

NEW PERMIAN ECHINODERMS FROM NORTHEASTERN OMAN HAVE CONNECTIONS WITH TETHYAN ECHINODERM FAUNAS FROM WEST TIMOR, WESTERN AUSTRALIA, AND RUSSIA

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Abstract. Permian blastoids and crinoids are described from the Batain region in northeastern Oman. New collections are from the Qarari Unit and are dated as late Kungurian to early Roadian. Six blastoid species assigned to three genera, 15 species-level crinoids assigned to 14 genera (some with question), and several crinoid taxa left in open nomenclature are described. New taxa include *Angioblastus qararii* sp. nov.; *A. omanensis* sp. nov.; *Deltoblastus sevastopuloi* sp. nov.; *Disgregacrinus aridus* gen. nov., sp. nov.; *Eoindocrinus ageri* sp. nov.; *E. spinosus* sp. nov.; *Jaramaherinus warlichi* gen. nov., sp. nov.; *Proindocrinus riesae* sp. nov.; *Qararicrinus batainensis* gen. nov., sp. nov.; *Roemeroocrinus? aridus* sp. nov., and *Synbathocrinus shackletoni* sp. nov. Also, *Platycrinites omanensis* Webster & Sevastopulo, 2007 is reassigned to *Pleurocrinus*, and *Calycoocrinus conicus* is recognized as a species. At the genus level, the Oman echinoderms are associated with Permian faunas in Australia, Russia, and West Timor; however, at the species level, the fauna is largely endemic to Oman. The occurrence of *Timoroblastus* is the first verifiable report of this genus outside of Timor.

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INTRODUCTION

Permian sediments occur widely in the Sultanate of Oman, in both autochthonous beds that accumulated on the Arabian Plate and allochthonous beds that formed in the Neo-Tethys Ocean and were obducted over the northeastern and eastern margins of Arabia, ~80–70 Ma and 65 Ma,

respectively. Crinoid ossicles have been described from many of the bioclastic carbonates of this age (e.g. Hudson & Sudbury 1959; Glennie et al. 1974; Pillecuit et al. 1997; Bendias et al. 2013; Angiolini et al. 2013).

Identifiable echinoderms are rarer with crinoids previously known from four locations and blastoids from one. Jell & Willink (1993) reported crinoid cups and crowns from the Sakmariyan Haushi Limestone adjacent to the graded road to the aban-

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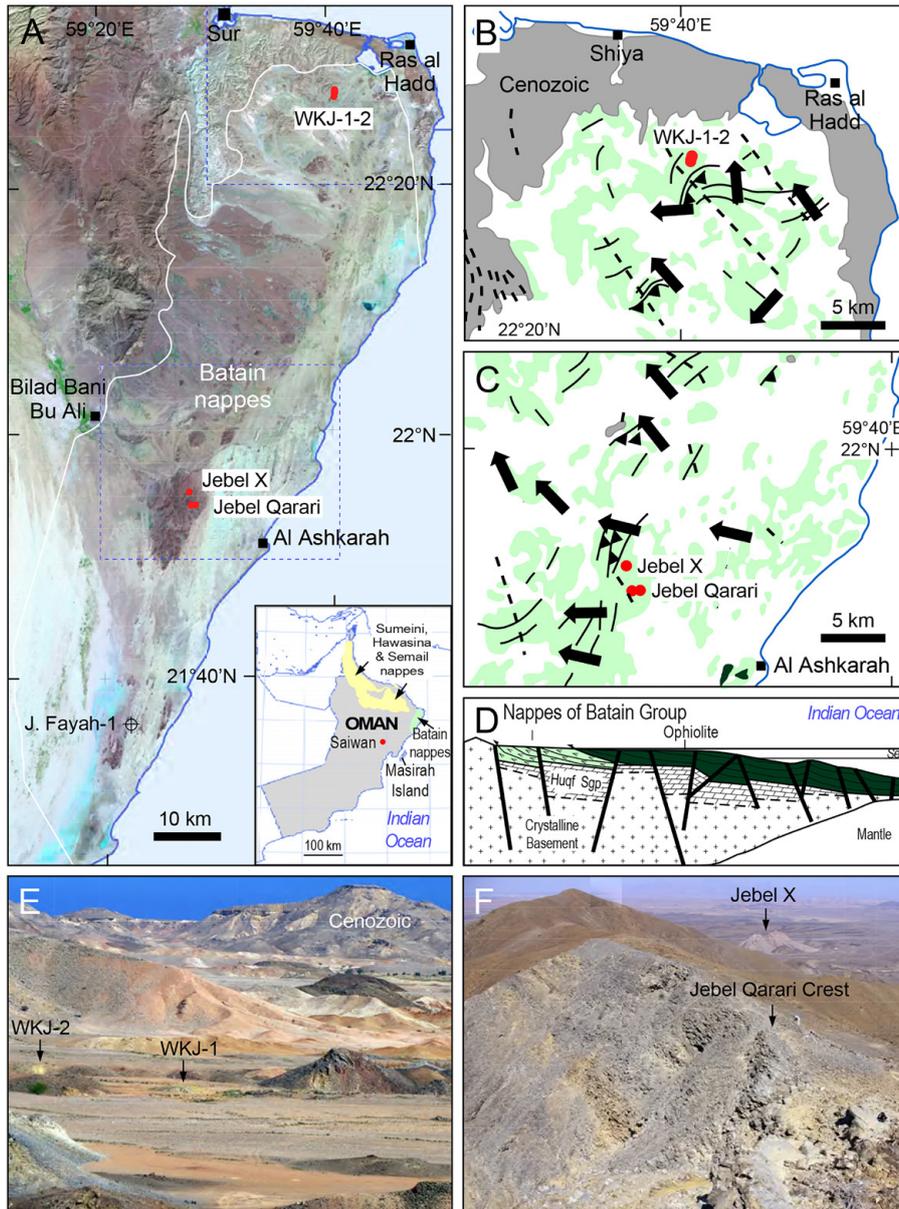


Fig 1 - A) Location map of the Batain area in the northeast of the Sultanate of Oman. B-F) maps (based on Immenhauser et al. 2000), field photos, and a cross section showing the allochthonous Batain nappes and ophiolite obducted over the eastern margin of the Arabian plate (based on Peters et al. 2001).

doned Saiwan-1 oil exploration well-site. Webster et al. (2009) described crinoids from the same locality (Saiwan Formation of the Bureau de Recherches Géologiques et Minières [BRGM]) and a brachial plate from the Wordian Khuff Formation, ca. 10 km to the north-northeast (Fig. 1). Shackleton et al. (1990) collected crinoid cups and blastoids from the Permian Qarari Unit (late Kungurian to early Roadian) of the Batain Melange of northeastern Oman, and this material was re-examined by Webster & Sevastopulo (2007). Most recently, Webster et al. (2022) described a crinoid crown from the Khuff Formation (Wordian) in the northern Huqf area. These echinoderms are important, along with other elements of the fauna, in having affinities with taxa reported from West Timor by Wanner (1916, 1924,

1937, 1949), Western Australia by Webster (1987), and Webster & Jell (1992, 1999).

STRATIGRAPHY AND PALEOGEOGRAPHIC SETTING

Much of the understanding of Oman's stratigraphy is the result of the search for and production of oil and gas (Hughes Clarke 1988; Forbes et al. 2010). The outcrop geology of the country was systematically mapped by BRGM during the 1980s on behalf of the Ministry of Petroleum and Minerals (Béchenec et al. 1993). Unfortunately, BRGM geologists sometimes introduced a differing stratigraphic nomenclature to that used by the oil com-

Location	Horizon	WGS84 Lat.	WGS84 Long.	Age	Comments
<u>Wadi Khawr Al Jaramah</u>	(outcrops occur over a distance of 1.25 km; not shown on map of Peters et al. 2001)				
WKJ-1	Qarari Unit	22°27'37.97"	59°40'50.75"	late Kungurian	450 m2, ~20 m section
WKJ-2	Qarari Unit	22°27'40.51"	59°40'50.92"	late Kungurian	In wadi bank, ~4 m of section
WKJ-3	Qarari Unit	22°27'43.24"	59°40'52.32"	late Kungurian	small location, only plates & columnals
WKJ-4	Qarari Unit	22°27'26.93"	59°40'45.22"	late Kungurian	small location, only plates & columnals
WKJ-5	Qarari Unit	22°27'8.52"	59°40'35.43"	late Kungurian	small location, only plates & columnals
<u>Jebel X</u>	(map of Peters et al. 2001 unfortunately does not extend this far west; location incorrectly marked by Lee (1990); specimens attributed to Jebel X by GDW and Sevastopulo (2007) likely to have been from loc. 604 (Jebel Qarari) as originally listed in Shackleton et al. (1990)				Loc. 302 of Shackleton et al. (1990), Jebel X? of Lee (1990) and Webster and Sevastopulo (2007).
3	Qarari Unit	21°55'03.40"	59°27'39.20"	late Kungurian - early Roadian	~20 m of greenish gritstones and conglomerates overlying basalts, fossiliferous near top, below brecciated carbonates (Qarari Unit or Asselah Unit?)
Several other fossiliferous locations at crest, on west side and northern end of Jebel. None have yielded crinoid cups or blastoids to APH					
<u>Jebel Qarari</u>	(map of Peters et al. 2001 unfortunately does not extend this far west)				
Wadi	Qarari Unit	21°53'56.82"N	59°27'43.79"E	late Kungurian - early Roadian	Loc. 604 of Shackleton et al. (1990), 60-170 m of section, wadi to crest. Partial silicification at some levels
Alluvial fan surface	Qarari Unit	21°53'57.61"N	59°27'40.66"E		
Crest	Qarari Unit	21°53'57.37"N	59°27'58.78"E		
Campsite	Aseelah Unit	21°53'37.80"N	59°27'46.90"E	-	Boulders of greenish carbonate with white blastoids and crinoid cups

Fig. 3 - Locations mentioned in the text and their stratigraphic assignment to the Qarari and Aseelah Units.

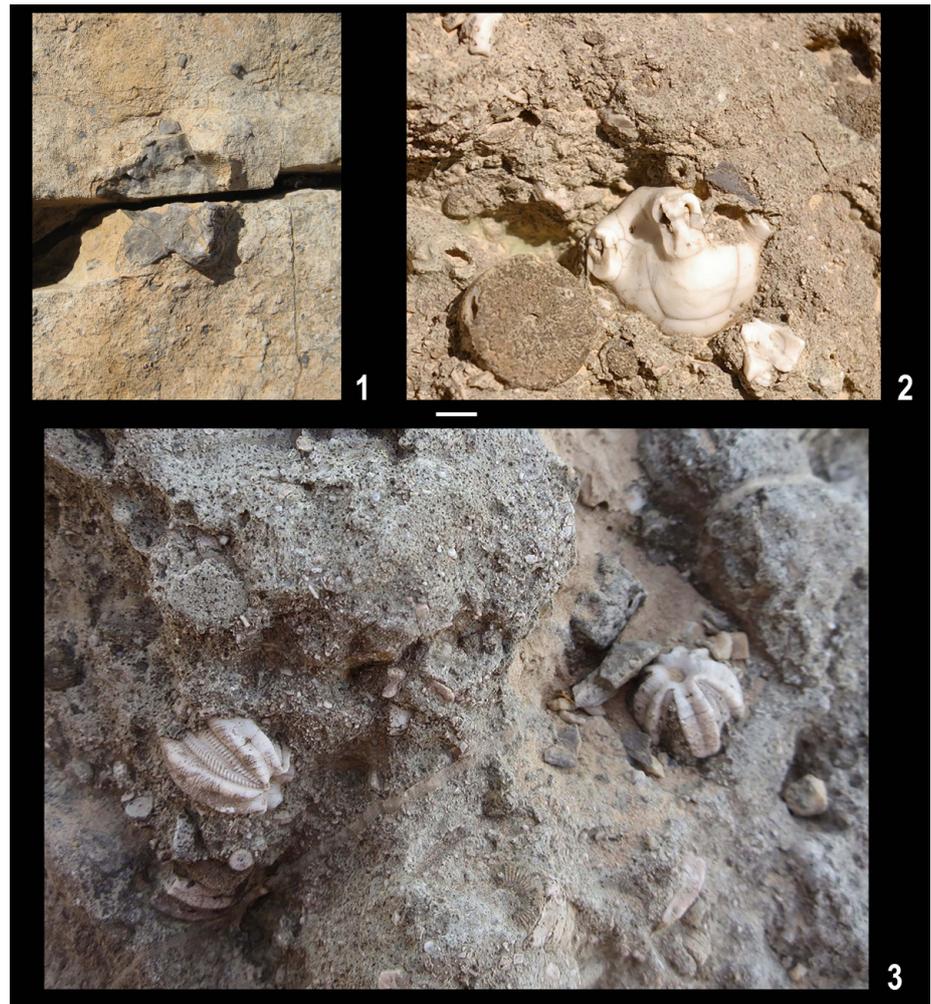
indicates that the oldest nappe of the Masirah ophiolite originated close to the margin of India (~38°S) during the Late Jurassic (Immenhauser et al. 2000). The sedimentary sequence of the Batain nappes is relatively thin (1.5–2 km), and the ophiolite was old and cold when obducted over the Arabian margin during the latest Maastrichtian/early Palaeogene (Fig. 1D). The Permian faunas that occur in the allochthonous Qarari and Aseelah Units are more diverse, better preserved, and differ from those on the Arabian Platform and the allochthonous Tethyan units of the Al Hajar Mountains (Vachard et al. 2002; Leven & Heward 2013; Fortey & Heward 2015; Viaretti et al. 2022). This is probably due to some combination of age, lithology, depositional environment, water depth, location relative to migration routes along Neo-Tethys Ocean, mode of preservation, and subsequent geological history.

The localities from which the new faunas have been collected are shown in Fig. 1, in relation to previously described faunas from near Saiwan and the Batain. Small outcrops of marls and limestones of the Qarari Unit to the west of Wadi Khawr Al Jaramah (WKJ) yielded the best preserved and most diverse faunas (Figs. 1B, 1E. 3, 4). The locations are in a line, probably as rafts in a thrust sheet. Spec-

imens were collected from the weathered surface and from bulk samples for blastoids, macrocrinoids and microcrinoids. A late Kungurian age is interpreted for these outcrops based on their fusulinid, conodont, trilobite, and brachiopod faunas (Leven & Heward 2013; Fortey & Heward 2015; Viaretti et al. 2022) (Figs. 2, 3).

The locations at Jebel Qarari are in the Qarari and Aseelah Units (Fig. 1). Earlier faunas collected by Chris Lee and Alison Ries during the early 1980s from two sites that were imprecisely located, being marked on a foldout map (loc. 604 is likely to be Jebel Qarari and loc. 302 Jebel X, Shackleton, et al. 1990). A late Kungurian–early Roadian age has been established for the Qarari Unit at Jebel Qarari based on ammonoids, conodonts, and brachiopods (Immenhauser et al. 1998; Fortey & Heward 2015; Viaretti et al. 2022). Clasts within the Aseelah Unit have been interpreted to range in age from Artinskian to Wuchiapingian (Yakhtashian to Dzulfian; Hauser et al. 2000). No attempt has been made to date fossiliferous clasts in the Asselah outcrops at Jebel Qarari by any other means, hence the echinoderm faunas, which occur in them (Fig. 4.2, 4.3) cannot, at the present time, be assigned with confidence to any stage in the Permian.

Fig. 4 - Outcrop photographs of blastoids and crinoids in the Qarari and Asselah Units of Oman. 1) *Timoroblastus coronatus*, Qarari Unit near crest of Jebel Qarari; 2) *Pleurocrinus omanensis* comb. nov.; 3) *Deltoblastus molengraffi*: 2 and 3 from the Asselah Unit, Jebel Qarari campsite location; scale bar = 2 mm.



Charlton et al. (2002) and Webster (1998) compiled the available biostratigraphic information on Permian echinoderms from Timor. Historically, all Timor localities containing large echinoderm collections were considered to have been Late Permian in age (Moore & Teichert 1978) suggesting a mass extinction of echinoderm taxa at the end of the Permian. Webster (1998) assigned an Artinskian to Kungurian age (late Cisuralian) for the Somohole localities and a Wuchiapingian age (Late Permian) for collections from Amarassi. The large complex of localities around Basleo have been considered Wordian (Middle Permian) in age based on cephalopod biostratigraphy (Wanner 1931). Webster & Jell (1992; 1999) suggested that the Basleo faunas might be Artinskian in age after comparing them with faunas from the Callytharra Formation in Western Australia.

Conodonts are rare in the Callytharra Formation. Nicoll & Metcalfe (1998) reported a small conodont assemblage in the upper part of the formation that they correlated to their *Mesogondolella bisselli-Sweetognathus inornatus* Zone. This assemblage

includes *Vjalovognathus australis*, which has been identified in the Maubisse Limestone in Timor. Based on the conodont data and other biostratigraphically important taxa, the Callytharra and the Maubisse are considered coeval and late Sakmarian to Artinskian in age (Haig et al. 2014; Haig et al. 2017).

MATERIALS AND METHODS

In 2009, Gary D. Webster encouraged more collecting from the Qarari Unit because of possible affinities to the famous Basleo faunas of West Timor. Part of GDW's interest was in trying to establish better age constraints for the Basleo crinoids. After two largely unproductive visits to Jebel Qarari, APH was alerted to another locality farther north where well-preserved trilobites had been discovered. Visits to locations near Wadi Khawr al Jaramah (WKJ) proved productive for a variety of faunal elements, including crinoids and blastoids.

Blastoids
<i>Angioblastus qararii</i> Webster et al. sp. nov., herein
<i>Angioblastus omanensis</i> Webster et al. sp. nov., herein
<i>Deltoblastus pseudodelta</i> Wanner, 1924
<i>Deltoblastus molengraaffi</i> (Wanner, 1924)
<i>Deltoblastus sevastopuloi</i> Webster et al. sp. nov., herein
<i>Timoroblastus coronatus</i> Wanner, 1924
Camerate Crinoids
<i>Pleurocrinus omanensis</i> (Webster & Sevastopulo, 2007) comb. nov., herein
Camptocrininae Indeterminate columnals
Dichocrinidae Indeterminate
Monbathrid Camerata Indeterminate radial plate 1
Monbathrid Camerata Indeterminate radial plate 2
Monbathrid Camerata Indeterminate radial plate 3
Platycrinitidae columnals
Disparid Crinoids
<i>Paracatillocrinus granulatus</i> Wanner, 1916
<i>Synbathocrinus shackletoni</i> sp. nov., herein
Flexible Crinoids
<i>Calyccrinus conicus</i> Wanner, 1930
<i>Prophylocrinus</i> sp.
Flexible Indeterminate
Euclidid Crinoids
<i>Disgregacrinus aridus</i> gen. nov., sp. nov., herein
<i>Eoindocrinus spinosus</i> sp., nov., herein
<i>Eoindocrinus ageri</i> sp. nov., herein
<i>Erisocrinus?</i> sp.
<i>Jaramahcrinus warlichi</i> gen. nov., sp. nov., herein
<i>Malaiocrinus</i> sp.
<i>Permiocrinus?</i> sp.
<i>Proindocrinus riesae</i> sp. nov., herein
<i>Qararicrinus batainensis</i> gen. nov., sp. nov., herein
<i>Roemerocrinus? artus</i> gen. nov., herein
Euclidid Indeterminate

Tab.1 - List of Oman blastoids and crinoids. Herein designates new taxa described or taxonomic reassignment made in this study.

Bulk samples were collected and proved particularly rich in microcrinoids (adults aboral cup/calycal heights <2 mm), as well as very small specimens of “macrocrinoids” and blastoids. Although the adult

aboral cup height of *Embryocrinus* Wanner, 1916 is >2 mm, this crinoid will be treated in a subsequent manuscript with other sympatric members of the Codiocrinidae that are microcrinoids. Two ~1.0 kg bulk samples were collected from crinoid-rich intervals from WKJ1, and four ~1.0 kg bulk samples were collected from WKJ2; Fig. 1A, 1B, 1E). GDW’s commitments and declining health left the documentation of this fauna unfinished at his death in 2021. That task has been taken up by JAW for the blastoids, WIA for the crinoids, and with APH contributing Oman-specific detail.

Institutional abbreviations. ONHM Oman Natural History Museum (Muscat, Oman); RGM, Rijksmuseum van Geologie en Mineralogie, Leiden, the Netherlands; and TCD, Trinity College, Dublin, Ireland.

General Faunal Analysis

Blastoids and crinoids are from two primary localities: Wadi Khawr Al Jaramah and Jebel Qarari, with the fauna from Wadi Khawr Al Jaramah much more diverse. As a whole, the faunal elements known from Jebel Qarari are larger in size. A total of six blastoid taxa and 28 crinoid taxa (as well as others left in open nomenclature above the family level) are now known from the Permian (Sakmarian to Wordian) of Oman (Table 1). This includes taxa described herein as well as those described by Jell & Willink (1993), Webster & Sevastopulo (2007), and Webster et al. (2009, 2022) (Table 2). The present paper only describes blastoids and macrocrinoids, and the systematics of the microcrinoid fauna will be described in a subsequent paper.

The blastoids and crinoids described herein were part of diverse, shallow-water paleocommunities containing ammonoids, bivalves, brachiopods, bryozoans, corals, echinoderms (blastoids, crinoids, echinoids, and ophiuroids), fusulinid foraminifera, gastropods, and trilobites. In general, the degree of *in vivo* bioencrustation and bioerosion on brachiopods is low, indicating that post-mortem bioencrustation and bioerosion are absent. Approximately 99% of the brachiopods are preserved with articulated valves, and some crinoids are preserved with articulated arms. Trilobites are commonly preserved enrolled and are interpreted to have been buried rapidly protecting them from subsequent distur-

<u>Blastoids</u>
<i>Deltoblastus</i> n. sp.? aff. <i>D. delta subglobosus</i> (Wanner, 1924)
<i>Timoroblastus</i> n. sp.? aff. <i>T. coronatus</i> Wanner, 1924
<u>Camerate Crinoids</u>
<i>Platycrinites omanensis</i> Webster & Sevastopulo, 2007
(herein reassigned to <i>Pleurocrinus</i>)
<u>Eucladid Crinoids</u>
<i>Campbellicrinus compactus</i> Jell & Willink, 1993
<i>Campbellicrinus nodosus</i> Webster et al., 2009
<i>Coeliocrinus arenaceus</i> Webster et al., 2009
<i>Exallocrinus khuffensis</i> Webster et al., 2022
<i>Huqfcrinus biserialis</i> Webster et al., 2009
<i>Moapocrinus?</i> <i>omanensis</i> Webster et al., 2009
<i>Omanicrinus secundus</i> Jell & Willink, 1993
<i>Texacrinus haushiensis</i> Jell & Willink, 1993
<i>Texacrinus</i> sp. Webster et al., 2009
Indeterminate sycocrinid <i>in</i> Webster et al., 2009
Eucladid Indeterminate <i>in</i> Webster et al., 2009

Tab. 2 - List of blastoids and crinoids described from the Permian of Oman prior to the present investigation.

bance. These preservational attributes do not represent “ecological snapshots”, but they are consistent with periodic, rapid burial events (tempestites) with limited subsequent disturbance (e.g., Taylor & Brett 1996; Ausich 2021).

In addition to West Timor and Oman, Tethyan Permian blastoids and crinoids have been reported by various authors from Australia (Webster 1987; Webster & Jell 1992, 1999; Willink 1980a, 1980b), China (Yunnan), Crete (Webster 2012), India (Waagen, 1887), New Zealand, Pakistan, Russia (southern Ural Mountains) (Yakovlev 1926, 1927, 1930, 1937, 1939; Yakovlev & Fass 1938; Yakovlev & Ivanov 1956; Arendt 1970), Sicily, Slovenia (Ausich et al. 2024), Thailand (Webster & Jell 1993), and Tunisia (Lane 1979). Echinoderms from these areas range in age from Asselian to Wuchiapingian. Both cooler water, higher latitude and warmer, tropical latitude paleoenvironments are present within various areas. The greatest diversity is in the West Timor faunas, with 212 identified crinoid species among 91 genera, 16 genera of blastoids, and 3 genera of echinoids (Webster & Jell 1999; Webster 2003; Webster & Webster 2014). Australian Permian echinoderms have the second greatest diversity with 48 named crinoid genera (100 species), with

the greatest diversity known from Western Australia faunas. Intermediate diversities are known from Oman, Slovenia, and Russia. As currently known, all other areas contain faunas of fewer than eight identified genera (Webster 2003; Webster & Webster 2014; Ausich et al. 2024). Although understudied, microcrinoids are also abundant and diverse in some of the West Timor, Western Australia, Oman, and Russian faunas. Two microcrinoids have also been reported from Thailand (Webster & Jell 1993).

Russian Permian crinoids from Krasnoufimsk have been described by Yakovlev (1926, 1927, 1930, 1937, 1939), Yakovlev & Fass (1938), and Arendt (1970, 1981). These crinoids (including some microcrinoids) were from marlstone and limestone in or adjacent to bioherms. Additionally, Yakovlev (1941, 1948) and Yakovlev & Ivanov (1956) reported a small blastoid and crinoid fauna from Sakmarian strata of the North Timan Ridge (Russia), and Biakov (2015) reported *Deltoblastus* sp. from the Okhotsk Basin of northeastern Asia (although an illustration of the specimen was not provided). A recent report of Asselian crinoids from northern China (Mao et al. 2018) is the first report of a significantly diverse fauna (13 genera) in a carbonate shallow marine setting, from what was the northern China plate during the late Paleozoic.

Ausich et al. (2024) reported a new Permian (Artinskian) crinoid fauna from the Trogkofel Group of the Southern Karavanke Mountains in northern Slovenia. This fauna contains five named species and three taxa left in open nomenclature. Only *Moapocrinus* co-occurs in both Slovenia and Oman.

The six blastoids and fourteen crinoids described from the Qarari and Asselah Units are considered only a portion of a considerably more diverse echinoderm fauna based on the number of loose echinoderm ossicles collected both on outcrop and in washings. There may also be other richly fossiliferous locations to be discovered among this incompletely-mapped landscape of low hills, gravel terraces, wadis, sand dunes, and sabkhas.

PALEOBIOGEOGRAPHY

Blastoids from Oman

Derek Ager (*in* Shackleton et al. 1990) made the first report of Permian blastoids from Oman.

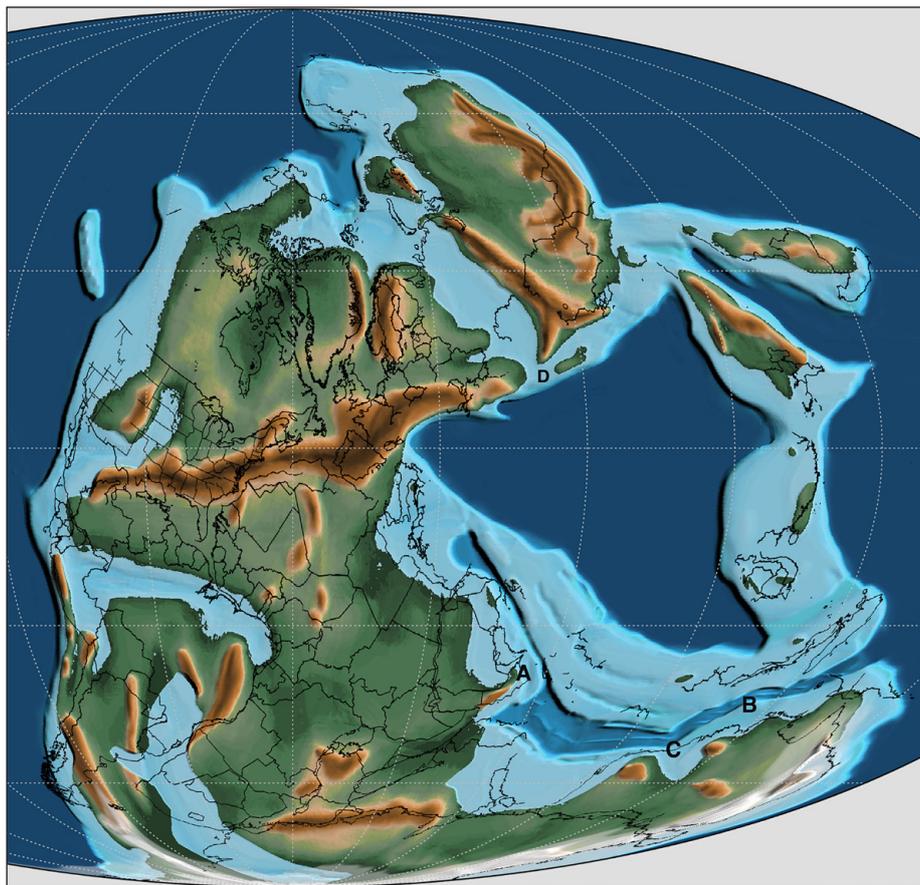


Fig 5 - Permian paleogeographic map indicating relative position of echinoderm-bearing locations: A) Oman; B) West Timor; C) Western Australia; D) Russia. (modified from Scotese 2021).

This echinoderm material was subsequently examined by Webster and Sevastopulo (2007), who identified the blastoids as *Timoroblastus* sp. nov.? aff. *T. coronatus* Wanner, 1924a and *Deltoblastus* sp. nov.? aff. *D. delta subglobosus* Wanner, 1924a. Subsequent fieldwork by APH and his wife identified additional blastoids from other localities. *Timoroblastus* and *Deltoblastus* were identified in the field at Jebel Qarari (Figure 4). Specimens of *Deltoblastus* in exotic blocks in the Aseelah Conglomerate from Jebel Qarari campsite location were also identified in the field. Specimens of *Deltoblastus* and *Angioblastus* were also collected from localities WKJ-1 and WKJ-2, part of a series of small mounds of yellow marly limestone west of Wadi Khawr al Jaramah. Thus far, three genera and six species of blastoids have been identified in Oman, *Deltoblastus* (three species, one new), *Timoroblastus* (one species), and *Angioblastus* (two new species) (Fig. 6).

Previous paleobiogeographic studies

The five species of trilobites known from the Qarari Unit are part of the paleo-equatorial, eastern Tethyan, realm extending from Sicily to southeastern Asia (Fortey & Heward 2015). The

more numerous brachiopods, 81 species thus far, have surprisingly few affinities with faunas from the northern margin of Gondwana except for some relationships with fauna from the late Kungurian of Myanmar (Viaretti et al. 2022, 2024).

Blastoids faunas in the Neo-Tethys

The blastoids from Oman are from the Batain nappes of northeastern Oman. They are important in that they expand the blastoid paleobiogeography along the margin of Neo-Tethys Ocean during the Permian. Well-preserved Permian blastoid faunas are known from Timor (Indonesia) and Australia, but the specimens from Oman are the first located on the Arabian Peninsula.

Paleogeographically all three areas were located between 30° and 50° south latitude along the Gondwanan margin of the rifting Neo-Tethys Ocean (Fig. 5). The Permian sequence in Oman was probably deposited in the Madagascan arm of the newly forming ocean (Viaretti et al. 2022 and references therein). The Permian sequences in Timor and Western Australia were likely deposited in arms of the East Gondwanan interior rift system (Hornsheng Mii et al. 2013; Haig et al. 2014, 2017).

Fig. 6 - Paleogeographic distribution of echinoderm genera that occur in Permian of Oman. Blue rectangle, present; Blue rectangle with question mark, questionable occurrence of genus; blank, genus absent.

		Oman	Australia	Canada	China	Crete	Russia	Sicily	Slovenia	West Timor	United States
Blastoid	<i>Angioblastus</i>										
	<i>Deltoblastus</i>				?						
	<i>Timoroblastus</i>										
Camerate	<i>Pleurocrinus</i>										
Disparids	<i>Paracatillocrinus</i>										
	<i>Synbathocrinus</i>										
Flexibles	<i>Calyccrinus</i>										
	<i>Prophylocrinus</i>										
Eucladids	<i>Campbellocrinus</i>										
	<i>Coeliocrinus</i>										
	<i>Disgregacrinus</i>										
	<i>Eoindocrinus</i>										
	<i>Erisocrinus</i>	?									
	<i>Exallocrinus</i>										
	<i>Hufqicrinus</i>										
	<i>Jaramahcrinus</i>										
	<i>Malaocrinus</i>										
	<i>Moapacrinus</i>			?							
	<i>Omanicrinus</i>										
	<i>Permiocrinus</i>	?									
	<i>Proindocrinus</i>										
	<i>Qararicrinus</i>										
	<i>Roemerocrinus</i>	?									
<i>Texacrinus</i>											

Understanding the depositional environments of the Permian sequence in the Batain nappes of Oman is difficult because sections are small and discontinuous. The Qarari Unit was likely deposited below storm wave base in a quiet, muddy, middle to outer shelf carbonate environment (Immenhauser et al. 1998; Fortey & Heward 2015; Viaretti et al. 2022).

The difficulties in delineating the depositional environments in the Permian of West Timor are exacerbated by the lack of stratigraphic sections containing *in situ* faunas and the post-Paleozoic structural complexities of Timor. The echinoderm bearing localities of West Timor are found within the Maubisse Formation (Charlton et al. 2002), which has its type locality in Timor Leste (Haig et al. 2014). In the vicinity of its type locality, the Maubisse Formation is a packstone dominated with bryozoan and crinoid fragments. Climatically sensitive indicators (present and absent) indicate that the Maubisse Limestone near its type section was deposited on a cool shallow shelf with bryozoan mound buildups and a paleotemperature less than 18° C (Haig et al. 2014). Echinoderm bearing localities near Basleo, West Timor, appear to have had a significant volcanic component in the carbonate deposition (Waters, field observations).

The blastoid fauna from Timor consists of 17 genera with *Deltoblastus* and *Timoroblastus* being the most abundant. *Deltoblastus* has been divided into 18 species and is known from dozens of localities in Timor. *Deltoblastus* is known from a single specimen at Somohole, from tens of thousands of specimens from the Basleo area, and from hundreds of specimens from Amarassi. Some of these species are valid, but others are the result of the morphologic variability inherent in populations of thousands of specimens. A wholistic review of *Deltoblastus* species has not been conducted. *Timoroblastus coronatus* is known from thousands of specimens from various localities in Timor. Wanner (1924a) divided the species into 16 subspecies as a reflection of the morphologic variability in the collections from Timor. Macurda (1983) interpreted all 16 varieties of *T. coronatus* to belong to one highly variable species.

In contrast to the Permian echinoderm bearing sequences in Oman and Timor, the Callytharra Formation in the Carnarvon Basin in Western Australia is well studied. The blastoid fauna from the Callytharra Formation in Western Australia consists of three genera and five species, most of which are known from disarticulated thecal plates. The Oman blastoid fauna contains genera also present in Timor, but not in Western Australia. All the Western

Australian genera are known from Timor. The occurrence of *Timoroblastus* in Oman is the first report outside Timor (Fig. 6). *Angioblastus* is a long-ranging (Pennsylvanian - Permian), geographically widespread blastoid. It is known from 7 species and has a global distribution, but it has not been identified in Western Australia. Two species have been described from Timor and two species from Oman are described herein.

Haig et al. (2014, fig. 14) illustrated a log of high order parasequences from a well-exposed section. Deposition in the Callytharra Formation was primarily limestone and fossiliferous siltstone. The Callytharra Formation contains a diverse fossil assemblage of shallow-marine benthos, such as foraminifera, corals, bryozoans, brachiopods, bivalves, gastropods, and echinoderms (Mii et al. 2013). The Callytharra Formation has been interpreted as a shallow-marine interior basin ramp with intermittent nutrient-rich inflows upwelled from the Neo-Tethys Ocean (Frank et al. 2012) and variable estuarine-like water conditions (Haig et al. 2017). Limestones in the Callytharra tend to be packstones with bryozoans and crinoids dominating the bioclasts in most units (Haig et al. 2014). Oxygen-isotope paleothermometry derived from brachiopods indicates that the Callytharra was deposited in cool temperate conditions less than 10 °C succeeding a time of glacially influenced sedimentation in the Asselian in Australia (Haig et al. 2014).

Yakovlev & Faas (1938) reported specimens of *Schizoblastus* cf. *permicus*, now *Deltoblastus permicus*, from the Sosio Limestone in Sicily, although the occurrence is now considered questionable. *Deltoblastus* has also been reported from Kashmir (Gupta & Webster 1976, 1980), but Webster (1991) considered the occurrence fabricated by Gupta in light of similar fabrications reported by Talent (1989). Luo (1984) reported an occurrence of *Deltoblastus* from the Middle Permian of Longhuixian, Hunan, south-central China. Three blastoid specimens were collected from a dark limestone at this locality. The veracity of this occurrence has not been independently confirmed. Biakov (2007) reported an occurrence of *Deltoblastus* from the Upper Permian (Wuchiapingian) from the Okhotsk Region of Russia but did not illustrate it. Like the Chinese reference, this occurrence has not been independently verified. Macurda (1967) reported a blastoid from the Artinskian of Melville Island in the Canadian

Arctic archipelago. The specimen is a steinkern and cannot be positively identified, but it is likely a specimen of *Deltoblastus*. *Deltoblastus* does not occur in Western Australia. The occurrence of *Deltoblastus* in Oman is important paleogeographically because it is the first verifiable occurrence of the genus outside Timor.

Crinoids

Tables 1 and 2 list the named crinoids reported from the Permian of Oman. Previous studies described crinoids from the Sakmarian Gharif Formation (Webster & Jell 1993), Sakmarian Saiwan Formation (Webster et al. 2009), the late Kungurian to lower Roadian Qarari Unit (Webster & Sevastopulo 2007), and the upper Wordian Khuff Formation (Webster et al. 2022). *Exallocrinus* Webster et al. 2022; *Huqfcrinus* Webster et al. 2009; and *Omanicrinus* Jell & Willink 1993 are only known from Oman. *Campbellicrinus* Jell & Willink, 1993 is known from Oman and Western Australia. The present study greatly expands the known crinoid biodiversity in Oman.

Similar to the blastoids, Permian crinoids are well documented in West Timor and Australia, as well as from Russia and elsewhere (Fig. 6). At the genus level, Oman crinoids form a unique fauna comprised of endemic genera and genera with varying paleogeographic distributions. Two crinoids in the Oman fauna, *Pleurocrinus* (camerate clade) and *Synbathocrinus* (disparid clade) are long-ranging, cosmopolitan genera. *Synbathocrinus* is known from the Late Devonian to the Permian, and *Pleurocrinus* is known from the Mississippian to Permian. The disparid *Paracatillocrinus granulatus* and the flexible *Calycocrinus conicus* are only known from Permian strata but were more geographically widespread (Fig. 6). Oman crinoids form a unique fauna with most species and many genera restricted to Oman. At the genus level, several eucladid crinoids are restricted to Oman, including *Campbellicrinus*, *Coeliocrinus* White, 1863 (only if Permian species are considered), *Disgregacrinus* gen. nov., *Exallocrinus*, *Jamarabcrinus* gen. nov., *Huqfcrinus*, *Omanicrinus*, and *Qararicrinus* gen. nov. (Fig. 6, Tabs. 1, 2). Seven genera from Oman also appear in West Timor, five also occur in Russia, and five occur in Western Australia.

As noted, all crinoid taxa restricted to Oman are eucladid crinoids. In a study of Mississippian crinoids, Kammer et al. (1997) concluded that species

longevity differences existed between clades and that species longevity differences were correlated to general ecological differences. Of interest, herein, is that Mississippian eucladids had significantly shorter species longevity than other Mississippian crinoid clades, which was the basis for recognizing eucladids, in general, as “ecological specialists.” If this can be extended to apply to Permian eucladids, it may help explain why most Oman eucladids were largely endemic. This distinction could be driven by latitudinal differences in the Neo-Tethys, similar to blastoids.

SYSTEMATIC PALAEOLOGY

Blastoid classification follows that of Fay and Wanner (1968) as modified by Macurda (1983) and Waters and Horowitz (1993). Blastoid terminology follows Macurda (1966). Abbreviations used in blastoid descriptions are RB, radial-basal suture, RD, radial-deltoid suture, and RR, radial-radial suture.

Crinoid suprafamilial classification used here follows Wright et al. (2017), Cole (2017), and Wright (2017a, b); and family-level classifications follow Moore & Teichert (1978). Crinoid morphologic terminology follows Ubaghs (1978a), Webster (1974), Ausich et al. (2020), and Ausich & Donovan (2023). The plating of interrays is given by the number of plates in each range from proximal-most plate to the last range before the tegmen. In the posterior interray, the primanal is indicated by “P,” and the first interradial plate in regular interrays is indicated by “1.” Abbreviations used in designating measurements include: CrH, crown height; CaH, calyx height; CaW, calyx width; CoH, column height; PA, primanal. An * indicates a measurement was incomplete. Measurements are in mm.

Class **BLASTOIDEA** Say, 1825

Order **Fissiculata** Jaekel, 1918

Family Neoschismatidae Wanner, 1940

Genus *Timoroblastus* Wanner, 1924b

Timoroblastus coronatus Wanner, 1924b

Fig. 4.1

1924b *Timoroblastus coronatus* – Wanner, p. 18, taf. 2, figs. 1–10, taf. 8, figs. 1–7.

1972 *Timoroblastus coronatus* – Breimer & Macurda, p. 37, pl. XXIII, figs. 2, 3, 5, 7; p1. XXVI, figs. 1, 4, 5, 8–11; pl. XXVII, figs. 1.3–5.9.

1983 *Timoroblastus coronatus* – Macurda, p. 139–147, pl. 34, figs. 1–10, pl. 35, figs. 1–6, pl. 36, figs. 1–11.

2007 *Timoroblastus* n. sp.? aft. *T. coronatus* – Webster & Sevastopulo, p. 401–403, fig. 2A–2C.

Holotype: Unknown.

Diagnosis: Theca boxlike with straight to sloping sides, convex to concave base and flattened vault. Pentagonal to stellate in plan view. Pentagonal in cross sectional view. Large deltoids, two anal deltoids, an epideltoid and a hypodeltoid. Small petaloid ambulacra. Ten hydrosphere groups with small hydrosphere slits, partially concealed.

Type locality and horizon: West Timor; Permian (unknown age).

Additional specimen: Two specimens (TCD 59007–TCD 59008) figured in Webster & Sevastopulo (2007).

Remarks. Webster & Sevastopulo (2007) described two specimens (TCD 59007–TCD59008) collected from Jebel X as *Timoroblastus* sp. nov.? aft. *T. coronatus*. We have a field photo of an additional specimen embedded in rock from near the crest of Jebel Qarari (Fig. 4A). All these specimens are referred to *Timoroblastus coronatus*. The specimens from Oman are in the morphological range of populations of *T. coronatus* known from Timor. We do not believe that potentially assigning the Oman specimens to a new species is warranted as Webster & Sevastopulo (2007) suggested.

T. coronatus was a bottom dwelling blastoid with a Type IV feeding mode of Breimer & Macurda (1972). It sat directly on the sea floor with a box or mound shaped theca and short ambulacra restricted to the oral surface. The thecal shape with expanded base provided hydrodynamic stability in currents. The diminutive stem suggests that *T. coronatus* may have been attached to the seafloor as in the pentacrinoid juvenile stage of modern comatulid crinoids. The stem was not sufficiently large to support the theca as an adult.

Wanner (1940) described a second species of *Timoroblastus*, *T. weiensis* Wanner, 1940, which is described and figured in Macurda (1983, p. 147–148; p. 36, figs. 5, 6). *T. weiensis* is smaller than the specimens from Oman, has a different thecal form and plate morphologies.

T. coronatus was previously known only from Timor, where it is abundant and morphologically diverse.

Geological age and geographic distribution. The original specimens of this species were Permian (unknown age) from West Timor. Webster & Sevastopulo (2007) reported *Timoroblastus coronatus* from Oman. They listed the occurrence as an un-

named djebel approximately 3 km west of Jebel Qarari (Kurayah), west of Al Ashkarah, northeastern Oman, but Shackleton et al. (1990), who collected the material, listed it as Jebel Qarari (location 604). Herein we regard the Qarari Unit at Jebel Qarari to be late Kungurian to early Rodian)

Family Codasteridae Etheridge and Carpenter 1886
Genus *Angioblastus* Wanner 1931

Type species: *Angioblastus variabilis* Wanner, 1931.

***Angioblastus qararii* sp. nov.**

Fig. 7.1–7.4.

Holotype: ONHM F-1433.

Diagnosis: Thecae small, modified hexagon in lateral view. Base of theca flattened. Theca pentagonal in plan view with slightly concave interambulacral areas. Greatest width of theca at junction of RR and RB. Vault small, restricted to summit of theca. Pelvis significantly larger than vault. Ambulacra small, do not reach the edge of thecal outline.

Etymology: The species is named for the Qarari Formation.

Additional specimens: ONHM F-1434 to ONHH F-1435.

Type locality and horizon: Wadi Khawr Al Jaramah (WKJ-1 or WKJ-2), Batain, Oman; Qarari Unit, Permian (late Kungurian).

Description. Thecae small. Length 6.5 mm. Theca modified hexagon in lateral view. Base of theca flattened. Greatest width of theca at junction of RR and RB. Greatest thecal width 6.5 mm. Vault small, restricted to summit of theca. Pelvis significantly larger than vault. Vault / Pelvis ratio 0.28. Theca pentagonal in plan view with slightly concave interambulacral areas. Ambulacra forming points of pentagon. Ambulacra small, do not reach the edge of thecal outline.

Basals three, in normal position. Bowl shaped with flattened base in lateral view. In basal view, basals occupy 60% of cross section. Stem attachment in slight invagination. Proximal stem plate circular, 0.7 mm in diameter. Ornamentation from papillate growth lines of RB sector of radials continues onto basals.

Radials five. Ornamented with coarse growth lines ornamented with papillae. Papillae on successive growth lines forms starburst ornament with origin at RR, RB and RD growth sectors. Lateral margin of radials strongly convex. Edge along the RR front slightly convex. Aboral edges concave where radial meets the basal. Radial occupies more than half of pelvis. RB axis (2.3 mm) longer than

RR axis (1.6 mm). RD axis small (0.87 mm). Width of radial at radial-basal suture (3.0 mm). Width of radial at radial-deltoid suture (2.5 mm).

Deltoids four with two anal deltoids. Deltoids and epideltoid form border to oral opening at peristome. Deltoids small, protrude above peristome in lateral view. Short straight edge bordering oral opening; width expands aborally along long straight deltoid-deltoid growth front (DDF). Adoral margins of deltoid contain main food groove with minor lobes and grooves. Greatest width at adoral end of ambulacrum. Aboral part of deltoid constricted by two troughs that slope adorally into hydrospires forming arrowhead shaped deltoid face. Troughs form a median ridge with a knob at the aboral end that overhangs the radial deltoid suture.

Anal deltoids two, an epideltoid and hypodeltoid. Epideltoid similar to adoral end of regular deltoid. Aboral edge of epideltoid embayed by anal opening. In lateral view epideltoid protrudes above the peristome. Hypodeltoid a small inconspicuous plate.

Ambulacra five, small, rhomboid, do not reach oral opening. Ambulacral length (1.5 mm). Ambulacral width (1.1 mm). Main food groove extends to mouth between lateral edges of the deltoids. Ambulacra depressed below deltoids but higher than hydrospire fields and coplanar with radial. Lancet exposed, rhombic. Brachiolar facets arrayed along aboral sides of ambulacrum.

Eight hydrospire groups, lacking in anal interarea, with two slits per group. Hydrospire slits short, present in aboral troughs in deltoid and cross radiodeltoid suture. In lateral view, hydrospires almost vertical with sets of hydrospire slits separated by deltoid medial ridge.

Oral opening pentagonal (0.7 mm) bordered by secondary lobes and grooves of main food groove. Anal opening ellipsoidal oriented almost vertically in lateral view.

Remarks. Breimer & Macurda (1972) and Macurda (1983) presented detailed descriptions and measurement for the seven species of *Angioblastus*. The four Permian species of *Angioblastus* are *Angioblastus boliviensis* Breimer & Macurda, 1972 from the Lower Permian of Bolivia, *Angioblastus miloradovitchi* Yakovlev, 1940 from the Sakmarian of the Pechora Region of Russia, *Angioblastus wanneri* Yakevlov, 1926 from the Permian, Krasnofimsk, Russia, and *Angioblastus variabilis* from Timor (Macurda 1983).

Angioblastus qararii sp. nov. most closely resembles *Angioblastus variabilis* with strongly ornamented radials and basals, restricted vault not reaching the edge of pentagonal profile, and hydrospire slits functional only over a short distance. *Angioblastus qararii* sp. nov. differs from *Angioblastus variabilis* in thecal shape, number of hydrospire slits and the presence of a sharp ridge that is lacking in *Angioblastus variabilis*. The deltoids of *Angioblastus qararii* sp. nov. most closely resemble those of *A. milorado-vitchi*, but the thecal shape is quite different.

***Angioblastus omanensis* sp. nov.**

Fig. 7.5–7.8

Holotype: Holotype: ONHM F-1436.

Diagnosis: Thecae small, elliptical in lateral view with long axis along the oral-aboral plane. Base of theca protruding cone. Greatest width of theca at aboral end of ambulacral sinus on radials. Vault small, restricted to summit of theca. Pelvis significantly larger than vault. Theca circular in plan view. Basals and radials have coarse growth lines with granular ornamentation.

Etymology: The species is named for the Sultanate of Oman.

Additional specimens: ONHM F-1437 to ONHM F-1445.

Type locality and horizon: Wadi Khawr Al Jaramah (WKJ-1 or WKJ-2), Batain, Oman; Qarari Unit, Permian (late Kungurian).

Description. Thecae small. Length 7.8 mm. Theca elliptical in lateral view with long axis along the oral-aboral plane. Base of theca protruding cone. Greatest width of theca at aboral end of ambulacral sinus on radials. Greatest thecal width 6.8 mm. Vault small, restricted to summit of theca. Pelvis significantly larger than vault. Vault/Pelvis ratio 0.33. Theca circular in plan view. Theca weathered, but basals and radials have coarse growth lines with granular ornamentation.

Basals three, in normal position. Bowl to broad cone shaped in lateral view slightly protruding stem attachment. In basal view, basal plates occupy 80% of cross section. Proximal stem plate circular, 0.7 mm in diameter. Ornamentation from growth lines of RB sector of radials continues onto basal plates. In aboral view, basal-radial sutures of zygous basals strongly convex. Azygous basal diamond shaped with lateral edges slightly convex.

Radials five. Ornamented with coarse growth lines. Granulae on successive growth lines forms starburst ornament with origin at RR, RB, and RD growth sectors. Lateral margin of radials slightly convex. Edge along the RR front straight in lateral view. Aboral edges slightly concave where radial

meets the basal. Radial occupies two thirds of pelvis. RB axis (2.7 mm) longer than RR axis (1.9 mm). RD axis straight (1.7 mm). Width of radial at radial-basal suture (3.6 mm). Width of radial at radial-deltoid suture (3.4 mm).

Ambulacra small, do not reach the edge of thecal outline. Ambulacra not well preserved, five, small, rhomboid, do not reach oral opening. Ambulacral length (1.5 mm). Ambulacral width (1.0 mm). Main food groove extends to mouth between lateral edges of the deltoids. Ambulacra at same level with deltoids, hydrospire fields and radials. Lancet exposed, rhombic. Brachiolar facets arrayed along aboral sides of ambulacrum.

Deltoids four with two anal deltoids. Deltoids and epideltoid form border to oral opening at peristome. Deltoids relatively large, adoral margin at level with peristome in lateral view. Short straight edge bordering oral opening; width expands aborally along long straight deltoid-deltoid growth front. Adoral margins of deltoid contain main food groove with minor lobes and grooves. Greatest width at adoral end of ambulacrum. Aboral part of deltoid constricted by broad hydrospire field. Exposed part of deltoid forms a median ridge that expands slightly aborally.

Anal deltoids two, an epideltoid and hypodeltoid. Epideltoid similar to adoral end of regular deltoid. Aboral edge of epideltoid embayed by anal opening. In lateral view epideltoid protrudes above the peristome. Hypodeltoid a small inconspicuous plate.

Eight hydrospire groups, lacking in anal interarea, with five slits per group. Hydrospire slits relatively long, present in aboral troughs in deltoid and cross radiodeltoid suture. In lateral view, hydrospires almost vertical with sets of hydrospire slits separated by deltoid medial ridge.

Oral opening pentagonal (0.9 mm) bordered by secondary lobes and grooves of main food groove. Anal opening ellipsoidal oriented almost vertically in lateral view. Width of anal opening 1.2 mm; length 2mm. The adoral part of the anal opening is elongated and projects above the peristome. Gonopore may be present in epideltoid.

Remarks. *Angioblastus omanensis* sp. nov. is differentiated from *A. qararii* sp. nov. by its thecal shape, the number of hydrospires, and the projection (or lack thereof) of deltoids above the peristome. The only other species of *Angioblastus* with five or more

hydrospires is *A. wanneri*. *Angioblastus omanensis* sp. nov. is differentiated from *A. wanneri* on basic thecal shape and constriction of the vault.

Order **Granatocrinida** Bather, 1900, emended
Waters & Horowitz, 1993
Deltoblastus Fay, 1961

Type species: *Schizoblastus delta elongatus* Wanner, 1924a.

Deltoblastus pseudodelta (Wanner, 1924a)

1924a *Schizoblastus pseudodelta* – Wanner, p. 68, pl. 6, figs. 2–3, pl. 7, fig. 24.
1961 *Deltoblastus pseudodelta* – Fay, p. 36–40.

Holotype: RGM 12313.

Diagnosis: Thecal ovate in lateral view; almost as wide as high. Pentalobate in cross-section; Ambulacra recessed in deep ambulacral sinus. Ambulacra flat in cross-section; radial deeply concave. Deltoid long, narrow; greatest width at RD suture Deltoids very thick, deltoid crests project above peristome. External surface of deltoid has rows of coarse granules/almost stubby spines along growth lines. In plan view, deltoid V shaped from RD suture to adoral tip of face. Two anal deltoids, an epideltoid and a hypodeltoid. Epideltoid very small. Hypodeltoid large; external surface as for other deltoids. Anus small elliptical.

Type locality and horizon: West Timor; Permian (unknown age).

Other material: TCD 59009 (Webster & Sevastopulo 2007, Figs. 2D–2E); ONHM F-1447 to ONHM F-1454.

Remarks. Webster & Sevastopulo (2007) attributed their specimen of *Deltoblastus* to *Deltoblastus* sp. nov.? aff. *D. delta subglobosus* Wanner, 1924a. They described the specimen as having “globular shape, deeply impressed basal invagination, high vault, wide ambulacra, deep grooves in the interambulacral regions, pit at the apices of the deltoid-radial suture, and thickening of the margins of the radials and deltoids along the ambulacral areas” (p. 403). Webster & Sevastopulo (2007) did not erect a new species based on the specimen because the oral area was covered; but clearly, they thought the specimen could be assigned to a new species. We concur with their description but reject the concept that the specimen likely represents a new species. As indicated above, *Deltoblastus* has significant variability in the large populations known from Timor, and the species-level taxonomy requires significant revision.

The specimen illustrated by Webster & Sevastopulo (2007) could be assigned to *D. delta* Bather, 1908, but it could just as easily be assigned to

D. pseudodelta (Wanner, 1924), which is our preference. New specimens of *Deltoblastus* reported here are from the Qarari Unit (late Kungurian to early Roadian) from Jebel Qarari. These are likely the same species as the specimen described by Webster & Sevastopulo (2007).

The significance of the specimens does not lie in their species assignment, rather in their occurrence. As indicated above, specimens of *Deltoblastus* have been reported from a number of other Permian localities, but the paper by Webster & Sevastopulo (2007) is the first verifiable occurrence of the genus outside Timor. The additional collections here confirms the initial report of *Deltoblastus* from Oman and sheds additional light on its distribution.

The “classic morphology” of *Deltoblastus* specimens from Jebel Qarari is a very different morphology than the specimens of *Deltoblastus* collected from Wadi Khawr al Jaramah locations WKJ-1 and WKJ-2. We assign these specimens to *Deltoblastus sevastopuloi* sp. nov., which is very similar to *Deltoblastus somobolensis* Wanner 1924, a species Wanner erected from a single specimen out of the tens of thousands of specimens of *Deltoblastus* known to him from Timor.

Geologic age and geographic distribution. Permian (unknown age), West Timor; Qarari Unit (late Kungurian to early Roadian), Jebel Qarari Crest, Oman.

Deltoblastus molengraaffi (Wanner, 1924a)

Figs. 4.3, 7.12

1924a *Schizoblastus molengraaffi* – Wanner, p. 44, pl. 4, figs. 9–19, text fig. 9.

1924a *Schizoblastus molengraaffi sebotensis* – Wanner p. 47, pl. 8, fig. 18.
1961 *Deltoblastus molengraaffi* – Fay, p. 36–40.

Holotype: RGM 345632

Type locality and horizon: West Timor; Permian (unknown age).

Other Material: ONHM F-1455 and ONHM F-1456.

Remarks. Specimens not well preserved; one partially silicified in a block of sediment. Specimens are referred to *Deltoblastus molengraaffi* based on the following characters: Specimens narrow elliptical with circular cross section. Deltoids very long. Side plates cover lancet below RD suture. Lancet progressively exposed adorally along deltoid. Ambulacra not indented or barely indented in the ambulacral sinus.

Geological age and geographic distribution. Permian (age unknown), West Timor; Qarari Unit, Permian (late Kungurian to early Roadian), Jebel Qarari, Batain, Oman.

***Deltoblastus sevastopuloi* sp. nov.**

Fig. 7.9–7.11

Holotype: ONHM F-1457.

Diagnosis: Theca small, godoniform to almost ovoid with very long recurved ambulacra. Theca ovoid with flat base in lateral view; pentalobate in cross section. Ambulacra broad, lanceolate, depressed relative to interambulacral areas. Interambulacral areas concave. Vault occupies 100% thecal length in lateral view; pelvis not. In basal view, basal circlet occupies about 20% of cross section. Greatest thecal width at radial-deltoid suture. Theca ornamented with coarse growth lines with granular to papillate ornamentation. Ten spiracles with those in anal area separate from anus.

Etymology: This species is named in honor of George Sevastopulo, who contributed significantly to the study of Paleozoic echinoderms.

Additional specimens: ONHM F-1458 to ONHM F-1478.

Type locality and horizon: Wadi Khawr Al Jaramah, Batain, Oman; Qarari Unit, Permian (late Kungurian).

Description. Theca small, godoniform to almost ovoid with very long recurved ambulacra. In lateral view, theca rounded ovoid shape with flat base. Pentalobate in cross section with ambulacra depressed relative to interambulacral areas. Ambulacra broad, lanceolate. Interambulacral areas are concave. Vault occupies total thecal length in lateral view. Pelvis not visible in lateral view. In basal view, basal circlet occupies about 20% of cross section. Greatest thecal width at radial-deltoid suture. Thecal length 7.0 mm; greatest thecal width 6.7 mm. Theca ornamented with coarse growth lines with granular to papillate ornamentation. Ten spiracles with those in anal area separate from anus.

Basals small, in normal position. In lateral view, basals flat, depressed below knobs in RB sector of radial at aboral end of the ambulacral sinus. Basal sutures with radials straight to slightly concave. Sutures between zygous and azygous basals short, straight. Stem cicatrix circular, depressed in basal circlet, 0.8 mm in diameter.

Radials short with broad ambulacral sinus. Convex to recurved in lateral view. Radial-radial suture slightly convex, Radial-basal suture short, straight. Radial-deltoid suture straight. RD axis 2.0 mm; RD front 1.1 mm. In lateral view, RR sector exposed only in aboral-most 10% of radial. In basal view, RR axis is concave. RR axis 1.2 mm; RR front 2.0 mm; RB sector very short and narrow. RB axis

0.6 mm; RB front 1.4 mm. Ambulacral sinus broad. Ambulacra depressed well below the prominent rim of ambulacral sinus. Radial body at aboral end of ambulacral sinus has a very prominent knob. RD sector with broad, coarse growth lines. RR and RB sectors have finer growth lines with granulose to papillate ornamentation.

Deltoids long, convex to slightly recurved in lateral view. Deltoids do not reach level of peristome in lateral view. Deltoid-radial suture straight. Lateral margins of deltoid form part of ambulacral sinus. Ambulacra depressed below deltoid margins. Slight scallops in lateral margin of deltoid may have supported proximal end of brachioles. Deltoid face has coarse growth lines with knobs that form a discontinuous medial ridge. Adorally, exposed deltoid face narrows and is pierced by pairs of spiracles. Adoral-most part of deltoid arrowhead shaped, carries main food groove, and forms margin of peristome.

Ambulacra long, lanceolate. Ambulacral length 6.25 mm; greatest width 1.7 mm. Lancet exposed throughout length of ambulacrum, side plates trapezoidal, outer side plates small. One hydrospire pore per side plate. Main food groove traverses length of lancet, secondary food grooves on both sides of side plates.

Anal deltoids two, large hypodeltoid and epideltoid. Hypodeltoid similar to other deltoids. Epideltoid hook-shaped. C-side sutures normally with hypodeltoid. D-side suture has a gap allowing D-side spiracle to integrate with anus.

Spiracles ten, paired and separate from anus in CD interarea. Spiracle length 0.4 mm; width 0.15 mm. Anal opening elliptical. Length 0.9 mm; width 0.5 mm. D-side spiracle larger than others because of gap in epideltoid, circular, 0.4 mm in diameter. Peristome small, circular, 0.4 mm in diameter.

Remarks. *Deltoblastus sevastopuloi* sp. nov. is a small blastoid and is most similar to *Deltoblastus somobolensis* (Wanner, 1922) from Timor. These species are morphologically very different from other species of *Deltoblastus*. The most prominent features in both species are small size, the knobs at the aboral ends of the radials, the granulose to papillate ornamentation of the plates, and “flower petal” appearance in the aboral view formed by the basals and the RB sector of the radials.

Deltoblastus sevastopuloi sp. nov. differs from *Deltoblastus somobolensis* with a pentalobate cross-section.

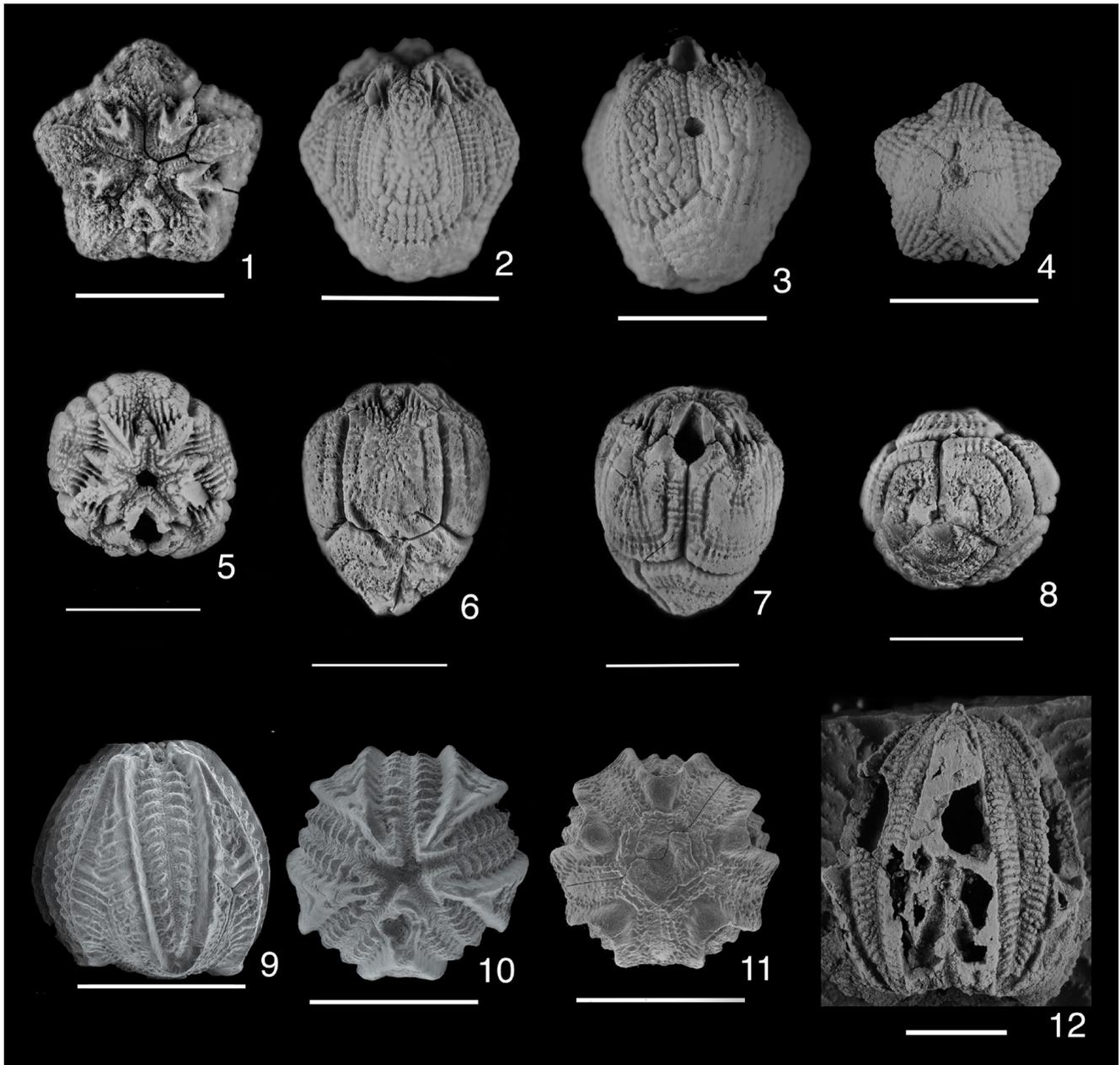


Fig. 7 - Blastoids from the Permian of Oman, scale bars = 5.0 mm. 1-4) *Angioblastus qararii* sp. nov., holotype, ONHM F-1433; 1, oral view; 2, A-ray view; 3, posterior view; 4, basal view. 5-8) *Angioblastus omanensis* sp. nov., holotype, ONHM F-1436; 5, oral view; 6, A-ray view; 7, posterior view; 8, basal view. 9-11) *Deltoblastus sevastopuloi* sp. nov., holotype, ONHM F-1457; 9, lateral view; 10, oral view; 11, basal view. 12) *Deltoblastus molengraaffi* ONHM F-1455, lateral view of a partially silicified and weathered theca.

tion theca with ambulacra protruding above concave interambulacra. *Deltoblastus somobolensis* has a very different cross-section from all other species of *Deltoblastus*.

Deltoblastus somobolensis is known from a single specimen from Somohole, Timor, interpreted to be the oldest blastoid-bearing locality in Timor. Webster (1998) and Charlton et al. (2002) assigned an Artinskian to Kungurian (late Cisuralian) age for the Somohole localities. Previous reports of blastoids

from Somohole include *Anthoblastus*, *Spheroschisma*, *Nannoblastus* (Macurda 1983), and *Corrugatoblastus* (Sprinkle & Waters 2013).

Class **CRINOIDEA** Miller, 1821

Infraclass **EUCAMERATA** Cole, 2017

Subclass **CAMERATA** Wachsmuth & Springer,
1885

Order **Monobathrida** Moore & Laudon, 1943

Remarks. The majority of camerate crinoid remains from the Permian of Oman are disarticulated calyx plates, pluricolumnals, and columnals. The exception is *Pleurocrinus omanensis* (Webster & Sevastopulo 2007), which is known from two nearly complete thecae and three partial thecae (see below). The remainder of the camerate species are difficult to identify with certainty.

Loose radial plates isolated in washings from the Qarari Unit clearly belong to monobathrid camerate crinoids. However, it is not possible to identify these radial plates to suborder because the suborder distinction is based on the presence or absence of a primanal within the radial cirlet, thus they are described herein as Monobathrida Camerate Indeterminate. At least three morphologies occur, and they display differences in the radial plate shape, morphology of the radial facets, and surface sculpturing.

Suborder **Compsocrinina** Ubaghs, 1978b
Family Hexacrinitoidea Wachsmuth & Springer,
1885

Family Dichocrinidae S.A. Miller, 1889
Subfamily Dichocrininae S.A. Miller, 1889

Dichocrinidae Indeterminate

Fig. 8.7

Specimen: ONHM F-1479.

Description. Primanal plate elongate, with gently convex sides, surface of fine calcite stereom. Gently convex longitudinally and transversely. Base slightly convex for attachment to basal cirlet, distal right shoulder roundly concave and is a notch for the anal opening (Fig. 8.7). Radial-radial sutures smooth for synostosomal articulation.

Remarks. Lacking a radial facet and with the upper right shoulder of this plate concave; therefore, this plate is regarded as a primanal plate of a dichocrinid. The arcuate upper right plate margin would have been the lower left portion of the anal opening. The entire opening would have been bordered by the primanal, the C radial plate, and one or more tegmen plates.

Measurement. ONHM F-1479: PAH, 4.6; PAW, 2.9.

Geological age and geographic distribution. The Dichocrinidae is a cosmopolitan, upper Paleozoic crinoid family. In Oman it occurs in

the Qarari Unit, Permian (late Kungurian) at Wadi Khawr Al Jaramah (WKJ-2), Batain, Oman.

Subfamily Camptocrininae Broadhead, 1981

Camptocrininae Indeterminate

Fig. 9.1–9.2

Specimens: ONHM F-1480 to ONHM F-1482.

Description. Columnals small, short, subelliptical to elliptical with mature elliptical columnals with long axis ~1.4 times wider than short axis, slightly concave sides without sculpturing. Facet divided by transverse ridge offset from the long axis with small medial fossa (Fig. 9.1), large elliptical fossa on outer side of articular ridge, small elliptical axial canal on inner side of articular ridge. Crenularium along approximately half of the outer rim of the facet. Latus with smooth sculpturing (Fig. 9.2).

Remarks. Numerous columnals and a few columnal pairs were isolated from washings from WKJ-1 and WKJ-2 that have an asymmetrically positioned articular ridge. These include forms that were nearly circular proximal morphotypes and more abundant, distal, strongly elliptical morphotypes. Similar columnals were described by Webster & Jell (1992) from Western Australia. Classically, such columnals would be identified as *Camptocrinus* Wachsmuth and Springer, 1897; but a second camptocrinid, *Neocamptocrinus* Willink, 1980a was described from the Permian of Australia. Willink (1980a) recognized a distinction between columnals of *Camptocrinus* and *Neocamptocrinus*, but Schoor et al. (2020) concluded that columnals of *Camptocrinus* and *Neocamptocrinus* were basically identical and that neither a generic nor specific name can be assigned to such specimens. The only identified differences between these genera were characters of the tegmen with more numerous plates in the tegmen of *Neocamptocrinus* (see Schoor et al. 2020). Herein, these distinctive columnals are assigned to Camptocrininae Indeterminate.

Measurements. ONHM F-1480: ColH, 0.67; ColMaxW, 1.53; ColMinW, 1.26.

Geological age and geographic distribution. The Camptocrininae is a cosmopolitan, upper Paleozoic crinoid subfamily. In Oman it occurs in the Qarari Unit, Permian (late Kungurian) at Wadi Khawr Al Jaramah (WKJ-1 and WKJ-2), Batain, Oman.

Suborder **Glyptocrinina** Ubaghs, 1978b
 Superfamily Platycrinitoidea Austin & Austin, 1842
 Family Platycrinittidae Austin & Austin, 1842

Remarks. Ausich & Kammer (2009) re-examined the Platycrinittidae and provided diagnoses for each genus and reassigned species to genera, as appropriate. A critical aspect of distinguishing platycrinittid genera is the presence or absence of an anal tube; and, if the anal tube is not present, the position of the periproct. Unfortunately, many named species of *Platycrinittes* were based on specimens in which the tegmen was absent or concealed by the arms, which necessitated assigning these species to *Platycrinittes* sensu lato, as opposed to *Platycrinittes* sensu stricto (Ausich & Kammer 2009).

This is relevant to the study of Permian platycrinittids because large, smooth sculptured platycrinittids exist either with or without an anal tube (see Warner 1916, 1937; Webster & Sevastopulo 2007; Webster & Donovan 2012). The large platycrinittids from the Qarari Unit are conspecific with *Platycrinittes omanensis* Webster & Sevastopulo 2007; however robust plating in the periproct region is absent from both specimens described by Webster & Sevastopulo (2007) and the new specimens. Thus, *Platycrinittes omanensis* is reassigned herein to *Pleurocrininus* as discussed below.

Genus *Pleurocrininus* Austin & Austin, 1843

Diagnosis: See Ausich & Kammer (2009).

Type species: *Pleurocrininus mucronatus* Austin & Austin, 1843.

Included Permian species: *Pleurocrininus depressus* Wanner, 1916 (Basleo, West Timor; uncertain age); *P. ellesmerense* (Broadhead & Strimple, 1977) (Canada; Guadalupian); *P. globosus* Wanner, 1916 (Basleo, West Timor; uncertain age); *P. goldfussi* Wanner, 1916 (Basleo, West Timor; uncertain age); *P. omanensis* (Webster & Sevastopulo, 2007) comb. nov. (Oman; late Kungurian to early Roadian); and *P. spectabilis* Wanner, 1916 (Basleo, West Timor; uncertain age).

Geological age and geographic distribution. The *Pleurocrininus* is a cosmopolitan, upper Paleozoic crinoid genus. Permian (late Kungurian) at Wadi Khawr Al Jaramah (WKJ-1), Batain, Oman and in the Qarari Unit, Permian (late Kungurian–early Roadian) at Jebel Qarari Crest, Oman,

Remarks. A full list of species currently assigned to *Pleurocrininus*, with the addition of *Pleurocrininus omanensis* (Webster & Sevastopulo, 2007), is listed in Ausich & Kammer (2009). This genus ranges from the Mississippian (Tournaisian) through at least the Cisuralian. *Platycrinittes omanensis* is reassigned to *Pleurocrininus*, herein, because *Platycrinittes* has a me-

dium to low bowl-shaped tegmen and an anal tube; whereas, *Pleurocrininus* has a flat, bowl-shaped tegmen and an anal tube is absent (see Ausich & Kammer 2009; tables 1 and 2).

Pleurocrininus omanensis (Webster & Sevastopulo, 2007) comb. nov.

Figs. 4.2, 8.1–8.6

2007 *Platycrinittes omanensis* – Webster & Sevastopulo, p. 403–404, fig. 2F–2H.

2014 *Platycrinittes omanensis* – Webster & Webster, p. 1757.

Holotype: TCD.59010.

Diagnosis: Medium bowl aboral cup shape, smooth plate sculpturing, lateral profile of basal circlet straight, gently convex radial plates shape, calyx plate sutures not impressed, numerous tegmen plates, tegmen plates small to large, flat bowl tegmen shape, anal opening subcentral, 20 free arms.

Paratype: TCD.59011.

Type locality and horizon: Webster & Sevastopulo (2007) gave the occurrence as an unnamed djebel approximately 3 km west of Jebel Qarari (Kurayah), west of Al Ashkarah, northeastern Oman, but Shackleton et al. (1990), who collected the material, listed it as Jebel Qarari (location 604), which is late Kungurian to early Roadian.

Additional material: ONHM F-1483 to ONHM F-1487.

Description. Crown medium bowl shape without a basal concavity (Fig. 8.2). Calyx plate sculpturing smooth (see Webster & Sevastopulo 2007) (Fig. 8.5). Basal circlet ~40% of calyx height with a short “neck” projecting proximally; in profile sides of the proximalmost portion of the basal circlet concave; sutures between basal plates very indistinct, total number of basal plates unknown. Radial circlet ~60% of calyx height, in lateral contact in all interrays; radial plates large, five, heptagonal, wider than high.

Regular interrays and CD interray plating absent in calyx. CD interray plating on tegmen margin; primanal hexagonal, followed by two large plates medially and two small plates laterally.

Fixed brachials through at least the first ter-tibrachial. First primibrachial axillary, symmetrical. First secundibrachials of different sizes with ad-medial secundibrachial large and abmedial secundibrachial much smaller. Fixed intrabrachials absent.

Tegmen flat bowl shaped, comprised of numerous plates of variable sizes and shapes. Periproct positioned subcentrally or approximately mid-way between the center and outer margin of the tegmen. Periproct area covered by numerous small plates (Fig. 8.1, 8.4).

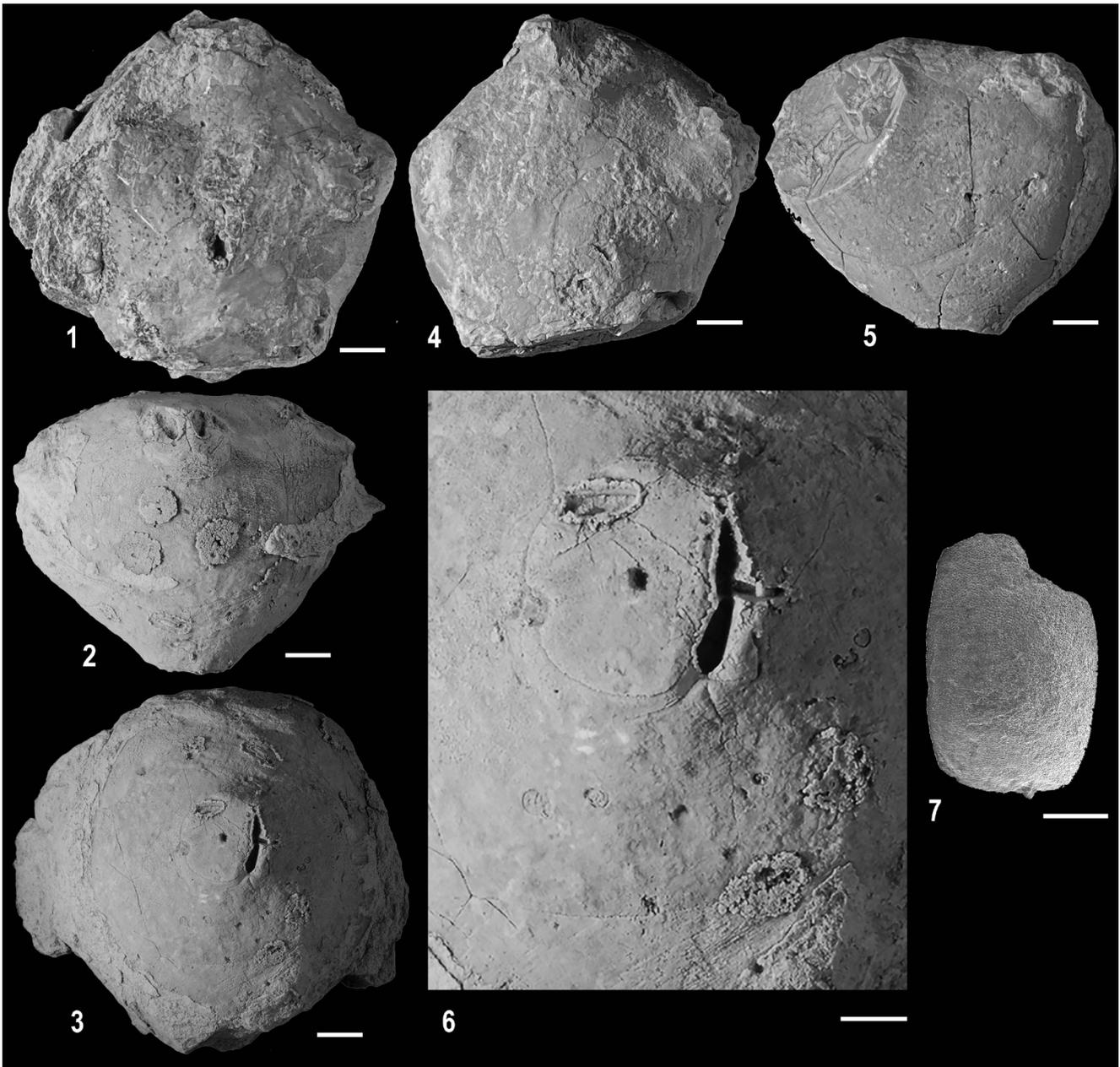


Fig 8 - Camerate crinoids from the Qarari Unit. 1-6) *Pleurocrinus omanensis* comb. nov. thecae; 1-3, 6, ONHM F-1483, scale bar = 5.0 mm; 1, oral view of tegmen, note subcentral position of anus; 2, side view of calyx, note circular borings and beekite rings; 3, basal view of calyx, note borings and beekite rings; 6, enlargement of base of Fig. 8.3, note circular articulation for column, very small lumen, and two types of borings, scale bar = 2.5 mm. 4, 5, ONHM F-1484, scale bar = 5.0 mm; 4, oral view of tegmen with a marginal anus; 5, side view of theca, note radial plates on left side fractured along a cleavage plane. 7) *Dichocrinidae* Indeterminate, ONHM F-1479, individual primanal plate, note large notch in upper right for the anal opening, scale bar = 1.0 mm.

Twenty free arm openings into theca of varying sizes. Other aspects of free arms unknown.

Column unknown but articulation to basal circlet circular (Fig. 8.3, 8.6).

Remarks. The type specimens of *Pleurocrinus omanensis* comb. nov. are moderately preserved, as are the new specimens. The primary question for the genus assignment is the presence or absence

of an anal tube and the position of the anus. In the diagnosis for *Pleurocrinus omanensis* comb. nov., Webster & Sevastopulo (2007, p. 403) describe an “anal tube low” and in the description (p. 403) they describe “anal tube low, formed by numerous small polygonal plates, with or without small central nodes.” However, in Webster & Sevastopulo (2007, figs. 2F and 2G), there is neither plating elevated

above the tegmen surface nor robust tegmen plates onto which an anal tube would be seated. Similar to the type specimens, two of the new specimens (C-5, C-6) have an anal area interpreted to be the periproct that is slightly swollen with collapsed small plates in a subcentral position on the tegmen. Thus, there is no evidence for an anal tube, which eliminates the assignment of this taxon to *Platycrinites*.

As noted above, there are six species of *Pleurocrinus* recognized from the Permian. *Pleurocrinus depressus* has a low bowl aboral cup shape, a basal circlet with a convex lateral profile, radial plates that are strongly convex, calyx plate sutures not impressed, relatively few tegmen plates, a flat bowl tegmen shape, the anus positioned at the tegmen-aboral cup margin, and ten free arms; *P. ellesmerense* has smooth aboral cup plate sculpturing, a basal circlet with a slightly concave lateral profile, and calyx plate sutures weakly impressed (aboral cup shape, radial plate shape, number of tegmen plates, shape of the tegmen, anus position, and arm number unknown); *P. globosus* has a medium bowl aboral cup shape, a basal circlet with a convex lateral profile, radial plates that are moderately convex, calyx plate sutures not impressed, relatively few tegmen plates, a flat bowl tegmen shape, the anus positioned at the tegmen-aboral cup margin, and ten free arms; *P. goldfussi* has a low bowl aboral cup shape, a basal circlet with a convex lateral profile, radial plates that are moderately convex, calyx plate sutures not impressed, relatively few tegmen plates, a very low bowl tegmen shape, the anus positioned at the side of the tegmen, and ten free arms; *P. spectabilis* has a low cone aboral cup shape, a basal circlet with a straight lateral profile, radial plates that are gently convex, calyx plate sutures not impressed, relatively few tegmen plates, a flat bowl tegmen shape, the anus positioned at the tegmen-aboral cup margin, and 20 free arms. In contrast, *Pleurocrinus omanensis* comb. nov. has a medium bowl aboral cup shape, basal circlet with a straight lateral profile, radial plate shape gently convex, calyx plate sutures not impressed, numerous tegmen plates, a flat bowl tegmen shape, the anus position subcentral, and 20 free arms.

The two more complete specimens both contain small, circular boreholes (Fig. 8.5, 8.6). Along the margin of the column facet, ONHM F-1483 also has a large, elongate boring preserved (Fig. 8.6).

Measurements. ONHM F-1483: TH, 30.7; CaH, 29.0; CaW, 37.8; BH, 12.8; RH, 19.1; RW, 24.2; TegH, 8.9. ONHM F-1484: TH, 3.3; CaH, 27.4; CaW, 37.7; BH, 8.1; BW, 13.9; RH, 19.7; RW, 12.1; TegH, 7.4.

Geological age and geographic distribution. Permian (late Kungurian to early Roadian) Qarari Unit, Jebel Qarari Crest, Batain, Oman; Wadi Khawr Al Jaramah (WKJ-1), Permian (late Kungurian) Jebel Qarari Crest, Batain, Oman.

Platycrinitidae Columnals

Figs. 9.3–9.10

Specimens: ONHM F-1488 to ONHM F-1492, and many specimens are in the following lots: ONHM F-1493 and ONHM F-1494.

Remarks. Middle to Upper Paleozoic elliptical columnals with a central articular ridge that is offset on opposite facets of a columnal should be regarded as a character of the Platycrinitidae (Ausich & Kammer 2009). The articular facets of Platycrinitidae columnals are elliptical with a bilaterally symmetrical facet defined by an articular ridge along the long diameter of the facet. Further in most platycrinitids, the orientation of the articular ridges on the upper and lower facets are offset, yielding a helically spiralled column. This contrasts with camptocrinids (see above) that have a bilaterally symmetrical facet in which the axis crosses the widest portion of the facet (Fig. 9.1, 9.2), and articular ridges on opposing sides of a single columnal are parallel. This arrangement yields the characteristic planispirally coiled column of camptocrinids.

It is possible in some cases to match columnals with identified crowns, but placing columnals and pluricolumnals into a platycrinitid genus or species is typically problematic. As noted above, characters of the crown, including the tegmen, are required for genus determination.

Among crinoidal remains in the Qarari Unit fauna, there are numerous platycrinitid columnals and pluricolumnals. Columnals vary in size from ~2.5 mm to >15.0 mm in maximum diameter, and there are several morphologically distinctive columnal morphologies. Five platycrinitid columnal morphologies are described below. Characters distinguishing these columnal types include the lateral profile of the columnal, the presence or absence of spines and/or nodes on the columnal latera, and the

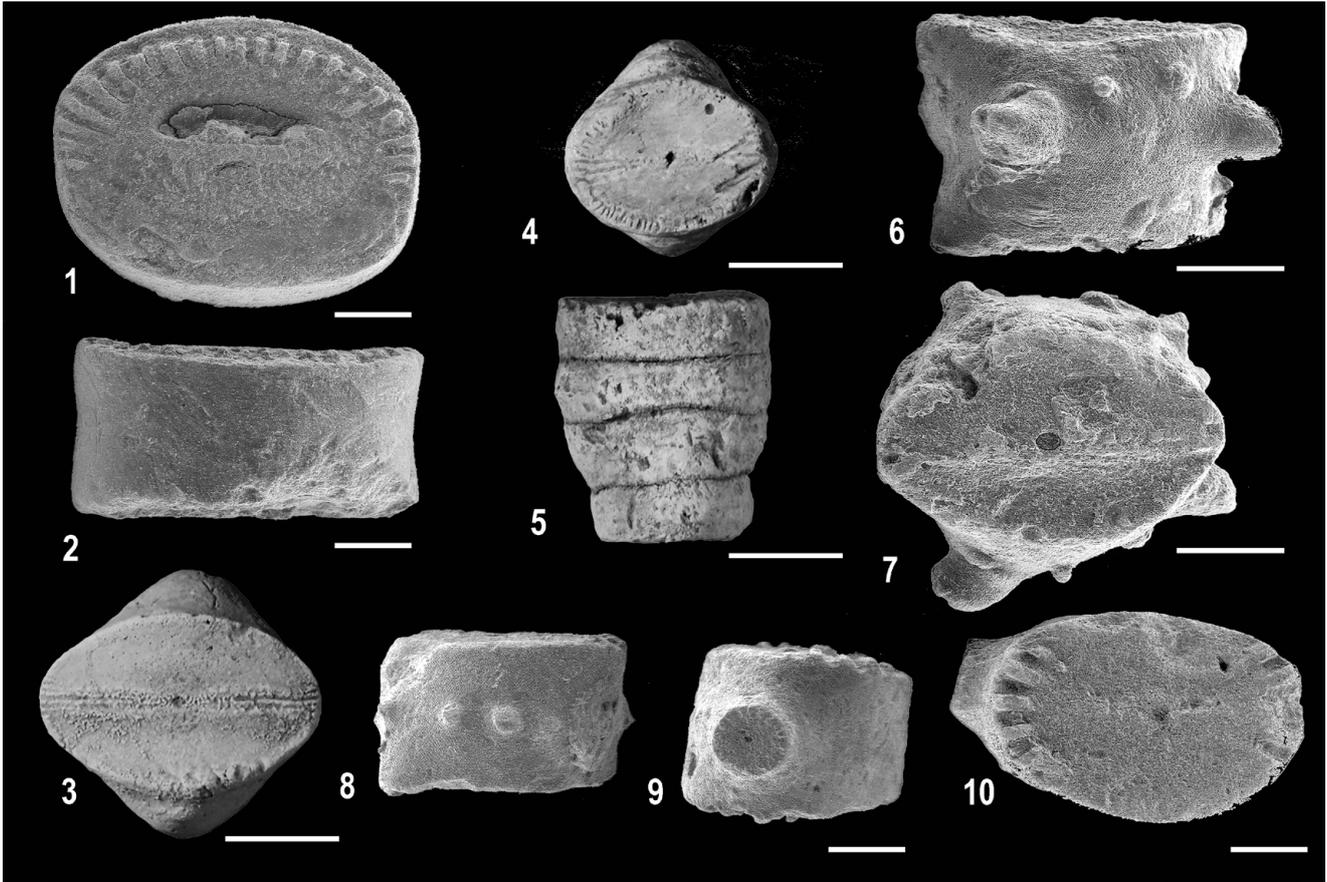


Fig. 9 - Camerate crinoid columnals and pluricolumnals from the Qarari Unit, all scale bars = 1 mm. 1, 2) Camptocrininae Indeterminate, ONHM F-1480; 1, articular facet, note offset articular ridge and crenularium; lateral view of columnal with smooth latus. 3–10) Platycrinitidae columnals; 3, ONHM F-1492, columnal with nearly a 180° offset of articular ridge on either side of facet; 4, 5) ONHM F-1490, pluricolumnal with slight offset of articular ridge on either side of facet; 6, 7) ONHM F-1488, columnal with large spines around latus; 8) ONHM F-1491, columnal with right of nodes around the center of the columnal; 9, 10) ONHM F-1489, columnal with one radice articulation but otherwise with a smooth latus.

presence or absence of any crenulae on the facet periphery. Platycrinitid columnals display a wide range of articular ridge offset (from the upper to the lower facet of a single columnal) and have varied sculpturing on the column latus. The column latus may be smooth (Fig. 9.3, 9.9, 9.10); may have a ring of small nodes at mid-height around the latus (Fig. 9.8); may have a few, seemingly random spines and/or nodes; or may have numerous spines and nodes around the column latus (Fig. 9.6, 9.7). Also, the degree of the offset of articular ridges between the upper and lower surfaces of a single columnal varies from relatively minor (Fig. 9.4, 9.5) to nearly 180° (Fig. 9.3).

Without complete crinoid specimens, it is not possible to determine the source(s) of this array of column morphologies. These morphotypes could represent distinct taxa, position along the column on a single individual, and/or be a reflection of vari-

ous ontogenetic stages. However, because platycrinitid aboral cups are relatively poorly sutured (thus more likely to disarticulate) and the wide array of columnal types, it is probable that more than one platycrinitid existed in the Qarari Unit.

Geological age and geographic distribution. Platycrinitid columnals are reported herein from the Qarari Unit, Permian (late Kungurian) at Wadi Khawr Al Jaramah (WKJ-1, WKJ-2), Batain, Oman.

Camerate Indeterminate

Remarks. Three small, well-preserved, distinct radial plates were recovered, and these belong to either the Dichocrinidae or the Platycrinitidae. They are treated herein as Monobathrid Camerate Indeterminate.

Monobathrid Camerate Indeterminate Radial Plate 1

Figs. 10.3, 10.4

Specimen: ONHM F-1496.

Locality and horizon: Wadi Khawr Al Jaramah (WKJ-2), Batain, Oman; Permian (late Kungurian), Qarari Unit.

Description. Radial hexagonal, higher than wide, surface sculpture of shallow pits and depressions among faint anastomosing ridges (Fig. 10.3). Proximal half of plate widest, narrowing gently distally with rounded distal shoulders. Two short proximal facets for attachment to the basal circlet, two elongate lateral facets for attachment to adjacent radial plates or an anal plate; gently convex transversely and longitudinally with a medial radial facet on the distal end. Radial facet peneplenary, ~77% of the distal radial plate width (Fig. 10.4), steeply declivate, with a large moderately concave outer ligament fossa; irregular transverse ridge poorly developed with small ligament pits on both sides of the adoral groove, and medial pore or central pit on adoral side. Inner half steeply upflaring to rounded prongs on sides of U-shaped adoral groove with rounded base. Radial-radial facets with horizontal crenulae for symplectial articulation from proximal to distal ends.

Remarks. The surface sculpture of Monobathrid Camerate indeterminate radial plate 1 is distinctive and differs from the other indeterminate monobathrid camerate radial plates that have fine calcite stereom and outer surfaces lacking other sculpturing. It also has better developed crenulae for a symplectial articulation on the radial-radial sutures. The dual synostiosal facets at the base of the plate suggest that they were attached to a basal circlet formed of two or more plates.

Measurements. ONHM F-1496: RH, 5.1; RW, 3.4.

Monobathrid Camerate Indeterminate Radial Plate 2

Fig. 10.1, 10.2

Specimen: ONHM F-1497.

Locality and horizon: Wadi Khawr Al Jaramah (WKJ-2), Batain, Oman; Qarari Unit, Permian (late Kungurian).

Description. Radial plate hexagonal, higher than wide, surface sculpture of fine stereom.

Proximal half slightly wider than distal half; gently narrowing distally. Base rounded slightly with one wide facet. Gently to moderately convex transversely, gently convex longitudinally. Medial radial facet slightly more than half distal width of radial angustary, ~60% of distal radial plate width (Fig. 10.2); steeply declivate, divided into an outer shallow concave margin area and inner steeply upflaring area terminating in two pointed shoulders on the sides of a box-shaped adoral groove (Fig. 10.1). Radial-radial sutures with well-developed transverse crenellae and crenulae for symplectial articulation. Articulation well developed from middle third through distal third, poorly developed in proximal third.

Remarks. The shape of the adoral groove and smooth plate sculpturing on the plate outer surface distinguishes monobathrid camerate indeterminate radial plate 2 from 1. Morphological differences in the radial facet and outline shape distinguish it from monobathrid camerate indeterminate radial plate 3. The single facet at the base suggests that it was attached to a fused basal circlet or part of a bipartite basal circlet.

Measurements. ONHM F-1497: RH, 5.8; RW, 4.2.

Monobathrid Camerate Indeterminate Radial Plate 3

Fig. 10.5, 10.6

Specimen: ONHM F-1498.

Locality and horizon: Wadi Khawr Al Jaramah (WKJ-2), Batain, Oman; Qarari Unit, Permian (late Kungurian).

Description. Radial subelliptical with convex sides, flat base, rounded distal surface dissected by small V-shaped adoral groove and distal third inclinate; surface with smooth sculpturing with well-preserved, fine stereom. Gently to moderately convex transversely, gently sigmoidal vertically. Radial facet peneplenary, ~85% of distal facet width (Fig. 10.5), slightly less than half width of distal width of radial. Radial facet strongly declivate on proximally protruded base; formed in three parts, a proximal shallow concave arcuate outer margin with an angular outer fossa, and arcuate ridge adaxially followed by the medially shallowly concave arcuate fossa with an adaxially positioned medial axial canal (Fig. 10.6). Distal third shallowly concave and irregular surface terminating in medial roundly V-shaped

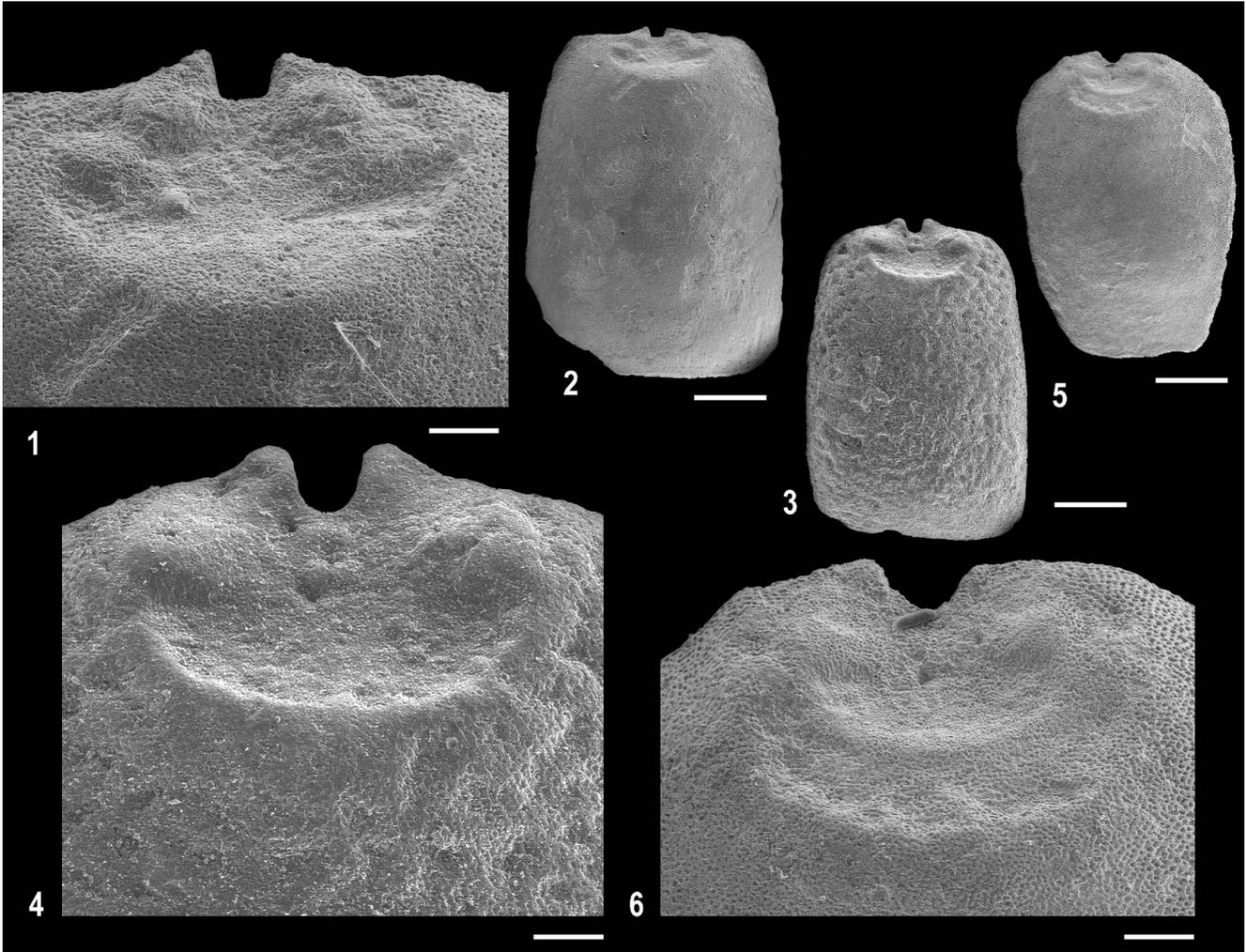


Fig. 10 - Monobathrid Camerate Indeterminate radial plates from the Qarari Unit. 1, 4, 6) scale bar = 0.25 mm, 2, 3, 5, scale bar = 1.0 mm. 1, 2 ONHM F-1497, Monobathrid Camerate Indeterminate 2) smooth plate sculpturing and a simple radial facet; 3, 4) ONHM F-1496, Monobathrid Camerate Indeterminate 1, radial plate with pustulose plate sculpturing; 5, 6) ONHM F-1498, Monobathrid Camerate Indeterminate 3, smooth plate sculpturing and a fossa in front of the aboral fossa.

adoral groove. Radial sutures bear well-developed transverse crenulae for symplectial articulation from middle third through distal third and very weakly developed in proximal third.

Remarks. The flat base suggests that the plate was attached to a fused basal circlet or part of a bipartite circlet with synostosomal articulation. The more rounded shape of the plate and the tripartite radial facet distinguishes Monobathrid Camerate Indeterminate radial plate 3 from Monobathrid Camerate Indeterminate radial plates 1 and 2.

Measurements. ONHM F-1498: RH, 4.8; RW, 3.2.

Subclass **PENTACRINOIDEA** Jaekel, 1894
 Infraclass **INADUNATA** Wachsmuth & Springer,
 1885

Parvclass **DISPARIDA** Moore & Laudon, 1943
DISPARIDA incertae sedis: Homocrinidae Kirk,
 1914

Superfamily **Allagecrinoidea** Carpenter &
 Etheridge, 1881

Family **Catillocrinidae** Wachsmuth & Springer,
 1886

Genus *Paracatillocrinus* Wanner, 1916

Diagnosis: Catillocrinids with aboral cup shape very low vase; basal circlet shape flat disk; basal circlet visible in lateral view; 1, 2, or 3 basal plates; radial plates project outward with a very convex distal rim; prongs on radial plates absent; a few arms on A radial plate, one arm on B radial plate, one arm on C radial plate, a few arms on D radial plate, one arm on E radial plate; ~21 total free arms; columnals elliptical proximally, circular distally; proximal column recurved ~180°.

Type species: *Paracatillocrinus granulatus* Wanner, 1916.

Included species: *Paracatillocrinus granulatus* Wanner, 1916 (West Timor, Baselo; uncertain age and Oman, late Kungurian);

P. shakhtanensis Arendt, 2007 (Russia, late Artinskian); *P. shammovi* Arendt, 2007 (Russia, late Artinskian); and *P. spinosus* Wanner, 1916 (West Timor, uncertain age).

Geological age and geographical distribution. Permian (age unknown), West Timor; Permian (Artinskian) Russia; Permian (late Kungurian), Oman.

Paracatillocrinus granulatus Wanner, 1916

Fig. 11.1–11.5

- 1916 *Paracatillocrinus granulatus* – Wanner, p. 10, pl. 96 (1), figs. 1–2; fig. 1.
 1916 *Paracatillocrinus ellipticus* – Wanner, p. 14, pl. 96 (1), figs. 4.
 1923 *Paracatillocrinus granulatus* – Springer, p. 29, pl. 5, fig. 22.
 1923 *Paracatillocrinus ellipticus* – Springer, p. 29, pl. 5, fig. 23–24.
 1924b *Paracatillocrinus granulatus* – Wanner, p. 125, pl. 20, figs. 1–2.
 1930 *Paracatillocrinus granulatus* – Wanner, p. 15, pl. 2, figs. 3–9, Fig. 9.
 1937 *Paracatillocrinus granulatus* – Wanner, p. 112, Fig. 29.
 1938 *Paracatillocrinus granulatus* – Bassler, p. 144.
 1943 *Paracatillocrinus granulatus* – Bassler & Moodey, p. 587.
 1943 *Paracatillocrinus ellipticus* – Bassler & Moodey, p. 587.
 1948 *Paracatillocrinus ellipticus* – Branson, p. 204.
 1948 *Paracatillocrinus granulatus* – Branson, p. 204.
 1978 *Paracatillocrinus granulatus* – Moore & Strimple in Moore & Teichert, p. T546, Fig. 340.1a–1e, li–1k.
 1978 *Paracatillocrinus ellipticus* – Moore & Strimple in Moore & Teichert, T546, fig. 340.1f–1h.
 1985 *Paracatillocrinus granulatus* – Smith, p. 170, pl. 7.4.20.
 1986 *Paracatillocrinus granulatus* – Webster, p. 227.
 1986 *Paracatillocrinus ellipticus* – Webster, p. 227.
 1988 *Paracatillocrinus granulatus* – Webster, p. 120.
 2003 *Paracatillocrinus granulatus* – Webster, p. 1324.
 2014 *Paracatillocrinus granulatus* – Webster & Webster, p. 1615.

Holotype: unknown.

Diagnosis: Aboral cup very low vase shape, oral view shape of aboral cup strongly elliptical, granulose plate sculpturing, basal circlet partially wedged out, broad blunt spines on distal portions of some basal plates, at least distal half of radial plates greatly expanded, 7–10 free arms on A radial plate, 5–8 free arms on D radial plate, proximal column not completely wedged out.

Paratype: RGM.873725.

New specimens: ONHM F-1499 to ONHM F-1501.

Type locality and horizon: Basleo, West Timor, Permian (uncertain age).

Description of Oman specimens. Aboral cup small, most of the aboral cup a very low cone shape in lateral view but expands substantially in radial circlet for an overall vase shape (Fig. 11.2, 11.4), elliptical in oral view (Fig. 11.1), height to width ratio of compressed aboral cup ~ 0.41 , granulose plate sculpturing.

Basal circlet $\sim 19\%$ of aboral cup height; three basal plates, much smaller than radial plates, partially wedged out at articulation with proximal columnal. Radial circlet $\sim 81\%$ of aboral cup height; five radial plates of variable width; all radial plates greatly expanded in the distal portion; B, C, E radial plates expand into a large blunt spine (Fig. 11.2, 11.5); A

and D radial plates expanded as a very convex lateral extension. Radial facets all very narrow. A and D radial plates large; A radial plate with seven arm facets, D radial plate with five or six radial facets. B, C, and E radial plates small, one radial facet on each plate. C radial plate supports one arm and the radianal plate.

Anal sac and free arms unknown.

Proximal column elliptical (Fig. 11.2–11.5), other characters unknown.

Remarks. Granulose plate sculpturing not as well defined as on Wanner's type material. Otherwise, the morphology of the Oman specimens conforms with those from Timor (Wanner 1916).

Measurements. ONHM F-1499: ACH, 3.1; ACW, 7.2; BH, 0.6; RH, 2.8. ONHM F-1500: ACH, 5.0; ACW, 12.1; BH, 0.9; RH, 3.9.

Geological age and geographic distribution. Permian (uncertain age), Basleo, West Timor; Permian (late Kungurian), Qarari Unit; Wadi Khawr Al Jaramah (WKJ-1 and WKJ-2), Batain, Oman.

Superfamily Belemnocrinoidea S. A. Miller, 1883

Family Synbathocrinidae S. A. Miller, 1890

Genus *Synbathocrinus* Phillips, 1836

Type species: *Synbathocrinus conicus* Phillips, 1836.

Included Permian species: *Synbathocrinus chenae* Mao et al., 2018 (China; Asselian); *S. companulatus* (Wanner, 1916) (West Timor, Basleo; uncertain age and Western Australia; late Sakmarian to early Artinskian); *S. companulatus elongatus* (Wanner, 1916) (Timor, Basleo; uncertain age); *S. companulatus inflatus* (Wanner, 1916) (Timor, Noil Tohini, uncertain age); *S. constrictus* (Wanner, 1916) (West Timor, Basleo; uncertain age); *S. constrictus sinuosus* (Wanner, 1916) (West Timor, Basleo; uncertain age); *S. cretensis* Webster, 2012 (Crete; Cisuralian); and *S. shackletoni* sp. nov. (Oman, late Kungurian).

Geologic age and geographic distribution. *Synbathocrinus* is a cosmopolitan crinoid ranging in age from the Devonian to the Permian.

Synbathocrinus shackletoni sp. nov.

Fig. 11.13, 11.14

Holotype: ONHM F-1502.

Diagnosis: *Synbathocrinus* with a low cone-shaped aboral cup, plate sculpturing not known, basal circlet of medium height, distal edge of radial plates not expanding beyond expected base on profile of plate, proximal rim of aboral cup truncate, node on radial plates absent, gentle convexity across width of radial plate, radial plate–radial plate sutures depressed, radial facet moderately declivate, anal plates and arms unknown.

Etymology: The species name recognizes Robert Shackleton, who led the group of geologists in the initial mapping of the Batain area in the early 1980s.

Type locality and horizon: Wadi Khawr Al Jaramah (WKJ-2), Batain, Oman; Qarari Unit, Permian (late Kungurian).

Description. Aboral cup small, low cone shape (Fig. 11.14) height to width ratio ~ 0.57 , plates gently convex, sutures slightly impressed, apparent plate sculpturing very fine pitting (which is interpreted to be stereom rather than sculpturing). Basal cirlet $\sim 32\%$ of aboral cup height; basal plates five, pentagonal, much smaller than radial plates. Radial cirlet $\sim 68\%$ of aboral cup height; radial plates five, ~ 1.4 times wider than high. Radial facets plenary, planate. Radial presumably sutured to distal corners of C and D radial plates (but not preserved).

Free arms unknown. Proximal columnal circular, lumen circular (Fig. 11.13); remainder of column unknown.

Remarks. *Synbathocrinus* is recognized as a Devonian–Permian cosmopolitan disparid crinoid. Its morphology is very simple with a conical aboral cup comprised of eight plates (3 basal plates and 5 radial plates). A single, partial specimen is available for study from the Qarari Unit (Fig. 11.13, 11.14).

Wanner (1916) described two species of *Synbathocrinus* from Timor. In both species he designated subspecies without establishing a parent subspecies. Herein, Wanner's *S. campanulatus* will be referred to as *S. campanulatus campanulatus* with two additional subspecies, *S. campanulatus elongatus* and *S. campanulatus inflatus*. Similarly, Wanner's *S. constrictus* will be referred to as *S. constrictus constrictus* with the sympatric subspecies *S. constrictus sinuosus*. More recently, *S. cretensis* Webster, 2012 was described from the Permian of Crete; and *S. chanae* was described from the Permian of North China. *Synbathocrinus shackletoni* sp. nov. is the fourth species from a third paleogeographic region.

Synbathocrinus shackletoni sp. nov. is reluctantly named a new species because it is represented by a single, incomplete aboral cup. It has a complete basal cirlet and three radial plates (Fig. 11.13, 11.14). However, despite being incomplete, it is morphologically distinct from other known Permian species of *Synbathocrinus*. *Synbathocrinus campanulatus campanulatus* has a low-bowl shaped aboral cup with the lower aboral cup bowl-shaped, upper aboral cup outflaring or straight, smooth aboral cup plate sculpturing, a relatively low basal plate cirlet, node on radial plates absent, gently convex across radial plates, radial plate-radial plate sutures not depressed, radial facets gently declivate, and anal plates and arms unknown; *Synbathocrinus campanulatus elongatus* has a low cone-shaped aboral cup with a cone-shaped lower

aboral cup, upper aboral cup straight, smooth aboral cup plate sculpturing, a relatively medium height of basal plate cirlet, node on radial plate absent, gently convex across radial plates, radial plate-radial plate sutures not depressed, radial facets gently declivate, and anal plates and arms unknown; *Synbathocrinus campanulatus inflatus* has a low cone-shaped aboral cup with an almost cone-shaped lower aboral cup, upper aboral cup convex with slight outflaring distally, smooth aboral cup plate sculpturing, a very low height of basal plate cirlet, central node on radial plates, strong convex across radial plates, radial plate-radial plate sutures not depressed, radial facets moderately declivate, and anal plates and arms unknown; *Synbathocrinus chanae* has a low bowl shape with a bowl-shaped lower aboral cup, upper aboral cup convex, smooth aboral cup plate sculpturing, a relatively low height of basal plate cirlet, node on radial plate absent, gently convex across radial plates, radial plate-radial plate sutures slightly depressed, radial facets inclinate, and anal plates slender and high, ridge running vertically along arms; *Synbathocrinus constrictus constrictus* has a low to very low aboral cup shape with a cone-shaped lower aboral cup, upper aboral cup straight or outflaring, smooth aboral cup plate sculpturing, a medium to high height of basal plate cirlet, node on radial plate absent, moderately convex across radial plates, radial plate-radial plate sutures not depressed, radial facets moderately declivate, and anal plates and arms unknown; *Synbathocrinus constrictus sinuosus* has a low cone-shaped aboral cup with a cone-shaped lower aboral cup, upper aboral cup straight or outflaring, smooth aboral cup plate sculpturing, a relatively low height of basal plate cirlet, node on radial plate present or absent, strongly convex across radial plates, radial plate-radial plate sutures not depressed, radial facets strongly declivate, and anal plates and arms unknown; *Synbathocrinus constrictus sinuosus* has a low cone-shaped aboral cup with a cone-shaped lower aboral cup, upper aboral cup straight or outflaring, smooth aboral cup plate sculpturing, a relatively low height of basal plate cirlet, node on radial plate present or absent, strongly convex across radial plates, radial plate-radial plate sutures not depressed, radial facets strongly declivate, and anal plates and arms unknown; and *Synbathocrinus cretensis* has a very low bowl-shaped aboral cup with a cone-shaped lower aboral cup, upper aboral cup straight, nodose aboral cup plate sculpturing, a relatively very low height of

basal plate circling, node on radial plate absent, moderately convex across radial plates, radial plate-radial plate sutures present, radial facets unknown, anal plate bulbous, and arms unknown. In contrast, *S. shackletoni* sp. nov. has a low cone-shaped aboral cup with a cone-shaped lower aboral cup, upper aboral cup straight, plate sculpturing presumably smooth, a relatively medium height of basal plate circling, node on radial plate absent, gently convex across radial plates, radial plate-radial plate sutures depressed, radial facets moderately declivate, and anal plates and arms unknown.

Measurements. ONHM F-1502: ACH, 3.0; ACW, 6.4; BH, 1.1; RH, 2.3; RW, 3.3.

Parvclass CLADIDA Moore & Laudon, 1943
 Superorder **Flexibilia** Zittel, 1895
 Order **Sagenocrinida** Springer, 1913
 Superfamily Lecanocrinoidea Springer, 1913
 Family Calycoocrinidae Moore & Laudon, 1943
 Genus *Calycoocrinus* Wanner, 1916

Type species: *Calycoocrinus curvatus* Wanner, 1916, original designation.

Included species: *Calycoocrinus amarassicus* Wanner, 1916 (West Timor, Koeafeoe; uncertain age); *C. curvatus conicus* Wanner, 1930b (West Timor, Basleo; uncertain age); *C. curvatus coronatus* Wanner, 1916 (West Timor, Basleo; uncertain age); *C. curvatus depressus* Wanner, 1924b (West Timor, Basleo; uncertain age); *C. curvatus elongatus* Wanner, 1924b (West Timor, Basleo; uncertain age); *C. curvatus informis* Wanner, 1924b (West Timor, Basleo; uncertain age); *C. curvatus labrosus* Wanner, 1930b (West Timor, Basleo, Soempek; uncertain age); *C. curvatus subcoronatus* Wanner, 1924b (West Timor, Basleo, Toenioen Eno; uncertain age); *C. curvatus subtrubatus* Wanner, 1924b (West Timor; uncertain age); *C. curvatus turbinatus* Wanner, 1916 (West Timor, Koeafeoe near Baung; uncertain age); *C. erectus* Wanner, 1930b (West Timor, Basleo; uncertain age); *C. granulatus granulatus* Wanner, 1916 (West Timor, Basleo; uncertain age); *C. granulatus altior* Wanner, 1924b (West Timor, Basleo; uncertain age); *C. kupangensis* Wanner, 1916 (West Timor, Loepang; uncertain age); *C. labiatus* Marez Oyens, 1940 (West Timor, Basleo, Taewei; uncertain age); *C. major* Wanner, 1916 (West Timor, Basleo; uncertain age); *C. malaianus* Wanner, 1916 (West Timor, Basleo; uncertain age); *C. millericrinoides* Wanner, 1924b (West Timor, Basleo; uncertain age); *C. nuciformis* Wanner, 1929a (West Timor, Basleo; uncertain age); *C. patella* Wanner, 1924b (West Timor, Basleo; uncertain age); *C. perplexus* Wanner, 1929a (West Timor, Basleo; uncertain age); *C. piriformis* Wanner, 1924b (West Timor, Basleo; uncertain age); *C. poculus* Wanner, 1916 (West Timor, Basleo; uncertain age); *C. rossicus* Yakovlev, 1927 (Russia, Ural Mountains; Artinskian); *C. similis* Wanner, 1930b (West Timor, Basleo; uncertain age); *C. spinosus* Wanner, 1916 (West Timor, Basleo; uncertain age); *C. tuberculatus* Wanner, 1930b (West Timor, Basleo; uncertain age); *C. venemai venemai* Wanner, 1930b (West Timor, Basleo; uncertain age); *C. venemai angulatus* Wanner, 1930b (West Timor, Basleo; uncertain age); and *C. venemai planus* Marez Oyens, 1940 (West Timor, Basleo; uncertain age).

Remarks. Wanner (1916) defined *Calycoocrinus* based on 11 species that shared a fused infrabasal circling, declivate radial facets, and short uniserial arms. In addition, the aboral cup of these crinoids is commonly asymmetrical and tilted toward one side. This asymmetry is the result of asymmetry in one aboral cup plate circling or all aboral cup plate circlets. However, the species assigned to *Calycoocrinus* by Wanner (1916; 1924b; 1929b; 1930b); Yakovlev (1927); and Marez Oyens (1940) display a significant amount of morphological disparity, including conical- and bowl-shaped aboral cups, aboral cups with or without a shallow basal concavity, and plenary and penepenary radial facets. This wide range of morphological disparity is typically expected between genera but not between species of a single genus.

Currently 22 species and 12 subspecies have been assigned to *Calycoocrinus*. All were named during 1940 or earlier (Webster & Webster 2014). Although beyond the scope of the current study, the disparate morphologies of species currently assigned to *Calycoocrinus* species and subspecies require systematic revision to evaluate both intraspecific variation as well as generic assignments.

The new specimens of *Calycoocrinus* from Oman belong to the *Calycoocrinus curvatus conicus* concept of Wanner (1930b). With *Calycoocrinus curvatus* the type species for *Calycoocrinus*, this Oman taxon can confidently be assigned to *Calycoocrinus*. Subspecies assigned to *Calycoocrinus curvatus* have two basic morphologies: 1) those with strong asymmetry of the aboral cup and large central nodes or spines on aboral cup plates; or 2) those with slight to no asymmetry in the aboral cup gently convex aboral cup plates lacking spines. *Calycoocrinus curvatus typus* Wanner, 1916 (note that Webster & Webster (2014) recognized this taxon as *Calycoocrinus curvatus*) has the latter characteristics that differ from *Calycoocrinus curvatus curvatus*, and we regard this as a compelling basis to elevate the subspecies *conicus* to the species rank.

Geological age and geographic distribution. Permian (uncertain age), West Timor; Permian (Artinskian), Russia; Permian (late Kungurian), Oman.

Calycoocrinus conicus Wanner, 1930b comb. nov.

Fig. 11.10–11.12

1930b *Calycoocrinus curvatus conicus* – Wanner, p. 26, pl. 2, figs. 13–15; fig. 15.

1937 *Calycoocrinus curvatus conicus* – Wanner, p. 100, pl. 8, figs. 32–33.

1943 *Calycoocrinus curvatus conicus* – Bassler & Moodey, p. 351.

1948 *Calycoocrinus curvatus conicus* – Branson, p. 183.

Holotype: RGM 883971.

Diagnosis: *Calycoocrinus* with a slight or no crown asymmetry, cone-shaped aboral cup, smooth aboral cup plate sculpturing, radial plates the dominant aboral cup plate cirlet, infrabasal plates visible in lateral view, infrabasal cirlet not in basal concavity, infrabasal plates gently convex, basal plates gently concave, basal cirlet not in basal concavity, radial plates gently convex, radial facets symmetrical, and no nodes on brachial plates.

New specimens: ONHM F-1503 to ONHM F-1504.

Description of Oman specimens. Crown small. Aboral cup medium cone shape, slightly asymmetrical; plates flat to gently convex, smooth plate sculpturing (Fig. 11.12).

Infrabasal fused into a single plate, visible in lateral view; ~17% of aboral cup height. Basal cirlet ~30% of aboral cup height; basal plates five, pentagonal, proximal side arcuate, smaller than radial plates, ~1.4 times wider than high. Radial cirlet ~53% of aboral cup height; radial plates five, pentagonal, ~1.8 times wider than high. Radial facets plenary, other details unknown (Fig. 11.11).

No CD interray plating incorporated into the aboral cup.

Arms short, atomous, form medium inverted bowl shape above aboral cup (Fig. 11.11). Four fixed primibrachials. much wider than high, uniseriate; first and second primibrachials approximately same width, third and fourth primibrachials much narrower (Fig. 11.10).

Parts of three proximal columnals preserved. Columnals circular, heteromorphic, zig-zag sutures.

Proximal column circular, holomeric, heteromorphic, (N1)1, narrow crenularium.

Remarks. Two specimens of *C. conicus* are known from Oman: one a complete crown and the other a nearly complete crown with some of the brachials missing. These are among the most complete specimens known from the Qarari Unit. Wanner (1930b) originally described the subspecies *Calycoocrinus curvatus conicus*. As noted above, this subspecies is elevated to the species rank.

Of the numerous species and subspecies of *Calycoocrinus* (see Webster & Webster 2014) only *C. conicus*, *C. perplexus*, and *C. nuciformis* have a slight or slight to no crown asymmetry, smooth aboral

cup plate sculpturing, and radial plates the largest plates in the aboral cup. *Calycoocrinus perplexus* has a slight asymmetry of the crown, globe- or cylindrical-shaped aboral cup, smooth aboral cup plate sculpturing, radial plates the dominant aboral cup plate cirlet, infrabasal plates not visible in lateral view, infrabasal cirlet completely in basal concavity, infrabasal plates slightly concave, basal plates gently concave, basal cirlet not in basal concavity, radial plates gently convex, radial facets questionably asymmetrical, and no nodes on brachial plates; and *C. nuciformis* has a slight asymmetry of the crown, bowl-shaped aboral cup, smooth aboral cup plate sculpturing, radial plates the dominant aboral cup plate cirlet, infrabasal plates visible in lateral view, infrabasal cirlet not in basal concavity, infrabasal plates gently convex, basal plates gently convex, basal cirlet not in basal concavity, radial plates gently convex, radial facets asymmetrical, and no nodes on brachial plates. In contrast, *Calycoocrinus conicus* has a slight or no crown asymmetry, cone-shaped aboral cup, smooth aboral cup plate sculpturing, radial plates the dominant aboral cup plate cirlet, infrabasal plates visible in lateral view, infrabasal cirlet not in basal concavity, infrabasal plates gently convex, basal plates gently convex, basal cirlet not in basal concavity, radial plates gently convex, radial facets symmetrical, and no nodes on brachial plates.

Measurements. Complete specimen: ONHM F-1503: CrH, 10.7; ACH, 7.2; ACW, 8.9; IH, 1.6; BH, 2.8; BW, 3.8; RH, 2.8; RW, 5.1; ColH, 2.0*.

Geological age and geographic distribution. Permian (uncertain age), Basleo, West Timor; Permian (late Kungurian) Qarari Unit, Wadi Khawr Al Jaramah (WKJ-1), Batain, Oman.

Family Prophyllocrinidae Moore & Strimple, 1973
Genus *Prophyllocrinus* Wanner, 1916

Type species: *Prophyllocrinus dentatus* Wanner, 1916, original designation.

Included species: *Prophyllocrinus dentatus* Wanner, 1916 (West Timor, Basleo; uncertain age); *P. sp. 1* in Webster & Jell, 1999, Western Australia; early Artinskian); *P. sp. 2* in Webster & Jell, 1999, Western Australia; early Artinskian); *P. sp. 3* in Webster & Jell, 1999, Western Australia; early Artinskian).

Geological age and geographic distribution: Permian, Timor (uncertain age); Permian. Australia (Artinskian); Permian, Oman (Artinskian).

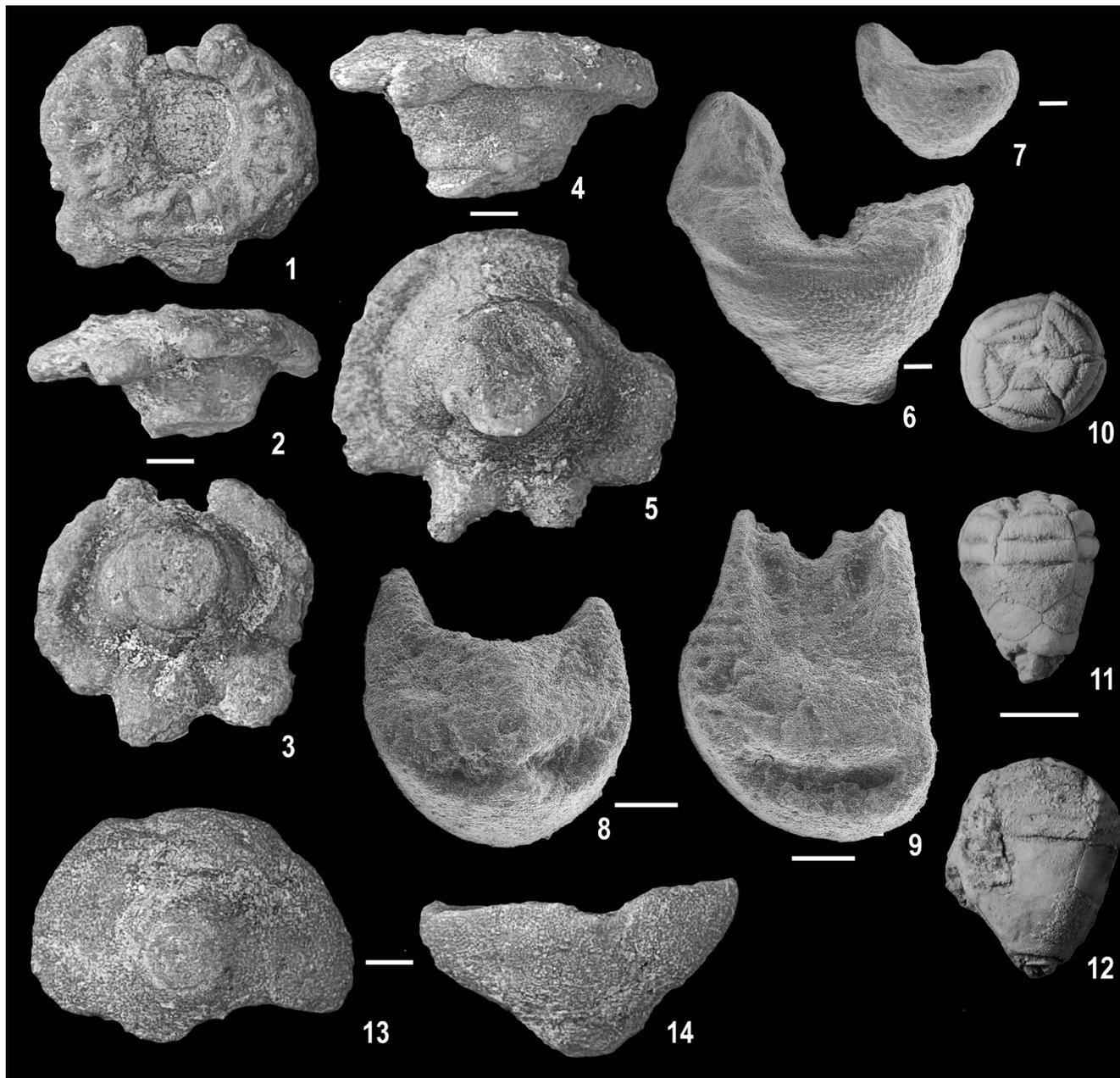


Fig. 11 - Disparid and flexible crinoids from the Qarari Unit. 1–5, *Paracatillocrinus granulatus*, scale bars = 1.0 mm; 1–3, ONHM F-1500, 1, oral view of aboral cup, note spinose radial plates; 2, lateral view of aboral cup, note wide expansion of radial plates distally; 3, basal view of aboral cup, not wide proximal columnal articular facet; 4, 5, ONHM F-1499, 4, lateral view of aboral cup, note spinose radial plates; 5, basal view of aboral cup, not wide proximal columnal articular facet; 6, 7, *Prophyllocrinus* sp. ONHM F-1505, ONHM F-1506, respectively, note asymmetrical distal prongs on both sides of radial facets, scale bar = 0.5 mm. 8, *Flexibilia* Indeterminate, ONHM F-1508, scale bar = 0.5 mm, articular facets on a axillary brachial plate of a flexible crinoid. 9, *Flexibilia* Indeterminate, ONHM F-1507, scale bar = 0.5 mm, articular facet of a flexible crinoid brachial plate. 10–12, *Calyptocrinus conicus*, comb. nov., ONHM F-1503, scale bar = 5 mm; 10, oral view of crown with intact arms; 11, lateral view of crown; 12, ONHM F-1504, lateral view of crown.; 13, 14, *Synbathocrinus shackletoni* sp. nov., ONHM F-1502, holotype, scale bar = 1.0 mm.

Prophyllocrinus sp.

Fig. 11.6, 11.7

New specimens: ONHM F-1505 and ONHM F-1506.

Description of Oman specimens. Small asymmetrical radial plate, plate sculpturing granu-

lose; radial facet angustary, ~33% of width of radial facet, positioned centrally; high radial plate projection to left of radial facet, approximately same height as height from radial proximal end of radial plate to the radial facet; radial plate projection to right of radial plate much lower.

Remarks. The *Prophyllocrinidae* is rep-

resented by three genera: *Ancistrocrinus* Wanner, 1924b; *Proapsidocrinus* Wanner, 1924b; and *Prophylocrinus*. These genera are characterised by, among other things, a small, symmetrical or asymmetrical, globose aboral cup; angustary radial facets deeply notched into the radial plates, and one or two upward projections on either side of the radial facets (Fig. 11.6, 11.7). Genera are differentiated on the size and convexity of aboral cup plates, position of the infrabasal circlet, the size and symmetry of the upward projections that flank the radial facet, the position of the radial facet on the radial plate (central or asymmetrical), and the presence of a pseudotegmen (see Ausich & Kammer 2016) formed by radial plate projections.

Two small prophylocrinid radial plates were recovered from the Qarari Unit. Although differences are present in these two radial plates, the following characteristics supports placement in *Prophylocrinus*: asymmetrical radial plate distal projections on either side of the radial facet and smooth plate sculpturing. Without knowledge of other aboral cup characters, species identification is not possible.

Measurements. ONHM F-1505: RH, 4.1; RW, 3.8; RFW, 1.4; LPH, 2.0; RPH, 0.3. ONHM F-1506: RH, 5.6; RW, 5.3; RFW, ~1.8; LPH, 2.4; RPH, 0.6.

Geological age and geographical distribution. Qarari Unit, Permian (late Kungurian); Wadi Khawr Al Jaramah (WKJ-2), Batain, Oman.

Flexibilia Indeterminate

Fig. 11.8, 11.9

New specimens: ONHM F-1507 and ONHM F-1508.

Remarks. Both axillary and nonaxillary brachials of a flexible crinoid occur in the washings from the Qarari Unit. Both have patelloid processes that are indicative of the Flexibilia. The nonaxillary brachials are much deeper than wide (Fig. 11.8); both the articular ridge and the indentation for the patelloid process of the superjacent brachial are nearly the entire width of the facet; one side of the facet is straight and the other side has a bulge; the inner side of the facet has a narrow ambulacral groove (~33% of brachial width), on either side is a raised shelf, and on the outside a narrow inward projection.

The axillary is approximately as wide as high (Fig. 11.9), asymmetrical with one side projected farther inward than the other, the proximal side has one facet with a patelloid process, and the distal has two facets each with its own depression for the superjacent patelloid process.

Measurements. ONHM F-1507: BrW, 2.2; BrD, 2.8. C-26: BrW, 2.1; BrD, 2.5.

Geological age and geographical distribution. Permian (late Kungurian), Qarari Unit; Wadi Khawr Al Jaramah (WKJ-2), Batain, Oman.

Magorder **Eucladida** Wright, 2017

Superorder **Cyathiformes** Wright et al., 2017

Superfamily Lophocrinoidea Bather, 1899

Family Pelecocrinidae Kirk, 1941a

Malaiocrinus Wanner, 1924b

Type species: *Zeacrinus?* *sundicus* Wanner, 1916

Included species: *Malaiocrinus crassitesta* Wanner, 1924b (West Timor, Basleo; uncertain age); *M. parviusculus* Moore & Plummer, 1940 (United States, Texas, Oklahoma; Moscovian); *M. pusillus* Wanner, 1937 (West Timor, Basleo; uncertain age); and *M. sundicus* (Wanner, 1916) (West Timor, Basleo; uncertain age).

Remarks. *Malaiocrinus* is poorly understood Pennsylvanian to Permian genus previously known from four species. All species have prominent sub-circular to elliptical, strongly declivate radial facets, three posterior plates in the aboral cup, and infrabasal plates confined or mostly confined to the basal concavity. However, calyx shape varies from very low bowl to medium bowl in shape; aboral cup plate sculpturing is either smooth or with small nodes; infrabasal plates are either visible or not visible in lateral view; basal plates are either upright or wrap around from the aboral cup base to the upright side of the aboral cup; height to width ratio of the radial plates varies from 8.6–1.0; and the radial facet height to width ratio varies from 0.64–0.81. No specimens have arms preserved.

Geologic age and geographic distribution. Pennsylvanian (Desmoinesian), United States; Permian (uncertain age), West Timor; Permian (late Kungurian), Oman.

Malaiocrinus sp.

Fig. 12.15–12.17

Specimen: ONHM F-1509.

Description. Aboral cup low or very low bowl shape, height to width ratio unknown, basal and radial plates strongly convex, plate sutures widely impressed, smooth plate sculpturing (Fig. 12.15). Infrabasal circlet unknown (Fig. 12.17). Only distal portion of basal plates known. Radial plates five, ~1.38 times wider than high; radial facets peneplenary, ~1.9 times wider than high, strongly declivate, elliptical in shape with a broad axial indentation (Fig. 12.16), articular ridge across most of facet and slightly below center, radial facet with oral-aboral oriented ridges, adoral fossae not delineated but rounded distal extensions at edges of facets.

Three posterior plates in aboral cup (Fig. 12.15), radianal largest posterior plate and above to left of the C-ray radial plate; anal X plate above and to left of radianal and CD basal plate, distal portion of right sac plate in aboral cup and sutured laterally to the C radial plate.

Anal sac, arms, and column unknown.

Remarks. OMNH F-1509 is a complete radial circlet with only the distal-most portion of basal plates preserved. The infrabasal plates, proximal portion of the basal plates, arms, and column are unknown. However, the radial plate circlet with very convex plates, broadly impressed plate sutures, and distinctive, declivate radial facets is very similar to *Malaiocrinus*, in particular *M. sundaicus*.

As known, *M.* sp. has a unique suite of characters. *Malaiocrinus* sp. probably has a low bowl shaped aboral cup, as does *M. pusillus* and *M. sundaicus*. Aboral plate sculpturing is small nodes, which is similar to some species of *M. crassitesta*. The basal plates of *M. parviusculptus*, *M. sundaicus*, and *M.* sp. wrap around from the base of the aboral cup to the vertical side of the aboral cup. The height to width ratio of the radial facets and the radial facet shape of *M.* sp. is distinct. This Oman species of *Malaiocrinus* may represent a new species. However, until its morphology can be more completely known (in particular, aboral cup shape and characters of the infrabasal circlet), it is ill-advised to describe a new species.

Measurements. ONHM F-1509: ACH, 20.4; RH, 5.0; RW, 7.5; RFH, 3.8; RFW, 7.4.

Geologic age and geographic distribution. Qarari Unit, Permian (late Kungurian); Wadi Khawr Al Jaramah (WKJ-1), Batain, Oman.

Family Indocrinidae Strimple, 1966

Included genera: *Contignatindocrinus* Arendt, 1981; *Eoindocrinus* Arendt, 1981; *Indocrinus* Wanner, 1916; *Proindocrinus* Yakovlev, 1939; *Pumilindocrinus* Arendt, 1981; *Rimosindocrinus* Arendt, 1981; *Yakovlevicrinus* Arendt, 1981.

Remarks. The Indocrinidae is an unusual, heterogeneous group of eucladids. They are typically quite small, globose or biconical in shape, have only three functional radial plates, one to three anal plates fixed in the aboral cup, and sculpturing varies from smooth calyx plates to multiple prominent ridges connection to like ridges to adjoining plates. Some genera have dominant spines on calyx plates, some are considered to have epispines across aboral cup plate sutures. Three new species of indocrinids are described herein, one in *Proindocrinus* and two in *Eoindocrinus*.

Genus *Proindocrinus* Yakovlev, 1939

Type species: *Proindocrinus pizovi* (Yakovlev, 1926).

Included species: *Proindocrinus mirabilis* Arendt, 1981 (Russia, Krasnoufimsk; late Artinskian); *P. parvus* Arendt, 1981 (Russia, Krasnoufimsk; late Artinskian); *P. pizovi* (Yakovlev, 1926) (Russia, Ural Mountains; Krasnoufimsk; late Artinskian); and *Proindocrinus riesae* sp. nov. (Oman, late Kungurian).

Geologic age and geographic position. Permian (Artinskian), Russia; Permian (late Kungurian), Oman.

Proindocrinus riesae sp. nov.

Fig. 12.4–12.6

Holotype: ONHM F-1510.

Diagnosis: Globose to biconical aboral cup shape, the aboral cup subcircular in basal outline, approximately eight prominent ridges from center of each basal plate connect to each adjoining plate in the aboral cup, at aboral cup triple junctions a triangular node, narrow central raised area on basal plates, radial facets peneplenary, radial facets planate or slope inward, two posterior plates in aboral cup, anal tray very small, and oral opening of aboral cup subelliptical.

Etymology: The species name recognizes Alison Ries, who helped to map the Batain area.

Paratypes: ONHM F-1511 to ONHM F-1513.

Type locality and horizon: Wadi Khawr Al Jaramah (WKJ-1), Batain, Oman; Qarari Unit, Permian (late Kungurian).

Additional specimens: ONHM F-1514 to ONHM F-1516.

Description. Aboral cup small in size, high globe shape (Fig. 12.5), may be slightly asymmetrical (Fig. 12.4), subcircular in outline from oral view (Fig. 12.3, 12.6), height to width ratio ~1.3, plates

convex; prominent ridges connecting to like ridges of adjoining plates, as noted below, no evidence of epispires; raised triangular nodes at plate triple junctions, some with a small shallow depression in center of raised triangular nodes.

Infrabasal plate cirlet ~18% of aboral cup height, visible in lateral view, slightly asymmetrical, projects proximally into a narrow neck (Fig. 12.5); infrabasals presumably three, unequal in size. Basal plate cirlet ~58% of aboral cup height; basal plates five, hexagonal, larger than radial plates, ~1.4 times higher than wide, eight prominent ridges project and connect to like ridges on adjoining plates. One ridge projects distally, one ridge projects proximally, and three on each side connect to adjoining basal plates. Radial plate cirlet ~24% of aboral cup height, proximal rim of radial plates and distal anal plates form dominant convex rim; radial plates five with three wide radial plates with radial facets (A, C, D rays) and two very narrow radial plates that lack radial facets (B and E rays), sculpturing with ridges that divide, ridges connect proximally to each supporting basal plate. Functional radial facets peneplenary, planate or sloping inward, articular ridges across full width of facet, an elongate and narrow aboral ligament fossa positioned centrally and two adoral fossae, one on either side of an oral groove. Oral opening into the aboral cup subcircular, very short anal tray projecting laterally and supported by anal plates.

Two equal sized posterior plates in aboral cup, radianal plate and the anal X side by side above CD basal plate and form part of the distal rim around the aboral cup. Radianal and anal X support short anal tray (Fig. 12.3, 12.6).

Anal sac and arms unknown.

Proximal columnal circular, holomorphic, other aspects of column unknown.

Remarks. *Proindocrinus* and *Yakovlevicrinus* are the two Indocrinidae with species having only two posterior plates (radianal and anal X) in the aboral cup, and both support the anal tray. The new taxon is not assigned to *Yakovlevicrinus* because the Oman specimens have strong ridges on aboral cup plates, peneplenary radial facets, and a subcircular oral opening to the aboral cup.

Proindocrinus is now recognized with four species. *Proindocrinus mirabilis* has a globose to biconical aboral cup shape, the aboral cup subcircular in basal outline, one to four ridges connect to each adjoining

plate in the aboral cup, at aboral cup triple junctions smooth or a few random ridges, wide central raised area on basal plates, radial facets plenary, radial facets slope outward, three posterior plates in aboral cup, anal tray and oral opening of aboral cup unknown; *P. parvus* Arendt has a subglobular aboral cup shape, the aboral cup circular in basal outline except for protruding anal tray, one ridge connects to each adjoining plate in the aboral cup, at aboral cup triple junctions smooth or a few random ridges, narrow central raised area on basal plates, radial facets peneplenary, radial facets slope outward, three posterior plates in aboral cup, anal tray elongate, and oral opening of aboral cup elongate ellipse; and *P. pizovni* has a globose to biconical aboral cup shape, aboral cup pentagonal in basal outline, ~8 ridges from center of basal plate adjoining plate in the aboral cup, at aboral cup triple junctions a smooth or a few random ridges, narrow central raised area on basal plates, radial facets peneplenary or plenary, radial facets slope outward, two or three posterior plates in aboral cup, anal tray elongate, and oral opening elongate ellipse. In contrast, *P. riesae* sp. nov. has a globose to biconical aboral cup shape, the aboral cup subcircular in basal outline, ~8 ridges from center of each basal plate connect to each adjoining plate in the aboral cup, at aboral cup triple junctions a triangular node, narrow central raised area on basal plates, radial facets peneplenary, radial facets planate or slope inward, two posterior plates in aboral cup, anal tray very small, and oral opening of aboral cup subelliptical.

Measurements. ONHM F-1510 (holotype): ACH, 3.5; ACW, 2.5; IBH, 0.5; IBW, 0.83; BH, 2.35; BW, 2.2; RH, 1.0; RW, variable. ONHM F-1511 (paratype): ACH, 3.1; ACW, 2.8; IBH, 0.9; BH, 2.1; BW, 2.9; RH, 0.8; RW, variable.

Other specimens. ONMH F-1514 to OMNH F-1416.

Genus *Eoindocrinus* Arendt, 1981

Type species: *Eoindocrinus praerimosus* Arendt, 1981.

Included species: *Eoindocrinus ageri* sp. nov. (Oman; late Kungurian). *E. praecontignatus*, Arendt, 1981 (Western Australia, Queensland; late Artinskian–early Wordian; Russia, Ural Mountains; late Artinskian), *E. praerimosus* Arendt, 1981 (Russia, Ural Mountains; late Artinskian), *E. spinosus* sp. nov. (Oman; late Kungurian).

Geologic age and geographic distribution: Permian (Artinskian), Russia; Permian (Artinskian to Wordian), Australia; Permian (late Kungurian), Oman.

***Eoindocrinus spinosus* sp. nov.**

Fig. 12.1., 12.2

Holotype: ONHM F-1517.

Diagnosis: *Eoindocrinus* with a medium globe-shaped aboral cup, pentastellate aboral cup outline in basal view with spines (pentagonal without spines), ~8 ridges radiating from the basal plate center to adjoining plates, pits at aboral cup plate triple junctions present due to ridges, long central spine in center of basal plates, radial facets peneplenary and planate or sloping inward, radial plate smallest in size of the three posterior plates in the aboral cup, anal tray elongate and projecting laterally, and oral opening strongly elliptical.

Etymology: The species name is a reference to the long central spines on the basal plates.

Type locality and horizon: Wadi Khawr Al Jaramah (WKJ-1, WKJ-2), Batain, Oman; Qarari Unit, Permian (late Kungurian).

Description. Aboral cup small in size, medium barrel shape, pentastellate in outline from oral view (Fig. 12.2), height to width ratio ~0.78 with spines and 1.22 without spines; ridges and spines as noted below.

Infrabasal plate circlet ~21% of aboral cup height, visible in lateral view, prominent convex rim around proximal edge of basal circlet; infrabasals three, unequal in size with small infrabasal in A ray. Basal plate circlet ~41% of aboral cup height; basal plates five, hexagonal, larger than radial plates, slightly wider than high, with long central spine from which eight prominent ridges project and connect to like ridges on adjoining plates (Fig. 12.1). One ridge projects distally, one ridge projects proximally, and three ridges on each side connect to adjoining basal plates. Radial plate circlet ~38% of aboral cup height, distal radial plates and distal anal plates form dominant convex distal rim; radial plates five with three wide radial plates with radial facets (A, C, D rays) and two very narrow radial plates that lack radial facets (B and E rays), sculpturing with ridge that divides and connects proximally to each supporting basal plate. Functional radial facets peneplenary, declivate, articular ridges across full width of facet, an elongate and narrow aboral ligament fossa positioned centrally and two adoral fossae, one on either side of an oral groove. Oral opening into the aboral cup elliptical, oriented along A-CD axis, distinct anal tray projecting laterally.

Three posterior plates are interpreted in aboral cup small, radial plate supports the anal X above and to the left, anal X and right sac plate form upper rim of aboral cup with a dominant distal boundary that connects to that of the radial plates, anal X and right sac plate support extended anal tray.

Anal sac and arms unknown.

Proximal columnal circular, other aspects of column unknown.

Remarks. The barrel-shaped aboral cup, aboral cup outline in basal view, and numerous raised ridges on basal plates ally *E. spinosus* sp. nov. with *Eoindocrinus*. *Eoindocrinus praecontignatus* has a medium globe-shaped aboral cup, pentagonal aboral cup outline in basal view, >14 ridges radiating from the basal plate center to adjoining plates, pits at aboral cup plate triple junctions present due to the raised ridges, low circular node in center of basal plates, radial facets plenary and planate or sloping inward, radial plate smallest or largest of the three posterior plates in the aboral cup, anal tray short and projecting laterally, and oral opening strongly elliptical; and *E. praeimosus* has a high globe-shaped aboral cup, pentagonal aboral cup outline in basal view, >14 ridges radiating from the basal plate center to adjoining plates, pits at aboral cup plate triple junctions absent, low vertically elongate node in center of basal plates, radial facets peneplenary and planate or sloping inward, radial plate smallest in size of the three posterior plates in the aboral cup, anal tray short, elongate and projecting upward and laterally, and oral opening moderately elliptical. In contrast, *E. spinosus* sp. nov. has a medium globe-shaped aboral cup, pentastellate aboral cup outline in basal view with spines (pentagonal without spines), ~8 ridges radiating from the basal plate center to adjoining plates, pits at aboral cup plate triple junctions present due to ridges, long central spine in center of basal plates, radial facets peneplenary and planate or sloping inward, radial plate smallest in size of the three posterior plates in the aboral cup, anal tray elongate and projecting laterally, and oral opening strongly elliptical; and *E. ageri* sp. nov. has a low globe-shaped aboral cup, circular? aboral cup outline in basal view, spines on basal plates absent, ~11 ridges radiating from the basal plate center to adjoining plates, pits at aboral cup plate triple junctions absent, node or central spine in center of basal plates absent, radial facets peneplenary and planate or sloping slightly outward, radial plate largest in size of the three posterior plates in the aboral cup, anal tray absent as known, and oral opening unknown.

Measurements. Holotype, ONHM F-1517: ACH, 3.2; ACW (including spines), 4.0; ACW (excluding spines), 2.9; IBH, 0.4; BH, 2.1; BW, 1.5; RH, 0.8; RW, variable.

Eoindocrinus ageri sp. nov.

Fig. 12.7, 12.8

Holotype: ONHM F-1518.

Diagnosis: *Eoindocrinus* with a low globe-shaped aboral cup, circular? aboral cup outline in basal view, spines absent, ~11 ridges radiating from the basal plate center to adjoining plates, pits at aboral cup plate triple junctions absent, node or central spine in center of basal plates absent, radial facets peneplenary and planate or sloping slightly outward, radial plate largest in size of the three posterior plates in the aboral cup, anal tray absent as known, and oral opening unknown.

Etymology: The species name recognizes Derek Ager, who in the 1980s, helped identify the Oman Permian fauna and recognized similarities with the fauna from Timor.

Type locality and horizon: Wadi Khawr Al Jaramah (WKJ-1), Batain, Oman; Qarari Unit, Permian (late Kungurian).

Description. Aboral cup small in size, probably a medium globe shape, height to width ratio ~0.70. Pits at aboral cup plate triple junctions absent but small node formed at convergence of all three plates and node surrounded by concentric triangles formed by ridges of all three plates in the triple junction.

Infrabasal plate circlet ~27% of aboral cup height, visible in lateral view, protruding convex rim at narrow base of infrabasal circlet into which the proximal columnal is situated (Fig. 12.8); infrabasal plates fused into a single plate. Basal circlet ~48%. Five basal plates pentagonal or hexagonal; each basal plate with multiple (~11) low, narrow ridges from center of basal plates and connecting to like ridges on all adjacent plates, larger than radial plates, slightly higher than wide. Radial plate circlet ~25% of aboral cup height, radial plates and anal plates form convex rim around the distal-most margin of the aboral cup; radial plates five; unequal in size; low narrow ridges project proximally from distal rim to connect to like ridges on abutting plates. Radial facets peneplenary, slightly declivate, topography of facets unknown. Shape of oral opening into aboral cup unknown, and anal tray interpreted to be absent.

Three small posterior plates in aboral cup, radial plate the largest and supports the anal X above and to the left and the right sac plate above and to the right, anal sac plate the smallest anal plate fixed in the aboral cup (Fig. 12.7).

Proximal columnal circular with very narrow lumen, other aspects of column unknown. First primibrachial preserved in two rays, narrows distally.

Remarks. The holotype of *E. ageri* sp. nov. is a complete, slightly crushed aboral cup without

arms or column. However, this aboral cup is sufficiently preserved to confidently designate a new species of *Eoindocrinus*. The aboral cup plate sculpturing is unique among species of *Eoindocrinus* (see discussion of *E. spinosus* sp. nov.).

Measurements. ONHM F-1518: ACH, 7.8; IBH, 2.8; BH, ~4.6; BW, ~4.6; RH, ~2.6 (variable); RW, variable.

Superfamily Erisocrinoidea Wachsmuth & Springer, 1886

Family Erisocrinidae Wachsmuth & Springer, 1886

Included genera: *Akijoshicrinus* Hashimoto, 1995; *Eperisocrinus* Burke, 1977; *Erisocrinus* Meek & Worthen, 1865; *Exaetocrinus* Strimple & Watkins, 1969; *Qararicrinus* gen. nov.; *Sinocrinus* Tien, 1926; and *Jaramabcrinus* gen. nov.

Remarks. Two new erisocrinid genera are present in the Qarari fauna: *Qararicrinus* gen. nov. and *Jaramabcrinus* gen. nov. The conical aboral cup, plenary radial facets, no posterior plates within the aboral cup, and the first primibrachials axillary align *Qararicrinus* gen. nov. with the Erisocrinidae. Similarly, the conical aboral cup, plenary radial facets, no posterior plates within the cup align *Jaramabcrinus* gen. nov. with the Erisocrinidae. As discussed below, diagnostic characters of the Erisocrinidae include symmetry of the aboral cup, aboral cup shape, aboral cup plate sculpturing, outline of the aboral cup in basal view, condition of the basal concavity, position of infrabasal plates, whether infrabasal plates are visible in lateral view, relative size of basal plates, radial facet orientation, number of anal plates in the posterior interray, presence or absence of spinose projections on the first primibrachials, type of secundibrachials, and shape of the proximal columnal.

As presently understood, Pennsylvanian Erisocrinidae are known from Brazil, China, Japan, Russia, Spain, and United States. In contrast, Permian Erisocrinidae are only known from Russia, Sicily, Oman, the United States.

Genus *Erisocrinus* Meek & Worthen, 1865

Type species: *Erisocrinus typus* Meek & Worthen, 1865.

Included Permian species: *Erisocrinus araxensis* Yakovlev, 1933 (Russia, Transcaucasia; Late Permian); *E. longvelli* Lane & Webster, 1966 (United States, Nevada; Cisuralian); *E. sp. cf. E. longvelli* in Pabian & Rushlau, 2002 (United States, Nebraska; Cisuralian); *P.*

pentangulatus Yakovlev & Faas, 1938 (Sicily; Wordian); *E. propinquus* Weller, 1909 (United States, Texas; Cisuralian); and *Erisocrinus?* sp. (Oman; late Kungurian).

Geologic age and geographic distribution: Pennsylvanian (uncertain age), Brazil; middle Carboniferous, China; Pennsylvanian to Permian (Moscovian to Late Permian), Russia; Permian (Wordian), Sicily; Pennsylvanian to Permian (Viséan?, Bashkirian to Cisuralian), United States; Permian (late Kungurian), Oman?.

Erisocrinus? sp.

Figs. 14.13–14.15

Specimen: ONHM F-1526.

Description. Aboral cup very low bowl shape (Fig. 14.14), height to width ratio of aboral cup ~0.42; circular in outline from basal view (Fig. 14.15); irregular coarse nodose sculpturing.

Infrabasal circler ~21% of aboral cup height; infrabasal plates five, equal in size, basically flat, in basal concavity, ~3.7 times wider than high, distal corners visible in lateral view. Basal circler ~37% of aboral cup height; basal plates five, hexagonal, moderately convex, smaller than radial plates, as wide as high. Radial circler ~41% of aboral cup height; radial plates five, gently convex, ~1.8 times wider than high. Radial facets plenary (Fig. 14.13), declivate, articular ridge nearly across entire width of radial facet, aboral ligament fossae in center of facet.

No CD interray plates fixed into the aboral cup, no apparent facet onto which any posterior plates would be attached.

Anal sac and free arms unknown.

Proximal column circular, impression of crenulae moderately impressed into infrabasal circler. Other aspects of column unknown.

Remarks. The Erisocrinidae is regarded as one of the primary late Paleozoic euclidid clades that lack any posterior interray plates in the aboral cup (although, note that *Eperisocrinus* Burke, 1977 is presently in the Erisocrinidae and has an elongate, narrow radianal in the aboral cup). Also note that different species within *Erisocrinus* have a variety of aboral cup shapes, including a very low bowl, as in the specimen from Oman, The Erisocrinidae as well as the genus *Erisocrinus* require a thorough re-evaluation to delineate taxonomic concepts at both the genus and species levels, but such an evaluation is far beyond the scope of the present investigation. Thus, this taxon is assigned to *Erisocrinus?* sp.

The characters that align *Erisocrinus?* sp. to the Erisocrinidae are a very low bowl-shaped aboral

cup that is subcircular in outline from a basal view, plenary radial facets, and no posterior plates fixed in the CD interray. In the Qarari fauna, *Erisocrinus?* sp. is represented by a single specimen that lacks column and arms. In addition, the aboral cup is rather coarsely preserved, which adds further uncertainty to the *Erisocrinus?* assignment.

Permian species of *Erisocrinus*, as listed in Webster & Webster (2014), include *E. araxensis*, *E. longwelli*, *E. pentangulatus*, and *E. propinquus*. Of these, only *E. longwelli* has preserved arms. For the purposes of this work, only two species characters are needed to distinguish among Permian species. *E. araxensis*, has a medium cone aboral cup, and infrabasal plates are visible in lateral view; *E. longwelli* and *E. propinquus* have a low bowl to cone aboral cup shape, and infrabasal plates are not visible in lateral view, and *E. pentangulatus* has a low cone aboral cup shape, and the infrabasal plates are not visible in lateral view. In contrast, *Erisocrinus?* sp. from Oman has a very low-bowl shaped aboral cup and infrabasal plates are visible in lateral view.

Measurements. ONHM F-1526: ACH, 4.8; ACW, 10.7; IH, 1.7; IW, 2.2; BH, 3.0; BW, 3.0; RH, 3.3; RW, 6.0.

Geologic age and geographic distribution. Qarari Unit, Permian (late Kungurian), Wadi Khawr Al Jaramah (WKJ-2), Batain, Oman.

Genus *Qararicrinus* gen. nov.

Diagnosis: Symmetrical aboral cup, very low cone-shaped aboral cup, smooth aboral plate sculpturing, pentagonal aboral cup outline in basal view, basal concavity present and shallow, infrabasal plates not confined to basal concavity, infrabasal plates slightly visible in lateral view, basal plates small, radial plates declivate, no posterior interray plates within the aboral cup, distal spinose projection from first primibrachial, as known second and third secundibrachials rectilinear uniserial, proximal columnal circular.

Etymology: The genus name recognizes the stratigraphic unit from which this new taxon was collected.

Type species: *Qararicrinus bataanensis* gen. nov., sp. nov.

Included species: Type species only.

Remarks. *Qararicrinus* gen. nov. is most similar to *Erisocrinus* and *Exaetocrinus* by sharing cone-shaped aboral cups, smooth aboral cup plate sculpturing, pentagonal calyx outlines in basal view, and infrabasal plates not confined to basal concavity. *Erisocrinus* has a very low cone-shaped aboral cup, little or no basal concavity, infrabasal plates not visible in lateral view, large basal plates, slightly declivate radial facets, one anal plate in notch between C and D

radial plates, distal spinose projection on first primibrachial absent, first secundibrachial chisel biserial, and proximal columnal circular; and *Exaetocrinus* has a low cone-shaped aboral cup, basal concavity absent, infrabasal plates visible in lateral view, small basal plates, planate radial facets, no posterior interray plates in aboral cup, primibrachials and secundibrachials unknown, and proximal columnal subpentagonal. In contrast, *Qararicrinus* gen. nov. has a very low cone-shaped aboral cup, a narrow and shallow basal concavity. Infrabasal plates visible in lateral view, small basal plates, declivate radial facets, no posterior interray plates in aboral cup, distal spinose projection on first primibrachial present, as known second and third secundibrachials rectilinear uniserial, and proximal columnal circular.

Qararicrinus gen. nov. is distinct from *Jaramabcrinus* gen. nov., its sympatric member of the Erisocrinidae, because *Qararicrinus* gen. nov. has a very low cone-shaped aboral cup, smooth aboral cup plate sculpturing, pentagonal outline of the aboral cup in basal view, a narrow and shallow basal concavity, declivate radial facets, and no posterior plates in the aboral cup. In contrast, *Jaramabcrinus* gen. nov. has a medium to low aboral cup shape, granulose aboral plate sculpturing, circular to slightly pentalobate aboral cup outline in basal view, and a basal concavity absent.

Qararicrinus batainensis gen. nov., sp. nov.

Figs. 12.9, 12.10, 13.1

Holotype: Holotype and only specimen ONHM F-1519.

Diagnosis: As for genus.

Etymology: The species name recognizes the region of Oman where this species was collected.

Type locality and horizon: Wadi Khawr Al Jaramah (WKJ-1), Batain, Oman; Qarari Unit, Permian (late Kungurian).

Description. Aboral cup symmetrical, probably very low cone shape (if uncompact), basal concavity shallow, height to width ratio of compressed aboral cup ~ 0.39 , pentagonal outline from basal view (Fig. 12.9); plates gently convex, probably smooth sculpturing.

Infrabasal circlet, not confined to basal concavity, visible in lateral view, $\sim 3\%$ of aboral cup height; presumably five infrabasal plates. Basal circlet $\sim 27\%$ of aboral cup height; basal plates five, small, hexagonal or pentagonal, relatively small, ~ 1.4 times wider than high. Radial circlet $\sim 70\%$

of aboral cup height; radial plates five, pentagonal ~ 1.8 times wider than high. Radial facets plenary, declivate, articular ridge across width of radial facet, a relatively narrow aboral ligament groove across only central portion of facet.

No posterior interray plates in aboral cup or separating C and D brachials (Fig. 12.9). Anal sac unknown.

Only proximalmost brachials preserved. First primibrachial wider than high, axillary; spine at distal center formed by radial facets for first secundibrachial jutting outward at an $\sim 30^\circ$ angle (Fig. 12.10). Distal surface of first primibrachial with 2 pentafacial facets separated by a vertical ridge. Only two secundibrachials preserved, both rectilinear uniserial, gently convex with ridges and grooves oriented in and out that interlocked when the crown was closed; secundibrachial facets nearly flat. First secundibrachial asymmetrical, higher on the outside than on the inside, approximately as high as wide; second secundibrachial as high as wide, symmetrical. Other aspects of free arms unknown.

Proximal column circular; other aspects of column unknown.

Remarks. Portions of the basal plates, radial plates, and brachials are encrusted with an unusual epizoan interpreted to be a coral (Fig. 12.9, 12.10). None of the plate sutures are overgrown, which allowed the arms to open and close freely. Thus, it is reasonable to assume that the encrustation occurred while this crinoid was alive.

Measurements. ONHM F-1519: ACH, 4.3; ACW, $\sim 11.0^*$; IH, 0.6; IW, 1.9; BH, 2.1; BW, 3.2; RH, 3.3; RW 6.7.

Genus *Jaramabcrinus* gen. nov.

Diagnosis: Symmetrical aboral cup, medium to low cone-shaped aboral cup, granulose aboral plate sculpturing, circular to subpentalobate aboral cup outline in basal view, basal concavity absent, infrabasal plates not confined to basal concavity, infrabasal plates clearly visible in lateral view, basal plates small, radial facets slightly declivate, posterior interray plates not within the aboral cup but sutured to shallow notch at C and D radial plate suture, free arms unknown, proximal columnal circular.

Etymology: The genus name recognizes Wadi Khawr Al Jaramah, where this crinoid was collected.

Type species: *Jaramabcrinus warlichi* gen. nov., sp. nov.

Composition: Type species only.

Remarks. *Jaramabcrinus* gen. nov. is compared to other Permian Erisocrinidae in the remarks of the Erisocrinidae and remarks of *Qararicrinus* gen.

nov. Having a conical aboral cup and having no anal plates within the aboral cup are unusual characters for Permian euclidids but align this taxon with the Erisocrinidae. Similar to some species in other genera of the Erisocrinidae, *Jaramahcrinus* gen. nov. has crenulae of the proximal column deeply impressed into the infrabasal circllet.

***Jaramahcrinus warlichi* gen. nov., sp. nov.**

Figs. 13.3, 14.1–14.6

Holotype: Holotype: ONHM F-1520.

Diagnosis: As for the genus.

Etymology: The species name recognizes Georg Warlich, who alerted A.P.H. about well-preserved fossils from Wadi Khawr Al Jaramah.

Paratypes: ONHM F-1521 to ONHM F-1525.

Type locality and horizon: Wadi Khawr Al Jaramah (WKJ-1; WKJ-2), Batain, Oman; Qarari Unit, Permian (late Kungurian).

Description. Aboral cup symmetrical, very small, low to medium cone shape (Fig. 14.4), sub-pentalobate in outline in basal view (Fig. 14.3, 14.6), height to width ratio of aboral cup ~ 0.58 , basal concavity absent; plates slightly convex, granulose plate sculpturing (Fig. 14.3, 14.6); slightly depressed along aboral cup plate sutures. Infrabasal circllet not confined to basal concavity, $\sim 18\%$ of aboral cup height (Fig. 14.1); infrabasal plates five, slightly visible in lateral view; proximal infrabasal circllet facet deeply impressed crenularium of proximal-columnal (Fig. 14.6). Basal circllet $\sim 43\%$ of aboral cup height; basal plates five, pentagonal, smaller than radial plates, as wide as high. Radial circllet $\sim 39\%$ of aboral cup height; radial plates five, pentagonal, ~ 2.2 times wider than high, radial plate-radial plate sutures depressed. Radial facets plenary (Fig. 14.5), slightly declivate, articular ridge across full width of facet, an aboral ligament groove across most of the width of the facet, adoral ligament pit undifferentiated, adoral groove.

Triangular facet on upper surface of suture between C and D radial plates that presumably supported the radianal plate (Fig. 14.1, 14.2).

Free arms, anal sac, and column unknown.

Remarks. All specimens of *J. warlichi* gen. nov. sp. nov. are quite small, which invites the question as to whether they may be juvenile specimens. However, their morphology is sufficiently distinct from other Permian species of euclidids that these Oman specimens are regarded as a new genus and species.

Measurements. ONHM F-1520 (holotype): ACH, 2.2; ACW, 3.8; IH, 0.5; IW, 0.6; BH, 1.2; BW, 1.2; RH, 1.1; RW, 2.4. ONHM F-1521 (paratype): ACH, 2.1; ACW, 3.5; IH, 0.4; IW, 0.9; BH, 2.6; BW, 1.2; RH, 1.1; RW, 1.9.

Family Graphiocrinidae Wachsmuth & Springer,
1886

Genus *Permiocrinus* Wanner, 1947

Type species: *Permiocrinus immaturus* Wanner, 1949 (West Timor, uncertain age).

Included species: *Permiocrinus immaturus* Wanner, 1949 (West Timor, uncertain age); *P. pumilus* (Wanner, 1916) (West Timor, uncertain age); *P. quinquelobus* (Wanner, 1916) (West Timor, uncertain age).

***Permiocrinus?* sp.**

Fig. 12.12–12.14

Material: ONHM F-1528.

Description. Aboral cup very small in size. Aboral cup very low cone shaped, height to width

Fig. 12 - Euclidid crinoids from the Qarari Unit. 1, 2) *Eoindocrinus spinosus* sp. nov., ONHM F-1517, holotype, scale bar = 1.0 mm; 1, lateral view of calyx, not long spines from center of basal plates; 2, oral view of aboral cup showing elongate anal tray. 3-6) *Proindocrinus risesae* sp. nov., scale bars = 1.0 mm; 3, 4, ONHM F-1511, paratype; 3, oral view of aboral cup; 4, lateral view of aboral cup, note slight asymmetry of aboral cup and a few columnals attached to the extended basal circllet; 5, 6, ONHM F-1510, holotype, 5, lateral view of aboral cup; 6, oral view of aboral cup, note the anal tray is not extended to any degree. 7, 8) *Eoindocrinus ageri* sp. nov., ONHM F-1518, scale bar = 2.5 mm; 7, lateral view of AE interray; 8, lateral view of D ray, note small posterior inter-radial plates to right of the narrow D-ray radial plate. 9, 10, *Qararicrinus batainensis* gen. nov., sp. nov., holotype, ONHM F-1519, scale bars = 5 mm, coral encrusted on several aboral cup plates; 9) basal view, note pentagonal calyx outline; 10) lateral view of aboral cup, note plenary facets and upward projecting distal node on first primibrachial plate, which is axillary. 11) *Disgregacrinus aridus* gen. nov., sp. nov., holotype, ONHM F-1527 scale bar = 5 mm; lateral view of incomplete crown, note three posterior plates in aboral cup, elongate first primibrachial constricted at mid-height. 12-14) *Permiocrinus?* sp., ONHM F-1528, scale bar = 2.5 mm; 12, oral of aboral cup; 13, CD interray lateral view of aboral cup; 14, basal view of aboral cup. 15-17) *Malaiocrinus* sp., ONHM F-1509, scale bar = 5 mm; 15, lateral view of CD interray, note truncated basal plate circllet and missing infrabasal circllet; 16, oblique lateral view of C radial plate showing the size and shape of the radial facet; 17, basal view of aboral cup with most of the basal circllet and the infrabasal circllet missing entirely.

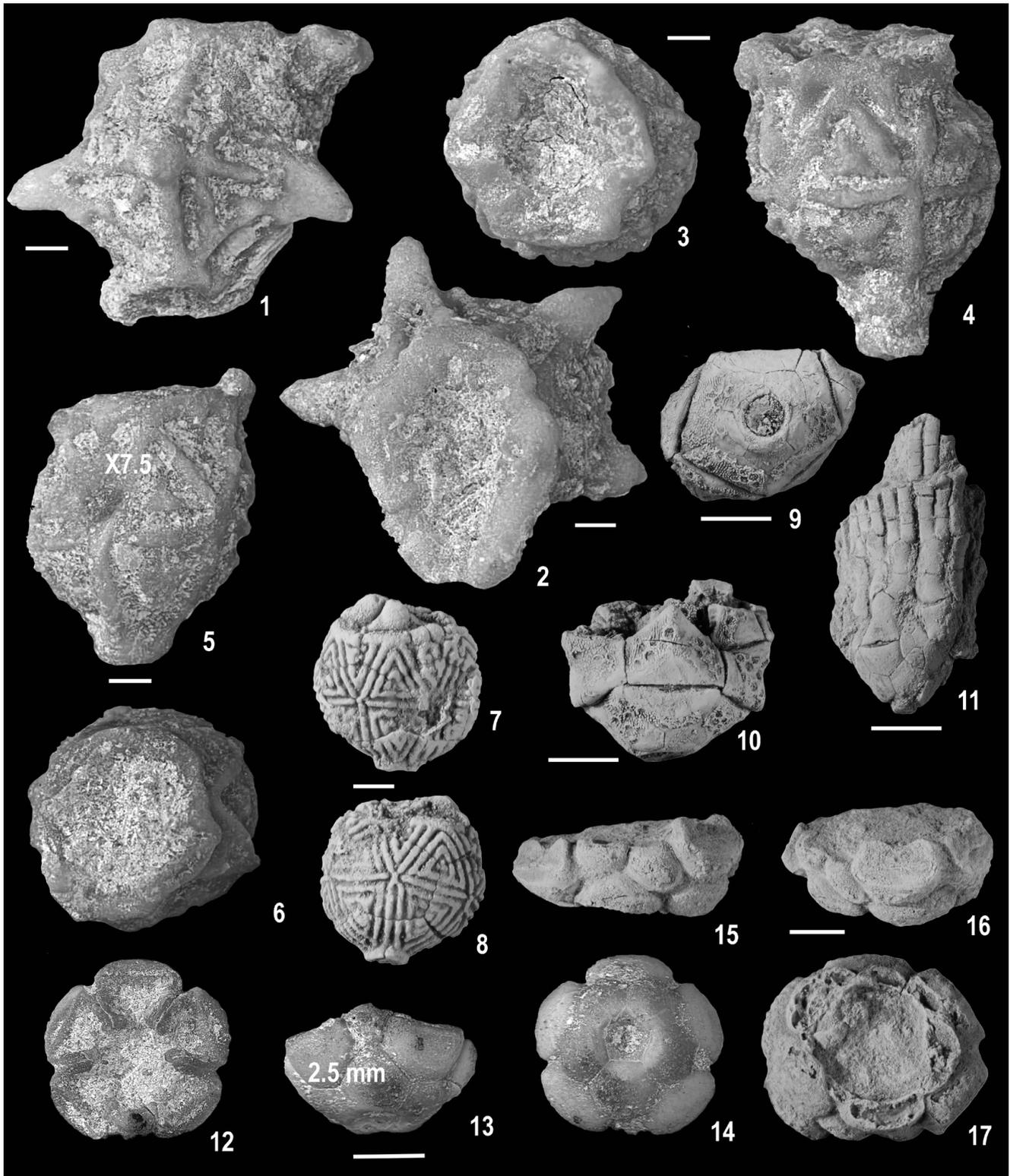


Figure 12

ratio of aboral cup ~ 0.42 ; basal and radial plates strongly convex, smooth sculpturing (Fig. 12.13), plate sutures deeply impressed (Fig. 12.14). Infra-basal circlet small, confined to basal concavity; five infrabasal plates. Basal circlet $\sim 40\%$ of aboral cup

height. Basal plates five, hexagonal (except CD basal plate that is heptagonal), smaller than radial plates, ~ 1.5 times wider than high. Radial circlet $\sim 60\%$ of aboral cup height. Radial plates five, ~ 1.4 times wider than high. Radial facets peneplenary (Fig.

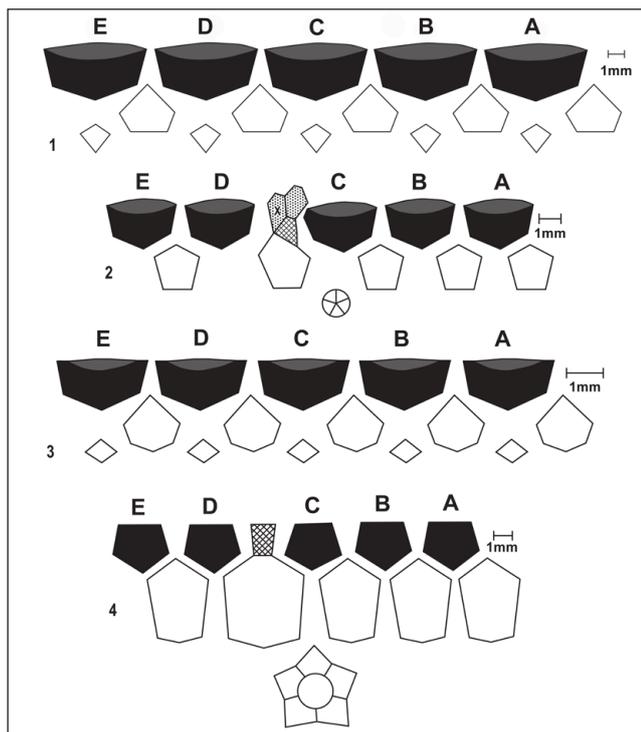


Fig. 13 - Aboral cup plate drawings of eucladid crinoids from the Qarari Unit. 1) *Qararicrinus batainensis* gen. nov., sp. nov.; 2) *Disgregacrinus aridus* gen. nov., sp. nov.; 3) *Jaramahcrinus warlichi* gen. nov., sp. nov.; 4) *Roemerocrinus? artus* sp. nov. Black, radial plates; gray, radial facets; cross-hatched pattern, radial plate; dotted pattern, additional CD interray plates above radial plate; X, anal X plate.

12.12), articular ridge nearly entire width of radial facet, deep adoral fossa, adoral fossae steep sided with deep adoral groove; upper margins of adjacent radial plates form a ridge that projects adaxially.

Radial only posterior interray plate in aboral cup. Two, equal-length sutures on upper surface of radial plate for anal X plate and right sac plate.

Anal sac and arms unknown.

Proximal-most columnal circular; lumen very small, circular; other aspects of column unknown.

Remarks. The single specimen assigned to *Permiocrinus?* sp. is an aboral cup lacking arms and column, which makes assignment to a genus problematic. However, with the infrabasal circling confined to the basal concavity, strongly convex basal and radial plates, a single anal plate in the aboral cup, peneplenary radial facets, and ridges formed by the upper shoulders of adjacent radial plates that project adaxially, this crinoid is similar to *Permiocrinus quinquelobus* (Wanner, 1916) (see Wanner, 1916, pl. 14). However, it does not fully comply with all morphological details of these illustrated specimens or the other two species currently recognized in *Per-*

miocrinus. Therefore, this taxon is identified as *Permiocrinus?* sp.

Measurements. ONHM F-1528: ACH 3.4, ACW 6.5, BH, 1.4, BW, 2.1; RH, 2.1; RW, 3.2; RAH, 1.6; RAW, 1.5.

Geologic age and geographic distribution. Qarari Unit, Permian (late Kungurian); Wadi Khawr Al Jaramah (WKJ-1), Batain, Oman.

Superfamily Texacrinoidea Strimple, 1961

Family Staphylocrinidae Moore & Strimple, 1973

Remarks. As presented in Moore & Strimple (1973), the Staphylocrinidae contain a diverse array of morphologies, most of which are distinct from *Staphylocrinus* Burdick and Strimple, 1969. However, *Disgregacrinus* gen. nov. is very similar to two members of this family: *Dinotocrinus* Kirk 1941b (Lower Carboniferous; United Kingdom and United States) and *Microcaracrinus* Strimple & Watkins, 1969 (Middle Pennsylvanian to Lower Permian; Russia and United States). These genera may very well represent a new family, but this should not be done until a comprehensive phylogenetic understanding of the eucladids is known.

Genus *Disgregacrinus* gen. nov.

Diagnosis: Staphylocrinid with a low cone-shaped aboral cup, smooth plate sculpturing, infrabasal plates not visible in lateral view, (fusion of infrabasal plates uncertain), basal plates not bulbous, radial facets plenary, three posterior plates in aboral cup in CD interray, right sac plate sutured to radial plate below, first primibrachial axillary in at least C and D rays (other rays unknown), first primibrachial constricted medially, free arm branching isotomous, brachials rectilinear uniserial, proximal column circular.

Etymology: The genus name is derived from *disgregus* (L.), meaning unlike, different.

Type species: *Disgregacrinus aridus* gen. nov., sp. nov.

Composition: Type species only.

Remarks. With basal plates not bulbous, plenary radial facets, first primibrachial constricted at mid-height, and twenty or more total free arms, *Disgregacrinus* gen. nov. is most similar to the following genera in the Staphylocrinidae: *Dinotocrinus*; *Harmotocrinus* Strimple, 1975; and *Microcaracrinus*. *Dinotocrinus* has a very low bowl aboral cup shape, smooth aboral cup plate sculpturing, right sac plate sutured beneath to the radial and anal X, first primibrachial constricted or not constricted medially, brachial plates weakly cuneate uniserial, and proximal col-

umn circular; *Harmostocrinus* has a low bowl aboral cup shape, granulose aboral plate sculpturing with pits in plate triple junctions, right sac plate sutured beneath to radial plate, first primibrachials constricted medially, brachial plates moderately cuneate uniserial, and a pentagonal proximal columnal; *Micrococrinus* has a low bowl aboral cup shape, aboral cup plate sculpturing smooth or with variously oriented ridges, right sac plate sutured beneath to the radial, first primibrachials constricted medially, brachial plates moderately cuneate uniserial, and a circular proximal columnal. In contrast, *Disgregacrinus* gen. nov. has a low cone aboral cup shape, smooth aboral cup plate sculpturing, right sac plate sutured beneath to the radial, first primibrachial constricted medially, brachial plates rectilinear uniserial, and circular proximal column.

Geologic age and geographic distribution. Qarari Unit, Permian (late Kungurian); Wadi Khawr Al Jaramah (WKJ-1), Batain, Oman.

***Disgregacrinus aridus* gen. nov., sp. nov.**

Figs. 12.11, 13.2

Holotype: ONHM F-1527.

Diagnosis: As for the genus.

Etymology: This species name refers to the climate of Oman, where this species was found.

Type locality and horizon: Wadi Khawr Al Jaramah (WKJ-1), Batain, Oman; Qarari Unit, Permian (late Kungurian).

Description. Crown small in size. Aboral cup low cone shaped, height to width ratio of aboral cup ~ 0.54 ; plates gently convex, smooth sculpturing (Fig. 12.11), plate sutures slightly impressed. Infrabasal plates completely covered by proximal column. Basal cirlet $\sim 45\%$ of aboral cup height. Basal plates five, presumably hexagonal, smaller than radial plates, ~ 1.4 times wider than high. Radial cirlet $\sim 55\%$ of aboral cup height. Radial plates five, ~ 1.4 times wider than high. Radial facets pleural, other details not known.

Three posterior plates in aboral cup, radial beneath and to left of the C ray radial plate; anal X above to left of radial, between D radial and right sac plate to the right, $\frac{1}{4}$ of plate above the cup; right sac plate immediately above radial, between anal X and C radial plate, $\frac{1}{2}$ of plate above the aboral cup (Fig. 12.11, 13.2).

Anal sac unknown.

Arms incomplete, presumably pinnulate,

branch twice with poor isotomy; 20 or more total arms. Brachials rectilinear uniserial. First primibrachial axillary, 1.4 times wider than maximum height, constricted at mid-height (Fig. 12.11). Two secundibrachials; first secundibrachial ~ 2.1 times wider than maximum height; secundaxil ~ 2.1 times higher than wide, slightly constricted mid-height. Tertibrachials ~ 0.5 mm wide but heights variable, straight sides.

Proximal-most column circular, holomeric; lumen circular; other aspects of column unknown.

Measurements. Holotype: ONHM F-1527: CrH, 20.0*; ACH, 2.3; ACW, 4.3; IH, 0.3; BH, 2.2; BW, 2.5; RH, 2.2; RW, 3.4.

Superfamily Scytalocrinoidea Moore & Laudon, 1943

Family Scytalocrinidae Moore & Laudon, 1943

Genus *Roemerocrinus* Wanner, 1916

Type species. *Roemerocrinus gracilis* Wanner, 1929.

Included species. *Roemerocrinus gracilis* Wanner, 1929; *R. gracilis granulatus* Wanner, 1937; *R. gracilis turbinatus* Wanner, 1937; and *R.?* *artus* sp. nov.

Remarks. *Roemerocrinus* is recognized exclusively from the Permian with three species and one subspecies from the Permian of West Timor. *R.?* *artus* sp. nov. from Oman is the fourth species of *Roemerocrinus*.

***Roemerocrinus?* *artus* sp. nov.**

Holotype: ONHM F-1548.

Diagnosis: *Roemerocrinus?* with a medium globe-shaped aboral cup, aboral cup plates gently convex, pits at the calyx plate triple junctions absent, infrabasal cirlet $\sim 20\%$ of aboral cup height, basal cirlet $\sim 50\%$ of aboral cup height, radial cirlet $\sim 30\%$ of aboral cup height, radial facets peneplenary and shallow, radial plate tetragonal and entirely within the aboral cup.

Etymology: *Artus* means narrow, tight, close (L., m.) and refers to the narrow radial plate.

Type locality and horizon: Wadi Khawr Al Jaramah (WKJ-2), Batain, Oman; Qarari Unit, Permian (late Kungurian).

Description. Aboral cup small, medium globe shape; plates gently convex, smooth plate sculpturing.

Infrabasal cirlet visible in lateral view, 20% of aboral cup height; 3 infrabasal plates, smallest infrabasal plate probably in the D ray. Basal plate cirlet $\sim 50\%$ of aboral cup height; five basal plates,

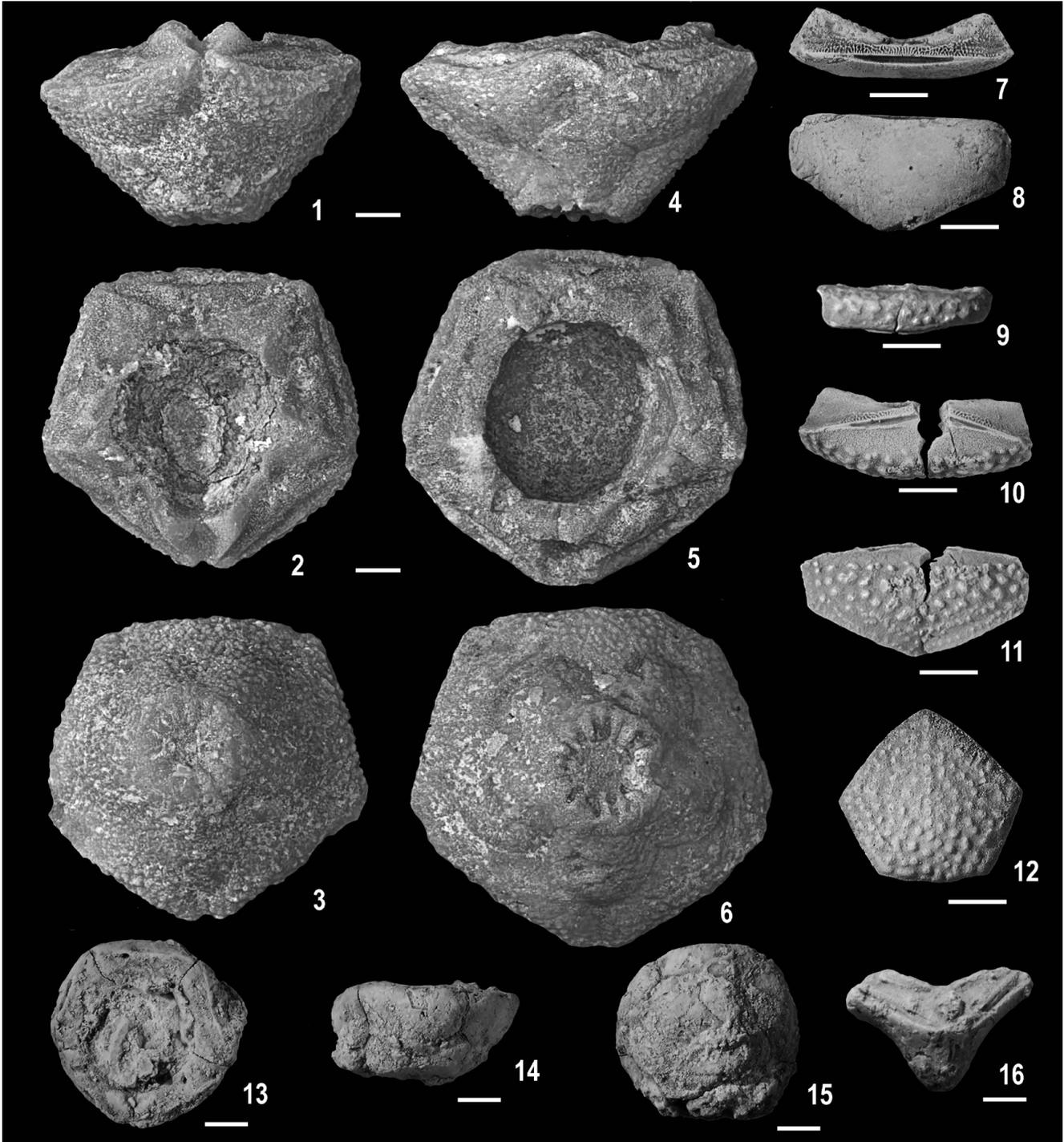


Fig. 14 - Eucladid crinoids from the Qarari Unit, all scale bars = 5 mm. 1-6) *Jaramaherinus warlichi*, scale bar = 1.0 mm; 1-3, ONHM F-1520, holotype, CD lateral, oral, and basal views, note peneplenary radial facets, notch at junction of C and D radial plates for posterior plates, granulose plate sculpturing; 4-6, ONHM F-1521, lateral, oral, and basal views respectively, note convex aboral cup plates with slight depression along sutures. 7-14) Eucladid Indeterminate; 7, 8, ONHM F-1529, radial plate with smooth plate sculpturing; 7, radial facet, note very narrow radial facet; 8, lateral view of radial plate. 9-12 eucladid indeterminate with coarse plate sculpturing, 9, ONHM F-1534, lateral view of axillary first primibrachial. 10, 11, ONHM F-1530, radial plate; 10, radial facet, note very wide aboral ligament fossa; 11, lateral view of radial plate. 12, ONHM F-1533, basal plate. 13-15) *Erisocrinus?* sp., ONHM F-1526, oral, lateral, and basal views, respectively, note lack of posterior plates in aboral cup and plenary facets. 16) ONHM F-1545, axillary first primibrachial with large, blunt spine; scale bar = 5.0 mm. All scale bars = 5.0 mm.

approximately as high as wide, much larger than infrabasal and radial plates. Radial circlet ~30% of aboral cup height, radial facets peneplenary.

Radial plate tetragonal, only CD interray plate in aboral cup, directly above CD basal plate along a horizontal suture, separates C and D radial

plates, ~2.0% higher than wide, and widen slightly distally.

Column and arms unknown.

Remarks. With a medium globe-shaped aboral cup and pleneplenary radial facets, *Roemerocrinus?* *artus* sp. nov. is most similar to *R. gracilis granulatus* and *R. scrobiculatus*. These species are distinguished because *R. gracilis granulatus* has gently convex aboral cup plates without pits at plate triple junctions, pleneplenary and probably deep radial facets, radial plate hexagonal and extends above radial plate circlet; and *R. scrobiculatus* has strongly convex aboral cup plates with deep pits at calyx plate triple junctions, pleneplenary and deep radial facets, and a hexagonal radianal plate that extends above the aboral cup. In contrast, *R.?* *artus* sp. nov. has gently convex aboral cup plates without pits at triple junctions, pleneplenary and shallow radial facets, a radianal that is tetragonal and does not extend above the radial plate circlet.

Roemerocrinus? *artus* sp. nov. is questionably assigned to *Roemerocrinus* because of its shallow radial facets and the tetragonal radianal plate that does not extend beyond the distal radial plates. Herein these and other characteristics are considered to be species diagnostic characters, although with complete knowledge of the morphology of this taxon it is possible that it could define a new genus.

Measurements. ONHM F-1548: ACH, 6.9; ACmaxW, ~6.1; ICH 2.0; ICmaxW, 5.3; BH, 4.0; BW, 4.0; RH, 2.7; RW, 3.2.

Euclidid Indeterminate

Fig. 14.7–14.12, 14.16

Specimens: ONHM F-1529 to ONHM F-1545.

Remarks. Disarticulated calyx plates are relatively common at Wadi Khawr Al Jaramah, and several individual plates and infrabasal circlets were collected. Plates include, basal plates, radial plates, and brachials that probably represent several taxa. Three taxa are discussed herein. One has large and thick plates with plate sculpturing of evenly distributed low nodes across the plate surface. These are represented by both radial and basal plates and brachial plates (Fig. 14.9–14.12). The brachial plates are ~4.3 times wider than high and include both axillary and nonaxillary plates.

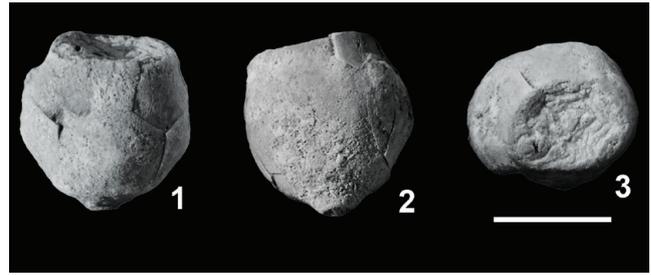


Fig. 15 - *Roemerocrinus?* *artus* sp. nov. ONHM F-1548, holotype, scale bar = 1.5 mm; 1) CD-interray view; 2) A-ray view; 3) oral view.

The second taxon is a similar, large, thick-plated radial plate with smooth plate sculpturing (Fig. 14.7, 14.8). In addition, smaller and thinner non-diagnostic euclidid aboral cup plates are also present as well as intact infrabasal circlets. Without knowing the shape of the aboral cup, presence or absence and arrangements of aboral cup plates, it is not possible to speculate on the affinities of these plates with any certainty. A third distinct taxon is represented by a single axillary primibrachial with a thick blunt spine (Fig. 14.16).

Geological age and geographic distribution. Qarari Unit, Permian (late Kungurian); Wadi Khawr Al Jaramah (WKJ-1, WKJ-2, WKJ-3, WKJ-4, WKJ-5), Batain, Oman.

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