

ALLAGECRINOIDEA AND CODIACRINOIDEA: MICROCRINOIDS (ECHINODERMATA) FROM THE UPPER KUNGURIAN (LOWER PERMIAN) OF OMAN

GARY D. WEBSTER¹, WILLIAM I. AUSICH² & ALAN P. HEWARD³

¹deceased

²School of Earth Sciences, The Ohio State University, Columbus, Ohio 43210, USA. E-mail: ausich.1@osu.edu

³Coach House, Mortimer Lodge, Hanley Swan, Worcs WR8 0DN, UK. E-mail: alanpheward@gmail.com

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Abstract: Upper Kungurian (Lower Permian) crinoids of the Allagecrinoidea and Codiacrinoidea are described from the Ash Sharqiyah South region of the Sultanate of Oman. These two taxonomic groups include both microcrinoids and small macrocrinoids that were isolated from washing bulk samples of the Qarari Unit from two sample sites near Wadi Khawr Al Jaramah, Batain, Oman. Eight genera, one new, and fourteen species, twelve new, are described. The Allagecrinoidea and Codiacrinoidea described herein complete our present understanding of crinoids from the Permian of Oman and help to better understand Permian echinoderm paleocommunities in the Neo-Tethys. The generic composition of this Oman microcrinoid fauna is intermediate in composition between those of Russia and West Timor.
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INTRODUCTION

Permian blastoids and crinoid from the Sultanate of Oman (Jell & Willink 1993; Webster & Sevastopulo 2007; Webster et al. 2009; Webster et al. 2022; and Webster et al. 2025) help in developing a global overview of echinoderms to improve understanding of the tempo, mode, and paleogeographic pattern of clade extinctions before and during the Permian mass extinction (e.g. Sepkoski 1981; Erwin 2006). In this study, microcrinoids and very small macrocrinoids from the late Kungurian (Early Permian) outcrops in Oman are described. Fourteen

species assigned to eight genera are described, which includes one new genus and twelve new species.

Pelmatozoan columnals are known from the Upper Permian (e.g., Reich 2007); and historically, the blastoid and crinoid remains from West Timor were believed to have been Upper Permian (e.g., Moore & Teichert 1978). However, it has been demonstrated that the age of the majority of echinoderm-bearing strata in West Timor is uncertain (Webster 1998). The co-occurrence of some West Timor species elsewhere (e.g. Western Australia: Webster 1987; Webster & Jell 1992; 1999; Jell & Willink 1993) suggests primarily a Lower Permian age (perhaps upper Sakmarian to Artinskian: Webster 1998; Charlton et al. 2002). However, the slightly younger Qarari Unit

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(which ranges in age from late Kungurian – possibly Wordian) expands the potential age range of the Timor faunas (Webster et al. 2025; this study).

In this study, members of the Allagecrinoidea (Disparida) and Codiacrinoidea (Eucladida) from Oman are described. These two superfamilies contain the majority of Paleozoic crinoids that are referred to as microcrinoids. Paleozoic microcrinoids (maximum-size aboral cup heights ≤ 2 mm) are cosmopolitan and recognized from the Silurian to the Permian; however, note that some members of the Codiacrinoidea exceed this arbitrary size limit. Many Paleozoic crinoids in the ≤ 2.0 mm size range are part of growth series of larger crinoids (e.g., Moore & Ewers 1942), and some taxa previously regarded as a microcrinoid have been determined to be juveniles of a regular-sized echinoderm (e.g., *Amphalipsadocrinus* Weller, 1930 is now regarded a juvenile of a platycrinid (Lane et al. 1985) and *Passalocrinus* Peck, 1936 is now regarded a juvenile blastoid; Sevastopulo 2005). However, in many examples where growth series are known in well-sampled strata, larger specimens corresponding to microcrinoids do not exist (e.g., Lane & Sevastopulo 1981). Thus, the largest examples of these very small crinoids are considered to be the adult size and are collectively referred to as microcrinoids.

STRATIGRAPHY AND PALEOGEOGRAPHIC SETTING

The most recent geologic mapping of north-eastern Oman was completed by Peters et al. (2001), who extended their work on Masirah Island northward into the Batain nappes region (Fig. 1). Peters et al. (2001) and others (e.g., Immenhauser et al. 2000; Angiolini et al. 2003; Golonka 2007; Shellnut et al. 2011; see further discussion in Webster et al. 2025) concluded that the Batain Basin represents the earliest opening of the Indo-Madagascan arm of the Neo-Tethys ocean ~ 290 Ma ago. Subsequently, these strata were obducted from the Indian Ocean as allochthonous nappes onto present-day north-eastern Oman. The strata have never been deeply buried (Fortey & Heward 2015).

The Allagecrinoidea and Codiacrinoidea reported here were isolated from bulk sediment samples from two localities of Wadi Khawr Al Jaramah (WKJ-1 and WKJ-2) ($22^{\circ}27'37.97''$ Lat.,

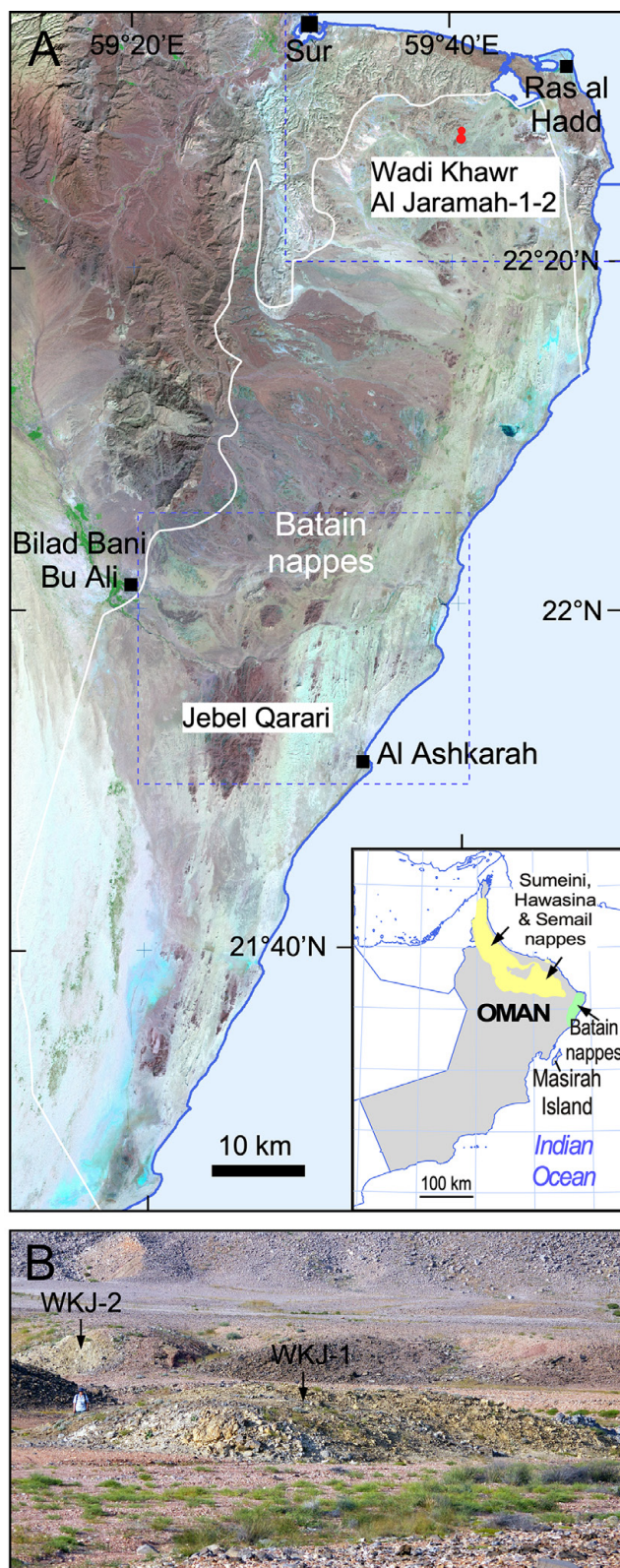


Fig. 1 – A. Location map of the Batain area in the northeast of the Sultanate of Oman. The extent inland of the Batain nappes is shown by the white line. The deposits that form the Batain nappes were deposited in a basin offshore in the Neo-Tethys and obducted over the eastern margin of the Arabian plate. B. Field photo of locations from which bulk samples were collected (modified from Webster et al. 2025).

Fig. 2 – Permian stratigraphical nomenclature for Oman for the Arabian plate and for allochthonous units from the Hawasina and Batain basis of Neo-Tethys (modified from Webster et al., 2025). Star indicates stratigraphic level of the microcrinoids described in this study.

Ma	PERMIAN	ISC stage	Autochthon	Tethyan	Allochthon (Neo-Tethys)	
			Arabian plate	stage	Hawasina basin	Batain basin
250	TRIAS (pars)		Sudair Fm. (pars)			Gal Fm. (pars) ? Aseelah Unit ?
260	Loping	Changhsingian	Khuff Fm.	Dorashamian	Hamrat Duru & Sumeini Gps (pars)	Exotics of Haybi Complex
		Wuchiapingian		Dzhulfian		
270	Guadalupian	Capitanian	Upper Gharif Mbr	Midian	-? -? -? -?	-? -? -? -?
		Wordian		Murgabian		
280	Roadian		Middle Gharif Mbr	Kubergandian	-? -? -? -?	Qarari Unit ★
		Kungurian		Bolorian		
290	Cisuralian	Artinskian	L. Gharif Mbr	Yakhtashian		Clasts within Aseelah Unit ↓
		Sakmarian		Sakmarian		
300	Asselian		Al Khlata Fm. (pars)	Asselian		

59°40'50.75" Long.; 22°27'40.51" Lat., 59°40'50.92" Long.; respectively) (Fig. 1). Bulk samples were collected from the marly facies within the Qarari Unit that consists of thin-bedded grey limestones interbedded with yellow marl. Based on fusulinid, conodont, and brachiopod faunas, the Qarari Unit at Wadi Khawr Al Jaramah is regarded as upper Kungurian (Kuberganian, Leven & Heward 2013; Fortey & Heward 2015, or upper Cisuralian and Guadalupian Series (Viaretti et al. 2022) (Fig. 2).

The Qarari Unit has been interpreted as toe of slope and basinal deposits (Immenhauser et al. 1998; however, the sedimentology and fossiliferous content may suggest a shelf setting (personal observations APH). The tectonic, sedimentologic, and chronostratigraphic settings of the echinoderm-bearing strata in the Batain Basin, northeastern Oman are discussed in detail in Webster et al. (2025).

Paleozoic microcrinoids are well documented from many locations around the world, however, the abundance and biodiversity of microcrinoids isolated from relatively small samples, as reported herein, suggests a high hidden biodiversity in many Paleozoic faunas and the need for more comprehensive sampling in other strata.

MATERIALS AND METHODS

The Wadi Khawr al Jaramah area was explored

by APH as part of an overall effort to document the paleontology of northeastern Oman. Outcrops in the Wadi Khawr Al Jaramah area were richly fossiliferous, including the remains of many small blastoids and crinoids. In addition to surficial collections, bulk samples were collected from two localities (Fig. 1). Approximately 1.0 kg samples were collected, with two samples from WKJ-1 and four from WKJ-2. The locations are 85 m apart across a dry water course but are not continuous outcrop as the beds strike and dip in directions at 90 degrees. WKJ-1 exposes approximately 20 m of section, whereas WKJ-2 exposes approximately 3 m. WKJ-2 has proven to be richer in echinoderm remains. GDW was keen on bulk sampling these locations having previously suggested that larger specimens should not be washed in case there were microcrinoids in attached sediment. Samples were washed through a sieve stack and individual specimens were isolated from the residue. Photography was completed with a scanning electron microscope for smaller specimens and an image-stacking camera/microscope with image-stacking software for larger specimens.

Faunal Analysis

The Allagecrinoidea described herein are four new species of *Litocrinus* Lane & Sevastopulo, 1982 and four species, three are new, of *Metallagecrinus* Strimple, 1966. The Codiocrinoidea genera from Oman are *Embryocrinus* Wanner, 1916; *Monobrachiocrinus* Wanner, 1916; *Batainacrinus* gen. n.; *Coelocystis*

	Oman	Australia	Russia	Sicily	Tunisia	United States	West Timor
<i>Litocrinus</i>							
<i>Metallagecrinus</i>							
<i>Embryocrinus</i>							
<i>Monobrachiocrinus</i>							
<i>Batainacrinus</i> gen. nov.							
<i>Coenocystis</i>							
<i>Dichostreblocrinus</i>							
<i>Hemistreptacron</i>							

Fig. 3 – Global Permian occurrences of the allagecrinid and codiacrinid genera reported from the Sultanate of Oman.

Allagecrinoidea	
	<i>Litocrinus delicatulus</i> sp. nov.
	<i>Litocrinus lanei</i> sp. nov.
	<i>Litocrinus ornatus</i> sp. nov.
	<i>Litocrinus sevastopuloi</i> sp. nov.
	<i>Metallagecrinus blothros</i> sp. nov.
	<i>Metallagecrinus indoaustralicus</i> (Wanner, 1924)
	<i>Metallagecrinus granulosus</i> sp. nov.
	<i>Metallagecrinus omanensis</i> sp. nov.
Codiacrinoidea	
	<i>Embryocrinus hanieli</i> Wanner, 1916
	<i>Monobrachiocrinus trochus</i> sp. nov.
	<i>Batainacrinus sulcus</i> gen. nov., sp. nov.
	<i>Coenocystis akros</i> sp. nov.
	<i>Dichostreblocrinus aequalis</i> sp. nov.
	<i>Hemistreptacrons concavus</i> sp. nov.

Tab. 1 - Allagecrinoidea and Codiacrinoidea genera and species described in this study from the upper Kungurian of Oman.

Girty, 1908; *Dichostreblocrinus* Weller, 1930, and *Hemistreptacron* Yakovlev, 1926, each represented by a single species of which five are new to science.

In contrast to the macrocrinoids described in Webster et al. (2025), which included several new genera, only one new genus is recognized among the Allagecrinoidea and Codiacrinoidea. The Allagecrinoidea and Codiacrinoidea genera from Oman are also known from Australia, Italy (Sicily), New Zealand (one very questionable occurrence), Russia, Tunisia, United States, and West Timor (Fig. 3). Five genera co-occur in the Permian of Russia, and six genera co-occur in the Permian of West Timor. However, at the species level only two Oman species occur elsewhere, *Metallagecrinus indoaustralicus* (Wanner, 1924) and *Embryocrinus hanieli* Wanner, 1916, which were described from West Timor.

Some of the Oman genera are known from the Carboniferous from other locations in the world (Webster & Webster 2014). However, during the Permian, these genera were largely confined to the Neo-Tethys, as currently known.

Institutional abbreviations. ONHM, Oman Natural History Museum (Muscat, Oman); RGM, Naturalis Biodiversity Center (formerly Rijksmuseum van Geologie en Mineralogie) (Leiden, The Netherlands).

SYSTEMATIC PALAEOLOGY

Crinoid suprafamilial classification used here follows Wright et al. (2017) and Wright (2017a, b), and family-level classifications follow Moore & Teichert (1978). Crinoid morphologic terminology follows Ubachs (1978) and Webster (1974) with updates from Kammer, et al. (2013), Ausich et al. (2020), and Ausich & Donovan (2023). The terminology of Ausich & Donovan (2023) represents terminology that is homologous among crinoids, blastozoans, and edrioasteroids. Note that the aboral cup includes the radial, basal, and infrabasal (if present) circlets; and the calyx is the aboral cup plus fixed brachials and interbrachials (if present) and the tegmen. Abbreviations used in designating measurements include: ACH, aboral cup height; ACmaxW, aboral cup maximum width; BCH, basal circlet height; BCmaxW, basal circlet maximum width; IH, Infrabasal height; ICmaxW, Infrabasal circlet maximum width; PPCP, primary peristomial cover plate; PPCPH, primary peristomial cover plate height; PPCPmaxW primary peristomial cover plate maximum width; RH, radial plate height; RmaxW, radial plate maximum width; TH, theca height. * indicates a measurement was incomplete.

Class **CRINOIDEA** Miller, 1821

Subclass **PENTACRINOIDEA** Jaekel, 1894

Infraclass **INADUNATA** Wachsmuth & Springer, 1885

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

Superfamily Allagecrinoidea Carpenter & Etheridge, 1881

Family Allagecrinidae Carpenter & Etheridge, 1881

Remarks. Of the two allagecrinid genera in the Oman fauna, the principal diagnostic character is the degree of development of the radial facets in adults. *Litocrinus* Lane & Sevastopulo, 1982 has very poor development of the radial facets with poorly defined articular ridges and poorly defined (or absent) ligament fossae. In contrast, *Metallagecrinus* Strimple, 1966 has well-developed radial facets with a clear articular ridge and well-defined ligament fossae. Diagnostic characters for allagecrinids are listed in the diagnoses of *Litocrinus* and *Metallagecrinus*.

Genus *Litocrinus* Lane & Sevastopulo, 1982

Type species: *Kallimorphocrinus punctatus* (Lane & Sevastopulo, 1981).

Included Permian species: *L. delicatulus* sp. nov.; *L. lanei* sp. nov.; *L. ornatus* sp. nov.; *L. pansus* Webster & Jell, 1992; *L. protuberans* Webster & Jell, 1992; and *L. sevastopuloi* sp. nov.

Diagnosis: Radial plates equal in width, one arm facet on each radial plate, no anal notch on C radial plate, hypertrophied distal extension on D and E radial plates absent, articular ridge on radial facets poorly developed, aboral ligament fossa on radial facets poorly developed or absent, primary peristomial cover plates in adults, anal series absent.

Remarks. *Litocrinus* was originally defined with the Mississippian (Viséan) species *Litocrinus punctatus*. It is currently known from the Mississippian (Viséan) through the Permian (late Kungurian). Four new species of *Litocrinus* are described herein, as well as one taxon left in open nomenclature. Previously, two species of *Litocrinus* were known from the Permian; both from Callythara Formation (upper Sakmarian or lower Artinskian) of Western Australia (Webster 1987; Webster & Jell 1992).

As listed below, diagnostic characters for Permian species of *Litocrinus* are shape of aboral cup in lateral view, shape of aboral cup in oral view, overall plate sculpturing, presence of distinctive radial plate sculpturing, presence or absence of fused basal plates, aboral cup expands markedly above basal cirlet, whether or not PPCPs occupy the entire oral surface, shape of PPCP cirlet, and presence or absence of central elongate depression along PPCPs.

Litocrinus is known from the Mississippian (Viséan) of the U.S.A., the Mississippian of Ireland and the United Kingdom, the Pennsylvanian of Iran and Russia, and the Permian of Western Australia (see Webster & Webster 2014).

Litocrinus delicatulus sp. nov.

Fig. 4.1, 4.2

Holotype: ONHM F-1549.

Diagnosis: Aboral cup high vase to bowl shape in lateral profile; aboral cup subpentalobate in oral view, does not expand markedly above the basal cirlet; smooth aboral cup plate sculpturing, except for very subtle, short ridges and grooves between adjacent radial plates; no ray ridges or nodes; basal plates unfused, aboral cup width not markedly expanded distally; PPCP plates occupy ~95% of aboral cup width, PPCP cirlet very low inverted bowl shape; each PPCP with central elongate radial depression.

Etymology: *Delicatulus* (L.) means delicate and is a reference to the slender and largely unsculptured aboral cup.

Paratypes: ONHM F-1650 to ONHM F-1554.

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

Other material: Sixty-three additional specimens are cataloged as ONHM F-1555 to ONHM F-1557 and are from WKJ-1 and WKJ-2.

Description. Aboral cup high vase to bowl shaped (Fig. 4.2), subpentagonal in oral view, does not expand markedly above the basal cirlet; aboral cup plate sutures not impressed, smooth aboral cup plate sculpturing, without ray ridges or nodes. Basal plate cirlet ~27% of aboral cup height, medium cone shape; basal plates unfused; basal cirlet narrows slightly at radial plate-basal plate suture. Radial plate cirlet ~73% of aboral cup height; five radial plates, higher than wide, each with one radial facet, radial plates with prominent convexity across a plate resulting in a strong oral-aboral convexity along radial plate heights and a corresponding broad concavity at radial plate-radial plate sutures. Each radial plate with one radial facet, angustary, subhorizontal, very poorly developed articular ridge and ligament fossae.

Anal notch and radianal plate absent. Primary peristomial cover plates (PPCP) present in adults, five, forming a very low inverted bowl-shaped cirlet, ~95% of aboral cup width; PPCPs positioned interradially, CD PPCP separates the BC and DE PPCPs, positioned interradially. Groove along suture between adjacent PPCPs and an equal sized groove in an interradial position along the center of a single PPCP (Fig. 4.1). Hydropore present (Fig. 4.2).

Five arms, details of arms unknown. Column attachment on basal cirlet circular, lumen circular; other details of column unknown.

Remarks. *Litocrinus delicatulus* sp. nov. and *L. pansus* are the only two species of *Litocrinus* with a vase-shaped aboral cup; the aboral cup with a subpentagonal outline in oral view; smooth plate

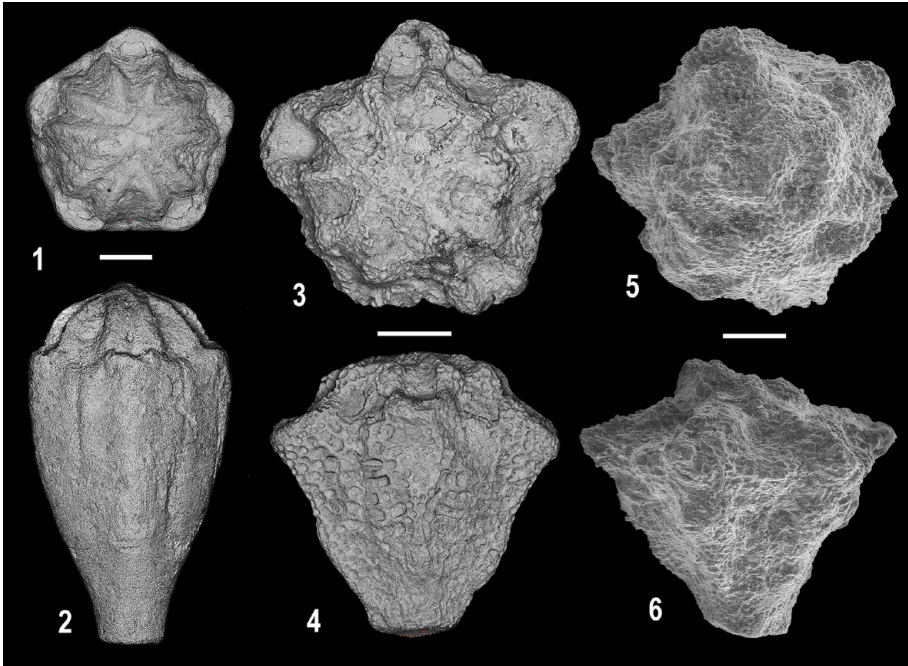


Fig. 4 – Allagecrinidae from the Qarari Unit. 1, 2, *Litocrinus delicatulus* sp. nov., holotype, ONHM F-1549, scale bar = 250 μ m; 1, oral view; 2, lateral view, hydropore on suture in lower position between two PPCPs. 3, 4, *Litocrinus lanei* sp. nov., holotype, ONHM F-1558, scale bar = 250 μ m; 3, oral view; 4, lateral view. 5, 6, *Litocrinus ornatus* sp. nov., holotype, ONHM F-1563, scale bar = 250 μ m; 5, oral view; 6, lateral view.

sculpturing; PPCP circling occupying the entire oral surface; and a very low, bowl-shaped PPCP circling. However, *L. pansus* has a medium vase to cone-shaped aboral cup and PPCPs with low convex outer surfaces. In contrast, *L. delicatulus* sp. nov. has a high vase to high bowl aboral cup shape and PPCPs with a central elongate radial depression.

Measurements: ONHM F-1549: TH, 1.94; ACH, 1.61; ACmaxW, 1.06; BH, 0.65; BCmaxW, 0.55; RH, 0.97; RmaxW, 0.55; PPCPH, 0.35; PPCPmaxW, 0.90. ONHM F-1550: TH, 1.23; ACH, 1.03; ACmaxW, 1.16; BH, 0.23; BCmaxW, 0.48; RH, 0.81; RmaxW, 0.45; ONHM, 0.26; PPCPmaxW, 1.06. ONHM F-1551: TH, 1.39; ACH, 1.06; ACmaxW, 0.81; BH, 0.35; BCmaxW, 0.42; RH, 0.65; RmaxW, 0.39; PPCPH, 0.32; PPCPmaxW, 0.68. ONHM F-1552: TH, 1.74; ACH, 1.42; ACmaxW, 1.03; BH, 0.55; BCmaxW, 0.45; RH, 0.97; RmaxW, 0.52; PPCPH, 0.32; PPCPmaxW, 0.81. ONHM F-1553: TH, 1.71; ACH, 1.00; ACmaxW, 0.90; BH, 0.56; BCmaxW, 0.48; RH, 0.90; RmaxW, 0.58; PPCPH, 0.39; PPCPmaxW, 0.77. ONHM F-1554: TH, 1.97; ACH, 1.48; ACmaxW, 1.03; BH, 0.16; BCmaxW, 0.68; RH, 0.97; RmaxW, 0.29; PPCPH, 0.48; PPCPmaxW, 0.84.

Litocrinus lanei sp. nov.

Fig. 4.3, 4.4

Holotype: ONHM F-1558.

Diagnosis: Aboral cup medium cone to globe shape in lateral profile, pentastellate in oral view, expands markedly above basal circling; plate sculpturing with distinct narrow median ray ridge beginning at the base of the radial plate and continuing to the proximal edge of the radial plate, narrow ridges project laterally from the median ridge to the lateral edges of the radial plate, much of the radial plate surface also with fine pits; basal plates fused, aboral cup width markedly expanded distally; PPCP circling ~75% of aboral cup width, very low inverted bowl shape; PPCPs with central elongate radial depression.

Etymology: For N. Gary Lane recognizing his pioneering work on Permian crinoids and his work on microcrinoids.

Paratypes: ONHM F-1559 to ONHM F-1561.

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

Other material: Three additional specimens are assigned to *Litocrinus lanei* sp. nov. (ONHM F-1562) and are from WKJ-2.

Description. Aboral cup medium cone to globe shaped, pentastellate in oral view (Fig. 4.3), expands markedly above basal circling; cup plate sculpturing with distinct narrow median ray ridge beginning at the base of the radial plate and extending to the height of the radial plate (Fig. 4.4), narrow ridges project laterally from the median ridge to the lateral edges of the radial plate, additionally much of the radial plate surface has fine pits; aboral cup plate sutures not impressed. Aboral cup width expands markedly above the basal plate circling. Basal plate circling ~16% of aboral cup height; basal plates fused; basal circling conical in shape. Radial plate circling ~84% of aboral cup height; five radial plates, higher than wide. One radial facet on each radial plate, radial facets angustary with weak transverse ridge, very small aboral ligament fossae.

Anal notch and radial plate absent. PPCP circling a very low inverted bowl shape; PPCP circling occupies ~75% of aboral cup width. PPCPs interradially positioned, five, positioned interradially, equal in size; CD PPCP separates BC and DE PPCPs. Groove formed along suture between two adjacent

PPCPs above radial facets and an equal sized depression in the interradial position along the center of a single PPCP. Hydropore and radial absent.

Five arms, details of arms unknown. Column attachment to basal cirlet circular; other details of column unknown.

Remarks. *Litocrinus lanei* sp. nov. and *L. ornatus* sp. nov. differ from other species of *Litocrinus* by having a pentastellate aboral cup outline in oral view. The two species are distinct because *L. lanei* sp. nov. has a medium cone- to globe-shaped aboral cup, fine pits as aboral plate sculpturing, radial plates with a narrow median ray ridge, ridges between adjacent radial plates, basal plates fused, PPCP cirlet occupying the entire oral surface, PPCP cirlet very low bowl in shape and occupies entire oral surface, and PPCPs with a central elongate depression. In contrast, *L. ornatus* sp. nov. has a low cone-shaped aboral cup, fine pustulose aboral cup plate sculpturing, a pronounced median ray ridge with two prominent nodes, basal plates not fused, PPCP cirlet shape a flat bowl, not occupying the entire oral surface, and PPCPs with a convex outer surface.

Measurements: ONHM F-1558: TH, 1.13; ACH, 0.81; ACmaxW, 1.10; BH, 0.19; BCmaxW, 0.39; RH, 0.81; RmaxW, 0.58; PPCPH, 0.32; PPCPmaxW, 0.74. ONHM F-1559: TH, 1.00; ACH, 0.61; ACmaxW, 0.71; BH, 0.13; BCmaxW, 0.29; RH, 0.52; RmaxW, 0.29; PPCPH, 0.39; PPCPmaxW, 0.65. ONHM F-1560: TH, 1.03; ACH, 0.71; ACmaxW, 1.00; BH, 0.26; BCmaxW, 0.26; RH, 0.35; RmaxW, 0.32; PPCPH, 1.00; PPCPmaxW, 65. ONHM F-1561: TH, 1.13; ACH, 0.81; ACmaxW, 1.06; BH, 0.16; BCmaxW, 0.48; RH, 0.68; RmaxW, 0.29; PPCPH, 0.32; PPCPmaxW, 0.81.

Litocrinus ornatus sp. nov.

Fig. 4.5, 4.6

Holotype: ONHM F-1563.

Diagnosis: Aboral cup low cone shaped in lateral profile; aboral cup pentastellate in oral view, expands markedly above basal cirlet; finely pustulose aboral cup plate sculpturing; two prominent nodes from pronounced radial ridge along central oral-aboral axis of radial plates; basal plates not fused, aboral cup width markedly expanded distally; PPCP cirlet flat bowl shape, ~ 45% of aboral cup width; PPCP plates without central, radial elongate depression.

Etymology: *Ornatus* (L.) refers to the strong ridges and nodes on radial plates.

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

Description. Aboral cup low cone shaped, expands markedly above basal cirlet (Fig. 4.6), pentastellate in oral view; two prominent nodes from pronounced, radial ridge along the oral-aboral axis

of radial plates, entire aboral cup with fine pustulose sculpturing; plate sutures not impressed. Basal plate cirlet ~27% of aboral cup height; basal plates fused; basal cirlet narrows slightly at radial plate-basal plate suture; proximal rim of basal cirlet with slightly rounded, low ridge. Radial plate cirlet ~73% of aboral cup height; five radials. Radial facets angustary, one radial facet on each radial plate, very poorly developed.

Anal notch absent, radial absent. Five PPCPs in adults, relatively small, interradially positioned in center of oral surface, nodose, PPCP cirlet a flat inverted bowl shape, occupies ~45% of aboral cup width (Fig. 4.5); CD PPCP separates BC and DE PPCPs. Ambulacral cover plate(s) between PPCPs and radial facet. All oral surface plates nodose. Hydropore absent.

Five or fewer arms, details of arms unknown. Column attachment to basal cirlet circular, other details of column unknown.

Remarks. *Litocrinus ornatus* sp. nov. is compared to other species of *Litocrinus* in the remarks of *L. lanei* sp. nov.

Measurements: ONHM F-1563: TH, 1.16; ACH, 0.97; ACmaxW, 1.23; BH, 0.19; BCmaxW, 0.32; RH, 0.81; RmaxW, 0.48; PPCPH, 0.19; PPCPmaxW, 0.94.

Litocrinus sevastopuloi sp. nov.

Fig. 5.1–5.3

Holotype: ONHM F-1564.

Diagnosis: Aboral cup high bowl shape in lateral profile, not expanding prominently above basal cirlet; aboral cup subpentalobate in oral view; smooth aboral cup plate sculpturing; radial plates gently convex along adoral-aboral axis, broadly concave along radial plate-radial plate sutures; basal plates fused, aboral cup width not markedly expanded distally; PPCP cirlet occupies ~80% aboral cup width, PPCP cirlet very low inverted bowl shape; each PPCP with central elongate depression.

Etymology: For George D. Sevastopulo, who published ground-breaking research on Paleozoic microcrinoids and on crinoids from Oman.

Paratypes: ONHM F-1565 to ONHM F-1567.

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

Other material: Eleven additional specimens are assigned to ONHM F-1568 and ONHM F-1569 and are from WKJ-2.

Description. Aboral cup high bowl shaped, not expanding prominently above basal cirlet (Fig. 5.3), subpentalobate in oral view; aboral cup plate sutures not impressed, smooth aboral cup plate sculpturing. Basal plate cirlet ~20% of aboral cup

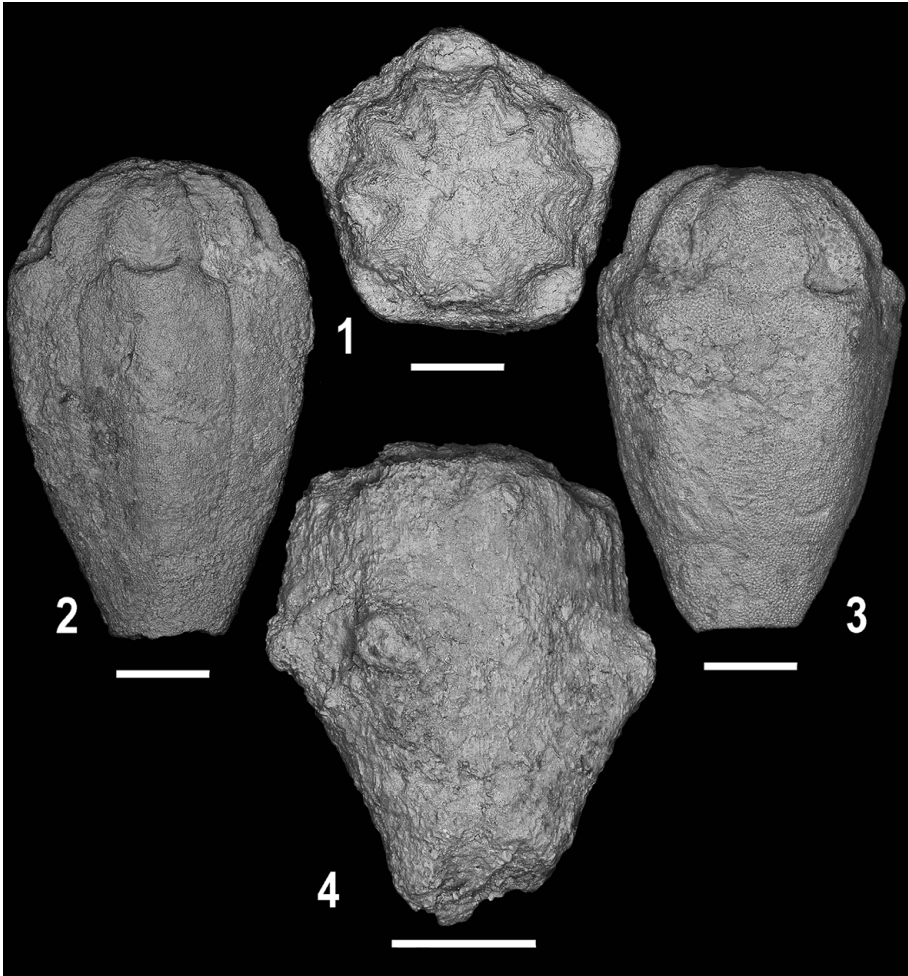


Fig. 5 – Allagecrinidae from the Qarari Unit. *Litocrinus sevastopuloi* sp. nov., holotype, ONHM F-1564, scale bar = 250 μ m; 1, oral view; 2, lateral view; 3, lateral view. 4, *Litocrinus?* sp., ONHM F-1570, scale bar = 250 μ m.

height, medium cone shape; basal plates fused. Radial plate cirlet ~80% of aboral cup height; five radial plates, radial plates higher than wide, gently convex across a plate (Fig. 5.2), each radial plate with one radial facet. Radial facet angustary declivate, aboral ligament fossa poorly developed, articular ridge moderately developed, adoral ligament fossae poorly developed.

Anal notch and radianal plate absent. Five PPCPs in adults; PPCP cirlet a very low inverted bowl shape, occupies ~80% of aboral cup width (Fig. 5.1); CD PPCP separates DE and BC PPCPs, positioned interradianally. Radially oriented depression along suture between adjacent PPCPs. PPCPs broadly convex in adults and with elongate radial depression in juveniles. Hydropore present.

Five arms in adults, details of arms unknown. Column attachment on basal cirlet circular, other details of column unknown.

Remarks. *Litocrinus sevastopuloi* sp. nov. and *L. protuberans* are distinct from other species of *Litocrinus* by having a pentalobate aboral cup shape in

oral view, smooth sculpturing, and PPCPs occupy the entire oral surface. However, *L. protuberans* has a medium vase-shaped aboral cup, radial plates with a prominent node at the distal margin, aboral cup expands markedly above the basal cirlet, PPCP cirlet flat bowl-shaped, and elongate central depression on PPCPs absent. In contrast, *L. sevastopuloi* sp. nov. has a medium bowl-shaped aboral cup, radial plates that are broadly convex across and correspondingly concave at radial-radial boundaries, an aboral cup that does not expand markedly above the basal cirlet, PPCP cirlet flat bowl in shape, and PPCPs with central elongate depression. *Litocrinus sevastopuloi* sp. nov. differs from *L. delicatulus* sp. nov. because *L. delicatulus* sp. nov. has an aboral cup that may expand into a high vase shape, short ridges and grooves between adjacent radial plates, and the PPCP cirlet occupies ~95% of the aboral cup width. *Litocrinus sevastopuloi* sp. nov. has an aboral cup that does not expand into a high vase shape, ridges and grooves between adjacent radial plates are absent, and the PPCP cirlet occupies ~80% of the aboral cup width.

Measurements: ONHM F-1564: TH, 1.55; ACH, 1.23; ACmaxW, 1.00; BH, 0.35; BCmaxW, 0.58; RH, 0.97; RmaxW, 0.48; PPCPH, 0.32; PPCPmaxW, 0.84. ONHM F-1565: TH, 0.81; ACH, 0.48; ACmaxW, 0.74; BH, 0.19; BCmaxW, 0.26; RH, 0.42; RmaxW, 0.29; PPCPH, 0.32; PPCPmaxW, 0.61. ONHM F-1566: TH, 1.10; ACH, 0.81; ACmaxW, 0.71; BH, 0.23; BCmaxW, 0.45; RH, 0.71; RmaxW, 0.32; PPCPH, 0.29; PPCPmaxW, 0.58.

Litocrinus? sp.

Fig. 5.4

Material: ONHM F-1570.

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

Description. Aboral cup high bowl shaped, does not expand prominently above basal cirlet, subcircular in oral view; aboral cup plate sutures not impressed, smooth aboral cup plate sculpturing with the exception of a small circular central node on each radial plate (Fig. 5.4). Basal plate cirlet ~20% of aboral cup height, medium cone shape; basal plates fused. Radial plate cirlet ~80% of aboral cup height; five radial plates, higher than wide, gently convex, each radial plate with one radial facet. Radial facet angustary, other details of radial facets unknown.

Anal notch and radianal plate apparently absent. PPCP cirlet damaged and missing. Five arms in adults, details of arms unknown. Column attachment on basal cirlet circular, other details of column unknown.

Remarks. ONHM F-1570 is an incomplete specimen assigned to *Litocrinus?* sp. Among Oman allagecrinids, *Litocrinus?* sp. is unique because of the presence of a distinct, circular node in the center of each radial plate. However, this single specimen is not well enough preserved to confidently assign to *Litocrinus* and to designate a new species.

Genus *Metallagecrinus* Strimple, 1966

Type species: *Allagecrinus quinquebrachiatus* Wanner, 1929.

Included Permian species: *M. acutus* (Wanner, 1929); *M. bothros* sp. nov.; *M. dux* (Wanner, 1930); *M. excavatus* (Wanner, 1929); *M. granulatus* sp. nov.; *M. indoaustralicus* (Wanner, 1924); *M. inflatus* (Wanner, 1929); *M. omanensis* sp. nov.; *M. ornatus* (Wanner, 1929); *M. palermoensis* Strimple and Sevastopulo, 1982; *M. procerus* (Wanner, 1929); *M. quinquebrachiatus* (Wanner, 1929); *M. quinquelobus* (Wanner, 1929); *M. uralensis* (Yakovlev, 1927); *M. uralensis nodocarinatus* (Yakovlev, 1927).

Diagnosis: Radial plates variable in width, one arm facet on each radial plate, no anal notch on C radial plate, hypertrophied distal extension on D and E radial plates absent, articular ridge on radial facets well developed, aboral ligament fossa on radial facets

well developed or absent, PPCPs poorly developed in adults, anal series absent.

Remarks. Fifteen Permian species of *Metallagecrinus* are known from West Timor, Russia, and Oman; and 20 characters are needed to differentiate among these taxa. The diagnosis for each Oman species includes these 20 diagnostic characters, but each new species is only compared to congeners to which it is most closely associated.

In contrast to *Litocrinus*, *Metallagecrinus* is known exclusively from the Permian. Wanner (1916, 1929, and 1930) described eight species now assigned to *Metallagecrinus*. Well-dated occurrences of *Metallagecrinus* are from the Artinskian of the Urals, Russia (Yakovlev 1927; Arendt and Hecker 1964) and the Wordian of Sicily (Strimple & Sevastopulo 1982). The Qarari Unit (upper Kungurian) occurrences of *Metallagecrinus* in Oman are congruent with the Lower and Middle Permian occurrences elsewhere and helps constrain the chronostratigraphic position of *M. indoaustralicus*, which was previously known only from Basleo, West Timor.

Metallagecrinus indoaustralicus Wanner, 1924

Fig. 6.5, 6.6

- 1924 *Allagecrinus indoaustralicus* – Wanner, p. 308, pl. 20, figs. 33-35; Fig. 61.
 1929 *Allagecrinus indoaustralicus* – Wanner, p. 15, pls. 1, fig. 13; 3, figs. 1-5.
 1933 *Kallimorphocrinus indoaustralicus* – Wright, p. 204.
 1943 *Kallimorphocrinus indoaustralicus* – Bassler & Moodey, p. 527.
 1948 *Kallimorphocrinus indoaustralicus indoaustralicus* – Branson, p. 198.
 1966 *Allagecrinus indoaustralicus* – Strimple, p. 105.
 1973 *Metallagecrinus indoaustralicus* – Webster, p. 175.
 2014 *Metallagecrinus indoaustralicus* – Webster & Webster, p. 1515.

Holotype: The holotype was not found in the Wanner collection at the Naturalis Biodiversity Center.

Diagnosis: *Metallagecrinus* with a medium bowl- to globe-shaped aboral cup, a pentalobate outline in oral view, smooth aboral cup plate sculpturing, aboral cup plate sutures not impressed, basal plates fused, basal cirlet 15% of aboral cup height, basal cirlet-radial cirlet sutures not impressed, broad convexity across a radial plate, radial plates higher than wide, of uniform widths, radial cirlet ~85% of the aboral cup height, radial plate-radial plate sutures in a broad concavity, radial facets peneplenary, radial facets well developed, five total, well-developed adoral ligament fossae, presence or absence of median pore on or near the articular ridge on radial facets unknown, PPCP cirlet very low inverted cone to inverted bowl shape, PPCPs concave in a cross section, small hydropore present, proximal column in a very shallow a basal concavity.

Type locality and horizon: Basleo, West Timor.

Other material: Sixty-one specimens from Oman are assigned to ONHM F-1571 to ONHM F-1579 and are from WKJ-1 and WKJ-2.

Description. Aboral cup medium bowl to globe shaped (Fig. 6.6), pentalobate in oral view; aboral cup plate sutures not impressed, smooth aboral cup plate sculpturing. Basal plate circling ~15% of aboral cup height, very low cone shape; basal plates fused. Radial plate circling ~85% of aboral cup height; five radial plates, higher than wide, broadly convex across a plate with a corresponding broad concavity along radial plate-radial plate sutures, of uniform widths. Radial facet peneplenary, one on each radial plate, planar, aboral and adoral ligament pits well developed, transverse ridge well developed, median pore present.

Anal notch and radianal plate absent. Primary peristomial cover plates (PPCP) five (Fig. 6.5), PPCP circling a very low inverted bowl shape, ~60% of aboral cup width; CD PPCP separates BC and DE PPCPs, positioned interradianally, pentagonal in shape. Radially oriented depression along lateral portion of PPCPs at suture between two adjacent PPCPs. PPCPs broad, elongate depression along each PPCP plate. Hydropore present.

Five arms in adults, details of arms unknown. Column attachment on basal circling circular, not in a basal concavity; lumen circular; other details of column unknown.

Remarks. *Metallagecrinus indoaustralicus* and *M. uralensis* share pentalobate cup shapes in oral view, basal plates form ~15% of (and radials 85%) of aboral cup height, and a hydropore on the CD PPCP. These are differentiated because *M. indoaustralicus* has a medium- to globe-shaped aboral cup, broadly convex across the radial plates, peneplenary radial facets, and a very low inverted cone- to bowl-shaped PPCP circling; in contrast, *M. uralensis* has a medium bowl-shaped aboral cup, very convex laterally across radial plates, angustary radial facets, and PPCP circling a very low inverted bowl.

Oman localities. Wadi Khawr Al Jaramah (WKJ-2), Batain, Oman; Qarari Unit, Batain Group, Permian (late Kungurian).

Measurements: ONHM F-1571: TH, 0.88; ACH, 0.59; ACmaxW, 0.59; BH, 0.24; BCmaxW, 0.41; RH, 0.35; RmaxW, 0.41; PPCPH, 0.29; PPCPmaxW, 0.59. ONHM F-1572: TH, 1.06; ACH, 0.90; ACmaxW, 0.90; BH, 0.16; BCmaxW, 0.42; RH, 0.77; RmaxW, 0.48; PPCPH, 0.16; PPCPmaxW, 0.84. ONHM F-1573: TH, 1.23; ACH, 1.16; ACmaxW, 1.06; BH, 0.10; BCmaxW, 1.23; RH, 1.06; RmaxW, 0.48; PPCPH, 0.23; PPCPmaxW, 0.81. ONHM F-1574: TH, 1.48; ACH, 1.23; ACmaxW, 1.19; BH, 0.19; BCmaxW, 0.68; RH, 1.19; RmaxW, 0.26; PPCPH, 0.16; PPCPmaxW, 0.94. ONHM F-1575: TH, 2.87; ACH, 2.33; ACmaxW, 2.20; BH, 0.40; BCmaxW, 2.27; RH, 1.93;

RmaxW, 1.07; PPCPH, 0.53; PPCPmaxW, 1.87. ONHM F-1576: TH, 3.33; ACH, 2.73; ACmaxW, 3.20; BH, 0.40; BCmaxW, 1.87; RH, 2.60; RmaxW, 1.60; PPCPH, 0.60; PPCPmaxW, 2.47.

Metallagecrinus blothros sp. nov.

Fig. 6.1, 6.2

Holotype: ONHM F-1580.

Diagnosis: *Metallagecrinus* with a medium bowl-shaped aboral cup, a pentalobate outline in oral view, finely pitted aboral cup plate sculpturing, aboral cup plate sutures not impressed, basal plates fused, basal circling 15% of aboral cup height, basal plate circling-radial plate circling suture not impressed, only moderate convexity across a radial plate, radial plates higher than wide, of different widths, radial circling ~85% of the aboral cup height, sutures between radial plates not in a broad concavity, radial facets vary from angustary to peneplenary, radial facets well developed, ten radial facets, well-developed adoral ligament fossae, median pore on or near the articular ridge on radial facets, PPCP circling very low inverted bowl shape, PPCPs concave in cross section, small hydropore absent, proximal column not in a basal concavity.

Etymology: *Blothros* (Gr.) means high or stately and refers to the distinct aboral cup sculpturing with ray ridges and pitted aboral cup plate sculpturing.

Paratypes: ONHM F-1581 and ONHM F-1582.

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

Description. Aboral cup medium bowl shaped (Fig. 6.2), pentalobate in oral view; aboral cup plate sutures not impressed, finely pitted aboral cup plate sculpturing, and with pits smaller on basal plates and along raised median ray ridge on radial plates. Aboral cup sutures not impressed. Basal plate circling ~15% of aboral cup height, very low cone shape, pentalobate in basal view; basal plates fused; basal concavity absent. Radial plate circling ~85% of aboral cup height; radial plates five, higher than wide, variable in width, moderately convex; one facet in A ray, three facets in B ray, one facet in C ray, three facets in D ray, two facets in E ray), median ray ridge that begins on basal circling and branches immediately below radial facets to form a ridge along aboral margin of radial plate; radial plate-radial plate sutures not in broad convexity. Radial facet angustary to peneplenary, aboral and adoral ligament pits well-developed, transverse ridge well developed, median pore present.

Anal notch and radianal plate absent. PPCPs five, PPCP circling a very low inverted bowl shape, ~70% of aboral cup width (Fig. 6.1); CD PPCP separates BC and DE PPCPs, positioned interradianally, pentagonal in shape. Radially oriented

indentation along lateral portion of PPCPs at suture between two adjacent PPCPs. PPCPs broad, elongate depression along each PPCP plate. Hydropore present.

In largest specimen, ten arms, details of arms unknown. Column attachment to basal cirlet circular, in basal concavity; other details of column unknown.

Remarks. *Metallagecrinus blotbros* sp. nov., *M. dux*, *M. inflatus*, and *M. uralensis nodocarinatus* are the only species of *Metallagecrinus* with multiple facets on radial plates. *Metallagecrinus uralensis nodocarinatus* has a medium bowl-shaped aboral cup, aboral cup with pentastellate outline in oral view, smooth aboral cup plate sculpturing, basal cirlet ~15% of aboral cup height, radial plates gently convex laterally, radial plates higher than wide and of equal width, radial plates ~85% of aboral cup height, radial facets angustary, and ~17 total radial facets; *M. inflatus* has a medium globe-shaped aboral cup, aboral cup with a pentalobate outline in oral view, finely pitted aboral cup plate sculpturing, basal cirlet ~20% of aboral cup height, radial plates higher than wide, strongly convex, radial plates of equal width, radial plates ~80% of aboral cup height, radial facets angustary to peneplenary, and a total of 9 radial facets; and *M. dux* has a very low vase-shaped aboral cup, circular aboral cup outline in oral view, smooth aboral cup plate sculpturing, the basal cirlet ~30% of aboral cup height, radial plates wider than high, moderately convex in cross section, of unequal widths, radial cirlet ~70% of aboral cup height, radial facets angustary, and a total of 10–12 radial facets. In contrast, *M. blotbros* sp. nov. has a medium bowl-shaped aboral cup, a pentalobate aboral cup outline in oral view, finely pitted aboral cup plate sculpturing, basal cirlet ~15% of the aboral cup height, radial plates moderately convex with a distinct median ray ridge, radial plates higher than wide and of unequal widths, radial plate cirlet ~85% of aboral cup height, radial facets angustary to peneplenary, and ~10 radial facets.

Measurements: ONHM F-1580: TH, 1.81; ACH, 1.97; ACmaxW, 1.81; BH, 0.32; BCmaxW, 0.45; RH, 1.29; RmaxW, 0.77; PPCPH, 0.19; PPCPmaxW, 1.29. ONHM F-1581: TH, 2.33; ACH, 1.67; ACmaxW, 2.00; BH, 0.47; BCmaxW, 2.00; RH, 1.40; RmaxW, 1.20; PPCPH, 0.67; PPCPmaxW, 1.87. ONHM F-1582: TH, 1.80; ACH, 1.60; ACmaxW, 1.87; BH, 0.40; BCmaxW, 0.67; RH, 1.20; RmaxW, 0.87; PPCPH, 0.13; PPCPmaxW, 1.20.

Metallagecrinus granulosis sp. nov.

Fig. 6.3, 6.4

Holotype: ONHM F-1583.

Diagnosis: *Metallagecrinus* with a low bowl to globe-shaped aboral cup, a pentalobate outline in oral view, small nodes for aboral cup plate sculpturing, aboral cup plate sutures not impressed, basal plates fused, basal cirlet ~20% of aboral cup height, basal plate cirlet-radial plate cirlet suture not impressed, strongly convex across radial plates, radial plates higher than wide, of equal width, radial cirlet ~80% of aboral cup height, radial plate-radial plate sutures not in a broad basal concavity, radial facets peneplenary, radial facets well developed, total number of radial facets 5, well-developed adoral ligament fossae, median pore absent on articular ridge of radial facets, PPCP cirlet very low inverted bowl, cross sectional shape of PPCPs concave, hydropore absent, proximal column not in a basal concavity.

Etymology: *Granulosus* refers to the distinctive granulose aboral cup plate sculpturing.

Paratypes: ONHM F-1584 to ONHM F-1586.

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

Other material: Ten additional specimens are assigned to ONHM F-1587 and ONHM F-1588 and are from WKJ-1 and WKJ-2. In addition, three specimens are questionably assigned to *M. granulosis* (ONHM F-1589).

Description. Aboral cup low bowl to globe shaped (Fig. 6.4), pentastellate in oral view; aboral cup plate sutures not impressed, plate sculpturing small nodes on all aboral cup plates. Basal plate cirlet ~20% of aboral cup height, very low cone shape; basal plates fused. Radial plate cirlet ~80% of aboral cup height; five radial plates, radial plates higher than wide, of equal width, broadly convex, one radial facet in each radial plate, broadly convex prominently convex across a plate with a corresponding prominent concavity along radial plate-radial plate sutures; radial plate-radial plate sutures in broad concavity. Radial facet peneplenary, planar, aboral and adoral ligament pits well developed, transverse ridge well developed, median pore on transverse ridge absent.

Anal notch and radianal plate absent. Primary peristomial cover plates five, PPCP cirlet a very low inverted bowl shape, ~80% of aboral cup width (Fig. 6.3); CD PPCP separates BC and DE PPCPs, positioned interradianally, pentagonal in shape. Radially oriented depression along lateral portion of PPCPs at suture between two adjacent PPCPs. PPCPs broad, elongate depression along each PPCP plate. Hydropore absent.

Five arms in adults, details of arms unknown. Column attachment to basal cirlet circular, not in basal concavity; lumen, very small circular; other details of column unknown.

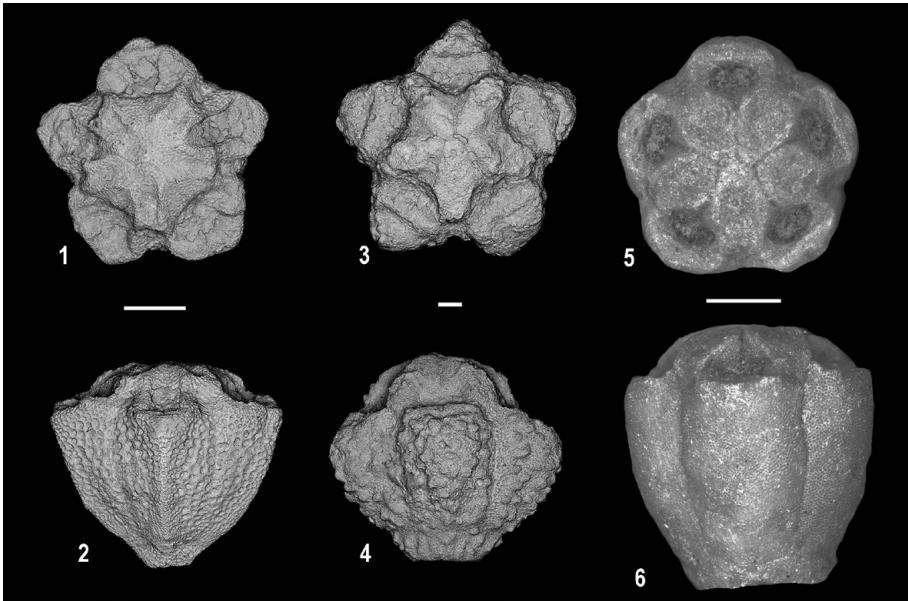


Fig. 6 – Allagecrinidae from the Qarari Unit. 1, 2, *Metallagecrinus blotros* sp. nov., holotype, ONHM F-1580, scale bar = 250 µm; 1, oral view; 2, lateral view. 3, 4, *Metallagecrinus granulosus* sp. nov., holotype, ONHM F-1583, scale bar = 250 µm; 3, oral view; 4, lateral view. 5, 6, *Metallagecrinus indoaustralicus* Wanner, 1924, ONHM F-1576, scale bar = 1.0 mm.

Remarks. Among Permian *Metallagecrinus*, *M. granulosus* sp. nov. is the only species with evenly spaced small nodes as aboral cup plate sculpturing. *Metallagecrinus* species with a pentastellate outline in oral view include *M. excavatus*, *M. granulosus* sp. nov., *M. uralensis nodocarinatus*. *Metallagecrinus excavatus* has a medium bowl-shaped aboral cup, horizontal ridges and grooves on aboral cup plates, a basal circling ~30% of the aboral cup height, the basal plate circling-radial plate circling suture impressed, radial plates moderately convex laterally, radial circling ~70% of aboral cup height, radial plate-radial plate sutures in broad concavity due to convexity of radial plates, plenary radial facets, five radial facets, a median pore associated with the articular ridge, convex PPCPs convex in cross section, a small hydropore, and the proximal column in a basal concavity; whereas *M. uralensis nodocarinatus* has a medium bowl-shaped aboral cup, smooth aboral cup plate sculpturing, a basal circling ~15% of the aboral cup height, basal plate circling-radial plate circling not impressed, radial plates gently convex, radial circling ~85% of the aboral cup height, radial plate-radial plate sutures not in broad concavity, angustary radial facets, a median pore associated the articular ridge on radial facets, presence or absence of a hydropore unknown, and the presence or absence of a basal concavity not known. In contrast, *M. granulosus* sp. nov. has a low bowl- to globe-shaped aboral cup, small nodes as aboral cup plate sculpturing, basal circling ~20% of aboral cup height, radial plates strongly convex laterally, basal plate cir-

clet-radial plate circling suture not impressed, radial plates strongly convex laterally, radial circling ~80% of aboral cup height, radial plate-radial plate sutures in broad concavity due to convexity of radial plates, peneplenary radial facets, five radial facets, concave PPCPs in cross section, hydropore absent, and basal concavity absent.

Measurements: ONHM F-1583: TH, 2.20; ACH, 0.93; ACmaxW, 2.67; BH, 0.40; BCmaxW, 1.33; RH, 0.87; RmaxW, 1.00; PPCPH, 0.60; PPCPmaxW, 1.60. ONHM F-1584: TH, 2.00; ACH, 1.47; ACmaxW, 2.27; BH, 0.33; BCmaxW, 1.00; RH, 1.13; RmaxW, 1.00; PPCPH, 0.53; PPCPmaxW, 1.40. ONHM F-1585: TH, 1.74; ACH, 1.19; ACmaxW, 1.87; BH, 0.42; BCmaxW, 0.48; RH, 1.39; RmaxW, 0.77; PPCPH, 0.55; PPCPmaxW, 1.29. ONHM F-1586: TH, 2.33; ACH, 1.67; Amax, 2.47; BH, 0.53; BCmaxW, 1.13; RH, 1.93; RmaxW, 0.93; PPCPH, 0.67; PPCPmaxW, 1.67.

Metallagecrinus omanensis sp. nov.

Fig. 7.1–7.3

Holotype: ONHM F-1590.

Diagnosis: Medium globe-shaped aboral cup, pentalobate outline in oral view, aboral cup plate sculpturing smooth or with irregular ridges around basal circling and radial plates with a distal node surrounded by concentric ridges, aboral cup plate sutures deeply impressed; basal plates fused, basal circling ~40% of aboral cup height, basal circling-radial circling sutures deeply impressed, strong convexity across a radial plate, radial plates of equal width, higher than width, radial circling ~60% of the aboral cup height, radial plate-radial plate sutures in a broad concavity, radial facets plenary, radial facets well developed, total number of radial facets five, well-developed adoral ligament fossae, median pore on or near the articular ridge on radial facets, PPCP circling very low inverted bowl shape, PPCP plates concave in cross section, small hydropore may be present, proximal column in a slight basal concavity.

Etymology: From the Sultanate of Oman.

Paratypes: ONHM F-1591 to ONHM F-1593.

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

Other material: An additional fifty-six specimens are assigned to *M. omanensis*: ONHM F-1594 to ONHM F-1599 and are from WKJ-1 and WKJ-2.

Description. Aboral cup medium globe shaped (Fig. 7.2), pentalobate in oral view; aboral cup plate sutures markedly impressed, smooth aboral cup plate sculpturing in smaller specimens, in large specimens smooth or irregular horizontal ridge around basal cirlet but each ridge does not continue around entire cirlet, radial plates very convex with deep impression between radial plates and between the radial cirlet-basal cirlet sutures, in large specimens sculpturing smooth or a node may be present below the radial facet and irregular concentric ridges may be present along most of radial plate height. Basal plate cirlet ~40% of aboral cup height, very low cone shape; basal plates fused. Radial plate cirlet ~60% of aboral cup height; five radial plates, radial plates higher than wide, strongly convex, of equal width, one radial facet on each radial plate. Radial facet plenary (Fig. 7.1), planar, aboral and adoral ligament pits well developed, transverse ridge well developed, medial pore present on articular ridge.

Anal notch and radianal plate absent. Primary peristomial cover plates (PPCP) five, PPCP cirlet a very low inverted bowl shape; CD PPCP separates BC and DE PPCPs, positioned interradianally, tetragonal; in shape. Radially oriented depression along lateral portion of PPCPs at suture between two adjacent PPCPs. PPCPs broad, elongate depression along each PPCP plate. Hydropore absent.

Five arms in adults, details of arms unknown. Column attachment to basal cirlet circular; in very shallow broad basal concavity; other details of column unknown.

Remarks. *Metallagecrinus omanensis* sp. nov. has a high degree of morphological disparity in both adults and through ontogeny. In the smallest specimens the width of the PPCP cirlet is ~100% of the aboral cup width, and the PPCP cirlet is ~50% of the aboral cup height. In the largest specimens the width of the PPCP cirlet is ~50% of the aboral cup width, and the PPCP cirlet is ~11% of the aboral cup height. Aboral cup plate sculpturing is also variable. The smaller specimens and some of the larger specimens have smooth plate sculpturing

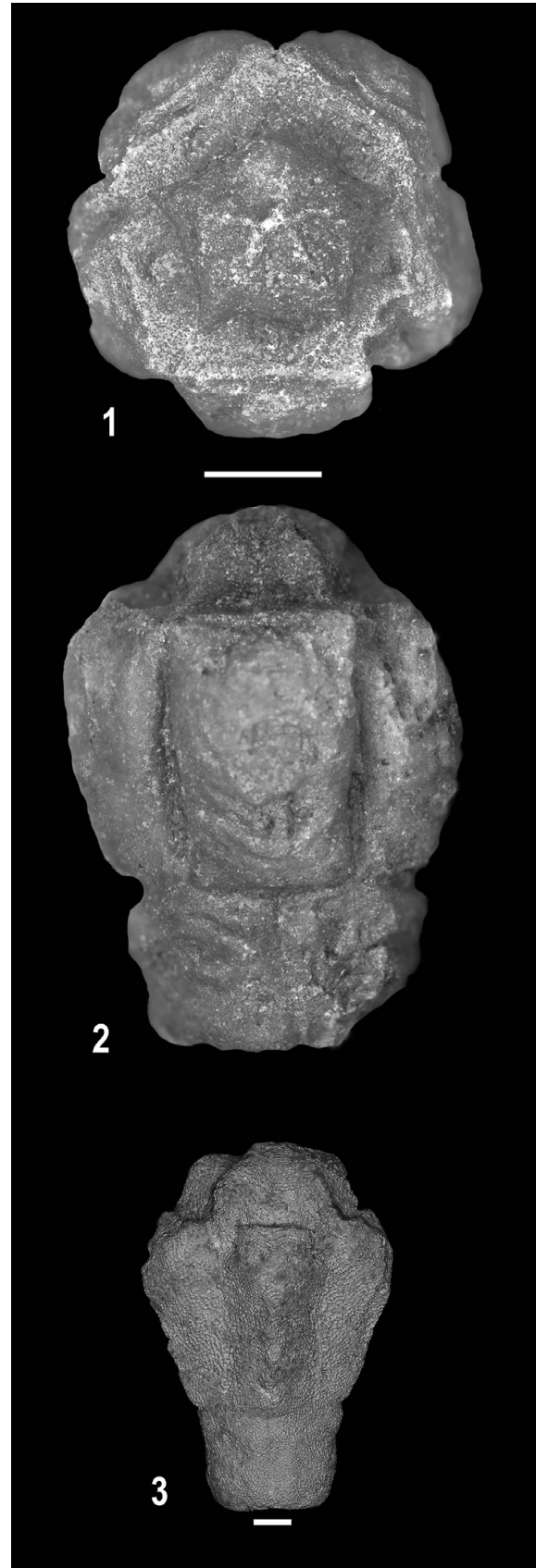


Fig. 7 – Allagecrinidae from the Qarari Unit. *Metallagecrinus omanensis* sp. nov. from the Qarari Unit. 1–3, 1, 2, holotype, ONHM F-1590, scale bar = 1.0 mm; 1, oral view; 2, lateral view; 3, ONHM F-1597, lateral view of juvenile, scale bar = 250 µm.

(Fig. 7.3), but the holotype and another large specimen have concentric ridges around a node position in the distal portion of radial plates (Fig. 7.2).

Metallagecrinus omanensis sp. nov. is most similar to *M. palermoensis* Strimple and Sevastopulo, 1982 from the Wordian of Sicily, Italy. The relatively large aboral cup with a high basal cirlet are shared by these two species of *Metallagecrinus*. They share the following characteristics: a large aboral cup with a high basal cirlet and correspondingly low radial cirlet, and plenary radial facets. These two species contrast morphologically because *M. palermoensis* has a medium globe- to vase-shaped aboral cup, circular outline in oral view, plate sculpturing with concentric wrinkles surrounding a subcentral node on radial plates, aboral cup sutures not impressed, basal cirlet ~50% of the aboral cup height, suture between basal plate and radial plate cirlets not impressed, radial plates gently convex laterally, radial plates not of equal width, radial cirlet ~50% of aboral cup height, and PPCPs convex in cross section, small hydropore present, and basal concavity absent; in contrast, *M. omanensis* has a medium globe- to vase-shaped aboral cup, pentalobate outline in oral view, plate sculpturing smooth or with irregular ridges around the basal cirlet or radials with irregular wrinkles around a node positioned in the upper portion of a radial plate, aboral cup plate sutures deeply impressed, basal cirlet ~40% of the aboral cup height, basal plate cirlet-radial plate cirlet suture deeply impressed, radial plates strongly convex laterally, radial plates of equal width, radial cirlet ~60% of aboral cup height, and PPCPs concave in cross section, small hydropore absent, and slightly impressed basal concavity.

Measurements: ONHM F-1590: TH, 5.00; ACH, 4.40; ACmaxW, 4.20; BH, 1.60; BCmaxW, 2.87; RH, 2.80; RmaxW, 2.67; PPCPH, 2.00; PPCPmaxW, 0.60. ONHM F-1591: TH, 4.67; ACH, 3.67; ACmaxW, 3.67; BH, 1.27; BCmaxW, 2.93; RH, 2.27; RmaxW, 1.73; PPCPH, 1.00; PPCPmaxW, 1.73. ONHM F-1592: TH, 4.60; ACH, 3.60; ACmaxW, 3.33; BH, 1.60; BCmaxW, 2.60; RH, 2.33; RmaxW, 1.73; PPCPH, 1.00; PPCPmaxW, 1.60. ONHM F-1593: TH, 3.33; ACH, 2.67; ACmaxW, 2.60; BH, 1.13; BCmaxW, 1.93; RH, 1.73; RmaxW, 1.20; PPCPH, 0.67; PPCPmaxW, 1.33. ONHM F-1594: TH, 1.03; ACH, 0.58; ACmaxW, 0.48; BH, 0.16; BCmaxW, 0.26; RH, 0.45; RmaxW, 0.29; PPCPH, 0.32; PPCPmaxW, 0.55. ONHM F-1595: TH, 1.55; ACH, 1.13; ACmaxW, 1.00; BH, 0.42; BCmaxW, 0.52; RH, 0.84; RmaxW, 0.45; PPCPH, 0.42; PPCPmaxW, 0.87. ONHM F-1596: TH, 1.90; ACH, 1.29; ACmaxW, 1.26; BH, 0.39; BCmaxW, 0.71; RH, 0.87; RmaxW, 0.61; PPCPH, 0.61; PPCPmaxW, 1.00. ONHM F-1597: TH, 2.35; ACH, 1.68; ACmaxW, 1.77; BH, 0.19; BCmaxW, 0.94; RH, 0.71; RmaxW, 0.68; PPCPH, 0.68; PPCPmaxW, 1.29.

Parvclass CLADIDA Moore & Laudon, 1943
Magnorder **Eucladida** Wright, 2017a
Superorder **Cyathoformes** Wright et al., 2017
Cyathoformes incertae sedis: 'Cyathocrinida'
Bather, 1899
Superfamily Codiacrinoidea Bather, 1890

Remarks. The geographic distribution of Oman Codiacrinoidea are illustrated in Figure 3. *Embryocrinus* and *Monobrachiocrinus* are also known from the Permian of West Timor (age unknown), the Urals region of Russia (Permian, Artinskian), and Sicily (Permian, Wordian). *Hemistreptocron* was previously only known from West Timor (Permian, age unknown) and Russia (Artinskian). *Coenocystis* was previously known from the United States (Middle Permian) and West Timor (Permian, age uncertain). *Dichostreblocrinus* was previously only recognized from the United States (Pennsylvanian) and West Timor (Permian, age unknown). Thus, as with the Allagecrinoidea, Oman Codiacrinoidea are most similar to faunas from West Timor and Russia.

Family Codiacrinidae Bather, 1890
Subfamily Codiacrininae Bather, 1890
Genus *Embryocrinus* Wanner, 1916

Type species: *E. hanieli* Wanner, 1916.

Included species: *Embryocrinus bashkiricus* Arendt, 1970; *E. hanieli* Wanner, 1916; and *E. variabilis* Arendt, 1970.

Embryocrinus hanieli Wanner, 1916

Fig. 8.1–8.2

Holotype: RGM. 892881.

Diagnosis: *Embryocrinus* with a low vase- to cone-shaped aboral cup, very low to low inverted bowl-shaped PPCP cirlet, PPCPs convex in cross section.

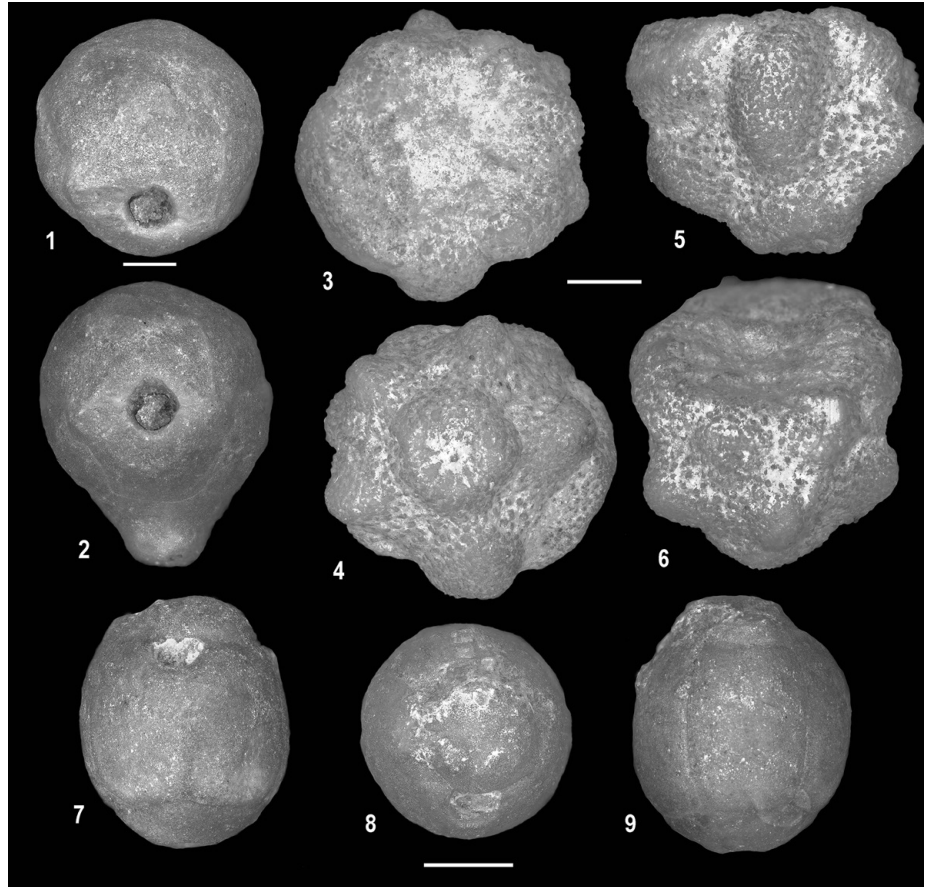
Type locality and horizon: Basleo, West Timor; Permian (uncertain).

Other material: Seven specimens are assigned to ONHM F-1600 and ONHM F-1601 and five specimens are assigned to ONHM F-1602. ONHM F-1603 (two specimens) are assigned to *E. hanieli*?. All are from WKJ-2.

Description. Aboral cup small, low vase-shaped (Fig. 8.2); plates gently convex, smooth plate sculpturing; shallow basal concavity.

Infrabasal cirlet visible in lateral view, ~50% of aboral cup height; three infrabasal plates with the smallest in the DE interray. Basal cirlet ~50% of aboral cup height; five basal plates, approximately the same overall size as the larger infrabasal plates.

Fig. 8 – Codiocrinidae from the Qarari Unit. 1, 2, *Embryocrinus hanieli* Wanner, 1916, ONHM F-1600, scale bar = 1.0 mm; 1, oral view; 2, CD lateral view. 3–6 *Batainacrinus sulcus* gen., sp. nov., holotype, ONHM F-1606, scale bar = 1.0 mm; 3, oral view; 4, basal view; 5, CD interray view; 6, A ray lateral view. 7–9 *Monobrachiocrinus trochos* sp. nov., holotype, ONHM F-1604, scale bar = 1.0 mm; 7, CD interray lateral view; 8, oral view; 9, lateral view.



Five very small radial plates, in a radial position, not in lateral contact, radial plate height ~25% of basal plate height.

No CD interray plating, anal opening centered on the CD basal plate and half in CD basal plate and half in the PPCP circlet (Fig. 8.1). PPCP circlet very low to low inverted bowl shape, five PPCPs, PPCPs convex in cross section; zig-zag suture separating adjacent PPCPs. Hydropore absent.

Column attachment to basal circlet circular, articulates with outer edge of shallow basal concavity, other details of column unknown. Arms absent.

Remarks. The three species of *Embryocrinus* from the Artinskian of Russia (Arendt 1970) have higher (relative to width) aboral cup heights and PPCPs with a concave cross section. In contrast, *E. hanieli* has a lower (relative to width) aboral cup shape and PPCPs that are convex in cross section.

Oman localities. Wadi Khawr Al Jaramah (WKJ-2) Batain, Oman; Qarari Unit, Batain Group, Permian (late Kungurian).

Measurements: ONHM F-1600: TH, 5.53; ACH, 3.73; ACmaxW, 4.47; IH, 1.47; ICmaxW, 3.00; BH, 1.67; BW, 2.33; RH, 1.00; RmaxW, 0.80; PPCPH, 2.20; PPCPmaxW, 4.47. ONHM F-1601: TH,

3.67; ACH, 2.33; ACmaxW, 3.40; IH, 1.20; ICmaxW, 2.80; BH, 1.60; BW, 1.87; RH, 1.33; RmaxW, 1.20; PPCPH, 1.33; PPCPmaxW, 3.40.

Family Sycocrinidae Lane, 1967 Genus *Monobrachiocrinus* Wanner, 1916

Type species: *M. ficiformis* Wanner, 1916.

Included species: *Monobrachiocrinus ficiformis* Wanner, 1916; *M. ficiformis carinatus* Wanner, 1929; *M. ficiformis elongatus* Wanner, 1916; *M. ficiformis granulatus* Wanner, 1920; *M. kohensis* Arendt, 1970; *M. oviformis* Yakovlev, 1926; *M. siciliensis* Yakovlev, 1930; and *M. waitzi* Marez Oyens, 1940.

Remarks. Note that *Monobrachiocrinus waipapaensis* Eagle, et al., 2018 was described from the Permian of New Zealand. If this is a *Monobrachiocrinus*, it is too poorly preserved to compare with other *Monobrachiocrinus*.

Monobrachiocrinus trochos sp. nov.

Fig. 8.7–8.9

Holotype: ONHM F-1604.

Diagnosis: Calyx symmetrical, medium globe shaped, calyx plate sculpturing smooth, infrabasal circlet ~22% of aboral cup height, infrabasal circlet convex in lateral view, basal plate circlet ~62% of aboral cup height, vertical ridges (and other ridges) not

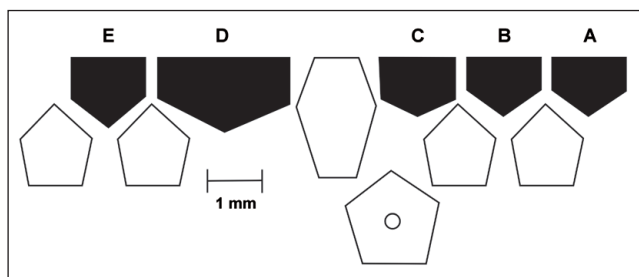


Fig. 9 – Aboral cup plating of *Batainacrinus sulcus* gen., sp. nov., holotype, ONHM F-1606; plates with solid black are radial plates.

present on basal plates; one radial plate, radial plate ~16% of aboral cup height.

Etymology: *Trochos* means wheel, ball (Gr., m.) and refers to the globe-shaped aboral cup.

Paratype: ONHM F-1605.

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

Description. Aboral cup small, medium globe-shaped (Fig. 8.8, 8.9); plates gently convex, smooth plate sculpturing; shallow basal concavity.

Infrabasal circling visible in lateral view, 22% of aboral cup height, lateral profile of infrabasal circling convex; 3 infrabasal plates with smallest in the AE interray. Basal plate circling ~62% of aboral cup height, shallow basal concavity; five basal plates, higher than wide, much larger than infrabasal plates and single radial plate, pentagonal or hexagonal. One radial plate in D ray, ~16% of aboral cup height, ~2.5 times wider than high, extends from the left shoulder of the C radial plate across the entire width of the D radial plate to the right shoulder of the E radial plate; radial facet on D radial plate angustary (Fig. 8.7).

No CD interray plating preserved, anal opening on the left shoulder of the C radial plate, the right shoulder of the D radial plate, and the CD and DE PPCPs (Fig. 8.7). PPCP circling very low inverted bowl shape, CD PPCP separates CD and DE PPCPs.

Column attachment to basal circling circular, articulates with the outer edge of the basal concavity, other details of the column unknown. Arms unknown.

Remarks. *Monobrachiocrinus* species are primarily differentiated by calyx symmetry, the shape of the aboral cup, aboral cup plate sculpturing, and lateral profile of the infrabasal circling. *Monobrachiocrinus trochos* sp. nov. is most similar to *M. kolvensis* because both species have a symmetrical globe-shaped

calyx with smooth aboral plate sculpturing and the lateral profile of the infrabasal circling convex. These two species differ in the shape of the aboral cup, with *M. kolvensis* a high globe shape and *M. trochos*, a medium globe shape.

Measurements: ONHM F-1604: TH, 6.80; ACH, 6.13; ACmaxW, 5.73; IH, 1.33; ICmaxW, 4.00; BH, 4.67; BW, 2.00; RH, 1.60; RmaxW, 1.87; PPCPH, 0.93; PPCPmaxW, 3.07. ONHM F-1605: ACH, 9.07; ACmaxW, 7.07; IH, 2.00; ICmaxW, 4.93; BH, 6.80; BW, 4.40; RH, 1.33; RmaxW, 3.33.

Genus *Batainacrinus* gen. nov.

Type species: *Batainacrinus sulcus* gen. and sp. nov.

Diagnosis: Sycocrinitidae with a low cone-shaped aboral cup, a low infrabasal circling, the infrabasal circling has convex sides in lateral view, infrabasal plates fused into a single plate, basal plates low, five radial plates, D radial plate much larger than other radial plates, D radial facet peneplenary and elongate.

Etymology: From the Batain Plain, where this crinoid was found.

Remarks. The Sycocrinitidae is a distinctive family of euclidids (Lane, 1967), and *Batainacrinus* gen. nov. differs in many ways from other genera in the family. Thus, it is regarded as a new genus. Like other members of the Sycocrinitidae, *Batainacrinus* gen. nov. is relatively small and has a single functional radial plate (D radial plate). *Allosycocrinus* Wanner, 1924 has a medium globe-shaped aboral cup, a low infrabasal circling, the infrabasal circling with concave sides in lateral view, it probably has three infrabasal plates but position of the presumed smaller infrabasal plate unknown, basal plates moderate in size, five radial plates, D radial plate approximately the same size as other radial plates, D radial facet angustary and subcircular; *Metasycocrinus* Wanner, 1920 has a high globe-shaped aboral cup, a high infrabasal circling, the infrabasal circling has concave sides in lateral view, three infrabasal plates, position of the smaller infrabasal plate in the C ray, basal plates high, five radial plates, D radial plate larger and higher than other radial plates, D radial facet angustary and subcircular; *Monobrachiocrinus* has a high globe-shaped aboral cup, a high infrabasal circling, the infrabasal circling has concave sides in lateral view, three infrabasal plates, position of the smaller infrabasal plate in the D ray, basal plates high, one radial plate (D radial plate), D radial facet angustary and subcircular; *Parasycocrinus* Marez Oyens, 1940 has a high globe-shaped aboral cup, a low infrabasal circling, the infrabasal circling has concave sides

in lateral view, three infrabasal plates, position of the smaller infrabasal plate in the C ray, basal plates low, four radial plates (C radial plate absent), D radial plate larger than others, D radial facet angustary and subcircular; and *Sycocrinus* Zittel, 1880 has a high globe-shaped aboral cup, a high infrabasal cirlet, the infrabasal cirlet has straight sides in lateral view, three infrabasal plates, position of the smaller infrabasal plate in the C ray, basal plates high, five radial plates, D radial plate larger than others; D radial facet angustary and subcircular; and *Monobrachiocrinus* has a high globe-shaped aboral cup, a high infrabasal cirlet, the infrabasal cirlet has concave sides in lateral view, three infrabasal plates, position of the smaller infrabasal plate in the D ray, basal plates high, one radial plate (D radial plate), D radial facet angustary and subcircular. In contrast, the diagnostic characters for *Batainacrinus* are listed above.

***Batainacrinus sulcus* gen. nov., sp. nov.**

Figs. 8.3–8.6, 9

Holotype: ONHM F-1606.

Etymology: *Sulcus* (L., m) means furrow, groove, and refers to the very convex plates and the corresponding deep depressions along aboral cup plate sutures.

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

Description. Aboral cup small, low cone shaped (Fig. 8.5); plates very convex, each a large nodose plate with plate sutures in deep depression (Fig. 8.4), fine nodose plate sculpturing, shallow basal concavity.

Infrabasal cirlet visible in lateral view, height ~25% of aboral cup height, with a basal concavity; infrabasal plates apparently fused. Basal plate cirlet ~50% of aboral cup height; five basal plates, all but CD basal plate as high as wide, much larger than infrabasal plates and somewhat larger than radial plates, pentagonal; CD basal plate very large (Fig. 8.5, 9). Radial plate cirlet ~25% of aboral cup height; five radial plates, radial plates of various sizes, only the larger D radial plate with a radial facet and much wider than other radial plates (Figs 8.6, 9); D radial plate with penepenary radial facet. One large radianal plate separates C and D radial plates and CD basal plate from the DE basal plate in sutural contact below the infrabasal cirlet. Radianal plate approximately twice as high as wide.

PPCPs not preserved (Fig. 8.3), anus not in aboral cup.

Column attachment to basal cirlet circular, other details of the column and details of the arms unknown.

Measurements: ONHM F-1606: ACH, 2.80; ACmaxW, 3.60; IH, 0.93; ICmaxW, 0.93; BH, 1.33; BW, 1.33; CDBH, 2.53; CD-BmaxW, 1.33; RH with an arm, 1.73; RmaxW, 2.67; RH without an arm, 1.20; RmaxW without an arm, 1.33.

Family Streblocrinidae Lane, 1967

Subfamily Streblocrininae Lane, 1967

Genus *Coenocystis* Girty, 1908

Included species: *Coenocystis angulosa* Wanner, 1929; *C. perforata* Wanner, 1929; *C. richardsoni* Girty, 1908; *C. somobolensis* Wanner, 1924; *C. timmeri* Strimple et al., 1971; and *C. akros* sp. nov.

Remarks. *Coenocystis* was initially described from the Permian of the United States (Texas). Additional species are now known from the Permian of the United States (Alaska), the Permian of West Timor, and the Permian of Oman. The shift of the PPCP cirlet into a radial position is the characteristic feature for this genus.

***Coenocystis akros* sp. nov.**

Fig. 10.1, 10.2

Holotype: ONHM F-1607.

Diagnosis: *Coenocystis* with aboral cup low to medium vase to globe shape, infrabasal cirlet ~40% of aboral cup height, basal cirlet ~60% of aboral cup height, PPCP cirlet medium inverted bowl shape, zig-zag sutures between PPCPs, PPCPs convex in cross section, zero to two hydropores on CD PPCP.

Etymology: *Akros* (G., m) means the highest point, end, tip and refers to the small distal cone shape formed by the distal most PPCPs.

Paratypes: ONHM F-1608 to ONHM F-1610.

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

Other material: Eleven additional specimens are assigned to ONHM F-1611 and ONHM F-1612 and are from WKJ-1 and WKJ-2, respectively.

Description. Aboral cup small, low to medium globe shape; plates gently convex, smooth plate sculpturing; shallow basal concavity.

Infrabasal cirlet visible in lateral view, 45% of aboral cup height; three infrabasal plates, sutures indistinct, smallest infrabasal plate in the A ray. Basal plate cirlet ~55% of aboral cup height; five

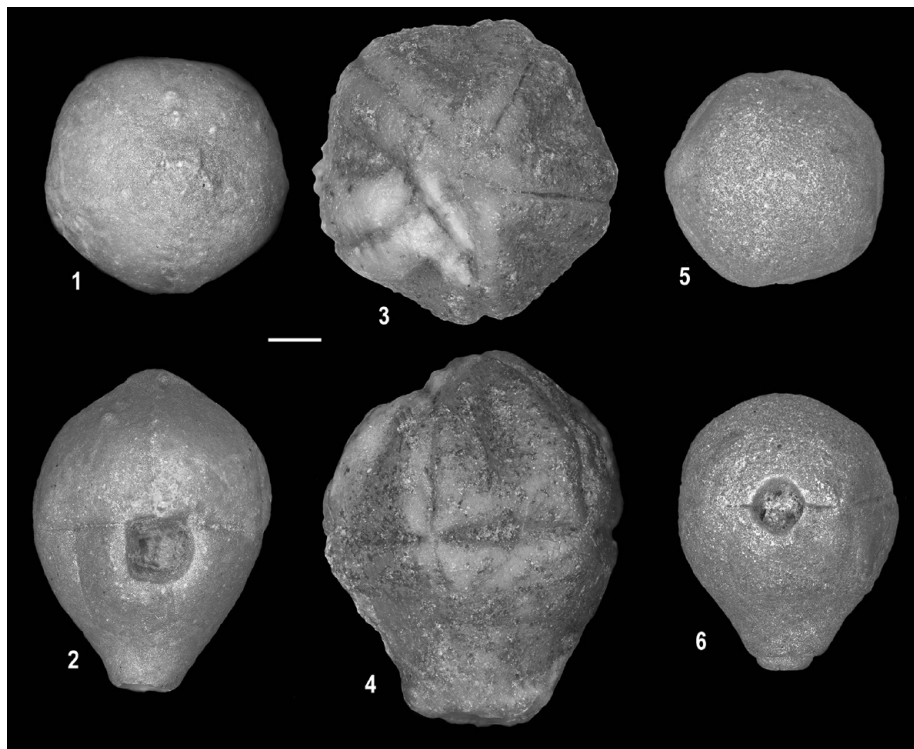


Fig. 10 – Codiocrinidae from the Qarari Unit. 1, 2, *Coenocystis akros* sp. nov., holotype, ONHM F-1607, scale bar = 1 mm; 1, oral view; 2, CD intertray lateral view. 3, 4, *Dichostreblocrinus aequalis* sp. nov., holotype, ONHM F-1613, scale bar = 1.0 mm; 3, oral view, note diagonal scratch in in lower half of primary peristomial cover plate circlet; 4, lateral view. 5, 6, *Hemistreptocron concavus* sp. nov., holotype, ONHM F-1616, scale bar = 1.0 mm; 5, oral view; 6, CD-intertray lateral view.

basal plates, wider than high, larger than infrabasal plates. Radial plates absent.

No CD intertray plating preserved. Anal opening on left shoulder of the C radial plate, right shoulder of the D radial plate, and either below or cutting slightly into the PPCP directly above. PPCP circlet medium inverted bowl shape, lower than aboral cup height, distal tip of the PPCP circlet raised into a cone; PPCPs shifted into a radial position, PPCPs convex in cross section, separated by a zig-zag suture; one or two very small hydropores on CD PPCP.

Column attachment to basal circlet circular, articulates with the inner edge of the basal concavity, lumen probably circular, other details of the column unknown. Arms unknown.

Remarks. *Coenocystis akros* sp. nov. is most similar to *C. perforata* because both species have zig-zag sutures between adjacent PPCPs and hydropores. *Coenocystis perforata* has a medium cone-to bowl-shaped aboral cup, infrabasal plate circlet ~30% of the aboral cup height, basal plate circlet ~70% of the aboral cup height, the PPCP circlet a low inverted globe shape, PPCPs are flat or slightly concave in cross section, and the CD PPCP has one hydropore. In contrast, *C. akros* sp. nov. has a low to medium vase- to bowl-shaped aboral cup, infra-

basal plate circlet ~40% of the aboral cup height, basal plate circlet ~60% of the aboral cup height, the PPCP circlet a medium inverted globe shape, PPCPs convex in cross section, and the CD PPCP has zero to two hydropores.

Measurements: ONHM F-1607: TH, 6.33; ACH, 2.80; ACmaxW, 4.67; IH, 1.33; ICmaxW, 2.73; BH, 1.80; BmaxW, 2.33; PPCPH, 3.53; PPCPmaxW, 4.67. ONHM F-1608: TH, 4.00; ACH, 2.00; ACmaxW, 3.47; IH, 0.53; ICmaxW, 3.73; BH, 2.27; BmaxW, 1.87; PPCPH, 2.00; PPCPmaxW, 3.60. ONHM F-1609: TH, 5.20; ACH, 2.53; ACmaxW, 3.47; IH, 1.20; ICmaxW, 2.07; BH, 1.33; BmaxW, 2.13; PPCPH, 2.67; PPCPmaxW, 3.87. ONHM F-1610: TH, 6.00; ACH, 2.67; ACmaxW, 4.67; IH, 1.33; ICmaxW, 3.33; BH, 2.27; BmaxW, 3.33; PPCPH, 3.33; PPCPmaxW, 4.67.

Genus *Dichostreblocrinus* J.M. Weller, 1930

Type species: *Dichostreblocrinus scrobiculus* J. M. Weller, 1930.

Included species: *Dichostreblocrinus aequalis* sp. nov., *D. iniquosus* Webster et al., 2011; *D. pyriformis* Strimple and Koenig, 1956, *D. scrobiculus* J. M. Weller, 1930; and *D. timorensis* Marez Oyens, 1940.

Remarks. *Dichostreblocrinus* is a long-ranging cosmopolitan genus. The type species was described from the Pennsylvanian (Moscowian) of the United States (Texas) and described subsequently from the Mississippian (Tournaisian) of the United States (New Mexico) and Permian (uncertain stage) of West Timor.

Dichostreblocrinus aequalis sp. nov.

Fig. 10.3, 10.4

Holotype: ONHM F-1613.**Diagnosis:** Aboral cup symmetrical, low vase-shaped aboral cup, subpentagonal in oral view, PPCP circlet ~50% of thecal height, smooth plate sculpturing, medial ridge on basal plates absent, PPCPs in interradian position, sutures between adjacent PPCPs impressed.**Etymology:** *Aequalis* (L.) means like, same, uniform and is a reference to the fact that the aboral cup height and the PPCP circlet height are the same.**Paratype:** ONHM F-1614.**Type locality and horizon:** Wadi Khawr Al Jaramah (WKJ-2), Batain, Oman; Qarari Unit, Batain Group, Permian (late Kungurian).**Other material:** Three additional specimens (ONHM F-1615) from WKJ-2 are questionably assigned to *D. aequalis* sp. nov.**Description.** Aboral cup relatively large for genus, low vase-shaped (Fig. 10.4), subpentagonal outline in oral view; plates concave or gently convex, smooth plate sculpturing; shallow basal concavity.

Infrabasal circlet visible in lateral view, 50% of aboral cup height; 5 infrabasal plates. Basal plate circlet ~50% of aboral cup height; five basal plates, wider than high. Radial plates absent.

No CD interray plating. Anal opening presumably on right shoulder of the CD basal and below PPCP circlet. PPCP circlet low inverted bowl shape, ~54% of thecal height; PPCPs in an interradian position; PPCPs concave, sides of PPCPs raised, convex in cross section with impressed straight sutures between adjacent PPCPs (Fig. 10.3); separated by a zig-zag suture; very small hydropore on CD PPCP.

Column attachment to basal circlet circular, articulates with the inner edge of the basal concavity, other details of the column unknown. Arms absent.

Remarks. *Dichostreblocrinus* is a morphologically diverse genus. All species of *Dichostreblocrinus* have the PPCPs in an interradian position or slightly rotated from an interradian position, radial plates absent, anal opening through the upper right corner of the CD basal plate, CD PPCP larger than other PPCPs and with a small hydropore. With a symmetrical theca, subpentagonal outline of in an oral view, smooth plate sculpturing, and the PPCPs in an exact interradian position, *D. aequalis* sp. nov. is most similar to *D. timorensis*, which is from the Permian of West Timor. These species differ because *D. timorensis* has a low bowl-shaped calyx, PPCP circlet ~40% of thecal height, a medial ridge on basalplates, PPCPs convex in cross section, and sutures between adjacent PPCPs not impressed; whereas *D. aequalis* sp. nov. has a low vase-shaped calyx shape, PPCP circlet ~50% of thecal height, a medial ridge on basal plates absent, PPCPs concave in cross section, and sutures between adjacent PPCPs impressed.**Measurements:** ONHM F-1613: TH, 6.93; ACH, 3.73; ACmaxW, 5.87; IH, 1.73; ICmaxW, 3.73; BH, 2.53; BmaxW, 3.33; PPCPH, 3.20; PPCPmaxW, 5.87. ONHM F-1614: TH, 2.93; ACH, 1.33; ACmaxW, 2.33; IH, 0.73; ICmaxW, 1.33; BH, 0.93; BmaxW, 1.67; PPCPH, 1.60; PPCPmaxW, 2.33.Genus *Hemistreptacron* Yakovlev, 1926**Type species:** *H. abrachiatum* Yakovlev, 1926.**Included species:** *H. abrachiatum* Yakovlev, 1926; *H. carinatum carinatum* Wanner, 1929; *H. carinatum ornatum* Wanner, 1929; *H. tebatlykense* Arendt, 1970.**Remarks.** Webster and Webster (2014) listed three species in *Hemistreptacron*, with one species, *H. carinatum*, with two subspecies. However, *H. carinatum carinatum* Wanner, 1929 and *H. carinatum ornatum* Wanner, 1929 have the PPCP circlet shifted to a nearly radial position and a very distinctive PPCP circlet. It is possible that neither of these two subspecies should be assigned to *Hemistreptacron*.*Hemistreptacron concavus* sp. nov.

Fig. 10.5, 10.6

Type specimens: Holotype: ONHM F-1616.**Diagnosis:** *Hemistreptacron* with a low vase-shaped aboral cup, infrabasal plate circlet ~45% of the aboral cup height, basal plate circlet ~55% of aboral cup height, PPCP circlet medium inverted-bowl shape.**Etymology:** *Concavus* (L., m.) means hollow or arched inwards and refers to the concave sides of the aboral cup.**Paratypes:** ONHM F-1617 to ONHM F-1620.**Type locality and horizon:** Wadi Khawr Al Jaramah (WKJ-2), Batain, Oman; Qarari Unit, Batain Group, Permian (late Kungurian).**Other material:** An additional twenty-three specimens (ONHM F-6121 and ONHM F-1622) from WKJ-1 and WKJ-2, respectively.**Description.** Aboral cup small, low vase-shaped (Fig. 10.6); plates gently convex, smooth plate sculpturing; shallow basal concavity.

Infrabasal circlet visible in lateral view, 45% of aboral cup height; 3 infrabasal plates, sutures indistinct, smallest infrabasal plate in the A ray. Basal plate circlet ~55% of aboral cup height; five basal plates,

slightly wider than high, similar in size to infrabasal plates; distal-most basal plate-basal plate suture angled in direction of PPCP shift. Radial plates absent.

No CD interray plating preserved. Anal opening in center of CD basal plate with half in basal plate and half in CD PPCP plate (Fig. 10.6). PPCP circlet medium inverted bowl shape, ~50% of the cal height; PPCPs shifted slightly from an interradyal toward radial position, PPCPs gently convex in cross section (Fig. 10.5), separated by a straight suture; very small hydropore on CD PPCP.

Column attachment to basal circlet circular, articulates with the inner edge of the basal concavity, lumen probably circular, other details of the column unknown. Arms absent.

Remarks. The *Hemistreptacron* from Oman is very similar to the two species from Russia (Yakovlev 1926; and Arendt 1970), *H. abrachiatum* and *H. tchatlykense*. *Hemistreptacron abrachiatum* has a medium bowl-shaped aboral cup, the infrabasal circlet is ~25% of the aboral cup height, the basal circlet is ~75% of the aboral cup height, the PPCP circlet shape is a low inverted bowl, and a hydropore is on the CD PPCP; and *H. tchatlykense* has a low globe-shaped aboral cup, the infrabasal circlet is ~20% of the aboral cup height, the basal circlet is ~80% of the aboral cup height, the PPCP circlet shape is a very low inverted bowl, and a hydropore may be absent on the CD PPCP. In contrast, *H. concavus* sp. nov. has a low vase-shaped aboral cup, the infrabasal circlet is ~45% of the aboral cup height, the basal circlet is ~55% of the aboral cup height, the PPCP circlet shape is a medium inverted bowl, and a hydropore is on the CD PPCP.

Measurements: ONHM F-1616: TH, 5.27; ACH, 3.33; ACmaxW, 4.33; IH, 1.80; ICmaxW, 2.67; BH, 2.00; BmaxW, 2.53; PPCPH, 1.40; PPCPmaxW, 4.13. ONHM F-1617: TH, 2.06; ACH, 0.77; ACmaxW, 1.87; IH, 0.55; ICmaxW, 0.24; BH, 0.94; BmaxW, 0.97; PPCPH, 1.29; PPCPmaxW, 1.87. ONHM F-1618: TH, 3.60; ACH, 1.80; ACmaxW, 3.60; IH, 0.87; ICmaxW, 1.93; BH, 1.60; BmaxW, 1.93; PPCPH, 1.80; PPCPmaxW, 3.40. ONHM F-1619: TH, 4.87; ACH, 2.67; ACmaxW, 4.33; IH, 1.33; ICmaxW, 3.67; BH, 1.73; BmaxW, 2.27; PPCPH, 2.20; PPCPmaxW, 4.33. ONHM F-1620: TH, 4.93; ACH, 3.00; ACmaxW, 4.20; IH, 1.27; ICmaxW, 2.67; BH, 1.87; BmaxW, 2.33; PPCPH, 2.60; PPCPmaxW, 4.20.

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