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LATEST DEVONIAN (FAMENNIAN) TO EARLIEST CARBONIFEROUS (TOURNAISIAN) BRACHIOPODS FROM THE BACHU FORMATION OF THE TARIM BASIN, XINJIANG PROVINCE, NORTHWEST CHINA

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Riassunto. Vengono descritti i brachiopodi provenienti da due orizzonti della Formazione Bachu nella provincia di Bachu nel Bacino del Tarim, Sinkiang, Cina nord-occidentale. I brachiopodi provenienti dalla parte basale della formazione sono attribuiti al Famenniano superiore, mentre quelli dell'orizzonte superiore si correlano con l'associazione a *Eochoristites-Martiniella* del Tournesiano inferiore della Cina meridionale. La fauna a Brachiopodi della Formazione Bachu ha forti affinità a livello generico e specifico con faune coeve della Cina meridionale, suggerendo la presenza di forti legami biogeografici. Sono descritte undici specie di brachiopodi, di cui una nuova, *Ptychomaletoechia bakuensis.*

Abstract. Brachiopods are described from two horizons of the Bachu Formation from the Bachu area of the Tarim Basin, Xinjiang Province, northwest China. We assign the brachiopods from the basal Bachu Formation to the late Famennian and correlate those from its upper part to the *Eochoristites-Martiniella* Assemblage of South China of the early Tournaisian. The brachiopod fauna of the Bachu Formation exhibits strong generic and specific links with coeval South Chinese faunas, suggesting a close biogeographical affinity with the South China block. Eleven species are described, including one new species, *Ptychomaletoechia bachuensis.*

Introduction.

The Xiaohaizi section studied in this paper is located about 20 km southeast of the Bachu County town near the central-western margin of the Takla Makan desert of the Tarim Basin in Xinjiang Province, northwest China (Fig. 1). The Bachu area is the only exposed area so far known in the deserts areas of Tarim Basin which develops an almost continuous Upper Devonian to Lower Permian sequence. As such, the Xiaohaizi section provides a key to the understanding of the subsurface sedimentary sequences of the Tarim Basin covered by deserts. Of particular note is the revelation by some recent studies (Chen, 1995, 1997; Liao W. H., 1995; Zhu and Zhan, 1996; Li *et al.*, 1996) that the oil-bearing strata under the deserts are comparable with the Late Devonian to Early Carboniferous rock sequence exposed in the Bachu area. The sequence stratigraphical correlation of the outcrops with boreholes reveals that the Famennian-Tournaisian Bachu Formation and its equivalents are extensively distributed both in outcrops and subsurface of the Tarim Basin (Chen, 1995, 1997). For these reasons, the Late Devonian-Carboniferous stratigraphy of Bachu and its adjacent areas has attracted considerable attention from geologists.

Recently, the biostratigraphy of the Xiaohaizi section of the Bachu area has been carried out by many authors (Wu N. Y., 1990; Xiong, 1991; Zhang *et al.*, 1993; Chen, 1995, 1997; Liao W. H., 1995; Li *et al.*, 1996). However, despite abundant microfossils including conodonts and foraminifers obtained from the Bachu Formation, the age of the formation is still of dispute due to the lack of characteristic zonal microfossils. Abundant brachiopods have also been discovered from the Bachu Formation and appear to provide a critical constraint on the age assignment of this formation (Chen, 1995). In this paper, we describe these brachiopods in an attempt to clarify the age of the Bachu Formation on the basis of the latest data. In addition, we also discuss the relationship of the early Tournaisian Tarim brachiopod fauna with that of South China with a view to elucidating their palaeobiogeographical and palaeogeographical links during the earliest Carboniferous.

Most of the specimens described here were collected from the Xiaohaizi Section and some boreholes of the Tarim Basin (Fig. 1) by the senior author when he investigated the Tarim Basin together with a geological exploration team of the Nanjing Institute of Geology and Palaeontology, Academia Sinica, in the summers of 1992 and 1993. In addition, two shells were obtained from the Bioclastic Limestone Member of the MC-1 and TZ-1 Wells (Fig. 1). The stratigraphic distribution and localities of the described species are shown in Tab. 1.

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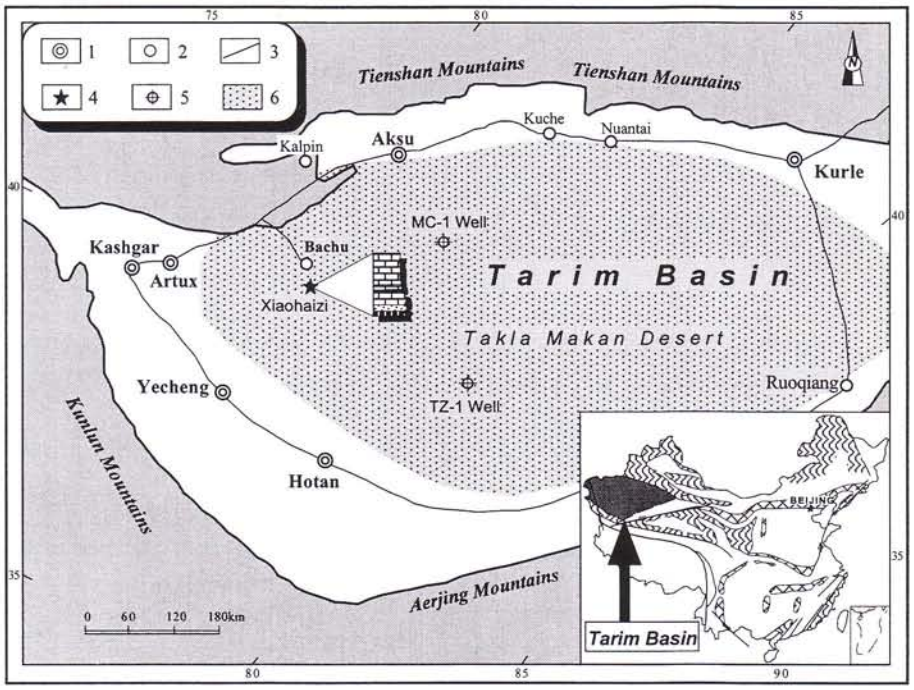


Fig. 1 - The map showing the fossil localities in the Tarim Basin of Xinjiang, NW China. 1. city, 2. county town, 3. highway, 4. outcrop section, 5. well, 6. deserts.

All described specimens are housed in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences (NIGP), and the Department of Invertebrate Palaeontology, Museum of Victoria (NMVP).

Brachiopod faunal subdivision and age of the Bachu Formation.

The Bachu Formation was first described by the Compiling Group of Regional Stratigraphic Chart of Xinjiang (RSCX) (1981). It is characterized by sandstones and sandy mudstones in the lower part and bioclastic limestones interbedded with sandstone and siltstone in the upper part. Recently, two stratigraphic units, the Donghetang and Ganmulik Formations, have been proposed to represent the lower part of the Bachu Formation while the upper part is restricted to the revised Bachu Formation (Liao W. H., 1995; Chen, 1995; Li *et al.*, 1996). The changes of the lithological and chronological subdivisions of the Bachu Formation are summarized in Table 2. The Bachu Formation, as defined above, comprises two limestone beds and siltstone interbeds and is herein divided into two members (Fig. 2). The lower member is composed mainly of siltstones above and limestones below, with the following brachiopod species: *Ptychomaletoechia panderi* (Semenov et Moeller), *Ptychomaletoechia* sp. indet., *P. kinlingensis* (Grabau), *Trifidorostellum longhuiensis* Tan and *Trifidorostellum* sp. The associated conodonts are *Bispathodus aculeatus aculeatus* (Branson et Mehl), *B.* cf. *spinalicostatus* (Branson), *Pseudopolygnathus* cf. *primus* Branson et Mehl, *Hindeodella* sp. (Liao W. H., pers. comm., 1994). In addition, Li et al. (1996) have also reported fossils from the same

Species	U. mem. of the Bachu Fm.	L. mem. of the Bachu Fm.	Bioclastic Limestone of MC-1 Well	Bioclastic Limestone of TZ-1 Well
Schuchertella guizhouensis Yang	††			
Cancrinella ? sp.	†			
Eochoristites neipentaiensis Chu	††††			†
Eochroistites leei Chu	††			
Ptychomaletoechia bachuensis sp. nov.	†††			
P. panderi (Semenov et Moeller)		††††		
P. sp. indet.		††		
P. kinlingensis (Grabau)	†††	††		
P. cf. *kinlingensis* (Grabau)			†	
Trifidorostellum longhuiense Tan		††††		
Trifidorostellum sp.		†		

††††: more than 20 specimens, †††: 10-20 specimens, ††: 5-9 specimens, †: 1-5 specimens

Tab. 1 - The stratigraphical distribution and localities of the described species.

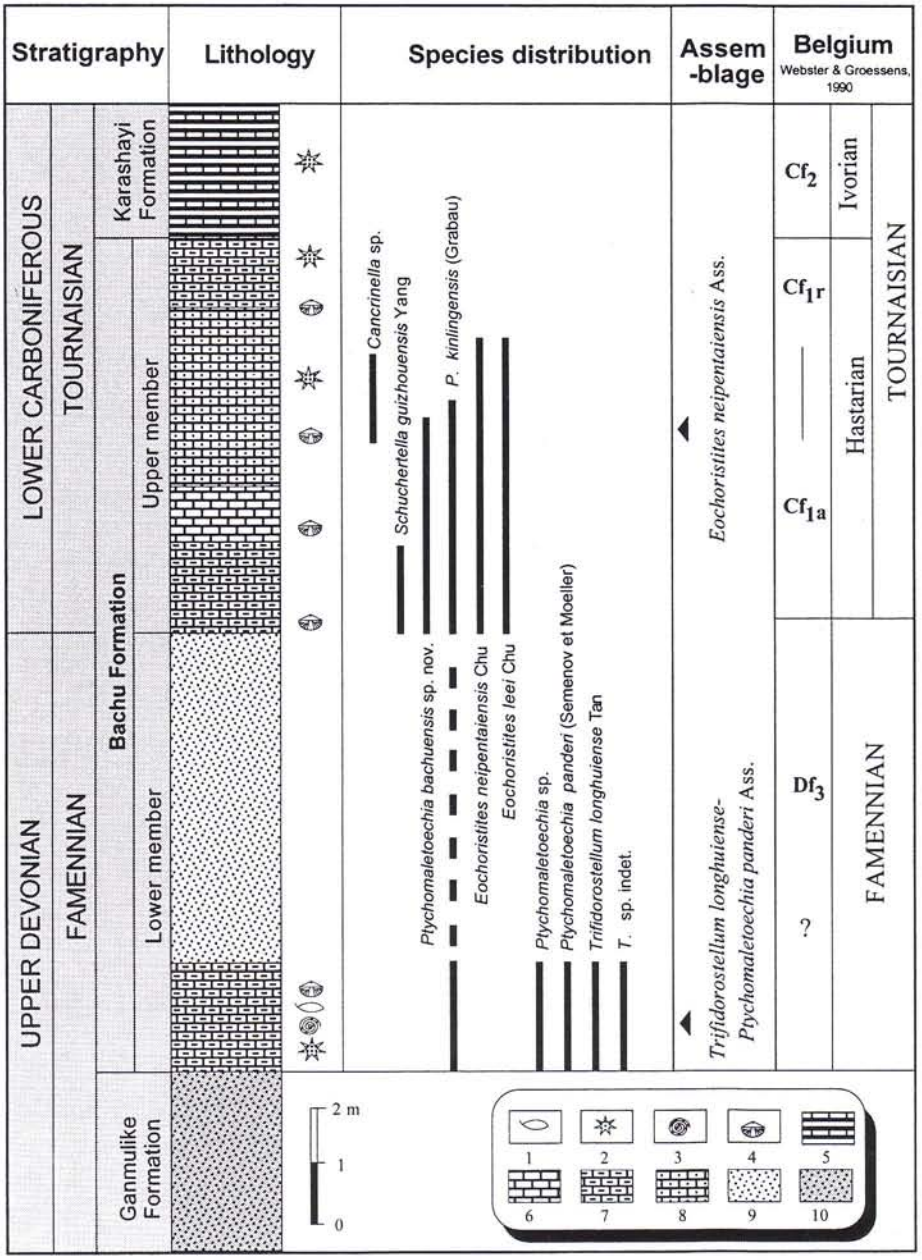


Fig. 2 - The lithological features and the stratigraphic distribution of brachiopods of the Bachu Formation from the Xiaohaizi Section, Bachu County, Xinjiang, NW China.
1. bivalves, 2. conodonts, 3. ammonoids, 4. brachiopods, 5. gypsiferous mudstone, 6. limestone, 7. argillaceous limestone, 8. calcarenite, 9. siltstone, 10. sandstone. Df_3 = Devonian foraminifer *Quasiendothyra* Zone; $Cf_{1\alpha}$ = The *Chernyshiella glomiformis -Septabrunsiina rudis - Tournayella beata* Subzone of the first foraminiferal zone of Carboniferous; $Cf_{1\beta}$ = The *Palaeospiroplectammina tchernyshinensis-Endothyra bulbiseptales* Subzone of the first foraminiferal zone of Carboniferous; $Cf_{1\gamma}$ = The *Spinoendothyra-Uviella-Septa tournayella segmentata* Subzone of the first foraminiferal zone of Carboniferous; Cf_2 = The second foraminiferal zone: *Tournayella-Paraendothyra* gr. *nalivkini* Zone.

level of this section, including conodonts: *Bispathodus aculeatus aculeatus* (Branson et Mehl), *B. aculeatus plumulus* (Rhodes, Austin et Druce), *B. aculeatus antiposicornis* (Scott), *B.* cf. *spinalicostatus* (Branson), *Pseudopolygnathus dentilineatus* Branson, *Clydagnathus gilwernensis* Rhodes, Austin et Druce; foraminifers: *Archaeosphaera minima* Suleimanov, *A. crassa* Lipina, *Eotuberitina reitlingerae* McMaclay; ammonoid: *Dolorthoceras xinjiangense* Li; brachiopods: *Pugnoides* cf. *mazhalaensis* Ching et Shi, *Ptychomaletoechia kinlingensis* (Grabau), *P. panderi* (Semenov et Moeller), *Trifidorostellum* cf. *longhuiensis* Tan; and bivalves: *Modiolus* cf. *qijiagouense* Yang.

Age determination of the lower member has relied upon its brachiopods because the associated conodont, ammonoid and foraminiferal species are all long-ranging forms, mostly from the Famennian of the Late Devonian to the Early Carboniferous (Chen, 1995; Li *et al.*, 1996). In view of the brachiopods, Chen (1995) has assigned the fauna from the lower member to the *Trifidorostellum longhuiense-Ptychomaletoechia panderi* Assemblage and suggested a late Famennian age.

The upper member of the Bachu Formation, consisting of bioclastic limestone (Fig. 2), is characterized by the appearance of abundant brachiopods and conodonts. The brachiopod fauna consists mainly of these forms: *Schuchertella gueizhouensis* Yang, *Cancrinella*? sp., *Eochoristites neipentaiensis* Chu, *E. leei* Chu, *Ptychomaletoechia kinlingensis* (Grabau), and *P. bachuensis* sp. nov. The conodonts include the following species: *Bispathodus aculeatus aculeatus* (Rhodes, Austin et Druce), *B. aculeatus plumulus* (Rhodes, Austin et Druce), *Hindeodella germana* Holms, *Polygnathus communis communis* Branson et Mehl, *P.* cf. *inornatus* Branson, *Spathognathodus stabilis* (Branson et Mehl), *Siphonodella* cf. *sulcata* (Hud-

RSCX, 1981			Xiong, 1991			Zhang *et al.*, 1993		Chen 1995			Liao W. H., 1995			Li *et al.*, 1996		This paper			
U. DEVON.	LOWER CARBONIFEROUS	Bachu Formation upper mem.	L. CARBON.	Bachu Formation	upper mem.	L. CARBON.	Bachu Formation	L. CARBON.	Bachu Formation	upper mem.	L. CARBON.	Bachu Formation	upper mem.	L. CARBON.	Bachu Formation	L. CARBON.	Tournaisian	Bachu Formation	upper mem.
		middle mem.			middle mem.					lower mem.			lower mem.			UPPER DEVONIAN	Famennian		lower mem.
		lower mem.	UPPER DEVONIAN		lower mem.	UPPER DEVONIAN		UPPER DEVONIAN	Ganmulik Fm.		UPPER DEVONIAN	Ganmulik Fm.		UPPER DEVONIAN	Ganmulik Fm.			Ganmulik Fm.	
	part of Keziertag Fm.			part of Keziertag Fm.			Mazatag Fm.		Donghe-tang Fm.			Donghe-tang Fm.			Donghe-tang Fm.			Donghe-tang Fm.	

Tab. 2 - The changes of lithological and chronological subdivisions of the Bachu Formation.

dle) and *Neoprioniodus barbatus* (Branson et Mehl) (Xiong, 1991; Zhang *et al.*, 1993).

Despite the presence of conodonts and brachiopods, the age of the upper member has remained in doubt. Xiong (1991) assigned the conodonts to early Tournaisian, in contrast with Zhang *et al.* (1993), who referred the conodonts from the same member to late Tournaisian. Chen (1995) referred the brachiopods from the upper member to the *Eochoristites neipentaiensis* Assemblage and correlated it with the *Eochoristites neipentaiensis-Martiniella chinglungensis* Assemblage of central Hunan Province, South China. This correlation is substantiated in this study by restudying these brachiopod species. With the exception of *P. bachuensis* n. sp., the other species of the *E. neipentaiensis* Assemblage are all shared with the *Eochoristites neipentaiensis-Martiniella chinglungensis* Assemblage of South China. For instance, *Schuchertella gueizhouensis* Yang has been reported from the Famennian Gelaohe Formation of Guizhou Province, South China (Yang, 1964; Wu X. H., 1990). *Eochoristites neipentaiensis*, *E. leei* and *Ptychomaletoechia kinlingensis* were first found from the Kinling Limestone in Nanjing of Jiangsu Province, South China (Chu, 1933; Hu, 1987); they are also present in the Tournaisian deposits of at least eight localities of South China (Jin, 1961; Yang, 1964, 1980; Feng and Jiang, 1978; Tan, 1987; Hu, 1987) (Fig. 3A and Table 3) and some remote regions, such as Heilongjiang Province of northeastern China (Lin, 1990, loc. 12 in Fig. 3A), eastern Tibet (Jin and Sun, 1981, loc. 9 in Fig. 3A), and Qinghai Provinces

Species	Author	Formation	Age	Locality (see Fig.3A)
Eochoristites neipentaiensis Chu	Chu, 1933	Kinling Limestone	Tournaisian	Loc. 7
	Jin, 1961	Kinling Fm.	Tournaisian	Loc. 6
	Yang, 1964	Tangpagou Fm.	late Tournaisian	Loc. 1
	Jin & Liao, 1974	Tangpagou Fm.	late Tournaisian	Loc. 3
	Yang, 1978	Tangpagou Fm.	late Tournaisian	Loc. 2
	Tan, 1987	Malanbian Fm.	late Tournaisian	Loc. 5
	Jiang & Yang, 1987	Majiaoba Fm.	Tournaisian	Loc. 8
	Xu & Yang, 1987	Liujiatang Fm.	Tournaisian	Loc. 5
	This paper	Bachu Fm.	early Tournaisian	Loc. 11
E. cf. *neipentaiensis* Chu	Jin et al., 1979	Chengqiangguo Fm.	Lower Carboniferous	Loc. 10
E. neipentaiensis var. *transversa* Chu	Chu, 1933	Kinling Limestone	Tournaisian	Loc. 7
E. neipentaiensis mut. *alpha* Chu	Chu, 1933	Kinling Limestone	Tournaisian	Loc. 7
E. neipentaiensis var. *lungtanensis* Chu	Chu, 1933	Kinling Limestone	Tournaisian	Loc. 7
E. neipentaiensis alata Jin	Jin, 1964	Kinling Formation	Tournaisian	Loc. 6
	Hu, 1987	Kinling Fm.	Tournaisian	Loc. 6
E. leei Chu	Chu, 1933	Kinling Limestone	Tournaisian	Loc. 7
	This paper	Bachu Fm.	early Tournaisian	Loc. 11
E. cf. *leei Chu*	Jin & Sun, 1981	Naxing Group	Lower Carboniferous	Loc. 9
E. elongata Chu	Chu, 1933	Kinling Limestone	Tournaisian	Loc. 7
E. sp.1	Chu, 1933	Kinling Limestone	Tournaisian	Loc. 7
E. sp. 2	Chu, 1933	Kinling Limestone	Tournaisian	Loc. 7
E. sp. 3	Chu, 1933	Kinling Limestone	Tournaisian	Loc. 7
E. chui Yang	Yang, 1964	Tangpagou Fm.	Tournaisian	Loc. 1
	Feng & Jiang, 1978	Aikuan Fm.	late Tournaisian	Loc. 1
	Jiang & Yang, 1987	Majiaoba Fm.	Tournaisian	Loc. 8
E. beichuanensis Jiang	Jiang & Yang, 1987	Majiaoba Fm.	Tournaisian	Loc. 8
	Xu & Yao, 1988	Guiling Fm.	Tournaisian	Loc. 4
E. sp.	Lin, 1990	Hongshuiquan Fm.	Tournaisian	Loc. 12

Tab. 3 - The geographical and stratigraphical distribution of Eochoristites Chu (1933).

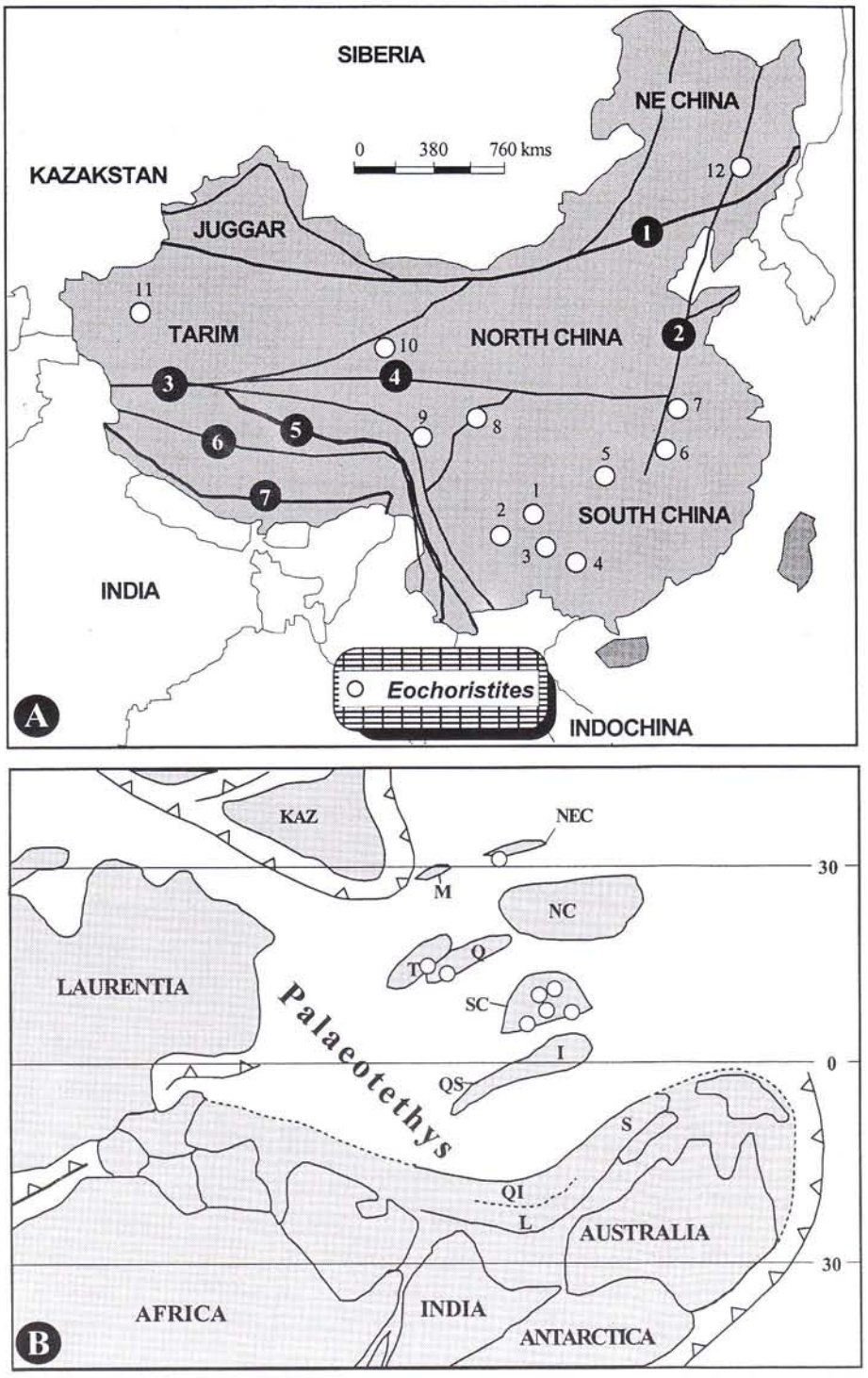


Fig. 3 - The geographical and paleogeographical distribution of *Eochoristites* Chu (1933).
A. Geographic distribution. *Eochoristites* is limited to China. Localities: 1. The Dushan section of Dushan County, Guizhou Province; 2. The Penxian section of Liupenshui City, Guizhou Province; 3. The Luodian section of Luodian County, Guangxi Province; 4. The Nanbiancun section of Guilin, Guangxi Province; 5. The Malanbian and Liujiaotang sections of central Hunan, Hunan Province; 6. The Wanghucun section of Xuancheng, Anhui Province; 7. The Longtan section of Nanjing, Jiangsu Province; 8. The Beichuan section of the Longmenshan area, Sichuan Province; 9. The Yinba section of Changdu County, Tibet Province; 10. The Wulandaban section of Wulandaban, Wulan County, Qinghai Province; 11. The Xiaohaizi section of Bachu County, Xinjiang Province. 12. The Heishantou section of Eergunayouqi, Heilongjiang Province. The major tectonic boundaries shown in Fig. 3A are: 1.Tienshan-Hinggan suture, 2. Tanlu fault, 3. Kunlun suture, 4. Qinling-Dabie suture, 5. Lancangjiang suture, 6. Banggong-Lujiang suture, 7. Indus Yarlung Zangbo suture.
B. Palaeogeographic distribution. *Eochoristites* occurred at Tethyan Realm (Palaeogeographic map is modified from Metcalfe 1996, 1997). Kaz.: Kazakstan Plate, M.: Inner Mongol, NEC.: Northeast China, NC.: North China, T.: Tarim Basin, Q.: Qaidam Basin, SC.: South China, I.: Indochina, QI.: Qiangtang terrane, L.: Lhasa terrane, S.: Shan-Thai Block.

of northwest China (Jin *et al.*, 1979, loc. 10 in Fig. 3A).

Since Chu (1933) reported the characteristic late Tournaisian coral *Pseudouralina* fauna associated with the brachiopod *Eochoristites neipentaiensis-Martiniella chinglungensis* fauna from the Kinling Limestone of the Nanjing area of Jiangsu Province, South China, the index genera *Eochoristites* and *Martiniella* have been found in association with the *Pseudouralinia* Zone over most areas of South China. Therefore, the *Eochoristites neipentaiensis-Martiniella chinglungensis* Assemblage have long been referred to the late Tournaisian in age (Yang *et al.*, 1962; Yang, 1964; Jin and Liao, 1985; Tan, 1987; Tan and Tang, 1987; Xu and Yang, 1987; Yang and Jiang, 1987; Chen, 1995; Liao Z. T., 1995).

To date, worldwide correlation of the *Eochoristites-Martiniella* Assemblage has been hindered by the restricted distribution of the brachiopod fauna and the lack of detailed knowledge of the associated microfossils. However, a recent study on the corals and foraminifers of the Malanbian Formation of the central Hunan area, South China, shows that the coral *Pseudouralinia* (=*Uralinia* of Poty and Xu, 1996) Zone extends from

the top of the $Cf_{1\alpha}$ foraminiferal subzone to the $Cf_{1\gamma}$ subzone (Hance, 1996; Poty and Xu, 1996). This implies that the age of the brachiopod *Eochoristites neipentaiensis-Martiniella chinglungensis* Assemblage should be equivalent to the Cf_1 (subzone (early Hastarian) to the $Cf_{1\gamma}$ subzone of the late Hastarian of the early Tournaisian, rather than the late Tournaisian as originally thought by some Chinese geologists.

As implied by the close correlation discussed above, the brachiopod fauna of the upper Bachu Formation exhibits strongest biogeographical affinity with coeval brachiopods of South China. This may indicate that the Tarim block was proximal to South China during the Early Carboniferous (Fig. 3B).

Systematic Palaeontology.

The classification of the Productida and Spiriferida follows the revisions prepared for the new Treatise by Brunton *et al.* (1995) and Carter *et al.* (1994).

Order Strophomenida Opik, 1934
Superfamily Orthoteoidea Waagen, 1884
Family Schuchertellidae Williams, 1953
Genus *Schuchertella* Girty, 1904

Type species. Streptorhynchus lens White, 1862

Schuchertella gueizhouensis Yang, 1964

Fig. 4D

1974 *Schuchertella gueizhouensis* - Jin & Liao, p. 275-276, pl. 142, fig. 1-3.
1978 *Schuchertella gueizhouensis* - Feng & Jiang, p. 240, pl. 87, fig. 3, 8.

Material. Five ventral valves, of these, one (NMV P149125) is herein figured.

Description. Medium size for genus; semicircle in outline; slightly biconvex to flat in lateral profile; hinge slightly narrower than shell width occurring at midvalve.

Ventral valve slightly convex to flat; beak low and small, incurved; interarea low and triangular, slightly oblique posteriorly. Dorsal valve moderately convex, lacking interarea. External surface ornamented by fine, dense and distinctive costellae, evenly spaced, bifurcating, crossed by fine and dense concentric growth lamellae.

Ventral interior lacking dental plates and median septum.

Measurements (in mm): 19.5 mm in length, 23.0 mm in width, 5.6 mm in thickness.

Discussion. The present species was first reported from the Gelaohe Formation of the Pingtang area of Guizhou, South China by Yang (1964), it was considered as one of the index brachiopod species of the lowest Carboniferous (Yang, 1980). Based on the studies of the conodont and foraminifer sequences, the Gelaohe Formation has been referred to the Famennian of the Upper Devonian (Wu X. H., 1990). Consequently, *Schuchertella gueizhouensis* Yang is a Famennian species in South China. However, *S. gueizhouensis* is also associated with the species of *Eochoristites* in the Bachu area (Fig. 2), and is indicative of an early Tournaisian age. Therefore, *S. gueizhouensis* bears an age range varying between the Famennian and the early Tournaisian.

Horizon and locality. *Eochoristites neipentaiensis* Assemblage of the upper member of the Bachu Formation, the early Tournaisian, the Bachu area of the Tarim Basin, northwest China.

Order Productida Sarycheva and Sokolskaya, 1959
Suborder Productidina Waagen, 1883
Superfamily Linoproductoidea Stehli, 1954
Family Linoproductidae Stehli, 1954
Subfamily Linoproductinae Stehli, 1954
Genus *Cancrinella* Fredericks, 1929

Type species. Productus cancrini Verneuil, 1845

Cancrinella ? sp.

Fig. 4P

Comments. A small (about 14 mm long and 12 mm wide) internal mould of ventral valve (NMV P149126) from the upper member of the Bachu Formation is assignable to *Cancrinella* Fredericks in view of its spine bases and weak concentric rugae.

Horizon and locality. *Eochoristites neipentaiensis* Assemblage of the upper member of the Bachu Formation, the early Tournaisian, the Bachu area of the Tarim Basin, northwest China.

Order Spiriferida Waagen, 1883
Suborder Spiriferidina Waagen, 1883
Superfamily Pheodossioidea Ivanova, 1959
Family Palaeochoristitidae Carter, 1994
Genus *Eochoristites* Chu, 1933

Type species. Eochoristites neipentaiensis Chu, 1933.

Diagnosis. Medium sized and slightly rounded shells with broad and triangular ventral interarea; delthyrium wide; sulcus and fold distinct; costae in sulcus and on fold, simple or bifurcating less than three times, costae on lateral areas simple and unbranching; ventral interior with strong and thickened dental plates, wedging deeply into shell (Fig. 5A); a low ridge com-

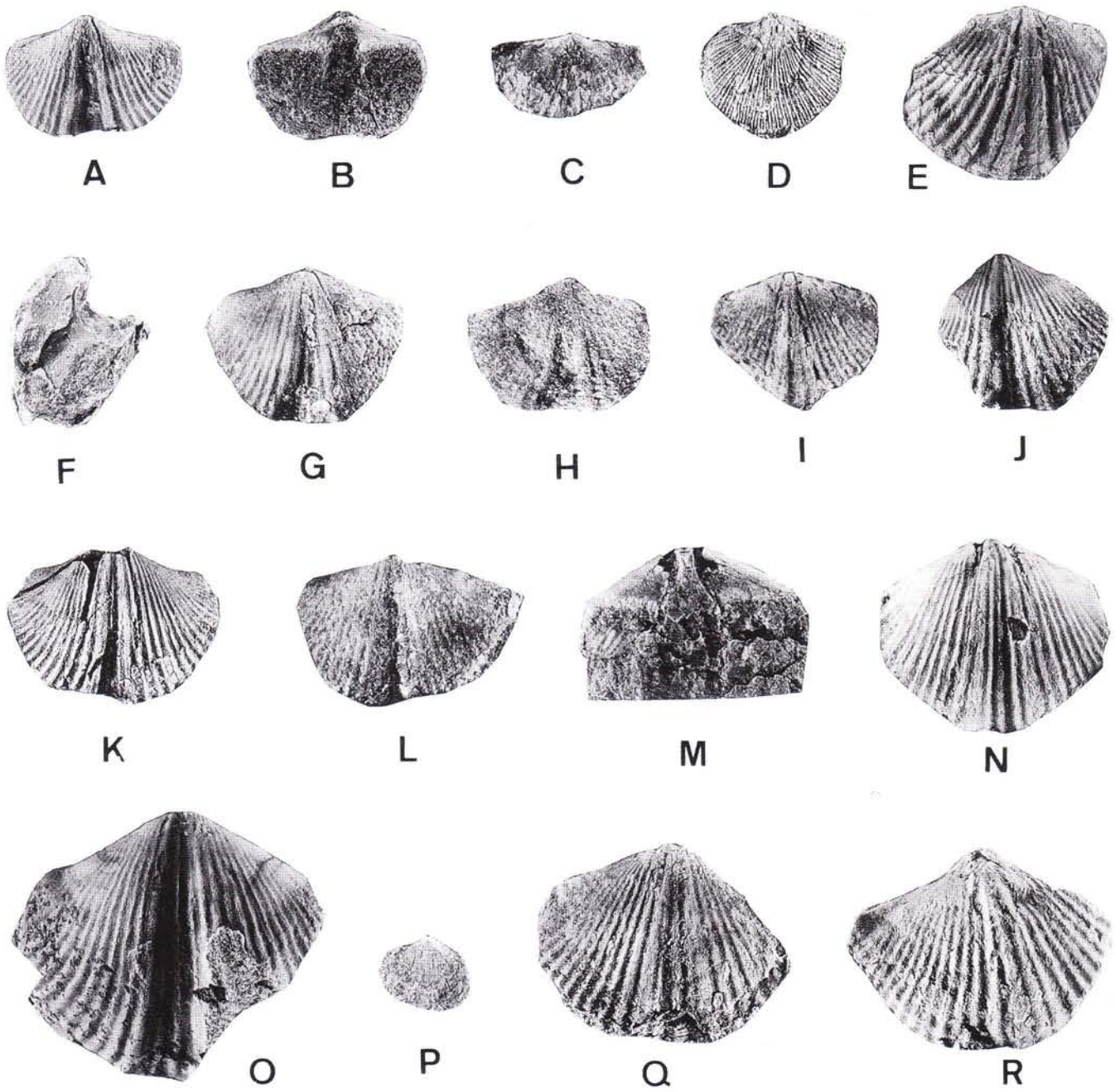


Fig. 4 - All figures are the natural sizes. A-C, E-N, R, *Eochoristites neipentaiensis* Chu, 1933. A-B, NIGP 123636, an incomplete ventral valve in ventral, interior views. C, NMV P 149115, an incomplete dorsal valve in dorsal view. E, NMV P 149116, an incomplete dorsal valve from TZ 104 well in dorsal view. F, NIGP 123638, a cross section along dental plate in lateral view, showing dental plate. G-H, NMV P149117-118, two ventral valves in ventral views. I, NMV P149119, a dorsal valve in dorsal view. J-L, NMV P 149120-122, three ventral valves in ventral views. M-N, NMV P 149123, a ventral valve in posterior, ventral views, showing ventral interarea. R, NMV P 149124, a dorsal vale in dorsal views. D, *Schuchertella guizhouensis* Yang, 1964. NMV P 149125, a ventral valve in ventral view. O, Q, *Eochoristites leei* Chu, 1933. O, Q, NMV P 149127-28, two ventral valves in ventral views. P, *Cancrinella* ? sp. NMV P 149126, a ventral internal mould in ventral view.

mencing between the thickened parts of the dental plates, extending forward (Fig. 5B); crural plates thin and short, diverging forward following the bounding furrows of median fold.

Discussion. *Choristites* Fischer de Waldheim (1825) bears remarkable resemblance with the present genus in many respects, but differs in having shorter, relatively thinner dental plates. In addition, *Choristites* also lacks crural plates.

Palaeochoristites Sokolskaya (1941) from the Moscow Basin (Sarycheva *et al.*, 1952) and the Kuznetsk Basin (Sarycheva *et al.*, 1963) of Russia is also comparable with the present genus in general features, but lacks a distinctive sulcus and fold, and possesses rather long crural plates.

Up to now, at least 14 species (subspecies) of *Eochoristites* Chu (1933) have been reported from the Lower Carboniferous (Fig. 3A, Table 3), all from China.

Most of these come from the Tournaisian of South China and the Tarim Basin of the Tethyan Province (Fig. 3A) (Yang, 1980, Liao Z. T., 1995). As pointed out above, species of *Eochoristites* are characteristic elements of the *Eochoristites-Martiniella* Assemblage, which has been always found in association with the coral *Pseudouralinia* fauna in South China. For this reason, the combined *Eochoristites-Martiniella* and *Pseudouralinia* fauna has long been considered to be an endemic South Chinese late Tournaisian fauna by many Chinese palaeontologists, mentioned above. In view of the Early Carboniferous palaeogeographical reconstruction provided by Metcalfe (1996, 1997), South China and the Tarim Basin were situated near the tropical and temperate zones (Fig. 3B). This may imply that *Eochoristites* lived in a warm-water environment during the early Early Carboniferous.

Eochoristites neipentaiensis Chu, 1933

Fig. 4A-C, E-N, R

1933 *Eochoristites neipentaiensis* Chu, p. 31-37, pl. 3, figs. 23-37; pl. 4, figs. 1-4, 6-11; pl. 5, figs. 6-7.
1955 *Eochoristites neipentaiensis* - Wang, p. 143, pl. 80, fig. 5, 7, 10.
1964 *Eochoristites neipentaiensis* - Wang et al., p. 481-482, pl. 84, fig. 15-19.
1982 *Eochoristites neipentaiensis* - Wang et al., p. 240, pl. 76, fig. 8.
1987 *Eochoristites neipentaiensis* - Tan & Tang, p. 172, pl. 2, fig. 40-43.
1987 *Eochoristites neipentaiensis* - Yang & Jiang, pl. 3, fig. 10.
1987 *Eochoristites neipentaiensis* - Xu - Yang, pl. 3, fig. 12-14.
1995 *Eochoristites neipentaiensis* - Chen, pl. 1, figs. 24-27.
1996 *Eochoristites neipentaiensis* - Li et al., pl. 11, fig. 28-32.

Material. Eleven ventral valves and six dorsal valves. Of these eight ventral valves (NIGP 123636, NIGP 123638, NMV P149118-23) and four dorsal valves (NMV P149115-116, NMV P149119, NMV P149124) are illustrated.

Description. Medium size for genus; subtriangular in outline; both valves moderately convex both longitudinally and transversely; hingeline narrower than shell width near midlength; cardinal extremities obtuse.

Ventral valve slightly more convex than dorsal valve; beak slightly incurved; interarea triangular and slightly concave and inclined, marked by fine horizontal growth lines; delthyrium large, the ratio of height and width about 5/4; median sulcus distinct, shallow, rounded in the posterior, flattened anteriorly, the angle of bounding margins about 20°. Dorsal valve moderately convex; beak small and incurved; median fold prominent, originating from beak.

External surface ornamented by simple and rounded costae with nearly equally spaced furrows; five costae in sulcus, bifurcating twice, the lateral sulcal costae rounded; one costa on the posterior part of the median fold, bifurcating twice anteriorly to form four costellae; 17 costae on each lateral area, simple, sharp and rounded.

Ventral interior with strong dental plates, thickened posteriorly and wedging deeply into the shell (Fig. 5A-B), diverging anteriorly, extending to one-third valve length, enclosing the oval muscular impression; a triangular fold occurring near beak, extending forward with rapidly reducing in height, becoming low ridge (Fig. 5A-B).

Dorsal interior crura plates thin and short, diverging forward following the bounding furrows of median fold.

Measurements (in mm):

Specimen	Width	Length	Thickness	Apical angle
NIGP 123636•	29.5	20.5	14.6	122°
NIGP 123638•	30.0	19.5	15.0	115°
NMV P149115Δ	24.5	15.0	6.5	128°
NMV P149116Δ	35.5	27.5	9.5	125°
NMV P149117•	32.50	24.5	14.5	125°
NMV P149118•	28.5	19.5	12.5	121°
NMV P149119Δ	30.0	21.5	7.5	138°
NMV P149120•	36.0	26.5	13.0	118°
NMV P149121•	35.5	27.0	13.5	115°
NMV P149122•	37.0	24.5	12.5	131°
NMV P149123•	37.5	30.5	14.0	117°
NMV P149124Δ	41.0	32.5	10.0	132°

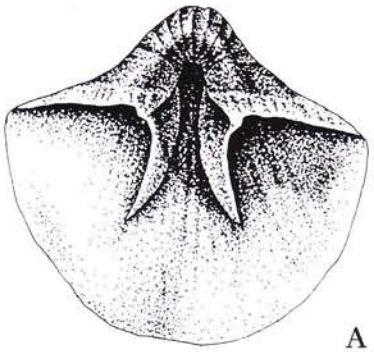
•:ventral valve; Δ:dorsal valve

Discussion. Jin (1961) proposed a new subspecies, *Eochoristites neipentaiensis alatus*, based on material from the Kinling Formation in the Wanghucun area of Xuancheng, Anhui Province (Loc. 6 in Fig. 3A) and the Longtan area of Nanjing, Jiangsu Province (Loc. 7 in Fig. 3A), South China. These specimens are distinguishable from the holotype of *E. neipentaiensis* Chu from the Kinling Limestone of Nanjing (Loc. 7 in Fig. 3A) in the possession of a more transversely triangular to semicircular outline and more mucronate cardinal extremities.

Eochoristites transversa Chu, *E. lungtanensis* Chu and *E. elongata* Chu from the Kinling Limestone of Nanjing, South China (Chu, 1933) are all comparable with the present species in general features. However, *E. transversa* is distinguishable in having a transverse outline, higher interarea, thinner shells, and a shallower and more flattened median sulcus. *E. lungtanensis* is small and its hingeline marks the maximum shell width. In addition, it possesses a deep and sharp median sulcus with a simple, ill-defined median costa. *E. elongata* can be separated from the present species in being elongate-oval in outline, with a more highly convex ventral valve and a lower, triangular interarea.

E. beichuanensis Jiang (in Yang and Jiang, 1987, p. 83, pl. 3, figs 6a-c) from the Majiaba Formation of the Beichuan area of Sichuan Province, South China, is characterised by a well-developed, deep sulcus lacking a median costa, unlike the present species which has more closely spaced costae on the lateral slopes and also a median costa within its broad and shallow sulcus.

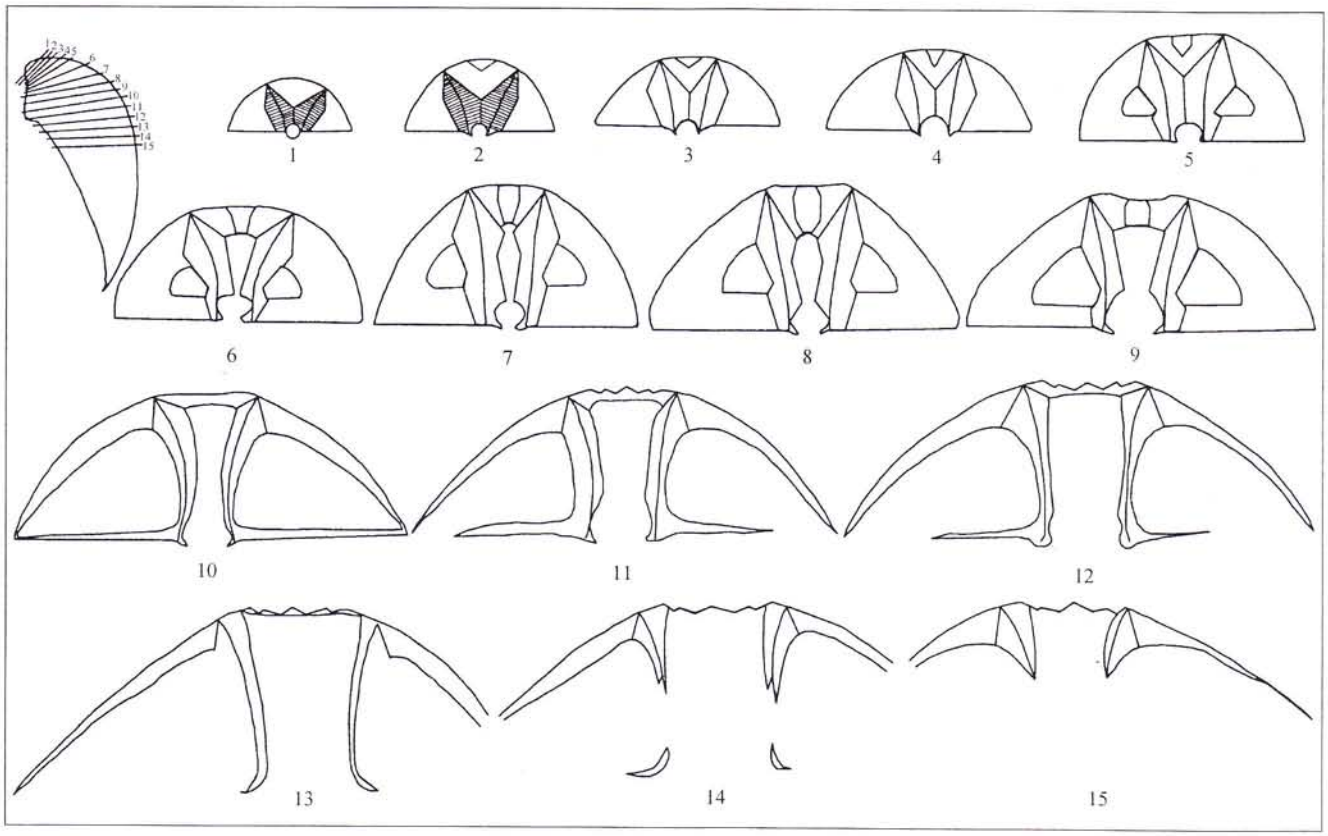
Horizon and locality. *Eochoristites neipentaiensis* Assemblage of the upper part of the Bachu Formation, the early Tournaisian, the Bachu area of the Tarim Basin, northwest China.



A

Fig. 5 - Interior of ventral valve of *Eochoristites neipentaiensis* Chu (1933). **A.** Reconstruction of ventral interior (based on the serial sections), x2. **B.** Serial sections of ventral valve of showing the dental plates. The number showing the position of each section, 1-15 sections at the distance 4.5 mm, 5.5 mm, 7.0 mm, 8.0 mm, 10.0 mm, 11.0 mm, 12.5 mm, 13.5 mm, 15.0 mm, 16.0 mm, 17.5 mm, 19.0 mm, 20.0 mm, 21.5 mm and 23.0 mm from the ventral beak, x3.

B



Eochoristites leei Chu, 1933

Fig. 4O, Q

1933 *Eochoristites leei* Chu, p. 40-42, pl. 4, fig. 13-19.
1961 *Eochoristites leei* - Jin, p. 277, pl. 1, fig. B. 1-3; pl. 2, fig. D. 1-4.
1964 *Eochoristites leei* - Wang et al., p. 483, pl. 84, fig. 20-23.
1982 *Eochoristites leei* - Wang et al., p. 240, pl. 77, fig. 1-2.
1987 *Eochoristites leei* - Hu, pl. 12, fig. 1-2, 5-6.

Material. Two ventral valves (NMV P149127-128) are figured herein.

Description. Medium size for genus; pentagonal in outline; unequally biconvex in lateral profile; hingeline much narrower than the greatest width near posterior of shell; cardinal extremities obtuse.

Ventral valve moderately convex; beak pointed and slightly incurved; interarea triangular, slightly concave and inclined; delthyrium large; median sulcus distinct and shallow, widening forward. Dorsal valve less convex than ventral valve; beak small and incurved; median fold high, strong and rounded. About 12 simple costae on each lateral area. Sulcus having weaker costae than lateral areas, costae originating from beak, median costa simple, lateral sulcal costae bifurcating; fold marked by four well defined costae.

The internal features are same as that of *E. neipentaiensis.*

Measurements (in mm):

Specimen	Width	Length	Thickness	Apical angle
NMV P149127•	50.5	42.5	16.5	122°
NMV P149128•	41.0	30.5	13.5	115°

Discussion. The present species is distinguishable from the other species of the genus from the Kinling Limestone of Nanjing, South China (Chu, 1933) by its pentagonal and unequally biconvex outline and undivi-

ded median costa in the sulcus. *Eochoristites chui* Yang (1964; Jin and Liao, 1974) from the Tanbagou Formation of Guizhou Province is similar to the present species in general features, but differs by its semicircular outline, smaller size and nearly parallel dental plates.

Horizon and locality. *Eochoristites neipentaiensis* Assemblage of the upper part of the Bachu Formation, the early Tournaisian, the Bachu area of the Tarim Basin, northwest China.

Order Rhynchonellida Kuhn, 1949

Suborder Rhynchonellidina Muir-Wood, 1955

Superfamily Porambonitoidea Davidson, 1853

Family Trigonirhynchiidae McLaren, 1965

Genus *Ptychomaletoechia* Sartenaer, 1961

Type species. *Rhynchonella omaliusi* Gosselet, 1877

Diagnosis. Costae simple, starting at umbo; number of costae variable, but high. Sulcus and fold pronounced, not starting at the beaks; deep cupule- to amphora-shaped, covered septalium, supported by a septum.

Discussion. This genus was first proposed by Sartenaer (1961), who later (Sartenaer, 1969) redescribed it. The above diagnosis follows Sartenaer (1969, p. 147). Externally, the present genus has remarkable resemblance with *Camarotoechia* Hall et Clarke (1893), an early Givetian genus (Sartenaer, 1961), in general outline and ornamentation so that some Chinese specimens of *Ptychomaletoechia* were previously referred to *Camarotoechia*. However, *Camarotoechia* can be differentiated from *Ptychomaletoechia* by its less convex shells, sulcus and fold with bifurcating costae crossed by strong concentric lamellae. Internally, *Camarotoechia* has a uncovered septalium supported by a septum, and the septalium of *Ptychomaletoechia* is covered by a connectivum.

By the above distinction, *"Camarotoechia" kinlingensis* (Grabau), *"C". panderi* (Semenov et Moeller) and *"C". xuanchengensis* Ching from the Late Devonian to Early Carboniferous strata of China should be assigned to *Ptychomaletoechia*.

In addition, *Pleuropugnoides* Ferguson, 1996, a Visean genus, is comparable with *Ptychomaletoechia* in size, outline and external ornamentation, but it can not be confused by having more distinct ribs with sharp crests, which originate at the beaks. The distinct sulcus and fold of *Pleuropugnoides* also commence at the umbo, whereas those of *Ptychomaletoechia* often start at anterior of the beaks. Internally, *Pleuropugnoides* has a uncovered septalium supported by a median septum, *Ptychomaletoechia* possesses a covered septalium.

Ptychomaletoechia bachuensis sp. nov.

Fig. 6A-E

1995 *Ptychomaletoechia* sp., Chen, pl. 1, fig. 1-5.

Etymology. Named for the Bachu area, where these specimens were collected.

Material. Three complete specimens, five ventral valves and six dorsal valves, of these a complete specimen with two valves conjoined (NIGP 123621), a ventral valve (NIGP 123622) and two dorsal valves (NIGP 123620, NIGP 123623) are figured.

Holotype. Specimen NIGP 123621 (Fig. 6B, D) from the upper part of the Bachu Formation of the Xiaohaizi Section, Bachu County, and housed in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences.

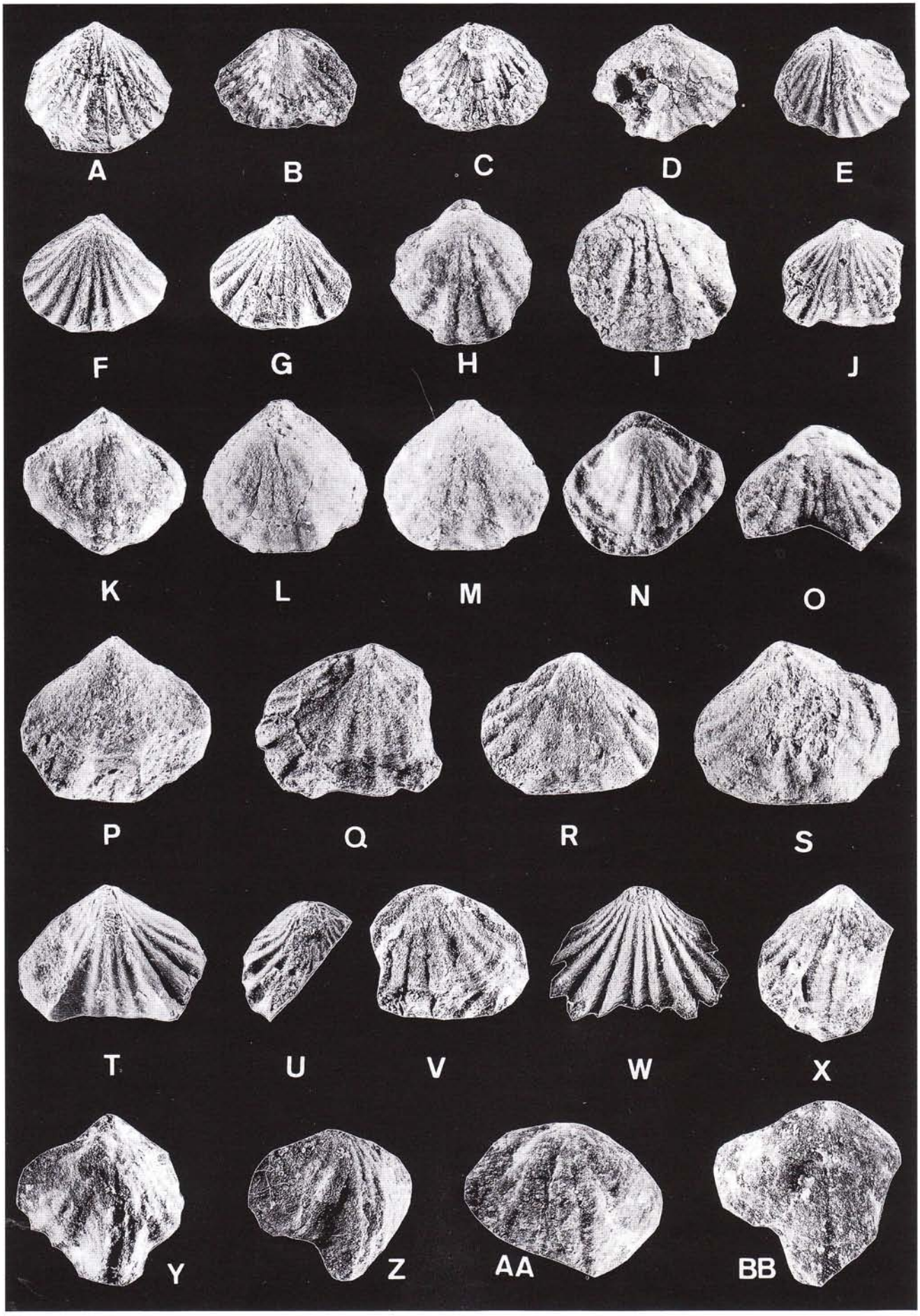
Diagnosis. Small species for genus; slightly subpentagonal to suboval shell; sulcus and fold moderately developed; costae low; ventral interior dental plates, short, strong; dorsal interior median septum long, high, supporting a large, prominent, covered septalium.

Description. Small in size; slightly subpentagonal to suboval in outline; unequally biconvex in lateral profile; dorsal valve more strongly convex than ventral valve.

Ventral valve slightly convex; beak small, incurved; sulcus indistinct, commencing at midvalve, becoming broad, shallow near anterior margin. Dorsal valve strongly convex with greatest convexity at umbonal region; beak small, strongly incurved; fold low, indistinct, originating near midvalve.

External surfaces ornamented by angular costae, simple, originating at anterior of the beaks; two costae in sulcus, three on fold; about five costae on each flank.

Fig. 6 - A-E, *Ptychomaletoechia bachuensis* sp. nov. A, paratype, NIGP 123620, a dorsal valve in dorsal view, x3; B, D, holotype, NIGP 123621, a conjoined specimen in ventral & dorsal views, x3; C, E, NIGP 123622-23, a ventral valve in ventral view, a dorsal internal mould in dorsal view x3. F-I, K-M, P, S, *Ptychomaletoechia panderi* (Semenov et Moeller, 1863). F-G, NIGP 123624, a conjoined specimen in dorsal, ventral views, x3; H-I, NIGP 123626, a conjoined specimen in dorsal and ventral views, x3, x3. 5; K, P, NIGP 1236123628, a conjoined specimen in dorsal and ventral views, x3, x3.2; L-M, NIGP 123625, a conjoined specimens in dorsal and ventral views, x3; R-S, NIGP 123627, a conjoined specimen in ventral and dorsal views, x3, x3.2. J, Q, U, *Ptychomaletoechia* sp. indet. J, NIGP 123642, a ventral valve in ventral view, x2; Q, U, NIGP 123631, NIGP 123643, a ventral valve in ventral view, x3, a dorsal valve in dorsal view, x2. N-O, T, V, *Ptychomaletoechia kinlingensis* (Grabau, 1930). N-O, NIGP 123629, a conjoined specimens in dorsal and ventral views, x3. T. V, NIGP 123644, NIGP 123632, two ventral valves in ventral views, x3. W, *Ptychomaletoechia* cf. *kinlingensis* (Grabau, 1930). NIGP 123639, a dorsal valve from the MC-1 well in ventral view, x3. X-Z, AA, *Trifidorostellum longhuiense* Tan, 1987. X-Y, NIGP 123633, a conjoined specimens in ventral and dorsal views, x3; Z, AA, NIGP 123634, NIGP 123640, two dorsal valves in dorsal views, x3. BB. *Trifidorostellum* sp. NIGP 123635, a dorsal valve in dorsal view, x3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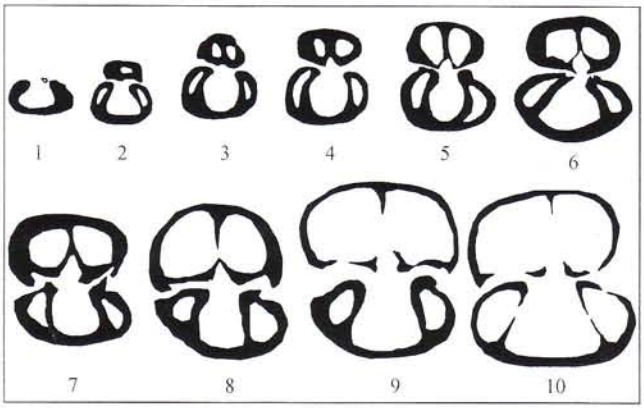

Fig. 7 - Serial sections of *Ptychomaletoechia bachuensis* sp. nov. 1-10 sections at the distance 1.0 mm, 1.3 mm, 1.6 mm, 2.3 mm, 2.6 mm, 2.8 mm, 3.1 mm, 3.5 mm, 4.0 mm and 4.5 mm from the ventral beak, x3.5.

Ventral interior with short, strong dental plates; teeth small, indistinct (Fig. 7). Dorsal interior with long, high median septum, extending forward over half valve length, supporting a long, broad septalium; crural bases strong (Fig. 7).

Measurements (in mm):

Specimen	Width	Length	Thickness	Apical angle
NIGP 123620Δ	10.3	8.7	3.5	115°
NIGP 123621	9.6	6.7	5.5	118°
NIGP 123622•	10.0	7.0	2.5	118°
NIGP 123623Δ	8.9	7.1	3.6	113°

Discussion. *Ptychomaletoechia panderi* (Semenov et Moeller) is the closest species to the new species with many features in common. Nevertheless, the new species is easily distinguishable by possessing a more suboval outline, a rather weak median sulcus and fold, the costae, which commence at anterior of the beaks, and a longer, higher dorsal median septum.

Ptychomaletoechia kinlingensis (Grabau) is somewhat comparable with the new species, but differs in having a distinct pentagonal outline, more strongly convex valves, and well-defined costae, which are more sharp.

When compared with the type species, P. *omaliusi* (Gosselet, 1877), figured by Sartenaer (1961, pl. 1, fig. 6a-e), *P. bachuensis* sp. nov. is slightly smaller, and has a relatively thinner profile, narrower, more rounded costae.

Ptychomaletoechia elburzensis Gaetani (1965, p. 710-715, pl. 68, figs. 4-7; pl. 69, fig. 1) from the Member A of the Geirud Formation of the Upper Devonian in the northern Iran is comparable with the present new species in size and general ornaments, but it can be differentiated by being more transverse and possessing stronger costae and a more pronounced fold and sulcus.

Horizon and locality. *Eochoristites neipentaiensis* Assemblage of the upper part of the Bachu Formation, the early Tournaisian, the Bachu area of the Tarim Basin, northwest China.

Ptychomaletoechia panderi (Semenov et Moeller, 1863)

Fig. 6F-I, K-M, P, S

1863 *Rhynchonella panderi* Semenov et Moeller, p. 233, pl. 2, fig. 7.
1937 *Camarotoechia panderi* - Nalivkin, p. 73, pl. 13, figs. 17-19.
1952 *Camarotoechia panderi* - Sarycheva et al., p. 164, pl. 46, fig. 249.
1956 *Camarotoechia panderi* - Simorin, p. 234-235, pl. 15, figs. 20-27.
1987 *Ptychomaletoechia panderi* - Tan, p. 125, pl. 18, figs. 11-12.
1995 *Ptychomaletoechia panderi* - Chen, pl. 1, figs 13, 15-16, 22.
1996 *Ptychomaletoechia panderi* - Li et al., pl. 11, figs 10-18.
1996 *Ptychomaletoechia kinlingensis* - Li et al., pl. 11, figs 19-22.
1996 *Trifidorostellum* cf. *longhuiense* - Li et al., pl. 11, fig. 9.

Material. Eight complete specimens with valves conjoined, of which five specimens (NIGP 123624-628) are figured.

Description. Medium sized for genus; moderately thick in profile; subpentagonal outline, unequally convex in lateral profile, ventral valve more strongly convex than dorsal valve; cardinal extremities rounded.

Ventral valve moderately convex; beak pointed, incurved, slightly overhanging dorsal beak; median sulcus well-defined, originating at anterior of the beak, extending anteriorly with increasing depth and width. Dorsal valve strongly convex; beak small, strongly incurved; median fold highly convex with flat crest, originating at anterior of the beak.

External ornamentation consisting of strong, rounded costae, simple, unbranching; two costae in sulcus, and three on fold, usually 3-4 costae on each lateral flank.

Dental plates long, prominent. Crural bases moderately developed.

Measurements (in mm):

Specimen	Width	Length	Thickness	Apical angle
NIGP 123624	9.1	6.8	4.5	114°
NIGP 123625	11.0	9.0	5.5	111°
NIGP 123626	9.2	8.7	5.2	114°
NIGP 123627	12.0	8.0	6.0	118°
NIGP 123623	11.0	8.0	5.6	117°

Discussion. This species is widely distributed in the Late Devonian to earliest Carboniferous in both China and Russia. Our specimens are close to those reported from the Shaodong Formation of the central Hunan area, South China (Tan in Tan *et al.*, 1987), which are also characterized by a thick profile, rounded costae, and two costae in the sulcus and three costae on the fold.

The present species shares with *Ptychomaletoechia xuanchengensis* (Ching, 1961) the same arrangement of costae in the sulcus and on the fold as well as in their general outlines, but can not be confused because the latter has 3-4 costae on each flank, in contrast to *P.*

xuanchengensis which has 5-6 costae on each flank. In addition, the fold or sulcus costae of *P. panderi* are as strong as those on the flanks, but the costae in the sulcus of *P. xuanchengensis* are considerably coarser than those on each flank.

Li *et al.* (1996) illustrated four specimens from the Bachu Formation of the Xiaohaizi section, of these, two specimens were referred to the present species (pl. 11, figs 10-18), and the other two were assigned respectively to *Trifidorostellum* cf. *longhuiense* Tan and *Ptychomaletoechia kinlingensis* (Grabau) (pl. 11, figs 19-22). However, the four specimens all are characterized by having a relatively small convexity, two costae in the sulcus and three costae on the fold, and thus, are readily different from *Trifidorostellum longhuiense* and *P. kinlingensis*. As such, we herein refer the illustrated specimens by Li *et al.* (1996) to the present species.

Horizon and locality. *Trifidorostellum longhuiense-Ptychomaletoechia panderi* Assemblage of the basal Bachu Formation, the late Famennian, the Bachu area of the Tarim Basin, northwest China.

Ptychomaletoechia sp. indet.

Fig. 6J, Q, U

1995 *Ptychomaletoechia pleurodon* - Chen, pl. 1, figs 11, 17, 19, 21.

Material. Two ventral valves (NIGP 123642, NIGP 123631) and a dorsal valve (NIGP 123643) are illustrated herein.

Comments. Our specimens are measured, on average, 9.5 mm long, 12 mm wide and 5.5 mm thick. The overall characteristics can be summarized as following: Inflated shells have moderately developed sulcus and fold, which originate at anterior of the beaks. The external ornaments are marked by rounded costae, extending from the anterior of the beak to the anterior margin. Four simple, unbranching costae are present in the sulcus, five unbranching costae are present on the fold. The costae on the flanks occasionally bifurcate. The concentric growth lines are prominent near anterior margins. All observed features of the specimens agree with *Ptychomaletoechia*. However, when compared with *P. omaliusi* (Gosselet), type species of the genus, the present specimens are distinguishable in having relatively flattened shells, a less developed fold and sulcus, more numbers of rounded costae in the sulcus and on the fold.

The present specimens can be separated from any known species of the genus by having more numbers of rounded, unbranching costae in the sulcus or on the fold, and more numbers of branching, rounded costae on the flanks. Consequently, they may represent a new species of *Ptychomaletoechia*. However, the specific assignment is indeterminate because of the poor preservation and inadequate material.

Externally, *Pleuropugnoides pleurodon* (Phillips) also possesses various costae, from 3 to 6, in the sulcus or on the fold, but differs from the present specimens by having the sulcus and fold, which commence at beaks, and the sharper costae, originating at the beaks.

Horizon and locality. *Trifidorostellum longhuiense-Ptychomaletoechia panderi* Assemblage of the basal Bachu Formation, the late Famennian, the Bachu area of the Tarim Basin, northwest China.

Ptychomaletoechia kinlingensis (Grabau, 1930)

Fig. 6N-O, T, V

1930 *Rhynchopora kinlingensis* Grabau, p. 40.
1933 *Camarotoechia kinlingensis* - Chu, p. 25-28, pl. 3, figs. 21-22.
1964 *Camarotoechia kinlingensis* - Wang et al., p. 364-365, pl. 60, figs. 13-14.
1978 *Camarotoechia kinlingensis* - Feng and Jiang, p. 272, pl. 101, fig. 5.
1982 *Ptychomaletoechia kinlingensis* - Wang et al., p. 232, pl. 76, fig. 16.
1987 *Camarotoechia kinlingensis* - Tan, p. 125, pl. 18, figs. 13-17.
1987 *Pleuropugnoides kinlingensis* - Yang & Jiang, pl. 2, fig. 12.
1987 *Ptychomaletoechia pleurodon* - Hu, pl. 12, figs. 10-11.
1995 *Camarotoechia kinlingensis* - Chen, pl. 1, fig. 12.
1996 *Ptychomaletoechia pleurodon* - Li et al., pl. 11, figs. 23-26.

Material. One complete specimen with two valves conjoined (NIGP 123629), two ventral valves (NIGP 123644, NIGP 123632), all illustrated herein.

Description. Small size for genus; pentagonal in outline; unequally biconvex in lateral profile; dorsal valve more strongly convex than ventral valve.

Ventral valve moderately convex; beak pointed, incurved, overhanging dorsal beak; median sulcus distinct, originating at anterior of the beak, extending anteriorly, increasing in depth and width, bounded by prominent sulcal costae. Dorsal valve strongly convex; beak small, strongly incurved; median fold highly convex with flat crest, originating at anterior of the beak.

External surface ornamented by symmetrically angular costae, originating at anterior of the beak; sulcal bounding costae sharp, highly elevated; costae in sulcus and on fold unbranching, three in sulcus, four on fold; four costae on each flank, which occasionally bifurcate once.

Ventral interior with strong dental plates, diverging obliquely; teeth indistinct, small; dorsal median septum well-defined, supporting a well-developed septalium; crural bases strong (Fig. 8).

Measurements (in mm):

Specimen	Width	Length	Thickness	Apical angle
NIGP 123629	10.0	9.1	5.0	121°
NIGP 123644•	12.0	8.1	3.5	118°
NIGP 123623•	12.8	8.5	3.6	116°

Discussion. This species was first proposed and listed by Grabau (1930) in his paper "Note on Chihsia Lime-

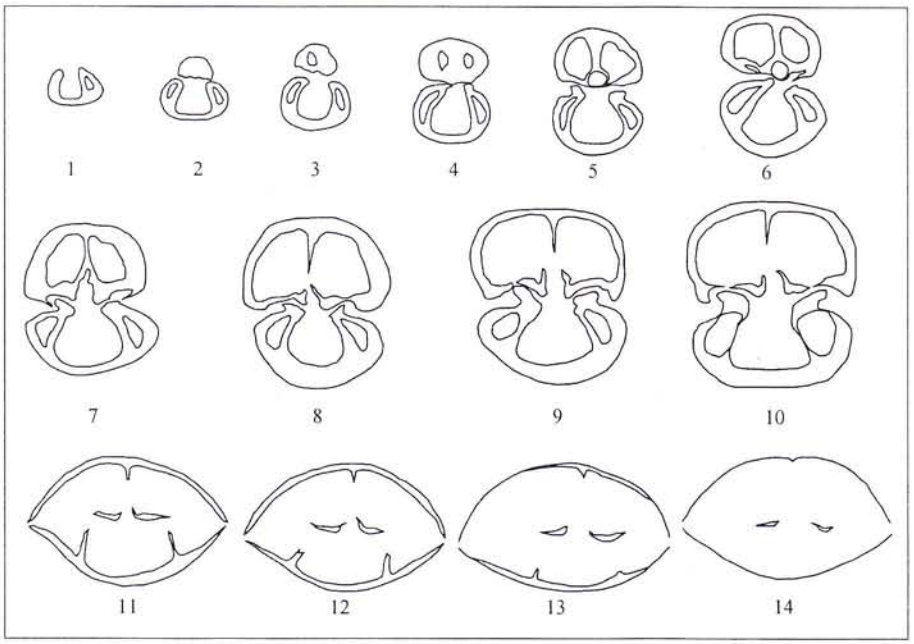

Fig. 8 - Serial sections of *Ptychomaletoechia kinlingensis* (Grabau, 1930). 1-14 sections at the distance 0.9 mm, 1.1 mm, 1.5 mm, 1.7 mm, 1.9 mm, 2.1 mm, 2.3 mm, 2.6 mm, 2.8 mm, 3.0 mm, 3.6 mm, 3.9 mm, 4.0 mm and 4.6 mm from the beak, x3.5.

stone", and first described by Chu (1933), but attributed to Grabau. Hence, we herein follow that authorship of *C. kinlingensis* is of Grabau, as implied by Chu (1933).

Ptychomaletoechia panderi (Semenov et Moeller) from the basal Bachu Formation of the Bachu area (Chen, 1995) is similar to the present species in many respects. However, *P. panderi* is characterized by its less strongly convex valves, two costae in the sulcus and three on the fold.

Ptychomaletoechia sulculifera Sartenaer (1969, pl. 16, figs 1-10) from the Famennian of the Canadian Rocky Mountains bears some common features to the present species, but it has a subrounded outline, and its median costa is coarser than other costae. In addition, the Canadian species has an occasional deep, broad furrow on the fold.

Ptychomaletoechia xuanchengensis (Ching) differs from the present species in having a stronger valve convexity, a narrower median sulcus, a less transverse outline, and numerous slender costae. The present species is also comparable with *P. omaliusi* (Gosselet) in outline and external ornamentation, but can be distinguished in having more angular costae and more highly elevated and sharper sulcal bounding costae.

Pleuropugnoides pleurodon (Phillips, 1836) is distinguished from the present species by possessing various costae, often 3-6, in the sulcus and on the fold, more sharper costae with angular crests, which originate at the beaks. A illustrated specimen previously referred to *"Ptychomaletoechia" pleurodon* by Li *et al.* (1996, pl. 11, figs 23-26) is typified by moderately biconvex shells, more rounded costae, which commence at anterior of the beaks, three rounded costae in the sulcus and four on the fold. These features imply that this specimen should belong to *Ptychomaletoechia kinlingensis.*

The present species resemble *Ptychomaletoechia elburzensis* Gaetani, 1965 in similar outline and well-defined fold and sulcus, but it is distinguishable by being larger and having a thicker profile.

Two subspecies described by Gaetani (1965) as *Ptychomaletoechia ? deltidialis deltidialis* (p. 716-725, pl. 69, fig. 2-8; pl. 70, fig. 1-4) and *P. ? deltidialis traversaria* (p. 725-726, pl. 70, fig. 5a-e) from the Member A of the Geirud Formation of the lower Famennian in the northern Iran are close to the present species in the possession of a similar size, a well-developed fold and sulcus, however, *P. ? deltidialis deltidialis* has a more elongate outline and more numbers of costae in sulcus (or on fold). Although *P. ? deltidialis traversaria* possesses a transverse outline, it is more rounded, whereas *P. kinlingensis* is subpantagonal. In addition, *P. ? deltidialis traversaria* has more numbers of costae in sulcus (or fold).

Horizon and locality. *Trifidorostellum longhuiense-Ptychomaletoechia panderi* Assemblage of the basal Bachu Formation, the late Famennian, and *Eochoristites neipentaiensis* Assemblage of the upper part of the Bachu Formation, the early Tournaisian, the Bachu area of the Tarim Basin, northwest China.

Ptychomaletoechia cf. **kinlingensis** (Grabau, 1930)

Fig. 6W

1933 *Camarotoechia kinlingensis* - Chu, p. 25-28, pl. 3, figs 21-22.
1995 *Ptychomaletoechia* cf. *kinlingensis* - Chen, pl. 1, fig. 29.

Discussion. A specimen (NIGP 123639), 8.2 mm long, 12 mm wide, 3.5 mm thick and with 116(apical angle, was obtained from the core of Well MC-1 of the Tarim Basin. The specimen is similar to *P. kinlingensis* (Grabau) in outline and size and apical angle, but it is

characterized by a deeper median sulcus, originating from the beak, and sharper, more angular costae on the external surface. These asymmetrically angular costae are defined by prominent, deep furrows, which are apparently unequally spaced. However, only one specimen was available in our collection, therefore, an accurate comparison with *P. kinlingensis* (Grabau) must wait until more material is obtained.

Horizon and locality. *Eochoristites neipentaiensis* Assemblage of the upper part of the Bachu Formation, the early Tournaisian, the Bachu area of the Tarim Basin, northwest China.

Genus *Trifidorostellum* Sartenaer, 1961

Type species. Leiorhynchus dunbarense Haynes, 1916

Comments. This genus was erected by Sartenaer (1961, p. 5) with *T. dunbarense* (Haynes) as the type species. The genus is characterized by uniplicate shells, conspicuous dorsal umbo commonly projected posteriorly beyond the ventral valve, and a deep sulcus and highly raising fold. In proposing the genus, Sartenaer (1961) thought that the genus was restricted to the lower Upper Famennian of Canada and USA. Later, Sartenaer and Xu (1989) restudied the species of *Trifidorostellum* Sartenaer, including specimens from China, North America and Russia, and proposed a world-wide *Trifidorostellum* Zone representing the latest Famennian brachiopod fauna. This brachiopod zone naturally incorporates the earlier established regional zones: *T. aldanicum* Zone of the Far East of Russia (Alekseeva and Sidiachenko, 1968) and the *T. longhuiense* Assemblage of Sartenaer and Xu (1989).

Trifidorostellum longhuiense Tan, 1987

Fig. 6X-Z, AA

1987 *Trifidorostellum* sp., Liu, p. 150.
1987 *Trifidorostellum cascadense cascadense* - Liu, p. 150-151.
1987 *Trifidorostellum dunbarense* - Liu, p. 150-151.
1987 *Trifidorostellum longhuiense* Tan in Tan et al., p. 126, pl. 18, figs. 26-35.
1987 *Trifidorostellum longhuiense uniplicatum* Tan in Tan et al., p. 126, pl. 18, figs. 41-45.
1987 *Trifidorostellum longhuiense triplicatum* Tan in Tan et al., p. 126, pl. 18, figs. 41-45.
1987 *Trifidorostellum longhueense* - Tan in Tan & Tang, p. 170, pl. 2, figs. 1-14.
1987 *Trifidorostellum longhueense uniplicatum* - Tan in Tan & Tang, p. 171, pl. 2, figs. 25-33.
1987 *Trifidorostellum longhueense triplicatum* - Tan in Tan & Tang, p. 170-171, pl. 2, figs. 15-24.
1989 *Trifidorostellum longhuiense* - Sartenaer and Xu, p. 50-55, pl. 1, figs. 1-8.
1995 *Trifidorostellum longhuiense* - Chen, pl. 1, fig. 30.
1995 *Trifidorostellum dunbarense* - Chen, pl. 1, figs. 18, 20, 28.

Material. Three complete specimens with conjoined valves and four dorsal valves are available. Of these a complete specimen with conjoined valves (NIGP 123633) and two dorsal valves (NIGP 123634, NIGP 123640) are illustrated herein.

Description. Small sized species for genus; transversely subelliptic to suboval outline; uniplicate to parasulcate; strongly unequally convex in lateral profile, dorsal umbo inflated and slightly projected posteriorly beyond ventral valve; anterior commissure deeply crenulated by costae.

Ventral valve moderately convex; beak small, acute, slightly incurved, commonly almost in contact with dorsal valve; palintrope short, low and indistinct; flanks regularly and moderately convex; median sulcus well-developed and deep, originating at anterior of the beak; widening and deepening abruptly anteriorly, reaching its greatest width at the anterior commissure; sulcal floor flat; tongue high with sharp borders.

Dorsal valve strongly convex, greatest convexity at costae on the fold; median fold originating anterior to the beak, rising abruptly anteriorly, where it is most prominent; top of fold slightly rounded; flanks steep, rapidly becoming vertical towards the commissure.

Costae strong, regular and simple; costae on fold and lateral flanks moderately developed, angular with rounded tops; median costae commencing at anterior of the beak; lateral costae beginning at the umbo; usually three fold costae and two in the sulcus.

Ventral interior with short and robust teeth; dental plates short. Dorsal interior with deep sockets; divided hinge plates with narrow outer plates; crural bases strong (Fig. 9).

Measurements (in mm):

Specimen	Width	Length	Thickness	Apical angle
NIGP 123633	12.1	11.4	8.5	105°
NIGP 123634△	12.0	9.5	5.5	119°
NIGP 123640△	13.0	8.5	5.8	117°

Discussion. The present species was proposed almost at the same time in two papers by Tan (in Tan *et al.*, 1987 and in Tan and Tang, 1987), with slightly different spellings: *T. longhuiense* and *T. longhueense*, but based on the same specimen. As the paper by Tan (in Tan *et al.*, June of 1987) in which *T. longhuiense* was proposed was published slightly earlier than his other paper (Tan and Tang, August of 1987), *T. longhuiense* Tan takes priority and is thus accepted. In the same paper, Tan also proposed two new subspecies under *T. longhuiense*, namely *T. longhuiense triplicatum* and *T. longhuiense uniplicatum*. However, Sartenaer and Xu (1989) broadened the definition of *T. longhuiense* to accommodate more intraspecific variations, therefore consolida-

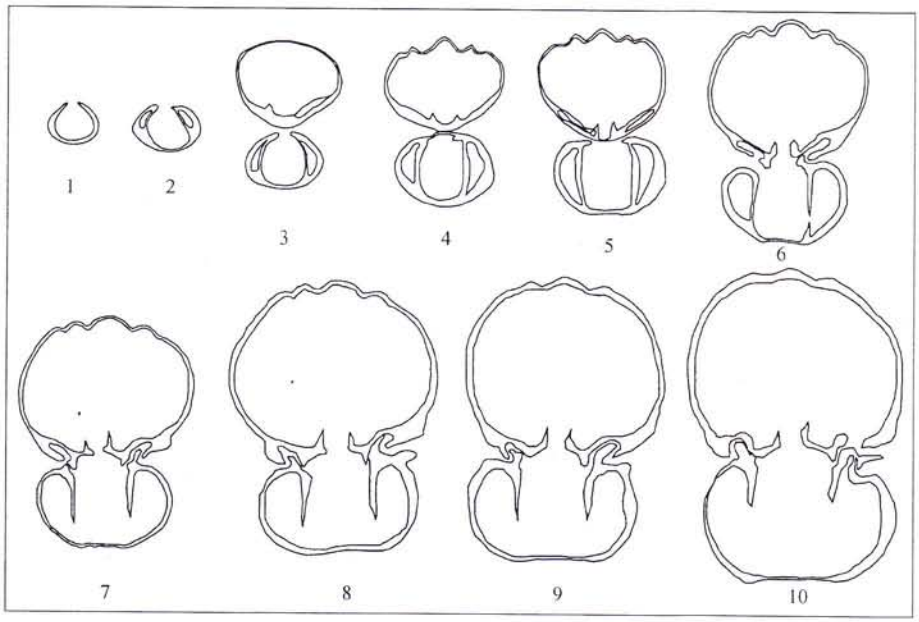

Fig. 9 - Serial sections of *Trifidorostellum longhuiense* Tan, 1987. 1-10 sections at the distance 0.9 mm, 1.4 mm, 2.0 mm, 2.4 mm, 2.8 mm, 3.4 mm, 3.6 mm, 3.9 mm, 4.1 mm and 4.7 mm from the beak, x4.2.

ting Tan's two subspecies into *T. longhuiense*. In the same paper, Sartenaer and Xu (1989) also synonymized specimens *Trifidorostellum dunbarense* (Haynes) of Liu (1987) from the Shaodong Formation of central Hunan with *T. longhuiense*. Although *Trifidorostellum dunbarense* (Haynes), as described and illustrated by Sartenaer (1961, p. 5-6, pl. 1, fig. 4a-e), is very similar to *T. longhuiense* in all external features, a careful reexamination of many specimens (Sartenaer and Xu, 1989) shows that *T. dunbarense* is significantly larger than the Chinese species. Therefore, we agree with Sartenaer and Xu (1989) in placing these Chinese specimens with *T. longhuiense* Tan.

Trifidorostellum longhuiense can be differentiated from *T. obscurum* Cooper and Dutro (1982) from the Upper Famennian of New Mexico by having larger and thicker shells. *Trifidorostellum cascadense cascadense* (Warren, 1927) from the Upper Famennian of Canada and T. uralicum fontis (Sartenaer, 1969) from the Upper Famennian of central Idaho of USA are also both distinguishable from the present species in having a medium to large size, less elevated costae and a more weakly crenulated anterior commissure.

Horizon and locality. *Trifidorostellum longhuiense-Ptychomaletoechia panderi* Assemblage of the basal Bachu Formation, the late Famennian, the Bachu area of the Tarim Basin, northwest China.

Trifidorostellum sp. indet.

Fig. 6BB

1995 *Trifidorostellum* sp., Chen, pl. 1, fig. 23.

Comments. A broken dorsal valve (NIGP 123635) is available in our collection. It is approximately 13.5 mm long, 11.2 mm wide and 6.5 mm thick. This dorsal valve is characterized by strong convexity and a highly, prominently elevated median fold. These features suggest *Trifidorostellum* Sartenaer (1961). In particular, it is close to some of the *T. longhuiense* specimens having fewer costae (e. g. *T. longhuiense uniplicatum* of Tan, 1987), but our specimen differs from the Hunan specimens in having a highly raising fold, with two ribs enclosing a median groove. Potentially, the present specimen may represent a new species of *Trifidorostellum*.

Horizon and locality. *Trifidorostellum longhuiense-Ptychomaletoechia panderi* Assemblage of the basal Bachu Formation, the late Famennian, the Bachu area of the Tarim Basin, northwest China.

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