A new locality of well-preserved silicified Early Permian brachiopods in Loei province, NE Thailand

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Abstract

Several localities of brachiopod faunas have been reported in the Loei area found mostly in late Palaeozoic shales and limestones. Silicified articulate brachiopods were observed in the Pha Dam section east of Loei, in the Nam Suay sub-district, Na duang district. This section is part of the Nam Mahoran Formation according to the geological map published by DMR. It consists of brown shales and siltstones interbedded with dark grey limestones and the brachiopod assemblage includes cf. *Chonetinella, Rhipidomella, Phricodothyris, Marginifera, Reticulatia,* STROPHOMENIDA *fam. indet.*, and SPIRIFERIDA *fam. indet.*. These specimens are relatively small in size, silicified and mostly consist of single-valves. The occurrence and characteristics of the brachiopods in this section differ from those reported by previous workers in the area. This locality also contains several other abundant and diverse invertebrate groups such as bryozoans, crinoids and solitary corals. The rocks from both sections consist of shale and limestone. The brachiopods, corals, bryozoans and crinoids are interpreted as having lived in shallow marine or shelf environments. Preliminary age determinations are based mainly on brachiopods and suggest that the rocks should be reassigned to the Lower Permian which is compatible with the age assigned in the geological map of Thailand.

Keywords: silicified brachiopods, invertebrate fossils, Loei province

Introduction

The Permian brachiopod faunas of Thailand are both diverse and abundant and are found both on the Sibumasu and Indochina Terranes. Thai brachiopods are very important for tectonic, palaeoclimatic, stratigraphic and palaeoenvironmental studies[1]. Thai Sibumasu brachiopods have been reported in many monographs and papers[2,3,4] but the Indochina faunas of Thailand have only been documented in a few relatively brief studies. Yanagida, et al. in 1974[5], 1999[6] and Pérez-Huerta, et al. in 2007[7] have described a total of 59 species from 49 genera. Thailand brachiopods have been described from the following localities.

This paper contains preliminary descriptions and age conclusions which will be refined in future studies. Specimens were collect by the writers in the dry seasons of 2010 – 2012 in collaboration with the staff of the Sirindhorn museum and Phuwiang Dinosaur museum, Department of Minerals Resources and Palaeontological Research and Education Centre, Mahasarakham University. The materials were collected in situ and an attempt was made to collect all visible specimens, they was cleaned in Sirindhorn museum's laboratory by pneumatic air pen. The brachiopods at this site are not highly - abundant and well preserved silicified sample. The brachiopods at this site are particularly abundant not particularly well preserved.

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Terminology and classification

The terminology used here follows Williams and Rowell, 1965[10]. The supraspecific classifications for taxa within the order Strophomenida follow Cocks. and Jia-Yu, 2000[11]. The supraspecific classifications for taxa within the order Productida follow Brunton et al., 2000[12]. The supraspecific classifications for taxa within the order Orthida follow Williams and Harper, 2000[13]. The supraspecific classifications for taxa within the order Spiriferida follow Carter et al., 2006[14].

Geological setting

The Pha Dam section is located in the Na-Duang district, Loei province. It is covered by marine sedimentary rock ranging up to the Upper Permian[8,9]. It is assigned to the Nam Mahoran Formation of the Saraburi Group, which consists predominantly of white to grey, thick-bedded limestone of algal reef origin, brownish shale, calcareous shale and in the lowest beds is reddish brown sandstone interbedded with chert. It outcrops in a North – South belt East of Muang district Loei province extending to the East and Southeast of Wang Sa Phung district Loei province. The Pha Dam section is a road-cut section between a small hill in the east of Loei by highway number 3117 (Figure 1), which contains folded brown siliceous shale intercalated with dark grey limestone.

Systematic palaeontology

Repository Studied specimens are housed in the Sirin dhorn Museum, Department of Mineral Resources, Kalasin, Thailand with specimen numbers prefixed herein SM.

Phylum BRACHIOPODA Duméril, 1805

Subphylum LINGULIFORMEA Williams et al., 1996

Class STROPHOMENATA Williams et al., 1996

1. STROPHOMENIDA *fam. Indet.*

Order STROPHOMENIDA Öpik, 1934

Figure 3 A

1.1 Examined specimen

Three poorly preserved external pedicle valves. Registered specimens SM2014-2-001 to SM2014-2-003

1.2 Diagnosis

See Cocks. and Jia-Yu, 2000[11] page 216

1.3 Description

Small-size shells are about 2 cm. wide; subtrigonal shell outline; the greatest width is at mid-length; weak sulcus; the surface ornamentation with strong plicae and sparse short spines. Internal structure cannot be observed.

1.4 Measurement (mm.)

Specimen	Length	Width	Thickness
SM2014-2-001	13.20	19.30	11.05
SM2014-2-002	13.15	18.30	7.45
SM2014-2-003	12.20	19.05	9.50

Subphylum RHYNCHONELLIFORMEA Williams et al., 1996

2. *Chonetinella* sp.

Order PRODUCTIDA Sarytcheva and Sokolskaya, 1959

Suborder CHONETIDINA Muir – Wood, 1955

Superfamily CHONETOIDEA Bronn, 1862

Family RUGOSOCHONETIDAE Muir – Wood, 1962

Subfamily RUGOSOCHONETINAE Muir – Wood, 1962

Genus *Chonetinella* Ramsbottom, 1952

Chonetinella sp.

Figure 3B

2.1 Examined specimen

Only one well preserved external pedicle valve. Registered specimen SM2014-2-004.

2.2 Diagnosis

See Grant, 1976[2] page 74 and Brunton et al., 2000[12] page 405

2.3 Description

Small-size shell is about 2 cm. wide; subtrigonal shell outline; the greatest width is at mid-length; weak sulcus; the surface ornamentation with strong plicae and sparse of short spines. Internal structure cannot be observed.

2.4 Discussion

Chonetinella sp is always characterized by a distinct sulcus and the bilobate character of lateral sides which originate near the umbo, remarkably ventral valve

convex with deep median sulcus. Our *Chonetinella* sp. is quite close to *Chonetinella* sp., Yanagida[15] (1975, p. 20, pl. 2, figs 8 – 9) from Huai Luang, Loei – described as "sulcus distinct, originating near beak as a distinct groove, surface ornamented by fine radial capillae"; and it is also are similar to *Chonetinella cymatilis*, Grant[2] (1976, p77, pl.16, figs. 1 – 58) from Ko Muk, Trang in general outline, sulcus and ornamentation. They also look similar to *Chonetinella andamanensis*, Waterhouse, et al.[3] (1981, p. 65, pl. 2, figs. 18 – 19, pl. 3, figs. 1 – 18) from Ko Yao Noi, Krabi and *Chonetinella* cf. *andamanensis*,Waterhouse Thonnarat, et al.[16] (2012, p. 41, pl. 4, figs. B – I) from Ban Ao Nam, Krabi – bisected by deep sulcus, very narrow floor.

2.5 Measurement (mm.)

Specimen	Length	Width	Thickness
SM2014-2-004	10.85	19.90	2.65

3. *Marginifera* sp.

Order PRODUCTIDA Sarytcheva and Sokolskaya, 1959

Suborder PRODUCTIDINA Waagen, 1883

Superfamily PRODUCTOIDEA Gray, 1840

Family PRODUCTELLIDAE Schuchert, 1929

Subfamily MARGINIFERINAE Stehli, 1954

Genus *Marginifera* Waagen, 1884

Marginifera sp.

Figure 3C

3.1 Examined specimens

Four well preserved external indeterminate valves and three external pedicle valves. Registered specimen in SM2014-2-005 to SM2014-2-011

3.2 Diagnosis

See Grant, 1976[2] page 106 and Thonnarat et al., 2012[16] page 45

3.3 Description

Small-size shells are about 2.5 cm. wide; Triangular droplike shell outline; beak prominent anderect; the ventral valve is not clear sulcus; the greatest width is mid-length; shell ornamented by strong plicae and sparse short strong spines, spines normally broken. Internal structure cannot be observed.

3.4 Discussion

Marginifera is characterized by its shell outline, costation, and spines. Our specimens are similar to *Marginifera arenaria* Grant[2] (1976, p109, pl.24, figs. 1 – 34) from Ko Muk, Trang from their spines and general outline and but it is quite different in ornamentation. While *M. drastica* Grant[2] (1976, p110, pl.26, figs. 1 – 23) from Ko Muk, Trang and *Marginifera* cf. *drastica* Thonnarat, et al.[16] (2012, p. 45, pl. 7, figs. A – F) from Ban Ao Nam, Krabi, *M. nesiotes* Grant[2] (1976, p112, pl.27, figs. 1 – 34), *M. otaria* Grant[2] (1976, p115, pl.25, figs. 1 – 24) from Ko Muk, Trang and *Marginifera drastica* Yanagida[6] (1999, p.129, pl.29, figs 2, 3, 5 – 9) from Khao Hin Kling area near Petchaboon are different in having weak costae. The Huay Nam Suay specimens are closely similar to *M. banphotensis* using its external characters, Yanagida[5] (1964, p.11, pl.3, figs 2 - 3) from near Tambon Ban Phot of Petchaboon province (Indochina terrane).

3.5 Measurement (mm.)

Specimen	Length	Width	Thickness
SM2014-2-005	20.10	22.25	1.70
SM2014-2-006	23.15	25.45	14.20
SM2014-2-007	19.20	21.55	11.10
SM2014-2-008	17.45	25.35	8.10
SM2014-2-009	14.90	24.10	6.25
SM2014-2-010	16.20	28.10	-
SM2014-2-011	12.45	16.40	-

4. *Reticulatia* sp.A

Order PRODUCTIDA Sarytcheva and Sokolskaya, 1959

Suborder PRODUCTIDINA Waagen, 1883

Superfamily PRODUCTOIDEA Gray, 1840

Family PRODUCTIDAE Gray, 1840

Subfamily DICTYOCLOSTINAE Stehli, 1954

Genus *Reticulatia* Muir-Wood and Cooper, 1960

Reticulatia sp.A

Figure 3D

4.1 Examined specimens

One external both of pedicle and brachial valves and ten external pedicle valves. Registered specimens SM2014-2-012 to SM2014-2-023

4.2 Diagnosis

See Brunton et al., 2000[12] page 496

4.3 Description

Small to medium - size shells are about 1.4 – 3.5 cm.; transversely subquadrate with hinge line making greatest width; sub-trigonal shell outline; Pedicle valve have strongly convex with slightly beak; beak prominent rather straight; cardinal extremities quite round to trianglular; the costae, about 10 – 12 costae in 1 cm., on surface; strong rugae found rarely on front to mid-length. Internal structure cannot be observed.

4.4 Measurement (mm.)

Specimen	Length	Width	Thickness
SM2014-2-012	17.55	20.05	9.10
SM2014-2-013	8.75	9.70	-
SM2014-2-014	11.30	11.20	-
SM2014-2-015	20.05	29.65	15.70
SM2014-2-016	27.70	19.70	-
SM2014-2-017	16.55	23.20	-
SM2014-2-018	16.75	21.40	10.80
SM2014-2-019	8.10	11.40	5.60
SM2014-2-020	13.35	22.20	11.35
SM2014-2-021	15.45	23.30	6.45
SM2014-2-022	15.40	20.90	-

5. *Reticulatia* sp.B

Figure 3E

5.1 Examined specimens

Two external both of pedicle and brachial valves and thirty-three external pedicle valves. Registered specimens SM2014-2-024 to SM2014-2-059

5.2 Diagnosis

See Brunton et al., 2000[12] page 496

5.3 Description

Small-size shells are about 1.4 – 3.5 cm.; transversely subquadrate with hinge line making greatest width; sub-trigonal shell outline; Pedicle valve is strongly convex with a slight beak; beak prominent rather straight; cardinal extremities quite round to triangular; the costae, about 10 – 12 costae in 1 cm. on surface; strong rugae found rarely on front to mid-length; sulcus and costae are weakly developed to very clear. Internal structure cannot be observed.

5.4 Discussion

Our *Reticulatia* sp is always characterized by a distinct sulcus and bilobate character of lateral side which originates near umbo, and a remarkable ventral valve convex with deep median sulcus. The *R*. sp. A specimens are difference from *R*. sp.B by well-developed to clear sulcus and costae which in *R*. sp.A cannot be observed. These specimens are similar to *Reticulatia* aff. *R. huecoensis*, Yanagida[15] (1975, p. 26, pl. II, figs 16 – 19; pl. III, Figs. 1 - 2) from Huai Luang, Loei and *Reticulatia uralica*, Yanagida[17] (1966, p. 54, pl. XVI, figs 7 - 8; pl. XVII, Figs. 1 - 4) and *Reticulatia moelleri*, Yanagida[17] (1966, p. 56, pl. XXIII, figs 2 - 7) from North – Central Thailand (all Indochina Terrane) in general outline, size and ornamentation.

5.5 Measurement (mm.)

Specimen	Length	Width	Thickness
SM2014-2-024	15.80	22.75	12.30
SM2014-2-025	14.35	22.00	9.95
SM2014-2-026	12.70	20.70	9.40
SM2014-2-027	14.50	18.60	7.75
SM2014-2-028	11.60	14.10	6.35
SM2014-2-029	8.55	11.45	-
SM2014-2-030	14.80	14.35	8.55
SM2014-2-031	11.35	15.75	9.65
SM2014-2-032	12.20	19.40	-
SM2014-2-033	20.70	26.00	14.60
SM2014-2-034	15.10	19.25	-
SM2014-2-035	19.80	22.35	11.90
SM2014-2-036	11.35	15.45	-
SM2014-2-037	8.70	21.40	-
SM2014-2-038	-	19.35	-
SM2014-2-039	-	45.50	32.65

5.5 Measurement (mm.) cont.

Specimen	Length	Width	Thickness
SM2014-2-040	8.90	11.30	4.30
SM2014-2-041	14.40	19.70	6.95
SM2014-2-042	13.00	20.80	9.05
SM2014-2-043	12.45	19.95	9.65
SM2014-2-044	16.75	21.1	14.65
SM2014-2-045	16.00	21.30	11.65
SM2014-2-046	12.40	16.10	10.9
SM2014-2-047	14.05	15.45	10.10
SM2014-2-048	10.10	20.70	6.50
SM2014-2-049	20.20	21.00	18.40
SM2014-2-050	9.00	13.50	-
SM2014-2-051	18.45	20.05	13.20
SM2014-2-052	16.10	22.70	16.25
SM2014-2-053	16.10	22.70	16.25
SM2014-2-054	16.30	19.40	-
SM2014-2-055	12.35	17.95	7.40
SM2014-2-056	16.90	19.25	-
SM2014-2-057	11.25	19.00	-
SM2014-2-058	-	19.50	14.90
SM2014-2-059	54.90	54.55	32.10

6. *Rhipidomella* sp.

Order ORTHIDA Schuchert and Cooper, 1932
Suborder DALMANELLIDINA Moore, 1952
Superfamily DALMANELLOIDEA Schuchert, 1913
Family RHIPIDOMELLIDAE Schuchert, 1913
Subfamily RHIPIDOMELLINAE Schuchert, 1913
Genus *Rhipidomella* Oehlert, 1890
Rhipidomella sp.
Figure 3F

6.1 Examined specimen

One incomplete external pedicle valves. Registered specimen SM2014-2-059.

6.2 Diagnosis

See in Grant, 1976[2] page 37

6.3 Description

Small-size shells are about 0.5 cm. wide; weakly convex, more convex transversely than longitudinally with largest convexity at mid-length; shell outline elongate sub-round trigonal; hinge line is short; surface ornamented by costellae. Internal structure cannot be observed.

6.4 Discussion

This specimen resembles *Rhipidomella* cf. *R. pecosi,* Yanagida[15] (1975, p. 18, pl. II, figs 5) from Huai Luang, Loei, *Rhipidomella cordialis,* Grant[2] (1976, p37, pl.2, figs. 31 – 41; pl.3, figs. 1 – 53) from Ko Muk, Trang, *Rhipidomella* cf *cordialis,* Thonnarat, et al.[16] (2012, p. 35, pl. 2, figs. A - F) from Ban Ao Nam, Krabi in general outline but differs in the sulcus and shell surface of the ventral and dorsal valves. In the Huai Luang specimens the shell surface is finely costellate with a clear sulcus whereas the Ko Muk specimens the shell surface is minutely roughened by a combination of fine growth lines and; and in the Ao Nam specimens the shell surface is minutely smooth while our specimen has coarse costellae and no sulcus.

6.5 Measurement (mm.)

Specimen	Length	Width	Thickness
SM2014-2-059	4.25	4.30	-

7. SPIRIFERIDA *fam. Indet.*

Order SPIRIFERIDA Waagen, 1883
Figure 3G

7.1 Examined specimen

Not well preserved three external pedicle valves. Registered specimens in SM2014-2-060 to SM2014-2-062.

7.2 Diagnosis

See in Carter et al., 2006[14] page 1689

7.3 Description

Small-size shells are about 2 cm. wide; oval shell outline with exceeds length; cardinal extremities quite sub-round; sulcus is slightly to not deep; shell ornament is not clear. Internal structure cannot be observed.

7.4 Measurement (mm.)

Specimen	Length	Width	Thickness
SM2014-2-060	6.70	14.10	-
SM2014-2-061	8.65	15.70	6.25
SM2014-2-062	11.10	18.15	8.20

8. *Phricodothyris* sp.

Order SPIRIFERIDA Waagen, 1883
Suborder SPIRIFERIDINA Waagen, 1883
Superfamily RETICULARIIDAE Waagen, 13
Family ELYTHIDAE Fredericks, 1924
Subfamily PHRICODOTHYRIDINAE Caster, 1939
Genus *Phricodothyris* George, 1932
Phricodothyris sp.
Figure 3H

8.1 Examined specimen

Quite not well preserved three valves; one of external pedicle valve, one of brachial valve; and one of both of pedicle and brachial valve. Registered specimens SM2014-2-063 to SM2014-2-065.

8.2 Diagnosis

See Carter et al., 2006[14] page 1866

8.3 Description

Small to medium size shells are about 1 – 4.5 cm. wide; sub-round trigonal shell outline; wider than high; cardinal extremities round and hinge line shorter than greatest width; beak prominent and strongly incurved; interarea not clear; sulcus absent except 1 sample show narrow sulcus; maximum width close to midlength; shell ornamented by rugae; faint growth lines. Internal structure cannot be observed.

8.4 Discussion

The *Phricodothyris* is always characterized by shell outline and by the remarkable character of the ornamentation. These specimens are similar to *Phricodothyris echinata*, Yanagida[15] (1975, p. 20, pl. 2, figs 8 – 9) from Huai Luang, Loei, Upper Carboniferous and *Phricodothyris* sp., Waterhouse, et al.,[3] (1981, p. 65, pl. 2, figs. 18 – 19, pl. 3, figs. 1 – 18) from Ko Yao Noi, Krabi, Lower Permian but our specimen have stronger growth lines and differ from mode of costae.

8.5 Measurement (mm.)

Specimen	Length	Width	Thickness
SM2014-2-063	8.80	8.00	-
SM2014-2-064	31.30	36.45	8.45
SM2014-2-065	8.35	17.05	1.45

Discussion

The main groups of silicified brachiopods obtained from shale in the Pha Dam section include cf. *Reticulatia, Marginifera, Phricodothyris,* STROPHOMENIDA *fam. indet.*, SPIRIFERIDA *fam. indet.*, *Chonetinella* and *Rhipidomela* and are illustrated respectively by number, in figure 2. Most of these specimens are small in size and with nearly complete valves. The faunais dominated by *Reticulatia* which constitute 76% of the total. This we can designate a *Reticulatia* assemblage *Marginifera* indicates an Early Permian age which supports the previous work of DMR[8]. The *Reticulatia* assemblage sediments, are interpreted as having been deposited in shallow marine conditions, Brachiopods assemblage are generally sessile low-level epifaunal suspension feeders. A low energy environment is indicated. More taxonomic and biostratigraphic work is necessary in order to fully appreciate the palaeogeographic, biogeographic and tectonic significance of this newly discovered fauna.

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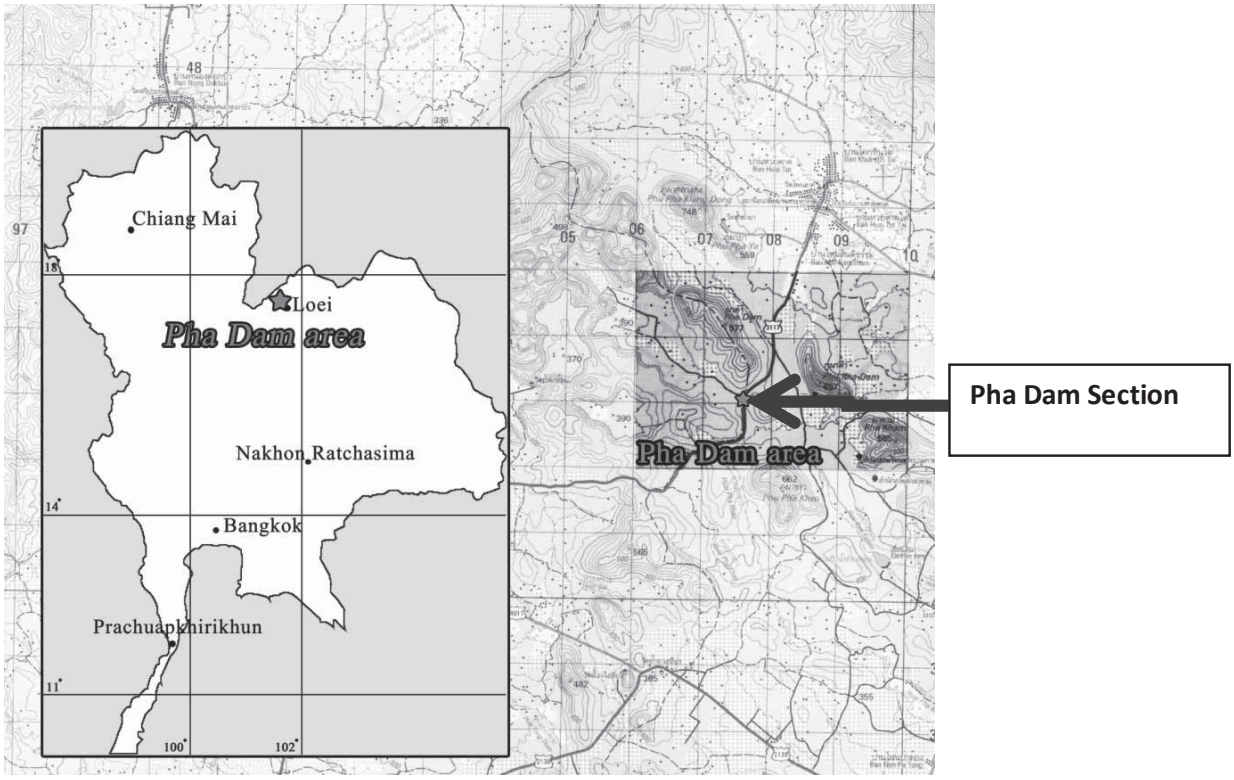

Figure 1 Map of site (Pha Dam Section) from where the fossils were collected.

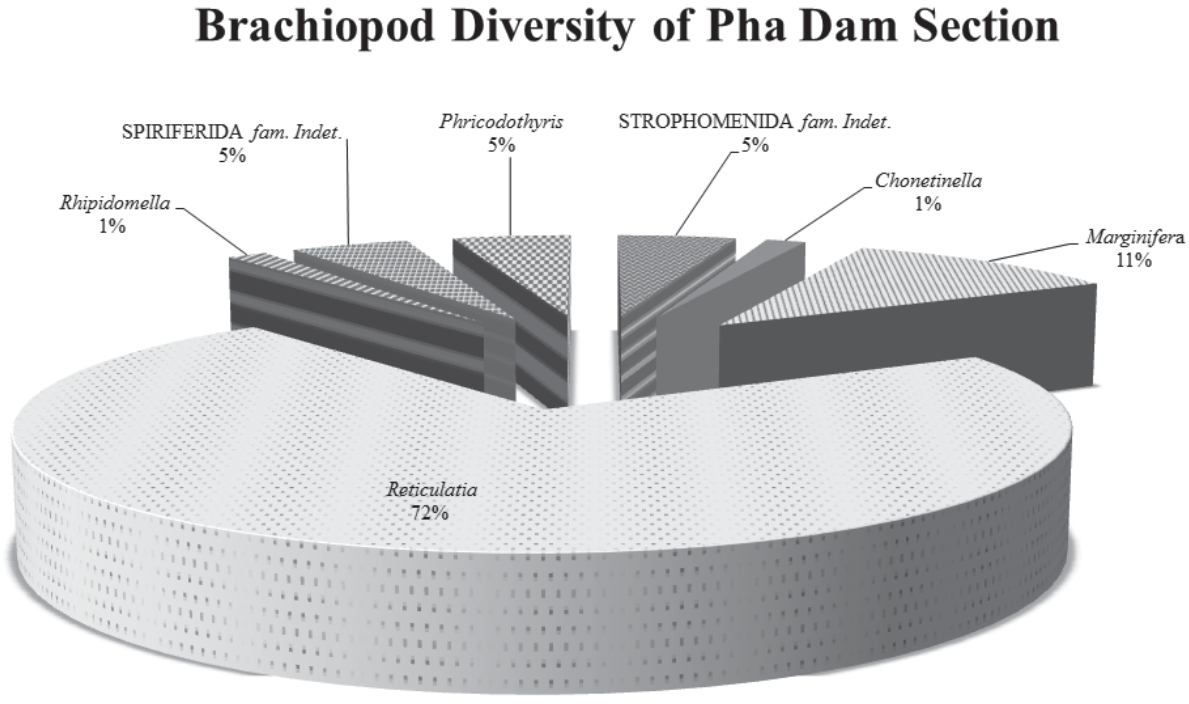

Figure 2 Distribution pattern of brachiopods diversity from the Pha Dam Section.

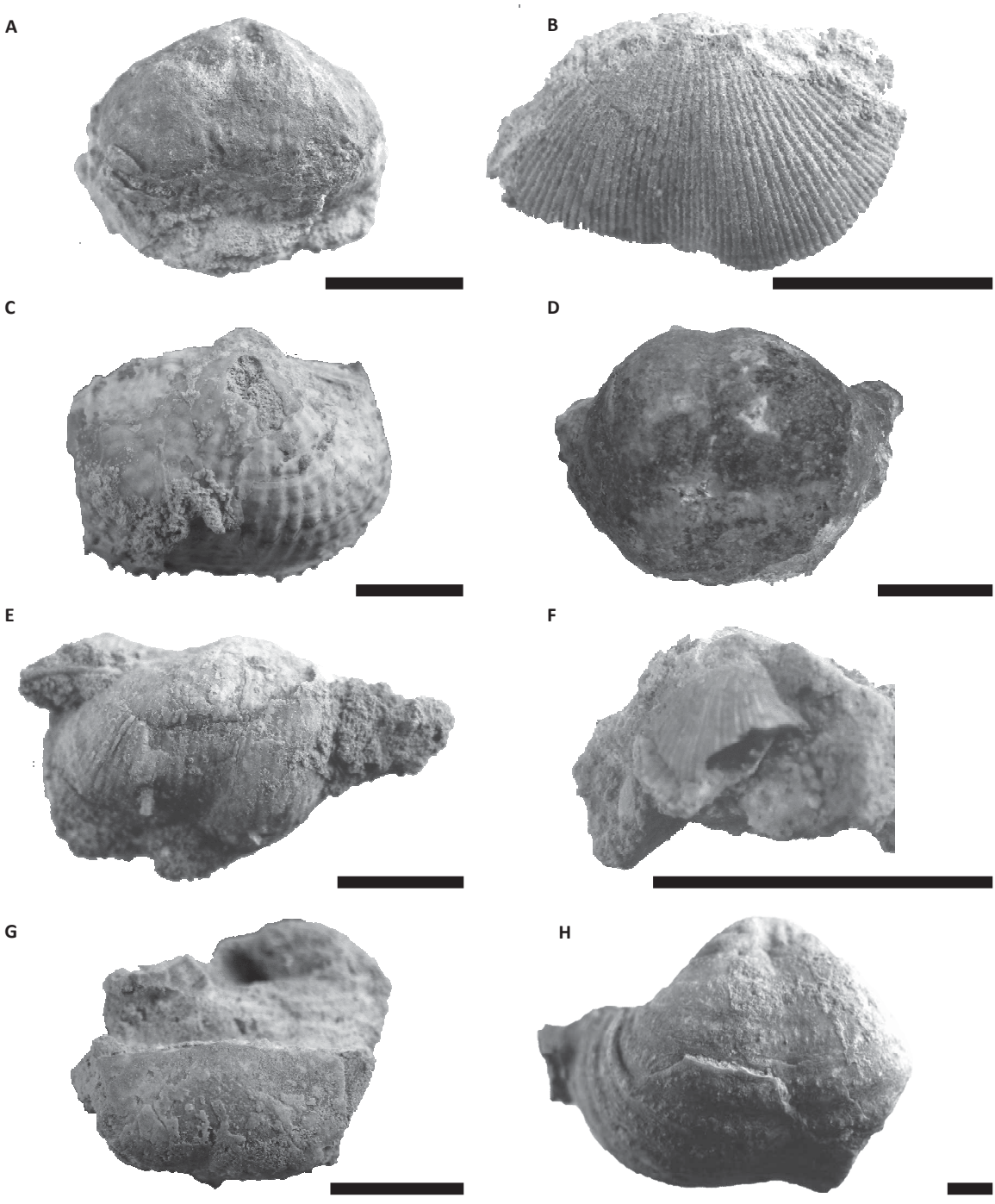

Figure 3 A: ventral view of STROPHOMENIDA *fam. Indet.*, B: ventral view of cf. *Chonetinella* sp., C: ventral view of cf. *Marginifera* sp., D: ventral view of cf. *Reticulatia* sp.A, E: anterior view of cf. *Reticulatia* sp.B, F: ventral view of cf. *Rhipidomella* sp., G: ventral view of SPIRIFERIDA *fam. Indet.*, H: ventral view of cf. *Phricodothyris* sp. , scale bar equal 1 cm.