; ventral umbonal slope sharply declined, lateral sides also strongly declined. Dorsal valve lidlike, fairly strongly convex both in lateral and anterior profile, greatest convexity slightly posterior to midvalve ; sulcus originating from umbonal region, slightly widening and deepening anteriorly.

Ventral interior with two strong dental plates, dental plates long (15 mm), nearly parallel anteriorly, but slightly converging toward valve floor. Dorsal interior with two strong brachiophore plates.

*Measurements (in mm).*—

| Specimen no. | L | W | T | HW | IH |
|---|---|---|---|---|---|
| NIGP141588 | 37.3 | 32.2 | 23.4 | 17.7 | 10.9 |
| NIGP141589 | 36.3 | 31.5 | 18.0 | 20.5 | 10.9 |
| NIGP141590 | 42.8 | 40.0 | 26.4 | 22.8 | 19.0 |
| NIGP141591 | >32.0 | 36.3 | 20.5 | 20.0 | – |
| NIGP141592 | 29.8 | 30.6 | – | – | – |
| NIGP141593 | 38.2 | 28.6 | – | 20.7 | – |

*Discussion*.—The present specimens generally fit with the type of *O. shuangtangensis* Liang from the Maokouan Tingchiashan Formation of Tonglu, Zhejiang Province in terms of outline, the high interarea and long dental plates. The specimen described as *Perigeyerella costellata* Wang by Jin and Ye (1979) from northern Qaidam Basin in Qinghai Province has separated and subparallel dental plates, an elongate outline, and a high, nearly erect interarea, all closely similar to those of the present species.

*Occurrence*.—A-26 ; B-19, G-55.

### ***Orthothetina ellipsoides*** **Shen, He and Zhu, 1992**

Plate 7, Figures 9-12

*Orthothetina ellipsoides* Shen *et al.*, 1992, p. 175, pl. 1, figs. 1-4.

*Perigeyerella costellata* Wang ; Chen in Chen *et al.*, 2005a, p. 350, figs. 7B, 7C, 8.

*Holotype*.—NIGP141594 (=CUMT8237), a complete conjoined shell from A-26 (Plate 7, Figures 9-12).

*Other material examined*.—an incomplete conjoined shell (NIGP141595).

*Diagnosis*.—Shell with transversely elliptical outline, very short hinge line, rectimarginate anterior commissure, rapidly attenuated beak and strongly domed dorsal valve.

*Description*.—Medium-sized for genus ; unequally biconvex, outline transversely elliptical, greatest width at shell midlength ; hinge 17.6 mm wide, straight, about half of shell width, cardinal extremities almost rounded ; lateral sides evenly and strongly rounded and anterior side broadly rounded ; anterior commissure nearly rectimarginate ; shell

surface with fine and dense costellae, intertroughs as wide as costellae, costellae increasing in number by intercalation, numbering 6 in 2 mm near front margin.

Ventral valve nearly flat in lateral profile, but moderately domed in anterior profile ; beak rapidly attenuated and pointed at about 45 degree ; interarea triangular in shape, slightly concave longitudinally ; pseudodelthyrium narrowly triangular with a monticulus along midway ; ventral umbonal slopes sharply steep, lateral slopes moderately declined ; dorsal valve lidlike, more convex than ventral valve ; umbonal region strongly swollen, then evenly declined outwards ; sulcus originating from umbonal region, extending to anterior margin without widening or deepening.

Ventral interior with two closely-spaced parallel dental plates, converging toward valve floor, attaining about quarter of shell length ; dorsal interior with two brachiophore plates diverging at about 120 degree.

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141594 | 34.4 | 38.0 | 22.3 | 17.6 |
| NIGP141595 | >31.5 | 39.0 | 23.2 | 17.5 |

*Discussion*.—This species is somewhat similar to *Orthothetina shuangtangensis* Liang in terms of its lateral profile and anterior commissure, but it can be readily distinguished by its transversely elliptical outline, strongly contracted beak and strongly convex dorsal valve. The specimens described as *Perigeyerella costellata* Wang by Chen in Chen *et al.* (2005a, p. 350, figs. 7B, C, 8) is apparently an *Orthothetina*, which is generally comparable with the present species, in terms of its two divergent parallel dental plates (see Chen in Chen *et al.*, 2005a, fig. 7$C_1$) and its relatively low beak. "*Perigeyerella*" usually possesses a more acute beak and its dental plates are convergent to form a distinct spondylium.

*Occurrence*.—A-26 ; G-55.

### *Orthothetina triangularis* Tong, 1978

Plate 7, Figures 13-20 ; Plate 26, Figure 7

*Orthotetina triangularis* Tong, 1978, p. 214, pl. 78, fig. 2.
*Orthothetina exquisit*a Shen *et al.*, 1992, p. 176, pl. 1, figs. 5-8.

*Material examined*.—Three complete conjoined shells (NIGP141596, 141597, NIGP141598=CUMT8234).

*Description*.—Shell small for genus, moderately biconvex, triangular to circularly triangular in outline, somewhat asymmetrical, maximum width anterior to shell midlength ; hinge short and straight ; cardinal extremities rounded ; posterior sides converging posteriorly at 60 to 90 degree, lateral sides regularly rounded, anterior side broadly rounded to nearly straight. Costellae prominent, increasing by intercalation, numbering 13 in 5 mm near anterior margin, intertroughs slightly narrower than costellae ; concentric wrinkles occasionally developed on both valves, increasing in number anteriorly ; anterior commissure rectimarginate.

Ventral valve flat in lateral profile, but slightly domed in anterior profile ; beak pointed and attenuated, nearly erect, sometimes slightly distorted ; interarea high and triangular in shape ; beak ridges conspicuous ; pseudodelthyrium convex with conspicuous monticulus along midway ; umbonal slopes sharply steep, front slope flatly declined, lateral slopes flattening anteriorly.

Dorsal valve lidlike, semicircular to subcircular in outline, moderately convex in lateral profile, maximum convexity slightly posterior to midvalve ; sulcus originating from umbonal region, generally weak, slightly widening and deepening anteriorly.

Ventral interior with two dental plates, converging toward valve floor, not united (Plate 26, Figure 7), rapidly diverging anteriorly in beak area, keeping subparallel forwards, extending to one-third of shell length. Dorsal interior with divergent brachiophore plates.

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW | IH |
|---|---|---|---|---|---|
| NIGP141596 | 15.2 | 15.5 | 8.6 | 8.0 | 6.3 |
| NIGP141597 | 22.5 | 19.4 | 13.0 | 9.5 | 9.0 |
| NIGP141598 | 18.6 | 19.2 | 9.7 | 9.5 | 6.3 |

*Discussion*.—Shen *et al.* (1992) proposed a new species named *Orthothetina exquisita* based on these specimens. However, subsequent studies on these same specimens show that they generally fit those described as *O. triangularis* by Tong (1978) from the Early Permian Chihsia Formation of South China.

*Occurrence*.—A-26 ; G-45.

### *Orthothetina elongata* Nakamura, 1972

Plate 7, Figures 21-24

*Orthotetina kayseri* (Jaekel) ; Hayasaka, 1963, p. 756, figs. 3a. 3c.
*Orthotetina elongat*a Nakamura, 1972, p. 379, pl. 1, figs. 3-6 ; pl. 2, fig. 1.
*Orthothetina rara* Shen *et al.*, 1992, p. 176, pl. 2, figs. 7-10.

*Material examined*.—A complete conjoined shell, NIGP141599 (=CUMT8233).

*Description*.—Shell small, 29.5 mm long, 25.3 mm wide, 11 mm thick, hinge 13 mm wide ; gently biconvex, elongately triangular in outline, greatest width anterior to shell midlength ; hinge straight, about half of shell width, slightly auriculate in dorsal view ; lateral sides moderately rounded and anterior side broadly rounded, posterior sides usually irregular, but generally converging posteriorly by about 45 degree ; anterior commissure rectimarginate ; shell surface with delicate costellae, fine but distinct, interspaced by narrower intertroughs, increasing by intercalation, numbering 9 in 2 mm on anterior valve ; growth lines occasionally developed, gradually becoming conspicuous anteriorly.

Ventral valve nearly flat longitudinally, but gently convex transversely ; beak pointed, attenuated, distorted, left beak ridge concave on dorsal view and right beak ridge convex ; interarea generally triangular but also distorted, not concave, gently apsacline ; pseudodelthyrium narrow, triangular, with highly convex monticulus ; ventral median region nearly flat or slightly concave, but moderately declined laterally ; dorsal

valve lidlike, nearly evenly convex, maximum convexity slightly posterior to midvalve; sulcus shallow, originating from midvalve, slightly widening and deepening anteriorly.

Ventral interior with long dental plates, attaining about half of shell length, dental plates converging toward valve floor, slightly united under beak, anteriorly rapidly separated and parallel anteriorly, middle part distorted in accordance with the asymmetrical beak; dorsal interior with two brachiophore plates.

*Discussion*.—This species is characterized by its elongately triangular outline, distorted beak, long and parallel dental plates and gently biconvex profile. It was referred to as a new species by Shen *et al.* (1992, p. 176, pl. 2, figs. 7–10). However, comparison with the specimens from the Kitakami Mountains in northeastern Japan reported by Hayasaka (1963) and Nakamura (1972) reveal that they share most external and internal features. *Hamletella* (=*Orthothetina*) *kitakamiensis* (Hayasaka, 1953, p. 93, pl. 9, figs. 1–2) is closely similar to *O. elongata* in its outline, but the former seems to have a slightly higher interarea.

*Occurrence*.—A–26.

### *Orthothetina frechi* (Huang, 1933)

Plate 7, Figures 25–29

*Schuchertella frechi* Huang, 1933, p. 21, pl. 3, figs. 2–4, 5, 6.
*Orthothetina ruber* (Frech); Feng and Jiang, 1978, p. 238, pl. 87, fig. 9.
*Orthothetina frechi* (Huang); Liao, 1980a, p. 254, pl. 2, fig. 12, non figs. 13, 14.

*Material examined*.—Ten incomplete ventral valves, six registered (NIGP141600–141605).

*Description*.—Shell medium in size for genus, transversely elliptical in outline; ventral valve flat or slightly concave in lateral profile; umbonal region usually swollen; beak blunt and erect; interarea low and widely triangular, catacline; hinge line straight, shorter than shell width at midvalve; cardinal extremities obtusely rounded; lateral sides evenly and moderately rounded, anterior side broadly rounded; anterior commissure rectimarginate; shell surface finely costellate, costellae increasing in number by intercalation, numbering about 15 in 5 mm near anterior margin, growth line only occasionally developed on anterior valve.

Ventral interior with short and distinct dental plates, about 3 mm long, diverging at about 10–30 degree; dorsal characters unknown.

*Measurements (in mm)*.—

| Specimen no. | L | W | HW |
|---|---|---|---|
| NIGP141600 | 25.0 | 29.9 | 20.0 |
| NIGP141601 | 24.0 | 30.2 | — |
| NIGP141602 | 23.0 | 28.5 | 21.5 |
| NIGP141603 | 26.4 | 33.9 | 26.7 |
| NIGP141604 | 15.8 | 23.0 | 19.2 |
| NIGP141605 | 24.3 | 34.4 | 32.5 |

*Discussion*.—This species is characterized by its very short, divergent dental plates and transverse and semielliptical outline. *Orthothetina ruber* (Frech, 1911) differs from the present species in its more rounded outline and nearly parallel and longer dental plates. Although Huang (1933. p. 21) described this species as having no dental plates, one of his specimens (Huang, 1933, pl. 3, fig. 5a, 5b) clearly shows the presence of short dental plates, therefore this species can be safely assigned to *Orthothetina* (Liao, 1980a, p. 254). The present species appears identical in outline with "*Schuchertella frechi*" Huang (1933, p. 21, pl. 3, figs. 2–4). Liao (1980a, p. 254, pl. 2, figs. 12–14) figured a few specimens from the Lopingian of western Guizhou Province. The specimen figured by Liao (1980a, fig. 12) is identical with the present species. On the other hand, Liao's another specimen (Liao 1980a, 13, 14) is very different from the type material of "*Schuchertella frechi*" Huang (1933) in terms of its elongate outline and strong dorsal convexity.

*Occurrence*.—D–5, 15, 18; F–7, 10, 16, 21, 22, 26, 27, 29; G–3.

## Genus *Paraorthotetina* He and Zhu, 1985

*Paraorthotetina* He and Zhu, 1985, p. 198.

*Type species*.—*Orthotetina provecta* (Liao, 1980a, p. 254, pl. 2, figs. 26–29) from the Lungtan Formation in Anshun, Guizhou, South China.

*Diagnosis*.—Large shell with greatest width at hinge, ventral interior with two slightly divergent dental plates, muscle scars extremely strong, usually elevated, ridges around muscle platform well developed; surface with fine costellae, but without plication.

*Discussion*.—*Paraorthotetina* differs from *Orthothetina* in its strong flabellate muscle platform in the ventral valve and divergent dental plates. The role of muscle platform in generic classification is still questionable and therefore further study should be carried out. Externally, *Paraorthotetina* differs from *Orthothetina* in its larger size, subquadrate outline and the greatest width at hinge. *Parameekella* He and Zhu, 1985 was considered to be a synonym of *Paraorthotetina* by Williams *et al.* (2000b), but can be readily distinguished by the presence of plication. Therefore, we regard *Parameekella* as a synonym of *Meekella* rather than *Paraorthotetina.*

### *Paraorthotetina provecta* (Liao, 1980a)

Plate 7, Figure 30

*Orthotetina provecta* Liao, 1980a, p. 254, pl. 2, figs. 26–28.
*Paraorthotetina provecta* (Liao); He and Zhu, 1985, p. 199, pl. 1, figs. 1–4.

*Material examined*.—An internal mould of ventral valve (NIGP141606).

*Description*.—Ventral valve large, 38.5 mm long and 51.3 mm wide, subquadrate in outline, greatest width at hinge; cardinal extremities short and small, nearly quadrate; umbonal region slightly inflated, but other regions flat; posterolateral sides nearly straight longitudinally and anterolateral sides gently rounded, anterior sides broadly rounded; beak fairly low, blunt; interarea widely triangular in shape.

Ventral interior with two dental plates, dental plates converging toward valve floor and diverging anteriorly at about 40 degree, attaining about a quarter of shell length; muscle scars very strong, 20.3 mm long, anterior side surrounded by a low ridge, consisting of radial shallow grooves, separated by low ridge on anterior muscle platform. Other characters unknown.

*Discussion*.—The present specimen is identical to *Paraorthotetina provecta* (Liao, 1980a, p. 254, pl. 2, figs. 26–28) from the Lungtan Formation of Guizhou. Xu (in Yang *et al.*, 1987, pl. 8, figs. 7–9) figured three dorsal internal moulds as *Orthotetina provecta* (Liao) from Fujian Province, southeast China; however, the interiors in the ventral valves of Xu's specimens are totally unknown, therefore casting doubt on their identity with the type material of *Paraorthotetina provecta* (Liao, 1980a).

*Occurrence*.—F–10.

### Genus *Perigeyerella* Wang, 1955a

*Perigeyerella* Wang, 1955a, p. 101.
*Perigeyerella* Wang; Grant, 1976, p. 60.
*Perigeyerella* Wang; Liang, 1990, p. 127.
*Perigeyerella* Wang; Williams *et al.*, 2000b, p. 664.

*Type species*.—*Perigeyerella costellata* Wang, 1955a, p. 101, pl. 6, figs. 1–10 from the Changhsing Formation in northern Guizhou, China.

*Diagnosis*.—Shell finely costellate but not plicate; weakly to moderately biconvex, ventral interior with dental plates meeting in beak to form spondylium, but slightly separated anteriorly and meeting valve floor like in *Meekella* and Orthothetina; dorsal interior with two divergent brachiophore plates; cardinal process long, stout and bilobed.

*Discussion*.—*Perigeyerella* differs from *Geyerella* Schellwien, 1900b in its absence of plication and from *Kiangsiella Grabau* in Chao, 1927, *Streptorhynchus* King, 1850 and *Tropidelasma* Cooper and Grant, 1969 in having dental plates united posteriorly and supported by a median septum. It differs from *Meekella* White and John, 1867 and *Orthothetina* Schellwien, 1900a in that the configuration of its dental plates begins with an elevated spondylium, much like in *Sicelia* Gortani and Merla, 1934, *Geyerella* Schellwien, 1900b and *Ombonia* Caneva, 1906, then passes through a sessile spondylium and terminates with parallel plates and no spondylium like in *Meekella* and *Orthothetina. Perigeyerella costellata* Wang, 1955a has been recognized as one of the most characteristic species of the Changhsingian in South China (Zhang and Jin, 1961; Grant, 1976; Feng and Jiang, 1978; Liao, 1980a, 1987; Liao and Meng, 1986; Liang, 1990; Shen, *et al.*, 1992; Xu and Grant, 1994, He and Shi, 1996 *etc.). Sicelia* Gortani and Merla, 1934 with *Canavaria acropedion* Merla [1928, p. 72, pl. 2(1), figs. 1–4, 8–10, 13–15] as the type species is nearly the same as *Perigeyerella* in terms of the internal structure of the ventral valve. Grant (1995) considered that *Sicelia* lies between *Ombonia* and *Perigeyerella* in terms of the nature of ventral spondylium. *Ombonia* has plates that join above the valve floor to form an elevated spondylium that remains elevated to its anterior termination. By contrast, *Perigeyerella* has the plates joined and the spondylium elevated only in the beak and then meet the floor and diverge to become distinct plates in adults. *Scielia* thus appears to be a transitional form between *Perigeyerella* and *Ombonia*, as it has the plates meeting at the floor in the beak, slightly diverging anteriorly but remaining so close together that the floor between them tends to become slightly thickened to be enough to term a spondylium (Grant, 1995, p. 666). But this is ambiguous. The secondary thickening between dental plates is quite variable in Orthotetoidea such as in *Meekella* discussed above. The species from South China previously assigned to *Perigeyerella* Wang, 1955a and the species of *Sicelia* from Greece (Grant, 1995) all possess a joint spondylium in beak and two slightly divergent dental plates in adults which can not be distinguished from each other in terms of the nature of spondylium. Howevere, *Sicelia* may be distinguishable from *Perigeyerella* by its conical ventral valve which is closer to *Geyerella* in view of this character (Greco, 1942, pl. 18, figs. 5–13).

*Perigeyerella* shows some transitional aspects with *Orthothetina* in some species. This is due to that some species of *Orthothetina*, such as *O. triangularis* Tong, 1978 and *O. elongata* Nakamura, 1972, seem to have their dental plates joined in the apex to form a pseudospondylium like some species of *Meekella*; however, in these species the pseudospondylium is not elevated on a median septum as in typical *Perigeyerella.* Xu and Grant (1994, p. 26) described and figured a specimen (USNM 455999) as *Perigeyerella costellata* Wang. The serial sections of this specimen show that it has no elevated spondylium in the ventral valve, suggesting that it probably belongs to *Orthothetina.*

*Occurrence*.—Permian; Thailand, South China.

### *Perigeyerella costellata* Wang, 1955a

Plate 8, Figures 1–16

*Perigeyerella costellata* Wang, 1955a, p. 101, pl. 6, figs. 1–10.
*Perigeyerella costellata* Wang; Wang, 1955b, p. 151, pl. 86, figs. 14, 16, 17.
*Perigeyerella costellata* Wang; Wang *et al.*, 1964, p. 211, pl. 31, figs. 1–5, 19.
*Perigeyerella costellata* Wang; Yang *et al.*, 1977, p. 321, pl. 133, figs. 7a–c.
*Perigeyerella costellata* Wang; Feng and Jiang, 1978, p. 239, pl. 87, figs. 1a–e.
*Perigeyerella* sp. Zhan in Hou *et al.*, 1979, p. 68, pl. 4, figs. 8a–b.
*Perigeyerella costellata* Wang; Liao, 1980a, pl. 2, figs. 10–11.
*Perigeyerella costellata* Wang; Liu *et al.*, 1982, p. 175, pl. 127, figs. 8a–c.
*Perigeyerella costellata* Wang; Wang *et al.*, 1982, p. 194, pl. 91, fig. 20.
*Perigeyerella costellata* Wang; Yang, 1984, p. 205, pl. 30, figs. 5a–b.
*Perigeyerella minuta* Liao, 1987, p. 99, pl. 1, figs. 14–20.
? *Perigeyerella costellata* Wang; Xu and Grant, 1994, figs. 14, 1–9.

*Perigeyerella costellata* Wang ; Zeng *et al.*, 1995, pl. 1, figs. 13–14.

*Material examined*.—15 complete conjoined shells. Registered specimens : Three complete conjoined shells (NIGP141607, 141608, 141613), two incomplete conjoined shells (NIGP141609, 141611) and two juveniles (NIGP141610, 141612).

*Description*.—Shell large at maturity, transversely oval in outline, nearly equally biconvex in profile, maximum width at midvalve ; hinge straight and short, usually much shorter than half of shell width, but wider than half of shell width in juveniles ; cardinal extremities almost rounded at maturity but slightly auriculate in juveniles in dorsal view ; lateral sides evenly rounded and anterior margin broadly rounded ; anterior commissure slightly sulcate. Surface with delicate, fine and dense costellae, primary costellae relatively strong and remaining so to anterior margin, secondary and, in some specimens, tertiary costellae grow anteriorly by intercalation between primary costellae ; costellae numbering 7 in 2 mm in total near anterior margin ; intertroughs usually wider than costellae ; growth lines irregularly spaced on valves, but usually increasing in frequency anteriorly

Ventral valve flatly convex in lateral profile ; beak erect, attenuated and pointed, umbonal angle about 60 degree ; beak ridges inconspicuous in adult specimens ; interarea triangular in shape, apsacline, slightly concave longitudinally ; pseudodelthyrium narrow, with convex monticulus along midline.

Dorsal valve unevenly convex in lateral profile ; umbonal region strongly curved longitudinally, maximum convexity at umbonal region, flattened anteriorly, evenly domed anteriorly ; sulcus shallow, originating from umbonal region, widening anteriorly.

Ventral interior with a tiny spondylium supported by median septum in the apex area, meeting valve floor at about 4 mm anterior to beak to form sessile spondylium in adult specimens ; dental plates then extending anteriorly along valve floor nearly parallel to one another for about one-third of shell length ; dorsal interior with two strong brachiophore supporting plates and strong bilobed cardinal process.

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW | IH |
|---|---|---|---|---|---|
| NIGP141607 | 49.9 | 51.5 | 32.3 | 21.6 | 15.5 |
| NIGP141608 | 42.8 | 43.2 | 28.5 | 23.4 | 12.9 |
| NIGP141609 | 33.2 | 42.0 | 19.7 | 24.0 | 9.8 |
| NIGP141610 | 6.1 | 6.6 | 3.7 | 3.6 | 1.8 |
| NIGP141611 | >28.5 | 33.2 | 18.6 | 20.0 | 11.6 |
| NIGP141612 | 7.6 | 9.6 | — | 7.0 | 4.0 |
| NIGP141613 | 37.4 | 28.4 | 26.4 | 25.0 | 7.8 |

*Discussion*.—The present species is characterized by its acute beak and fine and dense costellation in adult. In defining *Perigeyerella costellata*, Wang (1955a, p. 101) pointed out that the juvenile specimens of this species usually possessed comparatively coarse costellae and the mature valves had finer and dense costellae. This ontogenic variation in costellation therefore broadens the definition of *Perigeyerella costellata* and, accordingly, may well include, as its junior synonym, *Perigeyerella minuta* Liao (1987, p. 99, pl. 1, figs. 14–20) from the Heshan Formation, Heshan, Guangxi Province. *P. minuta* is characterized by a small size, coarse costellae and a low convexity, which all probably indicate aspects of a juvenile *Perigeyerella costellata* Wang.

*Occurrence*.—A–26 ; B–19, 22, 24 ; E–43 ; G–45 ; I–70.

### ***Perigeyerella fastigata*** **Liao and Meng, 1986**

Plate 8, Figures 17–30 ; Plate 9, Figures 1–11 ; Plate 26, Figures 13, 18

*Perigeyerella fastigata* Liao and Meng, 1986, p. 76, pl. 1, figs. 22–23.

*Perigeyerella altilosina* Xu and Grant, 1994, p. 26, figs. 14.10–10.14.

? *"Perigeyerella" subpelargonatus* Liang, 1990, p. 128, pl. 13, figs. 6–10 ; fig. 14.

*Material examined*.—16 specimens. Registered specimens : Nine conjoined shells (NIGP141614–141622).

*Description*.—Shell medium-sized for genus, concavo-convex to plano-convex in lateral profile, juveniles somewhat subcircular, adults elongate or somewhat triangular in outline, greatest width anterior to shell midlength ; hinge straight, about two-thirds of shell width ; posterior sides nearly straight, converging posteriorly at about 60 degree ; lateral sides regularly rounded, anterior margin broadly rounded ; anterior commissure rectimarginate or slightly sulcate ; surface with fine and dense costellae, costellae increasing anteriorly by intercalation, numbering 6 in 2 mm near anterior margin.

Ventral valve flat or concave in lateral profile, but gently domed in anterior profile ; beak attenuated, erect to suberect ; interarea fairly high, triangular ; pseudodelthyrium with convex monticulus along midline ; dorsal valve semicircular in outline, gently and evenly convex both in lateral and anterior profile, maximum convexity at midvalve ; sulcus absent or very weak.

Ventral interior with two dental plates, dental plates converging and united, forming a spondylium supported by a medium septum in beak (Plate 26, Figures 13, 18), then extending anteriorly parallel to each other in a nearly touching distance, attaining more than half of shell length ; dorsal interior with two brachiophore plates, diverging at about 90 degree.

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW | IH |
|---|---|---|---|---|---|
| NIGP141614 | 38.5 | 36.5 | 21.7 | 28.4 | 19.4 |
| NIGP141615 | 31.5 | 28.9 | 12.5 | 26.8 | 21.5 |
| NIGP141616 | >33.5 | 28.9 | 16.6 | 16.8 | >14.0 |
| NIGP141617 | 44.6 | 41.0 | 21.0 | 32.0 | 21.6 |
| NIGP141618 | 18.4 | 19.9 | 8.3 | 14.7 | 8.1 |
| NIGP141619 | >22.3 | 26.5 | 13.3 | 19.3 | >11.8 |
| NIGP141620 | 32.0 | 31.7 | 16.5 | 20.4 | 14.2 |
| NIGP141621 | 21.0 | 20.9 | — | 18.0 | 8.1 |
| NIGP141622 | 17.8 | 18.5 | 7.0 | 14.8 | 7.2 |

*Discussion*.—The present species differs from the *Perigeyerella costellata* Wang by lacking a sulcus, possessing long dental plates, a high interarea and a lower convexity.

The specimen of *Perigeyerella fastigata* Liao and Meng from Chenxian County, Hunan Province shows that the ventral valve is variable from concave to slightly convex in profile. The specimen described as *Perigeyerella altilosina* Xu and Grant (1994, p. 26, figs. 14.10–14.14) from the Longdongchuan Formation in Zhenan of Shaanxi Province is considered to be conspecific with the present species in terms of their similar outline, profile, characteristic high interarea and long dental plates forming spondylium. The specimen figured as *"Perigeyerella" subpelargonatus* by Liang (1990) is referrable to *Perigeyerella* in terms of the distinct ventral spondylium. Its general outline and high interarea are basically comparable with the present species.

*Occurrence*.—A–26 ; B–25 ; Jb–4 ; Jc–15.

### ***Perigeyerella tricosa* Grant, 1976**

Plate 9, Figures 12–19

*Perigeyerella tricosa* Grant, 1976, p. 64, pl. 2, figs. 1–30.

*Material examined*.—Two complete conjoined shells (NIGP141623, 141624).

*Description*.—Shell small for genus, moderately biconvex, transversely elliptical in outline, greatest width at shell midlength ; hinge straight, slightly wider than half of shell width ; cardinal extremities slightly auriculate in dorsal view ; lateral sides regularly rounded ; anterior commissure slightly sulcate ; shell surface finely costellate, increasing by intercalation, numbering 9 in 2 mm ; growth lines irregularly spaced.

Ventral gently convex in lateral profile and moderately convex in anterior profile ; beak blunt, suberect ; interarea low, slightly concave longitudinally, strongly apsacline ; pseudodelthyrium narrow, with convex monticulus ; beak ridges conspicuous ; dorsal valve unevenly convex in lateral profile, maximum convexity posterior to midvalve ; umbonal slope sharply steep ; sulcus originating from umbonal region, narrow and shallow, widening but not deepening anteriorly.

Ventral interior with two dental plates converging toward valve floor and united, forming an elevated spondylium in beak, then extending forward parallel to each other in a very small distance apart ; dorsal interior with two brachiophore plates.

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW | IH |
|---|---|---|---|---|---|
| NIGP141623 | 26.9 | 29.2 | 15.1 | 11.7 | 9.5 |
| NIGP141624 | >24.5 | 29.7 | 17.0 | 15.1 | 8.8 |

*Discussion*.—This species differs from *Perigeyerella costellata* Wang and *P. fastigata* Liao and Meng in its transverse outline and low and wide interarea. Although only two complete specimens are available for study, its external attributes are basically identical to those of *P. tricosa* Grant from the Rat Buri Limestone, Thailand except for that the latter has a slightly more conspicuous dorsal sulcus. *Sicelia explicate* Grant (1995, p. 668, figs. 10.1–10.12, 11.1–11.2) from the Guadalupian in Greece is also similar to the present species, but has stronger costellation.

*Occurrence*.—B–24, G–45.

### ***Perigeyerella chenxianensis* new species**

Plate 9, Figures 20–28

*Holotype*.—NIGP141625 from Jc–15 (Plate 9, Figures 20–24).

*Other material examined*.—A complete conjoined shell (NIGP141626).

*Diagnosis*.—*Perigeyerella* with a weak ventral sulcus and dorsal fold, two angular beak ridges, an erect interarea, gently uniplicate anterior commissure ; elevated spondylium, and long and non–divergent dental plates.

*Description*.—Medium to large in size for genus, somewhat pentagonal in outline ; posterolateral sides straight, converging posteriorly at about 120 degree, lateral and anterior sides regularly rounded ; greatest width slightly anterior to hinge ; anterior commissure gently uniplicate ; surface finely and evenly costellate, costellae as wide as interspaces, increasing by intercalation and bifurcation, numbering about 7 in 2 mm near anterior margin ; growth lamellae occasionally developed on anterior margin.

Ventral valve shallowly conical in lateral profile and moderately domed in anterior profile ; beak obtusely acute ; interarea transversely triangular in shape, flat, with a narrow convex monticulus ; beak ridges conspicuous and angular ; posterolateral slopes steep, but gradually flattened anteriorly, sulcus only developed on anterior part of valve, occupying about one–third of shell width ; dorsal valve transversely elliptical in outline, maximum convexity at umbonal region ; lateral slopes evenly inclined, middle part slightly elevated, tending to form fold ; beak and interarea undeveloped.

Ventral interior with a conspicuous and elevated spondylium united by two dental plates, dental plates extending anteriorly in a touching distance, attaining about half of shell length ; dorsal interior with two strong divergent brachiophore plates.

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW | IH |
|---|---|---|---|---|---|
| NIGP141625 | 45.5 | 47.8 | 25.7 | 39.8 | 21 |
| NIGP141626 | 39.6 | 43.2 | 21.4 | 28.1 | 16.5 |

*Discussion*.—This new species will not be easily confused with known species of *Perigeyerella.* Firstly, the present species possesses a well–elevated spondylium united by two dental plates which never become divergent anteriorly. Secondly, a weak ventral sulcus is present on the ventral valve and its anterior commissure is uniplicate, whereas all other species of this genus usually have a dorsal sulcus and sulcate anterior commissure. Finally, the new species has two conspicuous angular beak ridges and a flat interarea, being in contrast to other species which commonly have a slightly concave interarea.

*Occurrence*.—Jc–15.

### *Perigeyerella obesa* new species

Plate 9, Figures 29–32 ; Plate 10, Figures1–12

*Holotype*.—NIGP141628 from D–24 (Plate 9, Figures 29–32).

*Other material examined*.—Three complete conjoined shells (NIGP141627, 141629, 141630).

*Diagnosis*.—Small *Perigeyerella* with a pointed and distorted beak, short hinge and strong convexity.

*Description*.—Shell small to medium in size for genus, strongly biconvex, transversely elliptical in outline, greatest width at shell midlength ; hinge straight and short, usually about half of shell width ; cardinal extremities and lateral sides nearly rounded ; anterior commissure sulcate ; surface with fine and delicate and radial costellation, costellae increasing by intercalation and numbering 9 in 2 mm near front margin ; growth lines irregularly spaced ; concentric wrinkles usually developed around umbonal region.

Ventral valve moderately convex in lateral profile but strongly domed in anterior profile ; beak swollen, pointed, usually distorted ; interarea high, strongly concave, apsacline ; beak ridges conspicuous ; pseudodelthyrium convex, narrow and with a monticulus along midway ; umbonal regions sharply steep, lateral slopes moderately inclined ; dorsal valve unevenly strongly convex in lateral profile ; umbonal region strongly curved longitudinally and strongly domed transversely, maximum convexity at umbonal region, umbonal slopes strongly inclined, lateral slopes moderately steep ; sulcus wide and shallow, originating anterior to umbonal region, widening anteriorly.

Ventral interior with two converging dental plates ; dental plates united, forming a elevated spondylium in the apex, then extending parallel to each other in a fairly near distance ; dorsal interior with two divergent brachiophore plates.

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW | IH |
|---|---|---|---|---|---|
| NIGP141627 | 21.4 | 17.6 | 12.9 | 9.1 | 8.5 |
| NIGP141628 | 26.5 | 29.0 | 19.2 | 13.9 | 8.6 |
| NIGP141629 | 35.2 | 31.3 | 24.0 | 17.0 | 12.0 |
| NIGP141630 | 33.1 | 36.0 | 25.0 | 17.2 | 11.1 |

*Etymology*.—obese, Latin, means extremely fat referring to its strong convexity.

*Discussion*.—This new species resembles *Perigeyerella tricosa* (Grant, 1976) in its transverse outline, but differs by its pointed and distorted beak, short hinge and stronger convexity. It differs from *P. fastigata* Liao and Meng, 1986 by its stronger convexity and a narrow and strongly concave interarea.

*Occurrence*.—B–22, 24.

### *Perigeyerella* sp.

Plate 10, Figure 13

*Material examined*.—A ventral valve (NIGP141631).

*Description*.—Shell 23 mm long, 20 mm wide, and 10 mm thick ; asymmetrically elongate in outline, moderately convex in lateral profile, strongly and unevenly convex in anterior profile ; left-lateral slope moderately inclined, but right-lateral slope strongly geniculated in ventral view, anterior side broadly rounded ; beak fairly blunt, slightly curved ; beak ridges inconspicuous ; surface finely costellate, costellae increasing in number by intercalation, numbering 10 in 2 mm near front margin ; concentric wrinkles irregularly spaced, usually 1–2 wrinkles around umbo.

Ventral interior with two dental plates, converging and united, forming an elevated spondylium, dental plates fairly long, extending anteriorly in a nearly touching distance, attaining more than half of shell length.

*Discussion*.—Although only a ventral valve was collected, the elevated spondylium and surface ornamentation apparently suggests *Perigeyerella.* The asymmetrical outline and blunt beak, however, cannot be compared with any other species in the genus. Perhaps it represents a new form of *Perigeyerella.*

*Occurrence*.—A–26.

### Genus *Geyerella* Schellwien, 1900b

*Type species*.—*Geyerella gemmellaroi* Schellwien, 1900b, p. 12, pl. 1, figs. 7a, b from the Sosio Limestone, Sicily.

*Discussion*.—*Geyerella* is characterized by the presence of a spondylium supported by a median septum in the ventral valve. This character immediately separates it from some externally similar genera such as *Meekella* White and John, 1867 and *Kiangsiella* Grabau in Chao, 1927. *Ombonia* Caneva, 1906 and *Perigeyerella* Wang, 1955a also have a spondylium in ventral valve, but differs from *Geyerella* by its absence of plication on shell surface and non-conical shell.

### *Geyerella distorta* Schellwien, 1900b

Plate 10, Figures 14–24

*Geyerella disorta* Schellwien, 1900b, p. 25, pl. 3, figs. 6–13.
*Geyerella distorta* Schellwien ; Jin and Ye, 1979, p. 77, pl. 22, figs. 4–6.

*Material examined*.—Seven specimens. Four conjoined shells registered (NIGP141632–141635).

*Description*.—Medium for genus, deeply conical, unequally biconvex, transversely subelliptical in outline, widest at shell midlength, slightly irregular and distorted ; hinge straight, slightly narrower than greatest width ; sides evenly rounded ; surface costellate and plicate, costellae fairly weak, usually not preserved ; plicae fine, irregular, crests subangular to rounded ; interspaces slightly wider than plicae, numbering about 20 in total near front margin ; growth lamellae well developed on anterior region, commonly interrupting plication, anterior commissure gently sulcate.

Ventral valve deeply conical in anterior and lateral profile ; beak blunt, distorted ; interarea highly triangular, basically flat except for distorted apex, catacline, pseudodelthyrium flat but having a narrow convex monticulus along midline ; beak ridges conspicuous, bluntly angular ; dorsal valve lidlike, subelliptical in outline, moderately convex in lateral and anterior profile ; interarea low, broadly triangular ; maximum convexity at umbonal region ; lateral slopes gently inclined,

anteromedian part somewhat depressed to form ill-defined sulcus.

Ventral interior with narrow spondylium supported by thin median septum, extending to about one-third or slightly beyond; dorsal interior with large cardinal process and strong and divergent brachiophore plates.

*Measurements (in mm).*—

| Specimen no. | L | W | T | HW | IH |
|---|---|---|---|---|---|
| NIGP141632 | 29.0 | 31.9 | 41.8 | 22.0 | 30.8 |
| NIGP141633 | 48.0 | 36.0 | 39.0 | 21.0 | 26.0 |
| NIGP141634 | ~36 | ~38 | 57.6 | — | ~44 |
| NIGP141635 | 20.0 | 27.5 | — | — | >20 |

*Discussion*.—*Geyerella distorta* Schellwien closely resembles *Geyerella alphina*, which was also proposed by Schellwien (1900b). Grunt and Dmitriev (1973) considered that *G. distorta is* a junior synonym of *G. alphina.* However, comparison between our specimens and that figured by Grunt and Dmitriev (1973) indicates that both share similar general aspects, but *G. distorta* differs from *G. alphina* by its larger size, more plicae on both valves. Our specimens agree relatively better with *G. distorta* in general features. *Geyerella hessi* Cooper and Grant (1974, p. 378, pl. 89, figs. 2-4; pl. 121, figs. 1-24; pl. 122, figs. 1-10; pl. 123, figs. 1-21; pl. 124, figs. 14-20, pl. 671, fig. 19) from the Kungurian Skinner Ranch Formation in West Texas, USA is closely similar to the present species in number of plications and twisted beak, but appears to have stronger plication and slightly bigger size. Another West Texas species, *Geyerella kingorum* Cooper and Grant (1974, p. 381, pl. 119, figs. 1-31; pl. 120, figs. 1-33; pl. 124, figs. 1-10) from the Asselian Neal Ranch Formation and Sakmarian Lenox Hills Formation differs from the present species by its smaller size and less developed plication.

*Occurrence*.—Jb-4.

### Genus ***Meekellogeyerella*** **new genus**

*Type species*.—*Meekellogeyerella meekelloides* new species from the Changhsing Formation at Chenxian, Hunan Province, South China.

*Diagnosis*.—Shell with *Meekella*-like outline and plication, but ventral sulcus and highly-elevated spondylium supported by median septum like in *Geyerella.*

*Etymology*.—Combined from the names of the brachiopod genera *Meekella* and *Geyerella*, referring to its transitional characters between the two genera.

*Discussion*.—This new genus is similar to *Meekella* in outline, profile, costellation and plication, but *Meekella* has two dental plates which never meet above the valve floor to form a spondylium. In addition, *Meekella* usually has sulcus on the dorsal valve and a sulcate anterior commissure. *Geyerella* possesses a similar spondylium in ventral valve to that of the new genus, but is usually characterized by its highly coral-shaped ventral valve, high ventral interarea and twisted beak which probably indicate a different habitat. *Meekellogeyerella* can be readily distinguished from *Perigeyerella* by its plicate shell and ventral sulcus.

#### ***Meekellogeyerella meekelloides*** **new species**

Plate 10, Figures 25-30

*Holotype*.—NIGP141636, a complete conjoined shell from Jb-4 (Plate 10, Figures 25-29).

*Other material examined*.—A complete conjoined shell (NIGP141637).

*Diagnosis*.—As for genus.

*Description*.—Shell large, somewhat rhombinal in outline, subequally biconvex, greatest width at shell midlength; hinge straight, only about half of shell width; posterolateral and anterolateral sides nearly straight, converging posteriorly to form subrhomboidal outline; surface with fine costellae and irregular plications; costellae commonly not preserved, numbering about 10 in 2 mm near anterior margin; plications coarse, increasing by bifurcation, numbering 3-4 in 1 cm near anterior margin; concenrtic wrinkles strong, interrupting plications; anterior commissure moderately or gently uniplicate.

Ventral valve strongly convex in lateral and anterior profile; beak acute, suberect; interarea triangular, nearly flat; pseudodelthyrium narrowly triangular, beak ridges inconspicuous, without evident boundary with posterolateral slopes, umbonal slopes steep, lateral slopes evenly inclined; sulcus originating from midvalve, widening and deepening anteriorly, occupying about one-third of shell width, forming a weak anterior tongue; dorsal valve subelliptical in outline, gently convex in lateral profile, but strongly domed in anterior profile; interarea low; umbonal slopes very steep, lateral slopes moderately inclined, anteromedian part elevated, forming a fold.

Ventral interior with narrow spondylium supported by a thin median septum, extending to about one-third of shell length; dorsal interior with strong divergent brachiophore plates.

| Specimen no. | L | W | T | HW | IH |
|---|---|---|---|---|---|
| NIGP141636 | 46.0 | 43.2 | 32.2 | 22.5 | 22.0 |
| NIGP141637 | >36.0 | 42.0 | 26.5 | 25.7 | - |

*Discussion*.—The subrhomboidal outline and costellate and plicate shell surface seemingly indicate some species of *Meekella.* However, the ventral internal spondylium easily distinguishes it from any other species.

*Occurrence*.—Jb-4.

### Family DERBYIIDAE Stehli, 1954
### Genus *Derbyia* Waagen, 1884

*Type species*.—*Derbyia regularis* Waagen, 1884, p. 594, pl. 53, figs. 1-2, 4 from the Amb Formation in the Salt Range, Pakistan.

*Discussion*.—*Derbyia* is readily distinguished from others by its prominent and single median septum, lacking dental plates and spondylium in ventral valve. But the occasional development of a spondylium-like chamber in the ventral valve is easily confused with the small apical chamber of the genus *Orthotetes* Fischer de Waldheim, 1829 or one of its close relatives such as *Permorthotetes* Thomas, 1958 or *Werriea* Campbell, 1957. We agree with Campbell (1957)

and Thomas (1958) that the cardinalia of *Orthotetes* are significantly different from those of *Derbyia* by its plates in dorsal valve which are recurved and do not extend into the umbonal cavity anterolaterally. *Magiderbyia* Ting, 1965 was considered a junior synonym of *Derbyia* by Williams *et al.* (2000b) in the revised Treatise. However, *Magniderbyia* possesses a large massive shell and extremely strong muscle scar with low and strong ridges surrounding it, which can be readily distinguished from *Derbyia.* The *Derbyia* species in the Lopingian of South China never reach the size of *Magniderbyia. Paraderbyia* Sun (1983, p. 120) with *P. domaensis* as the type species is apparently a synonym of *Derbyia.* The so-called diagnostic median septum/ridge in the dorsal valve of *Paraderbyia* is clearly also present in all orthotetids, but commonly dependent on preservation of the specimens.

### *Derbyia acutangula* (Huang, 1933)

Plate 11, Figures 1–26

*Schellwienella acutangula* Huang, 1933, p. 24, pl. 3, figs. 12–18.
*Schellwienella acutangula* Huang ; Wang *et al.*, 1964, p. 206, pl. 30, fig. 16.
*Magniderbyia guangdongensis* Ni in Yang *et al.*, 1977, p. 325, pl. 134, figs. 7–8.
*Derbyia acutangula* (Huang) ; Tong, 1978, p. 215, pl. 78, fig. 7.
*Derbyia acutangula* (Huang) ; Zhan in Hou *et al.*, 1979, p. 68, pl. 4, figs. 10–11.
*Magniderbyia subquadrata* Jin and Zhu in Jin and Ye, 1979, p. 78, pl. 22, figs. 13–14.
*Derbyia mucronata* Liao, 1980a, p. 255, pl. 2, figs. 17, 20.
*Derbyia acutangula* Huang ; Liao, 1980a, p. 255, pl. 2, fig. 25.
*Derbyia acutangula* Huang ; Liao, 1987, pl. 3, figs. 14–17.
*Magniderbyia* sp. indet. Chen in Chen *et al.*, 2005a, p. 353, fig. 7J.

*Material examined*.—Numerous specimens, most of them are disarticulated valves. Regsitered specimens : Seven conjoined shells (NIGP141639, 141640–141642, 141647, 141650, 141651), three incomplete ventral valves (NIGP141638, 141644, 141646), a complete internal mould (NIGP141643), two incomplete internal moulds of ventral valve (NIGP141643, NIGP141649) and three complete internal moulds of dorsal valve (NIGP141645, 141648, 141652).

*Description*.—Shell large in size for genus, jeveniles and immature specimens usually semicircular to subquadrate, but adults transversely elliptical in outline, plano-convex to concavo-convex in profile, widest at hinge ; hinge straight ; jeveniles and immatures with nearly subquadrate cardinal extremities ; lateral sides generally evenly rounded, cardinal extremities of adults bending outwards rather abruptly near hinge, forming very acute and strongly mucronate angle with hinge and distinct wing-like ears ; anterior margin evenly and broadly rounded ; surface costellate, costellae increasing by intercalation, numbering 5 in 2 mm near anterior margin, usually interspaced by wider intertroughs ; growth lines irregularly spaced but becoming conspicuous on anterior valve.

Ventral valve nearly flat or slightly concave longitudinally and transversely except slightly inflated over umbonal region ; beak blunt and short ; umbonal angle slightly smaller than 180 degree ; interarea broadly triangular, strongly apsacline ; beak ridges angular ; pseudodelthyrium narrow and convex ; dorsal valve semicircular in outline, moderately convex to strongly convex in profile ; interarea linear in shape ; chilidium triangular, as wide as pseudodelthyrium ; umbonal region inflated, lateral and anterior slopes evenly inclined ; sulcus completely absent.

Ventral interior with two forward-projecting teeth ; median septum reaching about one-third of shell length, elevated, thin, attached to posterior half of pseudodelthyrium ; muscle scars not present to slightly imprinted ; dorsal interior with bilobed cardinal process, brachiophore plates widely divergent, defining posterolateral boundaries of muscle area ; muscle area faintly impressed, bisected by a low median ridge, muscle marks consisting of faint longitudinal grooves, extending about one-third of shell length.

*Measurements (in mm)*.—

| Specimen no. | L | W | T |
|---|---|---|---|
| NIGP141638 | — | 72.0 | — |
| NIGP141639 | 38.5 | 50.0 | 16.7 |
| NIGP141640 | 35.9 | 52.0 | 16.5 |
| NIGP141641 | 33.5 | 63.6 | 13.6 |
| NIGP141642 | 21.5 | 53.0 | — |
| NIGP141643 | 27.4 | 44.3 | 10.7 |
| NIGP141644 | 32.3 | 56.2 | 9.0 |
| NIGP141645 | 32.5 | 55.0 | — |
| NIGP141646 | 30.8 | 56.2 | — |
| NIGP141647 | 35.1 | >43.0 | ~7.6 |
| NIGP141648 | 22.0 | 38.8 | — |
| NIGP141649 | — | 40.9 | — |
| NIGP141650 | 23.1 | 25.5 | 7.3 |
| NIGP141651 | 29.2 | 40.3 | 11.2 |
| NIGP141652 | 32.8 | 50.0 | 10.0 |

*Discussion*.—This species was first assigned to *Schellwienella* by Huang (1933). Liao (1980a) showed that it had a ventral median septum undoubtedly suggesting *Derbyia.* This species is characterized by its acute and mucronate cardinal extremities and distinct wing-like ears in adults. The present species has been variably named since it was first described by Huang (1933) as *Schellwienella acutangula* (see synonyms above). We consider all of them to be the same species because they all share one basic specific characteristic, that is, variable mucronate cardinal extremities, in addition to their common identity in internal features. The wing-like ears in adults of the present species appears very different from that in juveniles and immatures with subquadrate outline, but ontogenetic variations of our specimens indicate that the cardinal extremities of the present species tend to extend laterally. Adults of the present species possess broadly alate cardinal extremities to an extent that they may be confused with *Magniderbyia* Ting, 1965. However, *Magniderbyia* is massive in size and has a large and strong muscle platform surrounded by ridges within both valves (see Ting, 1965, p. 265), unlike *Derbyia acutangula* which completely lacks these features.

*Occurrence*.—A-8, 9, 10, 26, 28 ; B-1, 22 ; C-15 ; D-2, 5 ;

F–18, 21, 22, 27, 28, 29 ; G–31, 32, 37, 45 ; I–56.

### *Derbyia regularis* Waagen, 1884

Plate 11, Figures 27–28 ; Plate 12, Figure 4

*Derbyia regularis* Waagen, 1884, p. 594, pl. 53, figs. 1–2, 4.
*Derbyia regularis* Waagen ; Tschernyschew, 1902, p. 203, pl. 25, figs. 1–3.
*Orthotetes regularis* Waagen ; Ustritsky *et al.*, 1960, p. 19, pl. 1, fig. 13 ; pl. 2, figs. 1–2.
*Derbyia regularis* Waagen ; Grant, 1976, pl. 6, figs. 13, 21, 26.
*Derbyia regularis* Waagen ; Yang *et al.*, 1977, p. 325, pl. 134, fig. 6.
*Derbyia regularis* Waagen ; Liu *et al.*, 1982, p. 176, pl. 128, fig. 5.

*Material examined*.—Two ventral valves (NIGP141653, 141654) and a juvenile (NIGP141655).

*Description*.—Shell large to medium in size, semicircular in outline ; hinge slightly shorter than greatest width at shell midlength ; cardinal extremities quadrate to subquadrate.

Ventral valve flat to concave in lateral profile ; beak inconspicuous ; interarea wide and low ; surface with fine costellae, costellae interspaced by wider intertroughs, increasing by intercalation, numbering about 5 in 5 mm near front margin, growth lines well developed but irregularly spaced.

Ventral interior with thin median septum, extending anteriorly for one-quarter of shell length from beak.

*Measurements (in mm)*.—

| Specimen no. | L | W | HW |
|---|---|---|---|
| NIGP141653 | 28.0 | 45.0 | 37.0 |
| NIGP141654 | 29.2 | 34.1 | 32.5 |
| NIGP141655 | 14.2 | 19.2 | — |

*Discussion*.—The present species differs from *Derbyia acutangula* (Huang) by its hinge line shorter than shell width and subquadrate outline.

*Occurrence*.—G–45 ; F–18 ; Jc–15.

### *Derbyia schellwieni* Frech, 1911

Plate 12, Figures 1–3

*Derbyia schellwieni* Frech, 1911, p. 125, pl. 8, fig. 3.
*Derbyia schellwieni* Frech ; Wang *et al.*, 1964, p. 213, pl. 31, figs. 14–15.
*Derbyia schellwieni* Frech ; Yang *et al.*, 1977, p. 325, pl. 134, fig. 5.
*Derbyia yangtzeensis* Jin and Hu, 1978, p. 108, pl. 1, figs. 12–16.
*Derbyia disalata* Liao, 1980a, p. 255, pl. 2, figs. 4–9.
*Derbyia yangtzeensis* Jin and Hu in Wang *et al.*, 1982, p. 195, pl. 85, figs. 10–11.
*Derbyia disalata* Liao, 1987, pl. 2, figs. 36–37.

*Material examined*.—11 ventral valves. Four ventral valves registered (NIGP141656–141659).

*Description*.—Shell small to medium in size, outline quadrately circular to subquadrate, greatest width slightly anterior to shell midlength ; hinge straight ; cardinal extremities subquadrate ; surface finely costellate, interspaced by wider intertroughs, increasing by intercalation, about 60–80 in number near anterior margin ; concentric wrinkles occasionally and irregularly spaced.

Ventral valve gently convex in lateral profile, umbonal region gently swollen ; beak blunt, occasionally distorted ; interarea low, broadly triangular, strongly apsacline.

Ventral interior with thin median septum connected with posterior part of pseudodelthyrium, extending to about one-third of shell length from beak.

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141656 | 18.0 | 24.9 | 2.5 | 20.3 |
| NIGP141657 | 14.2 | 19.5 | 5.0 | 15.0 |
| NIGP141658 | 19.5 | 27.0 | 5.2 | — |
| NIGP141659 | ~15.5 | ~21.8 | ~7.3 | 17.2 |

*Discussion*.—The present species is characterized by its small size, subquadrate outline, hinge line being narrower than shell width and gently convex lateral ventral valve. The specimens described as *Derbyia yangtzeensis* by Jin and Hu (1978, p. 108, pl. 1, figs. 12–16) and those named as *D. disalata* by Liao (1980a, p. 255, pl. 2, figs. 4–9) share most of the specific characters with the present species. It appears, therefore, that these species are synonyms of *D. schellwieni.*

*Occurrence*.—A–9, 26 ; F–6 ; G–45, 55, 56 ; I–26, 42, 57, 68, 77.

### *Derbyia guidingensis* Shen and He, 1994a

Plate 12, Figures 5–9

*Derbyia guidingensis* Shen and He, 1994a, p. 448, pl. 1, figs. 9–12.

*Holotype*.—NIGP141660 (=CUMT8162) from G–45 (Plate 12, Figures 5–8).

*Other material examined*.—A complete conjoined shell (NIGP141661) and a dorsal valve [NIGP141662 (= CUMT8163)].

*Description*.—Shell small in size for genus, bilobed by emargination of anterior margin and sulcation of dorsal valve, plano-convex in profile, greatest width near anterior margin ; hinge straight, about three-quarters of shell width ; cardinal extremities slightly auriculate ; sides rounded ; surface finely and densely costellate, increasing by intercalation, numbering 8 in 2 mm near anterior margin ; interspaces narrow.

Ventral valve strongly convex ; beak obtusely pointed, usually distorted ; beak ridges angular ; interarea high, concave, moderately apsacline ; pseudodelthyrium highly convex and with a median groove ; lateral slopes strongly inclined ; dorsal valve nearly flat except for the deeply incised sulcus ; umbonal slightly inflated ; sulcus wide, originating from midvalve and rapidly deepening anteriorly, forming a wide incision at anterior margin.

Ventral interior with an eccentric median septum, extending to about one-quarter of shell length from beak, connected with posterior part of pseudodelthyrium ; dorsal interior with two widely divergent brachiophore plates.

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141660 | 22.3 | 25.7 | 13.1 | 18.0 |
| NIGP141661 | 13.5 | 21.8 | 8.9 | 12.7 |
| NIGP141662 | 24.0 | 35.0 | 4.8 | 20.0 |

*Discussion*.—This species was briefly described by Shen and He (1994a) in Chinese. We herein provide a more comprehensive description. The bilobed outline and emarginate anterior margin can distinguish this species from any other species in *Derbyia.*

*Occurrence*.—G-45, 55.

### ***Derbyia dirata* Grant, 1993**

Plate 12, Figure 14

*Derbyia dirata* Grant, 1993, p. 8, figs. 7.1-7.7.

*Material examined*.—A ventral valve (NIGP141663).

*Description*.—Shell small, 11.8 mm long, 21 mm wide, and 5.8 mm thick, outline semicircular, widest at hinge ; ventral valve nearly flat in lateral profile, gently inflated in posterior profile ; beak obtusely pointed ; slopes evenly inclined toward margin ; interarea widely triangular, catacline and with convex pseudodelthyrium ; surface with distinct costellation, earliest costellae commonly remaining strongest near margins, finer costellae inserted between coarse ones, reaching about 7 in 2 mm at anterior margin.

Ventral interior with thin median septum about one-third of shell length.

*Discussion*.—The present specimen is generally comparable with *Derbyia dirata* Grant (1993) from Khios Island, Greece in terms of its size, low catacline interarea, semicircular outline and costellation, but only one specimen is available in our collection.

*Occurrence*.—A-26.

### ***Derbyia* sp. 1**

Plate 12, Figure 12

*Material examined*.—A ventral valve (NIGP141664).

*Description*.—Shell small, 21 mm long, 21.5 mm wide, and 3 mm thick ; semicircular in outline, greatest width at hinge ; cardinal extremities nearly quadrate ; ventral valve nearly flat in lateral and anterior profile, but posterolateral sides abruptly geniculated dorsally at about 9 mm from beak ; beak flat, inconspicuous ; interarea low ; surface with radial costellae, increasing by intercalation, numbering 5 in 2 mm near anterior margin ; concentric wrinkles well developed and irregularly spaced, producing cancellate effect.

Ventral interior with median septum, median septum short, about one-fifth of shell length.

*Discussion*.—The geniculated posterolateral sides, flat and semicircular ventral valve and developed concentric wrinkles show that the present species cannot be compared with any other species within *Derbyia.*

*Occurrence*.—G-45.

### ***Derbyia* sp. 2**

Plate 12, Figures 10-11

*Material examined*.—Two ventral valves (NIGP141665, 141666).

*Description*.—Shell small to medium for genus, slightly bilobed by ventral sulcation ; ventral valve somewhat triangular or transversely elliptical in outline, greatest width near anterior commissure ; cardinal extremities obtuse and flanks steep ; interarea high, broadly triangular, strongly apsacline, anterolateral sides narrowly rounded, anterior side emarginate ; surface finely costellate, costellae narrow, interspaced by wider intertroughs, increasing anteriorly by intercalation, numbering 4 in 2 mm near anterior margin ; concentric wrinkles irregularly spaced ; sulcus only developed on anterior part, sharply inclined dorsally.

Ventral interior with thin median septum.

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141665 | 15.1 | 24.5 | ~12 | 17.5 |
| NIGP141666 | 22.5 | 43.2 | ~9.3 | 30.4 |

*Discussion*.—The present two specimens are characterized by a sulcus on the ventral valve and emarginate anterior commissure. These two specimens may not be conspecific in terms of their slightly different outline. The specimen from Chenxian has a much wider outline than that from the Nantong Section at Wansheng. This species is similar to *Derbyia guidingensis* Shen and He (1994a, p. 448, pl. 1, figs. 9-12) in view of its bilobed outline and emarginate anterior margin, but the emarginate anterior margin in the Guiding species is formed from dorsal sulcation.

*Occurrence*.—B-24, Jc-15.

### ***Derbyia* sp. 3**

Plate 12, Figure 13

*Material examined*.—A ventral valve (NIGP141667).

*Description*.—Shell small in size, 16.2 mm long, 11.8 mm wide, 4.6 mm thick, hinge 7.6 mm wide ; outline elongate, greatest width at midvalve ; cardinal extremities slightly auriculate ; ventral beak strongly swollen and curved dorsally ; interarea concave, lateral sides broadly rounded, anterior margin evenly rounded ; surface finely costellate, numbering 7 per mm anterior to umbonal region ; concentric wrinkles well developed and irregularly spaced, usually stronger around umbonal region, numbering 13 in total on ventral valve.

Ventral interior with thick median septum, extending to about one-quarter of shell length.

*Discussion*.—The present species can be distinguished from any other species of *Derbyia* in its elongate outline, strongly swollen and curved umbonal region and more concentric wrinkles.

*Occurrence*.—G-45.

## Family SCHUCHERTELLIDAE Williams, 1953
## Subfamily STREPTORHYNCHINAE Stehli, 1954
## Genus *Streptorhynchus* King, 1850

*Type species*.—*Terebratulites pelargonatus* Schlotheim, 1816, p. 28, pl. 8, figs. 21–24 from the Kazanian, Gera, Germany.

*Discussion*.—*Streptorhynchus* differs from *Schuchertella* Girty, 1904 and *Diplanus* Stehli, 1954 in its presence of brachiophore plates (erismata) inside the dorsal valve. *Kiangsiella* Grabau in Chao (1927) is similar to *Streptorhynchus* in internal structure, but it has plication on the shell.

### *Streptorhynchus pelargonatus* (Schlotheim, 1816)

Plate 12, Figures 15–24

*Terebratulites pelargonatus* Schlotheim, 1816, p. 28, pl. 8, figs. 21–24.
*Streptorhynchus pelargonatus* Schlotheim ; Davidson, 1858, p. 32, pl. 2, figs. 32–42.
*Streptorhynchus pelargonatus* Schlotheim ; Waagen, 1884, p. 579, pl. 50, figs. 3–5, 7.
*Streptorhynchus pelargonatus* Schlotheim ; Frech, 1911, p. 122, pl. 18, fig. 7
*Streptorhynchus pelargonatus* Schlotheim ; Grabau, 1931, p. 143, pl. 24, figs. 2a–e.
*Streptorhynchus pelargonatus* Schlotheim ; Huang, 1933, p. 17, pl. 2, fig. 13.
*Streptorhynchus* cf. *pelargonatus* Schlotheim ; Grabau, 1934, p. 22, pl. 1, fig. 14.
*Streptorhynchus pelargonatus* Schlotheim ; Grabau, 1936, p. 92, pl. 10, fig. 4.
*Streptorhynchus pelargonatus* Schlotheim ; Wang *et al.*, 1964, p. 216, pl. 33, figs. 1–5.
*Streptorhynchus pelargonatus* Schlotheim ; Liao, 1980a, pl. 2, figs. 23–24.
*Streptorhynchus pelargonatus* Schlotheim ; Yang, 1984, p. 207, pl. 30, figs. 12a–12c.

*Material examined*.—Five specimens. Three complete and conjoined shells registered (NIGP141668–141670).

*Description*.—Shell very small in size, general outline variable, somewaht triangular, subquadrate or elongate ; hinge narrower than greatest width near anterior margin ; cardinal extremities slightly auriculate in dorsal view ; posterolateral sides nearly straight, meeting hinge at about 120 degree, anterolateral sides narrowly rounded, anterior margin straight to broadly rounded ; anterior commissure rectimarginate or slightly waved ventrally ; surface with fine costellae, increasing by intercalation, interspaced by intertroughs as wide as costellae, numbering 6 in 2 mm near anterior margin.

Ventral valve nearly flat longitudinally, strongly domed transversely ; beak inflated and pointed, suberect ; interarea high, triangular in shape, gently to strongly apsacline ; beak ridges conspicuous ; pseudodelthyrium narrow and convex along midline ; umbonal slopes sharply steep ; flanks gently inclined ; dorsal valve lidlike, semicircular in outline ; umbonal region faintly swollen, gently and evenly inclined toward margins ; sulcus shallow, slightly depressed.

Ventral interior without any septum ; dorsal interior with two divergent socket plates.

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141668 | 10.6 | 12.1 | 6.2 | 9.9 |
| NIGP141669 | 13.0 | 14.2 | 6.5 | 9.6 |
| NIGP141670 | 13.7 | 13.0 | 6.2 | 10.2 |

*Discussion*.—Sine this species was first introduced by Frech (1911) for some Chinese specimens, it has become one of the commonest species in the Lopingian of South China. However, the internal structures between the specimens from the Zechstein in Germany and the Lopingian in South China have never been compared in detail except for the absence of any septum in the ventral valve, despite the fact that the internal details of the dorsal valve are critical to understanding the familial and generic assignments within the Superfamily Orthotetoidea. Although this species has been figured many times by different authors, internal details in the dorsal valve remain poorly understood. The Zechstein specimens clearly have two broadly divergent brachiophore plates (Cooper and Grant, 1974, pl. 40, fig. 1) which have never been confirmed among the Chinese specimens. Nevertheless, Liao (1987) dissolved lots of silicified specimens from the Heshan Formation in Guangxi Province and obtained delicate internal structures of dorsal valve indicating the presence of typical *Streptorhynchus.* Therefore, this species is tentatively retained for the Chinese specimens before its dorsal internal detail is clearly revealed.

*Occurrence*.—A–26 ; E–50 ; G–32, 45, 55, 56.

### *Streptorhynchus tenuiplicatus* Liao, 1987

Plate 12, Figure 25

*Streptorhynchus tenuiplicatus* Liao, 1987, p. 97, pl. 2, figures 20–22, 24–25.

*Material examined*.—10 complete conjoined shells. Registered specimen : a conjoined shell (NIGP141671)

*Description*.—Shell of medium size, illustrated specimen measured 20 mm long and 17 mm wide ; elongate in outline, strongly unequally biconvex in profile, greatest width slightly anterior to shell midlength ; lateral and anterior sides evenly rounded ; ventral valve nearly flat in lateral profile, but strongly arched in anterior profile ; beak high, commonly distorted and with a small attachment scar ; posterolateral slopes sharply inclined ; interarea narrow and high, umbonal angle about 60–110 degree, apsacline, delthyrium about one-third of interarea width, covered by pseudothyridium ; hinge short ; dorsal valve semielliptical, gently and evenly convex in profile, maximum convexity at midvalve ; beak inconspicuous ; interarea not developed ; surface with dense, fine and regular costellae, increasing by intercalation, frequently intersected by irregular concentric wrinkles ; plication inconspicuous, anterior commissure nearly rectimarginate.

*Discussion*.—The present specimen is basically identical with the holotype of *Streptorhynchus tenuiplicatus* Liao in outline, size and profile despite slightly stronger plications

near margins. This species differs from *S. pelargonatus* by its stronger convexity, higher ventral interarea and weakly plicate appearance near the anterior margin.

*Occurrence*.—I-18, 23, 68, 70.

### Genus ***Pesudostreptorhynchus*** **new genus**

*Type species*.—*Pseudostreptorhynchus deflecta* new species from the Lungtan Formation at Daijiagou, Chongqing, South China.

*Diagnosis*.—Externally like *Streptorhynchus*, but with short hinge, rounnded cardinal extremities and acute commonly twisted beak, ventral interior without any septum; dorsal interior only with socket ridge, without socket plates; adductor fields medially divided by low ridge extending anterior to muscle field margin.

*Etymology*.—Pseudo-, false; *Streptorhynchus*, a brachiopod generic name.

*Discussion*.—Specimens from the Lopingian in South China assigned to this new genus were mostly attributed to *Streptrohynchus* King, 1850 largely based on the absence of any septum in the ventral valve. However, *Streptrohynchus* possesses the elongated forked cardinalia with long socket plates (dentifer) in the dorsal valve (see Cooper and Grant, 1974, p. 326, pl. 40, fig. 1; Liao, 1987, pl. 2, figs. 17, 18). By contrast, the new genus lacks such kind of structure. *Pseudostreptorhynchus* is somewhat similar to *Goniarina* Cooper and Grant, 1969 in terms of outline and ventral interiors, but *Goniarina* usually has a distinct *Schuch ertella*-like straight hinge line and ventral interarea, and distinct socket plates in dorsal valve. The dorsal interiors of the new genus also recall *Diplanus* Stehli, 1954, which is however characterized by a distinct dorsal interarea which is absent in the new genus.

*Occurrence*.—Late Permian, South China.

### ***Pseudostreptorhynchus deflecta*** **new species**

Plate 12, Figures 26-35

*Holotype*.—A complete internal mould (NIGP141672) (Plate 12, Figures 26-29).

*Other material examined*.—An incomplete conjoined shell (NIGP141673) and three internal moulds of ventral valve (NIGP141674-141676).

*Diagnosis*.—Subtrignoal shell, short hingline, fine costellae on surface and variably curved beak.

*Description*.—Small in size for genus, subtrignoal in outline; ventral valve moderately convex in all direction, greatest width anterior to shell midlength; hinge much narrower than shell width; posterolateral sides converging posteriorly by 70-90 degree, anterior side broadly rounded; anterior commissure rectimarginate; ventral beak pointed and commonly distorted; beak ridges obtuse or slightly transitional with umbonal slopes; interarea triangular, slightly concave, strongly apsacline; pseudodelthyrium narrow and convex; umbonal region highly swollen, lateral and umbonal regions evenly inclined; dorsal valve unevenly and gently convex in profile, maximum convexity posterior to midvalve; sulcus probably absent; surface with fine costellae, earlier costellae increasing by intercalation, but bifurcated anteriorly, numbering 6-12 in 2 mm; concentric wrinkles sparsely spaced near margins.

Ventral interior without any septum; muscle scars inconspicuous; dorsal interior without socket plates; cardinal process unknown.

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141672 | 19.6 | 20.4 | 11.3 | 10.0 |
| NIGP141673 | 22.8 | 21.6 | 13.6 | 9.9 |
| NIGP141674 | 16.9 | 20.0 | — | 10.0 |
| NIGP141675 | 22.0 | 22.6 | — | 16.6 |
| NIGP141676 | 14.5 | 16.2 | — | 12.2 |

*Etymology*.—deflect (Latin), to bend aside, referring to its difference from the *Streptorhynchus* species.

*Discussion*.—The specimens figured as *Streptorhynchus lenticularis* from the Wargal Formation in the Salt Rnage, Pakistan by Waagen (1884, p. 580, pl. 50, figs. 8a-d) and from the Lungtan Formation, Guizhou, South China by Huang (1933, p. 18, pl. 2, fig. 14) are externally largely comparable with the present species, but their internal structures are not known. *Streptorhynchus khwaense* Grant (1976, p. 49, pl. 7, figs. 1-4) from the Rat Buri Limestone of Thailand is also similar to the present species in terms of its outline, size, profile and the highly inflated and distorted beak, but possess distinct brachiophore plates in the dorsal valve.

*Occurrence*.—A-11, 20; E-66; G-55.

### ***Pseudostreptorhynchus*** **new species**

Plate 13, Figures 1-5

*Material examined*.—A complete internal mould (NIGP141677).

*Description*.—Shell medium in size, 31 mm long, 36 mm wide, 24 mm thick, hinge 18 mm wide, and interarea 6 mm high; subcircular in outline, nearly equally biconvex in profile, greatest width at shell midlength; lateral sides evenly rounded, anterior sides broadly rounded; ventral valve nearly flat longitudinally, moderately arched transversely; beak obtuse, suberect and short; interarea low and widely triangular; lateral slopes moderately inclined, anterior regions flattened; dorsal valve moderately convex in lateral and anterior profile; beak low and obtuse; maximum convexity near umbo; lateral slopes moderately inclined, anterior region slightly flattened; anterior commissure slightly sulcate.

Ventral interior without dental plates; teeth strong, knob-like; dorsal interior with deep sockets; socket plates not developed, but with a very short and low median ridge along midline of muscular scar; surface not preserved.

*Discussion*.—The present species is characterized by the subcircular outline and short, obtuse beak. This species differs from the type species described above by its larger size, more rounded outline and low beak. A specimen figured as *Stretorhynchus lenticularis* by Grabau (1934, p. 20, pl. 1, figs. 12a-c) from the Carboniferous-Permian Maping

Formation in Guizhou, South China is similar to the present species in size and outline, but the Guizhou species only has one ventral valve.

*Occurrence*.—F-8.

### Genus *Tropidelasma* Cooper and Grant, 1969

*Tropidelasma* Cooper and Grant, 1969, p. 3.
*Tropidelasma* Cooper and Grant, 1974, p. 333
*Parageyerella* He and Zhu, 1985, p. 201.

*Type species*.—*Tropidelasma culmematum* Cooper and Grant, 1969, p. 3, pl. 1, figs. 27-29 from the Wolfcampian, West Texas, USA.

*Diagnosis*.—Shape conical, outline triangular to elongate; ventral valve with a long interarea marked by a flat to slightly convex pseudodelthyrium, anteriorly notched, midline narrowly folded to form an elongate monticulus; dorsal valve lidlike, faintly to strongly convex and usually elliptical to circular in outline; ventral interior with two strong teeth, forming thick ridges under delthyrial margin; dental plates and septum completely absent; muscle field poorly defined and slightly impressed; dorsal interior with a large bilobed cardinal process; lobes long and slender and slit medially on the posterior surface, dentifers small, outside of sockets bounded by a small oblique ridge; socket plates long, gradually being eliminated; adductor field rounded, divided medially by an elevated myophragm.

*Discussion*.—Recently, numerous specimens assigned to the present genus were collected in South China. He and Zhu (1985) proposed a new genus *Parageyerella* based on specimens from the Daijiagou Section in Chongqing City. Its main features are that the ventral interior has an unsupported "spondylium merged by two dental plates, dorsal interior has no brachial supporting plates". However, a re-study of serial sections by the senior author has been unable to reveal the spondylium; the so-called "spondylium" displayed by He and Zhu (1985) is actually a structure formed by the three septa of the myocoelidium as in all richthofenids (Text-Figure 6). As displayed by the type specimen (He and Zhu, 1985, pl. 3, figs. 1-3), two strong teeth and ridges are present under the delthyrial margins. Acid treatment of specimens from Guiding of Guizhou Province and an examination of the serial sections of specimens from the Daijiagou section both show that the dorsal interior of the type species *Parageyerella daijiagouensis* He and Zhu of *Parageyerella* He and Zhu, 1985 has a strong bilobed cardinal process as in *Tropidelasma* Cooper and Grant, 1969. In addition, the shape and the pseudodelthyrium with a monticulus are also same as the genus *Tropidelasma* from West Texas.

Waterhouse and Gupta (1983, p. 189, pl. 1, figs. 6-9) described several specimens from Upper Shyok Valley, the Karakorum Range, northern Pakistan as *Tropidelasma karakorumensis* new species. This species is characterized by the low interarea, subquadrate outline and two short dental plates (Waterhouse and Gupta, 1983, p. 191), which suggest it may be a species of *Orthothetina.*

*Tropidelasma* is closely similar to *Chelononia* Cooper and Grant, 1974 in terms of their highly conical profile and absence of any plates in the ventral valve, but unlikely confused from each other in terms of their pseudodeltidia. The pseudodeltidium in *Chelononia* is strongly rounded from the margin of the delthyrium, whereas *Tropidelasma* possesses flat pseudodeltidium with monticulus.

*Occurrence*.—Permian, West Texas, USA and South China.

### *Tropidelasma zhongliangshanensis* (He and Zhu, 1985)

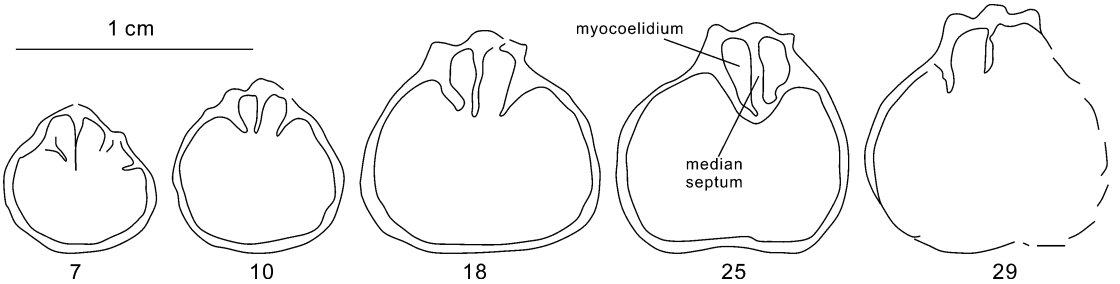
Plate 13, Figures 6-27

*Parageyrella zhongliangshanensis* He and Zhu, 1985, p. 202, pl. 3, figs. 4-9.

*Material examined*.—33 specimens. Registered specimens: Seven conjoined shells [NIGP141678 (=CUMT8166), NIGP141679 (=CUMT8167), NIGP141680 (=CUMT8168), NIGP141681 (=CUMT8164), NIGP141683-141685, 141687), two ventral valves (NIGP141682, 141686)].

*Description*.—Shell of medium size for genus, irregularly conical, hinge straight, narrower than width; anterior commissure irregular but slightly sulcate; widest at shell midlength; surface ornamented with fine costellae, costellae even in width and spaced by intertroughs as wide as costellae, increasing by intercalation, numbering about 9-10 in 2 mm, concentric wrinkles conspicuous, closely spaced on dorsal valve and anterior part of ventral valve, producing rugose apperance.

Ventral valve with a deeply conical beak, commonly twisted; interarea long, but not concave, bisected by flat pseudodelthyrium with narrow monticulus along midline; beak ridges obtusely angular; dorsal valve lidlike, subqua-




**Text-Figure 6.** Serial section of *Parageyerella daijiagouensis* He and Zhu (The Arabic numbers representing distance in mm from the sections to top of ventral beak, same herein after. After He and Zhu, 1985)

drate to subcircular in outline, moderately to strong convex in lateral profile, greatest convexity at umbo, anterior slope steep.

Ventral interior with strong teeth but without dental plates and septum ; muscle mark not impressed ; dorsal interior with thin bilobed cardinal process possessing two distant narrow and dorsally curved prongs, shaft bisected by low median ridge and each part with a low ridge tending posterolaterally in dorsal view.

*Measurements (in mm)*.—(VL=ventral length, DL=dorsal length).

| Specimen no. | VL | DL | W | T | HW | IH |
|---|---|---|---|---|---|---|
| NIGP141678 | 34.7 | 17.3 | 17.3 | 17.8 | 12.2 | 21.2 |
| NIGP141679 | 22.2 | 10.1 | 10.3 | 8.5 | 6.6 | 16.6 |
| NIGP141680 | 11.9 | 9.4 | 9.9 | 6.6 | 5.6 | 5.9 |
| NIGP141681 | >30.6 | 17.5 | 20.2 | 16.6 | 13.5 | >18.0 |
| NIGP141682 | 53.3 | — | 19.2 | — | — | 35.4 |
| NIGP141683 | 7.5 | 5.9 | 6.6 | 5.1 | 4.1 | — |
| NIGP141684 | >28.5 | 21.0 | 20.8 | 16.7 | 12.8 | >15.9 |
| NIGP141685 | >32.6 | 22.5 | 25.4 | 20.1 | 20.1 | >19.0 |
| NIGP141686 | 25.9 | — | 17.3 | — | — | 13.5 |
| NIGP141687 | >30.1 | 17.9 | 26.9 | 20.3 | 19.3 | >14.5 |

*Discussion*.—The present species is comparable to those from the Glass Mountains of West Texas, USA in shape and convexity, but differs by its weaker and fewer growth wrinkles and shorter shaft of the cardinal process.

*Tropidelasma ptomatis* Grant (1995, p. 661, figs. 6.1-6.14) from the Episkopi Limestone in Hydra Island (Greece) is closely similar to the present species in terms of its deeply conial profile, weak sulcus on dorsal valve and small size. The Greek species may be conspecific with the present species.

*Occurrence*.—A-26, 28 ; B-24 ; E-49 ; G-45.

### ***Tropidelasma triangularis* new species**

Plate 13, Figures 28-38

*Holotype*.—NIGP141689 from B-19 (Plate 13, Figures 31-34).

*Other material examined*.—Two conjoined shells (NIGP141688, 141690).

*Diagnosis*.—Shell with subtriangular outline and gently biconvex profile.

*Description*.—Shell medium in size for genus, biconvex, subtriangular in outline, greatest width near anterior margin ; hinge narrow, about half of shell width ; cardinal extremities inconspicuous ; posterolateral sides nearly straight, converging posteriorly at about 45 degree, anterolateral sides narrowly rounded, anterior margin straight ; anterior commissure slightly sulcate ; surface costellate, costellae fine and dense, numbering 9-10 in 2 mm near anterior margin, growth lines irregularly spaced but increasing in frequency anteriorly.

Ventral valve flat in lateral profile, but strongly domed in anterior profile ; umbonal and posterolateral slopes fairly steep ; beak pointed, suberect, beak ridges angular ; interarea quite high, apsacline ; pseudodelthyrium narrow, with a narrow median monticulus ; dorsal valve lidlike, gently and evenly convex in profile, greatest convexity at umbonal region ; umbonal and lateral slopes evenly and gently inclined, anterior slope sharply inclined ; sulcus shallow and wide, only developed near anterior margin.

Ventral interior with short blunt hinge teeth, without dental plates and septum

*Measurements (in mm)*.—

| Specimen no. | VL | DL | W | T | HW | IH |
|---|---|---|---|---|---|---|
| NIGP141688 | 33.0 | 19.5 | 32.0 | 18.0 | 17.1 | 14.5 |
| NIGP141689 | 35.2 | 21.5 | 28.0 | 16.2 | 18.5 | 22.0 |
| NIGP141690 | >38.5 | 21.2 | 32.1 | 17.8 | 20.0 | >22.0 |

*Etymology*.—Referring to its triangular outline.

*Discussion*.—There is no doubt that the material described above warrant a new species name. At first glance, it seems to be a *Streptorhynchus*, but the flat pseudodelthyrium with monticulus along the midline clearly suggests *Tropidelasma.* The new species is characterized by its triangular outline and gently biconvex profile, which can distinguish it from *T. zhongliangshanensis* (He and Zhu, 1985) and any other species from West Texas (Cooper and Grant, 1969, 1974). The new species is also very similar to *Streptorhynchus sulcatum* Grant, 1976 from the Rat Buri Limestone of Thailand in its high interarea, triangular outline and dorsal sulcus, but the latter possesses a more convex pseudodelthyrium, smaller size and more conspicuous costellae on surface.

*Occurrence*.—A-26 ; B-19, 24, C-15.

## Subfamily SCHUCHERTELLINAE Williams, 1953
## Genus *Schuchertella* Girty, 1904

*Schuchertella* Girty, 1904, p. 734.
*Schuchertell*a Girty, Weller, 1914, p. 53.
*Schuchertella* Girty ; Cooper and Grant, 1974, p. 261.
*Schuchertella* Girty ; Williams *et al.*, 2000b.

*Type species*.—*Streptorhynchus lens* White, 1862, p. 28 from the Upper Famennian, Missouri, USA.

*Discussion*.—*Goniarina* Cooper and Grant, 1969 is closely similar to *Schuchertella*, but Cooper and Grant (1974) suggested that *Goniarina* is more conical than *Schuchertella* and has extremely longer, slender and flattened dentifers. *Streptorhynchus*, which does not have dental plates as well, can not be confused with *Schuchertella* by its elongated forked cardinalia with socket plates.

### ***Schuchertella semiplana* (Waagen, 1883)**

Plate 13, Figures 39-44 ; Plate 14, Figures 1-5

*Orthotetes semiplana* Waagen, 1883, p. 608, pl. 55, figs. 1-2.
*Schuchertella* cf. *semiplana* Waagen ; Chao, 1927, p. 107, pl. 1, fig. 4.
*Schuchertella* cf. *semiplana* Waagen ; Grabau, 1936, p. 90, pl. 8, fig. 5.
*Streptorhynchus (Schuchertella) purdoni* Reed, 1944, pl. 2, figs. 14, 15.
*Schuchertella* cf. *semiplana* Waagen ; Wang *et al.*, 1964, p. 209, pl. 30, figs. 18-19.
*Schuchertella semiplana* Waagen ; Li *et al.*, 1980, p. 332, pl. 158, figs. 6-7.

*Schuchertella frechi* Huang ; Xu in Yang *et al.*, 1987, p. 219, pl. 7, figs. 23–25.
? *Schuchertella bassa* Grant, 1995, p. 658, figs. 4.1–4.16.

*Material examined*.—Two conjoined shells (NIGP141691, NIGP141692), three complete ventral valves (NIGP141697, 141694, 141696) and two complete dorsal valves (NIGP141693, NIGP141695).

*Description*.—Shell medium to small in size for genus, transversely elliptical in outline, greatest width slightly anterior to shell midlength ; hinge straight slightly shorter than greatest width ; cardinal extremities quadrate to abtuse ; lateral sides regularly rounded, anterior margin broadly rounded ; anterior commissure rectimarginate ; surface costellate, costellae crenulated, relatively strong on median region, numbering 4 in 2 mm, interspaced by wider intertroughs, but increasing by intercalation, becoming fairly dense and interspaced by narrower intertroughs near margins, numbering 6 in 2 mm ; concentric wrinkles developed only near margin, producing cancellate effect around margin.

Ventral valve gently convex in profile ; beak very low, abtusely pointed ; umbonal region weakly convex ; lateral and anterior slopes faintly inclined, but sharply inclined dorsally at about three-quarters of shell length ; interarea widely triangular, slightly concave, apsacline, gradually narrowing laterally ; pseudodelthyrium convex and fairly narrow ; dorsal valve flattened in profile, but slightly inclined around margins ; median part slightly flattened.

Ventral interior without dental plates ; dorsal interior with socket plates diverging at about 150 degree.

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141691 | 23.9 | 32.3 | 10.4 | 29.0 |
| NIGP141692 | 15.0 | 20.3 | 6.5 | 17.6 |
| NIGP141693 | 11.0 | 17.6 | — | 17.6 |
| NIGP141694 | 15.6 | 21.5 | 5.5 | 17.8 |
| NIGP141695 | 10.4 | 15.2 | — | 13.9 |
| NIGP141696 | 9.5 | 17.4 | — | 15.0 |
| NIGP141697 | 17.0 | 24.0 | — | 22.0 |

*Discussion*.—This species was first described by Waagen (1883, p. 608) as *Orthotetes* without showing internal features. It was subsequently referred to *Schuchertella* by many workers. Reed (1944) figured two specimens from the upper part of the Wargal Formation of the Salt Range, Pakistan as *Streptorhynchus* (*Schuchertella*) *purdoni* Reed. This species appears to be identical to *S. semiplana* Waagen in both external and internal characters except for a slightly smaller size. Our specimens from the Lopingian of South China are comparable with the type materials of *Schuchertella semiplana* in all observed aspects. The present species may be also confused with some species of *Orthothetina* if the internal characters are not studied. The specimens figured as *Schuchertella frechi* Huang by Xu in Yang *et al.* (1987) have the diagnostic characters of *S. semiplana*.

*Schuchertella bassa* Grant (1995, p. 658) from the Lopingian in Greece is closely comparable with the present specimens and also Waagen's (1883) specimens. Althuogh it is hard to say they belong to the same species their external characters are nearly identical.

*Occurrence*.—B–21 ; D–26 ; G–55, 56.

## Order ORTHIDA Schuchert and Cooper, 1931
## Superfamily RHIPIDOMELLOIDEA Schuchert, 1913
## Family RHIPIDOMELLIDAE Schuchert, 1913
## Genus *Rhipidomella* Oehlert, 1890

*Type species*.—*Terebratula michelini* LeVeille (1835, p. 39) from Visean in Belgium.

### *Rhipidomella hessensis* King, 1931

Plate 14, Figures 6–13

*Rhipidomella hessensis* King, 1931, p. 43, pl. 1, figs. 3–4.
*Rhipidomella hessensis* King ; Cooper and Grant, 1976a, p. 2610, pl. 663, figs. 11–12, 23–26, 32–68 ; pl. 665, figs. 1–66 ; pl. 666, figs. 1–33 ; pl. 667, figs. 27–43.
*Rhipidomella hessensis* King ; Shen and He, 1994a, p. 446, pl. 1, figs. 1–5.

*Material examined*.—Two complete conjoined shells (NIGP141698, NIGP141699).

*Description*.—Medium in size for genus, subcircular in outline, unequally biconvex, greatest width slightly anterior to shell midlength ; hinge narrow ; interarea low ; lateral sides regularly rounded, anterior side nearly straight ; surface finely costellate, costellae fairly regular, increasing by intercalation, numbering 7 in 2 mm near margin ; intertroughs as wide as costellae ; growth lines irregular, interrupting costellae, producing intermittent costellae ; anterior commissure rectimarginate.

Ventral valve nearly flat in all individuals and with very shallow sulcus ; beak not incurved, short and blunt ; posterolateral slopes moderately inclined, lateral slopes gently inclined ; dorsal valve much more strongly convex than ventral valve, neatly hemispherical in profile, maximum convexity slightly anterior to umbonal region.

Ventral interior with shallow delthyrial cavity ; teeth not preserved ; dental plates undeveloped ; muscle field large, fan-shaped, surrounded by a serrated low ridge, diductor scars partly divided into two lobes by a low and wide median ridge ; dorsal interior with deep cavity ; cardinalia thick and large, cardinal process prominent, but apex not preserved ; brachiophore strong, anteriorly projecting, sockets deep, bounded distally by internal ridges, proximally by brachiophores and their support plates, muscle field subcircular in outline, surrounded by very low transverse ridge and divided into two lobes by a low median ridge.

*Measurements (in mm)*.—

| Specimen no. | L | W | T |
|---|---|---|---|
| NIGP141698 | 23.4 | 22.9 | 16.2 |
| NIGP141699 | 20.9 | 20.8 | 14.1 |

*Discussion*.—*R. hessensis* was firstly described by King (1931) based on specimens with a wide range of variations. It is characterized by a subcircular to subtrigonal outline, well preserved low interarea and the typical tubeles along the sides of the ventral valve. The present specimens appear

to be the first reliable discovery of this genus in the Changhsingian in South China. They agree with the specimens figured by Cooper and Grant (1976a, pl. 663, figs. 32–68) from the Wolfcamp Series of the Glass Mountains, West Texas, in outline, profile and internal structures.

This species resembles, particularly in shell outline, *Rhipidomella penniana* (Derby, 1874, p. 26, pl. 5, figs. 13, 15, 17, 19, 20–22 ; pl. 8, fig. 2 ; also Newell *et al.*, 1953, p. 90, pl. 6, figs. 15a–17b) from the Upper Carboniferous–Lower Permian of Peru. The Peruvian species, however, is generally smaller and more convex than the Texan specimens. The anterior commissure of one of the figured Peruvian specimens by Newell *et al.* (1953, pl. 6, fig. 15b) is gently uniplicate. *R. cordialis* Grant (1976, p. 37, pl. 2, figs. 31–41 ; pl. 3, figs. 1–53) from the Rat Buri Limestone, south Thailand, shares the elongate outline and moderate convexity with our specimens but is much smaller.

*Occurrence*.—G–45, 46.

### ***Rhipidomella subcircularis*** **Shen and He, 1994a**

Plate 14, Figures 14–26

*Acosarina dorashamensis* Sokolskaja ; Wang *et al.*, 1982, p. 189, pl. 91, figs. 9a–c.
*Rhipidomella subcircularis* Shen and He, 1994a, p. 447, pl. 1, figs. 6–8.

*Holotype*.—NIGP141700 (=CUMT8161) from G–45 (Plate 14, Figures 14–16).

*Other material examined*.—Four complete conjoined shells (NIGP141701–141704).

*Description*.—Medium is size, subcircular in outline, gently equally biconvex, maximum convexity just anterior to beak ; lateral and anterior sides evenly rounded, hinge narrow, about one–third of shell width at shell midlength ; surface finely costellate, increasing by intercalation, numbering 5 in 2 mm near anterior margin, interrupted by regular concentric lines ; anterior commissure rectimarginate.

Ventral valve flattened over anterior region ; beak short, slightly incurved ; interarea very low, widely triangular ; posterolateral slopes moderately inclined ; dorsal valve evenly convex in lateral profile, maximum convexity at midvalve ; lateral slopes evenly inclined, weak, narrow sulcus originating from umbonal region, not widening, but slightly deepening anteriorly.

*Measurements (in mm)*.—

| Specimen no. | L | W | T |
|---|---|---|---|
| NIGP141700 | 14.5 | 13.8 | 6.1 |
| NIGP141701 | 13.1 | 13.5 | 6.6 |
| NIGP141702 | 18.0 | 19.0 | 7.6 |
| NIGP141703 | 15.0 | 16.2 | 6.4 |
| NIGP141704 | 12.0 | 15.6 | 6.1 |

*Discussion*.—The present species differs from *Rhipidomella hessensis* King in its smaller size and equally gently biconvex profile. Cooper and Grant (1976a, p. 2611) pointed out that *R. hessensis* King has a wide range of variations. For example, the specimens illustrated by King (1931, pl. 1, figs. 3a–b) are subtrigonal in outline, very convex and have a relatively narrow hinge ; this is in contrast to other specimens figured by Cooper and Grant (1976a), which are rather flat, with the dorsal valve being only slightly more convex than the ventral valve, consequently an elliptical rather than subtrigonal outline is developed. However, the specimens from the Wenjiangsi section, Guiding can be evidently divided into two groups with contrasting convexities and no discernible transitional types. Therefore, we consider that these two varieties might represent two different species. Wang *et al.* (1982, p. 189) described some specimens as *Acosarina dorashamensis* Sokolskaja from the Late Permian Loping Formation in Jiangxi Province. However, one of the specimens figured in plate 91, figs. 9a–c clearly shows that it does not have a conspicuous interarea in either valve but with a low beak, which would strongly suggest that it belongs to *Rhipidomella*, and is likely to be conspecific with the present species. *Rhipidomella cordialis* Grant (1976, p. 37, pl. 2, figs. 31–41 ; pl. 3, figs. 1–53) from the Rat Buri Limestone in Thailand is also comparable to the present species in size and convexity but has a slightly elongate outline.

*Occurrence*.—G–45.

## Superfamily ENTELETOIDEA Waagen, 1884
## Family SCHIZOPHORIIDAE Schuchert and LeVene, 1929
## Genus *Acosarina* Cooper and Grant, 1969

*Acosarina* Cooper and Grant, 1969, p. 2.
*Acosarina* Cooper and Grant, 1976a, p. 2619.
*Acosarina* Cooper and Grant ; Liao, 1987, p. 94.
*Acosarina* Cooper and Grant ; Liang, 1990, p. 353.
*Kotlaia* Grant, 1993, p. 4.

*Type species*.—*Acosarina dorsisulcata* Cooper and Grant, 1969, p. 2, pl. 5, figs. 19–23 [=*Acosarina minuta* (Abich, 1878)] from Middle Permian, West Texas, USA.

*Discussion*.—*Acosarina* is characterized by its small subquadrate to transversely rectangular or elliptical outline, subequally biconvex profile, rectimarginate to sulcate anterior commissure, low and long median septum and short dental plates in ventral valve. The fact that specimens from South China now assigned to this genus had been respectively placed in *Orthis*, *Dalmanella*, *Schizophoria* and *Orthotichia* in previous reports indicates the confusion over the identity of *Acosarina.* Abich (1878) described a specimen from the Transcaucasia under the name *Streptorhynchus peregrinus* var. *minutus.* Sokolskaja (in Ruzhentsev and Sarytcheva, 1965) firstly studied the detailed internal structures of a similar specimen from the same locality, but reassigned it to *Orthotichia.* Based on the specimens from the Glass Mountains of West Texas, Cooper and Grant (1969, p. 2) proposed *Acosarina* with *A. dorsisulcata* Cooper and Grant as the type species. This genus differs from *Schizophoria* and *Orthotichia* Hall and Clarke, 1892 by its long and low ventral median septum and rectimarginate to sulcate commissure. The former feature will immediately separates *Acosarina* from *Orthis* and *Dalmanella.* The differences between *Acosarina* and *Rhipidomella* are that *Acosarina* possesses a wide hinge and well developed palintropes in both valves.

In part the confusion may have been derived from the lack of a direct comparative study of specimens from different regions. Examination by the senior author in 1995 at the Palaeontological Institute, Moscow, of *Acosarina minuta* from the Transcaucasus originally studied by Abich (1878) and Sokolskaja (in Ruzhentsev and Sarytcheva, 1965) revealed that it has a low but long ventral median septum in ventral valve characteristic of *Acosarina*. *Orthis indica* Waagen (1884, pl. 56, figs. 7–8, 14–16) from the Salt Range clearly has a wide hinge, well-developed palintropes and multicostellae on the shell surface, all characteristics of *Acosarina* although no internal details were provided by Waagen (1884). However, specimens from South China that are considered conspecific with *O. indica* possess a very long ventral median septum and two dental plates, very much like in *Acosarina minuta* (Abich). We are, therefore, inclined to place *Orthis indica* Waagen (1884) as a junior synonym of *Acosarina minuta* (Abich, 1878).

In addition, comparison of *A. minuta* from the Transcaucasus and the Salt Range with *A. dorisulcata* from West Texas shows that they all possess a subquadrate outline, a well-developed dorsal sulcus and sulcate anterior commissure. The close identity in these features has prompted us to consider *A. dorsisulcata* Cooper and Grant (1969) to be also a junior synonym of *Acosarina minuta* (Abich, 1878). Thus, *Acosarina minuta* (Abich) is probably a very widely distributed species in the Permian.

*Kotlaia* Grant (1993, p. 4) was proposed based on specimens from Pakistan on the grounds that it has numerous tubular costellae on both valves and a very long median septum reaching the anterior margin of shell, unlike *Acosarina* in which the tubular costellae are mostly confined to the ventral valve and its median septum normally extends over to the anterior margin of the muscle area. According to our observation, however, *Acosarina* is very variable over the length of its median septum, ranging from near half of the shell length to almost reaching the anterior margin (Plate 15, Figures 1–3, 6, 11). In addition, tubular costellae are very common in *Acosarina* in terms of South Chinese specimens and probably due to the preservation of the silicified specimens. In view of the above comparisons, *Kotlaia* Grant, 1993 is herein considered as a junior synonym of *Acosarina* Cooper and Grant, 1969.

*Occurrence*.—Upper Carboniferous to lowermost Triassic; China, Pakistan, West Texas, USA, Thailand, Transcaucasia.

### *Acosarina minuta* (Abich, 1878)

Plate 14, Figures 27–38; Plate 15, 1–21

*Streptorhynchus peregrinus* var. *minutus* Abich, 1878, p. 78, pl. 9, fig. 1a.
*Orthis indica* Waagen, 1884, p. 568, pl. 56, figs. 7–8, 14–16.
*Dalmanella indica* (Waagen); Frech, 1911, p. 120, pl. 18, fig. 1.
*Dalmanella indica* (Waagen); Hayasaka, 1922, p. 76, pl. 4, fig. 3.
*Schizophoria indica* (Waagen); Ozaki, 1931, p. 167, pl. 15, fig. 3.
*Orthotichia indica* (Waagen); Zhan and Li, 1962, p. 443, pl. 1, figs. 1–2.
*Schizophoria indica* (Waagen); Wang *et al.*, 1964, p. 134, pl. 16, figs. 24, 25, 28.
*Acosarina dorsisulcata* Cooper and Grant, 1969, p. 2, pl. 5, figs. 19–23.
*Acosarina dorsisulcata* Cooper and Grant, 1976a, p. 2621, pl. 667, figs. 1–26.
*Acosarina indica* (Waagen); Yang *et al.*, 1977, p. 311, pl. 130, fig. 3.
*Acosarina dorsisulcata* (Waagen); Feng and Jiang, 1978, p. 235, pl. 85, fig. 10.
*Orthotichia indica* (Waagen); Tong, 1978, p. 211, pl. 27, fig. 3.
*Acosarina indica* (Waagen); Jin and Ye, 1979, p. 74, pl. 36, figs. 6–9.
*Acosarina indica* (Waagen); Wang *et al.*, 1982, p. 190, pl. 180, fig. 7.
*Acosarina dorashamensis* (Sokolskaja); Liao and Meng, 1986, pl. 1, fig. 14.
*Acosarina dorashamensis* (Sokolskaja); Liao, 1987, pl. 1, figs. 3–8.
*Acosarina* sp. Yanagida, 1988, pl. 29, figs. 1–12.
*Acosarina* cf. *minuta* (Abich); Zhan in Li *et al.*, 1989, pl. 25, figs. 2, 4.
*Acosarina indica* (Waagen); Liang, 1990, p. 354, pl. 1, figs. 6–10.
*Acosarina indica* (Waagen); Zhu, 1990, p. 62, pl. 9, figs. 5–7.
*Kotlaia capilosa* Grant, 1993, p. 5, figs. 4.1–4.6.
*Acosarina kanmerai* Yanagida and Nakornsri, 1999, p. 111, pl. 26, figs. 1–7.

*Material examined*.—Numerous conjoined shells. Registered specimens: 10 conjoined shells (NIGP141705–141710, 141713, 141714, 141716, 141717), two internal moulds of ventral valve (NIGP141715, 198) and a ventral valve (NIGP141712).

*Diagnosis*.—Small to large, subquadrate to subcircular in outline, subequally biconvex in profile, evident dorsal sulcus; ventral interior usually with a median septum longer than half of shell length.

*Description*.—Small to medium in size for genus, subequally biconvex in profile, width nearly equal to length or slightly greater than length, greatest width at shell midlength; hinge straight; lateral sides evenly rounded, anterior margin variable, gently rounded to slightly emarginate; anterior commissure gently sulcate to nearly rectimarginate; surface multicostellate, costellae somewhat tubular, increasing by intercalation, numbering 6 per 2 mm, tubules randomly scattered on both valves; growth lines occasionally developed near margin, interrupting costellae.

Ventral valve unevenly and flatly convex in lateral profile, posterior half more convex, anterior profile gently domed; beak suberect, bluntly pointed; interarea moderately to strongly curved; delthyrium narrowly triangular; beak ridges obtusely angular, umbonal region moderately swollen, median region slightly flattening, lateral slopes gently inclined; flanks flatly convex; dorsal valve moderately and unevenly convex in lateral profile; beak pointed, interarea strongly incurved, umbonal region narrowly swollen; flanks evenly inclined, sulcus narrow and shallow, originating from umbonal region, widening and slightly deepening anteriorly,

commonly forming slight emargination.

Ventral interior with small teeth and broad, short dental plates, dental plates separated at an angle of about 30 degree, median septum thin, variable in length, extending anteriorly more than half of valve length or near anterior margin ; dorsal interior with long projecting brachiophores ; sockets small, fulcral plates strong, extending anteriorly at an angle of about 80 degree, myophragm inconspicuous, but having a very short and low median ridge in the median part of myophragm.

*Measurements (in mm).*—

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141705 | 7.8 | 8.2 | 4.8 | 4.3 |
| NIGP141706 | 8.5 | 9.5 | 5.0 | — |
| NIGP141707 | 13.0 | 12.9 | 8.5 | 8.1 |
| NIGP141708 | 9.0 | 10.2 | 6.8 | 5.8 |
| NIGP141709 | 12.9 | 13.5 | 9.1 | 9.2 |
| NIGP141710 | 9.0 | 10.3 | 6.0 | 4.9 |
| NIGP141711 | 13.3 | 14.5 | 4.5 | 7.1 |
| NIGP141712 | 11.6 | 13.5 | — | 7.5 |
| NIGP141713 | 14.4 | 16.5 | 9.5 | 7.7 |
| NIGP141714 | 11.3 | 13.2 | 7.4 | 7.0 |
| NIGP141715 | 11.5 | 14.7 | 8.8 | — |
| NIGP141716 | 11.3 | 13.0 | 7.6 | 8.3 |
| NIGP141717 | 6.2 | 7.0 | 4.3 | 3.5 |
| NIGP141718 | 12.6 | 13.5 | — | — |

*Discussion*.—*Acosarina minuta* (Abich, 1878) seemingly has a continum of variation in size, outline and profile and the nature of its dorsal sulcus ; it is therefore unlikely that we are able to recognize distinct different groups in terms of their external chracters of the South Chinese specimens. Overall the species is commonly characterized by its subquadrate to subcircular outline and evident dorsal sulcus. Abich (1878) described a specimen from the Transcaucasus under the name *Streptorhynchus.* Sokolskaja in Ruzhentsev and Sarytcheva (1965) reassigned it to the genus *Orthotichia* and meanwhile proposed another species *O. dorashamensis* Sokolskaja (in Ruzhentsev and Sarytcheva, 1965) which differs from the former in its large size and transverse outline and weak sulcus. However, recent comparisons among a large collection of specimens from South China and the Transcaucasus done by the senior author indicates that the specimens from both areas basically have same size, outline, convexity, dorsal sulcus and internal structure. Therefore, the authors herewith consider that *Orthotichia minuta* (Abich), *Orthis indica* Waagen, 1884, *Acosarina dorsisulcata* Cooper and Grant, 1969, *Kotlaia capilosa* Grant, 1993 and *Acosarina kanmerai* Yanagida and Nakornsri, 1999 all belong to the same species. Some specimens of the present species with rectimarginate commissure are also generally comparable with *Acosarina rectimarginata* Cooper and Grant (1976a, p. 2624, pl. 674, figs. 1-46)

*Occurrence*.—A-8, 9, 10, 11, 12, 14, 18, 20, 26, 28, 31, 32, 34 ; B-1, 7, 19, 21, 22, 24 ; C-17 ; D-5, 8, 11, 17 ; E-38, 45, 48, 49 ; F-6, 7, 8, 12, 14, 15, 16, 17, 18, 19, 20, 21, 22, 24, 27, 29, 30, 32, 33, 41, 42, 43, 44, 46, 47 ; G-27, 36, 37, 39, 41, 45, 50, 52, 54, 56 ; H-1, 4, 130, 137 ; I-10, 33, 51, 56, 68 ; Ja-13 ; Jc-10, 15, 16.

***Acosarina antesulcata* Waterhouse, 1983**

Plate 15, Figures 22-25

*Acosarina antesulcata* Waterhouse, 1983, p. 115, pl. 1, figs. 2-9.

*Material examined*.—A complete conjoined shell (NIGP141719).

*Description*.—Large for genus, 14.2 mm long, 14.5 mm wide, 12.2 mm thick, and 7.7 mm along hinge ; strongly biconvex, subtriangular in outline, greatest width slightly anterior to shell midlength ; hinge only about half of greatest width ; posterolateral sides nearly straight, anterolateral sides regularly rounded, anterior margin slightly emarginate ; surface finely costellate, anterior commissure rectimarginate.

Ventral valve moderately convex in lateral profile but more strongly convex in anterior profile ; beak slightly incurved ; interarea concave, broadly triangular, umbonal region strongly swollen ; lateral slopes evenly inclined, anterior slope gently inclined ; anteromedian region slightly flattened, forming a narrow and shallow sulcus ; dorsal valve slightly more convex in lateral and anterior profile ; lateral slopes sharply steep ; beak blunt, curved ; interarea low, sulcus well-developed, originating from umbonal region, widening and slightly deepening anteriorly, forming emarginate anterior margin with ventral sulcus.

Ventral interior with two short dental plates and long median septum ; dorsal interior with two strongly divergent fulcral plates.

*Discussion*.—This species is characterized by a moderately biconvex profile, sulci on both valves and a umbonal angle less than 90 degrees, which combinedly readily distinguish it from any other species in this genus. Some of the Thai specimens figured by Waterhouse (1983) are too severely deformed to allow detailed comparisons, but our specimen is basically identical with the specimen TBR 391 figured by Waterhouse (1983, pl. 1, figs. 4-5).

*Occurrence*.—G-45.

## Family ENTELETIDAE Waagen 1884

### Genus *Camerenteletes* new genus

*Type species*.—*Camerenteletes enteletoides* new species from the Changhsing Formation in the Chenxian area, Hunan Province, South China.

*Diagnosis*.—Externally similar to *Enteletes*, but internally with triple plates in the ventral valve joining anteriorly and forming a highly elevated spondylium with high internal plate (Text-Figure 7).

*Discussion*.—Sperficially, specimens of this new genus may be identified with little doubt as *Enteletes* in view of their plication and costellation. However, serial sections of the specimens reveal that they possess a distinct, highly elevated V-shaped spondylium with internal plate in the ventral valve (Plate 26, Figures 19, 20) which can be readily distinguished from any other genera of the family Eneteletidae. *Parenteletes* King, 1931 differs from the present genus by its ∧-shaped chamber with the median septum rising onto the median camera in the ventral valve.

*Etymology*.—Camer-, Greek, chamber; *Enteletes*, a generic name of brachiopods.

*Distribution*.—Hunan, South China; Changhsingian.

### *Camerenteletes enteletoides* new species

Plate 15, Figures 38–39; Plate 16, Figures 1–6; Plate 26, Figures 16, 17, 19, 20; Text-Figure 7

*Holotype*.—NIGP141724 from Jb-4, Plate 15, Figures 38–39.

*Other material examined*.—Six complete conjoined shells and an incomplete external mould of ventral valve. Registered specimens: Two conjoined shells (NIGP141723, 141725).

*Description*.—Medium in size for genus, strongly and subequally biconvex, thickness much greater than width and length, outline slightly roundly elliptical; hinge slightly narrower than greatest width at shell midlength; both valves subequally deep, umbonal region at same height, sides strongly rounded; anterior commissure strongly serrate; umbonal region finely costellae; plicae beginning anterior to umbo, crests subangular, 2–3 on each side of ventral sulcus; sulcus narrow subangular, originating at about 7 mm anterior to beak; dorsal fold subangular and low, 3 plicae on each side of fold.

Ventral valve strongly convex and swollen in lateral profile, broadly and strongly convex in anterior profile; beak short and blunt, strongly incurved; interarea low, strongly concave; umbonal region narrowly inflated, median region strongly inflated; flanks sharply steep; dorsal valve also strongly convex in lateral profile, maximum convexity just anterior to umbo, anterior profile more strongly inflated than ventral valve; beak wide and thick, strongly incurved; interarea low; umbonal slopes sharply steep, lateral slopes strongly inclined.

Ventral interior with triple plates at beak cavity (Text-Figure 7; Plate 26, Figure 16), dental plates and median septum joining anteriorly and highly elevated as a V-shaped spondylium with high internal plate derived from median septum (Text-Figure 7; Plate 26, Figures 19, 20); dorsal interior with thick, strongly divergent fulcral plates and massive cardinal process (Plate 26, Figure 17).

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141723 | 18.5 | 18.4 | 20.0 | 12.6 |
| NIGP141724 | 15.8 | 17.5 | 19.1 | 12.3 |
| NIGP141725 | 11.5 | 13.0 | — | — |

*Etymology*.—*Enteletes*, a generic name of brachiopods; oides, similar to.

*Discussion*.—Externally, the described materials are characterized by their strong convexity and subangular plication, like in *Enteletes waageni* Gemmellaro, 1899. However, all the *Enteletes* species possess triple subparallel plates which never unite together to form spondylium.

*Occurrence*.—Jb-4, 5; Jc-15, 16.

### Genus *Enteletes* Fisher de Waldheim 1825

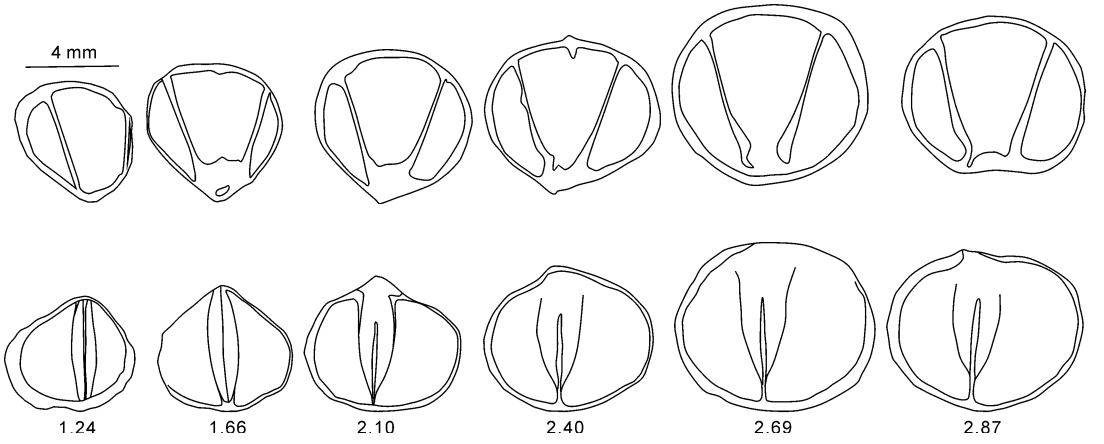
*Type species*.—*Enteletes glabra* Fisher de Waldheim, 1829, p. 193, pl. 26, figs. 6, 7 from the Namurian, Russia.

### *Enteletes kayseri* Waagen, 1884

Plate 15, Figures 26–37

*Syntrielasma hemiplicata* Hall; Kayser, 1882, p. 179, pl. 24, figs. 2–3.
*Enteletes kayseri* Waagen, 1884, p. 553.
*Enteletes kayseri* Waagen; Frech, 1911, p. 121.
*Enteletes kayseri* Waagen; Wang *et al.*, 1964, p. 148, pl. 19, figs. 13–16.
*Enteletes kayseri* Waagen; Li and Gu, 1976, p. 238, pl. 138, fig. 6.
*Enteletes kayseri* Waagen; Yang *et al.*, 1977, p. 307, pl. 129, fig. 1.
*Enteletes kayseri* Waagen; Tong, 1978, p. 210, pl. 77, fig. 2.
*Enteletes kayseri* Waagen; Liao and Meng, 1986, pl. 1, figs. 8, 9 (not 3–7).
*Enteletes kayseri* Waagen; Liao, 1987, pl. 1, figs. 1–2.

*Material examined*.—Nine complete conjoined shells. Registered specimens: Three conjoined shells (NIGP141720–141722)




**Text-Figure 7.** Serial sections of *Camerenteletes enteletoides* n. gen and n. sp. (NIGP141724)

*Description*.—Medium in size for genus, subequally biconvex, width greater than length, thickness normally smaller than length and width at maturity, transversely elliptical in outline ; hinge narrow, about half of greatest width at shell midlength ; sides regularly rounded, anterior margin evidently serrate ; surface ornamented with costellae and plication, costellae fine, 6–7 per mm near margin ; plicae few, originating from midvalve, crests broadly angular ; dorsal valve with a median plication, usually higher and stronger than those on flanks, each flank commonly with 1–4 plications depending on size ; ventral valve with a deep sulcus, corresponding to the ventral median plication ; sulcus originating just anterior to umbonal region, widening and deepening anteriorly, each flank with 2–4 plications ; anterior commissure strongly serrate.

Ventral valve slightly smaller than dorsal valve, strongly convex in lateral and anterior profile ; beak blunt and thick, slightly incurved, maximum convexity at umbonal region ; lateral slopes evenly inclined ; dorsal valve strongly convex in lateral and anterior profile ; beak wide and thick, strongly incurved under beak ; umbonal region strongly swollen, flanks evenly and moderately inclined.

Ventral interior with two strong dental plates and thin median septum. Dorsal interior with two strong and divergent fulcral plates.

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141720 | 10.5 | 12.9 | 9.7 | 6.9 |
| NIGP141721 | 12.0 | 13.0 | 9.5 | — |
| NIGP141722 | 14.7 | 15.8 | 11.5 | 8.6 |

*Discussion*.—*Enteletes kayseri* was first described by Kayser (1882) from the Upper Carboniferous of China as *Syntrielasma hemiplicata* Hall and Clarke, 1892. Waagen (1884, p. 553) reidentified Kayser's species as *Enteletes kayseri* based on material from the Salt Range, Pakistan and argued that the Chinese and Indian specimens represent a different species from *Enteletes hemiplicata* (Hall). He stated that the Chinese species differ from the American species by its longer hinge, much broader and less deeply sunk in sulcus of the ventral valve, and sharper and narrower lateral plications. Our study of *Enteletes* from the Upper Carboniferous and the Permian of China has confirmed these differences and revealed additional distinctive features of *E. kayseri* with respect to *E. hemiplicata* in that the former has narrow plicae and a shallow sulcus on the ventral valve. Liao and Meng (1986) figured several specimens from the Changhsing Formation of Chenxian, Hunan Province under the present species. However, the plications and anterior commissure of their specimens in figs. 3–7 of plate 1 have a relatively weak serrate anterior commissure and narrower plicae, recalling *E. retardata* Huang, 1933.

*Occurrence*.—F–46, 47 ; G–45 ; I–11 ; Jb–4, 5.

### *Enteletes gibbosus* Chronic in Newell *et al.*, 1953

Plate 16, Figures 7–40 ; Plate 26, Figure 15 ; Text-Figure 8

*Enteletes gibbosus* Chronic in Newell *et al.*, 1953, p. 92, pl. 16, figs. 9a–14.

*Enteletes gibbosus* Chronic ; Hayasaka and Kato, 1966, p. 281, pl. 34, figs. 1–4 ; pl. 35, figs. 1–4 ; text-figs. 1a–h, i ; 2a–q, r.

*Enteletes gibbosus* Chronic ; Yanagida and Hirata, 1969, p. 96, pl. 11, figs. 12a–e.

*Enteletes gibbosus* Chronic ; Yanagida, 1976, CP–6, 7a–e.

*Enteletes bisulcata* Liao and Meng, 1986, p. 75, pl. 1. figs. 1–2.

*Enteletes xiziensis* Liang, 1990, p. 363, pl. 6, figs. 1–15.

*Material examined*.—26 complete conjoined shells. Registered specimens : 12 conjoined shells (NIGP141726–141737).

*Description*.—Medium in size for genus, subequally and strongly biconvex ; umbonal region at same height in lateral profile ; anterior view cylindrical in profile, roundly triangular or subcircular in outline ; hinge narrower than greatest width at shell midlength ; anterior commissure strongly serrate ; both valves finely costellate and plicate.

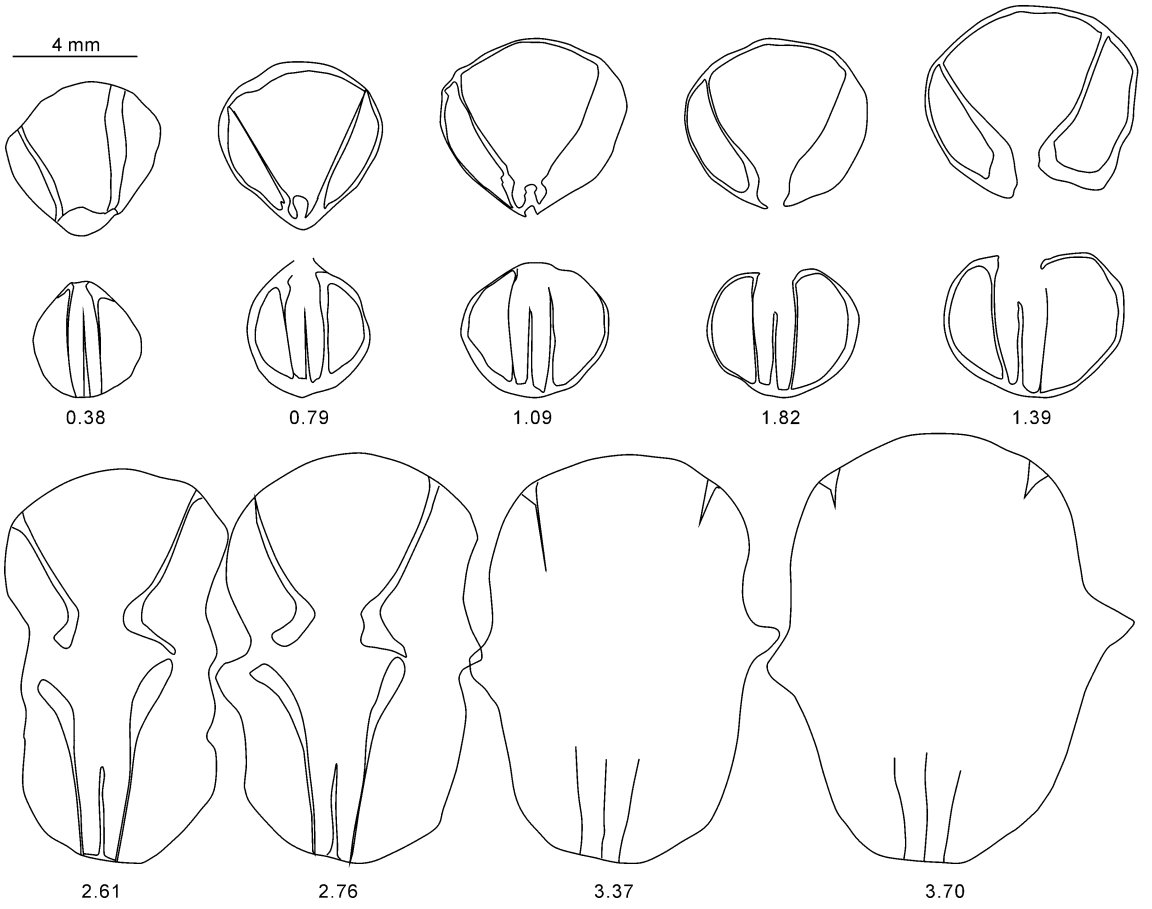
Ventral valve strongly inflated in lateral profile, but not very equal in longitudinal direction and with a geniculation at about 11 mm anterior to beak in adults ; beak thick, strongly incurved over interarea ; umbonal region smooth, strongly domed, lateral slopes evenly and moderately inclined ; sulcus narrower and shallower, originating anterior to umbo, not widening and deepening anteriorly, 3 plicae on each side of sulcus, crests rounded ; dorsal valve also strongly convex in lateral profile with a geniculation anterior to beak ; beak strongly incurved over interarea ; umbonal region strongly inflated ; fold narrow and flat, slightly lower than lateral plicae, appearing a flat sulcus present on dorsal valve, each side bearing 3 plicae.

Ventral interior with dental plates and thin median septum, subparallelly extending anteriorly (Text-Figure 8 ; Plate 26, Figure 15) ; dorsal interior with short brachiophores and flaring fulcral plates.

*Measurements (in mm)*.—

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141726 | 14.1 | 16.2 | 19.5 | 8.5 |
| NIGP141727 | 8.2 | 12.3 | 12.5 | 7.5 |
| NIGP141728 | 15.2 | 17.6 | 20.0 | — |
| NIGP141729 | 14.0 | 14.7 | 15.6 | — |
| NIGP141730 | 10.5 | 11.5 | 13.6 | 6.6 |
| NIGP141731 | 13.2 | 13.2 | 12.8 | 7.0 |
| NIGP141732 | 13.1 | 13.9 | 13.1 | 8.9 |
| NIGP141733 | 10.3 | 9.0 | 7.5 | 5.3 |
| NIGP141734 | 11.3 | 13.6 | 11.4 | 8.6 |
| NIGP141735 | 15.5 | 14.7 | 13.7 | 8.0 |
| NIGP141736 | — | 12.0 | 12.2 | — |
| NIGP141737 | 17.7 | 18.8 | 16.0 | 10.1 |

*Discussion*.—The cylindrical anterior profile, geniculated lateral profile in adults and a low dorsal fold can distinguished the present species from any other species of *Enteletes.* This species was named as *Enteletes bisulcata* by Liao and Meng (1986, p. 75, pl. 1. figs. 1–2) without comparison with the Peruvian species. The specimens in hand agree well with the type material of the species figured by Chronic in Newell *et al.* (1953, p. 92, pl. 16, figs. 9a–14) from




**Text-Figure 8.** Serial sections of *Enteletes gibbosus* Chronic (NIGP141735).

the Lower Permian of Peru and those figured by Hayasaka and Kato (1966) and Yanagida and Hirata (1969) from the Permian of Japan. *E. xiziensis* Liang (1990) has a cylindrical anterior profile, geniculated valves and a low dorsal fold, all matching well with the diagnosis of *E. gibbosus.*

*Occurrence*.—Jb-4, 5 ; Jc-15.

### ***Enteletes retardata*** **Huang, 1933**

Plate 16, Figures 41-48 ; Plate 17, Figures 1-4 ; Text-Figure 9

*Enteletes retardata* Huang, 1933, p. 7, pl. 1, figs. 7-10.
*Enteletes retardata* Huang ; Wang *et al.*, 1964, p. 107, pl. 19, figs. 5-9.
*Enteletes hemiplicata* Huang ; Liao and Meng, 1986, pl. 1, figs. 3-7 (non 8-9).
*Enteletes retardat*a Huang ; Liang, 1990, p. 360, pl. 6, figs. 31-35.

*Material examined*.—Numerous specimens. Registered specimens : Four conjoined shells (NIGP141738-141741).

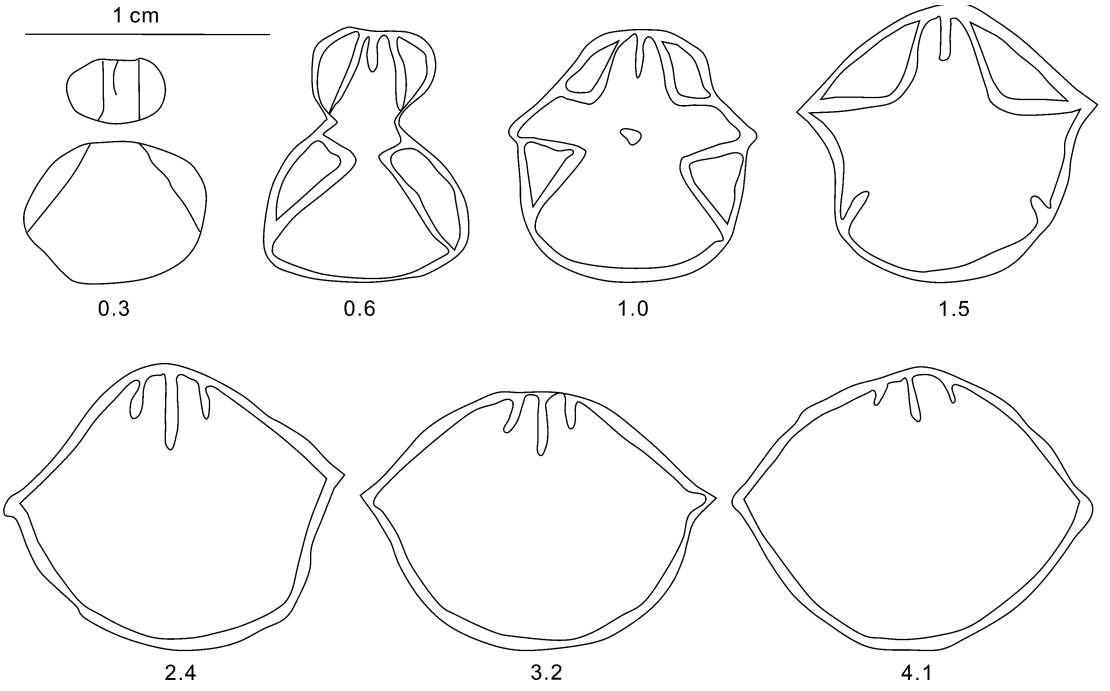
*Description*.—Medium in size for genus, unequally and gently biconvex, transversely elliptical in outline, greatest width at shell midlength ; lateral sides evenly rounded, anterior margin slightly emarginate ; hinge exceedingly short, less than half of shell width ; surface finely costellate and plicate, plication very weak, only developed near margins, producing wavy anterior commissure.

Ventral valve slightly smaller and less convex than dorsal valve ; beak thick, short and suberect ; interarea low and broadly triangular, maximum convexity at umbo, umbonal slopes moderately steep, lateral slopes gently and evenly inclined ; sulcus wide and shallow, widening and slightly deepening anteriorly ; dorsal valve slightly more convex than ventral valve, moderately convex in lateral and anterior profile, maximum convexity at umbonal region, beak thick and strongly incurved, umbonal slopes strongly inclined, flanks evenly and gently inclined, fold absent.

Ventral interior with thin and parallel dental plates ; median septum slightly longer than dental plates, attaining about one-third of shell length ; dorsal interior with divergent fulcral plates (Text-Figure 9).

*Measurements (in mm).*—

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141738 | 12.7 | 15.1 | 8.4 | 6.5 |
| NIGP141739 | 8.2 | 9.0 | 6.2 | 4.5 |
| NIGP141740 | 10.2 | 10.9 | 6.5 | 5.7 |
| NIGP141741 | 13.0 | 16.5 | 11.1 | — |




**Text-Figure 9.** Serial sections of *Enteletes retardata* Huang (NIGP141741).

*Discussion*.—This species bears some resemblance to *Enteletes kayseri* Waagen, 1884 in view of its convexity and size, but can be readily distinguishable by its less developed plication and sulcus on the ventral valve. Liao and Meng (1986, pl. 1, figs. 3–9) figured several specimens as *E. hemiplicata* (Hall and Clarke, 1892). However, their specimens shown in figures 3–7 of plate 1 are characterized by a weak sulcus, weaker plication and waved commissure, all being diagnostic features of the present species.

*Occurrence*.—Jb–4, 5.

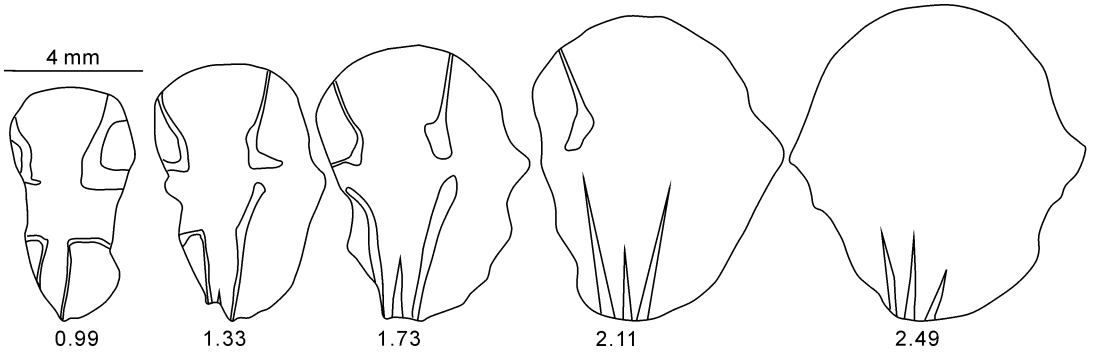
### *Enteletes* sp.

Plate 17, Figures 5–12 ; Text-Figure 10

*Material examined*.—Two complete conjoined shells (NIGP141742, 141743).

*Description*.—Small for genus, strongly and subequally biconvex, transversely roundly triangular in outline, greatest width slightly anterior to shell midlength ; hinge narrow ; lateral sides unevenly rounded, posterolateral sides more gently rounded, anterior margin broadly rounded ; surface finely costellate and plicate, plicae originating anterior to umbonal region, crests rounded, intertroughs slightly wider than plicae ; anterior commissure serrate.

Ventral valve slightly smaller than dorsal valve, strongly convex in lateral profile and strongly domed in anterior profile, greatest convexity at umbonal region ; beak thick, strongly incurved ; umbonal slopes sharply steep, lateral slopes moderately inclined ; sulcus narrow and shallow, only slightly wider than intertroughs between plica, originating from midvalve, not widening or deepening anteriorly, each flanks bearing 3–4 plicae ; dorsal valve slightly more strongly convex than ventral valve ; beak thick, strongly swollen,




**Text-Figure 10.** Serial sections of *Enteletes* sp. (NIGP141743).

umbonal region steep; flanks moderately inclined, fold inconspicuous, as wide as plicae, each flank having 3–4 plicae.

Ventral interior with subparallel dental plates and thin low median septum; dorsal interior with widely divergent fulcral plates (Text-Figure 10).

*Measurements (in mm).*—

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141742 | 7.4 | 10.1 | 6.8 | 5.0 |
| NIGP141743 | 9.2 | 10.0 | 8.6 | 5.3 |

*Discussion*.—The present species probably represents a new species in terms of its small size, earlier fine plication. However, only two specimens are available. It resembles *Enteletes meridionalis* Gemmellaro (1899, p. 279, pl. 28, figs. 10–12; pl. 29, figs. 1–5) from the Permian of Sicily and the specimens reported from Shanxi Province of China by Frech (1911, p. 121, pl. 27, figs. 4a–5b), but differs by its much smaller size, rounded plications, and a more swollen umbonal region.

*Occurrence*.—Jb–4.

### Genus *Peltichia* Jin and Liao in Jin and Sun, 1981

*Peltichia* Jin and Liao in Jin and Sun, 1981, p. 129
*Peltichia* Jin and Liao; Liang, 1990, p. 366.
*Peltichia* Jin and Liao; Xu and Grant, 1994, p. 20.
*Peltichia* Jin and Liao; Shen *et al.*, 1999, p. 49.

*Type species*.—*Parenteletes sinensis* mut. *zigzag* Huang 1933, p. 13, pl. 2, figs. 7a–e from the Lungtan Formation, Guizhou, South China.

*Discussion*.—Peltichia has now been recognized as a characteristic genus in the Lopingian (Upper Permian) of South China (Shen *et al.*, 1999). The closest genus is *Enteletina* Schuchert and Cooper (1931), a genus characterized as being "Externally like *Parenteletes* but internally like *Enteletes.*" In both of these genera, plications are obsolete or prominent. The distinctive difference between *Peltichia* and *Enteletina* may be in the dorsal valve, as *Peltichia* usually has an elevated muscle platform, which is absent in *Enteletina.* In addition, *Peltichia* is also closely similar to *Parenteletes* King in external details, but *Parenteletes* King, 1931 possesses a ∧-shaped camera under the dorsal median septum. Specimens from the Lopingian in South China were described in detail by Shen *et al.* (1999), therefore herein not repeated. Only those from the Talung Formation at the Dapaichong section in Chenxian, Hunan Province and the Lungtan Formation at the Tuanxi Section in Zunyi, Guizhou Province were not described before and provided herein.

*Occurrence*.—Late Permian; South China, Transcaucasus, Pamir, Thailand, and Vietnam.

### *Peltichia transversus* (Huang, 1933)

Plate 17, Figures 13–30

*Parenteletes sinensis* mut. *transversus Huang, 1*933, p. 14, pl. 2, figs. 8–10
*Enteletina sinensis* mut. *transversus* Huang; Wang *et al.*, 1964, p. 152, pl. 20, fig. 7.
*Enteletina sinensis* Huang; Jin and Ye, 1979, p. 74, pl. 36, figs. 31–34.
*Enteletina transversus* Huang; Liao, 1980a, p. 253, pl. 1, figs. 49–52.
*Peltichia planisinosa* Liang, 1990, p. 367, pl. 5, figs. 17–19.
*Peltichia* sp. 1, Liang, 1990, p. 368, pl. 5, figs. 20–21.
*Peltichia transversa* Huang; Shen and He, 1994a, pl. 1, figs. 29–32.
*Peltichia transversus* Huang; Xu and Grant, 1994, figs. 17–19, 21, 22 and 24.
*Peltichia schizoloides* Xu and Grant, 1994, p. 21, figs. 9, 1–10.
*Peltichia transversus* Huang; Shen *et al.*, 1999, p. 58, figs. 6. 8, 8.8–8.12, 10.11–10.25, 10.30.

*Material examined*.—21 internal moulds of conjoined shells and four internal moulds of dorsal valve. Registered specimens: Four internal moulds of conjoined shell (NIG P141744–141747) and two internal moulds of dorsal valves (NIGP141748, 141749).

*Description*.—Medium in size for genus, moderately and unequally biconvex, greatest width at shell midlength, transversely elliptical in outline; hinge about half of width; lateral sides evenly rounded, anterior margin broadly rounded; anterior commissure waved, lateral commissure nearly straight.

Ventral valve smaller than dorsal valve, gently convex in lateral and anterior profile; beak blunt and suberect; interarea low, broadly triangular; umbonal region moderately swollen, umbonal slopes steep, lateral slopes gently inclined, weak and low fold originating anterior to umbonal region, wide and rounded, gradually widening anteriorly and bordered on either side by a shallow depression, resulting in somewhat serrated anterior commissure; dorsal valve larger and much more strongly convex than ventral valve, evenly and regularly convex in lateral profile and strongly domed in anterior profile; beak thick, strongly incurved over interarea; umbonal region strongly swollen, umbonal slopes sharply steep and lateral slopes strongly inclined; sulcus beginning at umbonal region, shallow and slightly widening anteriorly; plication absent.

Ventral interior with thin and high, subparallel but slightly inwardly convergent dental plates, extending anteriorly about half of shell length; medium septum high, commencing from apex of beak, extending forward as long as dental plates; dorsal interior deeply concave, brachiophores very strong, tusk-shaped, ventrally curved, anteriorly divergent, supporting plates short, divergent, meeting valve wall and extending for short distance, anterior callus between these two plates united as an elevated platform (psendocruralium of Xu and Grant, 1994) and correspondent muscle-scar track at umbonal region, a low and short median ridge commonly well-developed anterior to pseudocruralium.

*Measurements (in mm).*—

| Specimen no. | L | W | T | HW |
|---|---|---|---|---|
| NIGP141744 | 31.0 | 36.0 | 25.2 | 18.1 |
| NIGP141745 | 31.0 | 32.4 | 22.1 | 16.5 |

| | | | | |
|---|---|---|---|---|
| NIGP141746 | 22.5 | 27.0 | 16.3 | 14.9 |
| NIGP141747 | 16.4 | 18.1 | 11.0 | 8.9 |
| NIGP141748 | >27.6 | >27.6 | — | — |
| NIGP141749 | 32.3 | >31.6 | — | — |

*Discussion*.—This species differs from *Peltichia zigzag* (Huang, 1933) by its transverse outline and non-zigzag anterior commissure. It differs from *Peltichia sinensis* (Huang, 1933) by its transverse outline.

*Occurrence*.—A-26 ; B-19, 21, 22, 24, 25 ; E-42, 43, 46 ; G-52, 54, 55 ; H-130 ; Jc-10, 15.

**Order RHYNCHONELLIDA Moore, 1952**
**Superfamily WELLERELLOIDEA Licharew, 1956**
**Family WELLERELLIDAE Licharew 1956**
**Subfamily UNCINUNELLININAE Savage, 1996**
**Genus *Uncinunellina* Grabau, 1931**

*Type species*.—*Uncinulus theobaldi* Waagen, 1883, p. 425, pl. 34, Figures 1a-c from the Wuchiapingian Kalabagh Member, Wargal Formation in the Salt Range, Pakistan.

***Uncinunellina timorensis* (Beyrich, 1864)**

Plate 17, Figures 31-42 ; Text-Figure 11

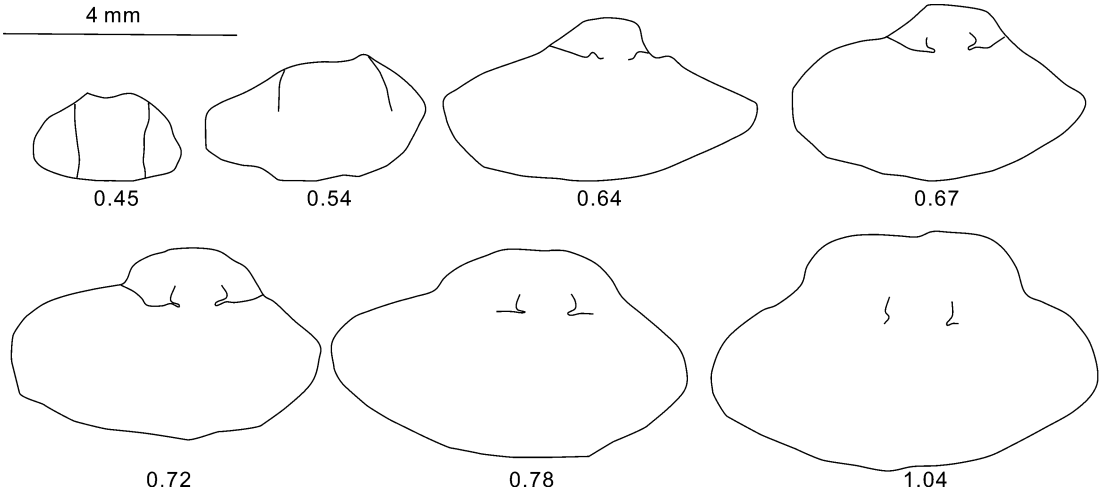
*Rhynchonella timorensis* Beyrich, 1864, p. 72, pl. 1, fig. 10.
*Uncinulus theobaldi* Waagen, 1883, p. 425, pl. 34, fig. 1.
*Rhynchonella timorensis* Beyrich ; Rothpletz, 1892, p. 87, pl. 10, fig. 6.
*Uncinulus timorensis* Beyrich ; Diener, 1897, p. 69, pl. 10, figs. 7-10.
*Rhynchonella (Uncinulus) timorensis* Beyrich ; Frech, 1911, p. 171.
*Uncinunellina theobaldi* Waagen ; Grabau, 1931, p. 72.
*Uncinunellina timorensis* Beyrich ; Huang, 1933, p. 61, pl. 10, figs. 30, 32.
*Uncinunellina timorensis* Beyrich ; Zhang and Jin, 1961, p. 404, pl. 1, figs. 9-16.
*Uncinunellina timorensis* Beyrich ; Wang *et al.*, 1964, p. 394, pl. 66, figs. 9-10.
*Uncinunellina theobaldi* Waagen ; Grant, 1976, p. 178, pl. 48, figs. 1-9.
*Uncinunellina theobaldi* Waagen ; Yang *et al.*, 1977, p. 378, pl. 150, fig. 5.
*Uncinunellina timorensis* Beyrich ; Tong, 1978, p. 240, pl. 85, fig. 5.
*Uncinunellina timorensis* Beyrich ; Zhan in Hou *et al.*, 1979, p. 95, pl. 10, fig. 4.
*Uncinunellina timorensis* Beyrich ; Wang *et al.*, 1982, p. 233, pl. 84, fig. 3 ; pl. 93, fig. 5.
*Uncinunellina timorensis* Beyrich ; Liu *et al.*, 1982, p. 192, pl. 138, figs. 11a-d.
*Uncinunellina timorensis* Beyrich ; Yang, 1984, p. 227, pl. 36, fig. 6.

*Material examined*.—23 complete conjoined shells. Three conjoined shells are registered (NIGP141750-141752).

*Description*.—Medium in size for genus, outline transversely elliptical, profile moderately strongly biconvex, dorsal valve much more strongly convex than ventral valve ; both valves geniculated near margins, lateral sides rounded, anterior margin slightly emarginate ; umbonal region slightly flattened, smooth ; costae beginning at or slightly anterior to shell midlength, low and rounded, with narrow intertroughs, crests flattened anteriorly, each crest bearing thin groove anterior to geniculation, intertroughs extended at margins, forming comb-like spines with opposite valve, anterior commissure uniplicate.

Ventral valve nearly flat in longitudinal profile ; beak short, straight ; interarea absent ; sulcus fairly wide and shallow, beginning at about midvalve, then flattened and broadly depressed anteriorly, geniculated near margins, forming a wide anterior tongue, 8-10 costae in sulcus and 12-14 costae on each flank ; dorsal beak not developed ; umbonal region smooth, slightly swollen, rapidly elevated anteriorly ; two flanks geniculated near margins ; fold slightly higher than flank, with 7-9 costae, each flank with about 13 costae.

Ventral interior with small teeth ; dental plates short, vertical to valve floor ; dorsal interior with divided hinge plates




**Text-Figure 11.** Serial sections of *Uncinunellina timorensis* Beyrich (NIGP141752).

narrowing anteriorly to form laterally twisted and ventrally curved crura; median septum absent (Text-Figure 11).

*Measurements (in mm)*.—

| Specimen no. | L | W | T |
|---|---|---|---|
| NIGP141750 | 7.1 | 10.0 | 6.6 |
| NIGP141751 | 9.4 | 12.6 | 9.1 |
| NIGP141752 | 8.1 | 11.0 | 6.3 |

*Discussion*.—*Uncinunellina timorensis* was first described by Beyrich (1864) as a species of *Rhynchonella* from the Carboniferous of Timor. In defining *Uncinulus theobaldi* from the Salt Range, Waagen (1883, p. 425) noted that the Salt Range species was different from *Uncinunellina timorensis* only in having a smooth umbonal region. However, these two species were considered conspecific by Diener (1897, 1903).

Grabau (1931) proposed *Uncinunellina* with *U. theobaldi* as the type species but did not discuss the relationship between the type species and *U. timorensis* (Beyrich). According to our specimens, *U. timorensis* has a relatively wide variety of external characters. The differences noted by Waagen (1883) were not sufficient to separate the two species in question. In fact, two distinct types of costation have been reported from and incorrectly ascribed to *U. timorensis*: one being characterized by a smooth umbonal region and simple costae as in the type material of *U. timorensis*, the other distinguished by bifurcating costae originating from beak, which is typical of *U. wangenheimi* (Pander), a species now assigned to *Anchorhynchia* Jin and Ye, 1979.

*Uncinulus mongolicus* Grabau (1931, pl. 5, figs. 7–8) is very similar to the present species and should belong to *Uncinunellina*, but it may differ from the latter in its less transverse outline and weak sulcus and fold. *U. mitigata* figured by Grant (1976, p. 179) from the Rat Buri Limestone of Thailand are also closely comparable to the present species, but it has a nearly equidimensional outline in youthful stages and a higher fold.

*Occurrence*.—B–18, 19, 21, 22; D–1; E–42, 46, 50; F–16, G–45, 55, 56; Jb–3, 4, 5, 6; Jc–10, 14, 15, 16.

### *Uncinunellina jabiensis* (Waagen, 1883)

Plate 18, Figures 1–12; Text-Figure 12

*Uncinulus jabiensis* Waagen, 1883, p. 427, pl. 34, figs. 2a–d.
*Uncinulus jabiensis* Waagen; Diener, 1903, p. 32, pl. 2, fig. 5.
*Uncinunellina jabiensis* (Waagen); Wang *et al.*, 1964, p. 392, pl. 66, figs. 1–4.
*Uncinunellina jabiensis* (Waagen); Jin and Ye, 1979, p. 100, pl. 30, figs. 18–20.
*Uncinunellina jabiensis* (Waagen); Liao, 1980a, pl. 7, figs. 1–5.

*Material examined*.—Three complete conjoined shells (NIGP141753–141755).

*Description*.—Slightly smaller than average size, moderately biconvex, subpentagonal in outline, dorsal valve slightly more convex than ventral valve; posterolateral sides almost straight to slightly concave, anterolateral sides rounded, anterior margin straight or broadly rounded; both valves geniculated near margins; umbonal region slightly convex, smooth; costae beginning at shell midlength or slightly earlier, simple, not bifurcating, crests low and rounded, flattened anteriorly, each crest bearing a fine groove near margin; anterior commissure uniplicate.

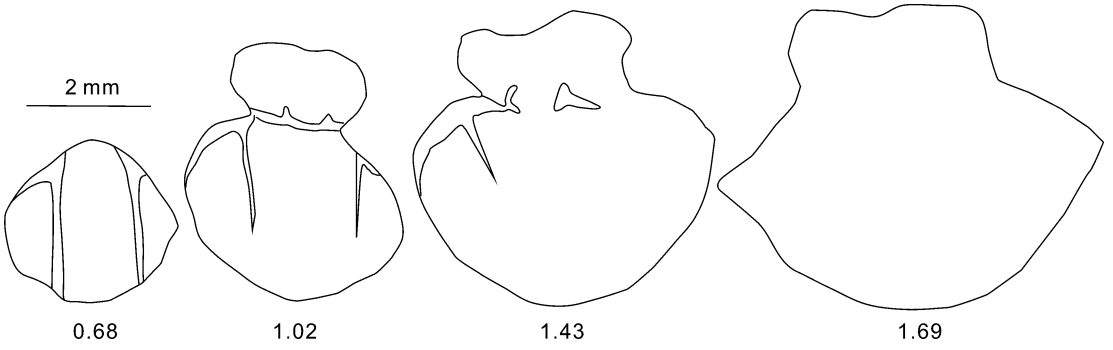
Ventral valve flatly convex in lateral profile; beak sharp, slightly attenuated; umbonal region gently inflated; flank gently inclined; sulcus beginning at midvalve, deepening and widening anteriorly, anterior ends rapidly bending toward dorsal valve, forming wide front tongue; costae numbering 4–6 in sulcus, each flank with 6–8 costae; dorsal valve unevenly convex in lateral profile, maximum convexity at anterior region, slightly flattened along midlength in anterior profile; fold low, only developed on anterior region, bearing 6–7 costae; flank strongly inclined, with 6–8 costae.

Ventral interior with two short dental plates reaching valve floor, fused to valve walls toward the beak, extending about 2–3 mm at a slightly divergent angle (Text-Figure 12).

*Measurements (in mm)*.—

| Specimen no. | L | W | T |
|---|---|---|---|
| NIGP141753 | 9.0 | 9.8 | 7.1 |
| NIGP141754 | 7.9 | 9.0 | 6.0 |
| NIGP141755 | 9.5 | 10.5 | 7.0 |

*Discussion*.—*U. jabiensis* is characterized by its subpentagonal outline, small convexity and short and relatively few costae on both valves. Our specimens basically agree with the type from the Salt Range in most external features, but differ in that the costae occur a little earlier.




**Text-Figure 12.** Serial sections of *Uncinunellina jabiensis* (Waagen) (NIGP141753).

This species is also closely similar to the specimens figured as *U. mongolicus* Grabau from the Permian in Inner Mongolia. However, the costae of Grabau's species clearly originate from beak, which suggests that it is attributable to *Anchorhynchia*. *U. jabiensis* somewhat resembles *U. timorensis* (Beyrich) in costation, but differs in its subpentagonal outline and small convexity.

*Occurrence*.—B-24; Jb-4; Jc-15.

### *Uncinunellina exilis* new species

Plate 18, Figures 13-24

*Holotype*.—NIGP141756 from B-22 (Plate 18, Figures 21-24).

*Other material examined*.—Two complete conjoined shells (NIGP141757, 141758).

*Diagnosis*.—*Uncinunellina* with very thin cavity and subelliptical outline.

*Description*.—Small to medium in size for genus, both valves very thin in lateral profile, outline slightly subtriangular in juveniles to transversely elliptical in adults, immatures commonly not geniculated, only slightly inclined near margins, adult specimens geniculated near margins; lateral sides rounded, anterior margin nearly straight or slightly emarginate; both valves with smooth umbonal region; costae beginning just anterior to umbonal region, low and rounded, with narrow intertroughs, crests flattened toward margins, bearing groove near margins, producing interlocking spine system with opposite valve.

Ventral valve nearly flat in lateral profile; beak acute and erect, umbonal angle more than 120 degree; sulcus only flattened on anterior region in immatures, but slightly geniculated dorsally in adults; flanks nearly flat; sulcus bearing 7 costae; each flank with 10-12 costae; dorsal valve also gently convex in lateral and anterior profile; umbonal region flattened, but slightly elevated near margins, forming a low fold; fold with 8 costae, each flank with more than 10 costae.

Ventral interior with dental plates; dorsal interior with divided hinge plates.

*Measurements (in mm)*.—

| Specimen no. | L | W | T |
|---|---|---|---|
| NIGP141756 | 6.6 | 7.1 | 2.9 |
| NIGP141757 | 9.1 | 11.6 | 4.8 |
| NIGP141758 | 5.7 | 7.9 | 2.8 |

*Discussion*.—Many specimens from South China have been assigned to *Uncinunellina* despite uncertainty of their internal details. Our specimens are identified with this genus by its costation and internal features. The new species is characterized by its very small convexity and subelliptical outline. The closest species is *U. jabiensis* (Waagen, 1883). Both have similar outline and profile. However, *U. jabiensis* has a subpentagonal outline and much stronger convexity. *U. plana* described by Tong *et al.* (1990) from the Carboniferous of Sichuan Province is also a very thin form rather like the present species in view of thin cavity and transversely elliptical outline, but the costae of the former are restricted in sulcus and on fold.

*Occurrence*.—A-26; B-22, 24.

## Genus *Anchorhynchia* Jin and Ye, 1979

*Anchorhynchia* Jin and Ye, 1979, p. 101.
*Anchorhynchia* Jin and Ye; Shen and He, 1994a, p. 448.
*Anchorhynchia* Jin and Ye; Savage in Williams *et al.*, 2002, p. 1372.

*Type species*.—*Anchorhynchia medoensis* Jin and Ye, 1979, p. 101, pl. 30, figs. 29-32, fig. 43 from the Middle Permian in Maduo, Qinghai Province, Northwest China.

*Diagnosis*.—Shape like *Uncinunellina*, but with bifurcating and fasicular costae on shell, costae commencing from beak, intertroughs extending laterally to interlock across anterior and anterolateral margins and forming spines with 5-7 lateral spurs, outline subpentagonal to transversely elliptical; sulcus and fold beginning from about midvalve; beak sharp; ventral interior with short dental plates fused to valve walls; dorsal interior with wide, flat and divided hinge plates, no cardinal process or median septum, crura curved ventrally.

*Discussion*.—*Uncinunellina* Grabau (1932) was established with *Uncinunellina theobaldi* (Waagen) as the type species. Grabau (1932, p. 76) characterized the genus as "Shell resembling *Uncinulus* in front view but of a more subtriangular outline, with the dorsal valve much more convex than the ventral valve, the greatest convexity being near the front, the fold and sinus are developed only near the front, where they are angular as in *Uncinulus* and the plications, which may become obsolete in the earlier part of the shell, are moderately fine and numerous and marked near the front by a median groove." Unfortunately, Grabau (1932) did not illustrate the internal details of the type species.

Grant (1976, p. 178) studied in detail the internal structures of *Uncinunellina* based on the silicified specimens from the Salt Range and Thailand. The wide and flat hinge plates and the absence of a median septum within the dorsal valve were believed to be sufficient to separate the genus from *Uncinulus*. In spite of this clarification, there still had been varied opinions on the costation pattern of *Uncinunellina*. For instance, Jin and Ye (1979) thought that species with bifurcating costae that originate from beak could be separated as another genus, which they named *Anchorhynchia* Jin and Ye. This genus is in contrast with *Uncinunellina*, which, according to the discussions and illustrations provided by Waagen (1883), Grabau (1932) and Grant (1976), is characterized by its smooth umbonal region, semicostate valves and simple costae on both valves. The costation of this genus has a wide variety based on our specimens from South China. All species of this genus have bifurcating costae which originate from beak, but some of them have fasicular costae on both valves.

Savage in Williams *et al.* (2002) regarded *Anchorhynchia* Jin and Ye as a *nomina dubium* which is a scientific name that is of unknown or doubtful application based on zoological nomenclature. However, *Anchorhynchia* was very well defined by Jin and Ye (1979, p. 101, fig. 43) both internally and

externally. *Nipponirhynchia* Yanagida and Nishikawa (1984) with *N. shutoi* from the Sakmarian Kawai Limestone in Hiroshima, Japan as the type species is externally close to the present genus, but differs by its median septum supporting a camarophorium in dorsal valve.

*Occurrence*.—Lopingian ; South China.

### *Anchorhynchia grandis* Shen and He, 1994a

Plate 18, Figures 25–42 ; Plate 19, Figures 1–2

*Anchorhynchia grandis* Shen and He, 1994a, p. 448, pl. 2, figs. 25–30.

*Holotype*.—NIGP141759 (=CUMT8183), a conjoined shell from G–45 (Plate 18, Figures 25–28).

*Other material examined*.—77 specimens. Registered specimens : Eight complete conjoined shells (NIG P141760–141767).

*Description*.—Large in size for genus, outline strongly transversely elliptical, profile strongly unequally biconvex, with dorsal valve much more strongly inflated than ventral valve ; both valves geniculated near margins ; surface costate, costae beginning at beak, increasing by bifurcation and intercalation, intertroughs narrow, bottom angular, costae before geniculation with subangular crests, but flattened toward margins, each crests bearing slight groove anterior to geniculation, intertroughs extended at margins to form interlocking spine system with opposite valve, each spine with about ten lateral spurs ; anterior commissure strongly uniplicate.

Ventral valve nearly flat longitudinally, slightly convex in posterior profile ; beak broad, low and suberect ; two flanks nearly flat ; sulcus originating just anterior to umbonal region, gradually widening and deepening anteriorly and suddenly geniculated dorsally near margin, forming a very wide and high front tongue, costae 11 within sulcus, 1–2 on each sulcus slope, each flank having about 20 costae ; dorsal valve much more inflated in lateral profile than ventral valve and strongly domed in anterior profile ; flank and umbonal region strongly inclined posteriorly ; fold originating from umbonal region, highly elevated near margins, costae numbering 13 on fold and more than 20 on each flank.

Ventral interior with small teeth ; dental ridges very short ; dental plates short, fused to valve walls toward beak ; muscle scar extending nearly to midvalve ; dorsal interior with deep sockets ; hinge plates wide, formed by 2 separated plates with deep median division, broad platforms of hinge plates narrowing anteriorly to form lateral twisted and ventrally curved crura ; crura thin and short ; adductor scars inconspicuous, extending to about midvalve ; cardinal process and median septum completely absent.

*Measurements (in mm)*.—(CIS=costae in sulcus)

| Specimen no. | L | W | T | CIS |
|---|---|---|---|---|
| NIGP141759 | 20.3 | 29.3 | 19.9 | 11 |
| NIGP141760 | 16.4 | 26.3 | 14.6 | — |
| NIGP141761 | 19.0 | 28.2 | 17.2 | 12 |
| NIGP141762 | 19.5 | 26.2 | 18.7 | 11 |
| NIGP141763 | 17.5 | 23.0 | 13.5 | 11 |
| NIGP141764 | 16.5 | 24.8 | 7.9 | 11 |
| NIGP141765 | 18.5 | 28.7 | 19.7 | 12 |
| NIGP141766 | 16.9 | 26.4 | 19.7 | 12 |

*Discussion*.—This species was briefly described in Chinese by Shen and He (1994a). It is characterized by its large size and more costae, which can distinguish it from any other species in the genus.

*Occurrence*.—G–45.

### *Anchorhynchia sarcinifromis* Shen, He and Zhu, 1992

Plate 19, Figures 3–22 ; Text-Figure 13

*Uncinunellina timorensis* (Beyrich) ; Huang, 1933, p. 61, pl. 10, figs. 31, 33–36 ; pl. 9, figs. 12–13.
*Uncinunellina timorensis* (Beyrich) ; Yang *et al.*, 1977, p. 378, pl. 150, fig. 2.
*Uncinunellina timorensis* (Beyrich) ; Feng and Jiang, 1978, p. 271, pl. 101, figs. 1–2.
*Uncinunellina timorensis* (Beyrich) ; Zhan in Hou *et al.*, 1979, p. 95, pl. 8, fig. 9.
*Uncinunellina timorensis* (Beyrich) ; Liao, 1980a, pl. 7, figs. 6–7.
*Uncinunellina timorensis* (Beyrich) ; Liao and Meng, 1986, pl. 4, fig. 27.
*Uncinunellina timorensis* (Beyrich) ; Yang *et al.*, 1987, p. 230, pl. 14, figs. 7–9 ; pl. 15, figs. 1–3.
*Uncinunellina timorensis* (Beyrich) ; Liang, 1990, p. 246, pl. 79, figs. 26–27.
*Uncinunellina timorensis* (Beyrich) ; Zhu, 1990, p. 80, pl. 16, figs. 29–30.
*Anchorhynchia sarcinifromis* Shen *et al.*, 1992, p. 181, pl. 3, figs. 30–33.
*Uncinunellina multicostifera* Xu and Grant, 1994, p. 35, figs. 21–22 (1–27).
*Uncinunellina multicostata* Zeng *et al.*, 1995, pl. 12, figs. 13–14.

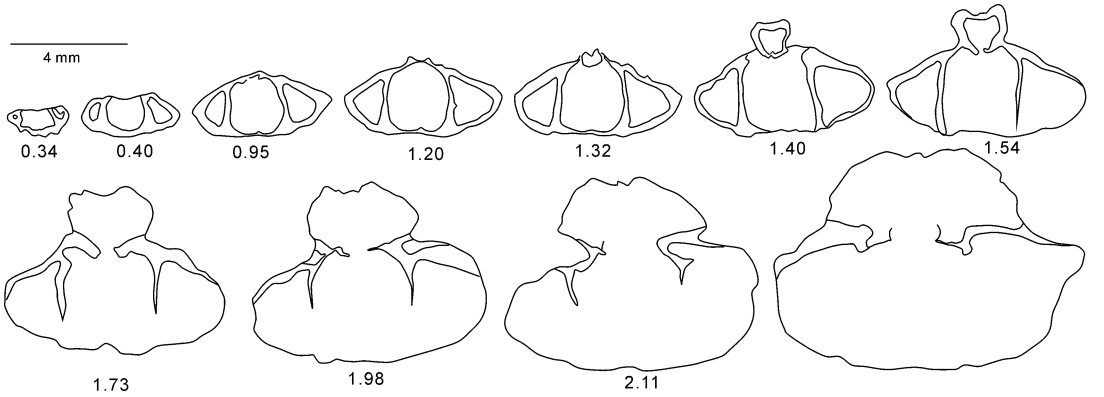
*Holotype*.—NIGP141768 (=CUMT8618), Plate 19, Figure 15–18.

*Material examined*.—Numerous complete conjoined shells. Registered specimens : Eight conjoined shells (NIG P141769–141776).

*Description*.—Average size for genus, unequally biconvex, transversely elliptical in outline ; dorsal valve much more strongly convex than ventral valve ; both valves geniculated near margins ; surface costate, costae beginning at beak, fasicular on umbonal region, increasing by bifurcation ; intertroughs narrower than costae, crests rounded posterior to geniculation, but flattened toward margins, each crests bearing slight groove anterior to geniculation, intertroughs extended at margins to form interlocking spines with lateral spurs ; anterior commissure uniplicate.

Ventral valve nearly flatly convex in lateral and anterior profile ; beak pointed, suberect ; sulcus flat and shallow, beginning at midvalve, but rapidly geniculated dorsally near margin ; costae numbering 6–10 within sulcus and 14–18 on each flank ; dorsal fold slightly higher than lateral region, costae numbering 8–10 on fold, each fold with 14–18 costae.

Ventral interior with two short dental plates fused to valve walls toward beak ; dorsal interior with divided hinge plates,




**Text-Figure 13.** Serial sections of *Anchorhynchia sarciniformis* Shen, He and Zhu (NIGP141775).

cardinal process and median septum absent (Text-Figure 13).

*Measurements (in mm).*—

| Specimen no. | L | W | T | CIS |
|---|---|---|---|---|
| NIGP141768 | 9.5 | 12.8 | 8.8 | 7 |
| NIGP141769 | 10.6 | 13.7 | 9.0 | 8 |
| NIGP141770 | 13.0 | 17.7 | 9.7 | 9 |
| NIGP141771 | 12.0 | 15.7 | 12.0 | 8 |
| NIGP141772 | 10.2 | 13.6 | 8.3 | 10 |
| NIGP141773 | 10.5 | 15.0 | 10.6 | 8 |
| NIGP141774 | 9.8 | 15.4 | 10.6 | 8 |
| NIGP141775 | 10.1 | 15.8 | 11.2 | 9 |
| NIGP141776 | 9.6 | 12.6 | 6.5 | 9 |

*Discussion*.—Specimens from many localities of South China have been assigned to the species of *Uncinunellina* since Huang (1933) first figured several specimens under the name of *U. timorensis* (Beyrich). However, detailed comparisons indicate that Huang's specimens are quite different from the type material described by Beyrich (1864, p. 72, pl. 1, fig. 10) in that the latter has a smooth umbonal region, whereas the former is costate to beak. Therefore, Shen *et al.* (1992) re-assigned them to the present species.

Broili (1916, pls.12 and 13) also illustrated several specimens from Timor under the name of *Uncinulus timorensis* (Beyrich) and *U. jabiensis* (Waagen). These were also assigned to *Uncinunellina* by Huang (1933, p. 62), but only one specimen (Broili, 1916, pl. 13, fig. 1) is comparable to some species of *Uncinunellina.* The others should be ascribed to *Anchorhynchia* because of their costae beginning from the beak. Grabau (1936) also described two specimens as *Uncinunellina wangenheimi* (Pander). However, the figures of these specimens clearly show costae originating from the beak, strongly suggesting *Anchorhynchia.* Based on several specimens from South China, Xu and Grant (1994) proposed a new species named *U. multicostifera* Xu and Grant, which is identical with *A. sarciniformis* Shen *et al.* (1992).

*Occurrence*.—A-20, 26, 28; B-19, 21, 22, 25; C-17; E-46; H-137, 139, 140; I-68; Jc-10, 15.

### *Anchorhynchia ignobilis* Shen, He and Zhu, 1992

Plate 19, Figures 23-34

*Anchorhynchia ignobilis* Shen *et al.*, 1992, p. 182, pl. 3, figs. 26-29.

*Holotype*.—NIGP141777 (=CUMT8615), Plate 19, Figures 24-26.

*Other material examined*.—Two complete conjoined shells (NIGP141778, 141779).

*Description*.—Slightly larger than average size, unequally biconvex, transversely elliptical in outline, width much greater than length, greatest width at shell midlength; lateral sides regularly rounded, anterior margin nearly straight; both valves geniculated near margin; surface costate, costae originating from beak, initially numbering 10 over umbo, then bifurcating at about 2-3 mm from beak, secondary costae usually divided once more at about 5-7 mm from beak, crests rounded posterior to geniculation, gradually flattened toward margins, each side bearing a thin groove anterior to geniculation; intertroughs extended to margins forming interlocking spines.

Ventral valve flatly convex in lateral and anterior profile; beak low and acute, suberect; sulcus beginning from midvalve, bottom flat, with about 9 costae, flank gently inclined, each with about 12 costae; dorsal valve much more strongly convex than ventral valve, lateral and umbonal region inclined posteriorly; fold beginning from midvalve, slightly higher than flank; 9 costae on fold, each flank with about 12 costae.

Ventral interior with dental plates, fused to valve walls toward beak; dorsal interior with divided hinge plates.

*Measurements (in mm).*—

| Specimen no. | L | W | T | CIS |
|---|---|---|---|---|
| NIGP141777 | 12.6 | 19.1 | 12.3 | 9 |
| NIGP141778 | 13.2 | 22.2 | 14.8 | 9 |
| NIGP141779 | 14.5 | 23.3 | 15.2 | 8 |

*Discussion*.—This species was first found from the Changhsing Formation at the Beifengjing section and briefly described by Shen *et al.* (1992) in Chinese. The present species is represented by three specimens from different localities. This species is characterized by regularly bifurcating costae. It is between *Anchorhynchia sarciniformis* and *A. grandis* in view of size.

*Occurrence*.—A–26; B–22, 24.

### *Anchorhynchia subpentagona* Shen, He and Zhu, 1992

Plate 20, Figures 1–8; Text–Figure 14

*Anchorhynchia subpentagona* Shen *et al.*, 1992, p. 182, pl. 3, figs. 34–37.

*Holotype*.—NIGP141780 (=CUMT8628) from A–20 (Plate 20, Figures 1–4).

*Other material examined*.—Nine complete conjoined shells. Registered specimens: one conjoined shell (NIGP141781).

*Description*.—Slightly smaller than average size, gently biconvex in profile, subpentagonal in outline, greatest width at shell midlength, posterolateral sides nearly straight, converging at about 120 degree, anterolateral sides regularly rounded, anterior margin nearly straight and gently geniculated; surface costate, costae originating from beak, numbering 8 at beak, increasing anteriorly by bifurcation and intercalation; intertroughs as wide as costae, bottom angular, crests subangular, flattened near margins, bearing a slight groove, anterior commissure uniplicate.

Ventral valve gently convex in lateral profile and flatly convex in anterior profile; beak acute, suberect, constrained by a circular foramen; sulcus originating just anterior to umbonal region; costae numbering 9 in sulcus, each flank with about 10 costae; dorsal valve gently convex in lateral profile, maximum convexity at midvalve, lateral profile gently inclined, fold low, only developed near margins, with 10 costae.

Ventral interior with short dental plates, fused to valve walls toward beak; hinge plate divided (Text–Figure 14).

*Measurements (in mm)*.—

| Specimen no. | L | W | T | CIS |
|---|---|---|---|---|
| NIGP141780 | 10.0 | 11.0 | 5.9 | 9 |
| NIGP141781 | 9.3 | 11.5 | 6.0 | 9 |

*Discussion*.—The small size, gently biconvex profile, subpentagonal outline and very sharp distinct costation can separate it from any other species in the genus.

*Occurrence*.—A–20; B–19, 21, 22, 24, 25.

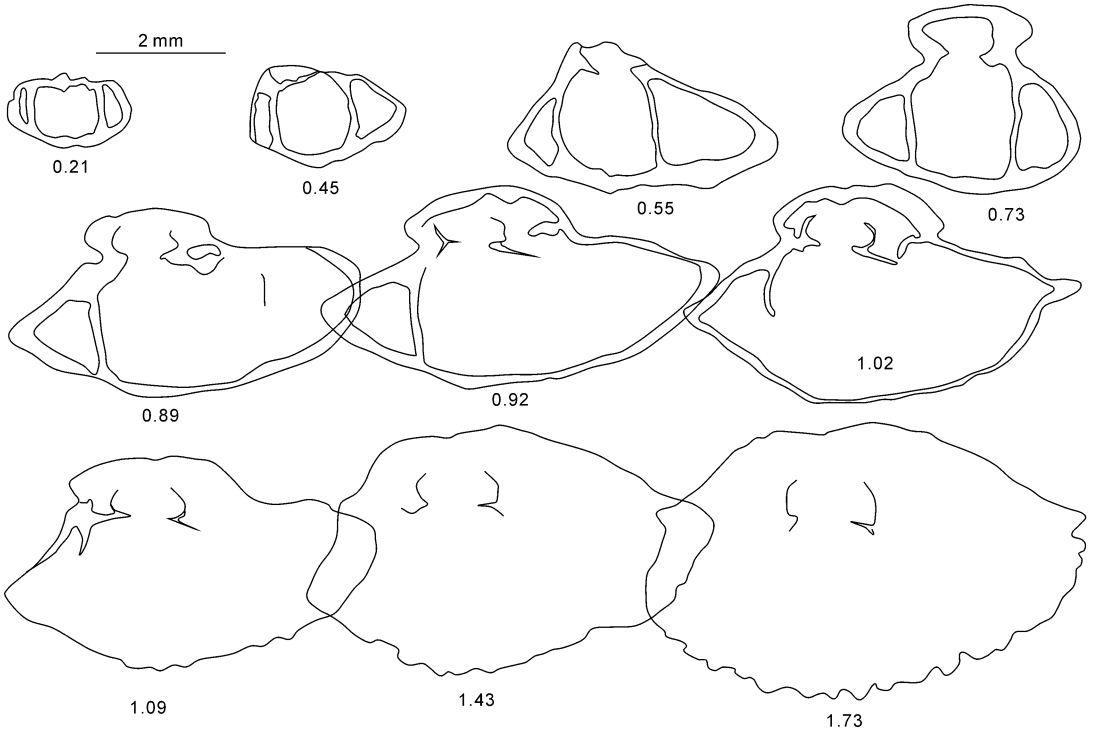
### Genus *Glyptorhynchia* Shen and He, 1994a

*Glyptorhynchia* Shen and He, 1994a, p. 448, 452.

*Glyptorhynchia* Shen and He, Savage in Williams *et al.* 2002, p. 1374.

*Type species*.—*Glyptorhynchia lens* Shen and He, 1994, p. 449, pl. 2, figs. 31–35 from the Changhsing Formation at Guiding, Guizhou, South China

*Diagnosis*.—Small, transversely elliptical in outline, much wider than long, greatest width at shell midlength; ventral valve nearly flat; sulcus originating from midlength, anterior region abruptly curved toward dorsal valve; dorsal valve more inflated than ventral valve; fold high; surface with simple costae; umbonal region generally smooth, costae without grooves, shell with 2 mm–wide stolidium around anterior and lateral commissure. Ventral interior with short dental plates reaching valve floor; dorsal interior with divided hinge plates; crura stick–shaped, extending straight




**Text–Figure 14.** Serial sections of *Anchorhynchia subpentagona* Shen, He and Zhu (NIGP141781).

toward anterior.

*Discussion*.—This genus was briefly described by Shen and He (1994a) in Chinese. It is closest, in internal details and most external features, to *Uncinunellina* Grabau, 1932 and *Anchorhynchia* Jin and Ye, 1979, but the latter two genera have a very strong convexity and a sulcus with distinct geniculated anterior tongue toward dorsal valve, grooves at the crests of costae and no *Stenoscisma*-type stolidium around anterior and lateral commissure. We consider that the stolidium reflects a different morphological function to bridge the gape between two valves from *Uncinunellina* and its relatives.

*Occurrence*.—Late Permian ; China, Pamir.

***Glyptorhynchia lens*** Shen and He, 1994a

Plate 20, Figures 9-31 ; Text-Figure 15

*Uncinunellina timorensis* (Beyrich) ; Grunt and Dmitriev, 1973, p. 113, pl. 8, figs. 16-18.
*Glyptorhynchia lens* Shen and He, 1994a, p. 449, pl. 2, figs. 31-35.

*Holotype*.—NIGP141782 (=CUMT8187), a conjoined shell from G-45 (Plate 20, Figures 9-12).

*Other material examined*.—22 complete conjoined shells. Registered specimens : 9 conjoined shells (NIGP141783=CUMT8188, NIGP141784-141791).

*Description*.—Medium in size, unequally biconvex, fairly transversely subelliptical in outline, greatest width at shell midlength ; shell with a 2 mm-wide stolidium around anterior and lateral commissure, stolidium commonly partly preserved, posterior sides straight, diverging at an than 150 degree, lateral sides regularly rounded and anterior margin emarginate except the marginal brim ; anterior commissure uniplicate ; surface costate, umbonal region smooth, costae beginning slightly anterior to midvalve, crests rounded ; intertroughs slightly narrower than costae.

Ventral valve nearly flat in lateral and anterior profile ; beak sharp, erect, slightly attenuated ; sulcus only developed near margins, rapidly geniculated toward dorsal valve, forming emarginate margins ; 5-7 costae in sulcus ; dorsal valve much strongly convex than ventral valve in lateral and anterior profile ; flanks steeply inclined ; fold originating from midvalve, slightly elevated, 6-7 costae on fold, each flank with 9-10 costae.

Ventral interior with fairly short dental plates about 1 mm long, fused to shell wall toward beak ; dorsal interior with divided hinge plates ; crura stick-shaped, extending anteriorly along length ; median septum completely absent (Text-Figure 15).

*Measurements (in mm)*.—

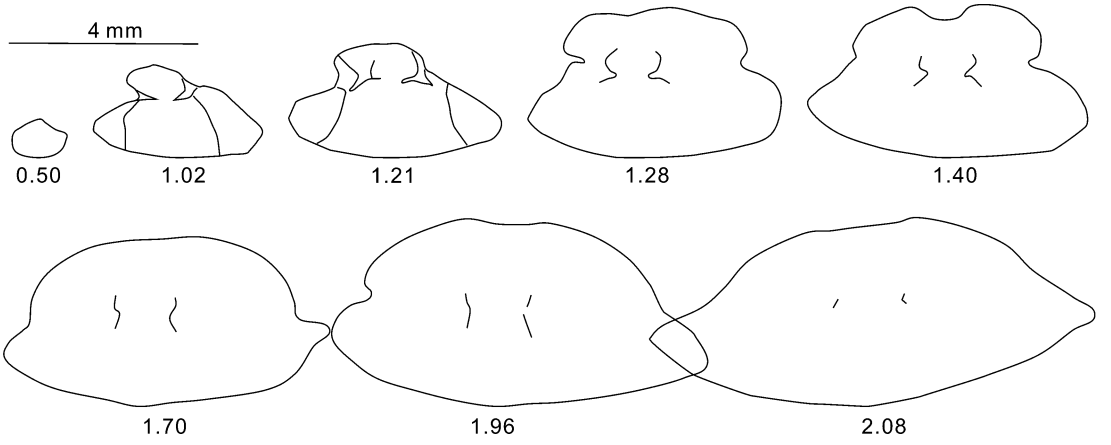
| Specimen no. | L | W | T | CIS |
|---|---|---|---|---|
| NIGP141782 | 9.5 | 14.0 | 6.7 | 6 |
| NIGP141783 | 7.2 | 12.2 | 7.6 | 7 |
| NIGP141784 | 7.3 | 11.6 | 6.4 | 6 |
| NIGP141785 | 7.4 | 14.0 | 8.7 | 6 |
| NIGP141786 | 6.8 | 11.5 | 5.7 | 6 |
| NIGP141787 | 6.9 | 11.5 | 6.1 | 6 |
| NIGP141788 | 8.5 | 12.3 | 5.6 | 7 |
| NIGP141789 | 7.6 | 11.4 | 6.0 | 5 |
| NIGP141790 | 7.7 | 12.0 | 6.0 | 5 |
| NIGP141791 | 8.7 | 12.3 | 6.7 | 7 |

*Discussion*.—The specimens from the Permian of Southeast Pamir figured as *Uncinunellina timorensis* (Beyrich) by Grunt and Dmitriev (1973, p. 113, pl. 8, figs. 16-18) are comparable to our specimens in general outline. The specimen in their figures 16-17 has a much wider sulcus, more costae in sulcus than our specimens and no apparent stolidium. However, the specimen in their figure 18 has a narrow sulcus bearing 6 costae and a marginal brim around the anterior margin of the sulcus much like in the present species. The other Pamiran specimens figured by Grunt and Dmitriev (1973, pl. 14, fig. 5) show identical internal structures to that of the present species.

*Occurrence*.—G-45 ; Jc-14, 15.

**Family PONTISIIDAE Cooper and Grant, 1976b**
**Genus *Prelissorhynchia* Xu and Grant, 1994**

*Prelissorhynchia* Xu and Grant, 1994, p. 36.
*Prelissorhynchia* Chen and Shi, 1999, p. 17.




**Text-Figure 15.** Serial sections of *Glyptohynchia lens* Shen, He and Zhu (NIGP141791).

*Prelissorhynchia* Xu and Grant, Savage in Williams *et al.*, 2002, p. 1275.

*Type species*.—*Pugnax pseudoutah* Huang, 1933, p. 64, pl. 10, figs. 1–8 from the Lungtan Formation in Guizhou, South China.

*Diagnosis*.—Small semicostate, strongly uniplicate family wellerellid with deeply indented anterior commissure; interior with subparallel dental plates and undivided and arched hinge plate, no median ridge or septum.

*Discussion*.—Previous members of this genus have been variably ascribed to *Pugnax*, *Neowellerella* and *Lissorhynchia*. Huang (1933, p. 64) first described a species under the name of *Pugnax pseudoutah* Huang principally based on the striking similar external features between his specimens and the Bolivian species *Pugnax utah* Marcou, figured by Kozlowski (1914, pl. 9, fig. 66). However, subsequent studies (Xu and Grant, 1994; Chen and Shi, 1999) revealed that the internal feature of Huang's species is significantly different from those of *Pugnax*. The South Chinese specimens possess undivided hinge plates and lack crural plates. *Lissorhynchia* was proposed by Yang and Xu (1966) basically for the Late Triassic specimens from central Guizhou Province. Without reference to Yang and Xu's work and comparison with *Lissorhynchia*, Dagys (1974) proposed *Neowellerella* with *N. vesca* Dagys, 1974 as its type species, also a Triassic form. Therefore, *Neowellerella* Dagys, 1974 is a junior synonym of *Lissorhynchia* Yang and Xu, 1966 in terms of their similar internal and external structures. *Neowellerella* was first introduced to China for some Late Permian species including *Pugnax pseudoutah* Huang, 1933 in view of their similar external structures by Liao (1980a, p. 263). Xu and Grant (1994), on the other hand, questioning the validity of referring south Chinese Late Permian materials to *Neowellerella* of Triassic age, preferred to group these Late Permian *Neowellerella*-like species under their proposed new genus *Prelissorhynchia*. In spite of this, the distinction between *Prelissorhynchia* Xu and Grant and *Lissorhynchia* Yang and Xu remains unclear. As Xu and Grant (1994) compared, *Lissorhynchia* is parasulcate and has few costae near the anterior margin externally. However, the parasulcate commissure may mean nothing because specimens of *Prelissorhynchia* in South China that have a single costa in the sulcus and two costae on the fold possess the same parasulcate pattern. The costation of *Prelissorhynchia* also begins late, therefore can not be distinguished from *Lissorhynchia*. According to Xu and Grant (1994, p. 38), *Prelissorhynchia* is distinguishable from *Lissorhynchia* internally in lacking median ridges in either valve and having a long crescentic crura. However, these discriminations do not appear to be definitive enough to separate *Prelissorhynchia* from *Lissorhynchia* Yang and Xu, 1966 because *Lissorhynchia* also lacks median ridges in either valve. *Prelissorhynchia* is possibly a synonym of *Pontisia* Cooper and Grant (1969) with *Pontisia stehlii* Cooper and Grant (1969, p. 13, pl. 4, figs. 7–10) as the type species. However, *Pontisia* differs by its more and earlier costae, a distinct foramen, notched and undivided hinge plates and a low median ridge in the dorsal valve (Cooper and Grant, 1976b, pl. 530, figs. 25, 28, 29, 42). *Alidina* Angiolini (1995, p. 209) is readily distinguished from *Prelissorhynchia* by its divided hinge plates.

*Occurrence*.—Late Permian; South China, ?Transcaucasia.

### *Prelissorhynchia pseudoutah* (Huang, 1933)

Plate 20, Figures 32–35; Plate 21, Figures 1–27; Text-Figure 16

*Pugnax pseudoutah* Huang, 1933, p. 64, pl. 10, figs. 1–8.
*Pugnax pseudoutah* Huang; Wang, 1955b, p. 134, pl. 73, figs. 13–16.
*Pugnax pseudoutah* Huang; Yang *et al.*, 1977, p. 381, pl. 151, figs. 3a–d.
*Pugnax pseudoutah* Huang; Tong, 1978, p. 241, pl. 85, fig. 11.
*Pugnax pseudoutah* Huang; Zhan in Hou *et al.*, 1979, p. 95, pl. 13, figs. 21–22.
*Neowellerella pseudoutah* (Huang); Liao, 1980a, p. 276, pl. 7, figs. 38–39.
*Neowellerella triplicata* Liao, 1980a, p. 263, pl. 8, figs. 18–20.
*Lissorhynchia pseudoutah* (Huang); Xu in Yang *et al.*, 1987, p. 229, pl. 13, figs. 15–16; pl. 14, figs. 10, 12.
*Neowellerella pseudoutah* Huang; Liao, 1987, pl. 8, fig. 1.
*Lissorhynchia triplicata* (Liao); Xu in Yang *et al.*, 1987, p. 229 pl. 13, figs. 18, 19; pl. 14, fig. 11.
*Lissorhynchia monoplicata* Shen *et al.*, 1992, p. 183, pl. 3, figs. 41–45.
*Lissorhynchia tetraplicata* Shen *et al.*, 1992, p. 183, pl. 3, figs. 38–40.
? *Prelissorhynchia pseudoutah* (Huang); Xu and Grant, 1994, p. 38, figs. 22: 28–48, 23.
*Prelissorhynchia pseudoutah* (Huang); Chen and Shi, 1999, p. 20, figs. 6A–F, H–J, L–R.
? *Prelissorhynchia xui* Chen and Shi, 1999, p. 23, fig. 4.

*Material examined*.—Numerous complete conjoined shells. Registered specimens: 12 conjoined shells [(NIGP141792–141799, NIGP141800 (=CUMT8669), NIGP141801 (=CUMT8670), NIGP141802 (=CUMT8671), NIGP141803)].

*Description*.—Average size for genus, unequally biconvex, subtriangular, oval or slightly transversely elliptical in outline, greatest width at shell midlength, posterolateral sides diverging at 90–150 degree; anterior commissure uniplicate; fold low to moderately high, beginning at about 3 mm anterior to dorsal beak, greatest convexity at anterior ends of costae; sulcus moderately deep, beginning 3.5 mm anterior to ventral beak; costae high, originating at about 3 mm anterior to beak; crests normally rounded, slightly angular near anterior ends; intertroughs nearly as wide as costae, bottom angular, 1–4 relatively strong costae in sulcus, 3 weak and short costae on each flank; each dorsal flank with three costae, but the outmost one very weak.

Ventral valve flatly convex in lateral profile and completely smooth in early stages, anterior part of sulcus geniculated toward dorsal valve; beak erect, cut by a circular foramen; dorsal valve much more strongly convex in lateral profile; lateral slopes and umbonal region inclined posteriorly.

Ventral interior with subparallel and vertical dental plates reaching valve floor; dorsal valve with undivided hinge

plates, outer hinge plate wider, inner hinge plate arched, crura crescentric (Text-Figure 16).

*Measurements (in mm).*—

| Specimen no. | L | W | T |
|---|---|---|---|
| NIGP141792 | 8.4 | 9.8 | 8.0 |
| NIGP141793 | 5.0 | 6.0 | 4.7 |
| NIGP141794 | 8.6 | 10.3 | 7.7 |
| NIGP141795 | 6.7 | 6.6 | 5.5 |
| NIGP141796 | 6.5 | 7.6 | 5.2 |
| NIGP141797 | 7.7 | 10.0 | 7.3 |
| NIGP141798 | 8.7 | 9.6 | 8.0 |
| NIGP141799 | 10.0 | 10.5 | 9.5 |
| NIGP141800 | 7.7 | 10.4 | 6.2 |
| NIGP141801 | 7.6 | 8.3 | 6.5 |
| NIGP141802 | 6.3 | 6.4 | 4.5 |
| NIGP141803 | 7.9 | 9.0 | 6.5 |

*Discussion.*—*P. pseudouta*h (Huang, 1933) was first designated by Huang (1933) using a few specimens from different localities in South China, but all are characterized by suboval outline, shallow to moderate sulcus and two costae in sulcus and three on fold. The costation in sulcus was subsequently used for defining different species in this genus. Liao (1980a) first proposed *Neowellerella triplicata* mainly based on triple costae in sulcus and accordingly four costae on fold. Subsequently, Shen *et al.* (1992) proposed two more species (*Lissorhynchia tetraplicata* and *L. monplicata*) following this criteria to define species. However, a restudy of numerous specimens from South China indicates that the number of costae in sulcus may not be a reliable character to separate different species in this genus. Specimens with 1–4 costae in sulcus are commonly preserved in the same locality and same horizon, and they have very close external and internal characters, which suggest an intraspecific variation. Therefore, we assign all those previously described species into one species of *Prelissorhynchia* in view of their similar outline, profile, sulcus and fold.

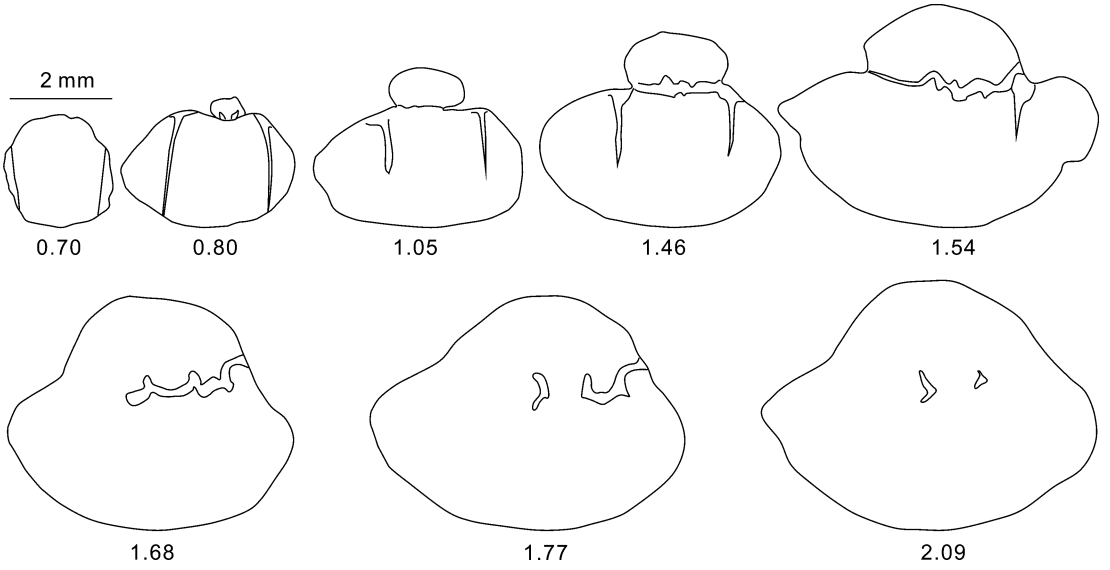
*P. triplicatioid* Xu and Grant (1994, p. 38) from the Lower Changhsing Formation of Huayingshan, Chongqing City appears to be comparable to the present species. However, Xu and Grant (1994) pointed out that the latter has costae commencing from the anterior of umbo and has a flat hinge plate according to Liao's definition (Liao, 1980a, p. 263, pl. 8, figs. 18–20), which seemingly shows that this species may belong to a different genus.

Sokolskaja (in Ruzhentsev and Sarytcheva, 1965, p. 233, pl. 40, figs. 7a–c, fig. 37) described a species as *Wellerella dorashamensis* Sokolskaja from the *Haydenella* Bed of the Dzhulfa Formation in Transcaucasia. The Transcaucasus species is externally identical to the present species and probably conspecific, but Sokolskaja (in Ruzhentsev and Sarytcheva, 1965, p. 233, fig. 37a) showed that the Transcaucasus species has a very short "septum". It is of note that the presence of *Prelissorhynchia pseudouatah* in the Lopingian of Transcaucasia has been confirmed (Kotlyar *et al.*, 2004).

The specimen from the Changhsingian in the Pengshui County, Sichuan Province was described as possessing divided hinge plates by Tong (1978, p. 242). However, no serial sections were provided and the figured specimen looks like typical *P. pseudoutah.* The genus *Pugnax* Hall and Clarke, 1893 has never been confirmed to be present in the Lopingian of South China.

The specimens figured by Xu and Grant (1994, p. 38, figs. 22 : 28–48, 23) all appear to be different from the lecotype chosen by Chen and Shi (1999) in terms of their shallow sulcus and somewhat rounded profile and plication, and therefore have been renamed by Chen and Shi (1999) as a new species, *P. xui.* However, this is probably questionable because our numerous specimens indicate that the outline and profile are quite variable.

*Occurrence.*—A–6, 8, 9, 10, 11, 12, 14, 20, 22, 26, 28, 32 ; B–




**Text-Figure 16.** Serial sections of *Prelissorhynchia pseudoutah* (Huang) (NIGP141792).

7, 19, 21, 22, 24, 25 ; C–17 ; D–12, 16, 19, 21, 23, 28, 30 ; E–40, 43, 45, 49 ; F–21, 27, 29, 30, 31, 32, 33, 34, 42 ; G–45, 46, 47, 51, 52, 54, 55 ; H–30, 130 ; I–68 ; Jc–10, 15.

### *Prelissorhynchia anteacus* (Xu and Grant, 1994)

Plate 21, Figures 28–47 ; Text–Figure 17

*Cyrolexis anteacus* Xu and Grant, 1994, p. 39, figs. 26(1–20) (not fig. 25).

*Material examined*.—Registered specimens : 10 complete conjoined shells (NIGP141804–141813)

*Diagnosis*.—Shell having a deep sulcus with 2–3 costae and highly–elevated wing–like flanks.

*Description*.—Average size for genus, unequally biconvex, subtriangular in outline, greatest width anterior to shell midlength ; posterolateral sides diverging at about 120 degree, anterior margin nearly straight ; anterior commissure strongly uniplicate with sharp zigzag ; surface costate, costae only developed near margins, simple and with rounded crests, 3–4 costae on fold, 2–3 in sulcus and 3 on each flank.

Ventral valve gently convex in lateral profile ; beak fairly acute, erect ; sulcus originating slightly anterior to midvalve, sharply deepening anteriorly, forming a long and elevated tongue ; two flanks slightly flattened at midvalve, but rapidly elevated toward anterolateral sides ; dorsal valve strongly inflated with steeply sloping lateral sides ; fold fairly high, beginning anterior to midvalve.

Ventral interior with subparallel dental plates, dental plates extending to about one quarter anterior to beak ; dorsal interior with undivided hinge plates (Text–Figure 17).

*Measurements (in mm)*.—

| Specimen no. | L | W | T |
|---|---|---|---|
| NIGP141804 | 7.7 | 9.8 | 6.8 |
| NIGP141805 | 9.4 | 10.3 | 7.7 |
| NIGP141806 | 7.5 | 10.3 | 7.0 |
| NIGP141807 | 8.1 | 9.3 | 6.7 |
| NIGP141808 | 7.0 | 8.4 | 6.3 |
| NIGP141809 | 7.5 | 7.9 | 5.5 |
| NIGP141810 | 7.5 | 10.0 | 9.1 |
| NIGP141811 | 7.5 | 7.7 | 6.3 |
| NIGP141812 | 7.5 | 8.2 | 7.0 |
| NIGP141813 | 7.0 | 8.6 | 7.5 |

*Discussion*.—Originally, Xu and Grant (1994) proposed a species of the genus *Cyrolexis* Grant, 1965 which possesses characteristic ventral spondylium supported by a high median septum and dorsal camarophorium. However, specimens used to define this species apparently belong to different genera. The specimen used for serial sections clearly shows the characteristic internal structure of stenoscismataceans (Xu and Grant, 1994, fig. 25). However, those used for the syntype in fig. 26 of Xu and Grant (1994) are typical of *Prelissorhynchia* in terms of the short dental plates in the ventral valve [see Xu and Grant, 1994, fig. 26 (10, 11, 14, 18, 19)] and costation. Nevertheless, the species as a *Prelissorhynchia* seems to be distinguishable from *P. pseudoutah* (Huang, 1933) in terms of its deep sulcus and highly–elevated wing–like flanks.

*Occurrence*.—A–26 ; B–19, 24 ; F–42, 43.

### *Prelissorhynchia plena* new species

Plate 22, Figures 1–23

*Holotype*.—NIGP141821, a conjoined shell from B–22 (Plate 22, Figures 1–4).

*Other material examined*.—Nine complete conjoined shells (NIGP141814–141820, 141822).

*Diagnosis*.—Shell with gently subequally biconvex profile and subtriangular outline.

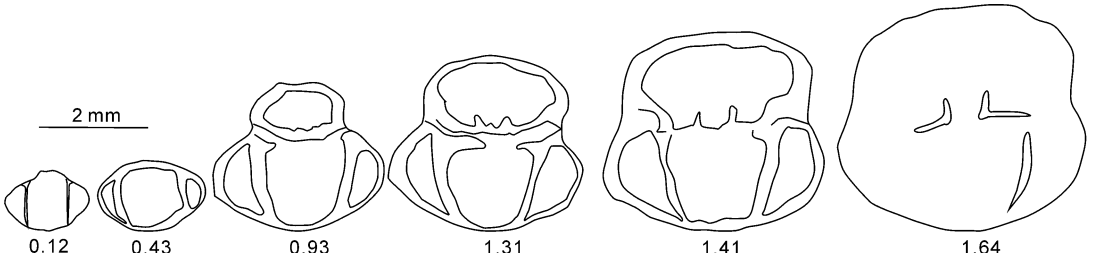
*Description*.—Small in size for genus, subtriangular in outline, gently subequally biconvex, greatest width slightly anterior to shell midlength ; posterolateral sides nearly straight, converging posteriorly at about 90 degree, anterolateral sides regularly rounded, anterior margin nearly straight, anterior commissure uniplicate ; surface costate, costae fairly short, crests rounded, beginning anterior to midvalve, 2 costae in sulcus and 3 on fold and 3 on each flank.

Ventral valve flatly convex in lateral profile, middle part slightly domed in anterior profile ; beak acute, suberect ; sulcus commencing slightly anterior to midvalve, slightly bending toward dorsal valve and producing a short front tongue, flanks gently inclined ; dorsal valve also gently convex in lateral and anterior profile ; fold only developed near margins, slightly higher than flanks.

Ventral interior with short vertical dental plates reaching valve floor ; dorsal interior with undivided hinge plates.

*Measurements (in mm)*.—

| Specimen no. | L | W | T |
|---|---|---|---|
| NIGP141814 | 6.1 | 6.3 | 3.4 |
| NIGP141815 | 6.8 | 7.1 | 3.4 |
| NIGP141816 | 7.0 | 7.6 | 4.3 |




**Text–Figure 17.** Serial sections of *Prelissorhynchia anteacus* (Xu and Grant) (NIGP141806).

| | | | |
|---|---|---|---|
| NIGP141817 | 7.5 | 7.8 | 4.5 |
| NIGP141818 | 6.4 | 6.8 | 3.8 |
| NIGP141819 | 7.6 | 8.4 | 4.5 |
| NIGP141820 | 6.5 | 7.6 | 4.0 |
| NIGP141821 | 6.1 | 6.7 | 2.6 |
| NIGP141822 | >6.0 | 7.6 | 2.5 |

*Etymology*.—plenus (Latin), full ; referring to its thin cavity.

*Discussion*.—*Prelissorhynchia plena* new species is close to *P. pseudoutah* (Huang, 1933) in view of its outline and costation in sulcus and on fold, but can be readily distinguished by its much less convex lateral profile and more acute beak.

*Occurrence*.—A-9, 11, 26 ; B-22, F-33.

### Genus *Wellerellina* Shen, He and Zhu, 1992

*Wellerellina* Shen *et al.*, 1992, p. 183.

*Type species*.—*Wellerellina chongqingensis* Shen *et al.*, 1992, p. 184, pl. 4, figs. 5-8 from the Changhsing Formation in Chongqing, South China.

*Diagnosis*.—Small, subelliptical to nearly circular in outline, dorsal valve more convex than ventral valve ; fold and sulcus prominent ; costae distinct, angular, originating at beak and spacing regularly and evenly and with roof-tiled appearance. Ventral interior with dental plates ; dorsal interior with undivided hinge plates, stout crura extending along their length from hinge plates to commissure.

*Discussion*.—*Wellerellina* can be readily distinguished from *Prelissorhynchia* Xu and Grant, 1994 and *Lissorhynchia* Yang and Xu, 1966 by its finer angular costae beginning at beak and roof-tiled appearance although they share most internal features. *Allorhynchus* Weller, 1910 resembles the present genus in costation but differs in its divided hinge plates. *Strigirhynchia* Cooper and Grant (1969) and *Wellerella* Dunbar and Condra, 1932 are both costate to the beak and have undivided hinge plates, but the presence of its dorsal median septum or ridge can easily separate them from *Wellerellina*. *Pontisia* Cooper and Grant, 1969 is somewhat similar to *Wellerellina* in general external characters. However, *Pontisia* usually has a later costation and a distinct dorsal median ridge and foramen.

*Occurrence*.—Lopingian ; South China.

#### *Wellerellina chongqingensis* Shen, He and Zhu, 1992

Plate 22, Figures 24-43 ; Text-Figure 18

*Wellerellina chongqingensis* Shen *et al.*, 1992, p. 184, pl. 4, figs. 5-8.

*Wellerellina triplicata* Shen *et al.*, 1992, p. 185, pl. 4, figs. 1-4.

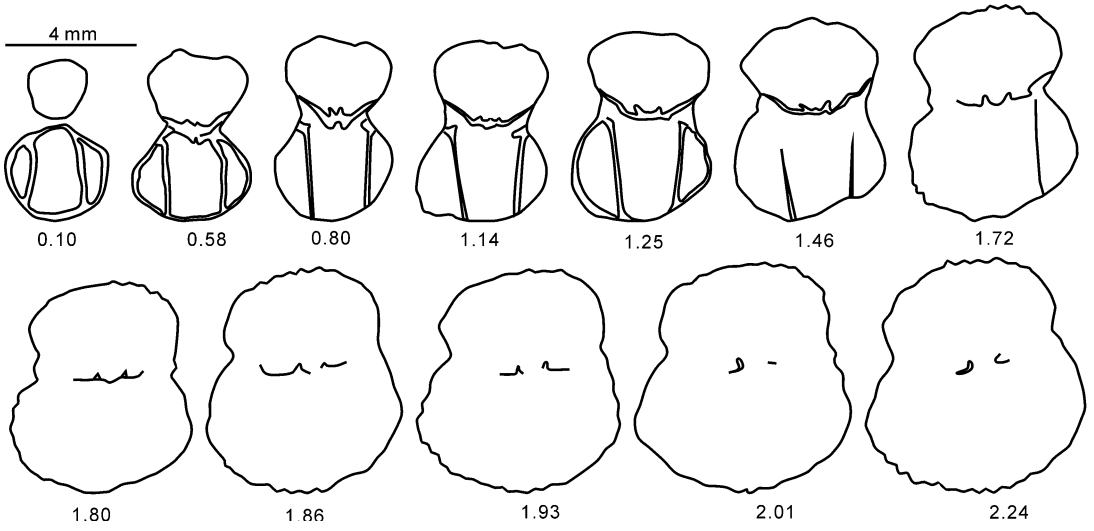
*Holotype*.—NIGP141823 (=CUMT8644), Plate 22, Figures 31-34.

*Other material examined*.—Eight complete conjoined shells [(NIGP141824 (=CUMT8643), NIGP141825-141832)].

*Description*.—Average size for genus, moderately subequally biconvex, subcircular in outline, greatest width at shell midlength ; sides regularly and evenly rounded, anterior margin broadly rounded ; anterior commissure uniplicate ; costae moderately high and subangular on ventral flanks and dorsal fold, lower and blunt in sulcus and dorsal flank, beginning at beak, numbering 4-6 on fold and 3-5 in sulcus, 5 on flanks, concentric lamellae well developed, producing roof-tiled appearance.

Ventral valve moderately convex in lateral profile ; umbonal region slightly more convex, anterior profile, gently convex, beak sharp, somewhat attenuated, umbonal slopes moderately inclined, but lateral slopes gently inclined ; interarea not developed ; sulcus fairly shallow, only slightly lower than flanks on anterior region, but strongly bending dorsally, forming a conspicuous anterior tongue ; dorsal valve slightly more convex than ventral valve, maximum convexity at midvalve ; lateral slopes evenly and moderately inclined, fold wide and low, only slightly elevated on anterior region.

Ventral interior with two short vertical dental plates reach-




**Text-Figure 18.** Serial sections of *Wellerellina chongqingensis* Shen *et al.* (NIGP141830).

ing valve floor, but diverging anteriorly at about 20 degree ; dorsal interior with undivided hinge plates, two outer hinge plates nearly flat, connected by arched inner hinge plates, median septum or ridge completely absent (Text-Figure 18).

*Measurements (in mm)*.—

| Specimen no. | L | W | T |
|---|---|---|---|
| NIGP141823 | 8.7 | 9.4 | 7.1 |
| NIGP141824 | 9.0 | 10.2 | 7.3 |
| NIGP141825 | 9.3 | 9.1 | 8.4 |
| NIGP141826 | 8.7 | 9.5 | 7.9 |
| NIGP141827 | 8.6 | 9.5 | 7.0 |
| NIGP141828 | 8.4 | 9.0 | 7.5 |
| NIGP141829 | 8.6 | 8.7 | 6.0 |
| NIGP141830 | 8.9 | 9.9 | 8.2 |
| NIGP141831 | 6.9 | 8.4 | 5.9 |
| NIGP141832 | 9.2 | >9.0 | 6.2 |

*Discussion*.—The present species resembles *Wellerella globosa* by Koczyrkevicz (in Kotlyar *et al.*, 1989, 147, pl. 13, figs. 5-7, fig. 8) in most external features. However, the serial sections of the latter clearly show a median septum in the apical cavity of the dorsal valve being characteristic of *Wellerella*. *Wellerellina triplicata* previously proposed based on the number of costae in sulcus by Shen *et al.* (1992) is combined into the present species in terms of their close outline and profile.

*Occurrence*.—A-14, 19, 26 ; B-24 ; F-29, 32, 34 ; Jc-15.

### ***Wellerellina opima*** **Shen, He and Zhu, 1992**

Plate 22, Figures 44-47 ; Plate 23, Figures 1-8

*Wellerellina opima* Shen *et al.*, 1992, p. 184, pl. 4, figs. 9-12.

*Lectotype*.—NIGP141835 (=CUMT9275), Plate 23, Figures 1-4.

*Other material examined*.—Two complete conjoined shells (NIGP141833, 141834).

*Description*.—Slightly smaller than average size for genus, juveniles moderately biconvex, but adults strongly biconvex, subpentagonal or slightly elongate in outline, greatest width at shell midlength ; lateral sides and anterior margin broadly rounded ; anterior commissure uniplicate ; costae beginning at beak, crests subangular, intertroughs narrower than costae, 4 in sulcus and 5 on fold, 6-7 on each flank ; concentric lamellae conspicuous, roof-tiled in appearance.

Ventral valve unevenly convex in lateral profile, maximum convexity slightly anterior to umbonal region, posterior outline strongly domed ; beak sharp, bending dorsally over dorsal beak ; umbonal region swollen, umbonal slopes sharply inclined, lateral slopes fairly steep ; sulcus originating from midlength, fairly shallow but bending dorsally, forming a wide front tongue ; dorsal valve slightly more convex than ventral valve, maximum convexity also slightly anterior to umbo ; anterior region gradually flattened, umbonal and lateral slopes sharply inclined ; fold moderately high, beginning at midvalve.

Ventral interior with two vertical dental plates reaching valve floor, slightly divergent anteriorly, extending about 4 mm anteriorly ; dorsal interior with undivided hinge plates, outer hinge plates flat, but connected by arched inner hinge plates.

*Measurements (in mm)*.—

| Specimen no. | L | W | T |
|---|---|---|---|
| NIGP141833 | 8.0 | 7.0 | 6.6 |
| NIGP141834 | 7.0 | 6.9 | 5.6 |
| NIGP141835 | 6.5 | 6.6 | 4.2 |

*Discussion*.—Externally the present species somewhat resembles the type species, but differs by its slightly smaller size, subpentagonal outline and a strongly curved beak. The original holotype of this species was lost under transportation ; we herein re-designate NIGP141835 as the holotype.

*Occurrence*.—A-14, 26.

### ***Wellerellina extensa*** **Shen, He and Zhu, 1992**

Plate 23, Figures 9-12

*Wellerellina extensa* Shen *et al.*, 1992, p. 185, pl. 4, figs. 13-16.

*Holotype*.—A complete conjoined shell, NIGP141836 (= CUMT8656) from A-26 (Plate 23, Figures 9-12).

*Description*.—The specimen measured 6.7 mm long, 7.7 mm wide and 5.3 mm thick, being slightly smaller than average size for genus, moderately biconvex, transversely elliptical in outline, greatest width at shell midlength ; sides regularly and evenly rounded, anterior margin broadly rounded ; anterior commissure gently uniplicate ; surface finely costate, costae beginning at beak, intertroughs slightly narrower than costae, crests subangular, numbering 4 in sulcus and 5 on fold, 6 on each flank, totally 16 on each valve, concentric lamellae not seen.

Ventral valve moderately convex in lateral profile ; beak acute, slightly blended dorsally ; median region slightly inflated, lateral slopes gently inclined, sulcus weak, fairly shallow, only flattened near anterior margin ; dorsal valve moderately and evenly convex in lateral profile and anterior profile, maximum convexity at midvalve ; fold low and wide, slightly elevated near margin.

Ventral interior with two subparallel dental plates.

*Discussion*.—Although only one specimen is available for study, its transversely elliptical outline, weak and shallow sulcus and low fold, and relatively more costae on both valves are readily distinguishable from all other species of *Wellerellina*. Unfortunately, its internal characters cannot be completely confirmed due to limited material available.

*Occurrence*.—A-26.

## Family ALLORHYNCHIDAE Cooper and Grant, 1976b
## Genus *Terebratuloidea* Waagen 1883

*Type species*.—*Terebratuloidea davidsoni* Waagen, 1883, p. 410, pl. 33, figs. 1-5 from the Chhidru Formation, Salt Range, Pakistan.

*Discussion*.—*Terebratuloidea* resembles some species of *Stenoscisma* Conrad, 1839 in external appearance, but it can be readily distinguished by its absence of any septum in either valve.

### *Terebratuloidea minor* Waagen, 1883

Plate 23, Figures 13–20 ; Text-Figure 19

*Terebratuloidea minor* Waagen, 1883, p. 420, pl. 33, figs. 11–12.
*Terebratuloidea davidsoni* Waagen ; Yang *et al.*, 1977, p. 393, pl. 155, figs. 9a–c.
*Terebratuloidea davidsoni* Waagen ; Zhan in Hou *et al.*, 1979, p. 96, pl. 8, figs. 11–13.

*Material examined*.—Six complete conjoined shells. Registered specimens : Four conjoined shells (NIG P141837–141840).

*Description*.—Small to medium for genus, moderately biconvex, subtriangular in outline, greatest width slightly anterior to shell midlength ; beak short and stout ; foramen subcircular, costae beginning slightly anterior to beak, strong on fold and in sulcus, weaker on flank, 2 in sulcus and 3 on fold, normally 3–4 on each flank ; anterior commissure strongly uniplicate.

Ventral valve moderately convex in lateral profile ; sulcus originating from umbonal region, moderately deep, rapidly bending dorsally near margins ; flank sharply inclined ; dorsal valve moderately convex in lateral profile, but strongly domed in anterior profile ; fold moderately high.

Ventral interior without dental plates ; dorsal hinge plates divided, median division actually cutting apex of beak (Text-Figure 19).

*Measurements (in mm)*.—

| Specimen no. | L | W | T |
|---|---|---|---|
| NIGP141837 | 11.5 | 10.8 | 7.6 |
| NIGP141838 | 10.5 | 11.0 | 8.6 |
| NIGP141839 | 6.0 | 6.6 | 4.2 |
| NIGP141840 | — | 11.5 | 7.2 |

*Discussion*.—Externally, this species closely resembles *Stenoscisma mutabilis* (Tschernyschew, 1902, p. 491, pl. 23, figs. 9–10 ; pl. 45, figs. 1–5) from the *Schwagerina* Beds of the Urals. However, it can be readily distinguished from it by the absence of any septum in both valves. *Terebratuloidea davidsoni* Waagen (1883, p. 410, pl. 33, figs. 1–5) from the Wargal Formation of the Salt Range, Pakistan is superficially similar to this species, but differs in its large size and more or less firmly depressed beak and 2–3 costae in sulcus. The specimens described by Zhan in Hou *et al.* (1979) and Yang *et al.* (1977) have small size and two costae in sulcus, which is seemingly more related to the present species than it is to the Salt Range species.

*Occurrence*.—Jb–4, 5 ; Jc–14, 15.

### Genus *Allorhynchus* Weller, 1910

*Allorhynchus* Weller, 1910, p. 509.
*Allorhynchus* Weller ; Cooper and Grant, 1976b, p. 2003.

*Type species*.—*Rhynchonella heteropsis* Winchell, 1865, p. 121 from the Lower Mississippian, USA.

*Diagnosis*.—Obtusely triangular in outline, moderately biconvex ; with conspicuous sulcus and fold ; anterior commissure uniplicate ; costae simple, low and roundly-crested, beginning just anterior to beak ; ventral beak acute, erect or slightly incurved ; ventral interior with two vertical dental plates ; dorsal interior with divided hinge plates, no median septum.

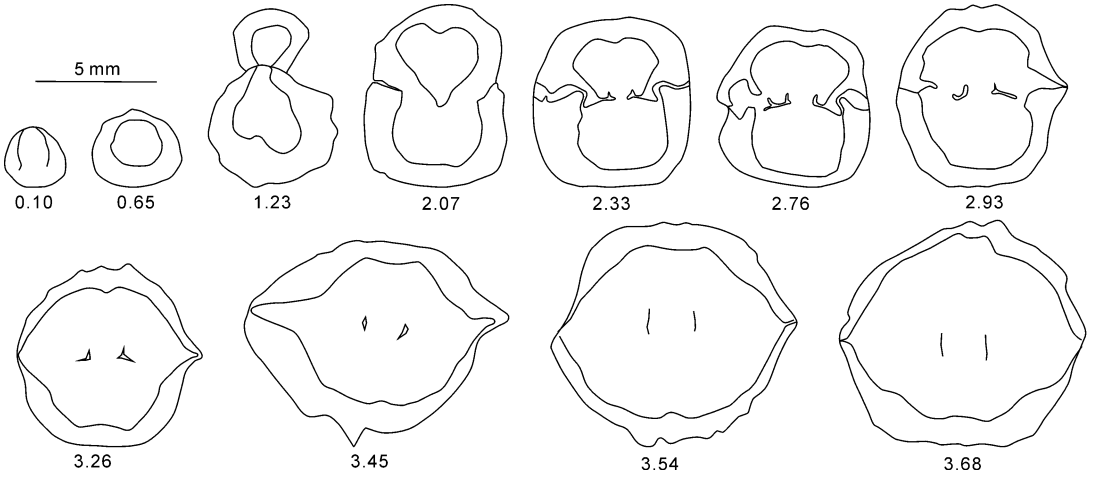
*Discussion*.—This genus shares the same short vertical dental plates and the divided hinge plates with *Pugnax* Hall and Clarke, 1892, from which it differs mainly in its costae beginning from near the beak. *Wellerellina* Shen *et al.*, 1992 is similar to *Allorhynchus* in costation, but the former has undivided hinge plates. *Alidina* Angiolini (1995) shares the same internal structures with *Allorhynchus* and *Pugnax* although its costation seems to agree better with that of *Pugnax*.

*Occurrence*.—Asia, America ; Carboniferous to Permian.

### *Allorhynchus hunanensis* Liao and Meng, 1986

Plate 23, Figures 21–24

*Allorhynchus hunanensis* Liao and Meng, 1986, p. 82, pl. 4, figs. 16–17, 28–30, fig. 3.




**Text-Figure 19.** Serial sections of *Terebratuloidea minor* Waagen (NIGP141838).

*Material examined*.—Two complete conjoined shells (NIGP141841, 141842).

*Description*.—Average size for genus, unequally biconvex, outline roundly triangular; sides diverging at about 120 degree, anterior margin straight; anterior commissure strongly uniplicate; costae moderately high, beginning slightly anterior to beak, crests rounded and flattened near margins, 4 in sulcus and 5 on fold, 5 on each flank.

Ventral valve flatly convex in lateral profile; beak slightly curved dorsally, shape, slightly attenuated; flank gently inclined; sulcus wide and shallow, beginning anterior to midvalve, geniculated dorsally near margins, producing wide anterior tongue; dorsal valve more convex than ventral valve, maximum convexity near margins; flank moderately inclined; median part slightly flattened; fold low, only developed near margins.

Ventral interior with vertical dental plates reaching valve floor, dental plates very short, slightly diverging anteriorly; dorsal interior with deeply-notched hinge plates, then gradually diverging anteriorly; crura extending anteriorly toward commissure.

*Measurements (in mm)*.—

| Specimen no. | L | W | T |
|---|---|---|---|
| NIGP141841 | 9.5 | 10.3 | 7.3 |
| NIGP141842 | 9.9 | 10.7 | 7.0 |

*Discussion*.—This species resembles *Allorhynchus formulosun* Cooper and Grant (1976b p. 2006, pl. 540, figs. 4–14), both having a subtriangular outline and 4 costae in sulcus, but the latter has a larger size, lower convexity and more costae on flanks.

*Occurrence*.—Jc–15.

### Superfamily STENOSCISMATOIDEA Oehlert, 1887
### Family STENOSCISMATIDAE Oehlert, 1887
### Subfamily STENOSCISMATINAE Oehlert, 1887
### Genus *Stenoscisma* Conrad, 1839

*Type species*.—*Terebratula schlotheimi* Buch (1835, p. 59, pl. 2, figs. 32a–c) from middle Upper Permian, Germany.

*Discussion*.—*Stenoscisma* has been widely used for the Carboniferous and Permian specimens in South China, although usually with little discussion or justification. The genus is easily confused with several other allied genera. Tschernyschew (1902, p. 489) pointed out that the Ural and Siberian stenoscismataceans can be divided into two groups: those with stolidium and those without it. Grant (1965) separated them into two different genera: *Stenoscisma* (s.s.) with a stolidium and *Cyrolexis* Grant without a stolidium. Stolidium has never been seen on the specimens from South China. *Camarophorinella* Licharew, 1936 is close to *Stenoscisma*, but differs by the absence of stolidium and intercamarophorial plate in the dorsal valve.

#### *Stenoscisma mutabilis* (Tschernyschew, 1902)

Plate 23, Figures 25–35; Plate 24, Figures 1–31; Text-Figure 20

*Camarophoria mutabilis* Tschernyschew, 1902, p. 491, pl. 22, figs. 18a–d; pl. 23, figs. 9–10; pl. 45, figs. 1–5; pl. 46, figs. 14a–d.

*Camarophoria mutabilis* (Tschernyschew); Grabau, 1931, p. 211, pl. 4, fig. 7; pl. 5, figs. 1–2.

*Camarophoria mutabilis* (Tschernyschew); Grabau, 1934, p. 16, pl. 2 figs. 1–2.

*Stenoscisma mutabilis* (Tschernyschew); Wang, 1955b, p. 135, pl. 94, figs. 5–9.

*Stenoscisma mutabilis* (Tschernyschew); Wang *et al.*, 1964, p. 423, pl. 70, figs. 31–34.

*Stenoscisma mutabilis* (Tschernyschew); Li and Gu, 1976, p. 272, pl. 159, figs. 14–17.

*Stenoscisma mutabilis* (Tschernyschew); Kalashnikov, 1980, p. 71, pl. 20, figs. 9–11.

*Stenoscisma mutabilis* (Tschernyschew); Shi and Waterhouse, 1996, p. 114, pl. 21, figs. 4–14.

*Material examined*.—Numerous complete conjoined shells. Registered specimens: 15 conjoined shells (NIGP141843–141856).

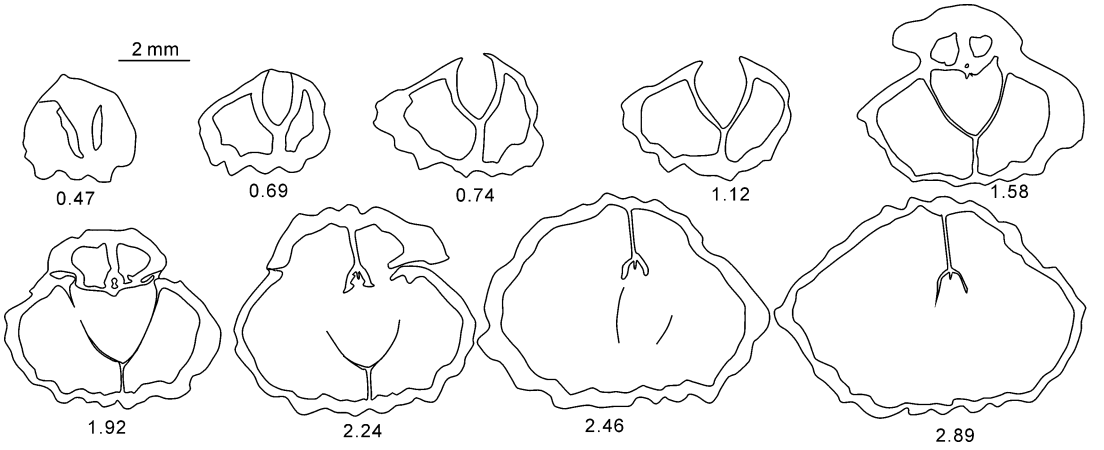
*Description*.—Average size for stenoscismataceans, subelliptical to broadly subtriangular in outline, sides diverging between 50 and 90 degree; greatest width just anterior to shell midlength, valves subequal in depth; no stolidium; surface costate except smooth umbo, costae uniform in size on flanks, fold and sulcus, beginning just anterior to beak, 2–5 in sulcus and 3–6 on fold with outer 2 usually depressed below median 2 or 3 if more than 3, each flank with 4–5 costae, outmost pair indistinct; crests rounded; anterior commissure strongly uniplicate.

Ventral valve moderately convex in profile; beak bluntly acute, slightly incurved and attenuated; umbonal region moderately swollen; flanks gently inclined; sulcus originating just anterior to umbo, rapidly widening and deepening anteriorly, gradually turning toward dorsal valve, forming short front tongue; dorsal valve evenly and moderately convex in lateral profile; flank moderately inclined; fold beginning at umbo, slightly widening anteriorly and highly elevated near margin.

Ventral interior with small teeth fused with valve sides; dental plates converging above floor to form boat-shaped spondylium supported by median septum, extending about 4 mm from beak. Dorsal interior with high median septum, capped by anteriorly expanding, spoon-shaped camarophorium, a short and low intercamarophorial plate present (Text-Figure 20).

*Measurements (in mm)*.—

| Specimen no. | L | W | T | CIS |
|---|---|---|---|---|
| NIGP141843 | 9.6 | 11.4 | 8.5 | 2 |
| NIGP141844 | 7.5 | 8.0 | 4.7 | 2 |
| NIGP141845 | 11.0 | 12.8 | 6.9 | 2 |
| NIGP141846 | 9.8 | 10.0 | 5.9 | 3 |
| NIGP141847 | 7.3 | 8.5 | 6.5 | 2 |
| NIGP141848 | 8.5 | 10.3 | 7.0 | 3 |
| NIGP141849 | 9.1 | 8.5 | 5.5 | 2 |
| NIGP141850 | 10.0 | 9.5 | 6.5 | 3 |
| NIGP141851 | 11.0 | 10.8 | 7.6 | 5 |
| NIGP141852 | 10.0 | 11.0 | 7.5 | 4 |




**Text-Figure 20.** Serial sections of *Stenoscisma mutabilis* (Tschernyschew) (NIGP141854).

| | | | | |
|---|---|---|---|---|
| NIGP141853 | 10.5 | 12.0 | 8.5 | 4 |
| NIGP141854 | 9.4 | 9.7 | 7.9 | 4 |
| NIGP141855 | 11.0 | 11.1 | 7.7 | 4 |
| NIGP141856 | 10.2 | 10.2 | 7.2 | 4 |

*Discussion*.—*Stenoscisma mutabilis* is characterized by its subelliptical to broadly triangular outline, moderately biconvex profile, strong costae with rounded crests and 2-3 costae in sulcus. The specimens illustrated by Tschernyschew (1902) from the *Schwagerina* Beds of Timan exhibit a wide range of variations in size and outline. Our specimens are generally comparable with those from Timan in size, outline and costation. However, the stolidium characterizing the genus *Stenoscisma* is unclear for the South Chinese specimens although an intercamarophorial plate is revealed (Text-Figure 20), which rules out the possibility of it belonging to *Cyrolexis* Grant, 1965 or *Camarophorinella* Licharew, 1936. The present species is perhaps closest to *Stenoscisma jingxianensis* Zhang and Jin (1961, p. 404, pl. 1, fig. 8), from which it differs in its smaller convexity and stronger costae. The specimens under seven different species described by Liang (1990) from the Capitanian Lengwu Formation in Zhejiang Province are generally distinguishable from the present species by their more and finer costae. The present species is perhaps closest to the specimens figured as "*Stenoscisma*" *jingxianensis* Zhang and Jin (1961, p. 404, pl. 1, fig. 8), from which it differs in its smaller convexity and stronger costae.

*Occurrence*.—A-26, 30 ; B-19, 22, 24 ; C-17 ; G-45 ; Jc-15.

### Subfamily CYROLEXINAE Savage in Williams *et al.,* 2002
### Genus *Cyrolexis* Grant, 1965

*Type species*.—*Cyrolexis haquei* Grant, 1965, p. 91, pl. 6, figs. 1-5 from the Amb Formation at Rukhala, Pakistan.

*Discussion*.—*Cyrolexis* is closely similar to *Camarophorinella* Licharew, 1936 as both lack intercamarophorial plate in the dorsal valve, but the former differs by its undivided hinge plates and later costation. *Hybostenoscisma* Liao and Meng, 1986 was considered to differ from *Cyrolexis* in having corrugated costae although they share identical internal structures. *Goleomixa* Grant, 1976 differs from *Cyrolexis* by its smooth flanks at all stages and stronger costae in sulcus. In addition, *Goleomixa* possesses a suberect beak with an open foramen, whereas the beak of *Cyrolexis* is pressed tightly against the dorsal beak and there is no foramen (Grant, 1976).

Liang (in Wang *et al.*, 1982, 1990) proposed two genera, *Zhejiangella* Liang (in Wang *et al.*, 1982, p. 236) and *Zhejiangellina* Liang (1990, p. 257) based on the specimens from the Capitanian Lengwu Formation at Tonglu, Zhejiang Province. The internal structures of these two genera are completely the same as *Cyrolexis* and *Stenoscisma.* The absence of stolidium of the specimens characterizes the genus *Cyrolexis* and the costation has no substantial differences from stenoscismataceans although Liang (1990) has claimed otherwise. Therefore, *Zhejiangella* and *Zhejiangellina* are both apparently junior synonyms of *Cyrolexis.* In addition, Liang (1990) proposed seven species (*Zhejiangella anneaplicata, Z. octoplicata, Z. paraplicata, Z. pentaplicata, Z. quadriplicata, Z. septaplicata, Z. sexplicata, Zhejingellina wangi*) under either the name *Zhejiangella* or *Zhejiangellina.* These species are mainly separated based on the number of costae in sulcus which is not a reliable character for defining species in rhynchonellids. Among them, *Zhejiangella anneaplicata* (Now *Cyrolexis anneaplicata*) appears different from other species by its very fine costation. However, all the other species are more or less similar to one another and probably assignable to one species. We herein adopt the name *Cyrolexis octaplicat*a (Liang, 1990).

*Occurrence*.—Carboniferous to Permian ; Russia, Japan, China, Pakistan.

### *Cyrolexis zhongliangshanensis* (Shen, He and Zhu, 1992)

Plate 24, Figures 32-47 ; Plate 25, Figures 1-4 ;
Text-Figure 21

*Stenoscisma zhongliangshanensis* Shen *et al.*, 1992, p. 185, pl. 4, figs. 17-24.

*Holotype*.—NIGP141857 (=CUMT8690), Plate 24, Figures

40–43.

*Other material examined*.—Six complete conjoined shells (NIGP141858–141863).

*Description*.—Medium size, spherical in profile, both valves strongly convex, outline subcircular, greatest width at shell midlength; lateral sides evenly rounded, anterior margin broadly rounded; anterior commissure uniplicate; surface costate, costae beginning near beak, weak on umbonal region, becoming distinct just anterior to umbo, crests rounded, 2–4 in sulcus and 3–5 on fold, 3–5 on each flank.

Ventral valve strongly and evenly convex in lateral profile; beak thick, moderately incurved, umbonal region slightly swollen; sulcus originating just anterior to umbonal region, evenly curved toward dorsal valve, forming long front tongue near margin; flanks moderately inclined; dorsal valve slightly more convex than ventral valve, maximum convexity slightly anterior to midvalve; fold originating from umbonal region, moderately distinct near margin; flanks strongly inclined.

Ventral interior with deep spondylium supported by a median septum, median septum low and thick near apex, slightly thinner and higher anteriorly, extending for about 3 mm anteriorly; dorsal interior with divided hinge plates, camarophorium high, cap-like, upper sides attached to underside of hinge plates in apical cavity, intercamarophorial plate absent (Text-Figure 21).

*Measurements (in mm)*.—

| Specimen no. | L | W | T | CIS |
|---|---|---|---|---|
| NIGP141857 | 10.9 | 12.2 | 10.6 | 2 |
| NIGP141858 | 10.3 | 10.5 | 8.9 | 4 |
| NIGP141859 | 8.8 | 9.3 | 6.5 | 2 |
| NIGP141860 | 10.0 | 10.5 | 9.0 | 2 |
| NIGP141861 | 7.2 | 8.7 | 7.6 | 2 |
| NIGP141862 | 9.5 | 9.5 | 7.8 | 2 |
| NIGP141863 | 9.6 | 10.5 | 8.1 | 2 |

*Discussion*.—This species was first described as *Stenoscisma.* However, further serial sections of this species reveal that the intercamarophorial plate and stolidium are absent and the costae originate from umbonal region, which suggest *Cyrolexis* Grant, 1965.

*Occurrence*.—A–26; B–19, 24.

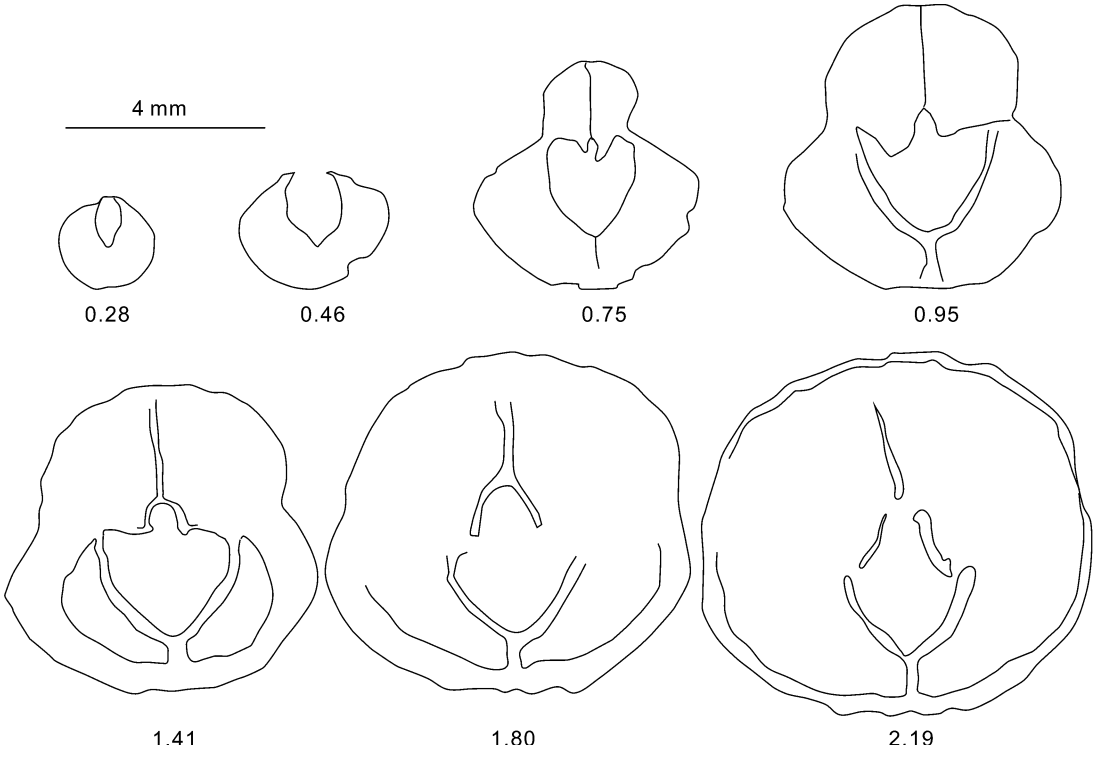
### *Cyrolexis* sp.

Plate 25, Figures 5–8

*Material examined*.—A complete conjoined shell (NIGP141864).

*Description*.—Specimen measured 9.8 mm long, 9.6 mm wide and 6.6 mm thick; moderately biconvex, rhomboid in outline, length slightly greater than width, greatest width just anterior to shell midlength; posterolateral sides diverging at an angle of about 70 degree, anterolateral margin converging at about 90 degree, costae simple, few, only beginning at about midvalve, crests rounded, 1 within sulcus and 2 on fold, 3 on each flank, anterior commissure uniplicate.

Ventral valve moderately convex in lateral profile, strongly




**Text-Figure 21.** Serial sections of *Cyrolexis zhongliangshanensis* (Shen, He and Zhu) (NIGP141862).

domed in posterior profile, but median region slightly flattened in anterior profile ; beak sharp and thick, slightly attenuated, strongly incurved over dorsal umbo ; umbonal slopes sharply inclined, but lateral slopes moderately inclined ; sulcus moderately wide, beginning at midvalve and with a median costa, slightly bending toward dorsal valve ; dorsal valve gently convex in lateral profile, but strongly domed in posterior profile, maximum convexity at midvalve ; flanks evenly and moderately inclined ; fold narrow, originating just anterior to umbo, composed of two costae interspaced by a narrow intertroughs, distinctly higher than flanks near margins.

Internal characters unknown except for a ventral median septum seen in the beak.

*Discussion*.—The outline and costation of the described specimen suggests *Cyrolexis* Grant, 1965. However, the rhomboid outline and one costa within the ventral sulcus cannot be compared with any other species of *Cyrolexis.*

*Occurrence*.—B-24.

## Family PSILOCAMARIDAE Grant, 1965
## Subfamily PSILOCAMARINAE Grant, 1965
## Genus *Camarophorinella* Licharew, 1936

*Type species*.—*Camarophorinella caucasica* Licharew (1936, p. 63) from the Upper Permian in North Caucasus.

*Discussion*.—As Grant (1965, p. 148) noted, the camarophorium of *Camarophorinella* Licharew, 1936 differs from most genera in stenoscismataceans in that the edge of its trough are directly attached to the sides of the undivided hinge plates, whereas in most other genera, the hinge plates are undivided and joined to the midline of the camarophorium by the intercamarophorial plate, weakly connected laterally, or the camarophorium and hinge plates are entirely unconnected. This genus differs from *Cyrolexis* Grant, 1965 by its divided hinge plates and probably earlier costation.

*Occurrence*.—Middle and Late Permian, North Caucasus and South China.

### *Camarophorinella xiangnanensis* Liao and Meng, 1986

Plate 25, Figures 9-16 ; Text-Figure 22

*Camarophorinella xiangnanensis* Liao and Meng, 1986, p. 84, pl. 4, figs. 8-10, fig. 5.

*Material examined*.—Two complete conjoined shells (NIGP141865, 141866).

*Description*.—Small in size, subequally and gently biconvex, roundly pentagonal in outline, lateral sides regularly rounded, anterior margin broadly rounded ; costae beginning just anterior to beak, simple and with rounded crests, 2-3 in sulcus and 3-4 on fold, 4 on each flank, the outmost pair fairly weak, costae in sulcus and fold slightly stronger than those on flanks, anterior commissure moderately uniplicate.

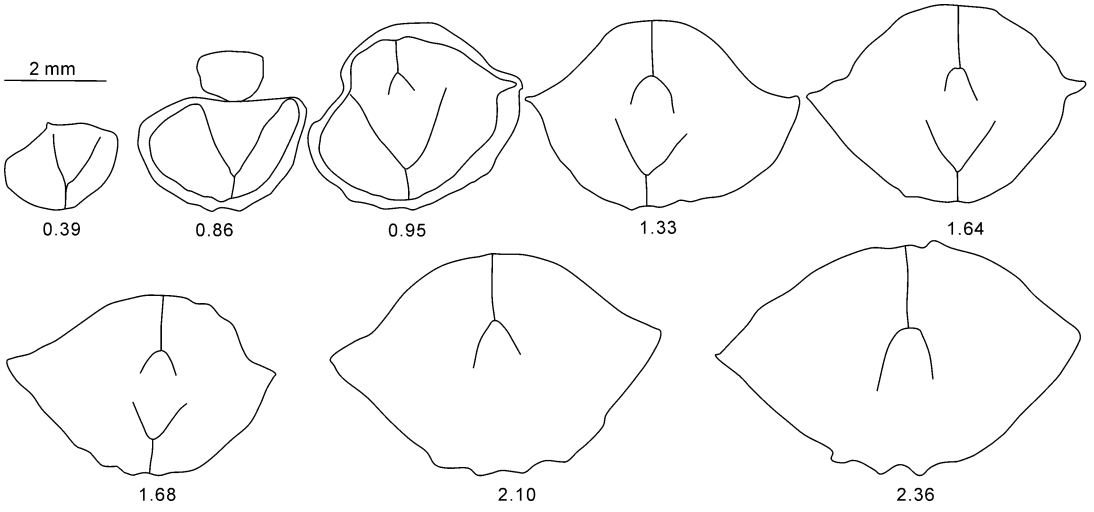
Ventral valve gently convex in lateral profile ; beak thick, suberect, umbonal region moderately domed in posterior profile ; flank gently inclined ; sulcus beginning just anterior to umbonal region, widening and deepening anteriorly, slightly bending toward dorsal valve near margin ; dorsal valve evenly and gently convex in lateral profile ; flanks regularly and moderately inclined ; fold commencing from umbonal region, becoming distinct near margins.

Ventral interior with deep spondylium supported by low median septum ; dorsal hinge plates divided, camarophorium cap-shaped, also supported by a thin and high median septum, intercamarophorial septum totally absent (Text-Figure 22).

*Measurements (in mm)*.—

| Specimen no. | L | W | T |
|---|---|---|---|
| NIGP141865 | 8.1 | 9.6 | 5.0 |
| NIGP141866 | 7.3 | 9.2 | 4.1 |

*Discussion*.—This species differs from *Camarophorinella huatangensis* Liao and Meng (1986, p. 85, pl. 5, figs. 32-35) by its fewer costae in the sulcus, from *C. leveni* Grunt (Grunt and Dmitriev, 1973, p. 126, pl. 8, fig. 15) from the Dzhulfa Formation of southeast Pamir in its spherical profile, not




**Text-Figure 22.** Serial sections of *Camarophorinella xiangnanensis* Liao and Meng (NIGP141865).

bifurcating costae and subcircular outline.

*Occurrence*.—Jb–5.

### Genus *Hybostenoscisma* Liao and Meng, 1986

*Type species*.—*Hybostenoscisma bambosoides* Liao and Meng (1986, p. 83, pl. 4, figs. 35–39, fig. 4) from the Changhsing Formation at Dapaichong, Chenxian, Hunan Province.

*Discussion*.—*Hybostenoscisma* is distinguished from *Cyrolexis* by its corrugated costation only which may be interspecific variations.

### *Hybostenoscisma bambosoides* Liao and Meng, 1986

Plate 25, Figures 17–36; Text-Figure 23

*Hybostenoscisma bambusoides* Liao and Meng, 1986, p. 83, pl. 4, figs. 35–39, fig. 4.

*Material examined*.—Six complete conjoined shells (NIGP141867–141872).

*Description*.—Shell moderately biconvex, subtriangular in outline, posterolateral sides diverging at about 110 degree, anterior margin irregularly convex anteriorly; anterior commissure strongly uniplicate; costae beginning from umbonal region, simple and with rounded crests, interrupted by 2–3 irregularly spaced concentric lamellae, producing corrugated appearance, 2 costae in sulcus and 3 on fold, 4–5 on each flank.

Ventral valve moderately convex in lateral profile; beak thick and blunt; umbonal region strongly domed; sulcus fairly deep, beginning near beak, slightly bending dorsally, forming a moderate front tongue; flanks moderately inclined; dorsal valve slightly more convex than ventral valve, maximum convexity anterior to midvalve; fold high, originating from beak; flanks moderately inclined.

Ventral interior with a wide V-shaped spondylium supported by a median septum; dorsal hinge plates unknown; camarophorium U-shaped, supported by high median septum, intercamarophorial plate unknown (Text-Figure 23).

*Measurements*.—

| Specimen no. | L | W | T |
|---|---|---|---|
| NIGP141867 | 12.1 | 13.7 | 9.1 |
| NIGP141868 | 12.5 | 16.4 | 9.9 |
| NIGP141869 | 11.6 | 12.8 | 8.6 |
| NIGP141870 | 8.5 | 10.3 | 5.8 |
| NIGP141871 | 10.0 | 11.4 | 7.6 |
| NIGP141872 | 10.8 | 11.2 | 7.0 |

*Discussion*.—*Stenoscisma armenica* Sokolskaja (in Ruzhentsev and Sarytcheva, 1965, p. 234, pl. 40, figs. 9a–c; Grunt and Dmitriev, 1973, p. 128, pl. 8, figs. 13–14; pl. 14, fig. 8) also has corrugated costae as in the present species, but it differs in its more transverse outline, stronger costae and 4 costae in sulcus.

*Occurrence*.—Jc–15.

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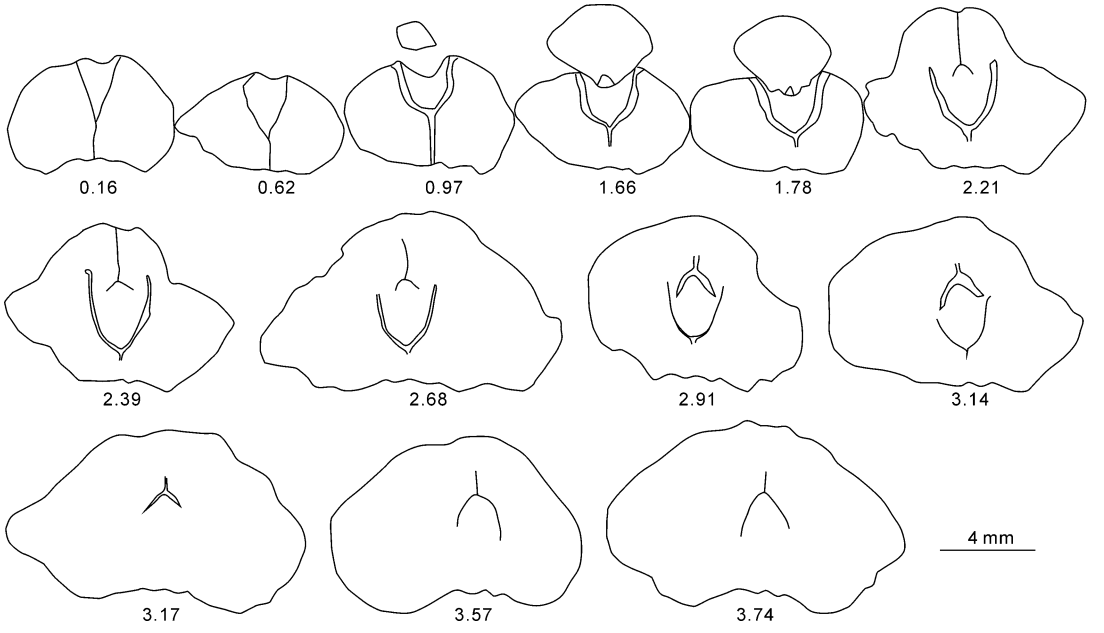


**Text-Figure 23.** Serial sections of *Hybostenoscisma bambosoides* Liao and Meng (NIGP141867).

and Zhu Mei-li of China University of Mining and Technology for their supervision when SSZ first studied the specimens during his PhD time in Xuzhou, China. Specimens from the Xiaoyuanchong, Dapaichong and Sanhe Sections in the Chenxian area, Hunan Province were collected by Zhang Zhipei. Specimens from the Tuanxi Section in Guizhou Province were collected by Men Dagong. Specimens from the Nantong and Yutianbao Sections in Chongqing were jointly collected by Zhang Chuan and SSZ. All other specimens were collected by SSZ. This work is also supported by the Major Basic Research Projects (2006CB806400) of the MST of China and NSFC (Grant nos. 40621062, 40225005, 40321202, 40328003) and CAS (2006-1-16) for both authors. GRS acknowledges the Australian Research Council and Deakin University for supporting his research on the Permian biotas and biogeography of the Asian-Pacific region.

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## Explanation of Plates

All specimens are in natural size unless otherwise illustrated.

### Plate 1

**Figures 1–11,** *Meekella kueichowensis* Huang. **1–4**, ventral, dorsal, lateral and anterior views, NIGP141516, from F–29, Changhsing Formation; **5–8**, ventral, lateral, dorsal and anterior views, NIGP141517, from F–18, Lungtan Formation; **9**, dorsal view, NIGP141520, from D–5, Wangjiazhai Formation; **10**, dorsal view, NIGP141518, from F–6, Changhsing Formation; **11**, ventral view with a *Permophricodothyris* on the left side of the specimen, NIGP141521; from F–6, Changhsing Formation.

### Plate 2

**Figures 1–12,** *Meekella kueichowensis* Huang. **1–4**, ventral, dorsal, lateral and anterior views, NIGP141519, from A–11, Changhsing Formation; **5–8**, a juvenile specimen, lateral, ventral, anterior and dorsal views, NIGP141527, from F–33, Changhsing Formation; **9**, ventral view, NIGP141523, showing two separated parallel dental plates, from F–20, Lungtan Formation; **10**, ventral view, NIGP141524, showing strong ventral muscle scars in mature specimen, from F–20, Lungtan Formation; **11**, ventral view, NIGP141522, from F–20, Lungtan Formation; **12**, ventral view showing two strong, but slightly convegent dental plates, from G–32, Wuchiaping Formation.

**Figures 13–26,** *Meekella arakeljani* (Sokolskaja). **13–15**, **17**, ventral, dorsal, anterior and lateral views, NIGP141529, from A–26, Beifengjing, Changhsing Formation; **16**, **18–20**, ventral, dorsal, lateral and anterior views, NIGP141528, from C–17, Changhsing Formation; **21–23**, lateral, ventral, and dorsal views, NIGP141530, from F–16, Lungtan Formation; **24–26**, all ventral views, NIGP141534, from G–32, Wuchiaping Formation, NIGP141532, from Jc–15, Changhsing Formation, NIGP141533, from H–137, Talung Formation.

### Plate 3

**Figures 1–6,** *Meekella* cf. *deltoides* Liao. **1–3**, Lateral, dorsal and ventral views, NIGP141536, from A–26, Beifengjing, Changhsing Formation; **4–6**, ventral, dorsal and lateral views, NIGP141535, from F–29, Lungtan Formation.

**Figures 7–17,** *Meekella sichuanensis* Shen, He and Zhu. **7–10**, ventral, dorsal, anterior and lateral views, NIGP141537, from A–26, Changhsing Formation; **11–14**, ventral, dorsal, lateral and anterior views, NIGP141539 (=CUMT8242), holotype, from A–26, Changhsing Formation; **15–17**, ventral, anterior and lateral views, NIGP141538, from A–26, Changhsing Formation.

**Figures 18–21,** *Meekella versiformis* Shen, He and Zhu. ventral, dorsal, lateral and anterior views, NIGP141540 (=CUMT8241), from A–26, Changhsing Formation.

### Plate 4

**Figures 1–4,** *Meekella heterofolda* Liang. Ventral, dorsal, anterior and lateral views, NIGP141541 (=CUMT8251), from A–26, Changhsing Formation.

**Figures 5–13,** *Meekella pusilloplicata* Liao. **5**, ventral view, NIGP141545, from G–32, Wuchiaping Formation; **6–9**, ventral, dorsal, lateral and anterior views, NIGP141542, from F–22, Lungtan Formation; **10–12**, lateral, dorsal and ventral views, NIGP141544, from E–29, Lungtan Formation; **13**, ventral view, NIGP141543, from F–21, Lungtan Formation.

**Figures 14–17,** *Meekella abnormalis* Huang. dorsal, lateral, anterior and ventral views, NIGP141546, from F–16, Lungtan Formation.

**Figures 18–25,** *Meekella beipeiensis* Chen. **18–21**, lateral ventral, anterior and dorsal views, NIGP141551, from B–25, Changhsing Formation; **22–25**, ventral, anterior, lateral and dorsal views, NIGP141548, from B–25, Changhsing Formation.

### Plate 5

**Figures 1–14,** *Meekella beipeiensis* Chen. **1–3**, ventral, lateral and anterior views, NIGP141555, from B–22, Changhsing Formation; **4–7,** ventral, lateral, anterior and dorsal views, NIGP141553, from B–22, Changhsing Formation; **8–11**, ventral, lateral, anterior and dorsal views, NIGP141557, from B–22, Changhsing Formation; **12–14**, ventral, dorsal and lateral views, NIGP141554, from C–15, Changhsing Formation.

**Figures 15–21,** *Meekella chenxianensis* n. sp. **15–17**, lateral ventral and dorsal views, NIGP141560, from Jc–15, Changhsing Formation; **18–21**, ventral, lateral, anterior and dorsal views, NIGP141559, holotype, from Jc–15, Changhsing Formation.

### Plate 6

**Figures 1–3,** *Meekella chenxianensis* n. sp. **1–2**, ventral and dorsal views, NIGP141563, from Jc–15, Changhsing Formation; **3**, ventral view, NIGP141562, from Jc–15, Changhsing Formation.

**Figures 4–18,** *Orthothetina ruber* (Frech). **4–7**, dorsal, ventral, anterior and lateral views, NIGP141577, ×2, from Jc–15, Changhsing Formation; **8**, dorsal view, NIGP141567, ×2, from A–20, Changhsing Formation; **9**, ventral view, NIGP141569, ×1.5, from F–6, Lungtan Formation; **10**, a ventral valve (right) and a dorsal valve (left), from G–3, Wuchiaping Formation; **11**, **12**, a specimen with two ventral internal moulds, NIGP141572 (left), NIGP141573 (right), external moulds of the sam specimen, from G–32, Wuchiaping Formation; **13**, ventral view, NIGP141570, from F–15, Lungtan Formation; **14**, ventral view, NIGP141565, from A–11, Changhsing Formation; **15**, ventral view showing two short dental plates, NIGP141576, from F–19, Lungtan Formation; **16**, dorsal view, NIGP141566, from A–9, Changhsing Formation; **17**, dorsal view showing two strongly divergent brachiophore plates, NIGP141568, from G–3, Wuchiaping Formation; **18**, dorsal view, showing two strongly divergent brachiophore plates, NIGP141575, from G–32, Wuchiaping Formation.

**Figures 19–24,** *Orthothetina regularis* (Huang). **19–22**, ventral, dorsal, lateral and anterior views, NIGP141582, ×2.5, from F–42, Changhsing Formation; **23**, ventral view, NIGP141580, ×2, from A–10, Changhsing Formation; **24**, ventral view showing two short dental plates, NIGP141578, ×2, from D–26, Wangjiazhai Formation.

**Figures 25–28,** *Orthothetina eusarkos* (Abich). **25**, ventral view, NIGP141586, from A–8, Changhsing Formation; **26**, dorsal view, NIGP141587, from A–8, Changhsing Formation; **27**, ventral view showing two close parallel dental plates, NIGP141585, from G–45, Changhsing Formation; **28**, dorsal view showing two strongly divergent brachiophore plates, NIGP141583, from G–45, Changhsing Formation.

**Figures 29–34,** *Orthothetina shuangtangensis* Liang. **29**, ventral view showing two close parallel dental plates, NIGP141589, from G–55, Talung Formation; **30–32**, ventral, dorsal and lateral views, NIGP141588, from A–26, Changhsing Formation; **33**, ventral view, NIGP141593, from A–26, Changhsing Formation; **34**, ventral view, NIGP141592, from A–26, Changhsing Formation.

**Plate 7**

**Figures 1–8,** *Orthothetina shuangtangensis* Liang. **1–4**, ventral, dorsal, lateral and anterior views, NIGP141590, from B–19, Changhsing Formation; **5–8**, lateral, ventral, dorsal and anterior views, NIGP141591, from C–26, Changhsing Formation.

**Figures 9–12,** *Orthothetina ellipsoides* Shen *et al.* ventral, lateral, dorsal and anterior views, NIGP141594 (=CUMT8237), from A–26, Changhsing Formation.

**Figures 13–20,** *Orthothteina triangularis* Tong. **13–16**, ventral, dorsal, anterior and lateral views, NIGP141598, ×1.5, from G–45, Changhsing Formation; **17–20**, ventral, dorsal, anterior and lateral views, NIGP141596, ×2.5, from A–26, Changhsing Formation.

**Figures 21–24,** *Orthothetina elongata* Nakamura. ventral, dorsal, lateral and anterior views, NIGP141599, from A–26, Changhsing Formation.

**Figures 25–29,** *Orthothetina frechi* Huang. **25**, ventral view, NIGP141603, from F–26, Lungtan Formation; **26**, external mould of a ventral valve, NIGP141601, from F–29, Lungtan Formation; **27**, ventral view, NIGP141600, from F–29, Lungtan Formation; **28**, ventral view showing two short dental plates, NIGP141604, from D–5, Wangjiazhai Formation; **29**, ventral view, NIGP141602, from D–18, Wangjiazhai Formation.

**Figure 30,** *Paraorthotetina provecta* (Liao). ventral interior showing two divergent dental plates and strong muscular scars, NIGP141606, from F–10, Lungtan Formation.

**Plate 8**

**Figures 1–16,** *Perigeyerella costellata* Wang. **1–4**, ventral, dorsal, lateral and anterior views, NIGP141607, from A–26, Changhsing Formation; **5–8**, ventral, dorsal anterior and lateral views of a juvenile specimen, NIGP141610, ×5, from A–26, Changhsing Formation; **9–12**, ventral, dorsal, lateral and anterior views, NIGP141613, from E–43, Changhsing Formation; **13–15**, anterior, ventral and dorsal views, NIGP141608, from A–26, Changhsing Formation; **16**, ventral view, NIGP141612, ×3, from I–70, Heshan Formation.

**Figures 17–30,** *Perigeyerella fastigata* Liao and Meng. **17–20**, ventral, dorsal, lateral and anterior views, NIGP141620, from Jc–15, Changhsing Formation; **21–23**, ventral, dorsal and lateral views, NIGP141619, from Jc–15, Changhsing Formation; **24–26**, lateral, posterior and ventral views, NIGP141614, from Jc–15, Chenxian, Changhsing Formation; **27–30**, anterior, lateral, ventral and dorsal views, NIGP141615, from Jb–4, Changhsing Formation.

**Plate 9**

**Figures 1–11,** *Perigeyerella fastigata* Liao and Meng. **1–3**, ventral, dorsal and lateral views, NIGP141617, from Jc–15, Changhsing Formation; **4–7**, ventral, dorsal, lateral and anterior views, NIGP141616, from B–25, Changhsing Formation; **8–10**, ventral, dorsal and lateral views, NIGP141618, from Jc–15, Changhsing Formation; **11**, ventral view, NIGP141621, ×2, from Jc–15, Changhsing Formation.

**Figures 12–19,** *Perigeyerella tricosa* Grant. **12–15**, ventral, dorsal, lateral and anterior views, NIGP141623, from G–45, Changhsing Formation; **16–19**, ventral, lateral, anterior and dorsal views, NIGP141624, from B–24, Changhsing Formation.

**Figures 20–28.** *Perigeyerella chenxianensis* n. sp. **20–24**, anterior, dorsal, lateral, posterior and ventral views, NIGP141625, holotype, from Jc–15, Changhsing Formation; **25–28**, anterior, lateral, ventral and dorsal views, NIGP141626, from Jc–15, Changhsing Formation.

**Figures 29–32,** *Perigeyerella obesa* n. sp. ventral, dorsal, anterior and lateral views, NIGP141628, holotype, from B–24, Changhsing Formation.

**Plate 10**

**Figures 1–12,** *Perigeyerella obesa* n. sp. **1–4**, ventral, dorsal, lateral and anterior views, NIGP141629, from B–24, Changhsing Formation; **5–8**, anterior, lateral, dorsal and ventral views, NIGP141630, from B–22, Changhsing Formation; **9–12**, ventral, dorsal, lateral and anterior views, NIGP141627, from B–24, Changhsing Formation.

**Figure 13,** *Perigeyerella* sp. ventral view, NIGP141631, from A–26, Changhsing Formation.

**Figures 14–24,** *Geyerella distorta* Schellwien. **14–15**, ventral and posterior views, NIGP141635, from Jb–4, Changhsing Formation; **16–19**, dorsal, anterior, posterior and ventral views, NIGP141633, from Jb–4, Changhsing Formation; **20–23**, anterior, posterior, lateral and dorsal views, NIGP141632, from Jb–4, Changhsing Formation; **24**, anterior view, NIGP141634, from Jb–4, Changhsing Formation.

**Figures 25–30**, *Meekeelogeyerella meekelloides* n. gen. and n. sp. **25–29**, ventral, lateral, anterior, posterior and dorsal views, NIGP141636, holotype, from Jb–4, Changhsing Formation; **30**, ventral view, NIGP141637, from Jb–4, Changhsing Formation.

**Plate 11**

**Figures 1–26,** *Derbyia acutangula* (Huang). **1–4**, ventral, lateral, dorsal and anterior views, NIGP141639, from A–8, Changhsing Formation; **5–8**, anterior, dorsal, ventral and lateral views, NIGP141640, from A–8, Changhsing Formation; **9–12**, ventral view showing the median septum in the ventral valve, lateral, dorsal and anterior views, NIGP141643, from D–5, Wangjiazhai Formation; **13–16**, anterior, lateral, dorsal and ventral views, NIGP141651, from A–28, Changhsing Formation; **17**, dorsal view of an adult specimen showing the mucronate ears, NIGP141641, from A–10, Changhsing Formation; **18**, ventral view of an adult specimen showing the mucronate ears, NIGP141638, from A–8, Changhsing Formation; **19**, ventral view, NIGP141645, from G–45, Changhsing Formation; **20**, ventral view, NIGP141649, from G–32, Wuchiaping Formation; **21**, dorsal view showing two widely divergent brachiophore plates, NIGP141648, from G–32, Wuchiaping Formation; **22**, ventral view, NIGP141642, from F–22, Lungtan Formation; **23–25**, dorsal, ventral and lateral view of an immature specimen, NIGP141650, from A–26, Changhsing Formation; **26**, dorsal view, NIGP141652, from D–2, Wangjiazhai Formation.

**Figures 27–28,** *Derbyia regularis* Waagen. **27**, ventral view, NIGP141655, from F–18, Lungtan Formation; **28**, ventral view, NIGP141654, from G–45, Changhsing Formation.

**Plate 12**

**Figures 1–3.** *Derbyia schellwieni* Frech. **1**, ventral view, NIGP141657, from G–55, Talung Formation; **2**, ventral view, NIGP141658, ×1.5, from A–9, Changhsing Formation; **3**, ventral view showing the median septum in the ventral valve, NIGP141656, from F–6, Lungtan Formation.

**Figure 4,** *Derbyia regularis* Waagen. Ventral view, NIGP141653, from F–21, Lungtan Formation.

**Figures 5–9,** *Derbyia guidingensis* Shen and He. **5–8**, lateral, ventral, dorsal and anterior views, NIGP141660 (=CUMT8162), holotype,

from G–45, Changhsing Formation; **9**, dorsal view, NIGP141662, from G–55, Talung Formation.
**Figures 10–11,** *Derbyia* sp. 2. **10**, ventral view, NIGP141665, from B–24, Changhsing Formation; **11**, ventral view, NIGP141666, from Jc–15, Changhsing Formation.
**Figure 12,** *Derbyia* sp. 1. ventral view, NIGP141664, from G–45, Changhsing Formation.
**Figure 13,** *Derbyia* sp. 3. ventral view, NIGP141667, from G–45, Changhsing Formation.
**Figure 14,** *Derbyia dirata* Grant. ventral view, NIGP141663, from A–26, Changhsing Formation.
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**Figure 25,** *Streptorhynchus tenuiplicatus* Liao. ventral view, NIGP141671, ×1.5, from I–18, Heshan Formation.
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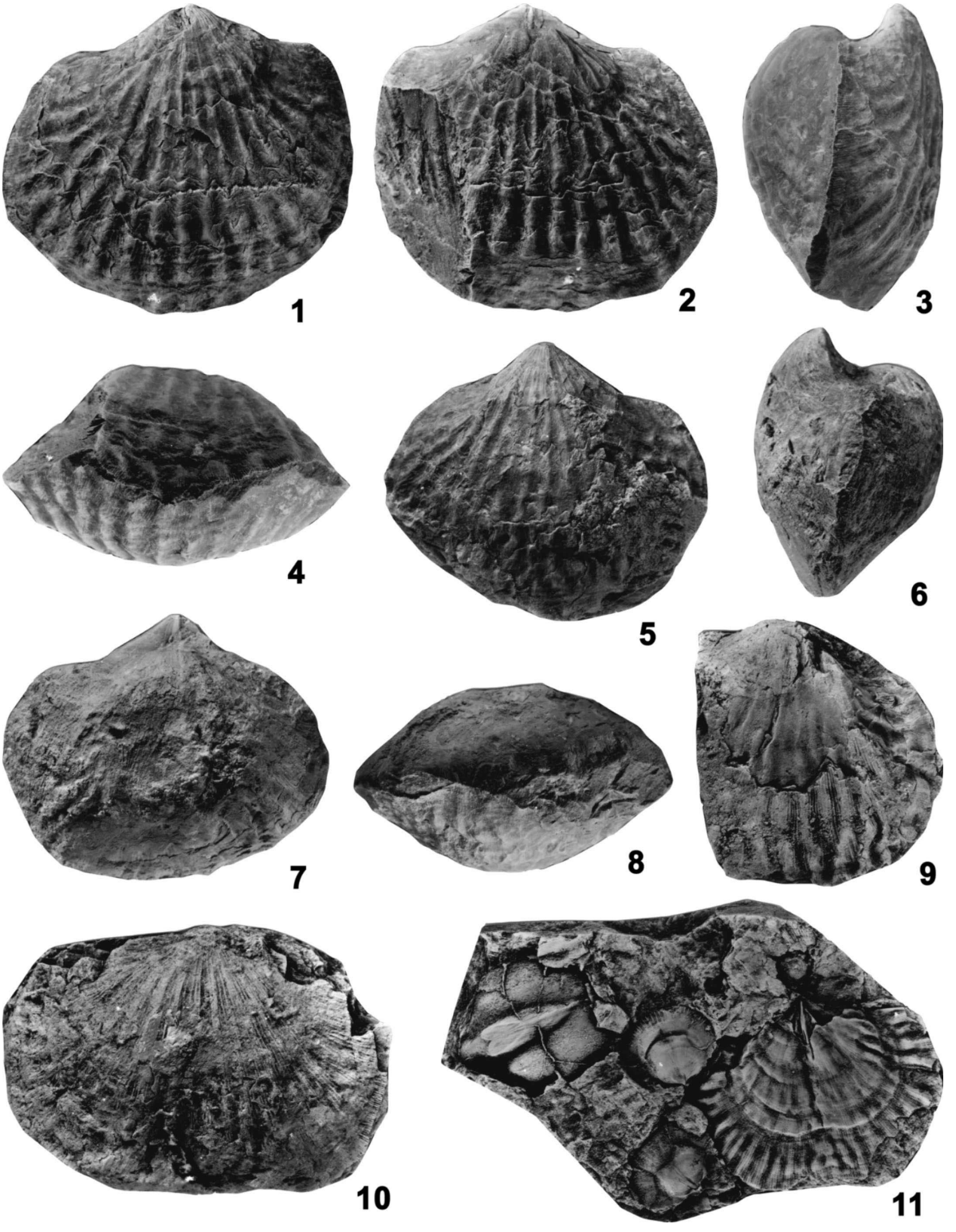


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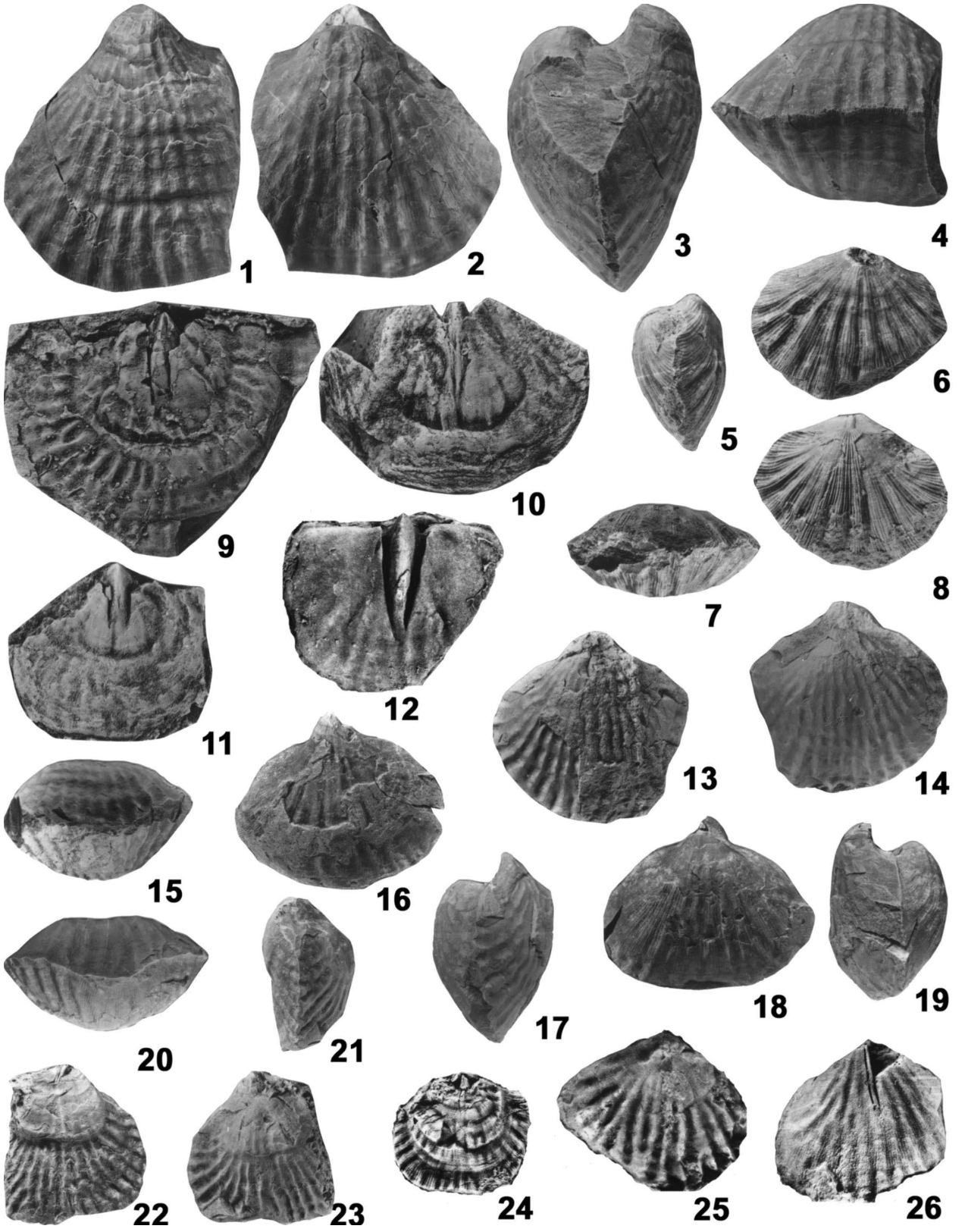


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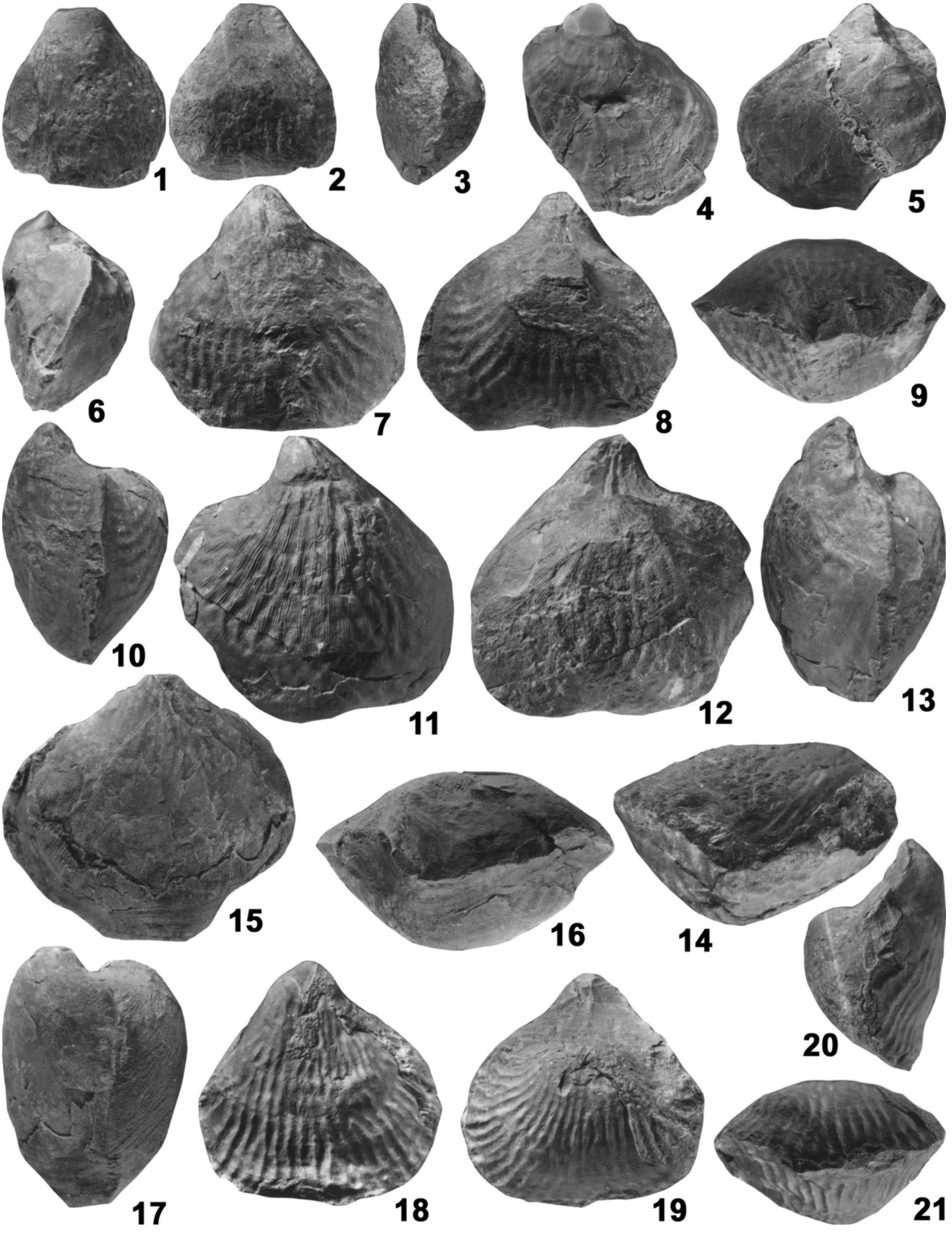


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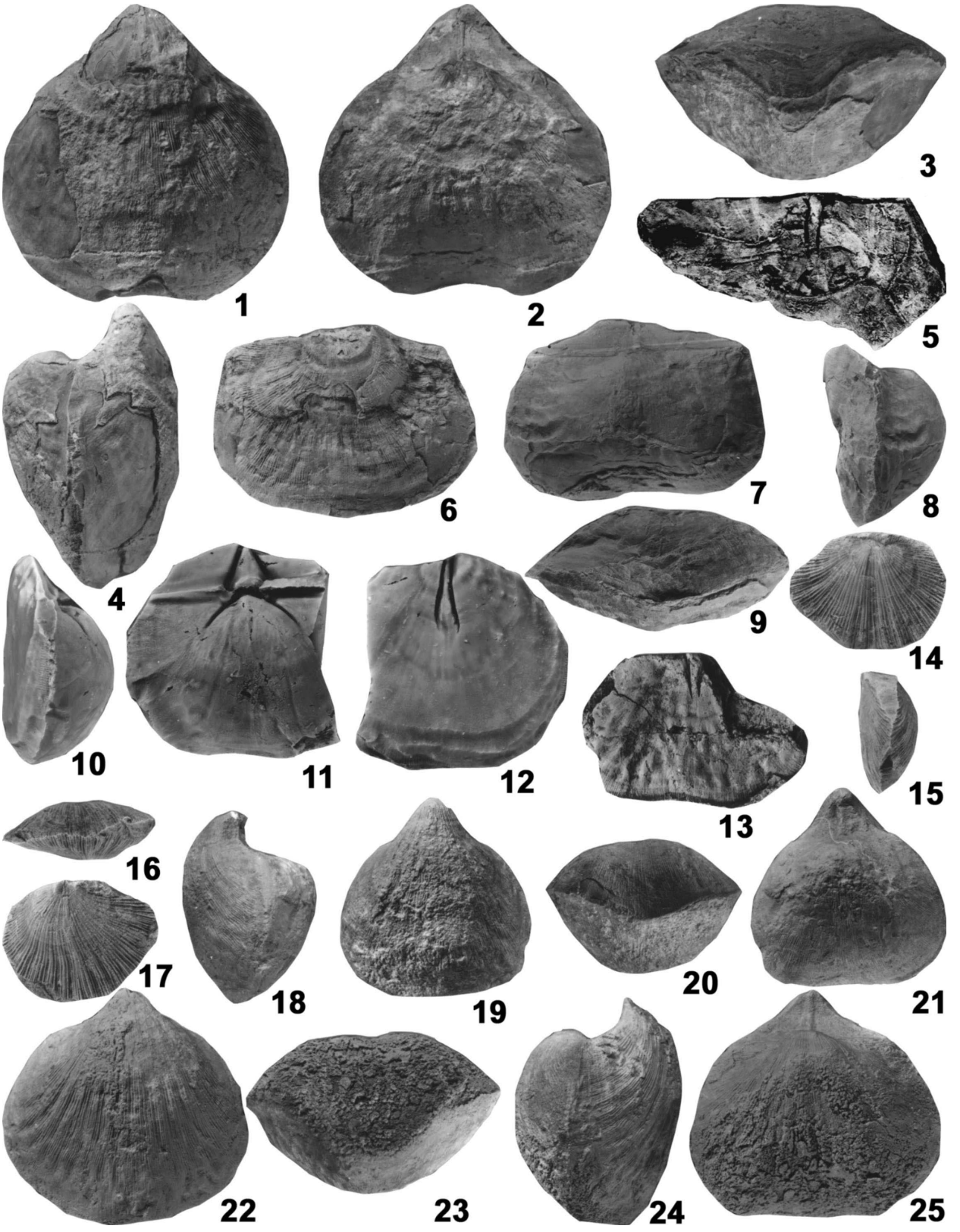


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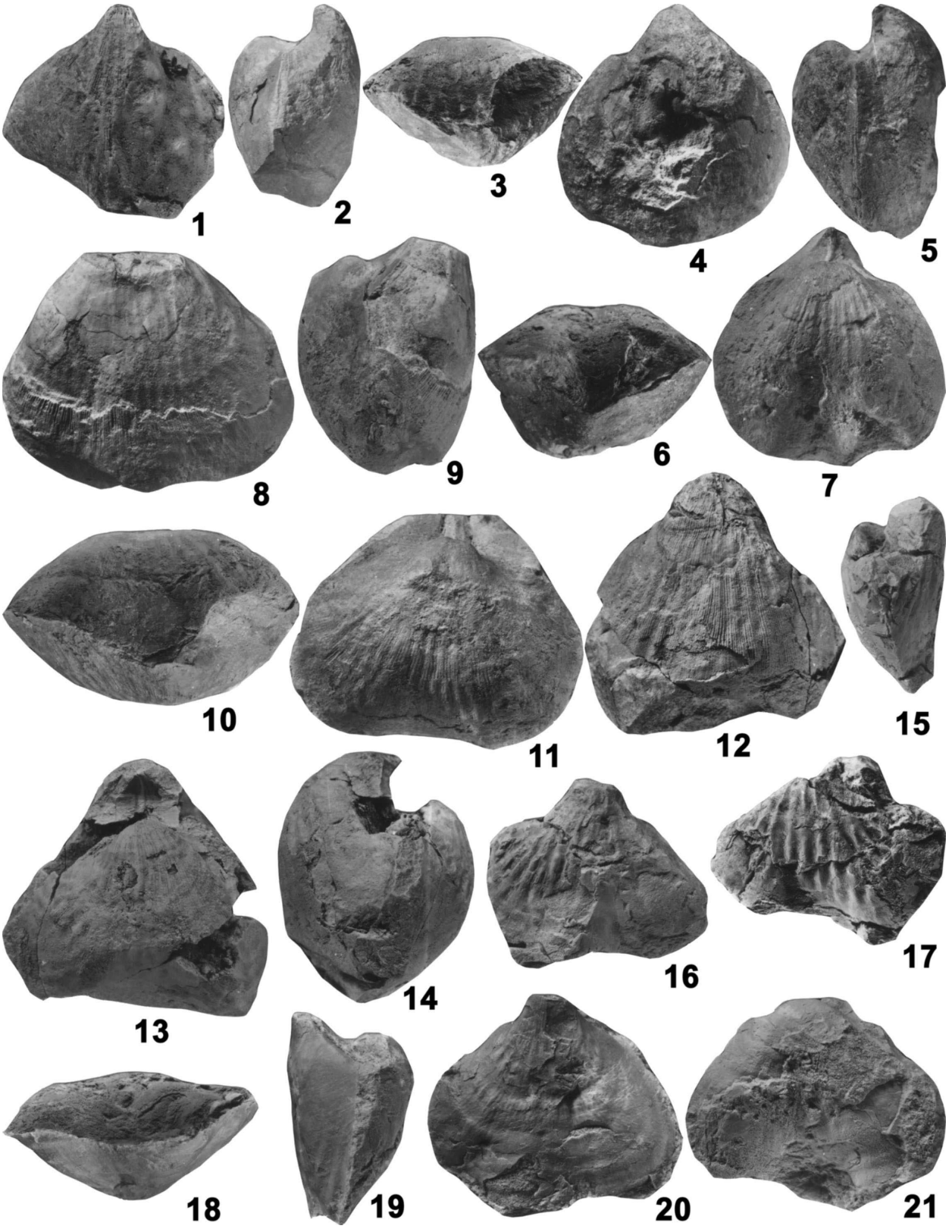


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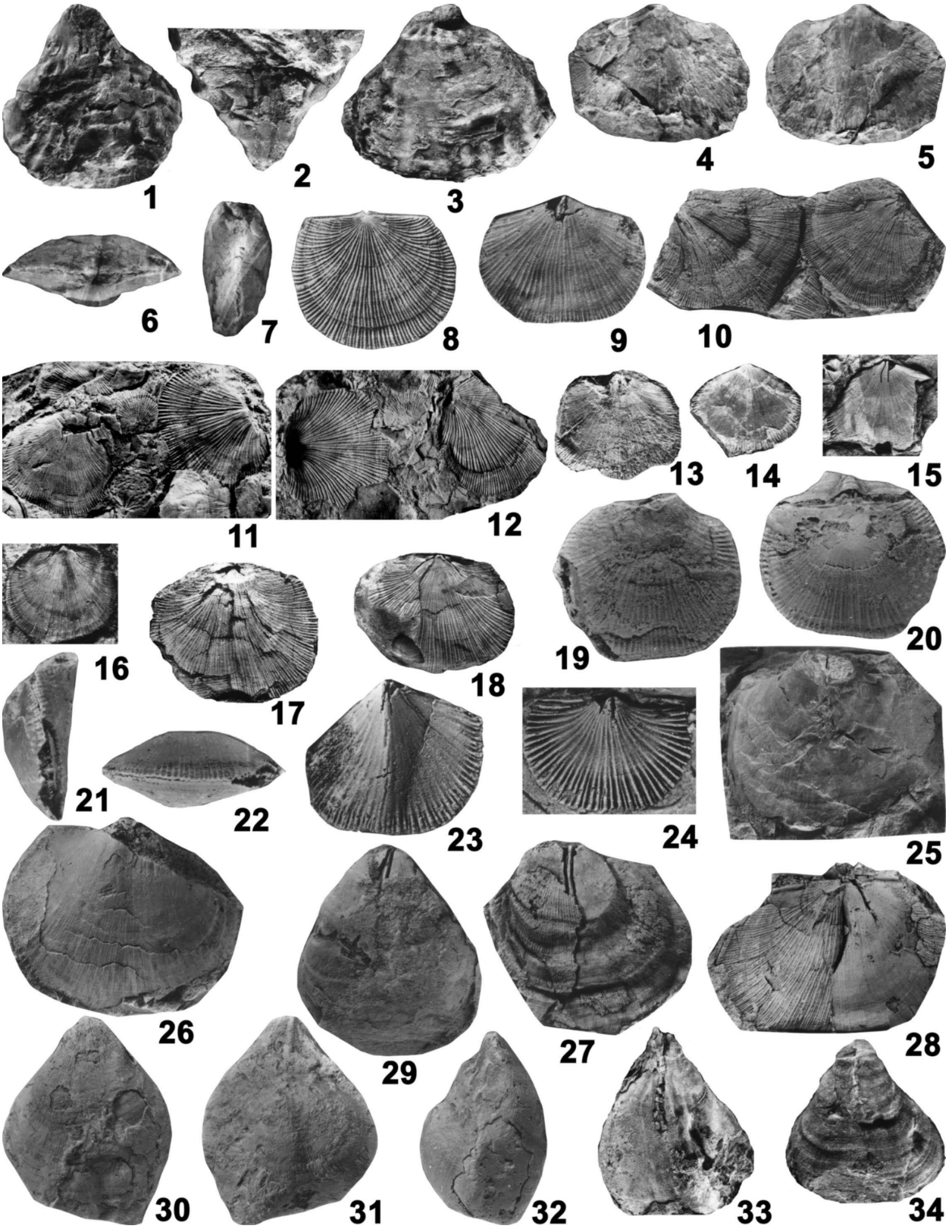
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Plate 6

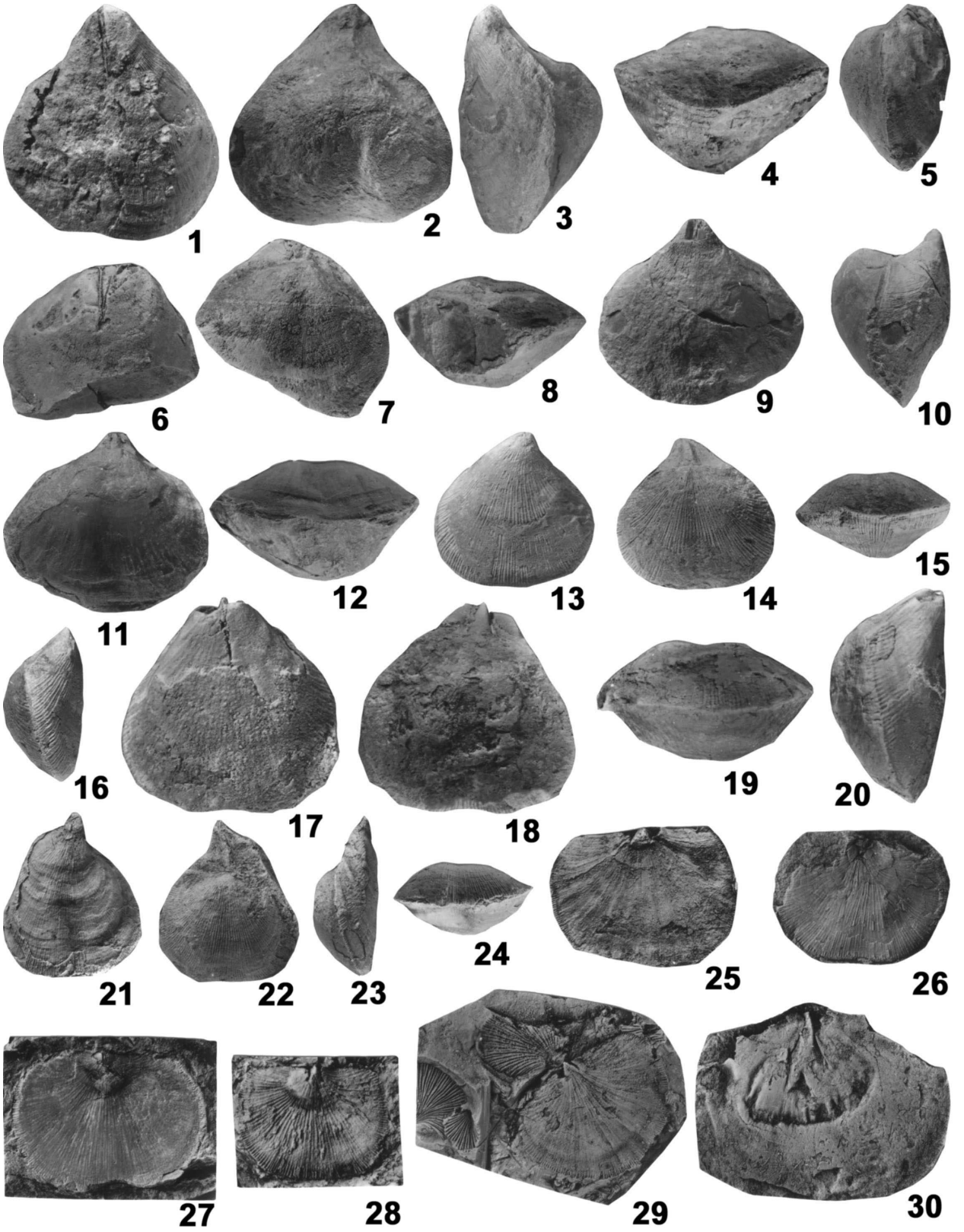
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Plate 7

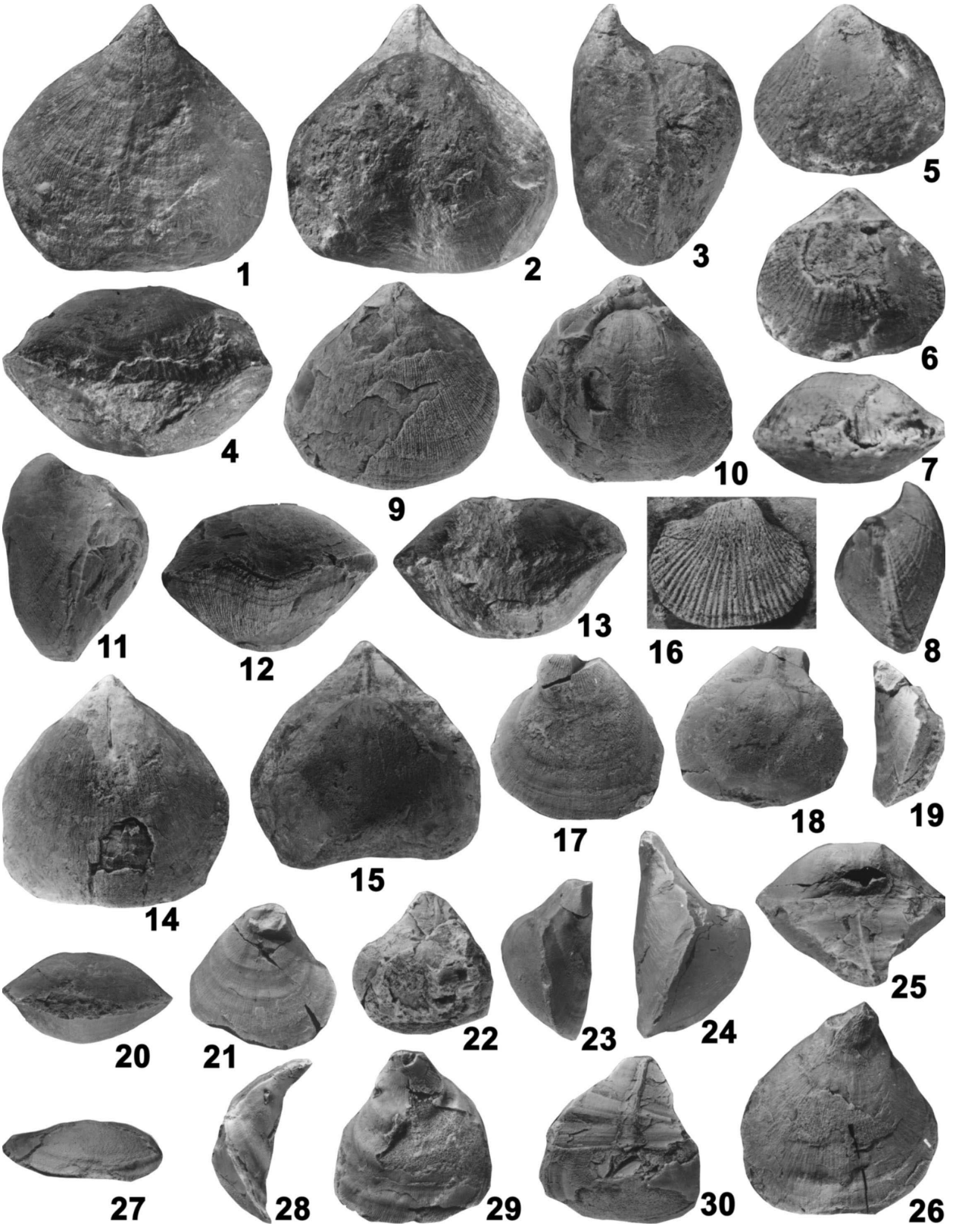
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Plate 8

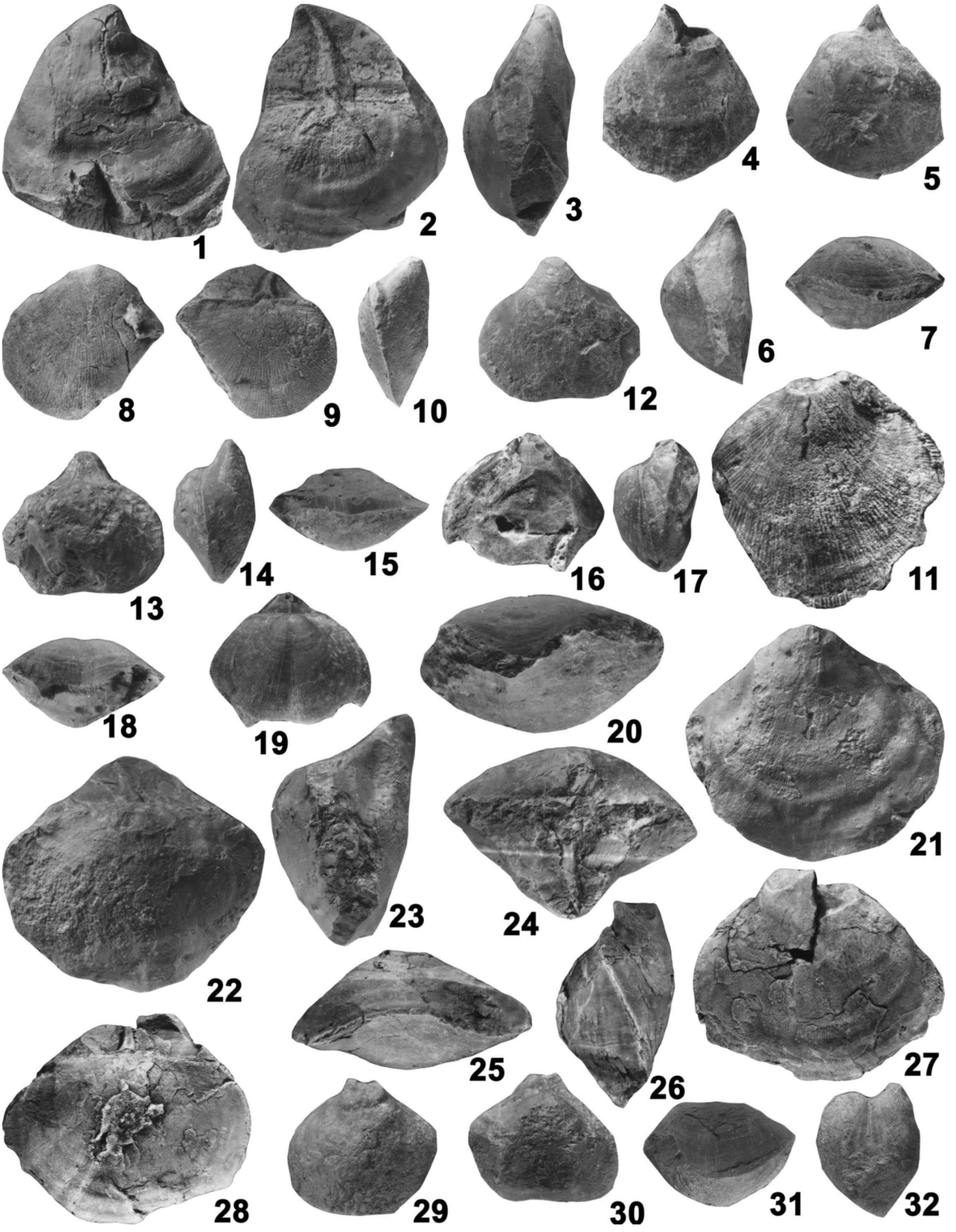
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Plate 9

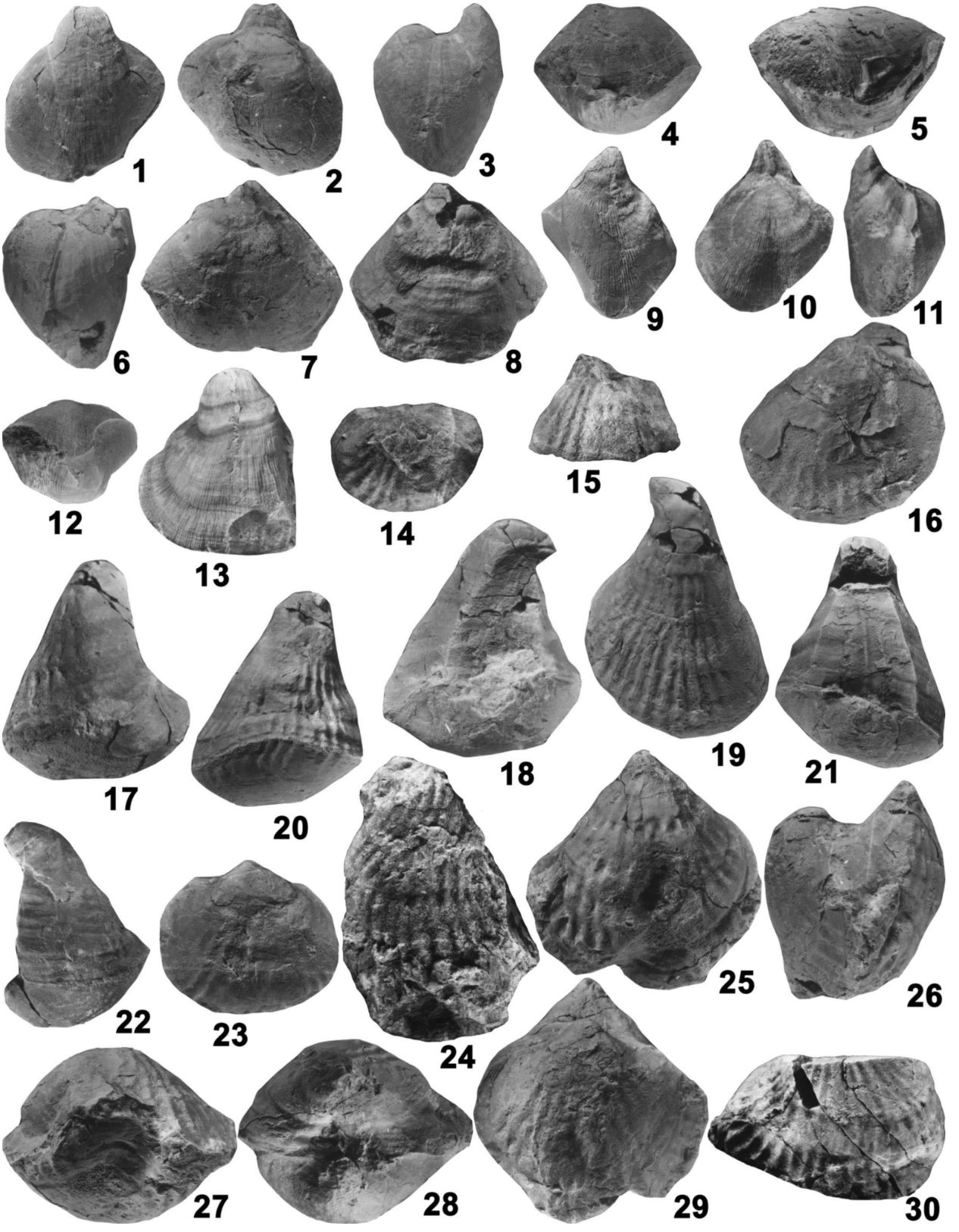
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Plate 10

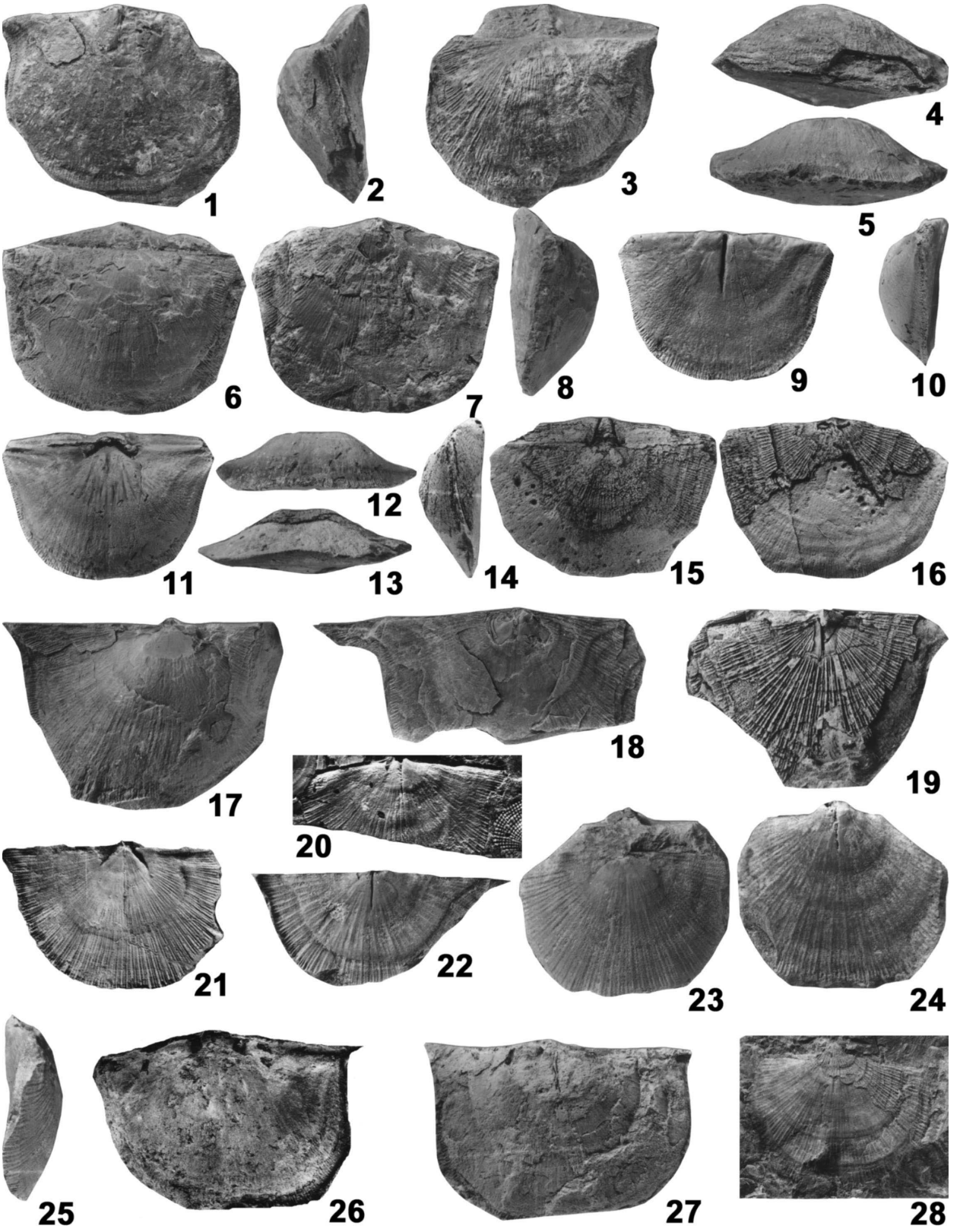


Plate 11

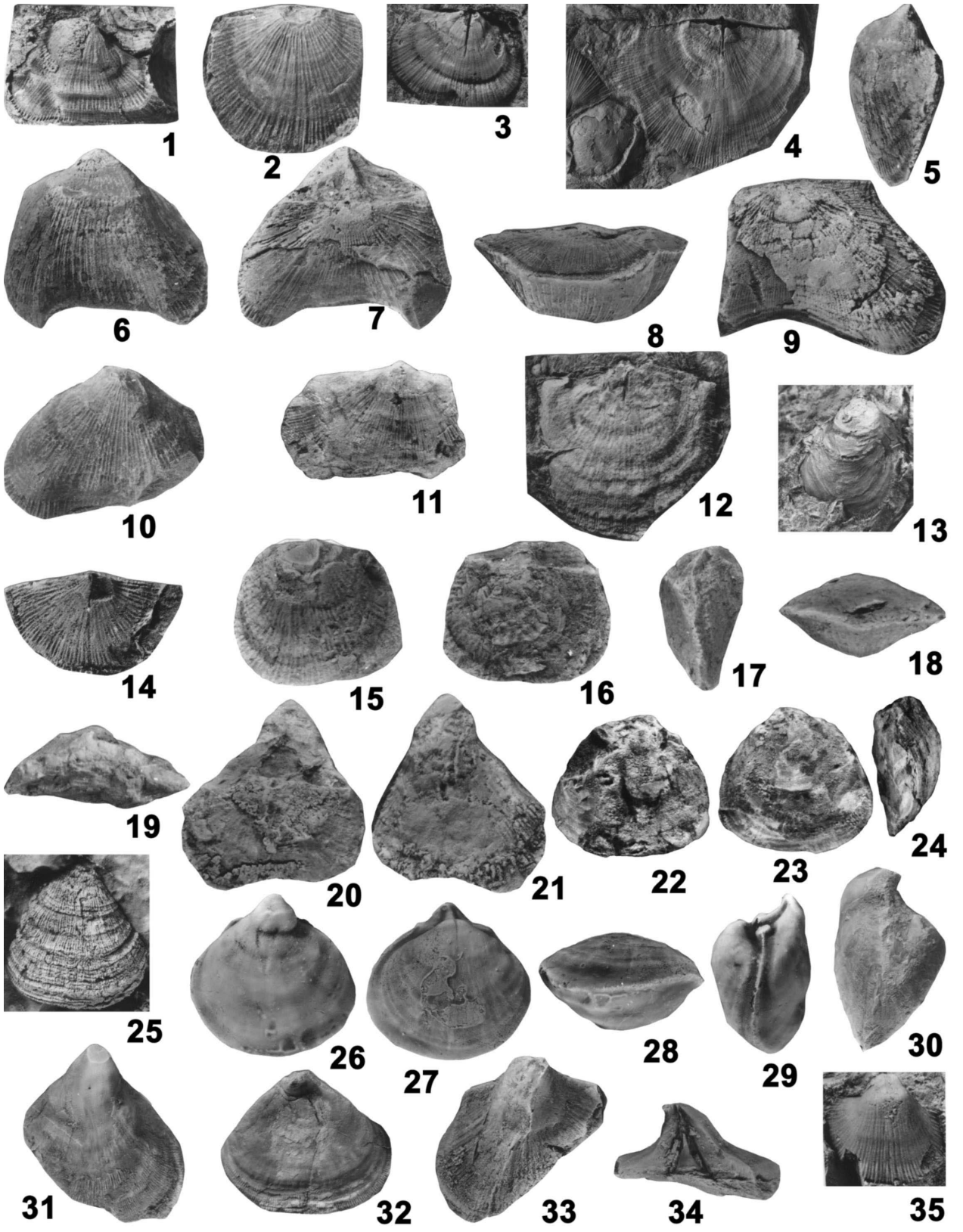
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Plate 12

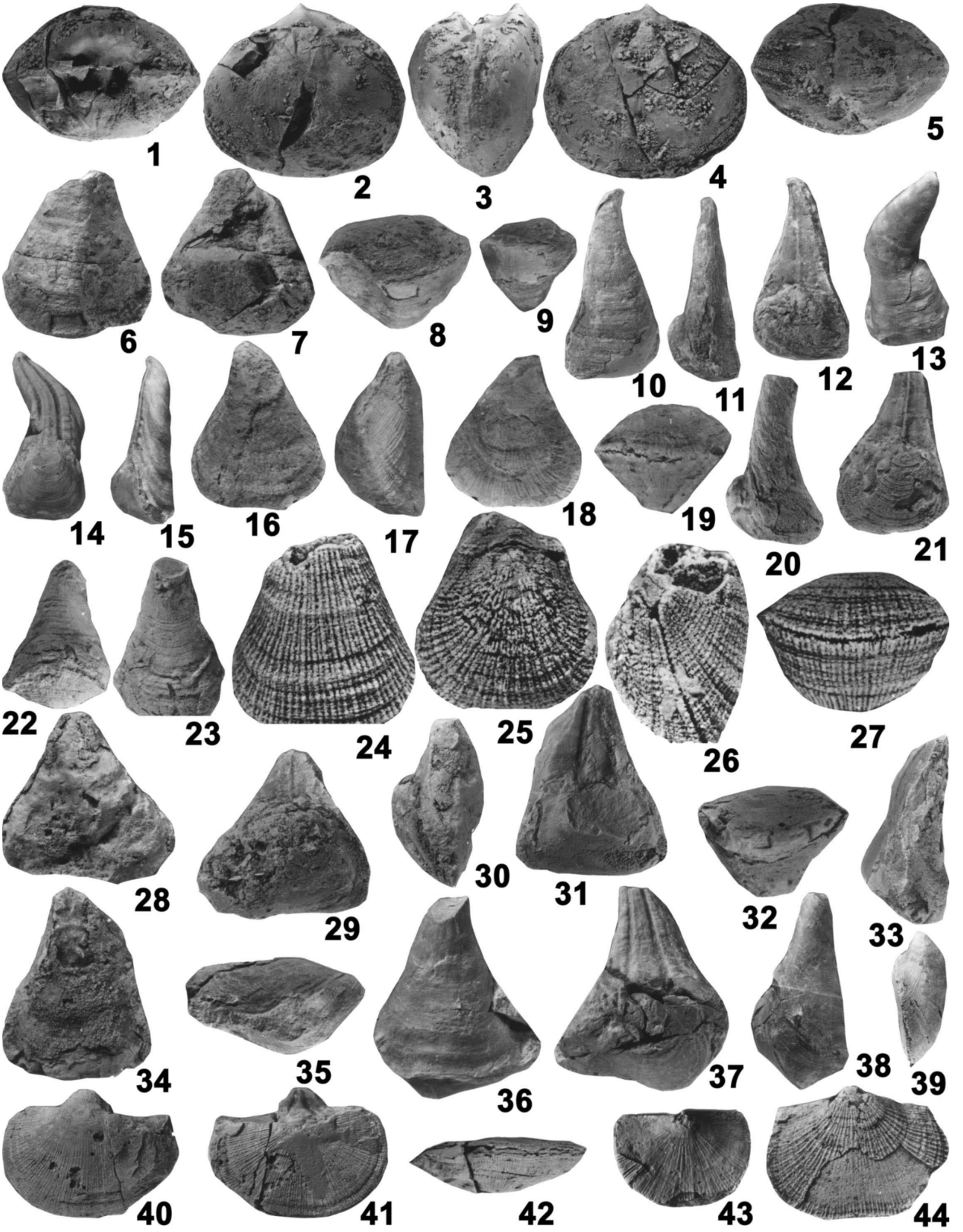
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Plate 13

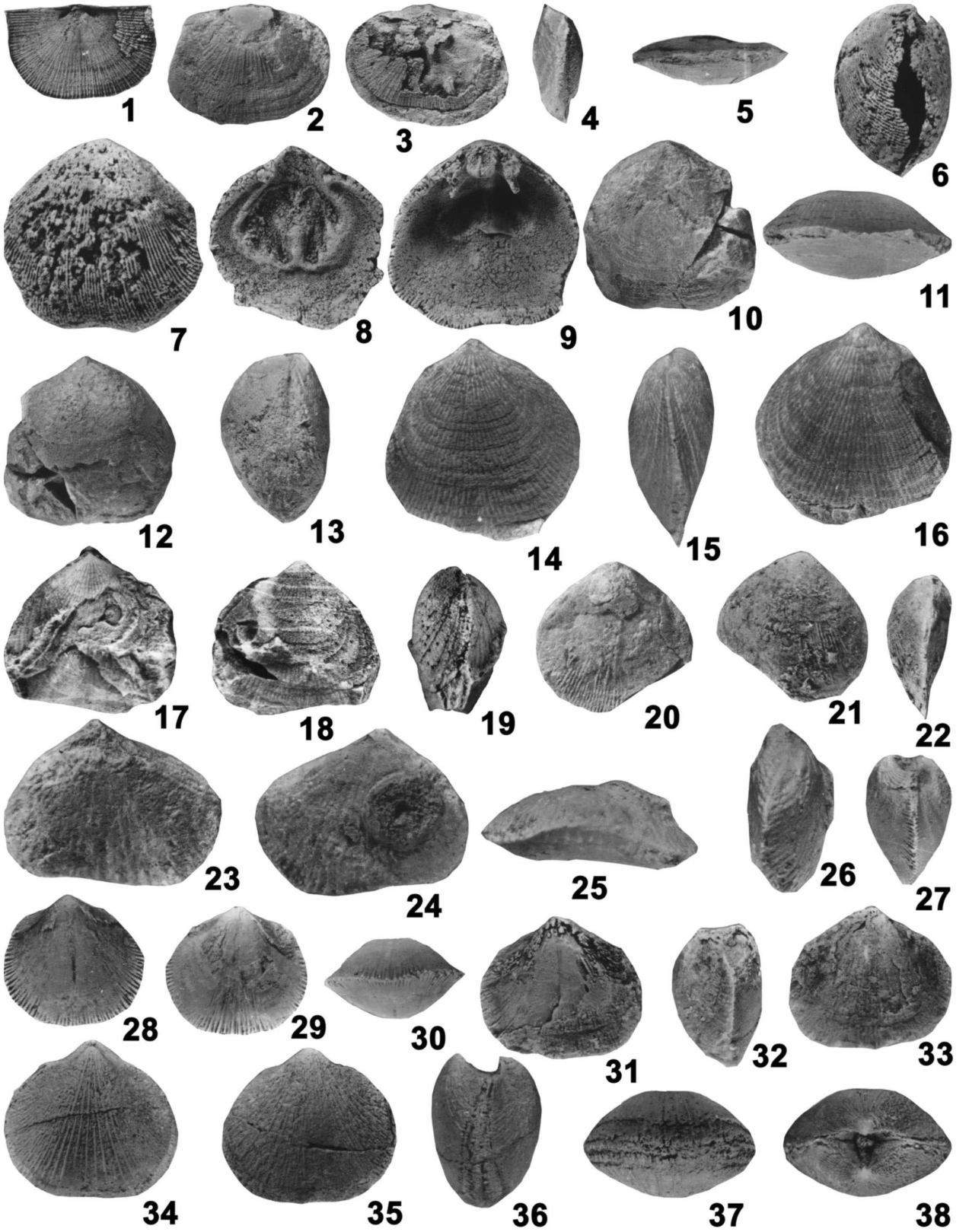
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Plate 14

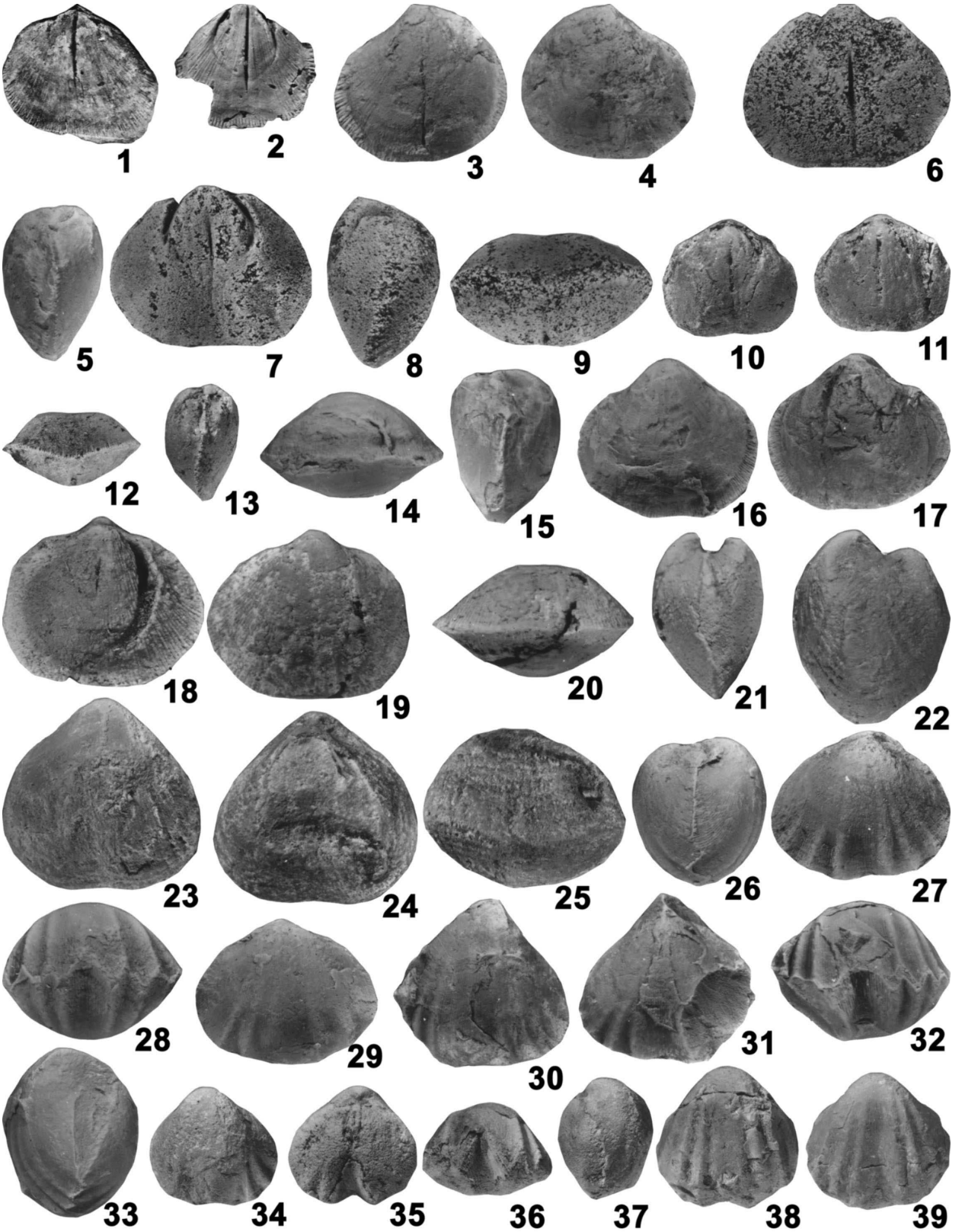
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**Plate 15**

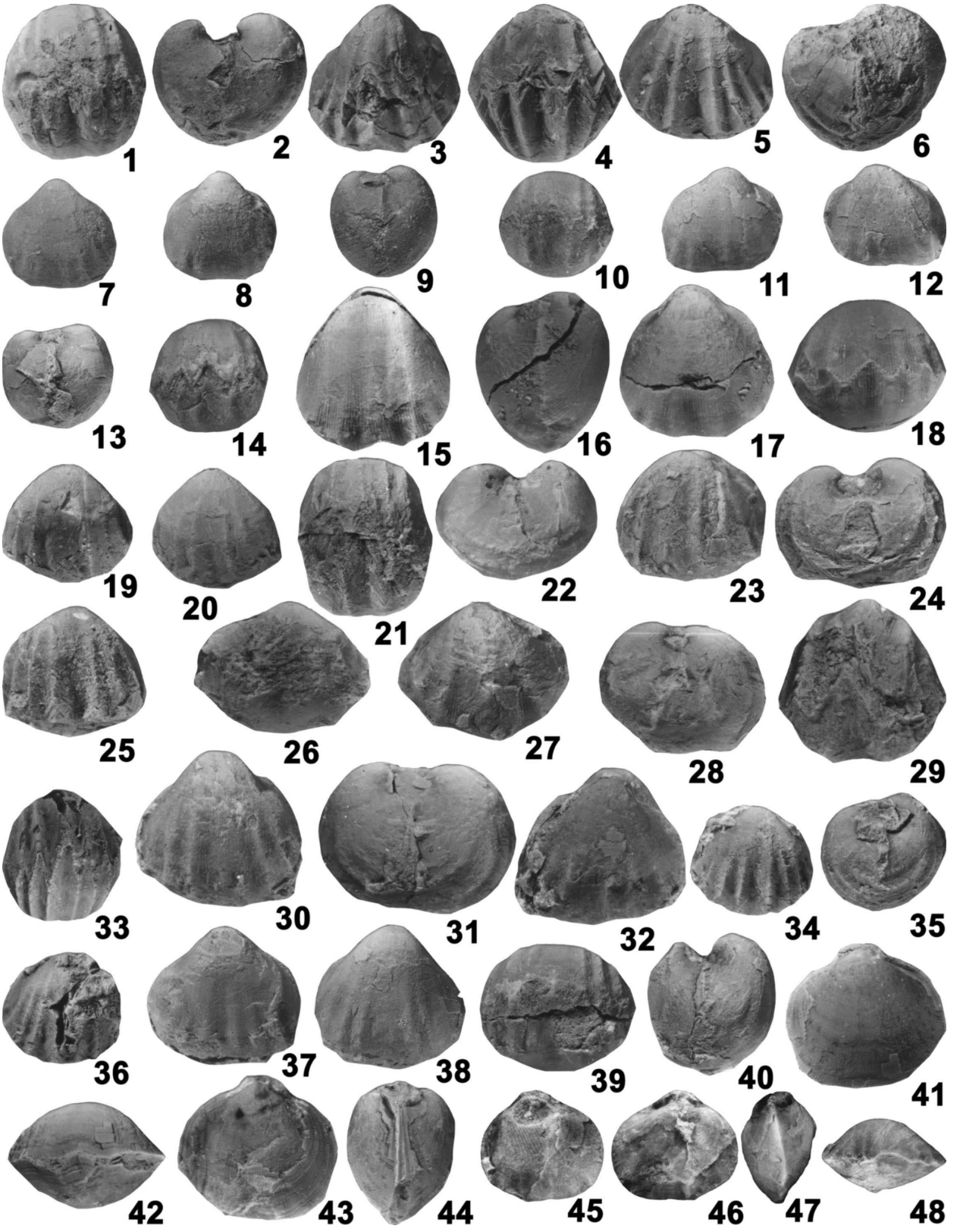
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Plate 16

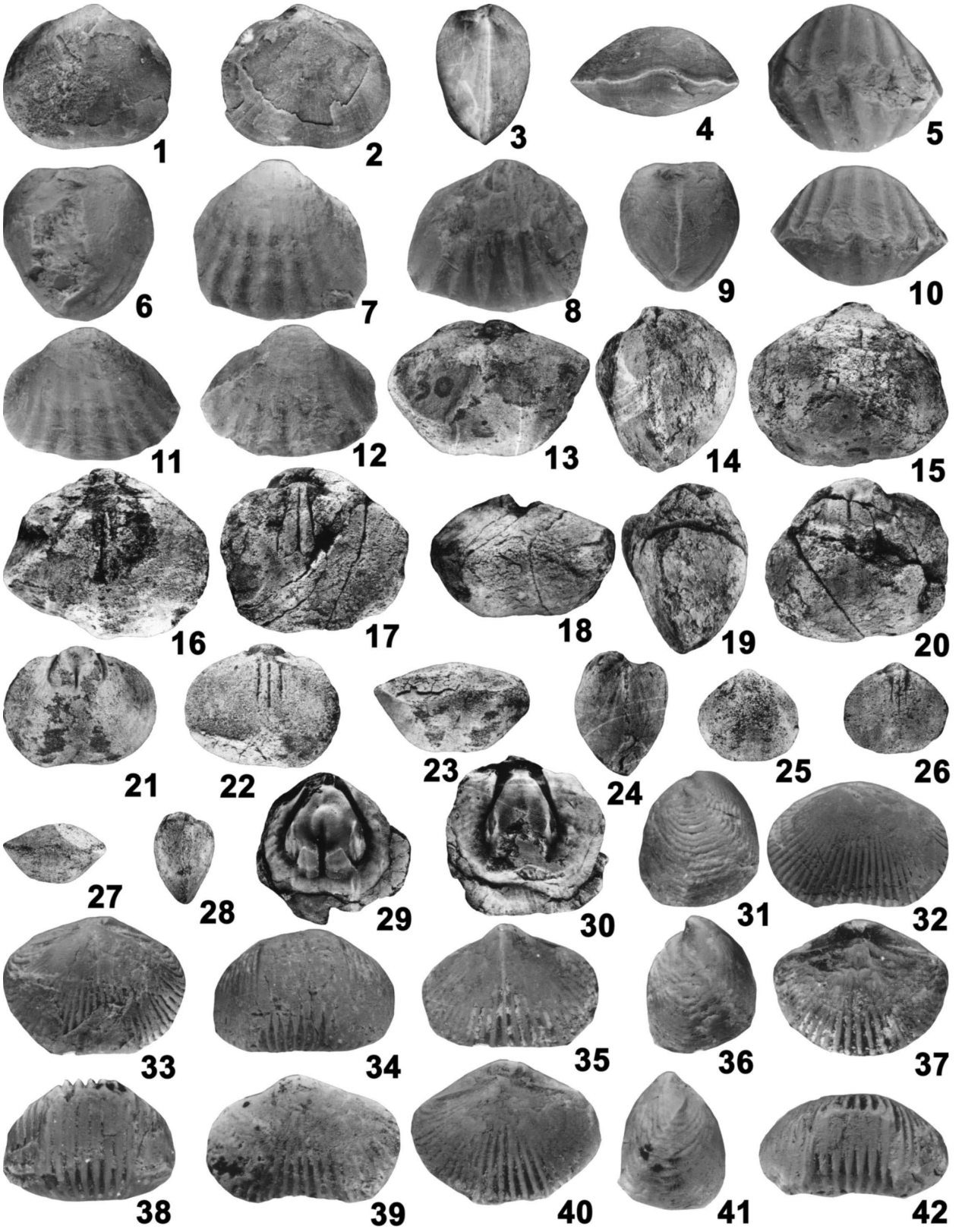
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**Plate 17**

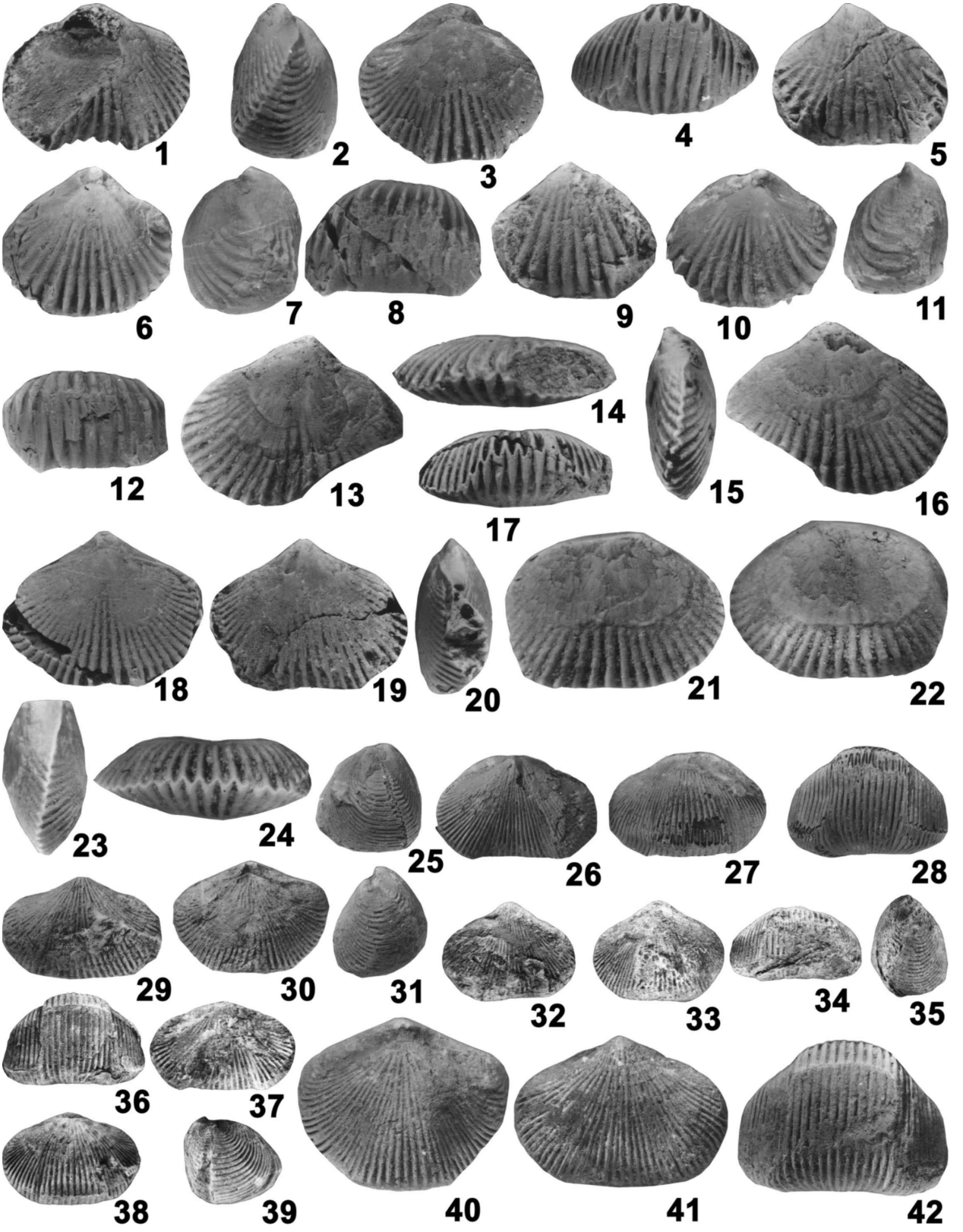
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Plate 18

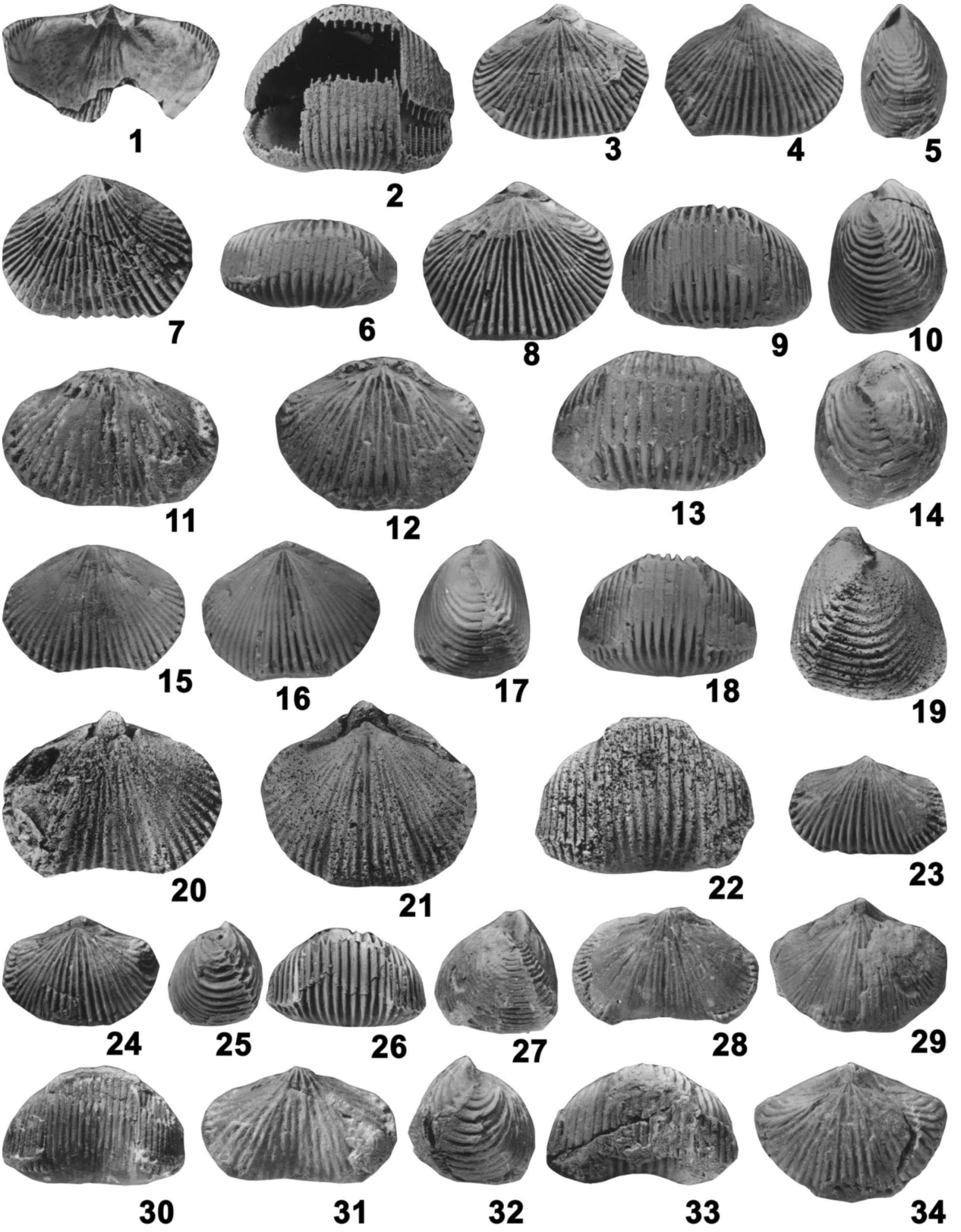
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Plate 19

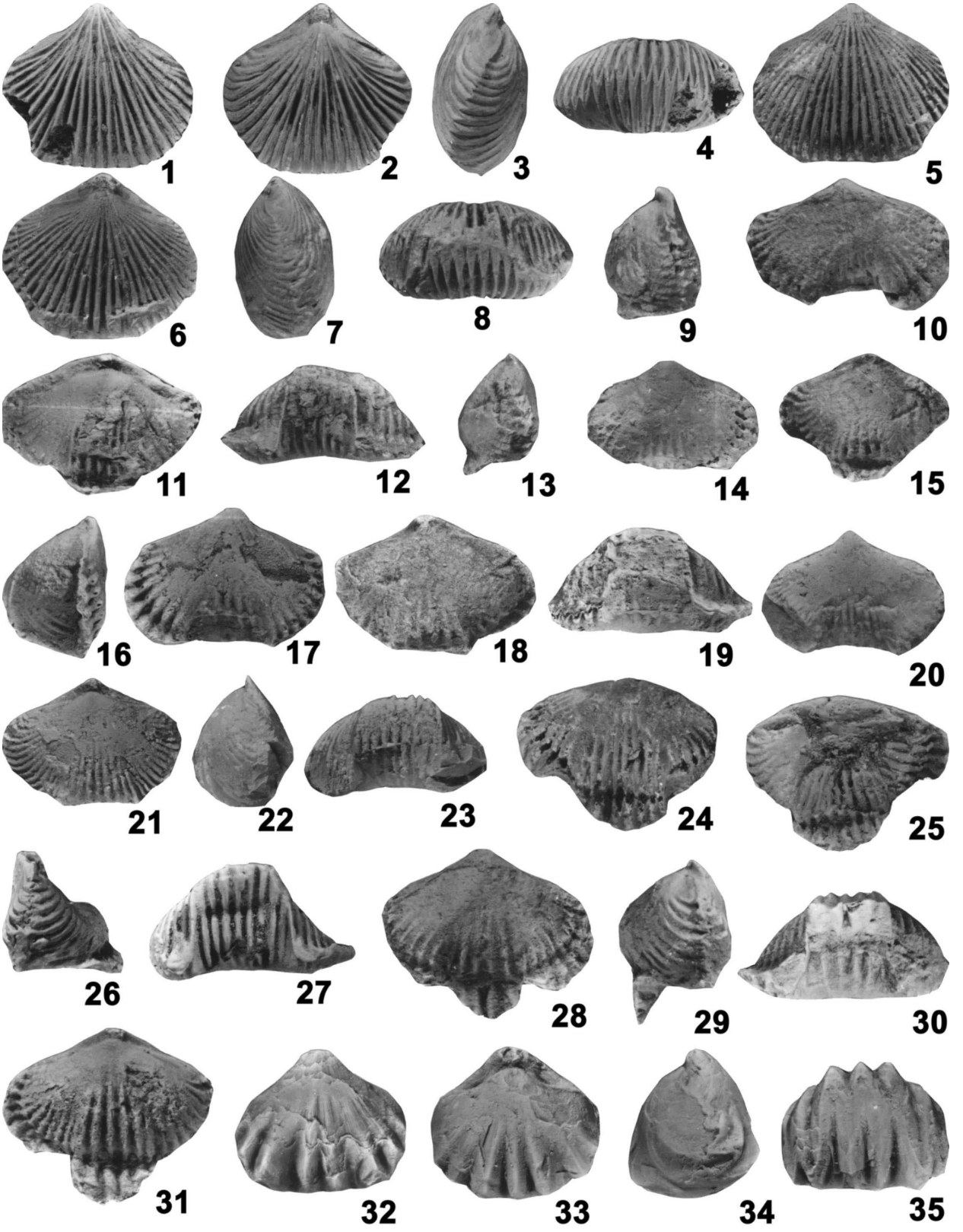
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Plate 20

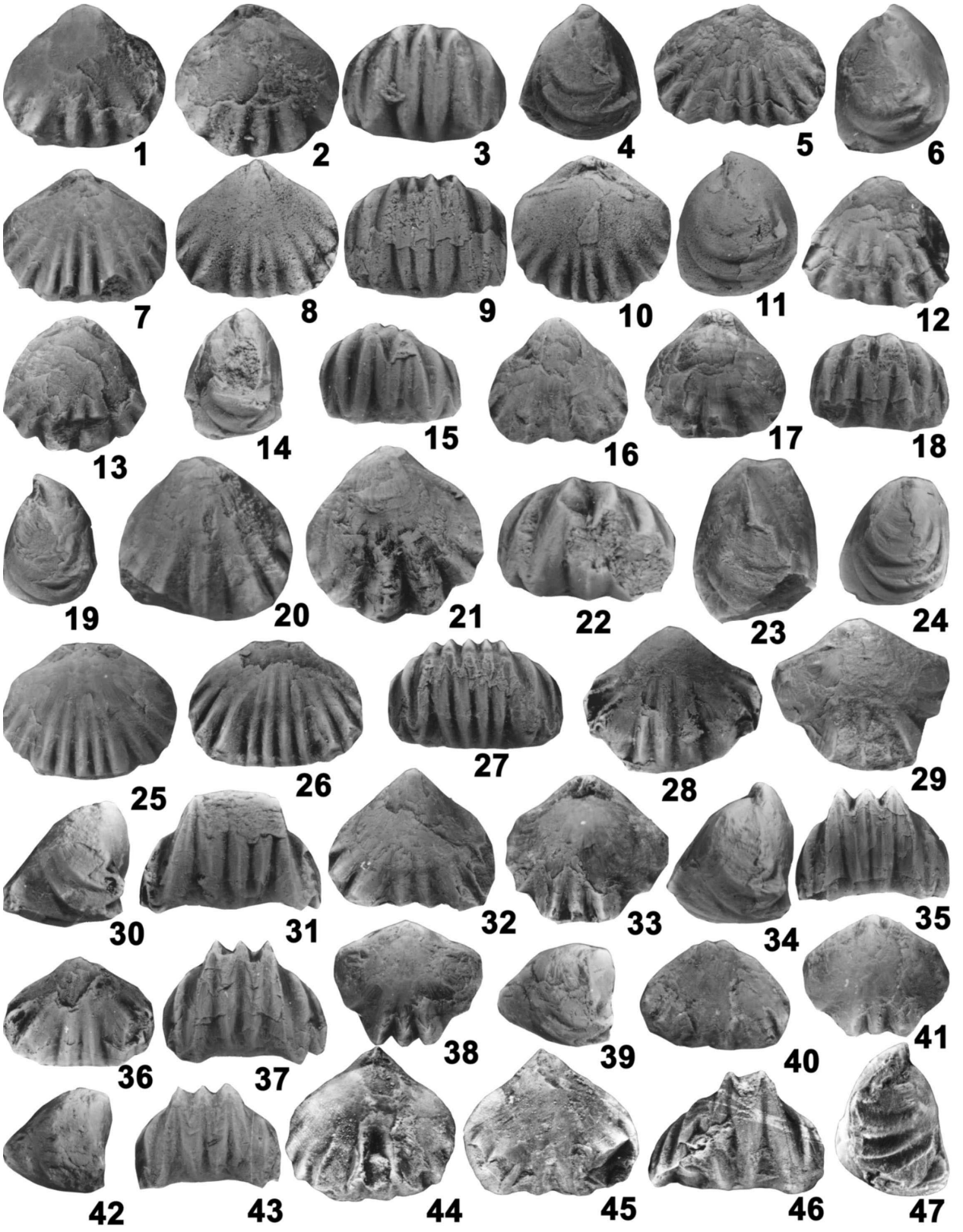
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**Plate 21**

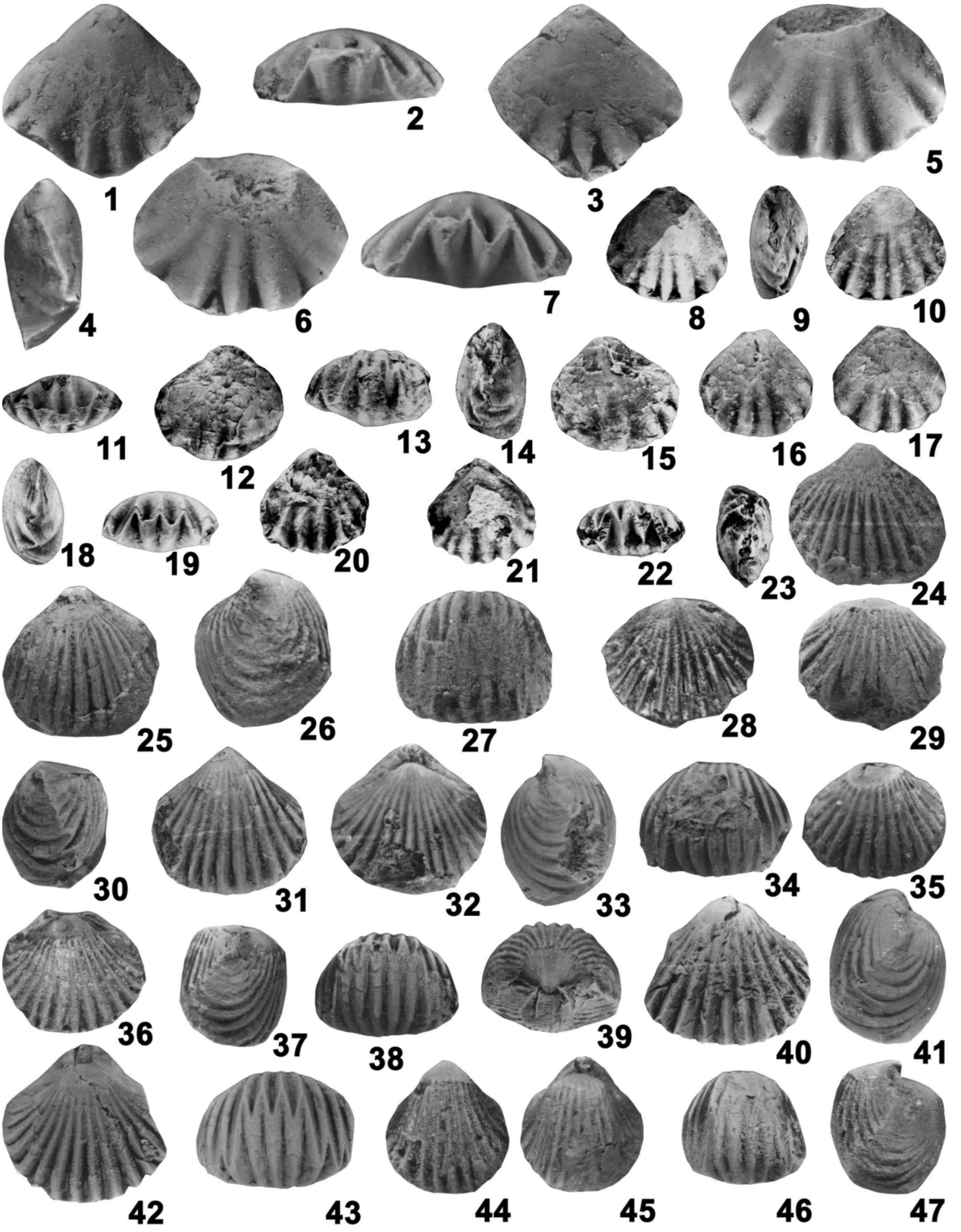
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Plate 22

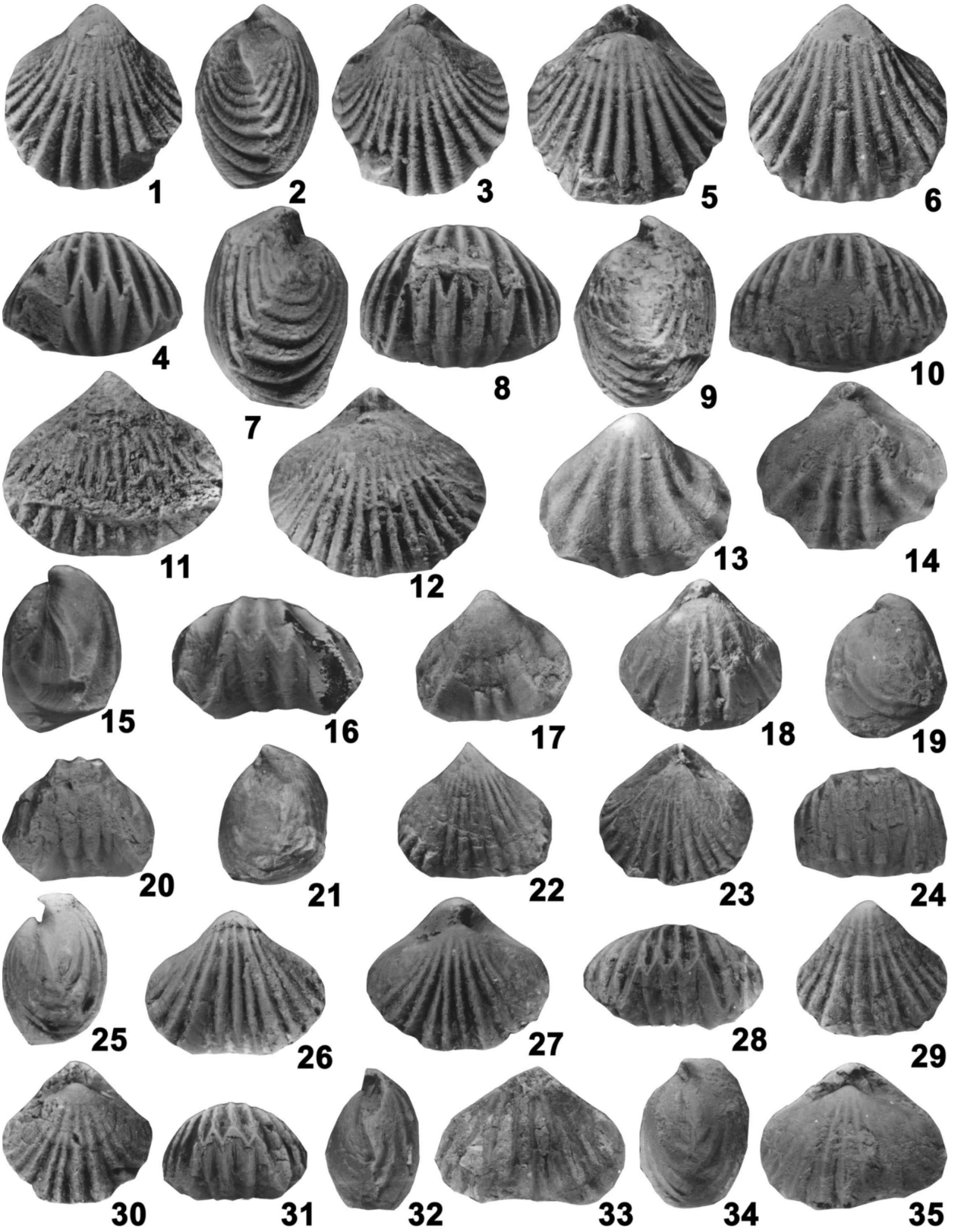
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Plate 23

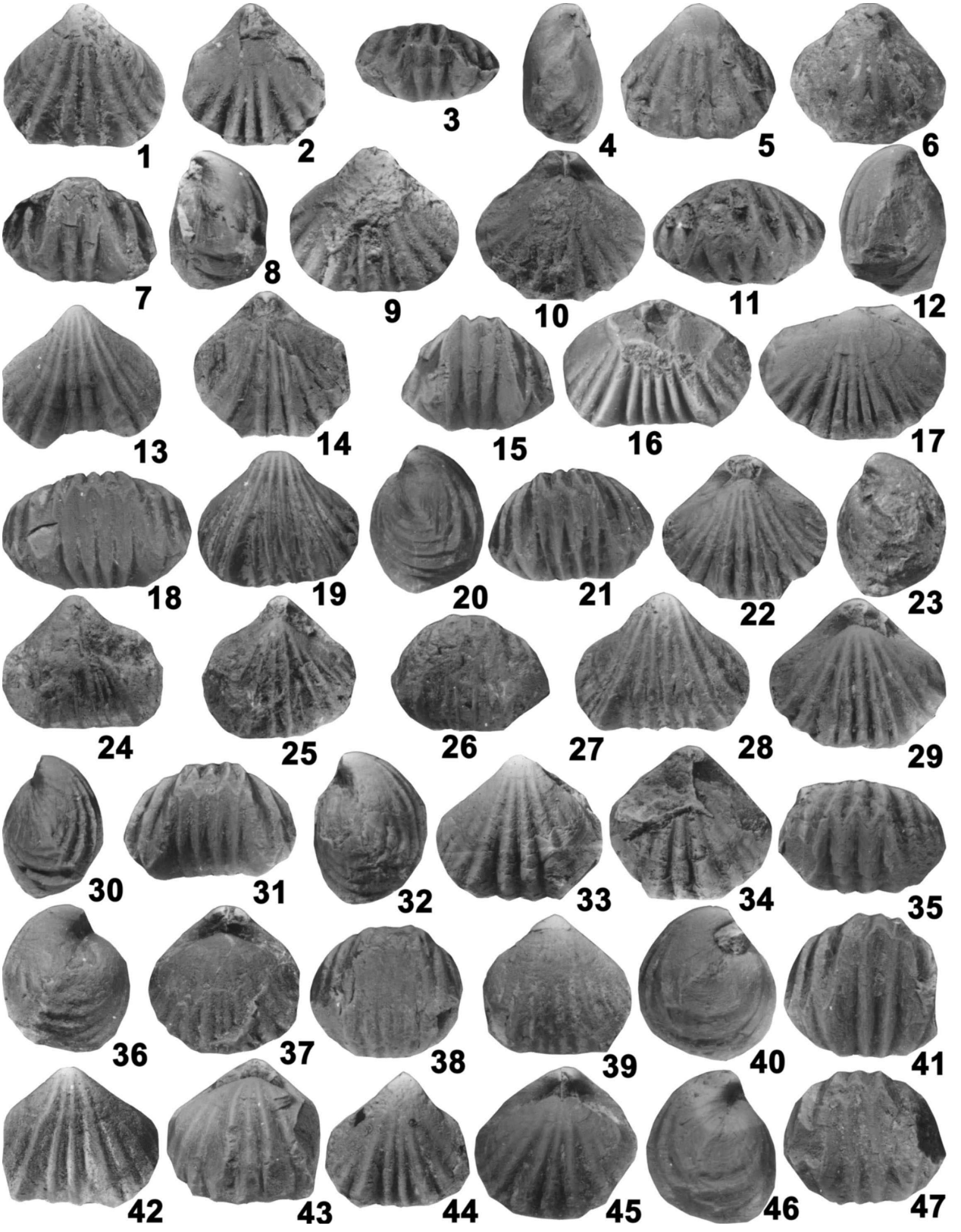
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Plate 24

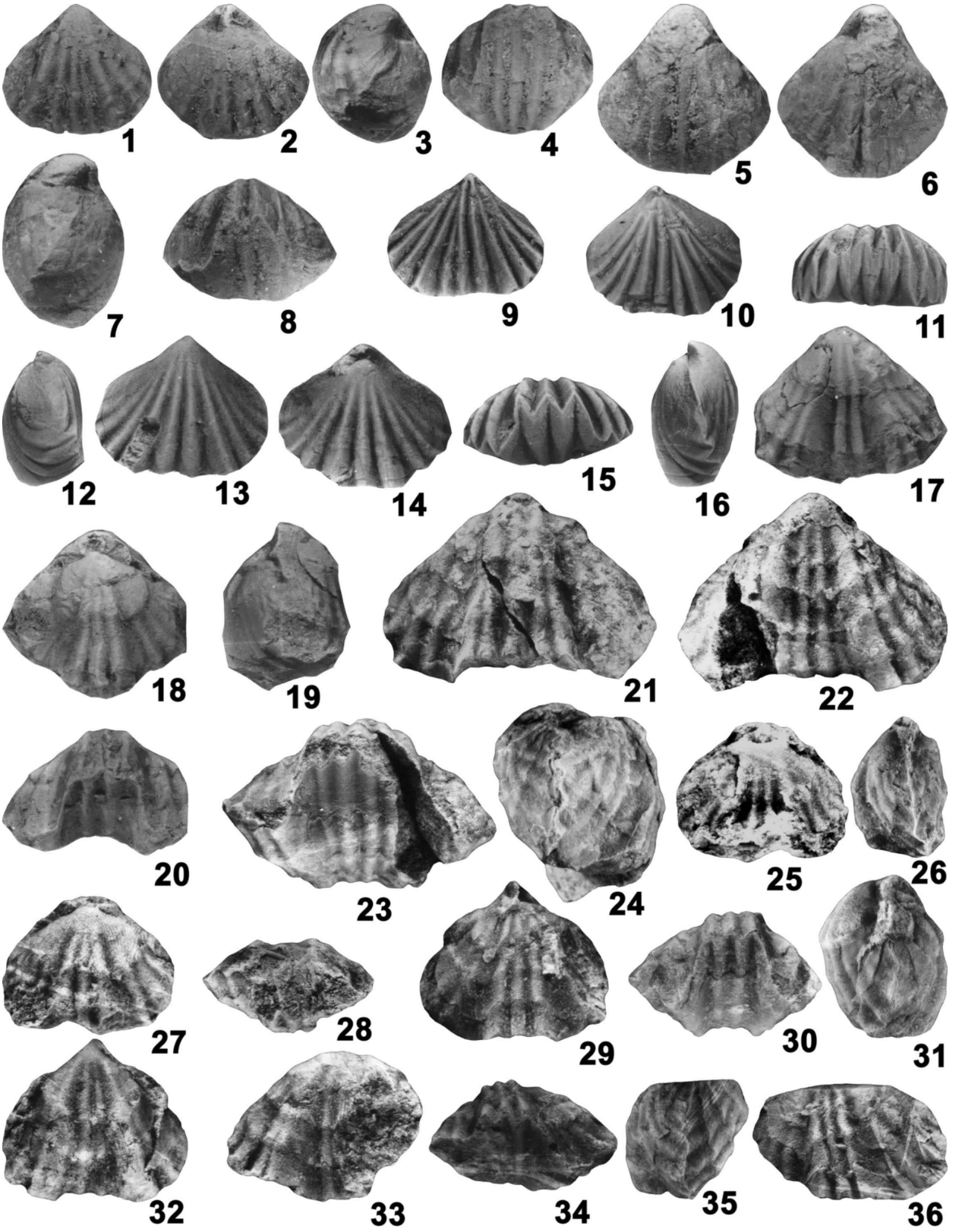
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Plate 25

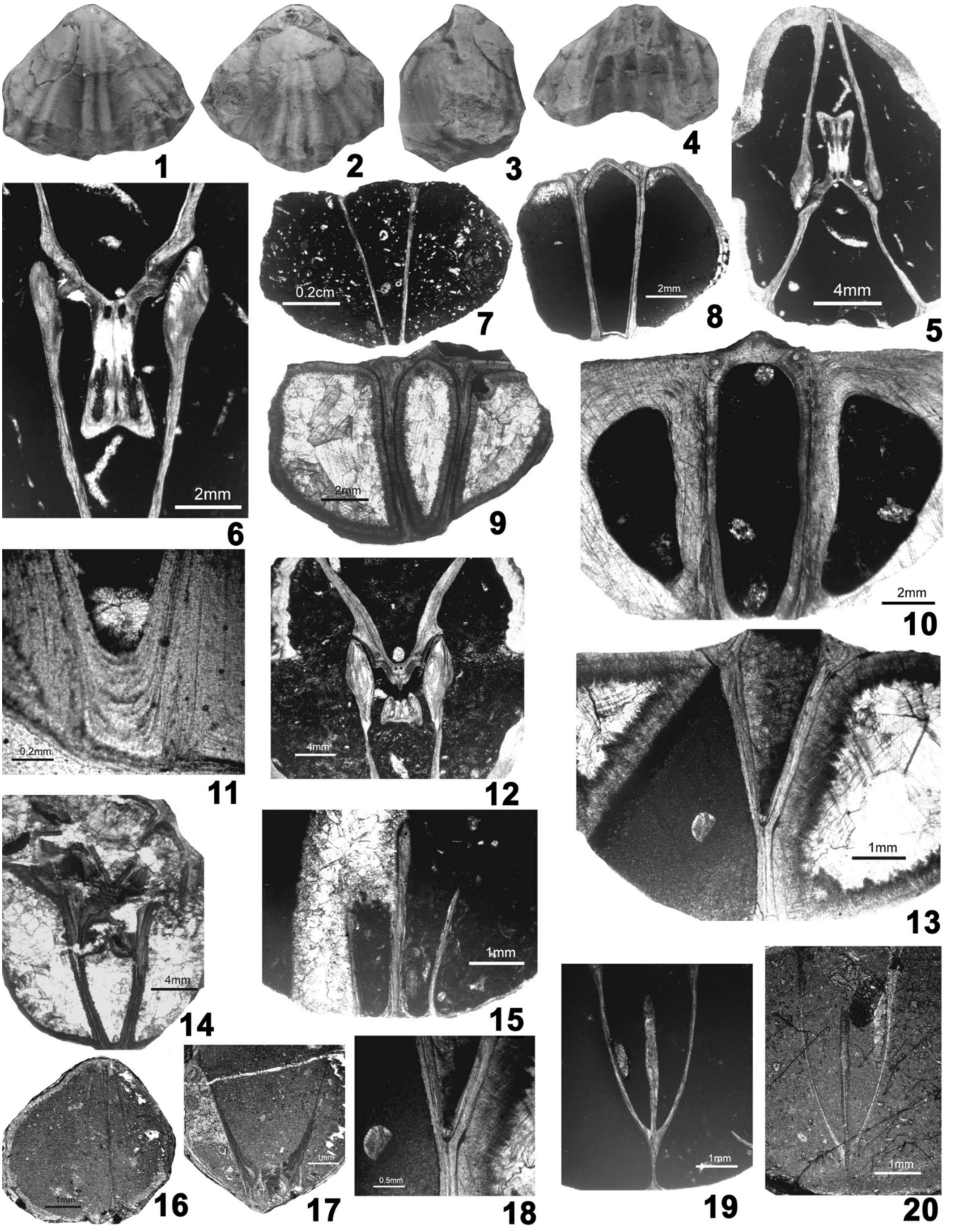
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Plate 26