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Early Pennsylvanian, Bashkirian, echinoderms from eastern Iran, a potential transitional fauna between Laurentia/Avalonia and the Paleotethys, and a Permian cromyocrinid from central Iran

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Abstract New echinoderm faunas are reported from the lower part of the Absheni Formation, Early Pennsylvanian, early Bashkirian, of central–eastern Iran. Southeastern localities near Howz-e-Dorah (southwestern side of the Shotori Range) are part of a carbonate-shelf deposit, and a northwestern locality near Shir Gesht is located within a marine bed within a siliciclastic deltaic sequence. The two horizons are considered coeval based on the co-occurrences of several echinoderm taxa and other fossils. The Howz-e-Dorah fauna is more diverse than the Shir Gesht fauna; both areas contain the most diverse micro-echinoderm faunas described. Faunas are transitional between Laurentia/Avalonia and Paleotethyan faunas. Both areas contain few articulated juvenile cups or crowns. However, disarticulated cup and stem ossicles are abundant and preserve the growth stages of some taxa. Similar ossicles occur in both areas. Microcrinoid and microblastoid thecae are also abundant with greater diversity in the Howz-e-Dorah area. In the 2- to 5-mm size fraction a number of radials with the radial facet on a stalk or a protruded platform are considered juveniles of uncertain adult taxa. Diversities of the faunas based on articulated specimens account for only one-quarter to one-third of the estimated diversity, including the disarticulated ossicles. A described microcrinoid thecae and a cup are considered the smallest described juvenile stages of *Platycrinites* and *Synbathocrinus*, respectively. New crinoid taxa introduced are *Shotoricrinus transitorius* n. gen. et sp., *Culicocrinus shotoriensis* n. sp., *Camptocrinus enigmaticus* n. sp., *Platycrinites pannosus* n. sp., *Amphipsalidocrinus arendti* n. sp., *Epihalysiocrinus absheniensis* n. sp., *Catillocrinus levatus* n. sp., *Synbathocrinus dastanpouri* n. sp., *Alcimocrinus*? *mediaensis* n. sp., *Dichostreblocrinus inaquosus* n. sp., *Lampadosocrinus stellatus* n. sp., *Allagecrinus sevastopuloi* n. sp., ?*Kallimorphocrinus lanei* n. sp., *Litocrinus bullatus* n. sp., *Litocrinus conus* n. sp., *Desmacriocrinus asperulus* n. sp., *Desmacriocrinus bulbus* n. sp., *Trophocrinus granulosus* n. sp. and *øRhysocamax magnificus* n. sp.

Keywords Echinoderms · Crinoids · Blastoids · Pennsylvanian · Bashkirian · Permian · Iran

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Introduction

Relatively few Paleozoic echinoderms have been reported from Iran. Blastoids, first described from the Sardar Formation near Shir Gesht (Flügel 1966), were assigned

incorrectly an Early Carboniferous age. Middle Ordovician rhombiferan cystoids were described from northeastern Iran by Alavi Naini (1972) and from east–central Iran by LeFebvre et al. (2005). Late Devonian and Carboniferous crinoids and blastoids from central, southeastern, and central–eastern Iran were illustrated by Webster et al. (2001), who also noted that additional collection should yield sufficient numbers of specimens for proper analysis of the faunas. Additional collections by Yazdi, M. Dastanpour, Maples, and Webster in May 2000 resulted in the description of Early Mississippian faunas from southeastern Iran (Webster et al. 2003) and Late Devonian and Early Carboniferous faunas from central and northern Iran (Webster et al. 2007). This report is an extension of these latter two reports based on collections by Yazdi (1996), the 1998 IGCP 421 field conference members, and the 2000 collections.

Coeval Pennsylvanian echinoderms were collected near Howz-e-Dorah (southwestern part of the Shotori Range) at several localities (Locality Index) and near Shir Gesht on the northwestern edge of the Shotori Range in central eastern Iran (Fig. 1). Loose macrofossils and bulk samples (approximately 20 kg) were collected and processed for echinoderm elements. Residues were split into three sizes (<2, 2–5, and >5 mm) for sorting. The residues were essentially echinoderm ossicle coquinas, including numerous specimens of microcrinoids and blastoids with minor amounts of other marine organisms. The echinoderm faunas are described and related to coeval faunas of Algeria, Japan, and North America.

Stratigraphy and tectonic setting

Leven and Taheri (2003) and Leven et al. (2006) recently revised the Carboniferous and Early Permian stratigraphic nomenclature of eastern Iran. Previously, the Carboniferous–Early Permian section was referred to as the Sardar Formation. The Sardar Formation was reported to consist of siliciclastic- and carbonate-shelf deposits, 600 m thick (base not exposed), of late Viséan to Early Permian age, and subdivided into two subunits (Stöcklin et al. 1965; Ruttner and Stöcklin 1966). The boundary between Sardar 1 and Sardar 2 was thought to approximate the Mississippian–Pennsylvanian boundary. Sardar 1 (Late Viséan–Serpukhovian) consists of interbedded olive-green argillaceous to silty shale, quartzitic sandstone and fossiliferous sandy limestones. Sardar 2 (Pennsylvanian–Early Permian) consists of the same lithologies in the lower part as Sardar 1, with mostly shale in the upper 200 m (Stöcklin and Setudehnia 1991). Leven and Taheri (2003) redefined the Late Pennsylvanian–Early Permian part of the Sardar Formation, designating it the Zaluda Formation. Leven et al. (2006) elevated the Sardar Formation to group status and renamed Sardar 1 the Ghaleh Formation, whilst recognizing the age as late Viséan to earliest Bashkirian.

Fig. 1 Locality map

They also designated the younger Bashkirian and Moscovian part of Sardar 1 the Absheni Formation (Fig. 2). Ages assigned by Leven and Taheri (2003) and Leven et al. (2006) were based on foraminifers.

Brachiopods, the most common fossil in the Sardar Group, are associated with corals, rare goniatites and other macroinvertebrates that are found mostly in the limestones (Stöcklin and Setudehnia 1991). More recently, Yazdi (1999) and Boncheva et al. (2007) described conodonts from numerous horizons within Sardar 1 and 2, confirming the Mississippian and Pennsylvanian ages previously assigned to the units. Boncheva et al. (2007) placed the echinoderm horizon in the basal part of the Sardar 2 (= basal Absheni Formation) in the *Declinognathus noduliferus* Biozone in central Iran in a section south of Isfahan.

The first record of echinoderms from Iran was a blastoid (*Iranoblastus nodosus* Flügel, 1966), from the lower part of Sardar 2 (now Absheni Formation) near Shir Gesht, northwest of Tabas, where it grades into a plant-bearing deltaic facies of interbedded shale and quartzitic sandstones with rare marine horizons. The marine *Iranoblastus*-bearing horizon was incorrectly assigned a Mississippian age (Flügel 1966), which was corrected to basal Bashkirian by study of the goniatites (Hairapetian et al. 2006). Thus, the echinderm horizons at Shir Gesht and Howz-e-Dorah are both earliest Bashkirian in age.

During the Early Pennsylvanian, the eastern part of Iran was part of the stable platform of northern Gondwana along the border of the western part of the Paleotethys (Vachard 1997) at approximately 33°S latitude (palaeogeographic maps, Golonka 2002). The Shotori Range was a part of the Tabas block in the complex geology of central and eastern Iran of Bagheri and Stampfli (2008).

Diversity of articulated cups and crowns

Articulated crinoid and blastoid cups have been found only in the lower part of the Absheni Formation in the vicinity of Howz-e-dorah and Shir Gesht, although isolated columnals and pluricolumnals are found in some shale and limestone horizons in both the Ghaleh and Absheni Formations at other localities in the Shotori Range.

<table>
<tr><td>Permian (part)</td><td>Early</td><td rowspan="6">Sardar Group</td><td rowspan="4">Sardar 2</td><td rowspan="2">Zaluda Formation</td></tr>
<tr><td rowspan="3">Pennsylvanian</td><td>Late</td></tr>
<tr><td>Moscovian</td><td rowspan="2">Absheni Formation</td></tr>
<tr><td>Bashkirian</td></tr>
<tr><td rowspan="2">Mississippian (part)</td><td>Serpukhovian</td><td rowspan="2">Sardar 1</td><td rowspan="2">Ghaleh Formation</td></tr>
<tr><td>Viséan</td></tr>
</table>

Fig. 2 Stratigraphic terminology currently applied to the Mississippian–Permian strata of central eastern Iran by various authors

Howz-e-Dorah: Specimens from Absheni localities near Howz-e-Dorah came from dip slopes of marls or shales in fault blocks along the southwestern end of the Shotori Range (Table 1). All except the large columnals (ø*Rhysocamax magnificus* n. sp.) are from the same horizon at four localities in close proximity to one another (Locality Index). Megafossils are moderately common and include gastropods, solitary corals, brachiopods, bryozoans and crinoids. Megafossils were found on weathered surfaces, and bulk sediment samples were taken for processing for microfossils. Preservation of the echinoderm specimens is variable: some are well preserved, some are solution etched, showing pressure-solution pitting, whilst others are overgrown with algae, bryozoans and other encrusters. Individual specimens are abraded or distorted by compaction and may be recently fragmented by the hooves of the sheep and goats repeatedly foraging the region.

Articulated echinoderms larger than 2 mm are rare in the marls, whereas articulated thecae of crinoids and blastoids smaller than 2 mm are moderately common. Table 1 lists 20 taxa (12 micro, eight mega) identified on articulated cups or crowns from Howz-e-Dorah. In addition, there are two pluricolumnal taxa and one ophiuroid. Associated microfossils not described include foraminifera, gastropods, brachiopod spat, ostracods, sponge spicules and disarticulated ossicles of echinoids and asterozoans.

Shir Gesht: The fossiliferous shale horizon in the lower part of the Absheni Formation at the Shir Gesht locality is a marine bed approximately 1 m thick (type locality for *Iranoblastus nodosus* Flügel, 1966) encased between non-marine clastics of a deltaic sequence. Megafossils are moderately common and consist of goniatites (*Homoceras*), blastoids, gastropods, solitary corals, brachiopods and rare crinoids. Except for the cephalopods, the specimens are small, generally less than 1.5 cm. The microfauna includes moderately abundant crinoid ossicles, crinoid and blastoid thecae, ostracods, gastropods, foraminfera and brachiopod spat. Many specimens are solution etched, and some are overgrown with bryozoans or other organisms. Table 1 lists 12 echinoderms (eight micro, four mega) identified on articulated cups or thecae from Shir Gesht.

Based on the articulated specimens, the diversity of the Howz-e-Dorah fauna is approximately 150% that of the Shir Gesht fauna. As may be noted in Table 1, the Howz-e-Dorah and Shir Gesht faunas have four identified taxa in common (two microcrinoids, one blastoid and *Platycrinites* spp. columnals), and no taxa based on articulated macrocrinoids in common. Faunal differences are attributed to different environmental settings; however, the faunas are

Table 1 Identified echinoderms from the Early Pennsylvanian Absheni Formation, Howz-e-Dorah and Shir Gesht areas, Shortori Range, eastern Iran

Taxa	Howz-e-Dorah[a]	Shir Gesht[a]
Blastoids		
Iranoblastus nodosus Flugel, 1966		A
Passalocrinus spp.	A	A
Crinoids		
Camerates		
Shotoricrinus transitorius n. gen. et sp.	A	
Camptocrinus? *enigmaticus* sp. nov.	X	A
Dichocrinidae? radial indeterminate 1	X	
Dichocrinidae? radial indeterminate 2	X	
Dichocrinidae? radial indeterminate 3	X	
Dichocrinitid indet.	X	
Culicocrinus shotoriensis n. sp.	A	
Platycrinites s.l. *djihaniensis*; Webster et al. 2003	A	
Platycrinites s.l. *pannosus* n. sp.	A	
Platycrinites? sp. (microcrinoid)		A
Platycrinitid?sp. A (radial)	X	
øPlatycrinites spp.	X	X
Amphipsalidocrinus arendti n. sp.	A	
Monobathrid radial indeterminate 1	X	
Disparids		
Epihalysiocrinus absheniensis n. sp.		A
Allagecrinus sevastopuloi n. sp.	A	
Kallimorphocrinus lanei n. sp.		A
Litocrinus bullatus n. sp.	A	A
Litocrinus conus n. sp.	A	A
Allagecrinid indeterminate 1	A	
Allagecrinid indeterminate 2		A
Allagecrinid indeterminate 3	A	
Allagecrinid indeterminate 4	A	
Allagecrinid indeterminate 5	A	
Desmacriocrinus asperulus n. sp.		A
Desmacriocrinus bulbus n. sp.	A	
Trophocrinus granulosus n. sp.	A	
Catillocrinus levatus n. sp.	A	
Synbathocrinus dastanpouri n. sp.	A	
Cladids		
øBarycrinidae indeterminate	A	
Dichostreblocrinus inaquosus n. sp.		A
Lampadosocrinus stellatus n. sp.	A	
Blothrocrinid indeterminate		A
Alcimocrinus? *mediaensis* n. sp.	A	
Cromyocrinidae indeterminate	A	
Primitive Cladid? radial indeterminate 1	X	
Primitive Cladid? radial indeterminate 2	X	
Primitive Cladid? radial indeterminate 3	X	
Primitive Cladid? radial indeterminate 4	X	
Primitive Cladid? radial indeterminate 5	X	
Primitive Cladid? radial indeterminate 6	X	
Primitive Cladid? radial indeterminate 7	X	
Advanced Cladid radial indeterminate 1	X	
Advanced Cladid radial indeterminate 2	X	
Advanced Cladid radial indeterminate 3	X	
Adv. Clad. Scytalocrinoidea? radial indeterminate	X	
Camerate or cladid radials indeterminate	X	
Flexibles		
Flexible indeterminate 1	X	
Flexible indeterminate 2	X	
Columnals unassigned to family		
øRhysocamax magnificus n. sp.	A	
Blade cirri? indeterminate	X	
Echinoids		
Archaeocidaris sp.	X	
Asteroids		
Ophuriodea indeterminate	A	

[a] A indicates articulated specimen; X indicates disarticulated ossicle

considered coeval based on the mutual occurrence of three microechinoderms and disarticulated ossicles discussed below.

Diversity of disarticulated ossicles

Searches for small specimens in washed residues revealed that diversities of the Howz-e-Dorah and Shir Gesht faunas were grossly underrepresented by the articulated specimens. For example, 45 infrabasal and basal circlets in the Howz-e-Dorah residues could not be unquestionably related to the identified articulated cups or thecae. One of these is likely a codiacrinid, one a dichocrinid and several are considered to be cladids; others are growth stages or variants of one another. We estimate that these ossicles belong to at least 35 different taxa. If these are combined with the 18 genera based on articulated specimens, the diversity of the fauna almost triples. Likewise, 25 infrabasal or basal circlets recognised in the Shir Gesht residues could not be related to any of the articulated cups or thecae. One is thought to be a codiacrinid, two are probably dichocrinids and several are judged to be cladids. Combining these with the nine genera based on articulated specimens nearly quadruples the diversity.

It also became apparent that additional crinoid taxa were common to the two areas and recognizable among the disarticulated juvenile cup and brachial ossicles. For

example, six different radials, three different flexible brachials, and ossicles of an asterozoan in the smaller residue fractions that are not recognised among the articulated specimens in either of the Iranian faunas are common to both faunas, supporting the coeval age of the faunas.

Diverse isolated basals, brachials and tegmen- and anal-ossicles were also recognised. If all of the different ossicles were to be separated and an attempt made to determine the diversity of the fauna, it would be grossly overestimated. After sorting, it became apparent that there was greater diversity among the radials than that recognised among the infrabasal and basal circlets. Therefore, the radials were selected to provide a better estimate of the diversity of both the Howz-e-Dorah and Shir Gesht faunas because plate morphologies and radial facets were more easily recognised, including growth stages. Features used to distinguish the radials in the three fractions include relative shape dimensions and ornamentation as well as the size, type, position and declination of the radial facet (Appendices Tables 5, 6, 7, 8, 9 and 10). However, detailed descriptions and illustrations of all the radial types are beyond the scope of this study.

Sorting of the three fractions of the Howz-e-Dorah residues (Appendices Tables 5, 6 and 7) yielded a total of 111 types of radials with 44 in the <2-mm fraction, 49 in the 2- to 5-mm fraction, and 21 in the >5-mm fraction. Among the 111 types recognised, 67 are based on single specimens and only two are based on more than five specimens. It was recognised that there was some duplication among the radials identified within each of the different fractions. For example, the two types recognised on more than five specimens are growth stages of a single species. Thus, the overall total of 111 is considered an overestimate of the true diversity. We also recognised that some radials could represent variation of one another as a result of changes with growth or relative position of the radial in the cup.

The 49 radial types in the 2- to 5-mm fraction were used as a conservative estimate of the diversity. With the addition of the 18 identified genera, two articulated pluricolumnals, an ophiuroid and an echinoid gives an approximate minimal estimate of the total diversity of at least 69 echinoderms in the Howz-e-Dorah fauna. This is considered a minimal estimate because some of the radial types recognised in the <2-mm and >5-mm fractions are not present in the 2- to 5-mm fraction. They could more than make up the possible over-counting of unrecognised variation and growth stages within the 2- to 5-mm fraction. Our conservative estimate of 69 taxa makes the Howz-e-Dorah fauna one of the more diverse Pennsylvanian echinoderm faunas known.

Sorting of the Shir Gesht residues (Appendices Tables 8, 9 and 10) yielded a total of 79 radial types: 25 being <2 mm, 41 being 2–5 mm and 13 being >5 mm. Among the 79 types, 15 are based on one or more specimens, and four of those are known from five or more specimens. Again, growth stages and possible variation are recognised within the different size fractions. If the 41 radial types in the 2- to 5-mm fraction are added to the nine genera based on articulated specimens, along with three flexible genera recognised on brachials (but not recognised among any of the radials), one echinoid (disarticulated ossicles) and one asterozoan (disarticulated ossicles), a minimal estimate of the total diversity would be 55 taxa. This is a diverse Pennsylvanian echinoderm fauna, but less than the Howz-e-Dorah fauna.

Most of the disarticulated radials cannot be identified to genus, family or order, but they add to the higher-level diversity of the crinoids through the recognition of flexibles and possible codiacrinids in the faunas. Some radials are judged to be indeterminate camerates and cladids, as described and illustrated in the Systematics section

Several other features present in the radials add to the importance of these faunas. Preservation of the Howz-e-Dorah ossicles is excellent to good, with some specimens overgrown by algae and bryozoans, whereas the Shir Gesht ossicles in the >5-mm fraction are solution weathered or abraded. The Howz-e-Dorah echinoderm ossicles include more than 2,500 specimens, whereas the Shir Gesht residues yielded fewer than 250 specimens. Still, the diversity of the two faunas is not that disparate. The difference in preservation and number of specimens is judged to reflect environmental control.

Among the different size fractions are some angustary and peneplenary radials that have elevated platforms or short to long stalks upon which the radial facet is positioned (Figs. 10k–m and 12m–p). Although the elevated radial facet is present on some adult Paleozoic macrocrinoids, the presence of a stalk is not common on adults. In the Howz-e-Dorah fauna, the elevated facet is present on nearly 50% of the radials in each of the three fractions: <2 mm, 48% (21/44); 2–5 mm, 45% (22/49); >5 mm, 48% (10/21). In the Shir Gesht fauna, the elevated facet is most common in the smaller size fractions: <2 mm, 68% (17/25); 2–5 mm, 32% (13/41); >5 mm, 8% (1/13). The presence of the stalked radial in the Howz-e-Dorah fauna is less common in all fractions: <2 mm, 10% (11/44); 2–5 mm, 12% (6/49); >5 mm, 5% (1/21). Likewise, the stalked radial is less common in all fractions in the Shir Gesht fauna: <2 mm, 8% (2/25); 2–5 mm, 10% (4/41); none in the >5 mm. The reason for the difference in the stalked radials in the two faunas is uncertain but reflects how these taxa were able to live in the different environments of the two localities. Immature forms may have used a stalked radial to exploit higher-level food particles. By effectively moving the arms farther away from the thecae in the immature stages, these could have resulted in increased food gathering ability. Also, the stalked adaptation may have made fouling by waste expulsion less likely.

The presence of a stalk for the radial facet is considered to be a growth feature of immature specimens of indeterminate crinoids. This assumption is supported by the lack of or small percentage in the >5-mm fractions. George Sevastopulo (personal communication) has seen similar radials (he considers possible *Platycrinites*) in some of his Pennsylvanian residues. The shape of some of our radials agrees with this, but also probably includes dichocrinids and possibly codiacrinids, among other taxa. It is unknown if other Pennsylvanian echinoderm faunas show morphological characters among the immature crinoid radials similar to the Iranian faunas.

Small, blade-shaped cirri(?), here questionably considered to belong to an indeterminate crinoid, have never been reported as a shape in the columnals or cirri of an echinoderm. They were only found in the Howz-e-Dorah fauna in the <2-mm and 2- to 5-mm fractions.

No flexible radials were found in Shir Gesht residues, but three types of flexible brachials are present, two of which are identical to ones in the Howz-e-Dorah fauna. Six different flexible radials along with five different flexible brachials (none of which could be unquestionably assigned to one of the radials) are present in the Howz-e-Dorah fauna. Thus, some—if not all—of the brachials may be from the same taxa as the radials. Therefore, we consider that the Howz-e-Dorah faunas have six flexible taxa and the Shir Gesht fauna has three. This is a large diversity of flexibles for Pennsylvanian faunas, a time when flexibles are usually represented by only one or two taxa (Lane and Webster 1980).

Significant differences in the presence of ornamentation were recognised within the faunas of both the Shir Gesht and Howz-e-Dorah sections. In the Shir Gesht fauna, the percentage of radials with ornamentation was much higher in the smaller fractions than in the largest fraction: <2 mm, 92% (23/25); 2–5 mm, 76% (31/41); >5 mm, 54% (7/13). In the Howz-e-Dorah fauna, the greatest percentages of radials with ornamentation are in the larger size fractions: <2 mm, 27% (12/44); 2–5 mm, 47% (23/49); >5 mm, 43% (9/21). Overall, the Shir Gesht fauna has a higher percentage of ornamented taxa than the Howz-e-Dorah fauna.

Palaeoenvironment

The palaeoenvironment of the marine band at Shir Gesht was interpreted by Webster et al. (2001) as a marine highstand incursion in which the invertebrate fauna (except goniatites) was impoverished or represents immature individuals living in marine water below the mixing deltaic freshwater. The crinoid larvae of most taxa that settled in the area were unable to survive past the immature stage of a cup diameter of a few millimetres and were low-trophic-level feeders (Webster et al. 2001). *Iranoblastus nodosus*, *Epihalysiocrinus* and a few indeterminate taxa were able to develop to larger sizes, as indicated by one loose indeterminate radial that is 16 mm wide and another that is 15 mm wide. *Iranoblastus* and *Epihalysiocrinus* are interpreted to be bottom dwellers with the filtration fan parallel to and close to the sea floor. This allowed these taxa to inhabit the marine incursion within the deltaic environment. Typical blastoids with morphologies similar to *Iranoblastus* usually have larger sized stem cicatrices, indicating thecal elevation above the sea floor on a stem of unknown length. *Iranoblastus* has a diminutive stem cicatrix and enlarged protruding basals as well as ambulacral structures that indicate an upright posture on the sea floor. Although *Iranoblastus* had a larger theca than many of the other low-trophic-level feeders at Shir Gesht, it was feeding in the lower tier.

The columnals of *Platycrinites* s.l. sp. are less than 12 mm (maximum dimension), while those of the camptocrinid are less than 5 mm (maximum dimension). These are both small for late Paleozoic species of these two taxa described from Permian strata of Australia (Webster and Jell 1999b) and Timor (Wanner 1937) and for Late Pennsylvanian platycrinitids reported from New Mexico by Bowsher and Strimple (1986). Higher-tier organisms requiring normal marine salinity could not exist in this environment because they would have been in the mixing freshwater near the surface.

In the Howz-e-Dorah area, the Absheni Formation was deposited in a shallow-shelf setting above the storm wave base. The fauna consisted of both upper- and lower-tier feeders as defined by Ausich and Bottjer (1985). The upper-tier feeders include *Platycrinites, Catillocrinus*, *Synbathocrinus*, and ?*Alcimocrinus*, whilst the lower-tier feeders would include all of the microcrinoid genera, echinoids and asterozoans. Specimens were not transported significantly post-mortem, but apparently they were disarticulated by scavengers or currents in or near the living site, as suggested by numerous holdfasts that are among the ossicles with few articulated crowns and cups. Ossicles were exposed long enough for bryozoans, crinoids and other organisms to encrust the exposed surfaces.

Pabian and Strimple (1985) reported Late Pennsylvanian crinoid faunas in the Stull Shale of Kansas dominated by ornate crinoids that lived near shore and inornate-dominated faunas that lived offshore. The Iranian faunas support their conclusion, with the Shir Gesht fauna having lived in a near-shore deltaic sequence and having a higher percentage of ornamented taxa than the Howz-e-Dorah fauna, which lived in a shallow-shelf environment.

The Early Permian cromyocrinid set of arms from the Chah-Reiseh area of central Iran is from an interbedded marine carbonate and sandstone sequence that was depos-

ited in a shallow-shelf enviroment (Yazdi and Ghazifard 1998) at approximately 22°S latitude (palaeogeograpic maps of Golonka 2002).

Faunal analysis

This is the third description of Early Pennsylvanian echinoderms from the Paleotethys, following the Japanese fauna described by Hashimoto (1984, 2001) and Australian crinoids described by Webster and Jell (1999a). The description of these Iranian echinoderms expands the preliminary report, illustrating some of the specimens of Webster et al. (2001). It also extends their palaeogeographic distributions.

The Absheni fauna is of particular significance for the occurrence of blastoids, which are rare in Pennsylvanian faunas (Macurda and Mapes 1982; Waters 1990), and the abundance of camerates, which are usually minor elements (or not present) in Pennsylvanian faunas. It should be noted that camerates were more common in Paleotethyan areas than in other parts of the world during the Pennsylvanian and Permian (Waters and Webster 2007, 2011). Another important feature in the Absheni fauna is the diversity of the allagecrinids, which is the greatest diversity known in the Pennsylvanian and is a continuation of the radiation of the allagecrinids that started during the Late Devonian and expanded during the Mississippian.

Iranoblastus and *Shotoricrinus* n. gen. are the only endemics recognised in the Absheni faunas, whereas all new species described are considered endemics. The Granatocrinidae, to which *Iranoblastus* belongs, is primarily known from the Mississippian of North America and Europe. Pennsylvanian genera include *Iranoblastus* and *Malchiblastus*. The latter is known from the Bashkirian of Australia and the Namurian of Argentina (Simanauskas and Sabattini 1997). Thus, the geographic distribution of the Granatocrinidae shows a significant shift to Gondwana during post-Mississippian times. This is the first report of a Pennsylvanian periechocrinid, *Shotoricrinus* n. gen., a taxon that is transitional between the periechocrinids and paragaracocrinids. It is considered to be the progenitor of younger paragaracocrinids in the Paleotethys reported by Lane et al. (1996) and Webster et al. (2009a, b).

This is the first report of *Passalocrinus* Peck 1936 from Iran. *Passalocrinus* previously was reported from Silurian to Pennsylvanian strata in North America (Sevastopulo 2005), Mississippian strata of the southern Ural Mountains (Arendt 1981) and Permian strata of Western Australia (Sevastopulo 2005). *Passalocrinus* should occur wherever blastoids occur, given proper environmental and preservation conditions.

Among the named camerates in Table 1, *Platycrinites* s.l. is considered to be a cosmopolitan taxon in the equatorial belt throughout the Pennsylvanian (Waters and Webster 2011). *Amphipsalidocrinus* Weller, 1930, a microcrinoid, has been reported from Silurian deposits of North America (Sevastopulo and Lane 1981), Devonian and Mississippian deposits in North America (Koenig and Meyer 1965, as *Tytthocrinus*), Mississippian strata of Ireland (Lane et al. 1985), Lower Pennsylvanian deposits in North America (Weller 1930) and Lower Permian strata of Russia (Arendt 2002); its palaeogeographic range is extended into Iran. This is the first report of a Pennsylvanian *Camptocrinus* Wachsmuth and Springer, 1897, a genus known from the Mississippian of the USA and Scotland and the Permian of Russia, Timor, Australia and Argentina (Webster 2003; Hlebszevitsch 2005). The stratigraphic range of *Culicocrinus* Müller, 1855 is extended upward into the Early Pennsylvanian and the palaeogeographic range into Iran; previously it was reported from Late Ordovician and Silurian deposits of North America and Devonian strata of Germany (Webster compilation: Webster et al. 2003).

Radials questionably referred to the Dichocrinidae are the oldest recognised in the Paleotethys and represent the potential evolutionary link between Mississippian (Europe, Russia and North America) and Pennsylvanian (North America) dichocrinids with Westphalian (Algeria) and Permian (Australia) dichocrinids (Broadhead 1981; Webster compilation: Webster et al. 2003).

Disparid crinoids in the Absheni fauna are dominated by allagecrinids, mostly microcrinoids, but they also include *Catillocrinus* Shumard, 1865 (Table 1). This is the first report of *Catillocrinus* from the Paleotethys (a genus previously reported from the Carboniferous of North America (Webster compilation: Webster et al. 2003). It is the first report of *Desmacriocrinus* Strimple, 1966, *Litocrinus* Lane and Sevastopulo, 1982, and *Trophocrinus* Kirk, 1930 from Pennsylvanian strata. *Desmacriocrinus* and *Trophocrinus* were both reported from Early and Middle Mississippian strata of North America (Webster compilation: Webster et al. 2003). Thus, their stratigraphic ranges are extended upward into the Early Pennsylvanian and their palaeogeographic range into the Paleotethys. *Litocrinus* has been reported from Mississippian strata of North America and Scotland (Lane and Sevastopulo 1982) and Mississippian and Permian deposits of Australia (Webster and Jell 1999a, b). The Iranian occurrence partially fills the gap between the Mississippian and Permian occurrences.

Two other disparids are recognised in the Absheni fauna. This is the first report of an Early Pennsylvanian occurrence of *Synbathocrinus* Phillips, 1836, which is one of the few long-ranging crinoid genera (Devonian–Permian). It is cosmopolitan in the Carboniferous and restricted to the Paleotethys in the Permian (Webster compilation: Webster et al. 2003). This is the only known occurrence of *Epihalysiocrinus* Yakovlev, 1927 in the Early Pennsylva-

nian and extends its range downward from the late Artinskian. The Iranian species probably gave rise to the Permian species reported from the southern Urals (Yakovlev 1927; Arendt 1965).

Absheni cladid crinoids are mostly disarticulated. However, two microcrinoids, *Dichostreblocrinus* Weller, 1930 and *Lampadosocrinus* Strimple and Koenig, 1956 are described, one macrocrinoid is questionably assigned to *Alcimocrinus* Kirk, 1938, one cup is considered to belong to the Blothrocrinidae, and a crown is an indeterminate cromyocrinid. *Dichostreblocrinus* has been reported from the Mississippian and Middle Pennsylvanian of North America and Permian of Timor (Webster 2003) as well as Early Pennsylvanian of China (Waters et al. 1989). *Lampadosocrinus* has been reported from the Mississippian and Early Pennsylvanian of North America and Early Permian of Australia (Webster compilation: Webster et al. 2003). *Alcimocrinus* has been reported from the Late Mississippian and Early to Middle Pennsylvanian of Oklahoma (Webster 2003). The Absheni Formation zeacrinitid, *Alcimocrinus*?, may represent a new genus, but is most like *Alcimocrinus* and most zeacrinitids are of Mississippian age. This is the first report of all of these genera from Pennsylvanian strata of the Paleotethys, and they are considered to be ancestral to related Permian taxa in Australia and Timor. In addition, a cup assigned to Blothrocrinidae indeterminate is most like *Moscovicrinus* Jaekel, 1918, a genus reported from Moscovian strata in Russia and Lower Permian strata in the USA and Indonesia (Webster 2003). The Cromyocrinidae indeterminate A is probably a *Mooreocrinus*, based on the uniserial rectilinear brachials, but the anals are not exposed for more positive identification. This cromyocrinid may be the progenitor of later Paleotethyan cromyocrinids recognised in Australia and Timor.

Other cladids include pluricolumnal sections of a pentameric stem that are assigned to the Barycrinidae and numerous indeterminate radials. Pentameric columnals are common in Ordovician and Silurian cladids, but uncommon thereafter. *Barycrinus* Wachsmuth (Meek and Worthen 1868), a Mississippian genus reported from North America, England, and Algeria, is the youngest taxon known from a cup with a pentameric stem. Webster and Jell (1992) described pentameric columnals from the Early Permian Callytharra Formation of Western Australia. The Iranian specimens are the first pentameric columnals reported from the Early Pennsylvanian and provide a potential ancestral lineage for Permian specimens from Western Australia.

The diversity of the Primitive Cladid? radials indeterminate (seven taxa described below) is of special importance in the Absheni fauna. These radials have morphologic characters of shape and radial facet lengths belonging to primitive macrodendrocrinids. Five of the seven have bifascial radial facets. Two of the seven, Primitive cladid? Radial indeterminate 2 and 6, have trifascial radial facets with ligament pits. These are not common in the primitive dendrocrinids. Webster and Maples (2008) did not recognize any primitive dendrocrinids with trifascial radial facets. However, they did note that some of the genera for which the radial facet type was unknown (because of lack of preservation or exposure) could have trifacial facets. Webster and Maples (2008) considered the primitive dendrocrinids to range from Ordovician–Mississippian, transitional dendrocrinids (Glossocrinoidea) from Silurian–Mississippian and advanced dendrocrinids from Devonian–Permian. The discovery of these radials implies that some primitive dendrocrinids survived, extending the range into the Early Pennsylvanian.

Primitive dendrocrinids are most diverse and have been described mostly from North America and Europe as compiled by Webster (2003), although newer discoveries of cups and crowns in Australia (Jell 1999) and South Africa (Jell and Theron 1999) have demonstrated that they were more diverse and more widely dispersed during the Devonian than previously thought. Without the cups, it would be speculation to relate the Iranian radials to described taxa from these other areas. The Iranian part of the western Paleotethys appears to have been the last occurrence of the primitive dendrocrinids. Hopefully, cups or crowns of these taxa will be discovered in the future to verify their full affinity within the cladids.

No disarticulated flexible radials or brachials are identifiable beyond the subclass level. They are recognised as flexibles based on the patelloid process on the brachials and the half-moon depression in the centre of the abapical edge of the radial facet on the radials and the distal facet of the brachials as well as the articular facet on loose brachials. The six flexible taxa recognised in the Howz-e-Dorah fauna and three in the Shir Gesht fauna (at least two taxa are the same in both faunas) are relatively high percentages of flexibles for most Paleozoic faunas.

Reports of microechinoderms in various Paleozoic faunas usually include only one to three taxa. Sevastopulo (2002) reported two undescribed diverse microfaunas (in addition to other less diverse microfaunas) from Mississippian strata in Ireland that he considered to be the most diverse known. However, the total number of taxa was not given for either fauna. Wanner (1929, 1930) described seven species of *Allagecrinus* from Permian strata of Timor. Strimple (1966) reassigned six of the species to *Metallagecrinus*, and Moore (1940) assigned the seventh to *Wrightocrinus*. Webster and Jell 1992 reported four species among three genera in the Early Permian Callytharra Formation of Western Australia. The presence of five genera (six species) in the Shir Gesht fauna and seven genera (eight species) in the Howz-e-Dorah fauna makes them the most diverse faunas of microechinoderms described. If the two juvenile microcrinoids of

Platycrinites s.l. and *Synbathocrinus* as well as the Allagecrinidae indeterminate are added to these, the total number of genera is increased to seven and nine, respectively, in each of the faunas.

When comparing the Shir Gesht and Howz-e-Dorah identified genera (Table 1), it appears that the disparids (seven identified genera) are the most diverse crinoids, with camerates (six identified genera) a close second, and cladids (three identified genera) less diverse. However, in the listed Howz-e-Dorah fauna (species level), the cladids (15 taxa) are the most diverse with the camerates (13 taxa) and disparids (11 taxa) slightly less diverse. In the listed Shir Gesht fauna (species level), the blastoids (two taxa) equal the cladids (two taxa), whereas flexible taxa are not listed and the disparids (six taxa) are the most diverse. The listings of Table 1 are misleading because the cladids are considered to dominate both faunas, and the flexibles would outnumber the blastoids if numbers of indeterminant taxa based on disarticulated radials and brachials were included. Only a small portion of the loose ossicles (mostly larger than 5 mm maximum diameter) is listed in Table 1 as well as described and illustrated.

The diversity of camerates in the Absheni faunas is significant when compared to described Pennsylvanian faunas, wherein camerates commonly are not present or occur in very limited diversity (Waters and Webster 2009, 2011). Camerates in the Absheni faunas are considered to be the forerunners of many later Paleotethyan genera. Likewise, the diversity of the disparids in the Absheni faunas is one of the largest known in the Pennsylvanian. We consider them to be the progenators of many younger Paleotethyan disparids. The Absheni faunas are not typical Pennsylvanian faunas wherein cladids are the dominate crinoids, because they contain highly significant numbers of camerates and disparids.

Correlation

At Howz-e-Dorah, *Reticuloceras* sp. occurs 25 m below the crinoidal horizon and *Gastrioceras* sp. occurs 100 m above the crinoidal horizon (Yazdi and Ghazifard 1998). Early Pennsylvanian conodonts were recovered from the lower part of the Absheni Formation by Yazdi (1999), wherein he placed the crinoid horizon in the combined *sinuatus-corrugatus-sulcatus* Conodont Biozone in the Bashkirian. Based on the common occurrence of the microblastoid, microcrinoids, and several loose ossicles, the marine band at Shir Gesht and the main crinoidal horizon at Howz-e-Dorah are considered coeval. Their age is now considered earliest Bashkirian based on the occurrence of goniatites in the Shir Gesht marine band (Hairapetian et al. 2006) and condonts in the Howz-e-Dorah area (Boncheva et al. 2007) as described above.

The Absheni fauna at Howz-e-Dorah shares the common occurrence of *Platycrinites* s.l. *djihaniensis* with the Early Pennsylvanian Djenien fauna of Algeria reported by Webster et al. (2004), but at the generic and family level it has greater affinity with the diverse Middle Pennsylvanian fauna from the Akiyoshi Limestone described by Hashimoto (1984, 2005). The Akiyoshi Limestone fauna contains paragaricocrinids, platycrinitids, catillocrinids, scytalocrinids, zeacrinitids and indeterminate flexibles. The Akiyoshi fauna also contains a number of generically identified cladids and camerates that may have representatives at the genus or family level in the indeterminate loose ossicles in the Absheni fauna. Although the only genus in the Akiyoshi fauna currently recognised in common with the Absheni fauna is *Platycrinites* s.l., the mutual occurrence of taxa at the family level suggests that both faunas were living in similar environments. However, the Absheni fauna was living at 33°S latitude, whilst the Akiyoshi fauna was living at 13°N latitude (palaeogeogaphic maps, Golonka 2002). The Absheni faunas are basically equatorial faunas and are the highest latitude Early Pennsylvanian faunas known.

The diversity of camerates (Table 1) in the Absheni faunas, including a periechocrinid and camptocrinids, supports the proposal by Waters and Webster (2007, 2009, 2011) that the Paleotethys was a refuge for non-cosmopolitan camerates in the Pennsylvanian. The recognition of primitive dendrocrinids in the Absheni fauna provides additional support for their proposal.

As noted above in the discussion of the genera, most of the Absheni crinoids have older representatives in North America, and the Iranian occurrence of these genera is the first Paleotethyan record. Webster et al. (2004) considered the Algerian Mississippian and Pennsylvanian faunas to be derived from North American and European faunas. The common occurrence of *Platycrinites* s.l. *djihaniensis* in Iran and Algeria suggests that the migration route was from North America and Europe to Northern Africa and into the Paleotethys. Waters and Webster (2011) pointed out that the Bashkirian Iranian and Japanese faunas, with younger Pennsylvanian faunas from Japan, Australia and western China, were the precursors of the Permian faunas of Australia and Timor. This would also apply to the Permian faunas of Oman described by Jell and Willink (1993), Webster and Sevastopulo (2007) and Webster et al. (2009c). Thus, we consider the Iranian faunas to be transitional between Laurentia/Avalonia faunas and Paleotethyan faunas.

Systematics

Remarks: Morphologic terminology follows that of Moore and Teichert (1978), with the following exceptions. Dimensions of length, width and depth follow the recom-

mendations of Webster and Jell (1999a). Noditaxis patterns follow Webster (1974). Anal terminology follows Webster and Maples (2006). The classification follows Simms and Sevastopulo (1993), with subsequent modifications as suggested by various authors.

All specimens are reposited in the Geology Department, University of Isfahan, Isfahan, Iran under the designation EUI.

Class Blastoidea Say, 1825
Order Granatocrinida Bather, 1900 (emended Waters and Horowitz, 1993)
Family Granatocrindae Fay, 1961

Genus *Iranoblastus* Flügel, 1966

Type species: *Iranoblastus nodosus* Flügel, 1966, original designation
Diagnosis: Small, bell-shaped spiraculate blastoid. Eight spiracles plus an anispiracle occurring between an epideltoid and a long hypodeltoid. One pore per each side plate, along margin of deltoids. Twice as many pores as side plates along margin of radials. One hydrospire fold on each side of an ambulacrum. Lancet partially covered by side plates and exposed along median for entire length. Deltoids longer than radials and overlap radials. Basalia concave.
Remarks: Flügel (1966) ascribed a Mississippian age to the portion of the Sardar (=Absheni) Formation containing specimens of *Iranoblastus*, but goniatites and rare conodonts from the blastoid-bearing beds indicate a Pennsylvanian (basal Bashkirian) age (Webster et al. 2001; Hairapetian et al. 2006).

Iranoblastus nodosus Flügel, 1966 (Fig. 3a–f, i)
1966 *Iranoblastus nodosus* Flügel, p. 55-57, pl. I–III

Description: Godoniform calyx (Fig. 3a, c), 10.0–15.0 mm long by 10–15 mm wide, oral view pentalobate (Fig. 3b), basal view pentagonal (Fig. 3e). Four pairs of spiracles plus an anispiracle surrounded by epi- and hypodeltoid (Fig. 3b). Basalia 3, in normal position, form diminutive invaginated pentagonal basalia with small round stem cicatrix (approx. 1.0 mm in diameter) (Fig. 3e). In side view, deltoids long (>50% of thecal height), short radials with prongs protruding aborally below basals (Fig. 3b, e). Ambulacra long and narrow.

Spiracles small, paired, oval to strongly elliptical, pierce arrowhead-shaped adoral tips of deltoids (Fig. 3b, f). Oral

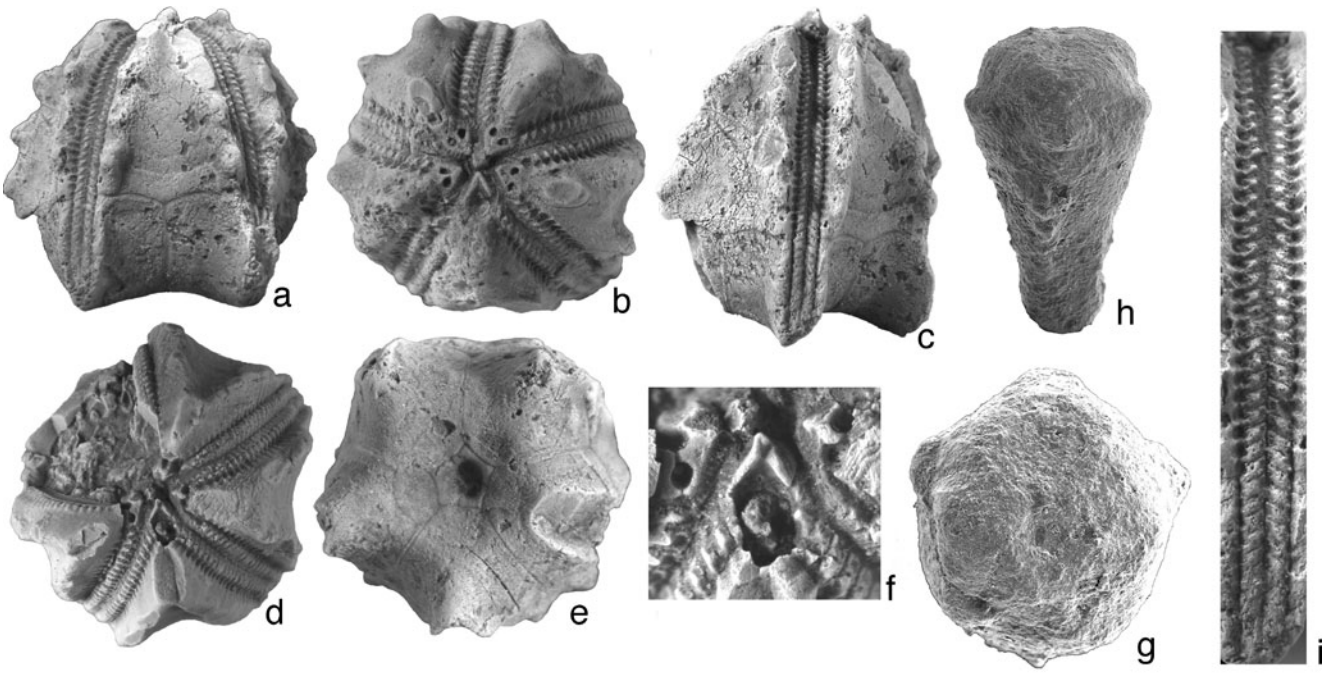

Fig. 3 **a-f**, **i** *Iranoblastus nodosus* Flügel, 1966. **a**, **c**, **i** EUI 8619: **a** BC-interray with large arrow-shaped deltoid with prominent lateral coronal processes (radials lack such processes), ×2.7, **c** C-ray with long narrow ambulacrum (note large hydrospire pores and brachiolar attachments on portion of ambulacrum bordered by deltoid), ×2.7, **i** C-ambulacrum, note large hydrospire pores and prominent brachiolar attachments on portion of ambulacrum bordered by deltoid (aboral portion of the ambulacrum bordered by the radial has smaller hydrospire pores and lacks brachiolar attachment scars), ×5.7. **b**, **e** EUI 8620, **e** basal view showing small stem impression and basalia: **b** oral view with paired spiracles piercing adoral tips of deltoids, adoral prongs of deltoids visible but broken, ×3.8. **d**, **f** EUI 8624: **d** oral view, ×3.0, **f** close-up of anispiracle with adoral-most tip of hypodeltoid and epideltoid (note external gonopore on adanal wall of epideltoid), ×8.7. **g**, **h** *Passalocrinus* sp. theca EUI 8623, lateral view with elongated triangular basals (×80) and oral view with three attachment facets for feeding, respectively (×110)

opening pentagonal, surrounded by four deltoid tips and epideltoid. Anispiracle positioned between epi- and long arrow-shaped hypodeltoid. Small external gonopore present on adoral wall of epideltoid (Fig. 3f). Aboralmost lip of epideltoid has two channels with similar diameter as gonopore that may have guided reproductive products released from gonopore (Fig. 3d, f).

Deltoids 4, long, arrow shaped, comprise >50% of theca lateral (Fig. 3a, c). Adoral tips of deltoids and hypodeltoid have prongs projecting above oral surface. Deltoids have large flat spine-shaped lateral processes adjacent to ambulacra extending the full length of the deltoid. Radiodeltoid suture convex. Deltoids overlap radials.

Radials short, equidimensional, with narrow ambulacral sinus. Radial-basal growth sector at right angles to radial and radio-deltoid sectors, not visible in side view. Ambulacral sinus forms prong extends below level of basals.

Ambulacra 5, recurved, narrow (Fig. 3i). Median portions of lancet, occupy 1/4 width, exposed along length of ambulacrum. One large pore and brachiolar attachment scar situated between adjacent side plates along deltoid margins. Two small pores per side plate along radial margins of ambulacrum. From the main food groove, side food grooves extend in aboral direction to central region of side plates at about 80º. One hydrospiral fold present on each side of ambulacrum.

Character of ambulacra changes significantly at the radio/deltoid suture. Large pores and brachiolar attachments stop abruptly (Fig. 3i), ambulacra appear to become narrower, hydrospire pores become much smaller.

Basalia 3, small, confined to basal invagination (Fig. 3e). Azygous basal in AB interray, normal position. Radio-basal sutures of azygous basal are straight as are basal/basal sutures. Zygous basals with concave radio/basal sutures. Basal/basal sutures straight. Stem cicatrix approximately 1 mm in diameter, crenulated, deeply impressed on aboral tips of basalia. Lumen circular.

Remarks: Flügel (1966) described *Iranoblastus nodosus* from four specimens collected from Locality 5. We have not been able to re-examine Flügel's type specimens, but we have 24 additional topotypes collected in 1998 and 2000. Illustrations of Flügel's holotype suggest that the oral surface is somewhat weathered. Some of our 24 specimens are better preserved, allowing us to delineate details unavailable to Flügel.

Breimer and Macurda (1972) summarized the autecology of fissiculate blastoids and divided them into four modes of life based on thecal shape, diameter of the stem cicatrix and configuration of the ambulacra. Some Permo-Carboniferous blastoids, such as *Timoroblastus*, were adapted to living directly on the substrate (Breimer and Macurda 1972). The theca is box-shaped, with the ambulacra confined to the upper surface and frequently expanding the lower part of the theca into radiate, star-shaped extensions. The small stem diameter was apparently of insufficient diameter to support a theca of the size involved. The expanded nature of the base suggests the animal sat directly on the substrate, with the expanded base helping to provide stability. The short ambulacra, confined to the upper surface, would have produced a filtration fan more or less parallel to the sea floor.

Iranoblastus is interpreted as a bottom dweller with a filtration fan parallel to the sea floor similar to that of *Timoroblastus* although the two genera have key differences. *Iranoblastus* has a diminutive stem that attached in a deep basal invagination similar in proportion to stems in *Timoroblastus*. Stem diameter in both genera appears to be inadequate to elevate the thecae above the sea floor. Unlike *Timoroblastus*, *Iranoblastus* has long recurved ambulacra similar to genera classified by Breimer and Macurda (1972) as Type III feeders. Typical Type III feeders have elongated ambulacra forming a complex three-dimensional filtration fan, presumably allowing these taxa to inhabit environments with higher rates of sedimentation. Typical members in this feeding class have normally sized stem cicatrices, indicating thecal elevation above the sea floor on a long flexible stem.

The morphology and presumed functionality of the ambulacra in specimens of *Iranoblastus* change dramatically at the level of the radio-deltoid suture. Brachioles clearly were attached to the ambulacra adjacent to the long deltoids, but they apparently were absent aborally along the portions bordered by the short radials. The number of pores per side plate and pore diameter also change at the same boundary, giving the appearance of ambulacra with feeding and hydrospire functions orally. Missing brachioles and smaller hydrospire pores along the aboralmost portion of the thecae are consistent with an interpretation of a bottom-dwelling mode of life. Although not as pronounced as in other genera, radial prongs in *Iranoblastus* could have stabilized the theca in the sediment on the bottom with the oral-aboral axis perpendicular to the sea floor. In this position, the ambulacra would produce a three-dimensional filtration fan parallel to the sea floor, whilst the absence of brachioles would minimize fouling near the sediment/water interface. The presence of associated fauna from the blastoid bed in the Absheni Formation, such as the crinoid *Epihalysiocrinus*, also suggests that the echinoderms present were all lower-tier feeders.

Material: Figured specimens EUI 8619, 8620; 22 specimens, plus fragments.

Locality: 5, Shir Gesht, Absheni Formation, Pennsylvanian, early Bashkirian

Genus *Passalocrinus* Peck, 1936

Remarks: Although Peck (1936) initially described *Passalocrinus* as a crinoid, Sevastopulo (1994, 2005) and Waters and Marcus (2002) have demonstrated that it is the larval stage in the development of blastoids. In addition, Sevastopulo (2005) suggested the following: (1) the name *Passalocrinus* should be retained for referring to juvenile specimens that may not be related to specific adults; (2) *Passalocrinus* could be used as referring to the passalocrinid growth stage; (3) passalocrinid specimens typically are associated with adult blastoids; (4) the form ranges from the Silurian into the Permian; (5) passalocrinids of different ages are larval stages belonging to several different genera of blastoids.

Passalocrinus spp. (Fig. 3g, h)

Description: Theca high cone, circular outline in oral view; base narrow, truncate, tegmen convex with flat summit. Basilia 3, very steeply upflared, forming two-thirds of the thecal length, straight to slightly concave longitudinally, strongly convexly rounded transversely. Radials 5, pentagonal/hexagonal, slightly wider than long, straight to slightly convex longitudinally with incurving distal tips, moderately convex transversely. Orals 5, triangular, proximally subvertical, incurving distally, distal tips subhorizontal, sutures slightly impressed or in elevated ridges; posterior oral largest, adjoining all others; other orals adjoin 2 adjacent orals only. Stem facet circular.

Remarks: *Passalocrinus* spp. is the most common species in the Absheni Formation in the Howz-e-Dorah region (235 specimens at locality 31) and is also common at Shir Gesht (26 specimens). Variation is noted in the length-to-width ratio of thecae, as some forms have a greater width at the summit of the radials than others of the same length. At Shir Gesht, adult specimens of *Iranoblastus* are common and the passalocrinid specimens there may represent the larval stage. *Iranoblastus* was not found at Howz-e-Dorah, but one fragment of an indeterminate blastoid radial was found. Thus, the passalocrinid specimens from the two areas may represent larval stages of two different genera.

Material: Figured specimen EUI 8620; 261 specimens: 26 specimens, 22 uncrushed, four partial, locality 5); 235 specimens, 153 uncrushed, 82 crushed, locality 2.

Localities: 2, Howz-e-Dorah; 5, Shir Gesht; Absheni Formation, Pennsylvanian, early Bashkirian.

Class Crinoidea J. S. Miller, 1821
Subclass Camerata Wachsmuth and Springer, 1885
Order Monobathrida Moore and Laudon, 1943
Superfamily Periechocrinoidea Bronn, 1849
Family Periechocrinidae Bronn, 1849

Remarks: Ausich and Kammer (2008) reviewed the stratigraphic and palaeogeographic distribution of the family Periechocrinidae. They noted the following: (1) the family ranged from the Silurian through the Mississippian; (2) the greatest diversity occurred in the Givetian; (3) Silurian, Devonian and Mississippian genera were reported from Laurentia and Avalonia; (4) Silurian genera were also known from Baltica; (5) Devonian genera were also described from Gondwana and Kazakhstan; (6) no Mississippian genera were known outside Laurentia and Avalonia. Waters and Webster (2011) summarized the Pennsylvanian stratigraphic and palaeogeographic distribution of Pennsylvanian crinoids and blastoids. They noted that Pennsylvanian periechocrinoid genera (paragaracocrinids) were restricted to the Paleotethys except for the report of the batocrinid *Eretmocrinus* Lyon and Casseday, 1859 from the Middle Pennsylvanian of North America (Itano et al. 2003) and the occurrences on the northwestern coast of Africa reported by Webster et al. (2004). The presence in the Absheni fauna of a periechocrinid that is transitional between the periechocrinids and paragaracocrinids represents an evolutionary link between the Mississippian and older periechocrinids (Ausich and Kammer 2008) and the late Early Pennsylvanian and younger Pennsylvanian paragaracocrinids reported from Japan (Hashimoto 2001, 2005) and the paragaracocrinids from China (Lane et al. 1996; Webster et al. 2009a, b).

Genus *Shotoricrinus* n. gen.

Type species: *Shotoricrinus transitorius* n. sp. here designated.

Etymology: Named for the mountain range where the specimens were found.

Diagnosis: A shallowing impressed flat-based bowl-shaped calyx with a moderately inflated tegmen, hexagonal first primibrachials in the A and E rays and pentagonal first primibrachials in the C and D rays.

Description: See description of *Shotoricrinus transitorius* below.

Remarks: *Shotoricrinus* n. gen. differs from all other periechocrinids by having pentagonal first primibrachials in the C and D rays and hexagonal first primibrachials in the E and A rays (B ray first primibrachial not preserved). The genus is based on three specimens, two partial thecae and one tegmen, considered to be conspecific. The partial calyces have relatively smaller radials and a smaller anal plate than those of *Athabascacrinus* Laudon et al. (1952), a Mississippian periechocrinid which also has a shallowly impressed base and wide bowl-shaped calyx.

The tegmen is part of a theca that is embedded in an encrinite with the arm openings not exposed. It is fractured and some plates are dislocated slightly. Otherwise, it is well preserved with minor weathering. The tegmen is quite

similar to that of *Athabascacrinus*, but it has eight large plates surrounding the posterior oral instead of six.

Specimens are assigned to the Periechocrinidae because the wide interrays appear to have continued onto the tegmen, the first primibrachials are pentagonal in the C and D rays, and there are three secundanals. The blunt oral spine is present in some genera of both the Periechocrinidae and Paragaricocrinidae, but it is most common in the Paragaricocrinidae. Paragaricocrinids lack ray lobes, interrays do not adjoin the tegmen, first primibrachials are quadrate, and there may be two or three secundanals. The presence of the pentagonal first primibrachial in the C and D rays and the prominent tegmen spine show affinity with the Paragaricocrinidae, whereas the hexagonal first primibrachials in the A and E rays and ray lobes in the tegmen show affinity with the Periechocrinidae. *Shotoricrinus* is transitional between the two families and is assigned to the Periechocrinidae because the first primibrachials have more than four sides.

Periechocrinids were previously considered to range from Silurian into Early Mississippian (Ausich and Kammer 2008). *Shotoricrinus* extends the range of the family upward into the Early Pennsylvanian.

Shotoricrinus transitorius n. gen. et sp. (Fig. 4aa–ee)

Etymology: Referring to the pentagonal first primibrachials, which are considered to be transitional from the periechocrinids that have hexagonal first primibrachials to the paragaracocrinids that have quadrate first primibrachials.
Diagnosis: As for the genus.
Description: Partial calyx, low bowl shape with shallowly impressed base, wider than long; ornamented with ridges and sculpted pits on radials and primibrachials. Basal circlet equally tripartite, downflaring, mostly covered by proximal stem. Basals 3, pentagonal, wider than long or equidimensional. Radials 5, hexagonal, wider (18.2 mm, slightly incomplete) than long (16.4 mm), widely outflaring, slightly upflaring. Primanal in radial circlet, hexagonal, wider than long; anitaxis 1:3:2 or uncertain. Primibrachials 2, with first primibrachial hexagonal (A and E rays) or pentagonal (C and D rays), wider than long, slightly upflaring, and axillary second primibrachial pentagonal, wider than long, gently upflaring. Single first interray plates hexagonal, followed by two plates. Axial canal pentalobate. Measurements are given in Table 2.

Tegmen large, diameter 43 mm, arms roundly grouped, wide interrays with interbrachials connected to tegmen plates. Each ray has a gently inflated rounded lobe above an unknown number of arm openings. Anal opening eccentric, adjacent to posterior oral opening, with anal tube of unknown length. Protruded blunt spine on posterior oral, surrounded by eight large plates. Tegmen plates numerous, bear coarse nodes on interambulacrals and slightly bulbous on ambulacrals. Tegmen gently inflated.

Remarks: The two partial calices of *Shotoricrinus transitorius* n. gen. et sp. are weathered free and are basically discs with very gently upflaring edges formed by the primibrachials and interray plates. This finding indicates that the cup has a wide bowl-shape with a shallowly impressed base, as is present on the periechocrinid *Athabascacrinus* Laudon et al. (1952) and flat-based species of *Paragaricocrinus*, as recognised by Waters and Webster (2009). The larger specimen has only the C-ray axillary second primibrachial preserved, lacking all other second primibrachials and the B-ray first primibrachial. Weathering has rounded and masked some ornamentation. The smaller specimen lacks all plates beyond the radials.
Material: Holotype EUI 8466; paratypes 1 and 2 EUI 8467, EUI 8468.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Suborder Compsocrinina Ubaghs, 1978
Superfamily Hexacrinitoidea Wachsmuth and Springer, 1885
Family Hexacrinitidae Wachsmuth and Springer, 1885
Family Dichocrinidae S. A. Miller, 1889

Remarks: Normally, hexacrinid genera have equal tripartite basals whilst dichocrinid genera have equal bipartite basals. The basals may be fused, however, and are unknown on some type species of genera assigned to both families. It is uncertain how much variation occurs in the number of basals within genera assigned to the two families. Hexacrinid genera range from Silurian through Devonian. Rare reports of Carboniferous and Permian specimens assigned to *Hexacrinites* Austin and Austin, 1843 are based on columnals [Early Carboniferous (Stache 1883); Permian (Gregorio 1930)] and may be misidentified; here, they are considered nomen dubia. Genera of the Dichocrinidae range from the Late Devonian into the Late Permian (Webster 2003; Webster et al. 2003). Additional study of the basals of the Hexacrinitidae and the Dichocrinidae is needed to determine the full significance of this morphologic character.

Subfamily Dichocrininae S.A. Miller, 1889
Subfamily Camptocrininae Broadhead, 1981

Remarks: Columnals of most hexacrinids and dichocrinids are circular in cross-section. However, some genera of the Camptocrininae Broadhead,1981, such as *Camptocrinus* Wachsmuth and Springer, 1897 and *Neocamptocrinus* Willink, 1980 have columnals that are circular or essentially circular in cross-section adjacent to the crown, rapidly

becoming elliptical distally. These elliptical columnals have a distinct articular facet, with the differing morphology adapted for enrollment on the two areas adjacent to the transverse ridge, thus allowing for easy recognition among disarticulated ossicles. Another elliptical columnal in the Paleozoic with a transverse ridge occurs in some genera of the platycrinitids, which have mirror image morphology on the two areas adjacent to the transverse ridge. These may occur with the elliptical columnals of the camptocrinids, but are easily distinguished by the differing morphology.

Hlebszevitsch (2005) considered *Neocamptocrinus* to be a junior synonym of *Camptocrinus* Wachsmuth and Springer,1897 because he considered the columnals of the two genera to be indistinguishable. Willink (1980) recognized *Neocamptocrinus* on the basis of an inflated tegmen and columnals that are bilaterally symmetrical for the entire length of the column. Although the tegmen of *Neocamptocrinus* is more complex than that of the Late Mississippian *Camptocrinus alabamensis* Strimple and Moore, 1973, the only species of *Camptocrinus* from which the tegmen is known. The proximal-most one or two columnals may be essentially circular in specimens of *Neocamptocrinus* (Webster and Jell 1999b). We tentatively accept the two genera on the basis of differences in the tegmen structure.

Genus *Camptocrinus* Wachsmuth and Springer, 1897

See Webster 2003 for synonomy 1897–1999.
2005 *Camptocrinus*, Hlebszevitsch, p. 599 (in part).

Remarks: Several species of *Camptocrinus* have been described with emphasis on the stem, and the cup has been described as the *Dichocrinus* type (Springer 1926, among others) without giving the number of plates in the basal circlet. The number of plates in the basal circlet is unknown for some species. Where known, the basal circlet of *Camptocrinus* is composed of two equal plates with the plane of symmetry in the A ray/posterior.

Camptocrinus? *enigmaticus* sp. nov. (Fig. 5a–e)

Etymology: From the Latin *aenigma* referring to the problem of the basal circlet.
Description: Cup medium bowl, sutures impressed, posterior side protruded, length 9 mm, width maximum through A ray–CD interray 11 mm, minimum 10.4 mm, average 10.7 mm; plate surfaces slightly irregular. Basal circlet formed of three equal plates, moderately upflared, forming lower one-third of cup wall, diameter 6.8 mm. Basals downflare proximally, distal two-thirds upflare, moderately convex transversely, slightly concave longitudinally in distal two-thirds, visible length 3.6 mm, width 5.5 mm.

Fig. 4 **a-c** *Culicocrinus shotoriensis* n. sp., cup, holotype EUI 8476, C-ray, basal (C ray at top of figure), and B-ray views, ×1. **d**, **e** *Culicocrinus shotoriensis* n. sp., tegmen plates, Paratypes 1–2, EUI 8495, 8496, aboral views, ×2. **f–u** *Culicocrinus shotoriensis* n. sp., radials, paratypes 1, 3–14, EUI 8477, 8479–8490, lateral views of radials show variation of ornament and shape with growth, ×2. Note radial **h**, **i**, illustrate lateral and oral views, and radial **j–l** illustrate oral, oblique and lateral views. Radials in **h–l** and **n** have attached primibrachials. **v–y** *Culicocrinus shotoriensis* n. sp., basal circlets, paratypes 1–4 EUI 8491–8494, aboral views, ×2. **aa**, **bb** *Shotoricrinus transitorius* n. gen. et sp., partial cup, holotype EUI 8466, interior and exterior views, ×2. **cc** Paratype 2, EUI 8468, oral view of tegmen, X1. **dd**, **ee** Partial cup, Paratype 1, EUI 8467, interior and exterior views, ×2

Radials 5, moderately convex longitudinally and transversely, slightly longer (5 mm) than wide (4.4 mm), expands gently distally to interradial notches, then tapers to radial facet; radial facet extends above shoulders. E-radial length 5.7 mm, width 5.2 mm. Interradial notches form a wide open V on declivate distal shoulders of radials. Radial facet angustary, (ratio width/radial width 0.5), gently declivate, horseshoe-shaped, 2.2 mm width, with short V-shaped ambulacral groove orally. Large primanal in line of radials, length 5.7 mm, width 3.7 mm. Secundanal and tertanal of equal size and equidimensional, 2.5 mm, resting on primanal, proximal halves below radial summit. Stem impression slightly elliptical, estimated diameter 2.5 mm long, 2.3 mm wide. Columnals variable in shape. Proximal columnals approximately equidimensional, distal columnals much wider (5 mm) than long (0.9 mm), faintly concave on inner side, gently convex on outer side, lateral ends strongly rounded or truncate for cirral attachment. Articular facets laterally symmetrical, bear smooth prominent transverse ridge with central elliptical lumen across central two-thirds, diverging into several small ridges on distal ends; bordered by asymmetrical ligament pits on both inner and outer sides. Columnals paired for shared cirrus, one on both ends of two adjacent columnals. Tegmen and arms not preserved. Cup measurements based on holotype; columnal measurements based on paratype 1.
Remarks: The cup surface of *Camptocrinus*? *enigmaticus* n. sp. is irregular, either from abrasion prior to ultimate burial and preservation or post-burial solution. A poorly preserved, small, crinoid holdfast is attached on the primanal plate, demonstrating that the cup was partly exposed before final burial. The small size of the cup and disarticulated radials and columnals suggests the specimens are immature.

The equatripartite basals suggest assignment of the cup to *Hexacrinites*. It is uncertain if this is a morphological character that is common with some camptocrinids or an aberrant specimen. However, the occurrence of disarticulated radials, identical to those of the cup, and the presence of the columnals precludes assignment to *Hexacrinites*.

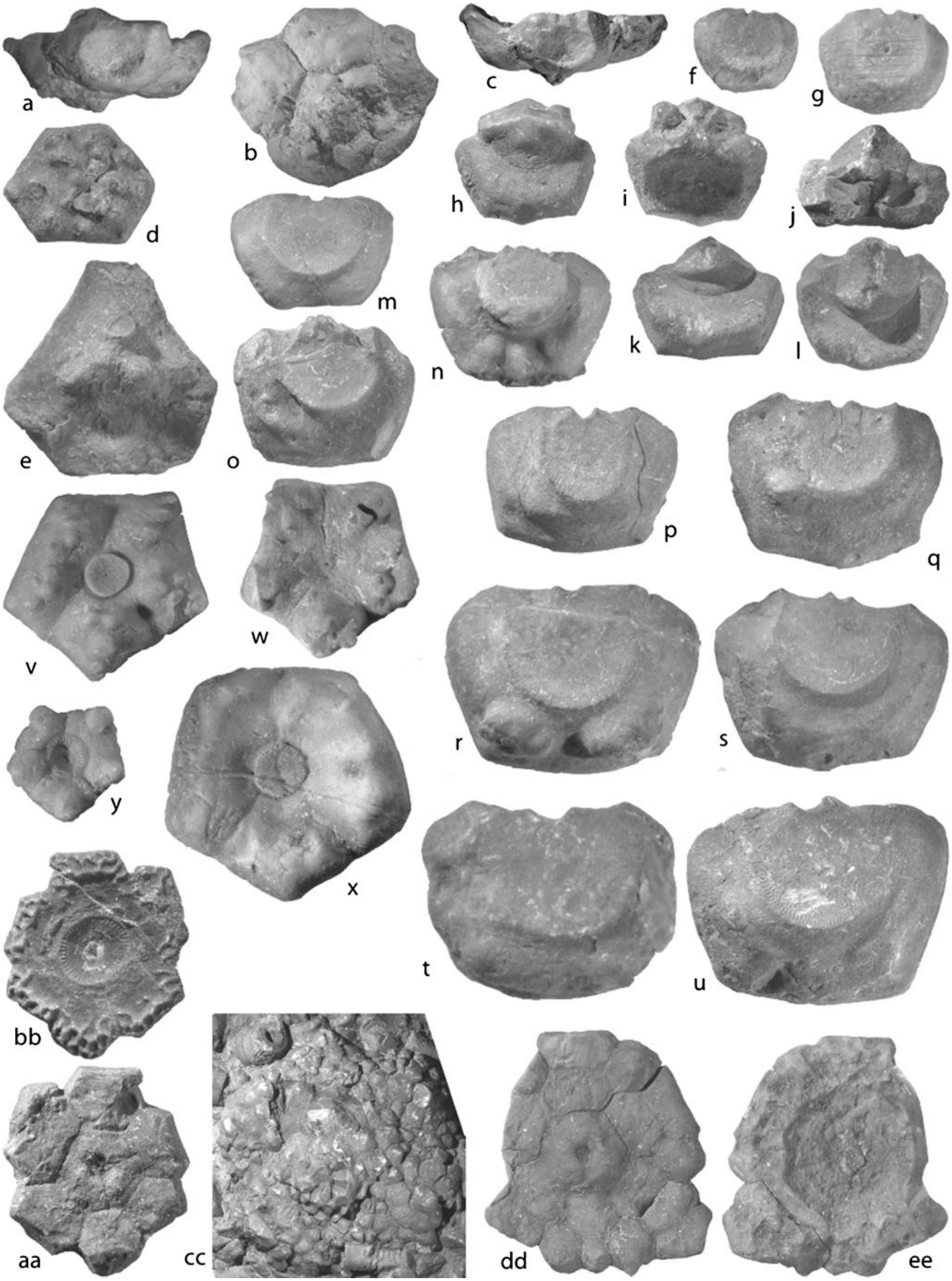
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Table 2 Measurements[a] determined for *Shorticrinus transitorius* n. gen. et sp.

Anatomical parameter	Holotype	Paratype
Calyx length (partial)	22	18.6
Calyx width (partial)	20	16.4
Basal circlet diameter	6.9	8
Basal length	3.4	4
Basal width	6.1	4
A-ray radial length	3.7	5.2
A-ray radial width	6.2	7.9
Primanal length	3.6	5.3
Primanal width	4.7	6.5
First primibrachial length	3.2	
First primibrachial width	7.2	
Second primibrachial length	3.3	
Second primibrachail width	6.4	

[a] All measurements are given in millimetres

This is the first report of a camptocrinid cup from the Bashkirian. The generic assignment is questioned because the tegmen is unknown. We agree with Burdick and Strimple (1983) who noted that greater emphasis is needed on the overall morphology for a better understanding of the camptocrinids.

Material: One cup and 35 ossicles. 24 specimens: holotype EUI 8469, cup; paratype 1 EUI 8470, radial; paratype 2 EUI 8471, columnal; five radials, 16 columnals, locality 5. Ten columnals, locality 2. Two columnals, locality 1.

Localities: 1, 2, Howz-e-Dorah; 5, Shirgesht; Pennsylvanian, early Bashkirian, Absheni Formation.

Dichocrinidae? radial indeterminate 1 (Fig. 5f)

Description: Radial pentagonal, laterally symmetrical, wider (14 mm) than long (12.2 mm), widening to distal end of radial/radial suture, gently convex longitudinally and transversely, slightly incurving proximally and distally; radial/basal sutures concave. Radial facet ovate, angustary, width 4.6 mm (ratio facet width/radial width 0.4), depth 3 mm, gently concave transversely. Facet morphology shallow central pit dividing transverse ridge formed of merging oblique ridges, distal ends splayed into anastomosing ridges extending to facet margin; outer ligment furrow bordered with crenulae that are less prominent centrally.

Remarks: Preservation of the 35 specimens of Dichocrinidae? radial indeterminate 1 is excellent to poor, with weathering or other taphonomic alteration obliterating detailed morphology of the facets with other cup plates and the radial facet on most specimens. The slight incurving of the proximal and distal ends of the radial suggests the cup would have a bowl shape with a low basal circlet. The radial facet morphology is similar to that of *Dichocrinus* illustrated by Broadhead (1981, pl. 5, fig. 4). Thus, specimens are tentatively considered to belong to the Dichocrinidae.

Material: 35 specimens: figured specimen EUI 8472 and 34 additional specimens.

Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Dichocrinidae? radial indeterminate 2 (Fig. 5g)

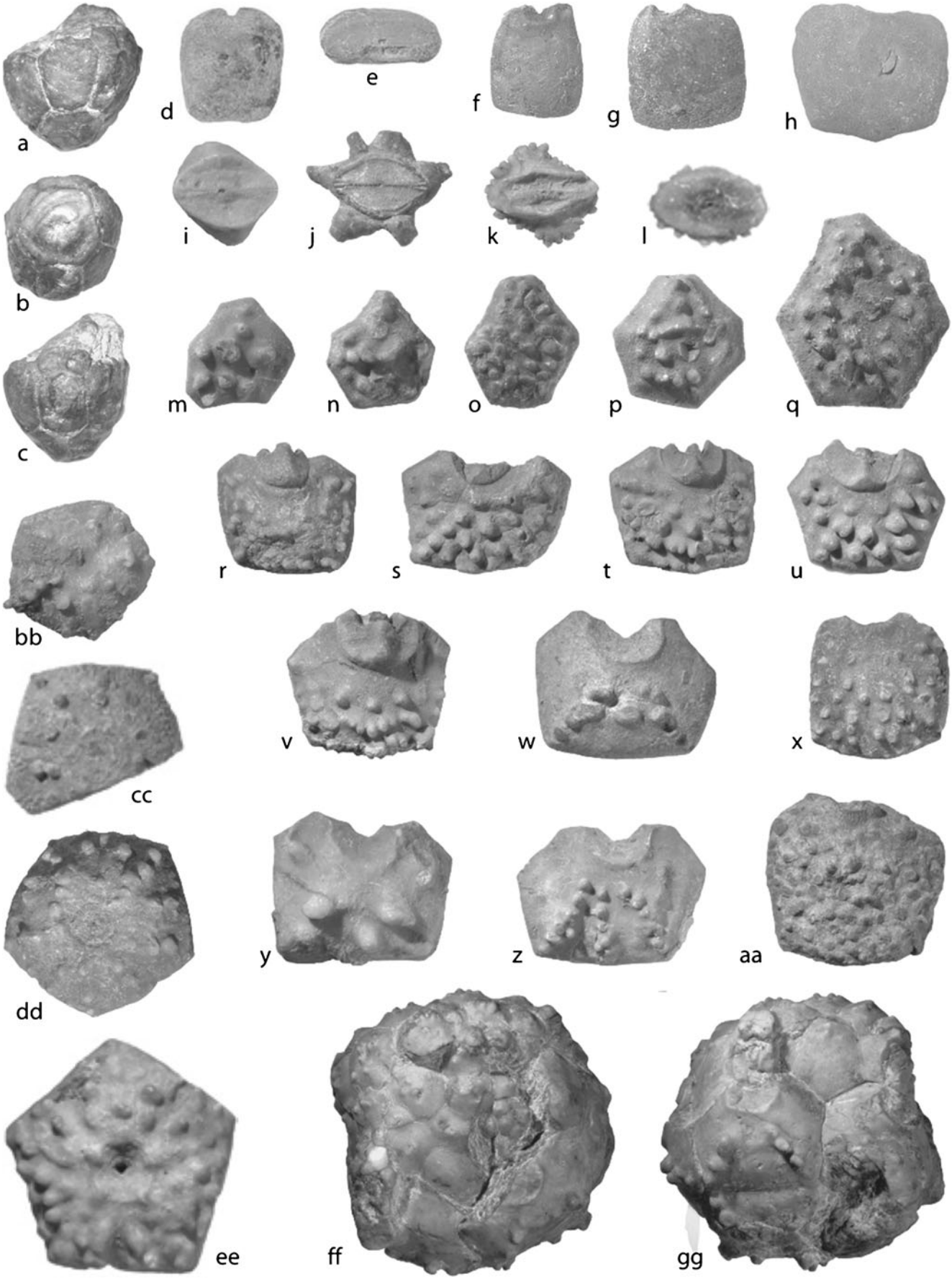
Description: Radial rectangular asymmetrical, length 10.5 mm, width 10.3 mm, widest slightly distal of midlength, tapering distally, gently convex longitudinally, moderately convex transversely, greatest convexity below radial facet; radial/basal facets form single gently convex arc. Radial facet semicircular, strongly concave transversely, moderately declivate, eccentric with interradial notch on right half width of left interradial notch. Facet bears transverse ridge weakly developed centrally, widening laterally, formed of coalesced irregular ridges and nodes. Outer margin of irregular ridges and nodes forming culmina. Distal half of radial facet projecting distally above shoulders forming interradial notches.

Remarks: Dichocrinidae? radial indeterminate 2 differs from Dichocrinidae? radial indeterminate 1 by its asymmetrical plate shape, greater convexity of the plate, strongly concave radial facet, differing facet morphology and relative positions of facet and interradial notches. The plate shape suggests the radial was part of a bowl-shaped cup. Plate asymmetry suggests it is the D radial with the wider interradial notch on the right side of the plate.

Material: Figured specimen EUI 8473.

Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Fig. 5 **a-c** *Camptocrinus*? *enigmaticus* sp. nov. cup, holotype EUI 8469, A-ray, basal and posterior views, ×3. **d** *Camptocrinus*? *enigmaticus* sp. nov. radial, paratype 1 EUI 8470, aboral view, ×4. **e**, *Camptocrinus*? *enigmaticus* sp. nov. columnal, paratype 2 EUI 8471, facetal view, ×4. **f**, Dichocrinidae? radial indeterminate 1, EUI 8472, aboral view, ×2. **g** Dichocrinidae? radial indeterminate 2, EUI 8473, aboral view, ×2. **h** Dichocrinidae? radial indeterminate 3, EUI 8474, aboral view, ×2. **i–l** ø*Platycrinites* s.l. spp. columnals: type 1 EUI 84630, 3 EUI 84632, 4 EUI 84633, and 2 EUI 84631, respectively, facetal views, ×2. **m–q**, *Platycrinites* s.l. *djihaniensis* Webster et al. 2003, tegmen plates 1–5 EUI 8512–8516, aboral views illustrating variation of ornamentation and shape, ×2. **r–aa**, *Platycrinites* s.l. *djihaniensis* Webster et al., 2003, radials 1–10 EUI 8498–8507, lateral views illustrating variation of ornamentation and shape, X2. Note that radials 1 and 3–5 have the primibrachial attached. **bb–ee** *Platycrinites* s.l. *djihaniensis* Webster et al., 2003, basal circlets 1–4 EUI 8508–8511, basal views illustrating variation of ornamentation, ×2. **ff**, **gg** *Platycrinites* s.l. *djihaniensis* Webster et al., 2003, Partially crushed theca EUI 8497, posterior oral and AE-interray views, ×2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Dichocrinidae? radial indeterminate 3 (Fig. 5h)

Description: Radial rectangular, symmetrical, longer (10.5 mm) than wide (8.2 mm), tapering distally, gently convex longitudinally and transversely. Radial facet ovate, angustary, strongly declivate, width 3 mm (ratio facet width/radial width 0.4), depth 2.7 mm. Facet bears wide transverse ridge formed of coalesced irregular ridges; margin of facet is an elevated rim with short crenula preserved on right distal edge. Shoulders forming interradial notches project distally beyond radial facet.
Remarks: Two of the three specimens of Dichocrinidae? radial indeterminate 3 are encrusted and incomplete with breakage along the rhombohedral cleavage planes in the proximal part of the ossicle. They differ from Dichocrinidae? radial interterminate 1 and 2 by their more elongate shape and by tapering distally from the basal articular surfaces. Plate shape suggests they were part of a slender vase-shaped cup with a shallow or moderately bowl-shaped base. The arm bases would have projected laterally when enclosed. Distally tapering plate morphology suggests relationship with the dichocrinids.
Material: Three specimens: figured specimen EUI 8474 and two partial specimens.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Dichocrinitid indet. (Fig. 6c)

Description: Basal circlet fused, widely flaring bowl, much wider than long, width 31 mm, length 9.7 mm, no ornament.
Remarks: The specimen is broken along two of the six basal/radial facets. Two sets of apposing facets are nearly parallel to one another and indicate the hexagonal morphology of the distal edge of the ossicle. Lengths of the unbroken facets range from 14 to 19 mm, although two are distorted or fractured. One of the broken facets appears to be shorter than the others (estimated length 12 mm) and probably represents the posterior basal/primanal facet.
Material: Figured specimen EUI 8475.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

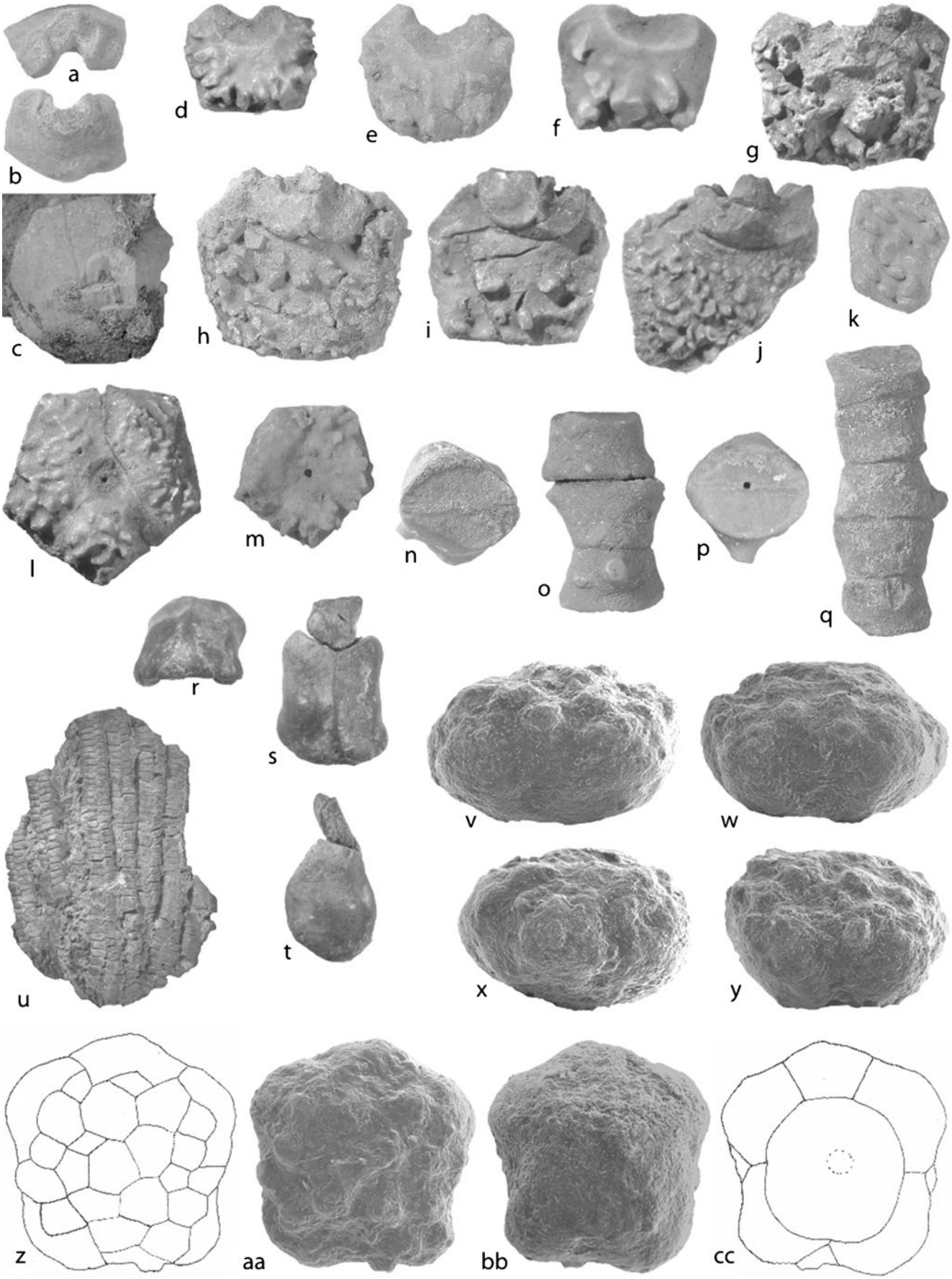
Suborder Glyptocrinina Moore, 1952
Superfamily Platycrinitoidea Austin and Austin, 1842
Family Hapalocrinidae Jaekel, 1895
Genus *Culicocrinus* Müller, 1855

Culicocrinus shotoriensis n. sp. (Fig. 4a-y)

1950 ?Base de *Platycrinites* sp. Termier and Termier, p. 86, pl. 227, figs. 22–24.
2001 Cf. *Culicocrinus* sp. Webster et al., pl. 2, figs. A–C.

Fig. 6 **a, b** *Platycrinites*? s.l. sp. A, radial EUI 8529, aboral and oral views, ×2. **c** Dichocrinitid indeterminate, partial basal circlet EUI 8475, basal view, ×1. **d–j** *Platycrinites* s.l. *pannosus* n. sp., radials 1–7, syntypes 1–7 EUI 8517–8523, aboral views illustrating variation of ornamentation, ×2. **k** *Platycrinites* s.l. *pannosus* n. sp.,tegmen plate, syntype 10 EUI 8526, lateral view, ×2. **l, m** *Platycrinites* s.l. *pannosus* n. sp., basal circlets 1, 2, syntypes 8, 9 EUI 8524–8525, basal views illustrating variation of ornamentation, ×2. **n–p** *Platycrinites* s.l. sp., pluricolumnal EUI 8534, lateral and facet views, ×2. **q** *Platycrinites* s. l. sp., pluricolumnal EUI 8535, lateral view, ×2. **r–t** *Epihalysiocrinus abshenienis* n. sp., partial crown, holotype EUI 8545, oral, radial, radial views, ×2. **u** Cromyocrinidae indeterminate B, partial set of arms EUI 8586, lateral view, ×1. **v–cc** *Platycrinites* sp., theca EUI 8528, D-ray, BC-interray, A-ray, CD-interray, oral plate diagram, oral, basal, and basal plate diagram views; sutures in plate diagrams all tentative, made on basis of impression in specimen, not observed sutures, ×40

Etymology: For the Shotori Mountains, where the specimens were found.
Diagnosis: A *Culicocrinus* distinguished by short radials, subvertical radial facets, and small node and ridge ornamentation.
Description: Based on partial cup and disarticulated thecal ossicles. Cup flattened, lacking distal parts of E, A and B radials, diameter 36 mm, monocyclic. Plates thick, ornamentation variable, commonly single irregular coarse inflated ridge paralleling edges of basals and radials, grading into coarse nodes at apices connected by less prominent ridge; sutures impressed. Basal circlet formed of one small and two equally large plates, proximally horizontal bearing stem facet, distal tips gently upflaring. Pseudobasal impression ringed by ridge or node ornament. Radials septagonal, nearly equidimensional in juvenile specimens, wider than long in adult specimens, with concave oral surface cut by small rounded adoral groove, C-radial (?), length 14.3 mm, width 20 mm. Radial facets angustary, width 11 mm, ratio width/radial width 0.55, semicircular, moderately concave, short crenularium along outer margin, strongly declivate. Interradial notches large, wide V-shaped. No anals in cup. Brachials short, strongly rounded transversely, semicircular in transverse section, bearing rounded transverse ridge, uniserial. Primibrachials 2; first primibrachial overlapped laterally by the triangular shaped axillary second primibrachial. Second primibrachial overlapped laterally by first secundibrachial. Primibrachials and first secundibrachials on radial facet, adjoined to tegmen by small plates along sides of adoral grooves merging into single groove at distal end of facet. Outer margin of facet of axillary primibrachials bear narrow crenularium of short crenulae for articulation with first secundibrachials. Branching isotomous, minimally ten arms. Stem holomeric. Proximal-most columnal circular in transverse section, diameter 5.2 mm, length 0.6 mm; latus roundly convex; crenularium narrow, approximately one-quarter facet radius, formed of short coarse crenula;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culmina approximately rectangular, flat surface with nearly right angle corners with sides; areola very wide; lumen small, circular. Distal arms, tegmen and distal stem unknown.

Remarks: The cup of the holotype of *Culicocrinus shotoriensis* n. sp. is distorted, plates are slightly disarticulated and other ossicles are not preserved. Based on the reconstruction of cups, by placing disarticulated radials on basal circlets, the uncrushed cup of *C. shotoriensis* n. sp. would have a low bowl shape with impressed sutures and subvertical radials. The base is not impressed but appears to have a ring of nodes surrounding the stem facet. This is referred to here as a pseudobasal impression. Loose radials (approx. 100 specimens) are among the most common cup ossicles found in the crinoidal horizon of the Howz-e-Dorah region. They are readily recognised by their ornamentation, relatively large radial facet and coarse node ornament and range in size from juveniles (smallest 5.5 mm length, 6.9 mm width) to gerontic (largest 18.2 mm length, 22.7 mm width) specimens. Ornamentation bulbosity tends to increase with growth, showing considerable variation, from roundly smooth to rounded elevated knobs. Some specimens have two large rounded knobs along the proximal surface.

The tegmen of *Culicocrinus shotoriensis* was probably formed of a few large plates with rounded centrally inflated elevations with irregular surfaces (Fig. 4xd, e). The anal opening is thought to have been above a large primanal on the shoulders of the posterior radials. One interradial notch on the holotype is larger than the adjacent two notches and is judged to be the posterior one. Described species of *Culicocrinus* have a primanal larger than the first interambulacral plates and followed by the anal opening surrounded by a series of small plates (Schmidt 1942). Loose orals, which are judged to belong to *C. shotoriensis*, are thick plates with prominent rounded elevated knobs. They vary from being five- to eight-sided and represent the five large central orals in the tegmen common to many crinoids. They also are common in the disarticulated ossicles. No other crinoid in the fauna has comparatively thick plates, except possible cromyocrinid radials, but the latter lack a plated tegmen. The two eight-sided orals are very similar to those of ?*C. spinosus* Springer (1926, pl. 11, fig. 4a), suggesting that the tegmen had several smaller interambulacrals rather than the five in *C. nodosus* Müller, 1854.

The distal arms of *C. shotoriensis* are unknown, but possibly became biserial shortly above becoming free with the second secundibrachial as they do, where known, in other species of the genus. *Culicocrinus shotoriensis* is distinguished from other species of the genus by having shorter radials, much larger radial facets that are subvertical instead of moderately declivate and a much smaller node or ridge ornament. All other species of *Culicocrinus* have longer radials distally to the node or ridge ornament and relatively smaller radial facets, with the exception of *C. spinosus* Springer, 1926, a Silurian form with smooth cup plates, and *C.*? *girardeauensis*, Brower, 1973, an Ordovician form with smooth cup plates and radial facets strongly projecting from the radial surface. The Viséan tripartite basal circlet figured by Termier and Termier (1950, pl. 227, figs. 22–24) shows the roundly elevated knobs and is virtually identical to the Iranian specimens.

The *Culicocrinus shotoriensis* occurring in the Early Pennsylvanian of the Absheni Formation appears to be a Lazarus taxon, extending the stratigraphic range of the genus upward from the Middle Devonian of Germany and the palaeogeographic range into the western Paleotethys deposits of northern Gondwana. However, it is possible that *C. shotoriensis* represents a new genus derived from a Mississippian platycrinitid. This would require thickening of the cup plates, lowering of the cup into a low bowl, development of subvertical radial facets and the addition of a second primibrachial. These extensive modifications are considered possible. However, the specimens are assigned to *Culicocrinus* because they resemble the cup of Devonian species of *Culicocrinus* and do not require the addition of a second primibrachial. If the Viséan basal circlet illustrated by Termier and Termier (1950), and referred to above, also belongs to *Culicocrinus*, it could be the progenitor of the Iran specimens and *Culicocrinus shotoriensis* would not be considered a Lazarus taxon.

Material: 95 specimens: Holotype EUI 8476, paratypes 1–20 EUI 8477-8496 and an additional 71 radials and six basal circlets.

Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Family Platycrinitidae Austin and Austin, 1842

Genus *Platycrinites* J.S. Miller, 1821

Remarks: Ausich and Kammer (2009) reviewed species assigned to *Platycrinites* Miller 1821 and objectively revised the Platycrinitidae including naming four new genera. In this revision they recognised *Platycrinites* sensu stricto as having an anal tube on top or on the upper margin of the tegmen among other morphologic charaters. In addition, they recognised the differences of calyx structure, arm projection, and tegmen characters among other platycrinitid genera wherein the tegmen was known. All species lacking the calyx and tegmen were relegated to *Platycrinites* sensu lato. This revision greatly improved the overall knowledge of the platycrinitds but left open the question of possible multiple evolution of some of the morphologic characters, such as the position of the anal opening and presence or absence of an anal tube. We consider this of considerable significance and believe that it

requires further study, because the tegmen of platycrinitids was one of the prime sites for attachment of the platyceratid gastropods throughout the Carboniferous as noted by Baumiller (2003).

Platycrinites s.l. *djihaniensis* Webster et al., 2003 (Fig. 5m-gg)

1950 *Platycrinus spinifer elongatus* Termier and Termier (non Wachsmuth and Springer, 1897) p. 86, pl. CCXI, figs. 1–5; pl. CCXXVI, fig. 38.
1950 *Platycrinus tuberculatus* Termier and Termier (non Miller, 1821), p. 86, pl. CCXII, figs. 10, 11.
2001 *Platycrinites* n. sp. Webster et al., p. 111, pl. 3, figs. I–N, ?P–Q (not fig. O).
2004 *Platycrinites djihaniensis* Webster et al., p. 34, pl. 8, figs. 14–19.

Description: Thecae medium size, globe shaped, 24 mm long, width 19.4 mm (minimum), 24.2 mm (maximum) 21.8 mm (average), bearing coarse nodose ornament on all cup plates and most tegmen plates. Basal circlet fused, diameter 11.2 mm, shallow saucer shaped, gently upflared, nodose ornament aligned, radiating from stem facet to interray corners of plate. Radials 5, form cup walls, slightly outflaring, steeply upflaring, large, length 10.7 mm, width 12.3 mm, moderately convex longitudinally and transversely, bearing aligned nodose ornament radiating from radial facet to proximal corners meeting with aligned nodes on basal circlet; may have unaligned random nodes on plate. Radial facet angustary, ovoid, 3.8 mm long, 4.6 mm wide, shallowly concave. Primibrachials 1, axillary, strongly convex transversely, no ornament. Anal plates 3, above radial, largest central, more distal plates, if present, very small and single row. Anal opening on side of tegmen, no anal tube. Single large interambulacral plate with narrow facet with large oral. Ambulacral plates smaller than interambulacrals, larger distally, terminating at orals. Orals 5, largest central forming cap of elevated tegmen. Stem facet small, circular, 1.6 mm diameter; crenularium wide, approximately three-quarter facet radius, crenula slender. Measurements taken on distorted theca.

Remarks: Loose radials, basal circlets and tegmen plates of *Platycrinites* s.l. *djihaniensis* are common in the weathered crinoidal horizon at several localities in the Absheni Formation, Howz-e-Dorah area. Thecae are rare. Considerable variation occurs in the ornamentation of the loose ossicles. On the basal circlets and radials, this involves the number and position of the coarse nodes, as originally described for *P. djihaniensis* by Webster et al. (2004). The basic pattern consists of aligned nodes radiating from the stem facet to the apices of the basal circlet and the corresponding aligned nodes forming an inverted V, radiating from the base of the radial facet to the proximal apices of the radials and aligned rows of nodes parallel to the plate edges. Variations on this include a few additional nodes to many nodes scattered irregularly on the basal circlet and radials. Nodes are also present on the tegmen plates. Four basal circlets, ten radials and two tegmen plates illustrate growth stages and some of the variation. *Platycrinites* columnals are also abundant in the loose ossicles, but it is uncertain to which of the species they belong.

Variations on loose ossicles include the following:

- Basal circlet (two complete, two partial)—three unequal plates, partially to completely fused, variable size of coarse nodose ornament, variable number of aligned rows of nodes, and widely expanded very shallow to shallow saucer shape.
- Radials (51)—slightly longer than wide to slightly wider than long; variation in number and size of nodes, some alignment of nodes radiating from radial facet toward proximal corners of plate.
- Brachials—articulated with radials, approximately one-third of specimens.
- Secundibrachials—strongly rounded transversely, extend beyond primaxial onto radial facet along lateral edges or confined to facet of primaxial; deep; no ornament.
- Tegmen plates (13)—large and small, variation in size of coarse nodose ornament.

Columnals, as described below, are common elements in the loose ossicles. However, five types of *Platycrinites* columnals are present, although none can be directly assigned to any one of the three species based on thecae or cup ossicles described herein.

Termier and Termier (1950) identified Algerian Viséan specimens as *Platycrinus* (sic) *spinifer elongatus* and Westphalian specimens as *Platycrinus* (sic) *tuberculatus*. Both of these specimens show the same nodose ornamentation and plate structure of *Platycrinites* s.l. *djihaniensis* to which they are here assigned.

The single theca of *Platycrinites* s.l. *dijhaniensis* is distorted, and the full relationship of the tegmen and calyx is uncertain. Also, the total number of plates in the tegmen and position of the anal opening are not precisely known. Hopefully a better specimen will be found that will allow a better generic assignment.

We recognise three species of *Platycrinites* (*P.* s.l. *djihaniensis*, *P.* s.l. *pannosus* n. sp. and *P.* s.l. sp.) in the Absheni fauna, extending the stratigraphic range of *P.* s.l. *djihaniensis* upward from Viséan to Westphalian and the palaeogeographic range into Iran from Algeria. Following the preliminary report of Webster et al. (2001), this is the first description of *Platycrinites* from Iran and a theca from the Early Pennsylvanian.

Material: 178 specimens plus numerous fragmentary ossicles. 168 specimens: figured specimens EUI 8497–

8516, 71 radials without attached proximal brachials, 17 radials with attached proximal brachials, four basal circlets, 56 tegmen plates, numerous fragmentary ossicles of various types, locality 2. Ten specimens: one poorly preserved theca, one basal circlet, two partial basal circlets, five radials, one tegmen plate, locality 4.
Localities: 2, 4, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Platycrinites s.l. *pannosus* n. sp. (Fig. 6d–m)

2001 *Platycrinites* n. sp. Webster et al., p. 111, pl. 2, fig. O only.
2004 *Platycrinites* sp. 4 Webster et al., p. 35, pl. 8, figs. 22–23.

Etymology: From the Latin, meaning ragged.
Diagnosis: Distinguished by coarse angular ridge ornament on basals, radials and tegmen plates.
Description: Based on disarticulated basal circlets and radials, some with articulated primibrachials. Basal circlet pentagonal, shallow basin shape, tripartite, two equally large pentagonal, one small quadrangular; ornamented with coarse irregular ridges; distal-most ridge parallel to plate edge and proximal ridges irregular or possibly parallel plate edges. Radials pentagonal, wider than long, gently to moderately convex longitudinally and transversely; ornamented with two or three irregular angular ridges parallel to plate edges and occasional coarse angular nodes; some ridges formed of coalesced angular nodes; additional fine granular ornament. Wide interradial notches. Radial facets angustary, horseshoe shaped, subvertical, distally with wide V-shaped adoral groove. Single primibrachial small, triangular, wider than long, straight to gently convex longitudinally, strongly convex transversely, axillary, confined to facet. First secundibrachials are rectilinear, moderately convex longitudinally, strongly convex transversely, overlap lateral edges of primibrachials onto radial, bear double adoral groove internally. Stem facet small, round, concave with crenularium approximately one-half the radius length. Tegmen plates large, polyhedral, moderately convex, ornamented with short irregular angular ridges. Distal arms and stem unknown.
Remarks: *Platycrinites* s.l. *pannosus* n. sp. is distinguished by the coarse angular ridge ornament. It is most similar to *Elegantocrinus saffordi* (Hall 1858), which has less coarse ornamentation, more elongate radials and a continuous twist stem. Although the stem is unknown on *P. pannosus* (see discussion under *Platycrinites* spp. below), it is probably a segmented twist type (Webster 1997) because continuous twist stems have not been reported previously for *Platycrinites* in post-Mississippian strata (see below).

The double adoral groove on the nonaxillary first secundibrachial of *Platycrinites* s.l. *pannosus* indicates once again the arms branch, perhaps on the second secundibrachial, making a minimum of four arms per ray. The large size of the tegmen plates indicates a tegmen formed of only a few plates, and the low convexity of the plates suggests that the tegmen was no more than moderately elevated.

The occurrence of the species is recognised as early Bashkirian in Iran and the upper part of the Hassi Kerma Formation of Algeria (Webster et al. 2004 as *Platycrinites*. sp. 4). Syntypes are designated for the taxon because it is recognised on disarticulated ossicles.
Material: 94 specimens. Syntypes 1–11 EUI 8517-8527; 13 basal circlets, 25 radials with attached proximal brachials, 25 radials without attached brachials, 25 tegmen plates, plus additional uncounted fragmentary plates.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Platycrinites s.l. sp. (microcrinoid) (Fig. 6v-cc)

Description: Theca low bowl, wider (maximum 1.06 mm in line of bilateral symmetry plane, minimum 1.04 mm) than long (0.6 mm); pentalobate in oral view outline. Cup low bowl, rounded base, very fine granular ornament. Basal circlet fused, shallow saucer shaped, widely outflaring, gently upflaring, posterior extended slightly separating adjacent basal corners of C and D radials, bearing small circular stem facet. Radials 5, wider than long, roundly convex longitudinally and transversely. Radial facets angustary, beginning to develop on B, C, D and E radials. Tegmen subhorizontal with faintly elevated center, formed of minimum of 12 polygonal plates with inflated coarse nodose centers and two weakly nodose plates. Pore in center of flatly terminated, laterally directed interambulacral plate on distal shoulders of C and D radials. Arms and stem unknown.
Remarks: The theca of *Platycrinites* sp. is slightly distorted, and sutures are not clearly evident. Lane et al. (1985) noted that one of the smaller growth stages of *P. bozemanensis* (Miller and Gurley 1897) illustrated by Laudon (1967, p. 493, text-fig. 1) had more than five tegminal plates. This specimen is the smallest specimen of the genus recognised, confirming that the tegmen may contain more than five plates in very small specimens of some species.

The slight extension of the posterior edge of the basal circlet indicates that it may have been in contact with an anal plate separating the C and D radials; however, no plate or suture is recognizable on the specimen. The cup is shallowly impressed between the two radials where a faint suture should occcur. Lateral projection and flat termination of the pore-bearing interambulacral plate on the distal shoulders of the C and D radials suggest that it might be the

initial anal vent. With growth it may have migrated from the top of the cup onto the tegmen. The fine granular ornament suggests that it might be the juvenile of *Platycrinites*? s.l. sp. A. The specimen is left in the open nomenclature of *Platycrinites* s.l. because it is a juvenile and the anal condition is uncertain.
Material: Figured specimen EUI 8528.
Locality: 5, Shir Gesht, Pennsylvanian, early Bashkirian, Absheni Formation.

Platycrinites? s.l. sp. A, Radial indet. (Fig. 6a, b)

Description: Radial hexagonal, slightly wider (10.7 mm) than long (8.5 mm), widest at apices of radial/basal sutures, slightly concave longitudinally along midline, slightly convex longitudinally along lateral sides, gently convex transversely. Fine granule ornament. Radial facet angustary, semicircular, strongly declivate, slight elevation on lateral edges where primibrachial terminates. Single primibrachial axillary, strongly convex transversely, bearing two coarse protrusions or nodes. Secundibrachials not preserved, overlap primibrachial laterally and in contact with radial.
Remarks: The radial of *Platycrinites*? s.l. sp. A is well preserved except along the radial/basal sutures. Left radial/basal edge of plate has been lost by breakage and right radial/basal suture is irregular and thinned by solution-weathering. The shape of the radial suggests the cup was bowl-shaped and the arms flared above the cup. It is assigned to the platycrinitids on the basis of morphology and presence of the primibrachial.
Material: Figured specimen EUI 8529.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

øPlatycrinites spp. (Fig. 5i–l)

Description:

- Type 1. Columnal short, much wider than long, elliptical or lobate quadrangular; fulcral ridges on opposite sides of elliptical facets parallel, offset at acute angles on lobate quadrangular specimens; latus smooth.
- Type 2. Columnals elliptical in transverse section with latus bearing laterally directed nodes. Nodes singular or multiple.
- Type 3. Columnals as in Type 2 with latus bearing laterally directed short or elongate spines. Spines singular or multiple, often coalesced at base.
- Type 4. Columnals as in Type 2 with latus bearing thin laterally directed medial flange formed of ridge with irregular edge or very short small spines. Flange may be continuous around latus, confined to one side or part of one or both sides.
- Type 5. Pluricolumnals continuous-twist type. Columnals elliptical in transverse section, length equal to width; fulcral ridges in elliptical facets on opposite sides of columnal offset at acute angles; latus smooth or bearing projecting cirral bases.

Remarks: The smooth-latus (Type 1) columnal is the most common morphotype, occurring on both non-twist and twist columnals. Flanged- and nodded- or spined-latus (Types 2–4) columnals are more common on non-twist columnals. This suggests that the stems were formed of segmented-twist columnals in which the smooth- or ornamented-latus non-twist columnals formed segments of the stem that alternated with smooth- or ornamented-latus twist columnals. In the absence of articulated stems with the calyces and based on comparable ornamentation, it can be speculated that the columnals with spines on the flange belong with *P.* s.l. *djihaniensis*, flanges with *P.* s.l. *pannosus* n. sp. and nodes with *P.* s.l. sp. However, such speculations need verification.

Continuous-twist columnals (one of two, one of three and one of five columnals) are considered the distal part of the stem because the individual columnals are much longer than most other platycrinitid columnals in the collections, and all have protruded cirral bases on one or more of the columnals. Webster (1997) described the earliest occurrence of the segmented-twist columnals of *Platycrinites* from late Kinderhookian strata in the western USA, noting that continuous-twist columnals were unknown after the Mississippian. However, the crown with the attached proximal column described by Webster (1997) lacked the distal parts of the column. If the interpretation of these Pennsylvanian continuous-twist columnals as part of the holdfast is correct, then the continuous-twist columnal continued as the holdfast on at least one species of *Platycrinites* into the Early Pennsylvanian. It is uncertain if these continuous-twist columnals merged into segmented-twist columnals in the medial part of the stem. This is the first report of platycrinitid continuous-twist columnals of post-Mississippian age.
Material: Figured specimens type 1 EUI 8530, type 2 EUI 8531, type 3 EUI 8532, type 4 EUI 8533, type 5 EUI 8534, 8535 and an additional 22 nodose, 15 spinose, 61 flanged and one continuous-twist specimens.
Localities: 2, all five types of columnals, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation; 5, columnal types 1, 2 and 3, Shir Gesht, Pennsylvanian, early Bashkirian, Absheni Formation.

Family Amphipsalidocrinidae Arendt, 1970
Genus *Amphipsalidocrinus* Weller, 1930

See Webster 2003 for full synonymy.

Remarks: An scanning electron microscopy (SEM) investigation of *Amphipsalidocrinus* by Lane et al. (1985) showed that there are no infrabasal plates in the cup. Among other characters this precluded including it in the cladid crinoids where Webster (2003) inadvertently left it. Lane et al. (1985) recognised that the systematic position was uncertain but considered it to be a monobathrid camerate related to platycrinitacids, differing by the anal vent located within the top of the radial circlet, just below, not within the tegmen. They also gave reasons for and against accepting *Amphipsalidocrinus* as a mature microcrinoid. They ended their review of the genus by not committing themselves; however, they did suggest that if *Amphipsalidocrinus* were judged to be a camerate microcrinoid it could be assigned to the Amphipsalidocrinidae as proposed by Arendt (1970). We accept *Amphisalidocrinus* as a camerate crinoid. Two Permian genera, *Eutelecrinus* Wanner, 1916 and *Pleisocrinus* Wanner, 1937, were questionably included in the Platycrinitacea family Hapalocrinidae in the Treatise (Moore and Teichert 1978). Both have the anal vent shared at the top of the radials and base of the orals, apparently lacking any surrounding anal plates. They are both macrocrinoids and may be derived from *Amphipsalidocrinus*. Here, they are removed from the Hapalocrinidae—which have the anal opening within the tegmen or orals—and transferred to the Amphipsalidocrinidae.

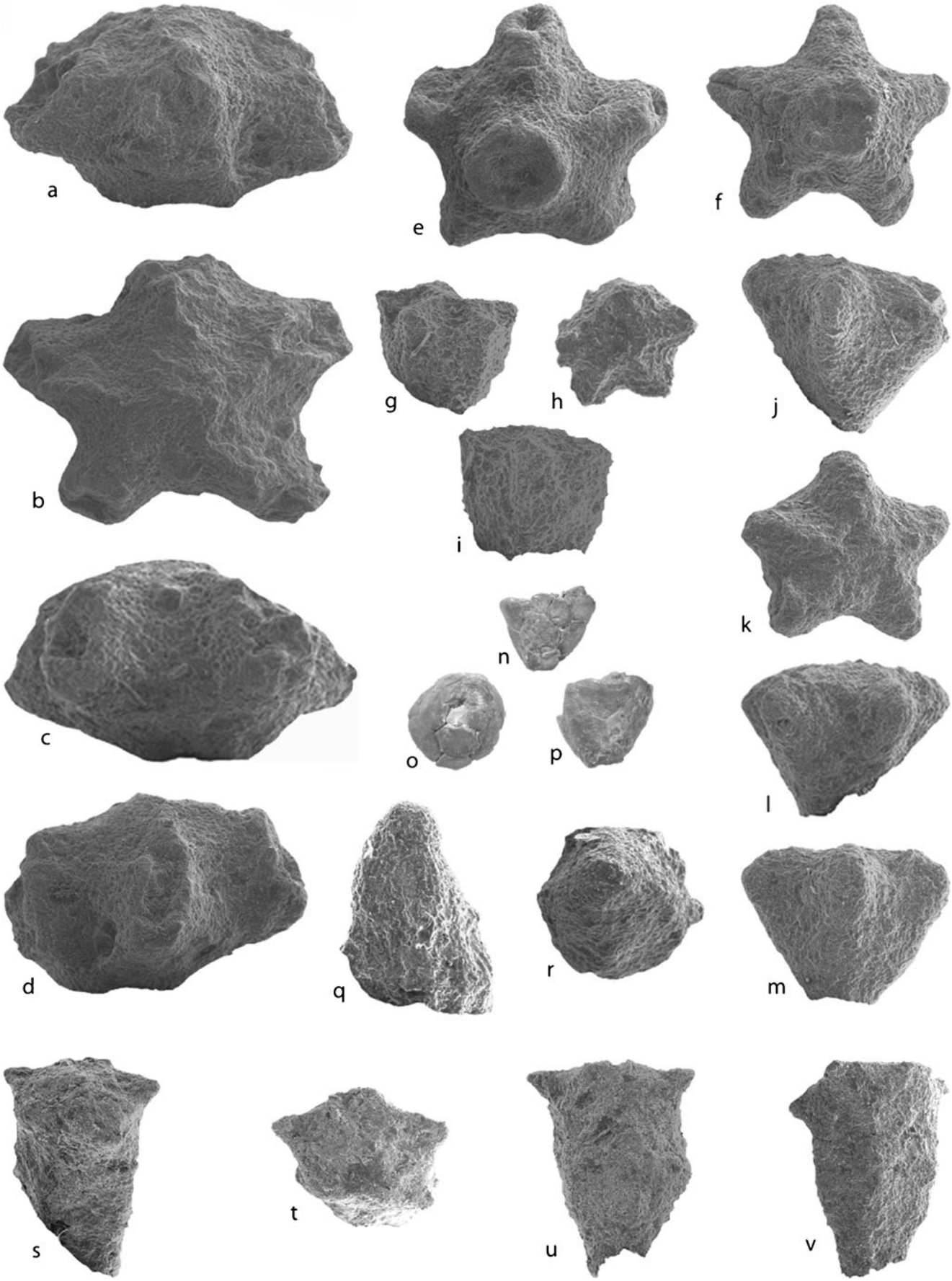
As noted by Lane et al. (1985), *Amphipsalidocrinus* is the longest ranging (Middle Silurian–Early Permian) crinoid genus known in the Paleozoic. They also recognised that it occurs with other camerate crinoids, most commonly platycrinitaceans, wherever it has been reported. This implies that the palaeoecologic requirements of *Amphipsalidocrinus* were similar to those of some of the platycrinitaceans.

In the Shotori Range of eastern Iran, *Amphipsalidocrinus* occurs with four camerate taxa, including the platycrinitacean *Platycrinites* s.l. and *Culicocrinus*. This extends the palaeogeographic range of the genus onto the northern edge of the African block and into the Paleotethys realm in the Early Pennsylvanian.

Amphipsalidocrinus arendti n. sp. (Fig. 7a–m)

Etymology: Named for Yu. A. Arendt in recognition of his numerous insightful contributions to the study of crinoids.
Diagnosis: Distinguished by strongly pentastellate outline in adult forms.
Description: Theca conical, flat to inflated orals, longer than wide to wider than long, pentagonal to slightly to strongly pentasellate in oral view outline, quite variable with growth. Cup medium cone, variable dimensions from wider than long to longer than wide, fine pit ornament. Basals 3, two larger equidimensional, one smaller in AE-interray; proximally horizontal with circular stem impression, distally steeply upflaring and gently outflaring in immature forms, more outflaring and moderately upflaring in some adult forms; forming lower one-quarter to one-half of cup wall. Radials 5, equidimensional to variable length to width ratios, straight to gently convex longitudinally, strongly convex transversely, with rounded protrusion below angustary radial facet. Anal vent in radial circlet surrounded by posterior basal, C and D radials, and posterior oral or C and D radials and posterior oral, more by C radial than D radial; not present in juvenile forms. Orals 5, triangular, concave transversely, declivate abaxially; form ridges with adjacent orals; adaxially may project slightly, forming tegmen summit or shallow tegmen depression. Posterior oral adjoins all four other orals, separating the two adjacent BC and DE orals. Ambulacral opening elongate slit, subvertical, shared with radial facet and overlying two orals. Holotype length 0.95 mm, maximum width 1.62 mm, minimum width 1.25 mm.
Remarks: Growth stages of *Amphipsalidocrinus arendti* n. sp. indicate a wide variation within the thecal plates with growth. This includes variation in the oral-view outline, ratio of basal-circlet length to radial length and the centre of the tegmen. Variation in the oral-view outline is due to growth stages, with juvenile forms having a pentagonal or slightly pentastellate outline with sharp points at the ray ends, whereas adult forms are moderately to strongly pentastellate. The basal circlet is generally very short, forming the basal part of the cup, but in some juveniles it forms one-half of the cup wall. Juvenile forms have steeply upflaring cup walls, whilst adult specimens have widely outflaring cup walls. The anal vent is not recognizable until the arms, and ambulacral openings are beginning to develop. Inflation of the tegmen tends to parallel growth, but in some juveniles the tegmen is inflated to be approximately one-half the thecal length. The tegmen is flat in the juveniles and inflated in adults. In some adults it is crushed into the cup, thus appearng to be flat, and abaxial parts of the orals are often broken, making the ambulacral slit appear to be sloping toward the linear axis instead of the subvertical where unbroken. Part of the basal circlet is often lost, with only one or two

Fig. 7 **a-d** *Amphipsalidocrinus arendti* n. sp., theca, holotype EUI 8536, A-ray, oral, posterior, and E-ray views, ×40. **e** *Amphipsalidocrinus arendti* n. sp., theca, paratype 1 EUI 8537, aboral view, A-ray at top, ×40. **f** *Amphipsalidocrinus arendti* n. sp., theca, paratype 3 EUI 8539, aboral view, ×40. **g–i** *Amphipsalidocrinus arendti* n. sp., theca, paratype 4 EUI 8540, AE-interray, aboral and E-ray views, ×80. **j–m** *Amphipsalidocrinus arendti* n. sp., theca, paratype 2 EUI 8538, A-ray, oral, posterior, and E-ray views, ×40. **n–p** Blothrocrinid indeterminate, cup EUI 8583, D-ray, basal and CD-interray views, ×3. **q**, **r** *Lampadosocrinus stellatus* n. sp., theca, paratype EUI 8582, undesignated ray and basal views, ×80. **s–v** *Lampadosocrinus stellatus* n. sp., theca, holotype EUI 8581, C-ray, oral, A-ray and B-ray views, ×40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plates retained. Some specimens are distorted into various shapes that are usually recognised in adult forms by the stellate projection of the rays and by the inflated or crushed tegmen in juveniles.

Amphipsalidocrinus arendti is distinguished from all other described species of the genus by the much stronger pentastellate outline in the adult form. It is most similar to *A. posterior* Arendt, 1970, a Permian species from Russia, to which it may have been ancestral. Except for *A. posterior*, all other species of *Amphipsalidocrinus* are known from the USA and Ireland, where the genus range is Silurian–Pennsylvanian.

Material: 130 specimens. Nine specimens, holotype EUI 8536 and eight other specimens, locality 3. 44 specimens: paratypes 2–7 EUI 8537–8543, and 38 other specimens, locality 2. 77 specimens, locality 1.

Localities: 1, 2, 3, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Monobathrid? radial indeterminate (Fig. 14ee)

Description: Radial hexagonal, wider (24.6 mm) than long (16.4 mm), slightly convex longitudinally, moderately convex transversely, thin, no ornament, radial/radial articular surfaces with anastamosing ridges. Radial facet slightly concave, crescent shaped, width 8.9 mm, depth 6.5 mm, angustary (ratio width/radial width 0.4), strongly declivate. Facet morphology includes weakly developed straight transverse ridge, wide outer marginal area, denticulate marginal ridge, no central pit or intermuscular furrow, moderately wide and deep adoral areas, wide rounded adoral groove.

Remarks: Weathering has destroyed or masked facet morphology and radial/basal sutures are broken along cleavage planes (right side) or broken and weathered irregularly (left side) on the single specimen of Monobathrid? radial indeterminate. The large size and convexity of the plate suggest it was part of a bowl-shaped cup, possibly a platycrinitid, with the base of the arms outflared in the enclosed position.

Material: Figured specimen EUI 8544.

Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Subclass Disparida Moore and Laudon, 1941
Order Calceocrinida Meek and Worthen, 1869
Superfamily Calceocrinacea Meek and Worthen, 1869
Family Calceocrinidae Meek and Worthen, 1869
Genus *Epihalysiocrinus* Arendt, 1965

Epihalysiocrinus absheniensis n. sp. (Fig. 6r-t)

2001 *Epihalysiocrinus* n. sp. Webster et al., p. 111, Pl. 2, figs. D, E.

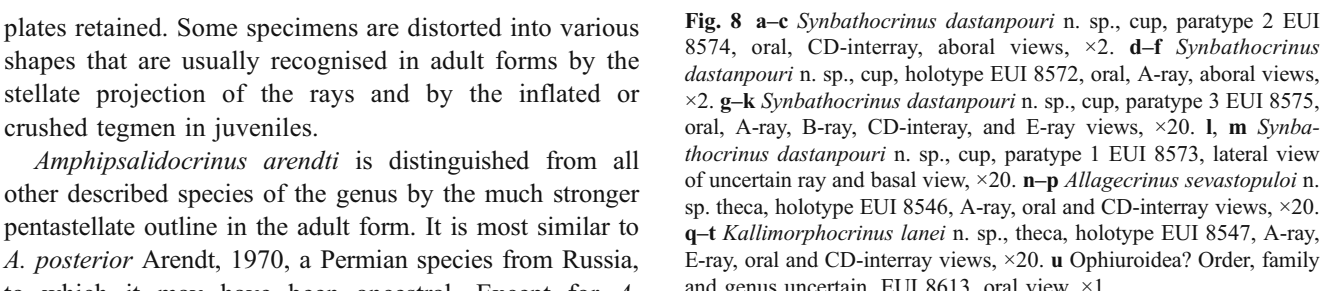


Fig. 8 **a–c** *Synbathocrinus dastanpouri* n. sp., cup, paratype 2 EUI 8574, oral, CD-interray, aboral views, ×2. **d–f** *Synbathocrinus dastanpouri* n. sp., cup, holotype EUI 8572, oral, A-ray, aboral views, ×2. **g–k** *Synbathocrinus dastanpouri* n. sp., cup, paratype 3 EUI 8575, oral, A-ray, B-ray, CD-interay, and E-ray views, ×20. **l**, **m** *Synbathocrinus dastanpouri* n. sp., cup, paratype 1 EUI 8573, lateral view of uncertain ray and basal view, ×20. **n–p** *Allagecrinus sevastopuloi* n. sp. theca, holotype EUI 8546, A-ray, oral and CD-interray views, ×20. **q–t** *Kallimorphocrinus lanei* n. sp., theca, holotype EUI 8547, A-ray, E-ray, oral and CD-interray views, ×20. **u** Ophiuroidea? Order, family and genus uncertain, EUI 8613, oral view, ×1

Etymology: From the Absheni Fomation.

Diagnosis: An *Epihalysiocrinus* distinguished by a small E inferradial and deeper V-shaped notch for the proximal end of the E superradial.

Description: Cup elongate, length 11.6 mm (without E superradial), width 9.9 mm, slightly hourglass-shaped with slight constriction above the base of A and D radials, strongly convex transversely, slightly concave longitudinally, distorted by compaction. Very fine polygonal ornament on all cup plates. Basals fused, length 2.5 mm, width 7.4 mm, forming isosceles triangle with very small triangular inferradial, length 1 mm, width 1.8 mm. A and D radials pentagonal, widest at base, longer (10.1 mm) than wide (7.9 mm), forming obtuse V-shaped notch on mutual distal shoulders for superradial. Superradial incomplete, lacking distal end, length 4.9 mm, width 5.4 mm, moderately convex transversely.

Remarks: The holotype of *Epihalysiocrinus absheniensis* n. sp. was distorted by compaction, with the lateral sides of the A and D radials compressed towards one another and the incomplete E superradial dislocated and between the A and D radials. The cup was partly reconstructed by gluing the E superradial into its approximate original position. *Epihalysiocrinus absheniensis* differs from *E. tuberculatus* by having a relatively much smaller E inferradial and much deeper V-shaped notch for the proximal end of the E superradial.

Epihalysiocrinus was initially reported from the Permian (Artinskian) Sargin Horizon in the southern Urals (Yakovlev 1927). This extends the stratigraphic range of the genus downward into the Early Pennsylvanian and is the first species known from the northern border of Gondwana.

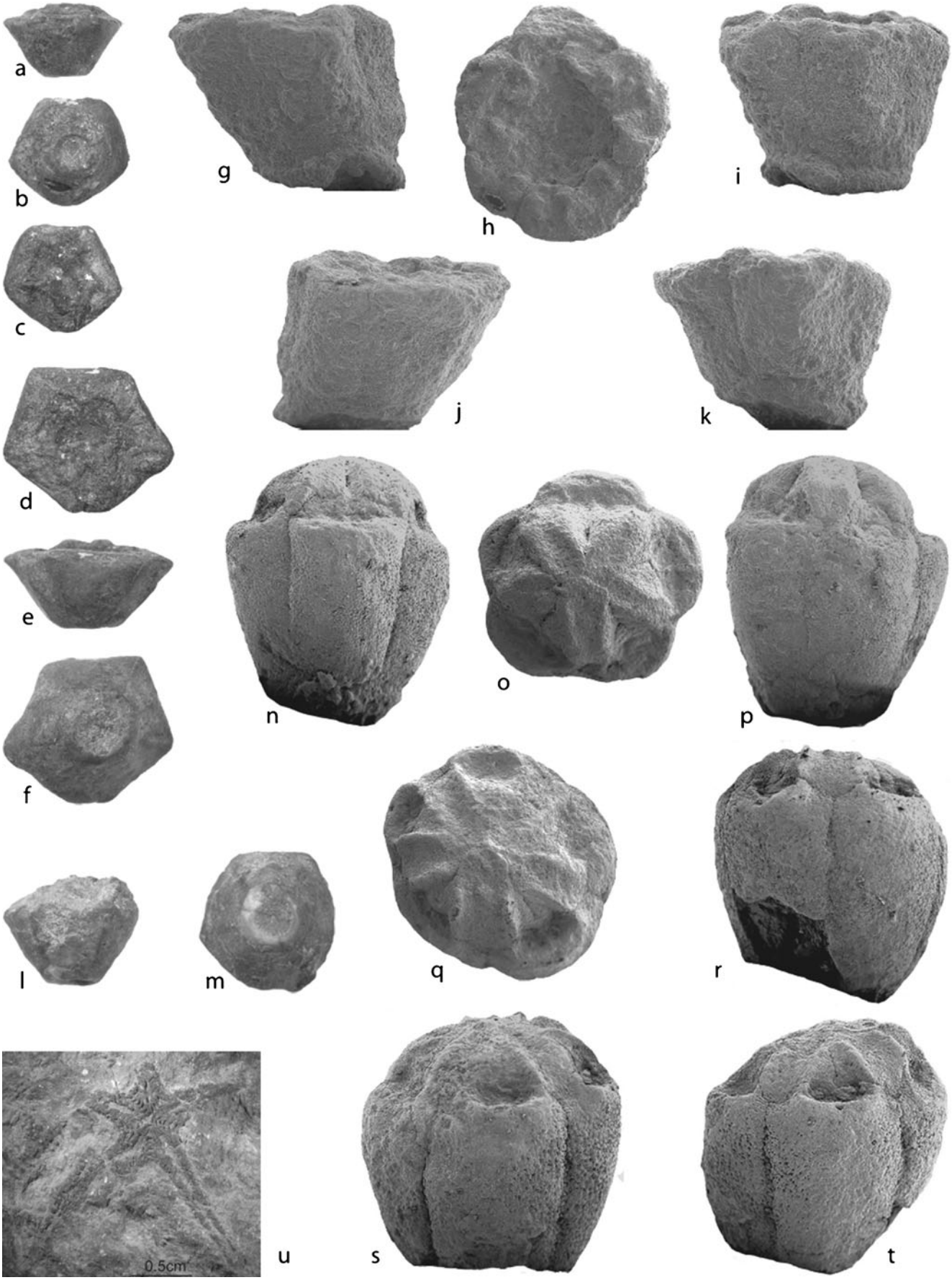
Material: Holotype, EUI 8545.

Locality: 5, Shir Gesht, Pennsylvanian, early Bashkirian, Absheni Formation.

Superfamily Allagecrinoidea Carpenter and Etheridge, 1881
Family Allagecrinidae Carpenter and Etheridge, 1881
Genus *Allagecrinus* Carpenter and Etheridge, 1881

Allagecrinus sevastopuloi n. sp. (Fig. 8n–p)

Etymology: In recognition of the contributions of George Sevastopulo to the knowledge of *Kallimorphocrinus*.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0.5cm

Diagnosis: Distinguished by the combination of a medium bowl-shaped cup with basals visible in lateral view, roundly pentalobate outline in oral view, 10 arms (A- and D-rays 3 each; B-ray 2; C- and E-rays 1 each) and fine-pitted texture in adult forms.

Description: Thecae medium conical, elongate, length 2.4 mm, width 2 mm, base truncate, oral outline widely pentalobate, sutures mildly impressed; surface sculpture fine pits in anastamosing meshwork. Cup medium bowl, walls gently convex. Basal circlet fused, short, proximally horizontal bearing circular stem facet, distally steeply upflared forming one-sixth of cup wall. Radials 5, longer than wide, widen distally in proximal half, uniform width in distal half, moderately convex transversely, gently convex longitudinally, incurving distally. Radial facets, angustary, crescent-shaped, moderately deep with elevated outer rim. Arms 10: A-ray 3, B-ray 2, C-ray 1, D-ray 3, E-ray 1. Anal notch on posterior shoulder of C radial. Oral circlet inset from radial summit in lateral view, gently arched summit, forms one-fifth of thecal length. Orals 5, triangular, longer than wide, widest at proximal facet, shallow to moderately deep medial depression opening adorally. Oral/oral sutures twice length of oral/radial sutures in deep wide V-shaped trough. Orals meet centrally; posterior oral larger with small hydropore, meets all others near axial pole, separates BC and DE orals. Measurements on holotype.

Remarks: There are good growth stages among the 55 specimens of *Allagecrinus sevastopuloi* n. sp., and most specimens are well preserved, although the matrix obscures the radial facets and base of the cup on some specimens. With growth, the following morphologic modifications are noted: (1) the radials are initially straight longitudinally but become moderately convex; (2) there is no anal notch until the arms begin to form; (3) initially the orals form a disc that is essentially the same diameter as the radial circlet, but they have a smaller diameter in larger forms; (4) the oral view outline modifies from roundly pentagonal to roundly lobate pentagonal as oral facets develop; (5) sutures become impressed in adult forms.

A review of *Allagecrinus* species found that most are macrocrinoids and have more than ten arms distinguishing them from *A. sevastopuloi*. Chesterian microcrinoid species (Gutschick 1968) assigned to *Allagecrinus* have fewer than ten arms, and the orals do not extend to the edge of the radial circlet. *Allagecrinus sevastopuloi* is assigned to the genus because it retains the orals in maturity, the basals are visible in lateral view and the cup walls are relatively straight. However, it may be an intermediate form between *Allagecrinus* and *Kallimophocrinus*, a Pennsylvanian microcrinoid, thought to be derived from *Allagecrinus*. This is the first report of a Bashkirian *Allagecrinus* and extends the palaeogeographic range into Iran and the western Paleotethys from North America and Europe

Material: 35 specimens. Holotype, EI 8546.

Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Genus *Kallimorphocrinus* Weller, 1930

See Webster 2003 for synonomy.

Remarks: *Kallimorphocrinus* Weller, 1930 was revised by Lane and Sevastopulo (1982) and recognised as a Pennsylvanian and Permian allagecrinid with more than five arms, distinguishing it from *Litocrinus* Lane and Sevastopulo, 1982, a Mississippian form with five or fewer arms. A literature review of species assigned to *Kallimorphocrinus* suggests two general morphotypes may be recognised. One has a cup that is a low bowl with the basals not visible (most common) or barely visible in lateral view and a roundly pentalobate outline in oral view in the adult stage. This group includes *K. astrus* Weller, 1930, *K. barnettensis* (Strimple 1975), *K. bassleri* (Strimple 1938), *K. intermedius* (Pabian and Strimple 1980; originally recognised as a subspecies of *K. bassleri* and herein recognised as a separate species because the basals are visible in lateral view and the cup walls are concave instead of convex), *K. constellatus* (Moore 1940), *K. copani* (Strimple 1949), *K. eaglei* (Strimple 1966), *K. graffhami* (Strimple 1949), *K. illinoiensis* Weller 1930), *K. knighti* Weller, 1930, *K. kylensis* (Strimple 1948), *K. lanei* n. sp., *K. lasallensis* (Strimple and Moore 1971), *K. sevastopuloi* n. sp. and *K. status* (Strimple 1951). The second group has a low-to-medium bowl-shaped cup with protruding radials that result in an angularly pentastellate outline in the adult stage. The second group includes *K. dignatus* (Moore 1940), *K. donetzensis* (Yakovlev 1930), *K. inaquosus* Webster and Lane 1970, *K. inhumectus* Webster and Lane 1970, *K. lilus* Weller, 1930, *K. odiosus* (Weller 1930), *K. piasaensis* Weller, 1930, *K. pecki* (Moore 1940), *K. strimplei* (Kirk 1936), and ?*K. vanpelti* Weller, 1930. These two groups are not considered separate genera or subgenera because the lineages are uncertain. Also, it has been shown by Moore (1940) for *K. constellatus* that the radials protrude as angular ridges in the immature stage and as rounded lobes in the adult stage, resulting in the oral outline transforming from pentastellate to pentalobate.

The Iranian occurrence of *Kallimorphocrinus* is the first report of the genus in the Early Pennsylvanian as it was previously known from Moscovian strata in Russia and Middle Pennsylvanian into Early Permian formations in the USA as compiled by Webster (2003). This extends the palaeogeographic range into Iran and the northern margin of Gondwana. The Viséan occurrence in Scotland recorded by Webster (2003) is incorrect as Mississippian species previously assigned to *Kallimorphocrinus* were transferred to *Litocrinus* by Lane and Sevastopulo (1982).

?Kallimorphocrinus lanei n. sp. (Fig. 8q–t)

Etymology: In recognition of the contributions of N. Gary Lane to the study of *Kallimorphocrinus*.
Diagnosis: Distinguished by the combination of a medium bowl-shaped theca, basal circlet barely visible in lateral view, ten arms (2 per ray), anal notch shared by the C and D radials, slightly pentalobate roundly pentagonal outline in oral view and very fine pit ornament in adult forms.
Description: Theca medium bowl, longer (2.3 mm, lacking basal circlet) than wide (2.1 mm), base truncate, slightly pentalobate roundly pentagonal outline in oral view, very fine pit ornament, sutures impressed in adult specimen. Cup medium bowl, longer than wide. Basal circlet fused, discoid, barely visible in lateral view, forming approximately 1/20 of cup wall, proximally bears circlar stem facet, distally steeply upflared. Radials 5, longer than wide, proximally widen gently distally, distally uniform width, gently convex longitudinally and transversely, smoothly merge with basals proximally. Radial facets angustary, semicircular narrowing adorally, two per ray on adults. Anal notch shared on mutual shoulders of C and D radials. Oral circlet gently arched, slightly inset from radial facets, forming one-ninth of thecal length. Orals 5, triangular, longer than wide, gently arched adorally with shallow medial trough; posterior oral largest, bears prominent hydropore, meets all others centrally, separates BC and DE orals. Oral/oral sutures in wide deep ambulacral trough. Arms 10, not preserved. Stem unknown. Measurements on holotype.
Remarks: The basal circlet is lost on the holotype of ?*Kallimorphocrinus lanei* n. sp. and the paratype is slightly distorted. The ten arms (2 per ray), slightly pentalobate roundly pentagonal outline in oral view, and anal notch shared by the C and D radials are the distinguishing features of ?*K. lanei*. The combination of these features along with the fine pit ornament, medium bowl shape and basal circlet barely visible in lateral view distinguish ?*K. lanei* from all other species of the genus. The presence of two arms in all rays suggests that ?*Kallimorphocrinus lanei* may represent a new genus or is the immature form of an allagecrinid with multiple arms in all rays. Hopefully, future studies of the eastern Iran faunas will discover additional specimens to resolve the problem.
Material: Holotype EUI 8547, paratype EUI 8548
Localities: 5, Shir Gesht, Pennsylvanian, early Bashkirian, Absheni Formation.

Genus *Litocrinus* Lane and Sevastopulo, 1982

Litocrinus bullatus n. sp. (Fig. 9a–f) (Fig. 10)

Etymology: From the Latin *bulla*, referring to the inflated bulbous nature of the radials and oral circlet.
Diagnosis: A *Litocrinus* distinguished by a conical cup, roundly inflated radials and inflated orals, projecting aborally beyond the radial/oral sutures, forming a decagon in oral view outline.
Description: Thecae medium cone, longer (1.67 mm) than wide (1.51 mm), expanding distally with a constriction at the radial summit; decagon with rounded lobes in oral view, radials forming outer pentagon and orals forming slightly smaller inner pentagon; pits in anastamosing meshwork ornament. Cup medium cone shape, six-tenths thecal length. Basal circlet short, proximally horizontal bearing round stem facet and round axial canal, distally barely-to-not visible in lateral view, steeply upflaring, forming slight fraction of cup wall. Basals 3 or fused. Radials 5, longer than wide, merge with basals proximally, widen gently distally, rounded linear ridge longitudinally, incurl distally, strongly rounded transversely. Radial/radial sutures in deep wide depression between linear radial ridges. Radial facets angustary, shallow, semicircular, one per ray. No anal notch. Oral circlet projects roundly above cup, strongly inflated, wider than long, forming slightly over one-third thecal length. Orals 5, triangular, oral/oral sutures longer than oral/radial sutures, proximally widely up- and outflaring, projecting aborally beyond oral/radial sutures but not beyond radial linear ridges, distally gently upflared with elongate shallow central depression open distally. Posterior oral largest, in contact with other four, may bear hydropore in proximal one-third. Arms and stem not preserved. Measurements on holotype.
Remarks: Thecae of *Litocrinus bullatus* n. sp. are moderately well preserved, although the largest specimens may be cracked or have lost the basals. Large specimens partly covered with matrix or overgrowths of undetermined organisms. *Litocrinus bullatus* is most similar to *L. protuberans* Webster and Jell, 1992 with the rounded inflated radials and orals. However, the cup of *L. bullatus* is conical with straight to slightly convex walls, whereas that of *L. protuberans* flares distally, with concave walls up to the nodes below the radial facets. No other *Litocrinus* species have this cup shape.

This is the first report of a Pennsylvanian species of *Litocrinus*. It fills part of the stratigraphic gap from the Middle Mississippian into the Early Permian as recognised by Webster and Jell (1992) and extends the palaeogeographic range into Iran.
Material: 49 specimens. Holotype EUI 8549, paratypes 1–3 EUI 8550–8552, three other specimens, locality 5; 19 specimens, locality 1; 23 specimens, locality 2.
Localities: 1, 2, Howz-e-Dorah; 5, Shir Gesht; Pennsylvanian, early Bashkirian, Absheni Formation.

Litocrinus conus n. sp. (Fig. 9q–t)

Etymology: From Latin, referring to the shape of the cup.
Diagnosis: A *Litocrinus* distinguished by a conical cup, angularly rounded radials, radials outflaring proximally.

Description: Thecae high cone in juveniles, medium cone in adult, slightly longer (1.67 mm) than wide (1.64 mm), expanding distally with constriction at radial summit; oral view outline roundly to angularly pentagonal; fine pits in an anastamosing meshwork ornament. Cup medium cone-shaped, approximately three-quarters thecal length. Basal circlet short, proximally horizontal bearing round stem facet and round axial canal, distally steeply upflared, Forming one-half of cup wall. Basals 3, 2, or fused. Radials 5, longer than wide, proximally sharply expanding laterally, widen gently distally, strongly rounded transversely, incurl distally, form prominent angularly to rounded longitudinal ridge. Radial/radial sutures in deep wide depression between radial ridges. Radial facets angustary, shallow semicircular pits, one per ray. Oral circlet projects above cup, gently inflated, wider than long, forming one-quarter thecal length. Orals 5, triangular with oral/oral sutures longer than oral/radial sutures, proximally widely up- and inflared, distally gently upflared with elongate central depression open distally. Posterior oral largest, in contact with the other four, may bear double node in trough. Other orals may bear a single node, but not common. Arms and stem not preserved. Measurements on holotype.

Remarks: Thecae of *Litocrinus conus* n. sp. are moderately well preserved, but larger specimens may be cracked or have some plates missing. *Litocrinus conus* is most similar to *L. bullatus*, but differs by the radials outflaring proximally. The longitudinal ridge of the radials is angularly rounded, the orals do not expand aborally proximally, depressions in the orals are deeper and the tegmen summit is less inflated. No other species of *Litocrinus* has radials that proximally expand as greatly laterally or has as angularly rounded radials.

Material: 30 specimens. Holotype EUI 8553, paratypes 1–3 EUI 8554–8556, six other specimens, locality 5. 20 specimens, locality 1.

Localities: 1, Howz-e-Dorah; 5, Shir Gesht; Pennsylvanian, early Bashkirian, Absheni Formation.

Allagecrinids indeterminate

Remarks: Five allagecrinid specimens have distinctive shapes and degrees of ornament development that differ from other allagecrinids described. It is uncertain if these are immature specimens or represent additional species in the Absheni faunas. They are illustrated for completeness of the faunas.

Allagecrinid indeterminate 1 (Fig. 11a–d)

Description: Theca small, length (0.83 mm) approximately equal to width (0.88 mm maximum, 0.82 mm minimum), oral view pentagonal with multiple lobes, lateral view somewhat triangular, base truncate; ornamentation small pits in roughened surface. Cup medium cone, length 0.59 mm, widest at radial nodes. Basal circlet merges with radials without notch or visible sutures, forming small part of cup wall. Basals fused. Radials 5, longer than wide, proximally moderately convex transversely, gently concave longitudinally, distally strongly convex transversely and longitudinally, projected as knobs prior to incurling to radial summit. Tegmen inset at radial summit, walls subvertical, summit gently convex. Tegmen plates triangular, proximally subvertical, rounded transversely, distally shallowly impressed. Posterior tegmen plate largest, adjoining all others, separating BC and CD plates. Stem facet circular.

Remarks: Specimen slightly distorted and sutures poorly exposed.

Material: Figured specimen EUI 8557.

Locality: 1, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Allagecrinid indeterminate 2 (Fig. 11e–h)

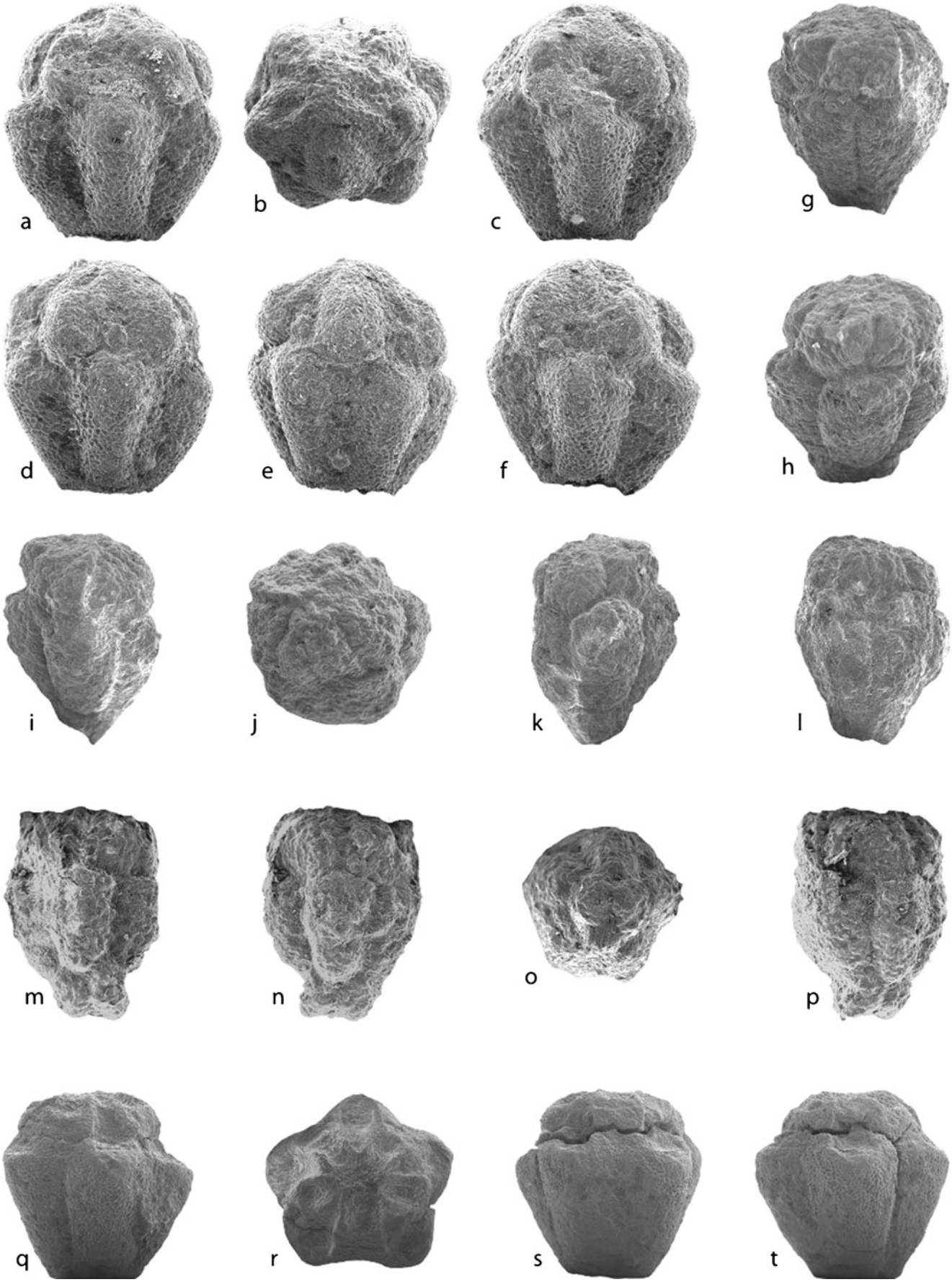
Description: Theca ovate, longer (1.59 mm) than wide (1.32 mm), widest at radial summit, oral view pentagonal with lobate projections, all plates with well-developed pitted sculpture in irregular to aligned meshwork. Cup medium bowl, length 1.15 mm, width 1.34 mm, base truncate, walls gently expanding distally, incurling at radial summit. Basal circlet short, length 0.11 mm, forming a small part of cup wall. Basals 3?, may be fused. Radials 5, longer than wide, proximally strongly convex transversely, longitudinally straight, distally roundly incurling, distal ends may be protruded into rounded knobs; radial/radial sutures in deep wide groove. Tegmen roundly domed, length 0.25 mm, width 1.34 mm, pentalobate in oral view. Tegmen plates triangular, proximally roundly lobate, laterally projecting beyond radial summit with wide medial depression shallowing distally. Posterior tegmen plate largest, adjoining all others, separating BC and CD plates. Stem facet circular.

Remarks: Specimen has a crack from near the base of the A radial to the base of the incurling of the C radial. Most sutures are very tight and not visible. Pit ornament is the best developed of the five indeterminate allagecrinids.

Material: Figured specimen EUI 8558.

Locality: 5, Shir Gesht, Pennsylvanian, early Bashkirian, Absheni Formation.

Fig. 9 **a-f** *Litocrinus bullatus* n. sp., theca, holotype EUI 8549, A-ray, oral, E-ray, D-ray, CD-interray, and C-ray views, ×20. **g–l** *Desmacriocrinus asperulus* n. sp., theca, holotype EUI 8562, AE-interray, B-ray, A-ray, oral, C-ray, and CD-interay views, ×40. **m–p** *Desmacriocrinus asperulus* n. sp., theca, paratype EUI 8563, D-ray, A-ray, aboral, and AB-interray views, ×40. **q–t** *Litocrinus conus* n. sp., theca, holotype EUI 8553, A-ray, oral, CD-interray, and C-ray views, ×30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Allagecrinid indeterminate 3 (Fig. 11i–k)

Description: Theca wider (1.21 mm) than long (0.99 mm), slightly oblate pentagonal in lateral view, oral view pentagonal with rounded lobes, base truncate; ornamentation round pits in poorly developed meshwork on all plates; plate surfaces rough. Cup medium bowl, wider (1.21 mm) than long (0.66 mm), widest below radial summit, forming two-thirds of thecal length. Basal circlet short, wide, inset within base of radials, forming small part of cup wall. Basals 3(?), may be fused, sutures not clear. Radials 5, length approximately equal to width, moderately convex transversely, straight longitudinally, incurling at radial summit. Arm facet developing on C radial. Tegmen low, forming one-third of tegmen length, proximally inwardly sloping walls, summit gently rounded. Tegmen plates triangular, proximally moderately rounded, distally bear very shallow medial depression. Posterior tegmen plate largest, adjoining all others, separating BC and CD plates. Stem facet circular.
Remarks: Specimen is very short and wide compared to the other Allagecrinid indeterminate specimens.
Material: Figured specimen EUI 8559.
Locality: 1, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Allagecrinid indeterminate 4 (Fig. 11l–o)

Description: Theca high cone, length 1.94 mm, width distorted (1.54 mm maximum, 1.14 mm minimum), oral view distorted roundly pentagonal, base truncate; ornament rounded pits in moderately to well-developed meshwork on all plates. Cup high cone, length 1.46 mm, width 0.48 mm, walls slightly irregular, radial/radial sutures in wide shallow grooves. Basal circlet proximally flat, distally steeply upflared, length 0.11 mm, forming small part of cup wall. Basals 3, two large, one small. Radials 5, longer than wide, moderately convex transversely, straight to irregular longitudinally, incurving at radial summit. Tegmen forming one-quarter of thecal length, inset at radial summit with inwardly sloping walls, summit rounded. Tegmen plates triangular, proximally moderately rounded, distally bear moderately deep medial depression. Posterior tegmen plate largest, adjoining all others, separating BC and CD plates. Stem facet circular.
Remarks: Allagecrinid indeterminate 4 is the most delicate of the five indeterminate allagecrinids. It is easily distinguished by its high-cone shape.
Material: Figured specimen EUI 8560.
Locality: 3, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Allagecrinid indeterminate 5 (Fig. 11p–t)

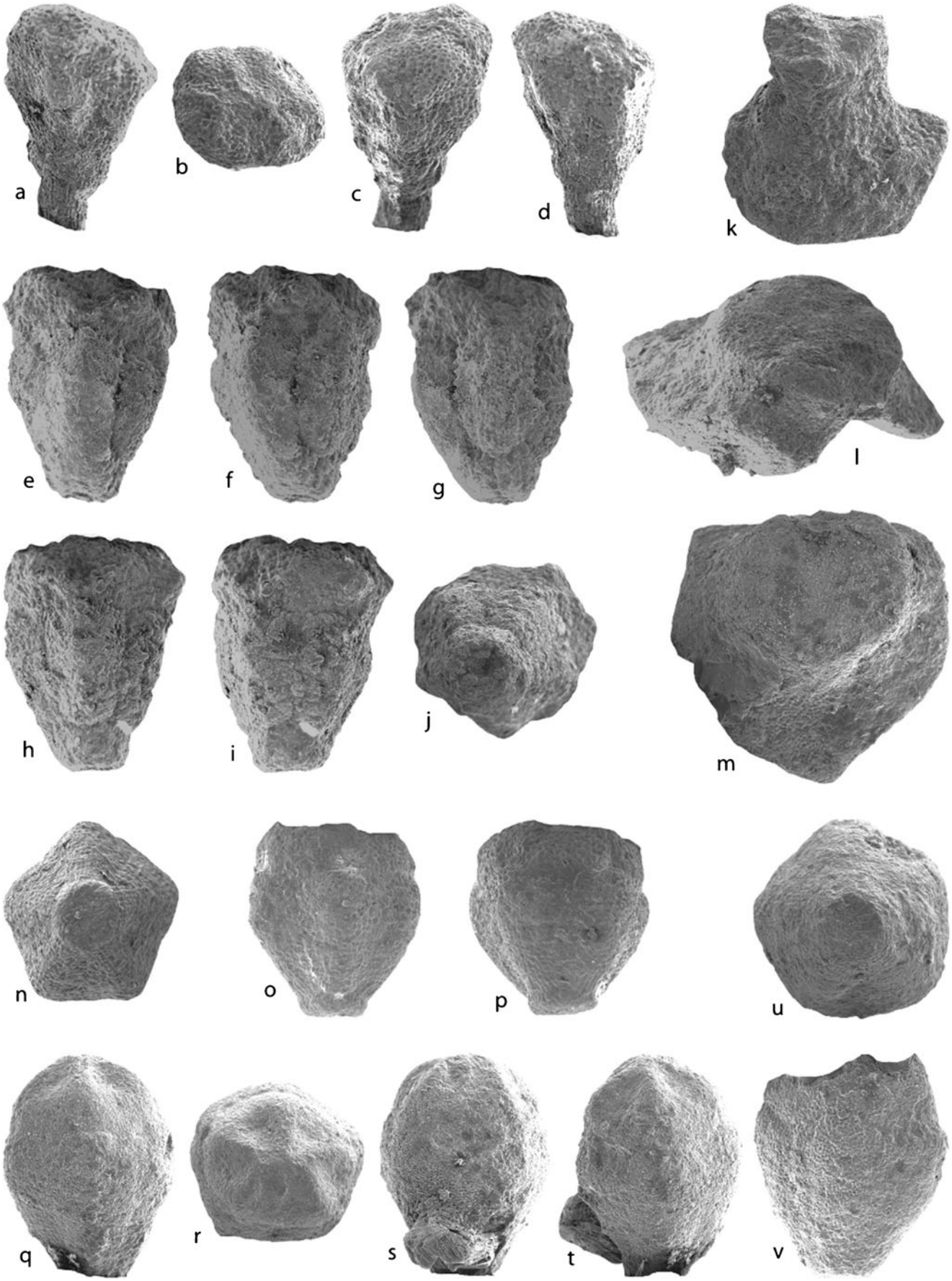
Description: Theca ovate in lateral view, oral view roundly pentagonal, small, longer (0.58 mm) than wide (0.48 mm), widest below radial summit, base truncate. Ornament pits in moderately developed irregular meshwork on all plates. Cup medium bowl, length 0.39 mm, two-thirds of thecal length. Basal circlet short, forming one-fifth of cup wall, proximally horizontal, distally steeply upflared. Basals 3, two large, one small. Radials 5, longer than wide, gently convex transversely, slightly convex longitudinally, radial summit inset. Radial facet developing on C radial. Tegmen short, forms rounded cap on cup. Tegmen plates triangular, proximally sloping gently inward, horizontal distally, no medial depression. Posterior tegmen plate largest, adjoining all others, separating BC and CD plates. Stem facet circular.
Remarks: The ovate shape of this small specimen has well-developed cup sutures, but poorly developed thecal sutures.
Material: Figured specimen EUI 8561.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Fig. 10 **a–d** *Desmacriocrinus bulbus* n. sp., theca, holotype EUI 8564, C-ray, oral, A-ray and BC-interray views, ×40. **e–j** *Desmacriocrinus bulbus* n. sp., theca, paratype 1 EUI 8565, A-ray, AE-interray, E-ray, D-ray, CD-interray and basal views, ×50. **k** Immature radial 2 EUI 8615, aboral view, ×50. **l**, **m** Immature radial 1 EUI 8614, oblique and lateral facetal views, ×50. **n–p** *Desmacriocrinus bulbus* n. sp., theca, paratype 2 EUI 8566, aboral and two undesignated ray views, ×50. **q–t** *Dichostreblocrinus inaquosus* n. sp., theca, holotype EUI 8579, A-ray, oral, CD-interray and B-ray views, ×50. **u**, **v** *Dichostreblocrinus inaquosus* n. sp., theca, paratype EUI 8580, basal and undesignated ray views, ×80

Genus *Desmacriocrinus* Strimple, 1966

Emended diagnosis: To include forms with an anal opening shared on mutual distal shoulders of C and D radials and base of posterior oral; include forms with three basals.
Remarks: *Desmacriocrinus* Strimple, 1966 was defined as having a rather large oral circlet overshadowing the radials and having five basals, five radials, five orals and no anal notch in the posterior interradius. The presence of the five basals distinguished *Desmacriocrinus* from *Kallimorphocrinus* Weller, 1930. The type species, *Kallimorphocrinus weldensis* Strimple and Koenig, 1956, lacks the anal notch; however, *Coencystis moreyi* Peck, 1936, which Strimple (1966) also assigned to *Desmacriocrinus*, was initially described and illustrated by Peck (1936, p. 289, pl. 46, fig. 2) as having a small inconspicuous anal opening. As described below, *D. asperulus* n. sp. has five or three basals. Thus, the generic diagnosis is emended to include forms with an anal opening and five or three basals. The inflated tegmen is an important character of *Desmacriocrinus*.

Based on the two species originally assigned to the genus, *D. weldensis* and *D. moreyi*, the stratigraphic range was recognised as Mississippian (Tournaisian), and the palaeogeographic range as North America (Oklahoma and Missouri). The recognition of *Desmacriocrinus* in Iran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extends the stratigraphic range upward into the Early Pennsylvanian (Bashkirian), and the palaeogeographic range into the western part of the Paleotethys and northern edge of Gondwana.

Desmacriocrinus asperulus n. sp. (Fig. 9g–p)

Etymology: From the Latin, *asper*, referring to the rough irregular texture of the thecal plates.
Diagnosis: Distinguished by the rough irregular texture of the thecal plates.
Description: Theca pear-shaped, longer (0.93 mm) than wide (0.7 mm), oral outline roundly pentagonal, surface of all plates very rough and irregular with some pitting. Cup high bowl, truncate base, walls mildly convex. Basal circlet short, proximally horizontal with circular stem facet, distally steeply upflared, forms one-quarter of cup wall. Basals 5 or 3. Radials 5, longer than wide, expanding sightly distally, then narrowing slightly at radial summit, roundly to angularly inflated transversely, mildly convex longitudinally. Radial facets angustary, semicircular, present only on larger forms, project slightly aborally, uncertain full number. Anal opening impressed on mutual distal shoulders of C and D radials and base of middle of proximal edge of posterior oral. Oral circlet forms gently arched dome with long subvertical to slightly aborally sloping walls that may extend slightly aborally beyond the radial/oral suture, forms one-third of thecal length. Orals 5, triangular, proximally subvertical or sloping slightly aborally, distally gently upflared to summit, bear shallow wide medial depression open aborally. Posterior oral largest, meets all other orals at summit, separates BC and DE orals, may bear small node (hydropore?) in center of depression. Oral/oral sutures in ridges formed by upturned lateral edges of orals. Proximal columnal circular. Arms and distal stem unknown. Measurements are given in Table 3.
Remarks: Most thecae of *Desmacriocrinus asperulus* n. sp. are well preserved, but some specimens are slightly deformed from compaction. Paratype 1 has what appears to be rough plates around the anal opening, but it is uncertain whether these are actual plates or the result of recrystallization. The presence of small plates surrounding the anal opening is not normal in the allagecrinids, suggesting that it is recrystallization or the specimen may be abnormal. The presence of a radial facet on the E radial of paratype 2 suggests that the specimen was nearing maturity. *Desmacriocrinus asperulus* differs from other species assigned to the genus by the rough, irregular texture of the thecal plates.
Material: Seven specimens. Holotype EUI 8562, paratype 1 EUI 8563, and five specimens, locality 5.
Locality: 5, Shir Gesht, Pennsylvanian, early Bashkirian, Absheni Formation.

Fig. 11 **a–d** Allagecrinid indeterminate 1, theca EUI 8557, A-ray, oral, B-ray, and E-ray views, ×40. **e–h** Allagecrinid indeterminate 2, theca EUI 8558, A-ray, oral, D-ray, K- and CD-interray views, ×30. **i–k** Allagecrinid indeterminate 3, theca 8559, A-ray, oral, and CD-interray views, ×40. **l–o** Allagecrinid indeterminate 4, theca 8560, A-ray, oral, CD-interray and E-ray views, ×20. **p–t** Allagecrinid indeterminate 5, theca 8561, A-ray, oral, oblique CD-interray, D-ray and E-ray views, ×60

Desmacriocrinus bulbus n. sp. (Fig. 10a–j, n–p)

Etymology: From Latin, referring to the inflated nature of the theca.
Diagnosis: Distinguished by the fine pitting ornament on the thecal plates.
Description: Theca elongate cone, longer than wide to approximately equidimensional, oral outline roundly pentagonal in smaller forms, lacking radial facets, stellate rays in outline in forms with radial facets, summit slightly arched, surface of all plates ornamented with fine pitting. Cup high cone, truncated base, walls straight with bulge at radial summit as radial facets develop, forms nearly three-quarters of thecal length. Basal circlet short, proximally horizontal bearing round stem facet, distally steeply upflared, forms one-seventh of cup wall. Basals 5 or 3, small. Radials 5, longer than wide, gently widening distally, roundly inflated to angularly rounded transversely, straight to slightly convex longitudinally. Radial facets 1–4, angustary, semicircular, present only on larger forms, project slightly aborally, inclinate. No anal opening or impression. Oral circlet overhangs radials in small forms, inset slightly as radial facets develop on larger forms, slightly arched summit, subvertical to overhanging proximal walls extending slightly adorally beyond the radials, forms one-quarter of thecal length. Orals 5, triangular, proximally subvertical or sloping slightly aborally, distally gently upflaring to summit, bear very shallow to medium-deep wide medial depressions opening aborally. Posterior oral largest, adjoins all other orals at summit, separates BC and DE orals, may bear small node (hydropore?) in centre of depression. Oral/oral sutures flush or in shallow trough formed by upturned lateral edges of orals. Stem holomeric, homeomorphic, circular; latus with linear ridges. Arms unknown. Measurements are given in Table 3.
Remarks: Most thecae of *Desmacriocrinus bulbus* n. sp. are deformed from compaction. All other species assigned to *Desmacriocrinus* have surface ornamentation differing from the fine pitting of *D. bulbus*.
Material: 19 specimens. Eight specimens: holotype EUI 8564, paratypes 1, 2 EUI 8565, 8566, and five specimens, locality 2. 11 specimens: paratype 3 8625, and ten additional specimens, locality 1.
Localities: 1, 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

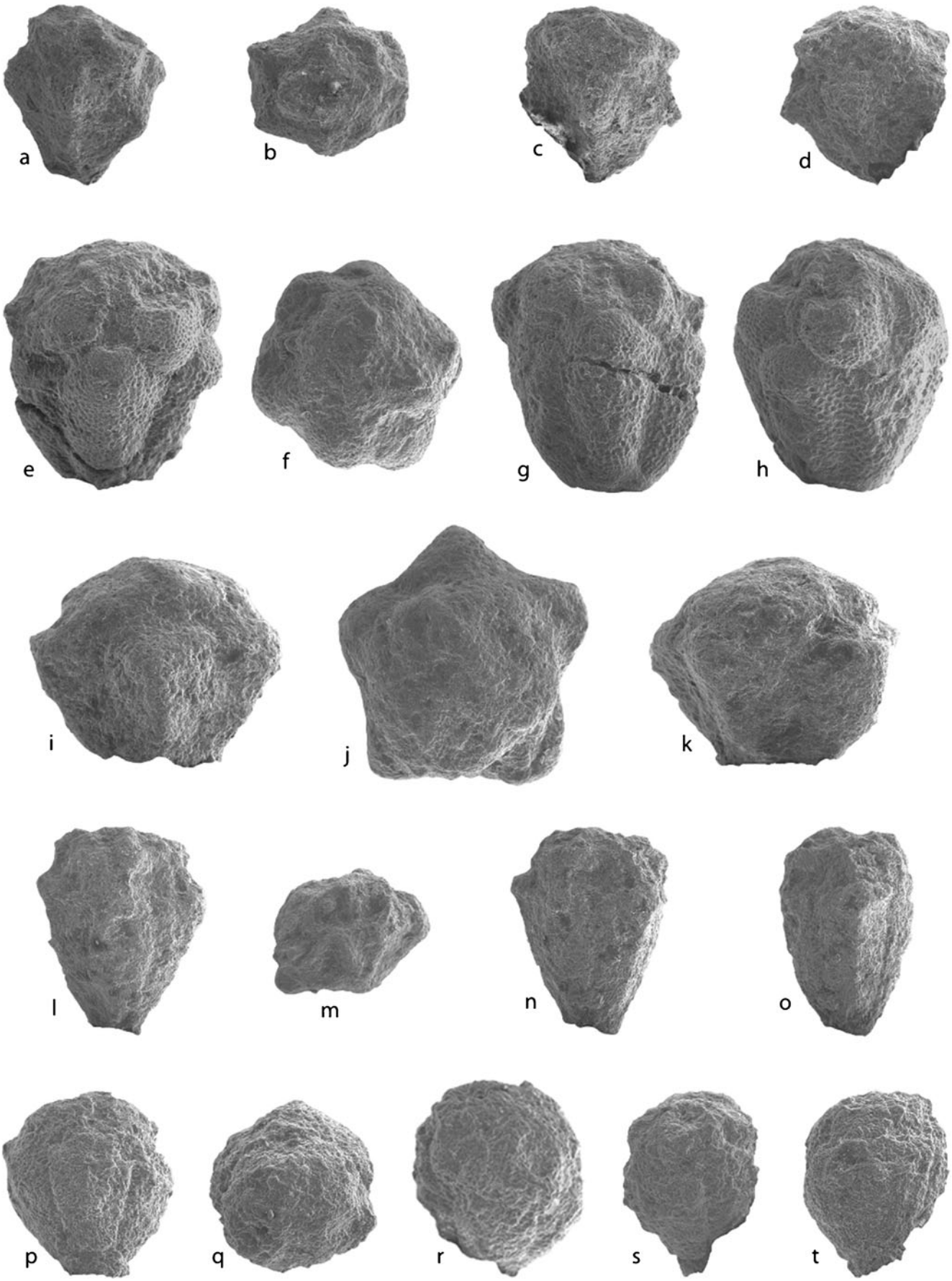
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Table 3 Measurements[a] determined for *Desmacriocrinus bulbus* n. sp.

Anatomical parameter	Holotype[b]	Paratype
Theca length	0.64	0.73
Theca width	0.61	0.68
Cup length	0.42	0.53
Cup width	0.52	0.68
Stem diameter	0.21	0.21

[a] All measurements are given in millimetres

[b] Distorted

Genus *Trophocrinus* Kirk, 1930

Trophocrinus granulosus n. sp. (Fig. 12a–l)

Etymology: For the small granules on the surface of all cup plates.

Diagnosis: A single pouched *Trophocrinus* distinguished by the fine granular ornament of the thecal plates.

Description: Theca high cone, longer than wide, very small granular ornament on radials. Tegmen roundly inflated with flat or slightly elevated summit, forms one-quarter to one-third of thecal length. Oral view circular in outline unless crushed into elliptical outline with long axis in pouch/BE-interray symmetry plane. Basals 3 or fused; basal circlet small, short, forming approximately one-eighth to one seventh of thecal length, with round stem facet on proximal surface. Radials 5, longer than wide, widening gently distally before narrowing slightly, steeply upflared, forms one-half to two-thirds of thecal length. Extension pouch confined to E radial in smaller specimens, on D and E radials in larger forms, never curls over orals, but extends outside oral summit laterally in largest specimens. Angustary radial facets develop only on larger specimens. Orals 5, triangular, with depressed medial trough opening aborally, forming arched tegmen; posterior oral largest, bearing medial node or hydropore, adjoins all other orals centrally, separates BC and DE radials. Some specimens with elevated ribs along oral sutures. Holotype length 0.73 mm, maximum width 0.64 mm (slightly crushed), minimum width 0.38 mm (slightly crushed).

Remarks: All large specimens of *Trophocrinus granulosus* n. sp. with the pouch are crushed or distorted, and the oral surface is typically distorted or partially covered with secondary calcite. A few of the immature specimens with the pouch beginning to develop are not distorted and possess a node (rarely a depression) or hydropore in the posterior oral. Adult specimens without the pouch were not recognised. *Trophocrinus granulosus* is most similar to *T. brevis* Strimple and Koenig 1956 in cup shape, however it differs from the six species assigned to the genus (Kirk 1930; Peck 1936; Strimple and Koenig 1956) by the granulose ornament. The other species have finely pitted surface ornament or lack ornamentation.

Fig. 12 **a–d** *Trophocrinus granulosus* n. sp., theca, holotype EUI 8567, oblique oral view (CD oral at *upper left*), oral (A ray on *left*), A-ray, and DE-interray views, ×60. **e–h** *Trophocrinus granulosus* n. sp., theca, paratype 2 EUI 8569, oblique view of pouch, oral, DE-interray, and A-ray views, ×60. **j–l** *Trophocrinus granulosus* n. sp., theca, paratype 1 EUI 8568, oral (DE interray at *top* of figure), C-ray, and DE-interray views, ×60. **m**, **n** Immature radial 3 EUI 8616, lateral and aboral views, ×50. **o**, **p** Immature radial 4 EUI 8617, lateral and aboral views, ×50. **q–s**, øBlade cirri? 1 EUI 8584, facet, oral, and aboral views, ×40. **t–w**, øBlade cirri? 2 EUI 8585, oral, facet, aboral, and facet views, ×40

Trophocrinus granulosus is the first Pennsylvanian species reported for the genus and is considered to extend the stratigraphic range upward into the Early Pennsylvanian from the Middle Mississippian. It extends the palaeogeographic range from North America into the Paleotethys. It is not considered to be a second evolution of the morphotype. Many potential Visean and Serpukhovian crinoid localities have not been investigated for microcrinoids. Until such investigations have shown the absence of *T. granulosus*, we do not consider this species to represent a Lazarus taxon. *Trophocrinus* was known previously only from the Mississippian (Tournaisian) of North America, Kinderhook of Missouri and Kinderhook and Osage of Oklahoma.

Material: 36 specimens. 20 specimens: holotype EUI 8567, and 19 specimens, locality 2. 16 specimens: Paratypes 1–3 EUI 8568–8570, and 13 specimens, locality 1.

Localities: 1, 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Family Catillocrinidae Washsmuth and Springer, 1886

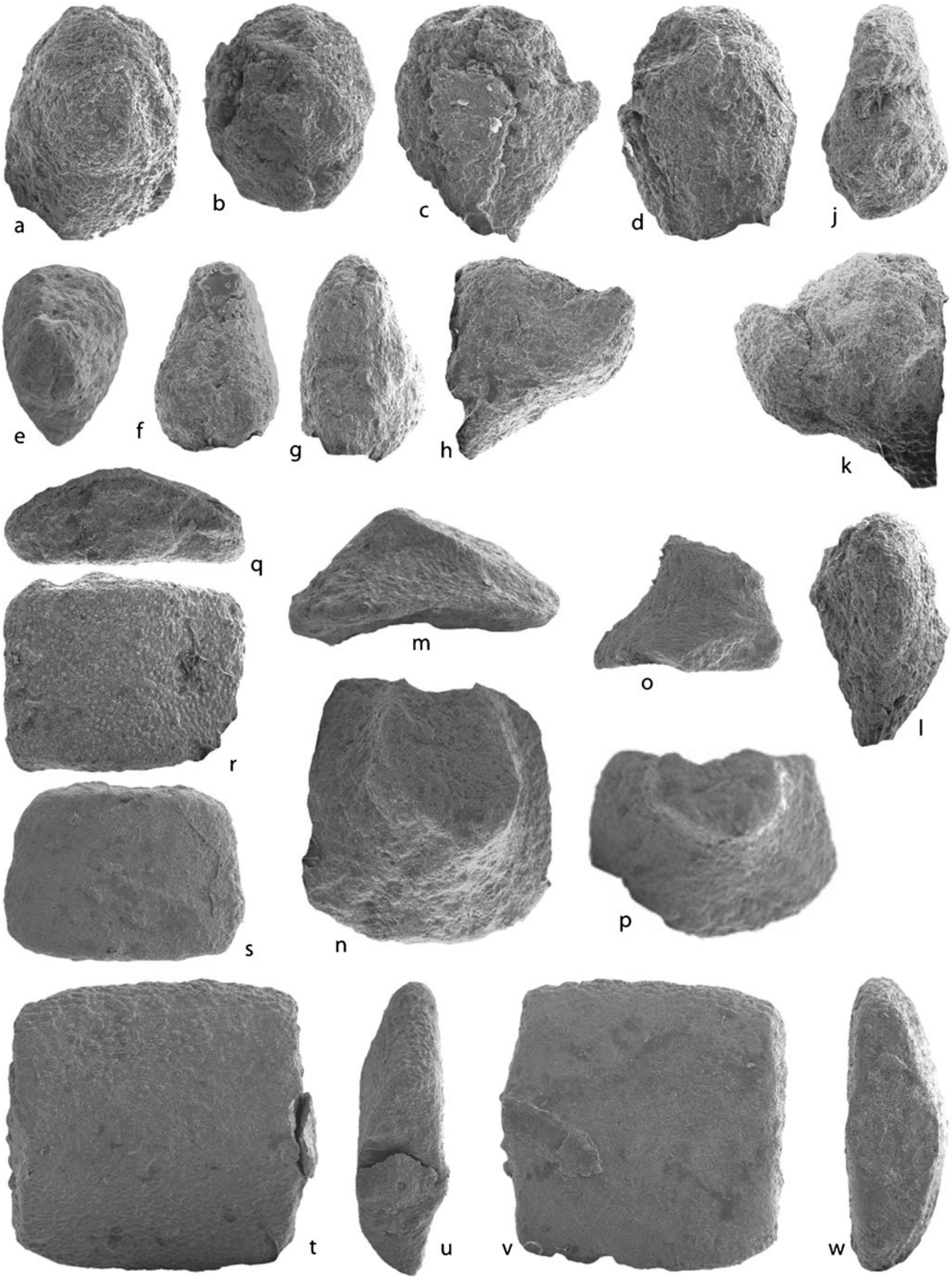
Genus *Catillocrinus* Shumard, 1865

Catillocrinus levatus n. sp. (Fig. 13m)

Etymology: From the Latin *levo*, referring to the elevated areas on cup plates.

Diagnosis: Distinguished by the faint elevations on cup plates.

Description: Specimen partial crown with proximal stem, length 62.4 mm, width at radial summit 21 mm. Crown slender elongate, incomplete length 33.1 mm. Cup medium conical, length 10.8 mm, width 21 mm, surface with faint elevated areas, but not granulate, sutures weakly impressed. Basal circlet short, diameter 12 mm, visible length 3.2 mm. Radials moderately convex transversely, concave to straight longitudinally, variable width, A and D radials widest with many arm facets, B, C and E radials narrower with smaller number of arms; D radial approximately 19 mm width, 7 mm length; E radial length 8.6 mm, maximum width 6.8 mm, tapering in distal one-third. Tegmen stout, elliptical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cross section with deep V-shaped anal groove above the E-ray; surface bearing shallow narrow grooves for arms in enclosed position, minimum 11 arms on A radial, seven on D radial. Stem round, preserved length 29.3 mm, proximal diameter 10.9 mm, distal 7.7 mm, holomorphic until last columnal which is longer than the others. Arms, distal end of tegmen, and distal stem not preserved.

Remarks: The specimen of *Catillocrinus levatus* n. sp. was shattered in part when collected and parts of the radials lost. Fracturing and later calcite-vein filling masked the B and C radial areas. The plate structure is similar to that of the primitive catillocrinids, with multiple arms on the A and D radials and a single or few arms on the B, C and E radials. Based on the exposed part of the tegmen, it is estimated that the total number of arms was a minimum of 40 and probably closer to 50. The generic assignment is based on the similarity of cup and tegmen shapes and is questioned because the number of arms on the B-and C-rays are unknown. No other *Catillocrinus* species has similar cup ornament.

Material: Holotype EUI 8571.

Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Superfamily Belemnocrinoidea S. A. Miller, 1883
Family Synbathocrinidae S. A. Miller, 1889
Genus *Synbathocrinus* Phillips, 1836

Synbathocrinus dastanpouri n. sp. (Fig. 8a-m)

2001 *Synbathocrinus* sp. A Webster et al., p. 111, pl. 3, figs. F–H.

Etymology: Named for Dr. Mohammad Dastanpour in recognition of his work on the geology of the Kerman region of southeastern Iran.

Diagnosis: Distinguished by granular ornamentation and one low node at the centre base of each radial, which may extend as a narrow ridge onto distal part of basal circlet.

Description: Cup low cone-shaped, wider than long, ornament of medial ray ridge formed as continuous ridge or discontinuous nodes from distal end of basal circlet to just below radial facet, granules on radials, and a single low node at centre base of each radial. Basal circlet low, unequal tripartite or fused; small basal in AB-interray, two equally large basals. Basals proximally slightly downflared below stem facet, distally upflared, tips visible in lateral view, forming base of cup wall. Radials 5, pentagonal, moderately outflaring, wider than long, straight to slightly convex longitudinally, slightly convex transversely, wide convex V-shaped transversely. Radial facets plenary, gently declivate. Anal notch wide, unequal V-shaped on C and D radials, mostly on C radial. Stem facet circular, slightly impressed into basal circlet; axial canal pentagonal. Crenularium narrow, occupying one-quarter facet radius; crenulae coarse cogs. Arms and stem not preserved. Measurements are given in Table 4.

Remarks: The holotype of *Synbathocrinus dastanpouri* n. sp. is slightly larger than that of paratype 1; both specimens are well preserved. Development of the longer and solid medial ridges on the larger holotype is considered to be a growth factor of specific variation. The medial ridges of paratype 1 are present only on the distal ends of the basals and proximal ends of the radials as nodes. Paratype 2 is replaced with iron oxides.

Paratype 3 is a juvenile with the medial ray ridge and node ornament beginning to develop and the anal notch a shallow V, shared on the C and D radials. A second juvenile specimen, with the same size as paratype 3, is broken and lacks most of the D radial, but otherwise has the same morphology as paratype 3.

Moore and Ewers (1942) described *Synbathocrinus texasensis* and illustrated a series of small specimens (text-figs. 2–5, 8–27) up to 2.7 mm in diameter. Some of these illustrations were also published in the Treatise (Moore and Teichert 1978, text-fig. 352, nos. 1g–p). These authors considered the small specimens to be the growth stages of *S. texasensis*. These small specimens all retain the five orals and node ornament; however, the radial summit lacks any development of the anal notch or a notch on the mutual shoulders of any pair of radials. Small specimens of *Synbathocrinus*, although not quite as small as the new specimens from Iran studied by us in collections of the Springer collection in the U.S. National Museum and other collections, are in agreement with paratype 3 and the non-type juvenile with an anal plate in the primibrachial circlet, the aboral surface flush with the aboral surface of the adjacent primibrachials and positioned in a small notch on the C and D radials. These also agree with illustrated specimens of *Synbathocrinus* (i.e. *S. anglicus* Wright, 1946, among others). Thus, the anal plate was present and

Fig. 13 **a**, **b** ø*Rhysocamas magnificus* n. sp., pluricolumnal, paratype 1 EUI 8608, lateral views with cirral scars and attached cirri on *lower left* and *upper left*, respectively, ×1. **c** ø*Rhysocamas magnificus* n. sp., pluricolumnal, paratype 3 EUI 8610, facetal view with undistorted lumen, ×1. **d** ø*Rhysocamas magnificus* n. sp., pluricolumnal, paratype 4 (part) EUI 8611, facetal view showing distortion, ×1. **e** ø*Rhysocamas magnificus* n. sp., pluricolumnal, holotype EUI 8607, facetal view with crenellae extending full width of crenularium, ×2. **f**, **g** ø*Rhysocamas magnificus* n. sp., pluricolumnal, paratype 2 EUI 8609, lateral views, ×1. **h** ø*Rhysocamas magnificus* n. sp., pluricolumnal, paratype 4 (part) EUI 8611, lateral view, ×1. **i**, **j** øBarycrinidae indeterminate, pluricolumnal EUI 8577, oral and aboral views of pluripentamere, ×2. **k**, **l** øBarycrinidae indeterminate, pluricolumnal EUI 8576, oral and lateral views of slightly distorted pluricolumnal, ×2. **m** *Catillocrinus levatus* n. sp., partial crown, holotype EUI 8571, lateral view, ray uncertain, ×2

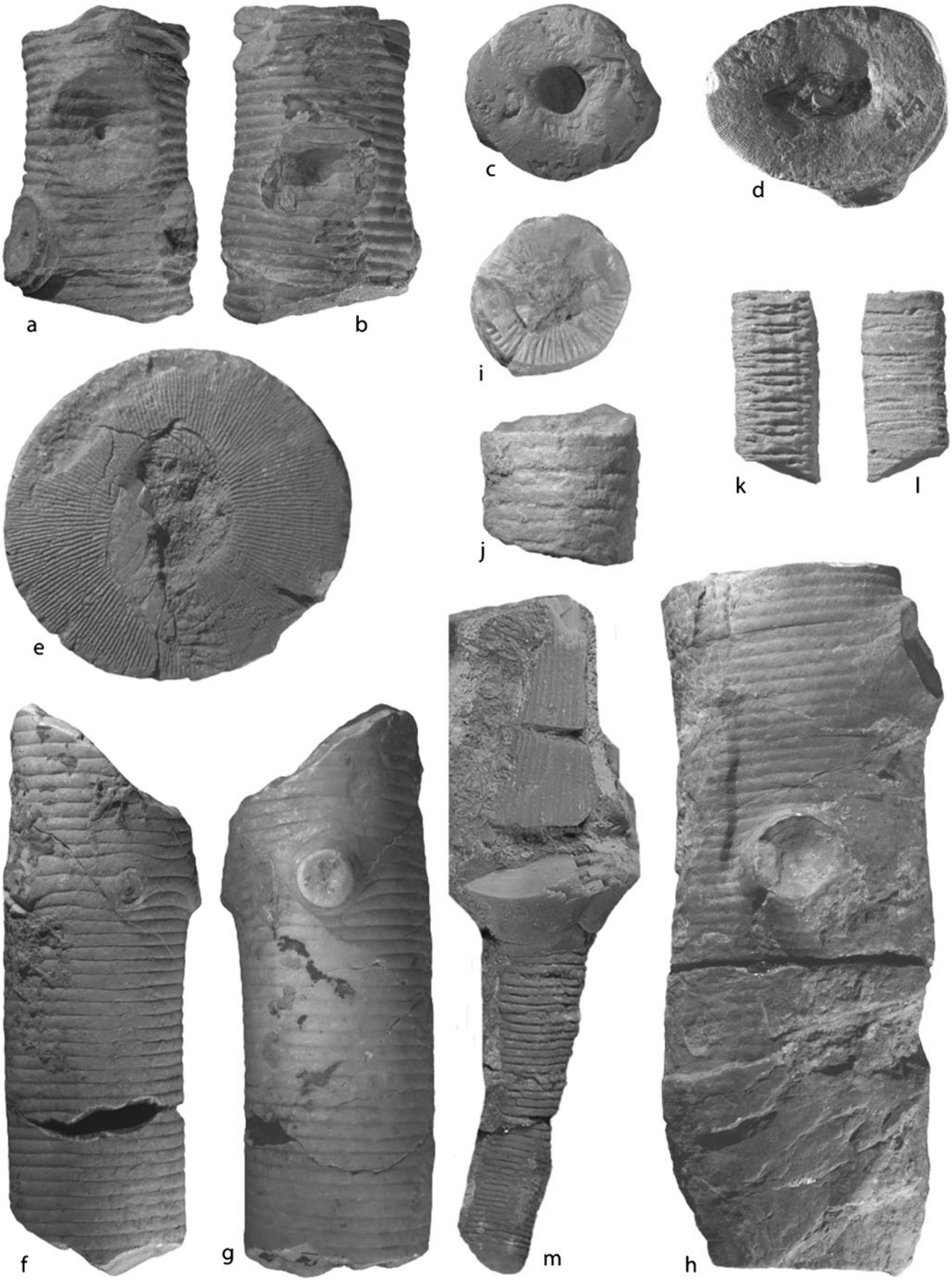
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Table 4 Measurements[a] for *Synbathocrinus dastanpouri* n. sp.

Anatomical parameters	Holotype	Paratype 1	Paratype 3
Cup length	4.8	4.5	1.5
Cup width	8.6	6.7	2.1
Basal circlet diameter	4.8	4	1.6
Radial length	4.2	3.5	
Radial width	5	3.6	
Stem facet diameter	2.7	2	1.5

[a] All measurements are given in millimetres

developed in very small juvenile specimens of *Synbathocrinus*, at or before a diameter of 2 mm, and is smaller than some of the specimens illustrated by Moore and Ewers. The specimens that Moore and Ewers (1942) considered to be juvenile growth stages of *S. texasensis* are here judged to be growth stages of five-armed specimens of one or more species of *Litocrinus* Lane and Sevastopulo, 1982.

Loose brachials probably belonging to *S. dastanpouri* are present in the disarticulated crinoid ossicles at several localities in the Howz-e-Dorah area. Some arm fragments consist of two or rarely three articulated brachials. Brachials are thick, uniserial, rectilinear plates with a medial longitudinal ridge, straight longitudinally and have a wide V-shape transversely; laterally, plates have two or three rectangular ridges and grooves extending from the exterior to the interior edges of the plate that would have intermeshed with brachials of the adjacent arms. The ambulacral groove is very wide V-shaped (obtuse angle), covering the entire interior of the plate. The brachials closely resemble *Synbathocrinus* brachials reported by various authors on crowns of Devonian (Springer 1923) to Permian age (Webster 1987).

The radial longitudinal ridge ornament on species of *Synbathocrinus* began in the Devonian with a broad rounded ridge on *S. michiganensis* Kesling and Smith 1963. In the Mississippian, *S. texasensis* Moore and Ewers, 1942 has a narrower longitudinal ridge. In the Permian of Timor and Western Australia, *S. constrictus* (Wanner 1916) has longitudinal ridges that may be a solid narrow elevation with or without nodes along the crest.

As compiled by Webster (2003), *Synbathocrinus* ranges from the Devonian—Permian. The earliest representatives are recognised in the Devonian of North America, and the genus is considered to be cosmopolitan in the equatorial belt in the Carboniferous. It was known in the Paleotethys only in the Permian (Webster 2003), although a Permian specimen from Vancouver Island of western Canada was questionably referred to the genus by Webster et al. (2009d). However, that specimen is part of the Wrangellian accreted terrane, probably originating to the west of the North American continent and may not have been in the Paleotethys. Webster et al. (2009d) considered the Permian fauna of Vancouver Island to have a greater affinity with North American faunas than with the Paleotethyan faunas. The Iranian Bashkirian occurrence of *Synbathocrinus* is the earliest record of the genus in the Paleotethys. *Synbathocrinus dastanpouri* may be ancestral to Permian taxa in Timor and Australia.

Material: Five specimens. Holotype EUI 8572, paratype 1 EUI 8573, and paratype 3 EUI 8575, locality 2; paratype 2 EUI 8574, locality 3; one specimen, locality 1.

Localities: 1, 2, 4. Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Order Cladida Moore and Laudon, 1943
Suborder Cyathocrinina Bather, 1899
Superfamily Cyathocrinitoidea Bassler, 1938
Family Barycrinidae Jaekel, 1918

øBarycrinidae indeterminate (Fig. 13i–l)

Description: Columnals pentameric, homeomorphic or heteromorphic (noditaxis N212). Lengths of pentameres: nodals 2 mm, large internodal 1 mm, small internodal 0.4 mm. Internally lateral ends of nodals and larger internodals divide into three prongs with the central prong smaller. Lateral ends of smaller internodals divide into two prongs. Prongs end with anastomosing ridges for articulation with adjacent pentameres. Crenularium occupies most of pentamere depth with narrow areola. Culmina medium width, rarely branch on distal end, few inserted medially. Symplexy articulation. Latus slightly concave.

Remarks: Among the four pluripentameres—each one sequence of pentameres from a pentameric pluricolumnal—of øBarycrinidae indeterminate, one is homeomorphic lacking a nodal whilst the others are heteromorphic including a nodal. All are slightly abraded or solution-weathered. This is the first report of a Pennsylvanian pentameric columnal and possibly represents a new genus. Pentameric columnals are known on several genera of camerates and cladids in the Ordovician, Silurian and Devonian. Mississippian pentameric columnals are known in the Barycrinidae Jaekel, 1918 on *Barycrinus* Wachsmuth in Meek and Worthen 1868. The column is holomeric or unknown on the other genera assigned to the Barycrinidae. Webster and Jell (1992) reported Early Permian pentameric columnals from Western Australia that they referred to the Barycrinidae. The Australian specimens have only two prongs on the lateral ends of the pentamere and lack the coarse anastomosing ridges on the ends of the prongs. They also probably represent a new genus. The Iranian specimens provide another link between North American Mississippian taxa and Permian taxa of the Paleotethys.

Material: 14 specimens. Figured specimens EUI 8576 and EUI 8577, unfigured specimen EUI 8578, and 11 additional pluripentameres.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Superfamily Codiacrinoidea Bather, 1890
Family Streblocrinidae Lane, 1967
Subfamily Streblocrininae Lane, 1967
Genus *Dichostreblocrinus* Weller, 1930

Dichostreblocrinus inaquosus n. sp. (Fig. 10q–v)

Etymology: From the Latin, meaning desert, in reference to the wadi where the specimens were found.
Diagnosis: Distinguished by a combination of less sharply pronounced linear ridges on basals, lower infrabasal circlet and roundly pentagonal outline in oral view.
Description: Thecae conical, longer (0.83 mm) than wide (0.62 mm), oral view roundly pentagonal outline, ornament finely pitted meshwork on all plates. Infrabasal circlet short, plates fused, pierced by fine axial canal, forms lower one-fifth of cup, steeply upflaring distally. Infrabasal/basal sutures recognizable more as faint depressions than marked plate boundaries. Basals 5, longer than wide, expanding gently distally, roundly inflated transversely, straight longitudinally incurving distally, faint central linear ridge longitudinally becoming pronounced with growth; posterior basal may bear anal depression on upper right corner. Orals 5, offset from basals, medially depressed, sharply upturned along sides forming ridges along sutures with adjacent basals; posterior oral largest, in contact with all four orals centrally, separates BC and DE orals, bears medially elevated node (hydropore?). Oral circlet moderately large, roundly elevated centrally, may overlap basals in larger specimens, forming approximately one-sixth of thecae.
Remarks: The holotype and paratype of *Dichostreblocrinus inaquosus* n. sp. are well preserved, but sutures are poorly defined. It is most similar to *D. scrobiculus* Weller, 1930; but linear ridges on the basals are less sharply pronounced, the infrabasal circlet forms a smaller proportion of the cup walls, and the oral circlet is more rounded. The proportions of the cup plates of *D. inaquosus* differ markedly from other species of the genus.
Material: Ten specimens. Holotype EUI 8579, paratype EUI 8580, and eight additional specimens.
Locality: 5, Shir Gesht, Pennsylvanian, early Bashkirian, Absheni Formation.

Subfamily Pentececrininae Lane, 1967
Genus *Lampadosocrinus* Strimple and Koenig, 1956

Lampadosocrinus stellatus n. sp. (Fig. 7q–v)

Etymology: For the stellate outline on larger forms.
Diagnosis: Distinguished by more sharply projecting orals forming a distinct pentastellate outline in oral view in larger forms.
Description: Cup conical, bearing pitted meshwork ornament with some alignment parallel to linear axis, with variation with growth: smaller specimens have a maximum width near oral surface approximately three-quarters of the length; larger specimens have a maximum width at oral surface slightly over four-fifths of the length. Infrabasal circlet approximately one-fifth of thecal length in small and large specimens. Basals slightly more than one-half the thecal length in small specimens and slightly more than two-fifths the thecal length in large specimens. Orals approximately one-third thecal length in small and large specimens. Thecal walls impressed along infrabasal/basal and basal/oral sutures. Orals with rounded projections in small specimens, rounded to pointed projections in large specimens; oral view outline roundly pentagonal in small specimens, pentalobate to pentastellate in large specimens. Infrabasals 5, 3, or fused, steeply upflaring, above circular stem facet, gently convex longitudinally, moderately convex transversely. Basals 5, longer than wide, moderately convex longitudinally and transversely, become more bulbous with growth. Orals 5, triangular, proximally expanding distally, distally subhorizontal narrowing to adjoin at centre of tegmen. Posterior oral largest, adjoins all others medially, separates BC and DE orals from adjoining medially. Anal pit at junction of BC and CD basals and C oral on some larger specimens. Orals offset 3º to 5º from basals. Oral circlet roundly inflated with flat summit, projecting abaxially beyond basals, forming maximum width of theca. Holotype theca length 1.01 mm, width 0.83 mm.
Remarks: *Lampadosocrinus stellatus* n. sp. is most similar to *L. frustulum* Strimple, 1979, differing by having a more pentastellate outline, which distinguishes it from all other species of the genus. Preservation of specimens is variable; many are crushed or skewed to one side and the ornamentation is weathered on many specimens. This is the earliest report of the genus from the Paleotethys realm and the second report from the Early Pennsylvanian. *Lampadosocrinus* is known from the Tournaisian of Ireland (Sevastopulo 2008), Mississippian (Osagean) and Pennsylvanian (Morrowan) from the USA, and the Permian (late Sakmarian or early Artinskian) of Western Australia as compiled by Webster (2003).
Material: 76 specimens: Holotype EUI 8581, and six specimens, locality 2; paratype EUI 8582, and 68 specimens, locality 1.
Localities: 1, 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Suborder Dendrocrinina Bather, 1899

Blothrocrinid indeterminate (Fig. 7n–p)

Description: Cup truncated medium cone; plates lack ornament. Infrabasal circlet low, maximum diameter 4.2 mm, proximally concave with impressed stem facet (2.4 mm diameter), distally steeply upflaring. Infrabasals 5, dart-shaped, visible length 1.6 mm, width 1.9 mm. Basals 5, gently convex longitudinally, moderately convex transversely, steeply upflared, form approximately one-half of cup wall; DE, EA, and AB basals hexagonal, slightly longer (3.2 mm) than wide (3 mm); BC and CD basals septagonal, equidimensional, 3.5 mm. Radials 5, gently convex longitudinally, moderately convex transversely, steeply upflared, of variable width and length: B radial 2.8 mm long, 3.5 mm wide; C radial 2.3 mm long, 2.8 mm wide; D radial 2.6 mm long, 3.9 mm wide; C radial truncated on proximal end for attaching to distal end of BC basal. D radial facet width 3.3 mm; peneplenary (ratio width/radial width 0.84), narrow interradial notches, but lateral edges of primibrachials may extend internally to abutt one another. Articular facet bears smooth narrow transverse ridge, deep-wide ligament pit sloped under transverse ridge, outer ligament furrow with short radiating ridges and grooves; inner half with narrow shallow intermuscular furrow lacking central pit, muscle areas deepest adjacent to intermuscular furrow, smooth rounded oblique ridges. Anals 3, menoplax 3 condition, primanal pentagonal, largest, length 2.5 mm, width 1 mm, resting on BC and CD basals, slightly notching under right side of secundanal. Secundanal hexagonal, length 1.5 mm, width 1.7 mm, distal one-third above radial summit. Tertanal not preserved, proximal tip horizontal, on primanal. Arms and tegmen unknown. Stem facet circular, bearing wide crenularium with coarse culmina. Lumen uncertain shape.
Remarks: The cup of Blothrocrinid indeterminate lacks most of the C and D infrabasals, A and E radials and tertanal. C and D radials are much narrower than the other radials. The narrower radials with narrow interradial notches show affinity with *Moscovicrinus*. The specimen is of insufficient quality to identify to genus.
Material: Figured specimen EUI 8583.
Locality: 5, Shir Gesht, Pennsylvanian, early Bashkirian, Absheni Formation.

Superfamily Cromyocrinoidea Bather, 1890
Family Cromyocrinidae Bather, 1890

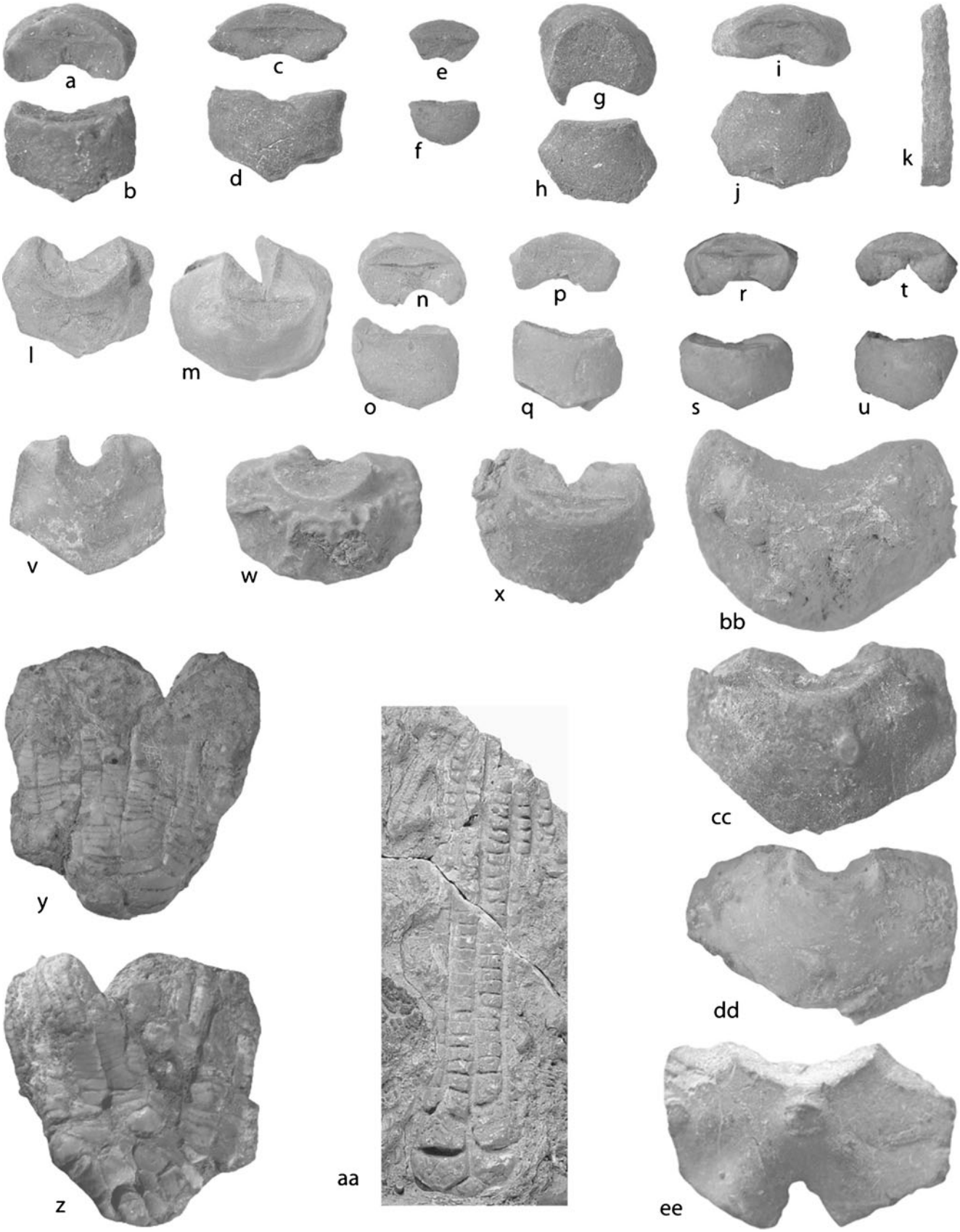
Cromyocrinidae indeterminate A (Fig. 14aa)

Description: Crown cylindrical, length 4 cm, width 1 cm. Cup medium bowl, coarse node ornament on cup plates and primibrachials. Sutures impressed. Radials subvertical, wider than long, gently convex longitudinally and transversely. Radial facets plenary. Primibrachials axillary, no distal branching, two arms per ray. Brachials rectilinear to faintly cuneate, wider than long.
Remarks: The crown of Cromyocrinidae indeterminate A is partially exposed, showing the distal part of the cup, arms of two rays and distal tip of the arms of a third ray. The two arms per ray that are exposed suggest there were a total of ten arms. The base of the cup is not exposed and presence of a basal invagination cannot be determined. Orientation of the crown as exposed does not allow determination of the number of anal plates. These factors preclude an unquestioned generic identification. Among the four genera of Early Pennsylvanian crinoids with ten uniserial arms, *Mooreocrinus* Wright and Strimple, 1945 is the only one with rectilinear brachials to which this specimen possibly belongs.
Material: Figured specimen EUI 8618.
Locality: 1 Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation

Cromyocrinidae indeterminate B (Fig. 6u)

Description: Partial set of biserial arms crushed, length 53 mm, width 48.5 mm. Brachials chisel-shaped in outer view with short wedge-shaped inner end interlocking with two opposing brachials; laterally rounded, bear small node on inner end immediately lateral to interlocking wedge, giving alternating longitudinal row of nodes along middle of arm. Irregular development of laterally directed coarser short blunt spine or node on outer margin of every fourth to ninth cuneate brachial. One slender elongate pinnule per brachial. Pinnulars slender, roundly convex transversely, straight longitudinally.

Fig. 14 **a**, **b** Advanced cladid radial indeterminate 1 EUI 8596, oral and lateral views. **c**, **d** Advanced cladid radial indeterminate 2 EUI 8597, oral and lateral views. **e**, **f** Advanced cladid radial indeterminate 3 EUI 8598, oral and lateral views. **g**, **h** Flexible radial indeterminate 1 EUI 8605, oral and lateral views. **l**, **j** Flexible radial indeterminate 2 EUI 8606, oral and lateral views. **k** *Archaeocidaris* sp., partial spine EUI 8612, lateral view. **l** Primitive cladid? radial indeterminate 1 EUI 8588, lateral view. **m** Primitive cladid? radial indeterminate 2 EUI 8589, lateral view. **n**, **o** Scytalocrinoidea? radial indeterminate 1 EUI 8599, oral and lateral views. **p**, **q** Scytalocrinoidea? radial indeterminate 1 EUI 8600, oral and lateral views. **r**, **s** Scytalocrinoidea? radial indeterminate 1 EUI 8601, oral and lateral views. **t**, **u**, Scytalocrinoidea? radial indeterminate 1 EUI 8602, oral and lateral views. **v**, Primitive cladid? radial indeterminate 4 EUI 8591, oral and lateral view. **w** Primitive cladid? radial indeterminate 5 EUI 8592, lateral view. **x** Primitive cladid? radial indeterminate 7 EUI 8597, lateral view. **y**, **z** *Alcimocrinus*? *mediaensis* n. sp., crown, holotype EUI 8587, AB-interray and C-ray views. **aa** Cromyocrinid indeterminate A, Crown EUI 8618, lateral view. **bb** Primitive cladid? radial indeterminate 6 EUI 8593, lateral view of weathered specimen. **cc** Primitive cladid? radial indeterminate 6 EUI 8594, lateral view. **dd** Primitive cladid? radial indeterminate 3 EUI 8590, lateral view. **ee** Monobathrid? radial indeterminate EUI 8544, lateral view of partial specimen. All fig parts, ×2, with the exception of *Alcimocrinus*, ×1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Remarks: There are seven arms on one side of the set of arms of Cromyocrinidae indeterminate, and parts of four arms on the opposite side, for a minimum of 11 arms in total. Weathering has destroyed most of the arms on the side with four arms. There were probably a total of 16–20 arms on the original specimen. The arms are similar to biserial arms of *Parethelocrinus rectilatus* (Lane and Webster 1966) from the Early Permian of southern Nevada and to other Pennsylvanian cromyocrinids. However, nodes or spines on the brachials are not recognised on the described cromyocrinids.
Material: Figured specimen EUI 8528, float; found by M. Kebria-ee.
Locality: 6, Permian, Chah-Reiseh area, central Iran.

Superfamily Zeacrinitoidea Bassler and Moodey, 1943
Family Zeacrinitidae Bassler and Moodey, 1943
Genus *Alcimocrinus* Kirk, 1938

Alcimocrinus? *mediaensis* n. sp. (Fig. 14y, z)

2001 *Zeacrinites*? n. sp. Webster et al., p. 110, p. 2, figs. R, S.

Etymology: From the Latin, *medius*, meaning middle, referring to the Middle East where the specimen was found.
Diagnosis: Distinguished by rectilinear to weakly cuneate brachials, two anals in the cup.
Description: Crown ovate, crushed normal to plane of D-ray/AB-interray, length 50.8 mm, width 46.5 mm, arms splayed. Cup discoid with deep basal invagination, plates smooth, estimated length 6 mm, maximum width 16.5 mm, minimum width 11.9 mm, 14.2 mm average. Infrabasals downflared, confined to basal invagination, not visible in lateral view, covered by proximal stem. Basals 5, hexagonal (except CD basal septagonal), length uncertain, minimum 5.6 mm, width 5.5 mm), gently convex transversely, moderately convex longitudinally, downflared proximally, subhorizontal medially, with slightly upflared distal tips; forms base of cup. CD basal largest, estimated length 5.3 mm, width 4.8 mm, extended well into radial circlet, truncated distally for secundanal. Radials 5, pentagonal, length 5.7 mm, width 10 mm, gently convex longitudinally, strongly convex transversely, outflaring, proximal tips in basal plane. Radial facets plenary, gently declivate. Anals 2 (possibly 3), in line of radials. Larger primanal adjoining C radial, BC and CD basals, secundanal, and uncertain number of additional plates; notched under lower right three-fifths of smaller secundanal. Secundanal longer than wide, adjoining primanal, CD basal, D radial, unknown additional plates. Brachials uniserial, rectilinear to faintly cuneate, much wider than long, gently convex transversely, slightly convex to straight longitudinally. Arms uniserial, branching isotomously on primibrachials 2, endotomously on secundibrachials 4 or 6, tertibrachial 8, and one more distal branching. Two primibrachials per ray in D, E, and A rays. Four to six secundibrachials per half-ray. Eight tertibrachials on inner half of each half-ray. Stem transversely circular, diameter 4.1 mm, heteromorphic. Noditaxis N212 minimal. Columnals with narrow circular lumen, convex latus. Tegmen and pinnules not exposed; distal stem unknown.
Remarks: Generic assignment of *Alcimocrinus*? *mediaensis* n. sp. is questioned because the specimen lacks the distal biserial brachials common to *Alcimocrinus* and may have only two anals in the cup. The specimen cannot be assigned to other genera of the Zeacrinitidae because they all have a single primibrachial or the A-ray has three or more primibrachials. The specimen may represent a new genus.

Compaction of the crown resulted in an inward crushing along the anal/C radial suture and slight splaying of the arms. Crushing and slight dislocation of plates have masked the distal end of the primanal, which probably projected above the radial summit. The secundanal is nearly out of the cup, with only a narrow suture with the distally projected tip of the CD basal. The B- and C-ray arms were lost along with a part of the A-ray arms. Some crushing distorted the proximal parts of these arms prior to exposure.
Material: Holotype EUI 8587.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Primitive Cladid? radial indeterminate 1 (Fig. 14l)

Description: Radial pentagonal, wider (14 mm) than long (11.2 mm), widest at distal end of radial/radial sutures, moderately thickened under radial facet, gently concave longitudinally, gently convex transversely, ornamented with widely rounded stellate ridges to adjacent plates and shallow apical depressions; radial/radial and radial/basal sutures denticulate along aboral half. Wide interradial notches with sharp angular ridge continuing onto adjoining radial. Radial facet bifascial, concave, crescent-shaped, wider (10.5 mm) than deep (6.6 mm), angustary to peneplenary, width/radial width 0.75, strongly declivate. Facet morphology with transverse ridge a wide obtuse angle of approximately 170º, formed of anastomosing ridges and central gap, not full width of facet; no ligament pit; outer ligament furrow moderately wide; outer marginal ridge sharply angular; no central pit; muscle areas concave, wider than deep; rounded ambulacral groove wide.
Remarks: Preservation of the five specimens of Primitive Cladid radial indeterminate 1 is generally good, but two specimens are broken along the cleavage planes along the side and base. Three of the specimens are asymmetrical, with the radial facet slanted (two to the left, one to the right). These specimens are probably the

D and C radials, respectively, whereas the two symmetrical specimens are E, A or B radials. A basal plate with basal/radial articular surfaces matches the curvature morphology of the gentle stellate ridges and is probably conspecific with these radials. The large size, morphology and curvature of the plates suggest they were part of a large bowl- or cone-shaped cup of a primitive cladid, possibly a poteriocrinitid as restricted by Webster et al. (2003).
Material: Figured specimen EUI 8588, nine others and one basal plate.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Primitive Cladid? radial indeterminate 2 (Fig. 14m)

Description: Radial roundly pentagonal, wider (15 mm) than long (8.2 mm), moderately thick (4 mm centrally), asymmetrical with radial facet strongly skewed left, left interradial notch much wider than right interradial notch, strongly convex longitudinally and transversely; ornamented with exceedingly fine granules, widely rounded single stellate ridges to adjacent plates and moderate apical depressions; radial/radial and radial/basal articular facets slightly concave to slightly convex. Plate appears crenulated from basal view. Wide interradial notches rounding inward. Radial facet trifascial, strongly concave, tear-drop shaped, slightly wider (8.4 mm) than deep (8 mm), angustary, width/radial width ratio 0.56, strongly declivate. Facet morphology with straight transverse ridge with short central gap, approximately 80% of facet width; ligament pit shallow, sloping under transverse ridge; outer ligament furrow wide, concave; outer marginal ridge roundly angular; central pit in intermuscular furrow not preserved if present; muscle areas concave, deep; ambularcal groove narrow, elongate V-shaped.
Remarks: Preservation of the specimen of Primitive Cladid? radial indeterminate 2 is generally good, but solution-weathering has destroyed some details of the radial facet morphology. The asymmetry with the facet skewed to the left suggests the specimen is the D radial. The large size, facet morphology, and curvature of the plate suggest that it was part of a moderately large bowl-shaped cup of a primitive cladid. Radial facet morphology has differentially weathered into growth rings in the muscle areas, showing up to four major rings with minor rings between some of the four. Internally, the plate shows six major growth rings. Shape of the plate is similar to that of some glossocrinids.
Material: Figured specimen EUI 8589.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Primitive Cladid? radial indeterminate 3 (Fig. 14dd)

Description: Radial pentagonal, wider (26.4 mm) than long (17 mm), thick (4 mm centrally), asymmetrical with left interradial notch much narrower than right interradial notch, gently concave to convex longitudinally, moderately convex transversely; ornamented with medium granules, gently rounded single stellate ridges to adjacent plates, shallow apical depressions and coarse spine or large node below middle of radial facet; radial/radial and radial/basal articular surfaces weathered. Radial facet bifascial, gently concave, crescentic, more than twice as wide (13.2 mm) as deep (6.2 mm), angustary (width/radial width ratio 0.5), moderately declivate. Facet morphology with transverse ridge a wide obtuse angle of approximately 170º and a central gap, positioned in front of the full width of facet; no ligament pit; outer ligament furrow narrow, concave; outer marginal ridge denticulate; central pit and intermuscular furrow not preserved if present; muscle areas shallowly concave, narrow; ambulacral groove wide, open V-shaped.
Remarks: Preservation of the specimen of Primitive Cladid? radial indeterminate 3 is moderate, with solution-weathering having destroyed part of the details of the radial facet morphology and the marginal edges of the plate, including a V-shaped notch in the proximal apical part of the plate. Thus, all measurements are minimal. The asymmetry of the plate may be exaggerated by differential weathering. The central spine or node below the radial facet is broken off. The large size, facet morphology and curvature of the plate suggest that it was part of a large bowl- or cone-shaped cup of a primitive cladid with the proximal arms outflaring. There are two adoral grooves on the interior side of the plate below the radial facet leading into the cup. This indicates that the arms branched a short distance above the radial, perhaps on primibrachial 1 or 2. The shape of the plate and ornamentation suggest affinity with primitive dendrocrinids.
Material: Figured radial EUI 8590.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Primitive Cladid? radial indeterminate 4 (Fig. 14v)

Description: Radial pentagonal, length 13 mm, width 14.4 mm, thin, widest at base radial/radial facets narrowing slightly distally, straight longitudinally, gently convex transversely, moderately incurved distally along wide interradial notches; ornament of three gentle ridges extending from base radial facet to apices with basal plates. Radial facet bifascial, asymmetrical, horseshoe shape, gently concave, slightly longer (6.4 mm) than wide (6.3 mm), angustary (ratio width/radial width 0.43), subvertical. Radial facet morphology poorly preserved; transverse ridge straight, low, at proximal edge of U-shaped adoral groove; wide outer ligament furrow, no ligament pit or central pit, muscle areas moderately deep.

Remarks: The nearly equidimensional plate, longer radial facet and ridge ornament extending to the apices of the basal plate distinguish Primitive Cladid? radial indeterminate 4 from Primitive Cladid? radial indeterminate 1 and 2. The shape of the plate suggests that the cup was a medium or high cone. The position and orientation of the radial facet suggest that the base of the arms projected laterally in the enclosed position. The asymmetry of the radial facet suggests that the plate is the C radial. The faint ridges and shape of the plate resemble the radial of some botryocrinids.
Material: Figured specimen EUI 8591.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Primitive Cladid? radial indeterminate 5 (Fig. 14w)

Description: Radial pentagonal, length 13 mm, width 17.8 mm, thick (6.6 mm below radial facet), widest at midpoint of radial/radial facets narrowing slightly distally, strongly convex longitudinally and transversely, moderately incurved distally along wide interradial notches; ornament of four irregular sharp ridges extending from margin of radial facet to centre of adjacent plates and moderately wide apical pits. Radial facet symmetrical, elliptical, wider (9.6 mm) than deep (7.5 mm), gently concave, angustary (ratio width/radial width 0.73), steeply declivate. Radial facet bifascial, morphology poorly preserved; full-width transverse ridge straight with narrow central gap, low; wide outer marginal area; no ligament pit or central pit; muscle areas nearly mirror image of outer marginal area.
Remarks: The ornamentation and elliptical radial facet distinguish Primitive Cladid? radial indeterminate 5 from the other primitive cladid radials. The shape of the plate and ornamentation suggest affinity with primitive dendrocrinids.
Material: Figured specimen EUI 8592.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Primitive Cladid? radial indeterminate 6 (Fig. 14bb, cc)

Description: Radial hexagonal, wider (25 mm) than long (14.4 mm), slightly convex longitudinally, strongly convex transversely, moderately thick medially thinning to proximal and lateral edges; ornament of spaced medium granules, four coarse nodes paralleling radial facet, and gentle medial ridges to adjoining basals and radials with shallow apical pits; radial/radial and radial/basal articular surfaces with short crenularium along outer margin. Radial facet concave, semicircular, width 12.4 mm, depth 8.4 mm, angustary (ratio width/radial width 0.5), strongly declivate. Radial facet bifascial; morphology includes wide straight transverse ridge full width of facet with central gap, no ligament pit, wide outer marginal area, denticulate marginal ridge, central pit not distinguishable from intermuscular furrow, wider than deep muscle areas, wide rounded adoral groove.
Remarks: Weathering has destroyed or masked smaller details of the facet morphology and much of the granular ornament of Primitive Cladid? radial indeterminate 6. A second specimen has more prominent nodes and medial ridges but is solution-weathered and encrusted with caliche masking the granular ornament. Primitive Cladid radial indeterminate 6 differs from the other Primitive Cladid radials indeterminate by combination of the plate thickness, ornament and facet morphology. The large size and convexity of the plate suggest it was part of a bowl-shaped cup, possibly a dendrocrinid, with the base of the arms outflared in the enclosed position.
Material: Figured specimens EUI 8593, 8594.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Primitive Cladid? radial indeterminate 7 (Fig. 14x)

Description: Radial pentagonal, wider (16.7 mm) than long (13.8 mm), straight longitudinally, moderately convex transversely, moderately thick medially (5 mm) thinning to proximal and lateral edges; no ornament. Radial facet trifacial, concave, elliptical, width 11.7 mm, depth 5.9 mm, angustary (ratio width/radial width 0.7), strongly declivate. Radial facet bears straight transverse ridge not extending full width of radial and with small central adoral and aboral expansion, distinct ligament pit sloping under transverse ridge, wide outer marginal furrow, rimmed outer margin, central pit and narrow intermuscular furrow and widely upflaring muscle fields.
Remarks: The specimen of Primitive Cladid? radial indeterminate 7 is well preserved except for solution-weathering along the radial/radial and radial/basal facets. It is most similar to Primitive Cladid? radial indeterminate 2, differing by having a relatively wider and less deep radial facet that is symmetrical. The shape of the plate and lack of ornamentation suggest affinity with some primitive dendrocrinids.
Material: Figured specimen EUI 8595.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Advanced Cladid radial indeterminate 1 (Fig. 14a, b)

Description: Radial pentagonal, symmetrical, length 7.9 mm, width 12.1 mm, moderately thick, slightly concave longitudinally, strongly convex transversely; coarse granular ornament in medial part of radial. Radial facet trifascial, plenary, semicircular, gently concave transversely, gently declivate. Facet morphology includes straight transverse

ridge, deep ligament pit, wide outer ligament furrow, sharp outer margin ridge, shallow central pit, wide intermuscular furrow, broad gently concave muscle fields, wide obtuse intermuscular notch.
Remarks: Weathering has slightly increased the depth of the ligament pit and enhanced the appearance of the coarse granular ornament on Advanced Cladid radial indeterminate 1. The shape and radial facet are similar to a number of advanced dendrocrinids, such as some scytalocrinids, aphelecrinids and erisocrinids.
Material: Figured specimen EUI 8596, one additional specimen.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Advanced Cladid radial indeterminate 2 (Fig. 14c, d)

Description: Radial pentagonal, slightly asymmetrical, length 7.3 mm, width 12.4 mm, moderately thin plate, slightly convex longitudinally, gently convex transversely. Medium granule ornament. Radial facet trifacsial, elliptical, no interradial notch on right side, narrow interradial notch on left side. Facet 11.1 mm wide, peneplenary (ratio width/radial width 0.9), 5 mm deep, subhorizontal; transverse ridge straight, narrow; shallow ligament pit, narrow, sloping inward; outer ligament furrow moderately wide, sharp outer margin ridge; moderately deep muscle fields.
Remarks: The facet is weathered and morphological features are partly modified or lost on Advanced Cladid radial indeterminate 2. Plate asymmetry suggests that it is the C radial with the presence of the interradial notch on the left side but not on the right side. Radial facet and plate shape are similar to some laudonocrinids and pachylocrinids.
Material: Figured specimen EUI 8597.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Advanced Cladid radial indeterminate 3 (Fig. 14e, f)

Description: Radial pentagonal, length 4.4 mm, width 6.6 mm, thickness 3.2 mm, slightly asymmetrical with right radial/radial suture shorter than left, moderately convex longitudinally and transversely, no ornament; radial/radial and radial/basal articular surfaces slightly concave, smooth. Radial facet wedge-shaped, plenary, depth 3.3 mm, symmetrical, subhorizontal. Facet morphology trifascial with full-width straight transverse ridge, shallow narrow ligament pit sloping under transverse ridge; narrow outer marginal area; denticulate marginal ridge inset from outer side of plate; muscle areas large, concave, deep; adoral groove wide obtuse angle.
Remarks: Advanced Cladid radial indeterminate 3 is well preserved and was probably the D radial of a moderately low-bowl-shaped cup. The thickness, plate shape and radial facet morphology and shape are similar to those of some genera of the erisocrinids.
Material: Figured specimen EUI 8598.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Scytalocrinoidea? radials indeterminate (Fig. 14n–u)

Description: Radial pentagonal, wider (10 mm) than long (7.4 mm), moderately thick, slightly convex longitudinally, strongly convex transversely, coarse granule ornament. Narrow interradial notches. Radial facet elliptical, width 7.9 mm, depth 5 mm, slightly declivate, peneplenary (ratio width/width radial 0.79). Facet morphology with straight transverse ridge tapering to distal ends slightly in front of widest part of facet; deep wide ligament pit sloping slightly under transverse ridge; outer ligament furrow moderately wide; outer marginal ridge sharp, forming slightly obtuse angle with cup wall; central pit wider than short intermuscular furrow; muscle areas concave, wide, deeper than outer ligament furrow; ambularcal groove moderately wide V-shape. Facets with other cup plates concave.
Remarks: The specimens of Scytalocrinoidea? radials indeterminate are advanced cladids. Three of the four specimens of Advanced Cladid Scytalocrinoidea? radials indeterminate are symmetrical (E, A or B radials), and one is slightly asymmetrical with the radial facet skewed to the left (D radial). The granular ornament preservation ranges from poor to lost on the asymmetrical specimen. The measured specimen has a small crinoid holdfast attached on the right radial-basal articular surface and interior of the plate. The radial facet is similar to that illustrated by Moore and Teichert (1978, fig. 425, no. 3f) for *Moscovicrinus multiplex* (Trautschold 1867). These radials were parts of cups with a moderately high bowl or conical shape as the proximal tip is not incurved. The peneplenary radial facet is a primitive feature of most cladids. The specimens are considered to be an indeterminate scytalocrinacid, perhaps a blothrocrinid.
Material: Four specimens: figured specimens EUI 8599–8602.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Camerate or cladid radials indeterminate (unfigured)

Remarks: Broken fragments and weathered radials include a minimum of eight additional taxa differing significantly in terms of plate shape and radial facet morphology from described camerate and cladid radials. These specimens are too fragmentary or weathered for proper description. Most are probably primitive cladids with angustary radial facets,

wide interradial notches and strongly declivate to subvertical radial facets. They are unfigured, but mentioned for completeness of the fauna.
Material: 16 specimens: lot EUI 8621, seven specimens; lot EUI 8622, nine specimens.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Order Taxocrinida Springer, 1913

Flexible radial indeterminate 1 (Fig. 14g, h)

Description: Radial hexagonal, asymmetrical, wider (9.8 mm) than long (7.1 mm), basal facet subhorizontal, left radial suture longer (6.5 mm) than right suture (5.3 mm), strongly convex tranversely, straight longitudinally, no ornament. Radial facet semicircular, on projected platform, strongly declivate, width 7.5 mm, depth 5.5 mm, narrow denticulate rim. Patelloid process, width 5 mm, length 0.3 mm.
Remarks: The declivate radial facet on a projected platform suggests that the arms were widely spreading on the crown of Flexible radial indeterminate 1. The subhorizontal basal facet and unequal length of the two radial sutures suggest that this is the C radial, with the longer left facet adjoining an extended posterior basal or an anal plate. There are no apparent sutures on the shoulders of the extended neck of the radial facet, suggesting that the arms were free of the interray plates or had flexible sutures.
Material: Figured specimen EUI 8605
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Flexible radial indeterminate 2 (Fig. 14i, j)

Description: Radial septagonal, slightly asymmetrical, wider (12.6 mm) than long (8.9 mm), moderately convex transversely, slightly convex longitudinally, right radial/basal suture 5.4 mm, left radial/basal suture 4.9 mm, radial/radial sutures equal, 5 mm, ornament of broad low granules. Radial facet crescent-shaped, subhorizontal, width 8.7 mm, depth 4.2 mm. Patelloid process, width5.1 mm, length 0.8 mm.
Remarks: The strong convexity of the radial and the subhorizontal radial facet suggests that the crown of Flexible radial indeterminate 2 would have had an elongate shape, with the arms protruded at least in the cup region but not widely flaring as suggested for Flexible indeterminate 1. The slight asymmetry of the plate suggests it is the B or E radial. A second specimen considered to be conspecific is slightly smaller, although weathered and partly covered by caliche, has the same ornament, is more asymmetrical and considered to be the D radial of another specimen.
Material: Two specimens: Figured specimen EUI 8606 and one additional.
Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Genus *Rhysocamax* Moore and Jeffords, 1968

øRhysocamax magnificus n. sp. (Fig. 13a–h)

Etymology: From the Latin meaning noble or splendid and refers to the large size
Diagnosis: A *Rhysocamax* distinguished by gently convex unornamented latus, very small scalloping sutures, and cirri overlapping up to five columnals on either side of columnal bearing cirral canal.
Description: Columnals large, length 2.6 mm average, diameter 32.4–36.1 mm, crenularium extends full facet width, no areola; lumen large, circular, diameter 8.5 mm. Crenellae very fine, inserted or branching once or twice (rarely) distally. Symplexy articulation; very small scalloped sutures. Latus gently convex, no ornament. Single or multiple cirri (up to 4 in 1 circlet), large, 15.4 mm diameter at attachment facet, overlapping four or five adjacent columnals either side of columnal bearing circular cirral canal. Cirri morphology same as columnals, but cirri diameters tapering distally.
Remarks: All specimens of *øRhysocamax magnificus* n. sp. are part of the distal column bearing large and abundant cirri for attachment in the limestone or shale matrix in which they were found. The six specimens from limestone and marl beds below the crinoidal horizon at locality 2 are not crushed, whereas, the eight pluricolumnals that are part of a single column from shales at locality 1 below the crinoidal horizon are distorted into elliptical cross-sections.

The three species of *øRhysocamax* (*øR. cristata*, *øR. grandis* and *øR. tuberculata*) described by Moore and Jeffords (1968) are from the Osagean Burlington Limestone of Iowa. All have larger scalloping of the sutures and ornamented latera. This extends the stratigraphic range of *øRhysocamax* into the Pennsylvanian and the palaeogeographic distribution into northern Gondwana and Iran.
Material: Six specimens. five specimens: holotype EUI 8607 and paratypes 1–3 EUI 8608-8609, locality 2. Paratype 4 EUI 8610, specimen in eight pieces, shales at base of locality 1.
Localities: 1, 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation

"Blade" cirri? indeterminate (Fig. 12q–w)

Description: Specimens small, 0.3–1 mm in length and width. In lateral view, square to more commonly rectangular, wider than long, rarely longer than wide, with square or rounded corners. In oral view, elongate elliptical, widest centrally, tapering distally to rounded

or rarely nearly sharp ends; rarely flat or slightly concave on one side. Articular facets flush or more commonly slightly elevated, circular, occupy approximately one-third to one-half the width of oral or aboral ends. Facet with poorly developed crenularium approximately three-fifths of radius, planar areola approximately one-quarter of radius, and small circular lumen. Surface with microgranules.

Remarks: The small size of the specimens of "Blade" cirri? indeterminate suggests they are cirri, not columnals. Most cirri and columnals of short to long lengths are circular, pentagonal or elliptical in cross-section. In contrast, these specimens resemble a section cut out of a double-edged sword with a facet on both ends. Specimens with one side flat or slightly concave probably grew in a restricted environment, flat side on substrate.

Material: 239 specimens: Figured specimens EUI 8584, 8585, 233 additional specimens, locality 2. Four specimens, locality 1.

Localities: 1, 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Class Echinoidea Leske, 1778
Subclass Perischoechinoidea M'Coy, 1849
Family Archaeocidaridae M'Coy, 1844
Genus *Archaeocidaris* M'Coy, 1844

Archaeocidaris sp. (Fig. 14k)

Remarks: Fragments of weathered or abraded round spine shafts assigned to *Archaeocidaris* sp. expand medially, then taper to the distal tip. They bear abundant nodes, which occur randomly or in spirals. Weathered and fragmentary spine-bearing interambulacal plates are also present in the 2- to 5-mm fraction of samples from localities 1, 2, 3 and 5. Specimens are assigned to *Archaeocidaris* because they are similar to described Carboniferous *Archaeocidaris* ossicles. Lacking the corona, they are left in open nomenclature.

Material: Figured specimen EUI 8612, and 12 additional specimens, locality 2.

Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

Subhylum Asterozoa Zittel, 1895
Class Stelleroidea Lamarck, 1816
Subclass Ophiuroidea Gray, 1840

Ophiuroidea? Order, Family, and Genus uncertain (Fig. 8u)

Remarks: A single specimen lacking critical parts for identification (Dan Blake, personal communication, 18/12/09) is questionably referred to the ophiuroids. Preservation of the specimen precludes identification beyond assigning it to Ophiuroidea? Order, family, and genus uncertain. Starfish ossicles are present in the <2 mm size fraction from localities 1, 2, 3 and 5.

Material: Figured specimen EUI 8613.

Locality: 2, Howz-e-Dorah, Pennsylvanian, early Bashkirian, Absheni Formation.

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Appendix

Table 5 Howz-e-Dorah, characters of radials <2 mm

Radial Number	Length>Width	Length~Width	Width>Length	Unornamented	Ornamented	Apical Pits	Plate thin	Plate moderately thick	Plate thick	Facet angustary	Facet peneplenary	Facet plenary
1			X	X				X		X		
2			X	X				X		X		
3			X	X				X		X		
4			X	X				X		X		
5		X		X				X		X		
6			X	X				X		X		
7			X		X			X		X		
8			X	X				X		X		
9			X	X				X		X		
10			X	X				X		X		
11			X	X				X		X		

Table 5 (continued)

Radial Number	Length>Width	Length~ Width	Width>Length	Unornamented	Ornamented	Apical Pits	Plate thin	Plate moderately thick	Plate thick	Facet angustary	Facet peneplenary	Facet plenary
12			X		X		X			X		
13			X	X			X			X		
14	X				X				X	X		
15			X	X			X			X		
16			X	X			X			X		
17			X	X					X		X	
18			X	X				X			X	
19			X	X				X			X	
20		?		X				X		X		
21	X			X					X	X		
22			X	X			X			X		
23			X	X				X		X		
24			X	X		X		X			X	
25			X		X	X	X				X	
26			X	X				X			X	
27			X		X			X			X	
28			X	X				X				X
29		X			X			X			X	
30			X	X				X				X
31			X	X				X			X	
32		X		X		X			X		X	
33			X	X			X				X	
34		X		X			X				X	
35			X	X					X			
36			X		X	X		X			X	
37			X	X					X			
38			X	X			X				X	
39	X				X				X		X	
40	X				X				X	NA		
41	X				X				X	NA		X
42	X				X				X			
43	X				X			X		NA		X
44			X	X		X	X					X
Total	7	5	32	32	12	5	10	24	10	20	15	5

Radial Number	Peneplenary/ Plenary	Facet simple	Facet bifascial	Facet trifascial	Facet inclinate	Facet horizontal	Facet gently declivate	Facet strongly declivate	Facet flush	Facet on platform	Facet on stalk	Patelloid notch	Number of specimens
1			X					X			X		1
2		X						X			X		2
3				X				X			X		1
4			X					X		X			1
5		X						X		X			1
6		X						X			X		1
7		X					X				X		1
8			X					X			X		1
9			X					X			X		1
10				X				X		X			1
11				X				X			X		1
12			X					X		X			1
13				X				X			X		1
14		X			X				X				1
15		X						X		X			1
16		X						X			X		1
17		X					X		X				1
18				X				X		X			1
19			X					X			X		1
20		X						X		X			1
21		X						X		X			1
22			X					X		X			1

Table 5 (continued)

Radial Number	Peneplenary/ Plenary	Facet simple	Facet bifascial	Facet trifascial	Facet inclinate	Facet horizontal	Facet gently declivate	Facet strongly declivate	Facet flush	Facet on platform	Facet on stalk	Patelloid notch	Number of specimens
23				X				X		X			1
24				X				X		X			1
25				X			X			X			4
26				X			X			X			1
27				X				X	X				1
28		X						X		X			1
29				X			X		X				1
30		X					X		X				1
31				X				X		X			1
32				X				X		X			1
33			X					X		X			1
34				X			X		X				1
35				X		X			X				1
36				X				X		X		X	4
37	X			X				X		X			29
38			X				X			X			1
39		X				X			X				1
40		NA				X			X				2
41		NA				X			X				2
42			X			X			X				2
43		X				X			X				1
44				X				X		X			1
Total	1	14	10	18	1	6	8	29	12	21	11	1	82

Table 6 Howz-e-Dorah, characters of radials 2 mm - 5 mm

Radial Number	Length>Width	Length~ Width	Width>Length	Unornamented	Ornamented	Apical Pits	Plate thin	Plate moderately thick	Plate thick	Facet angustary	Facet peneplenary	Facet plenary
1		X			X			X		X		
2			X	X				X		X		
3			X		X				X	X		
4			X	X			X			X		
5		X			X	X		X		X		
6			X	X					X	X		
7		X		X					X	X		
8	X			X					X			X
9		X			X			X		X		
10			X	X				X				X
11			X		X			X			X	
12			X		X				X			X
13		X			X			X		X		
14		X			X				X	X		
15			X		X			X		X		
16		X			X				X	X		
17		X		X					X	X		
18			X		X			X				X
19			X	X		X			X		X	
20			X		X				X			X
21			X	X					X		X	
22			X	X				X				X
23			X		X			X			X	
24			X	X				X			X	
25			X		X		X				X	
26			X		X		X			X		

Table 6 (continued)

Radial Number	Length>Width	Length~ Width	Width>Length	Unornamented	Ornamented	Apical Pits	Plate thin	Plate moderately thick	Plate thick	Facet angustary	Facet peneplenary	Facet plenary
27		X			X					X		
28			X	X					X	X		
29			X		X		X			X		
30			X	X				X			X	
31			X		X		X					X
32			X		X		X			X		
33	X			X		X			X			X
34			X		X				X		X	
35			X		X				X		X	
36			X		X		X					X
37		X			X				X	X		
38			X	X			X			X		
39			X		X				X	X		
40		X		X			X				X	
41			X		X			X				X
42			X		X				X		X	
43			X	X					X			X
44			X		X				X			
45		X		X					X	X		
46			X	X					X			X
47			X		X				X		X	
48			X		X		X				X	
49		X			X				X	X		
Total	2	13	34	19	30	3	10	14	25	23	13	12

Radial Number	Peneplenary/ Plenary	Facet simple	Facet bifascial	Facet trifascial	Facet inclinate	Facet horizontal	Facet gently declivate	Facet strongly declivate	Facet flush	Facet on platform	Facet on stalk	Patelloid notch	Number of specimens
1			X					X			X		2
2		X						X			X		2
3		X						X		X			2
4		X					X			X			1
5		X						X		X			1
6		X						X	X				2
7				X				X		X			1
8				X		X			X				2
9			?					X					1
10				X		X			X		X		1
11				X		X			X				3
12				X			X		X				1
13			X					X		X			1
14			?					X		X			2
15			X				X			X			1
16			X							X			1
17			X				X	X		X			1
18		X				X			X			X	2
19				X			X		X				1
20				X				X		X			1
21				X	X				X				1
22				X		X			X				1
23				X	X					X			1
24		X			X				X				1
25			X					X		X			1
26		X			X				X				1
27		X						X		X			1
28		X					X			X			1
29		X						X		X			1

Table 6 (continued)

Radial Number	Peneplenary/ Plenary	Facet simple	Facet bifascial	Facet trifascial	Facet inclinate	Facet horizontal	Facet gently declivate	Facet strongly declivate	Facet flush	Facet on platform	Facet on stalk	Patelloid notch	Number of specimens
30		X				X			X				1
31		X				X			X			X	1
32		X					X				X		1
33				X		X			X				1
34				X			X			X			2
35				X				X		X			5
36			X			X			X			X	1
37		X						X			X		2
38			X					X			X		1
39		X						X		X			1
40		X				X			X			X	1
41		X				X			X			X	1
42				X			X			X			1
43		X				X			X			X	1
44	X			X			X			X			15
45		X				X			X				1
46				X			X		X				1
47				X			X			X			1
48				X		X				X			3
49		X				X			X				1
Total	1	21	10	18	4	15	12	18	21	22	6	6	80

Table 7 Howz-e-Dorah, characters of radials >5 mm

Radial Number	Length>Width	Length~ Width	Width>Length	Unornamented	Ornamented	Plate thin	Plate moderately thick	Plate thick	Facet angustary	Facet peneplenary
1			X		X		X		X	
2			X	X				X	X	
3			X	X			X		X	
4	?			X				X		X
5			?		X		X		X	
6			?	X			X		X	
7			X		X		X		X	
8			X	X			X		X	
9			X	X		X			X	
10		X		X		X			X	
11			X		X			X	X	
12			X		X			X	X	
13			X		X			X		
14			X	X			X			
15			X	X				X		
16			X		X			X		X
17			X	X		X			X	
18	X				X	X				X
19	X			X		X			X	
20	X			X		X			X	
21			X		X	X			X	
Total	4	1	16	12	9	7	7	7	15	3

Radial Number	Facet plenary	Facet simple	Facet bifascial	Facet trifascial	Facet gently declivate	Facet strongly declivate	Facet flush	Facet on platform	Facet on stalk	Number of specimens
1		X				X		X		2
2		X			X		X			1
3		X				X			X	1

Table 7 (continued)

Radial Number	Facet plenary	Facet simple	Facet bifascial	Facet trifascial	Facet gently declivate	Facet strongly declivate	Facet flush	Facet on platform	Facet on stalk	Number of specimens
4		X				X		X		1
5			X		X			X		1
6		X			X			X		1
7		X				X		X		3
8			X			X	X			1
9		X			X			X		1
10		X				X		X		1
11			X			X		X		1
12			X			X		X		1
13	X			X	X		X			1
14	X			X	X		X			1
15	X			X	X		X			1
16				X	X		X			1
17			X			X	X			1
18			X		X		X			1
19			X		X			X		2
20			X			X	X			1
21			X		X		X			1
Total	3	8	9	4	11	10	10	10	1	25

Table 8 Shir Gesht, characters of radials <2 mm

Radial Number	Length>Width	Length~ Width	Width>Length	Unornamented	Ornamented	Plate thin	Plate moderately thick	Plate thick	Facet angustary	Facet peneplenary	Facet plenary
1			X		X			X	X		
2	X			X				X	X		
3		X			X			X	X		
4	X				X		X		X		
5	X				X		X		X		
6	X			X			X		X		
7	?				X		X		X		
8			X		X		X		X		
9			X		X	X			X		
10			X		X		X		X		
11			X		X		X		X		
12		X			X			X		X	
13			X		X			X		X	
14		X			X			X		X	
15			X		X			X		X	
16			X		X			X		X	
17	X				X			X		X	
18	X				X			X	X		
19	X				X			X	X		
20		X			X		X			X	
21			X		X			X			
22	X				X			X		X	
23			X		X	X					X
24		X			X			X			X
25			X		X			X			X
Total	9	5	11	2	23	2	8	15	13	8	3

Radial Number	Peneplenary/ Plenary	Facet simple	Facet bifascial	Facet trifascial	Facet horizontal	Facet gently declivate	Facet strongly declivate	Facet flush	Facet on platform	Facet on stalk	Number of specimens
1		X					X		X		1
2		X				X				X	1

Table 8 (continued)

Radial Number	Peneplenary/ Plenary	Facet simple	Facet bifascial	Facet trifascial	Facet horizontal	Facet gently declivate	Facet strongly declivate	Facet flush	Facet on platform	Facet on stalk	Number of specimens
3		X				X			X		1
4			X				X		X		1
5		X					X	X			1
6		?				?				X	1
7		X					X	X	X		1
8		X				X					1
9				X		X			X		1
10				X		X			X		2
11		X				X			X		1
12				X		X			X		1
13				X		X			X		1
14				X		X			X		1
15				X		X			X		1
16		?			X				X		1
17			X			X			X		3
18		X			X				X		4
19		X			X				X		5
20				?		X			X		1
21	X			X		X			X		14
22		X				X		X			1
23			?		X			X			1
24				X		X		X			1
25				X	X			X			2
Total	1	12	3	10	5	16	4	6	17	2	49

Table 9 Shir Gesht, morphologic characters of radials 2–5 mm

Radial Number	Length> Width	Length~ Width	Width> Length	Unornamented	Ornamented	Apical Pits	Plate thin	Plate moderately thick	Plate thick	Facet angustary	Facet peneplenary	Facet plenary	Peneplenary/ Plenary
1		X		X				X		X			
2	X			X					X	X			
3		X			X		X			X			
4		X		X					X	X			
5			X		X			X		X			
6			X		X			X		X			
7			X		X				X	X			
8			X		X			X		X			
9			X		X			X		X			
10		X		X					X	X			
11			X		X			X			X		
12			X		X			X		X			
13			X		X				X		X		
14			X		X				X		X		
15			X		X				X				X
16			X		X				X			X	
17		X					X				X		
18			X		X				X		X		
19			X		X				X		X		
20			X		X			X		X			
21	X			X				X			X		
22			X		X				X	X			
23			X		X		X					X	
24		X		X					X	X			
25			X	X					X		X		
26			X	X					X			X	
27			X		X	X			X				X

Table 9 (continued)

Radial Number	Length> Width	Length ~ Width	Width> Length	Unornamented	Ornamented	Apical Pits	Plate thin	Plate moderately thick	Plate thick	Facet angustary	Facet peneplenary	Facet plenary	Peneplenary/ Plenary
28			X		X	X		X			X		
29		X			X				X		X		
30			X		X				X			X	
31	X				X				X			X	
32	X				X			X		X			
33			X	X				X				X	
34		X			X			X		X			
35			X		X				X		X		
36			X		X				X		X		
37		X		X					X			X	
38			X		X			X		X			
39			X		X				X		X		
40			X		X				X		X		
41		X			X				X			X	
Total	4	10	27	10	31	2	3	14	24	17	14	8	2

Radial Number	Facet simple	Facet bifascial	Facet trifascial	Facet inclinate	Facet horizontal	Facet gently declivate	Facet strongly declivate	Facet flush	Facet on platform	Facet on stalk	Number of specimens
1	?					X		X			1
2		?				X			X		1
3	X						X			X	4
4	X						X		X		3
5		X					X		X		1
6			X			X				X	1
7			X				X		X		1
8			X		X			X			1
9	?					X			X		1
10			X			X			X		1
11			X			X		X			4
12			X			X			X		1
13			X		X				X		1
14			X			X			X		5
15			X		X			X			2
16			X		X			X			1
17			X			X		X			1
18			?			X		X			1
19			X			X		X			2
20			X			X		X			1
21		X				X		X			1
22			X			X		X			1
23			X	X				X			1
24	X					X		X			1
25			X			X		X			1
26			X		X			X			6
27			X		X				X		12
28			X		X				X		1
29			X			X			X		3
30			X	X				X			1
31			X			X		X			1
32	X						X		X		1
33			X	X				X			1
34			X			X				X	1
35			X			X		X			1
36			X			X				X	1

Table 9 (continued)

Radial Number	Facet simple	Facet bifascial	Facet trifascial	Facet inclinate	Facet horizontal	Facet gently declivate	Facet strongly declivate	Facet flush	Facet on platform	Facet on stalk	Number of specimens
37			X			X		X			1
38	X					X		X			1
39			X			X		X			1
40			X		X			X			1
41			X	X				X			1
Total	7	3	31	4	8	24	5	24	13	4	73

Table 10 Shir Gesht, characters of radials >5 mm

Radial Number	Length ~ Width	Width> Length	Unornamented	Ornamented	Plate moderately thick	Plate thick	Facet angustary	Facet peneplenary	Facet plenary
1		X	X			X			X
2		X		X		X			X
3		X		X		X			X
4		X		X		X		X	
5	X		X		X		X		
6		X		X		X			X
7	X		X		X		X		
8		X		X		X		X	
9		X		X		X		X	
10		X	?			X		X	
11		X	X		X				X
12	X			X	X		X		
13		X	?			X			X
Total	3	10	6	7	4	9	3	4	6

Radial Number	Facet simple	Facet bifascial	Facet trifascial	Facet inclinate	Facet gently declivate	Facet strongly declivate	Facet flush	Facet on platform	Number of specimens
1			X	X			X		1
2			X		X		X		1
3			X				X		1
4			X		X		X		1
5		?			X		X		1
6			X		X		X		1
7	X					X	X		1
8			X		X		X		1
9			X		X			X	1
10			?		X		X		1
11			X	X			X		1
12	X				X		X		1
13			X		X		X		1
Total	2	1	10	2	9	1	12	1	13

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Locality Index

1. Roadside cut, faulted Early Pennsylvanian, Bashkirian, Absheni Formation: Howz-e-Dorah, GPS: 33°20'47"N, 57°18'40"E. Interbedded shales and limestone above black shale. Crinoidal horizon in third shale above base of limestone. Basal 6 m contain large columnals.

2. Dip slope, rich crinoidal horizon in fault block, Absheni Formation, approximately 50– 60 m south of GPS: 33°21'3 6"N, 57° 20'17"E.

3. Dip slope, rich crinoidal horizon, fault block, Absheni Formation. GPS: 33°20'45"N, 57°18'55"E.

4. Dip slope, rich crinoidal horizon, Absheni Formation. GPS: beween 33°22’51”N, 57° 20’34”E and 33°24’49”N, 57°20’36”E.

5. Marine shale, approximately 1 m thick, above sandstone, deltaic sequence; Absheni Formation, Bashkirian, *Iranoblastus* type locality; GPS: 33°58'18"N 56°45'23"E to 33°58'26"N 56°45'17"E.

6. Permian, Chah-Reiseh area, central Iran, GPS: 32°59'11"N, 52° 3'36"E. Float.