Chinese origin and radiation of the Palaeozoic Crinoid Family Petalocrinidae

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Abstract

The Ordovician to Devonian family Petalocrinidae includes 28 species belonging to 5 genera. This family is unique because the arm plates are fused into a large fan or cylinder. Paleobiogeographic occurrences of this family include Laurentia, Baltica, Avalonia, South China, Sibumasu, and Perunica blocks. The family has the oldest petalocrinids from China. An early radiation of this clade resulted in three genera during the Llandovery of China. *Petalocrinus* became cosmopolitan during the Llandovery and Wenlock, and the youngest genus is present in the Lower Devonian of the Czech Republic. Taxonomic determination for the Petalocrinidae is based on the fused arm plates instead of cup plates. The diverse morphology of these arm plates suggests a variety of aerosol suspension-feeding modes may have been used by petalocrinids.

Keywords: Crinoidea; *Eopetalocrinus*; *Petalocrinus*; *Vadarocrinus*; Paleozoic; South China

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1. Introduction

Large, isolated, fan-shaped plates with bifurcating grooves from the Silurian of Gotland, Sweden, were considered to be crinoidal remains by F.A. Bather (Bather, 1898), but their affinity was sufficiently problematic that he did not discuss them in his 1893 study (see Bather, 1893). With the description of *Petalocrinus mirabilis* Weller and Davidson (1896) (in the new genus *Petalocrinus*), the anatomy of this most unusual crinoid was finally understood. In addition to isolated fan-shaped plates, Weller and Davidson described two complete specimens, each with five fan-shaped arms radiating from a small, subspherical aboral cup (in oral view). In *P. mirabilis*, each arm consists of two plates. The first arm plate is a typical, rectilinear brachial plate, but the remainder of the arm is one large, subtriangular plate that contains an ambulacrum that bifurcates numerous times. This crinoid was sufficiently distinctive that Weller and Davidson (1896) also erected the Petalocrinidae for their new species. In contrast to *Petalocrinus*, other genera of the Petalocrinidae are relatively poorly understood.

Unfortunately, *Spirocrinus* Mu and Wu, 1974 was not included in the Treatise on Invertebrate Paleontology (Lane and Moore, 1978). Subsequently, three additional petalocrinid genera have been described: *Vadarocrinus* Prokop, 1984 (Lower Devonian, Czech Republic); *Sinopetalocrinus* Mu and Lin, 1987 (lower Silurian, China); and *Eopetalocrinus* Li, 1993 (Ordovician, China). In this contribution, we present objective diagnoses for genera in the Petalocrinidae and summarize the geographic, paleoecologic, and evolutionary history of this fascinating crinoid family.

2. History of study

A total of 28 species belonging to five genera are assigned to the Petalocrinidae (Table 1) (Fig. 1). The family was first proposed by Weller and Davidson (1896), who described articulated specimens of *Petalocrinus mirabilis* from the Hopkinton Dolomite of Iowa (Llandoverly), which resembled a flower with five petals when fully expanded. Bather (1898) reviewed the history, geological relations, anatomical description, systematics, and the affinities of six species of *Petalocrinus*, and he

recognized this taxon as a dicyclic cladid rather than a monocyclic crinoid (Fig. 1C).

Occurrences of *Petalocrinus* in China were first documented by Mu (1950), who recognized two new species on the basis of the specimens from the Shihniulan Limestone (Llandovery) at Wuchuan, Guizhou Province. In 1974, Mu and Wu described the new genus *Spirocrinus* from the Leijiatum Formation (Llandovery) in the same province. Prokop (1984) reported a new genus of this family from the Koněprusy Limestone (Lower Devonian, Pragian) on the basis of a single specimen, which was the first record of the Petalocrinidae from the Czech Republic. Mu and Lin (1987) described numerous petalocrinids from China, including the new genus *Sinopetalocrinus*. Finally, Li (1993) reported two specimens from the Dawan Formation (now called Zitai Formation in this region; Zhang et al., 2002; Chen and Zhan, 2006; Wu et al., 2007; Zhang, 2009) (Floian–Darriwilian, Ordovician; Hubei Province, China) and named a new genus *Eopetalocrinus*. Because *Eopetalocrinus* is the oldest record of the family, Li (1993) hypothesized potential evolution trends among *Eopetalocrinus*, *Petalocrinus*, *Sinopetalocrinus*, and *Spirocrinus* in South China. Significantly, Fearnhead and Donovan (2007) reported new articulated specimens of *Petalocrinus* from the British Isles, confirming the crown morphology of this genus.

3. Petalocrinidae evolutionary history

Today, the Petalocrinidae is known from the Ordovician (Floian–Darriwilian) through the Early Devonian (Pragian) (Fig. 2). *Petalocrinus* is now recognized as having a cosmopolitan distribution during the Llandovery and Wenlock, as noted by Witzke et al. (1979). However, the significance of China for petalocrinid evolutionary history was not fully understood until the work of Mu and Lin (1987) and Li (1993), who described three new Chinese petalocrinid genera that ranged in age from the Ordovician through the early Silurian.

The Petalocrinidae presumably originated on the South China Block during the Ordovician (Floian–Darriwilian) with the appearance of *Eopetalocrinus*. Li (1993) hypothesized that three new petalocrinids evolved in China during the Silurian from

this initial stock, including *Petalocrinus*, *Sinopetalocrinus*, and *Spirocrinus*. The oldest petalocrinid outside of China is *Petalocrinus* sp. cf. *P. visbyensis* from the Mulloch Hill Formation (Rhuddianian; Llandovery; Fearnhead and Harper, 2007) of Scotland (Laurentia) (Fig. 2). However, by at least the late Llandovery *Petalocrinus* had migrated to Avalonia and Baltica. The youngest members of *Petalocrinus* are from the Wenlock of Laurentia (*P. longus*, Indiana, USA) and Baltica (*P. visbyensis*, Sweden). Finally, the youngest petalocrinid is *Vadarocrinus*, which is only known from the Early Devonian of Perunica (Czech Republic).

In general, the Ordovician was characterized by endemic faunas (Paul, 1976; Lefebvre et al., 2013), whereas the Silurian had more cosmopolitan faunas (Witzke et al., 1979; Cocks and Fortey, 1990). The global distribution of *Petalocrinus* was earlier than the typical cosmopolitan Wenlock faunas (Witzke et al., 1979).

A glacial epoch began during the late Ordovician and continued through the Llandovery (Grahns and Caputo, 1992; Brenchley et al., 1994, 2003; Ghiennie, 2003; Ghiennie et al., 2007; Schönian and Egenhoff, 2007; Gutiérrez-Marco et al., 2010). Sea level rose significantly during Llandovery interglacials, as evidenced by widespread carbonates in eastern Laurentia (e.g., Brassfield Limestone, Ohio; Hopkinton Dolomite, Iowa), and *Petalocrinus* must have migrated globally during a Llandovery interglacial. As suggested by Fearnhead and Harper (2007), the geographic distribution of *Petalocrinus* may be indicative of geographic proximity of tectonic blocks within a sub-equatorial distribution.

4. Feeding paleoecology of the Petalocrinidae

The unique aspect of this family is the fused arm plates, and this has attracted speculation on the function of the arms during life. Living crinoids, and, by inference, extinct stalked crinoids, are adapted to rheophilic feeding as passive, epifaunal suspension feeders that employed aerosol suspension feeding (see Ausich, 1980; Ausich et al., 1999). As such, crinoids with different filtration fan densities were adapted to preferentially capture food particles of different sizes.

Interpretative drawings of *Petalocrinus* in life position were first constructed by

Ubaghs (1953, fig. 85), then reproduced subsequently (Tien and Mu, 1955, text-fig. 31; Müller, 1963, fig. 463; Moore and Jeffords, 1968, fig. 5.2; Fearnhead and Donovan, 2007, text-fig. 5; Prokop and Petr, 2010, fig. 1), and followed by Frest and Strimple (1977, text-fig. 2). Furthermore, Prokop and Petr (2010, fig. 2) used this as a model and modified it for their Devonian form. All of these reconstructions position the five arms as if they were an umbrella, thus in a position to capture particles falling vertically from the water column. This is undoubtedly an unrealistic reconstruction, because, as is known, crinoids are typically adapted to unidirectional currents with the filtration fan positioned more-or-less vertically when feeding, thus perpendicular to the current. Further, modern crinoids in this posture typically have the tips of the arms bent back into the current to produce a parabolic filtration fan (Macurda and Meyer, 1974), which has been shown to be more efficient in particle capture compared to a planar fan (Warner, 1977). Interestingly, the arched morphology of the fused arm plates of some petalocrinids (Fig. 1D) resulted in an obligate parabolic shape for the overall filtration fan. Better preserved and articulated specimens are needed in order to fully assess feeding posture hypotheses; however, it is much more probable that the petalocrinid feeding posture was more like that of other stalked crinoids. It should have only assumed the umbrella posture in slack currents.

In typical crinoids, currents pass through and eddy around the arms, and particle capture was either by direct interception on the aboral side of the arms or on the oral side from currents eddying around the arms (Rubenstein and Koehl, 1977; Ausich, 1980). The petalocrinids deviated from this basic model. On the solidly plated arms of *Eopetalocrinus*, *Petalocrinus*, and *Vadarocrinus*, feeding must have been accomplished primarily from currents eddying around from the aboral to the oral side of the filtration fan. Feeding from direct interception could have only occurred along the distal margin of the fused arms. *Sinopetalocrinus* had ambulacra on both the oral and aboral sides of the solid arm plates, so that food capture could have occurred both by direct interception on most of the aboral side of the arms and from eddy currents on the oral side of the arms. In contrast, *Spirocrinus* had ambulacra spiraled around a cylindrical fused arm. Their filtration fan was very open, and food capture could have

occurred from any direction. A modern analog may be the multidirectional filtration fan posture of some comatulid crinoids that live in reefal environments with multidirectional currents (Meyer, [1979](#)). Interestingly, one could argue from a filtration fan and feeding perspective that *Sinopetalocrinus* and *Spirocrinus* had more optimal feeding designs. Yet, *Petalocrinus* was ultimately the most successful genus of the Petalocrinidae.

5. Systematic paleontology

Class CRINOIDEA Miller, [1821](#)

Subclass CLADIDA Moore and Laudon, [1943](#)

Order CYATHOCRININA Bather, [1899](#)

Superfamily GASTEROCOMACEA Roemer, [1854](#)

Family PETALOCRINIDAE Weller and Davidson, [1896](#)

Remarks: The Petalocrinidae is a unique crinoid family with each arm being entirely (or primarily) a single plate. The assumption by all previous authors was that this plate represents the fusion of numerous brachial plates. This assumption is probably correct. However, the alternative hypothesis is that the arm plate is the expansion of a single brachial plate, and this alternative has not been falsified.

Arm fragments, especially those of *Vadarocrinus*, may superficially look like species of *Gissocrinus* with greatly widened brachials (e.g., *G. magnibrachiatus* Springer, [1926](#), pl. 32, figs. 3-6). However, *G. magnibrachiatus* has axillary brachials with a single bifurcation of the ambulacrum, and their non-axillary brachials contain a single, straight ambulacrum. This contrasts with petalocrinids that have multiple bifurcations on the single arm plate.

In general, *Petalocrinus* has a relatively small aboral cup with five fused arm plates. These characteristic arm plates are robust and can be transported after death as isolated plates. Unusual among crinoids, the genera and species of the Petalocrinidae are based primarily on the fused arm plates instead of aboral cup plates (Fearnheard and Donovan, [2007](#)). A diagnostic table is included for quick identification at the

generic level (Table 2).

Genus *Petalocrinus* Weller and Davidson, 1896

Type species: Petalocrinus mirabilis Weller and Davidson, 1896.

Occurrences: Hopkinton Dolomite, Caralline Member, Silurian (Llandovery), Iowa, USA; Scotch Grove Formation, Silurian (Llandovery), Iowa, USA; Buck Creek Member, Scotch Grove Formation, Silurian (Llandovery), Iowa, USA; Sandpile Formation (Laurentian), Silurian (Llandovery–Wenlock), British Columbia, Canada (Norford, 1962); lower Silurian strata, western Yunnan Province, China (Chen and Yao, 1993).

Included species: *P. angustus* Bather, 1898, Visby Formation (undifferentiated), Silurian (Llandovery–Wenlock), Gotland, Sweden. *P. bifidus* Donovan and Fearnhead in Fearnhead and Donovan, 2007, *Petalocrinus* Limestone, Silurian (Llandovery), Scotland, United Kingdom; Haugh Wood Formation, Silurian (Llandovery), United Kingdom. *P. chiai* Mu, 1950, Leichiatus Formation (approximately age equivalent to Xiangshuyuan Formation and Shihniulan Limestone), Silurian (Llandovery), Guizhou Province, China. *P. eximius* Mu and Wu, 1974, Leichiatus Formation, Silurian (Llandovery), Guizhou Province, China. *P. expansus* Bather, 1898, Visby Formation (undifferentiated), Silurian, (late Llandovery to Wenlock), Gotland, Sweden. *P. guizhouensis* Mu and Lin, 1987, Xiangyuangsi Formation, Silurian (Llandovery), Guizhou Province, China. *P. inferior* Bather, 1898, Hopkinton Dolomite, Silurian (Llandovery), Iowa, USA; Laurel Limestone, Silurian (Wenlock), Indiana, USA; Cedarville Limestone, Silurian (Wenlock), Ohio, USA; Shihniulan Limestone, Silurian (Llandovery), Guizhou Province, China; Luoreping Formation, Silurian (Llandovery), Sichuan Province, China; Silurian (Llandovery), Hubei Province, China. *P. inflatus* Mu, 1950, Shihniulan Formation, Silurian (Llandovery), Guizhou Province, China. *P. involucrus* Mu and Wu, 1974, Leichiatus Formation, Silurian (Llandovery), Guizhou Province, China. *P. latus* Mu and Lin, 1987, Xiangyuangsi Formation, Silurian (Llandovery), Guizhou Province, China. *P. longus* Bather, 1898, Laurel Limestone, Silurian (Wenlock), Indiana, USA. *P. magnus* Mu and Lin, 1987,

Xiangyuangsi Formation, Silurian (Llandovery), Guizhou Province, China. *P. sinensis* Mu and Wu, 1974, Loureping Group (now Loureping Formation), Silurian (Llandovery), Hubei Province, China; Xiangyuangsi Formation, Silurian (Llandovery), Guizhou Province, China. *P. tenuis* Mu and Lin, 1987, Xiangyuangsi Formation, Silurian (Llandovery), Guizhou Province, China. *P. validus* Mu and Wu, 1974, Leichiutum Group (now Leijiutum Formation; Mu et al., 1986), Silurian (Llandovery), Guizhou Province, China. *P. visbyensis* Bather, 1898, Visby Formation (undifferentiated), Silurian (late Llandovery to Wenlock), Gotland, Sweden; Slite Formation, Silurian (Wenlock), Gotland, Sweden. *Petalocrinus* sp. cf. *P. visbyensis* Bather, 1898 in Fearnhead and Harper, 2007, Mulloch Hill Sandstone Formation, Silurian (Llandovery, Aeronian), Scotland, United Kingdom.

Diagnosis: Semicircular-shaped articular facets, fused brachials subtriangular and expanding distally, as many as 32 distal ambulacra, adjacent arms not in lateral contact, ambulacral grooves only on oral surface.

Remarks: This is the most characteristic genus of the family with a worldwide distribution. A total of 17 species has been documented (Table 1). Although articulated specimens have been reported from the USA (Weller and Davidson, 1896; Bather, 1898), United Kingdom (Donovan and Fearnhead, 2007) (Fig. 1B, C), and China (Chen and Yao, 1993) (Fig. 3), isolated arm plates are the most common elements preserved in the fossil record (Fig. 1E-G). The ambulacral cover plates are only preserved in a few specimens (see Fig. 1T).

Genus *Eopetalocrinus* Li, 1993

Type species: *Eopetalocrinus sinensis* Li, 1993.

Occurrences: Zitai Formation (age equivalent to the Dawan Formation), Ordovician (Floian–Darriwilian), Hubei Province, China.

Diagnosis: Fusiform-shaped articular facets and forming a sub-pentagonal, fused brachials subtriangular and expanding distally, 18-29 distal ambulacra, adjacent arms in lateral contact, ambulacral grooves only on oral surface.

Remarks: This is the earliest occurrence of the family. The reported specimens were

deposited at the Yangtze University (JHJ). Due to the relocation of the university, the type and figured specimens of *E. sinensis* were lost. Nevertheless, published figures and drawings are of good quality (see Fig. 1A), and an ongoing priority is to collect new topotype material and to designate a neotype. A recent visit indicated that the fossil section is dominated by reddish limestones; thus, it is best to call it the Zitai Formation instead of Dawan Formation, which is richer in yellow-green limestones (Chen and Zhan, 2006). Currently, the age of the unit (Zitai or Dawan Formation) ranges from Floian to Darriwilian (Wu et al., 2007); however, echinoderm ossicles are relatively common in the middle portion of the unit based on the field observation, and thus the approximate age for *Eopetalocrinus* is Dapingian (Fig. 2).

Genus *Sinopetalocrinus* Mu and Lin, 1987

Type species: *Sinopetalocrinus involutus* Mu and Lin, 1987.

Occurrences: Leijiatus Formation, Silurian (Llandovery, Aeronian), Guizhou Province, China.

Other species: *S. robustus* Mu and Lin, 1987, Leijiatus Formation, Silurian (Llandovery), Guizhou Province, China. *S. shiqianensis* Mu and Lin, 1987, Leijiatus Formation, Silurian (Llandovery), Guizhou Province, China.

Diagnosis: Horseshoe-shaped articular facets; fused brachials expand in width rapidly for short distance, then are parallel sided and finally a convex distal margin; as many as 40 distal ambulacra, adjacent arms not in lateral contact, ambulacral grooves on oral and aboral surface.

Remarks: This genus is endemic to Silurian strata of South China (Mu and Lin, 1987). A total of three species has been documented (Table 1) (Fig. 1I-M).

Genus *Spirocrinus* Mu and Wu, 1974

Type species: *Spirocrinus typicus* Mu and Wu, 1974.

Occurrences: Leijiatus Formation, Silurian (Llandovery), Guizhou Province, China.

Other species: *S. abnormis* Mu and Lin, 1987, Leijiatus Formation, Silurian (Llandovery), Guizhou Province, China. *S. longus* Mu and Wu, 1974, Leijiatus

Formation, Silurian (Llandovery), Guizhou Province, China. *S. multiramus* Mu and Lin, 1987, Leijiatun Formation, Silurian (Llandovery), Guizhou Province, China. *S. pauciramus* Mu and Lin, 1987, Leijiatun Formation, Silurian (Llandovery), Guizhou Province, China. *S. uniformis* Mu and Lin, 1987, Leijiatun Formation, Silurian (Llandovery), Guizhou Province, China.

Diagnosis: Horseshoe-shaped articular facets, fused brachials cylindrical and tapered at both ends, as many as 10-12 distal ambulacra, adjacent arms not in lateral contact, ambulacral grooves spiraled around fused arm with left-hand spiral.

Remarks: This is endemic to Silurian strata in the South China block (Mu and Wu, 1974; Mu and Lin, 1987; Mao et al., 2013). A total of six species has been documented (Table 1) (Fig. 1N-P).

Genus *Vadarocrinus* Prokop, 1984

Type species: *Vadarocrinus vassa* Prokop, 1984.

Occurrences: Koněprusy Limestone, Devonian (Pragian), Bohemia, Czech Republic; Lodenice Limestone, Devonian (Pragian), Bohemia, Czech Republic.

Diagnosis: Broad and smooth articular facets, fused brachials subtriangular and expanding distally, number of distal ambulacra unknown, adjacent arms not in lateral contact, ambulacral grooves only on oral surface.

Remarks: This species was reported originally from one specimen (Prokop, 1984) (Fig. 1Q-S). Subsequently, eight additional specimens were recovered from the type locality (Prokop and Petr, 2010). This is the only known occurrence of the genus (and the family) in both the Devonian and the Perunica microcontinent.

6. Conclusion

In the Treatise, the family Petalocrinidae was only represented by one genus with a wide distribution during the middle Silurian (Keim, 1978, p. 383; Lane and Moore, 1978, fig. 371). Presently, the family contains five genera, ranging from Ordovician to Lower Devonian. Previously, many workers had hypothesized on the origin of this family. Based on the facts that the South China block contains both the oldest

occurrences of the family and most diversified forms (four genera, whereas other paleocontinents only have one genus), China is the key origination center for the Petalocrinidae. Despite arms consisted of fused plates, feeding probably occurred with several modes of aerosol suspension feeding.

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Table and figure captions

Table 1. List of known species of Petalocrinidae.

Table 2. Diagnostic table for the Petalocrinidae.

Fig. 1. Representatives of five genera of Petalocrinidea, All scale bars = 1 cm. (A) *Eopetalocrinus* Li, 1993 (JHJ-0001), Dawan Formation (Floian–Dapingian), Hubei, China; oral side of crown (modified from Li, 1993, pl. 1, fig. 1). (B, C) *Petalocrinus bifidus* from Fearnhead and Donovan (2007) (BMNH E70060, BMNH E49625), *Petalocrinus* Limestone (Llandovery), Woolhope Inlier, Herefordshire; (B) oral side of crown; (C) aboral side of crown. (D–H) *Petalocrinus inflatus* Mu, 1950 (GSC 6887), Shihniulan Limestone (Llandovery), Guizhou, China; (D) lateral view of arm plate (arm-fan of Mu and Lin, 1987); (E) front view of distal furrows; (F) oral side of arm plate; (G) facet view of arm plate; note that the articular facet is horseshoe-shaped; (H) aboral side of arm plate. (I–M) *Sinopetalocrinus robustus* Mu and Lin, 1987 (NIGP 73971), Leijiatun Formation (Llandovery), Guizhou, China; (I) lateral view of arm plate (arm-roll of Mu and Lin, 1987); (J) front view of distal furrows; (K) oral side (ventral view) of arm plate; (L) facet view of arm plate; note that the articular facet is horseshoe-shaped; (M) aboral side (dorsal view) of arm plate; note that furrows on the dorsal side. (N–P) *Spirocrinus uniformis* Mu and Lin, 1987 (NIGP 73990), Leijiatun Formation (Llandovery) of Guizhou, China; (N) front view of distal furrows; (O) lateral view of arm plate (arm-twine of Mu and Lin, 1987); (P) facet view of arm plate. (Q–S) *Vadarocrinus vassa* Prokop, 1984 (NML 20040), Koněprusy Limestone (Lower Devonian), Bohemia, Czech (modified from Prokop, 1984, pl. 1, figs. 1–3); (Q) lateral view of arm plate; (R) oral side of arm plate; (S) aboral side of arm plate. (T) *Petalocrinus exmimius* Mu and Wu, 1974 (NIGP 22901), Leijiatun Formation (Llandovery) of Guizhou, China; ventral view of arm plate with preservation of ambulacral plates. Depositories: Yangtze University (JHJ); Natural History Museum, London (BMNH); Nanjing Institute of Geology and Palaeontology,

Chinese Academy of Sciences (GSC, NIGP); National Museum in Prague (NML).

Fig. 2. Stratigraphic and paleogeographic distribution of the Petalocrinidae, compiled from references listed in Table 1.

Fig. 3. *Petalocrinus mirabilis* Weller and Davidson, 1896, Renheqiao Formation, Yunnan, China (No. 332; re-deposited at NIGP); aboral side of crown with five arms completely. Scale bar = 0.5 cm.

Table 1

Genus	Species	Distribution	Age	Holotype
<i>Eopetalocrinus</i>	<i>E. sinensis</i>	South China	Floian-Darriwilian	Li, 1993, text-fig. 2; pl. 1, fig. 1
<i>Petalocrinus</i>	<i>P. angustus</i>	Sweden	Wenlock	Bather, 1898, pl. 25, fig. 26
	<i>P. bifidus</i>	British Isles	Llandovery	Donovan and Fearnhead, 2007, text-fig. 3d
	<i>P. chiai</i>	South China	Llandovery	Mu, 1950, text-fig. 3, no. 7
	<i>P. exmimius</i>	South China	Llandovery	Mu and Wu, 1974, pl. 97, fig. 32
	<i>P. expansus</i>	Sweden	Wenlock	Bather, 1898, text-figs. 13,14; pl. 25, fig. 34
	<i>P. guizhouensis</i>	South China	Llandovery	Mu and Lin, 1987, pl. 4, fig. 6
	<i>P. inferior</i>	USA, South China	Llandovery-Wenlock	Bather, 1898, text-fig. 10; pl. 26, fig. 57
	<i>P. inflatus</i>	South China	Llandovery	Mu, 1950, text-fig. 3, no. 4
	<i>P. involucrus</i>	South China	Llandovery	Mu and Wu, 1974, pl. 97, fig. 27
	<i>P. latus</i>	South China	Llandovery	Mu and Lin, 1987, pl. 4, fig. 3
	<i>P. longus</i>	USA	Wenlock	Bather, 1898, text-figs. 11, 12; pl. 26, fig. 60
	<i>P. magnus</i>	South China	Llandovery	Mu and Lin, 1987, pl. 4, fig. 5
	<i>P. mirabilis</i>	USA, Canada, South China, Sibumasu	Llandovery-Wenlock	Weller and Davidson, 1896, pl. 6, figs. 2-5*
	<i>P. sinensis</i>	South China	Llandovery	Mu and Wu, 1974, pl. 97, fig. 24
	<i>P. tenuis</i>	South China	Llandovery	Mu and Lin, 1987, pl. 4, fig. 1
	<i>P. validus</i>	South China	Llandovery	Mu and Wu, 1974, pl. 97, fig. 16
	<i>P. visbyensis</i>	Sweden, UK	Llandovery-Wenlock	Bather, 1898, pl. 25, fig. 5
	<i>P. cf. P. visbyensis</i>	Scotland, UK	Llandovery	Fearnhead and Harper, 2007, fig. 1a-e*
<i>Sinopetalocrinus</i>	<i>S. involutus</i>	South China	Llandovery	Mu and Lin, 1987, pl. 5, fig. 5
	<i>S. robustus</i>	South China	Llandovery	Mu and Lin, 1987, pl. 6, fig. 1
	<i>S. shiqianensis</i>	South China	Llandovery	Mu and Lin, 1987, pl. 5, fig. 1
<i>Spirocrinus</i>	<i>S. abnormis</i>	South China	Llandovery	Mu and Lin, 1987, pl. 7, fig. 12
	<i>S. longus</i>	South China	Llandovery	Mu and Wu, 1974, pl. 97, fig. 8
	<i>S. multiramus</i>	South China	Llandovery	Mu and Lin, 1987, pl. 7, fig. 15
	<i>S. pauciramus</i>	South China	Llandovery	Mu and Lin, 1987, pl. 7, fig. 1
	<i>S. typicus</i>	South China	Llandovery	Mu and Wu, 1974, pl. 97, figs. 1-3
	<i>S. uniformis</i>	South China	Llandovery	Mu and Lin, 1987, pl. 7, fig. 5
<i>Vadarocrinus</i>				

Table 2

	Articular Facets	Fused Brachial Shape	Maximum Number of Ambulacra	Adjacent Arms in Lateral Contact	Position of Ambulacral Groove
<i>Petalocrinus</i>	Semicircular	Subtriangular, expand distally	<~32	No	Oral side
<i>Eopetalocrinus</i>	Fusiform-shaped and forming a pentagon	Subtriangular, expand distally	18-29	Yes	Oral side
<i>Sinopetalocrinus</i>	Horseshoe shaped	Subtriangular, rapid expansion for short distance, then parallel- sided	~40	No	Oral and aboral sides
<i>Spirocrinus</i>	Horseshoe shaped	Cylindridal, tapers at both ends	10-12 ambulacral grooves	No	Around entire brachial with left- handed spiral
<i>Vadarocrinus</i>	Broad, smooth	Subtriangular, expand distally	Unknown	No	Oral side

Figure 1

Figure 2

Figure 3