

## Late Cretaceous Echinoids from the Seymareh Member (Lopha Limestone Member), Kabir Kuh Anticline, Southwest of Iran

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### Abstract

In the present study, The Seymareh or Lopha Limestone Member (Gurpi Formation) in Kabir Kuh Section, have been Selected. The member has yielded a rich echinoid fauna and 21 species of Echinoid belonging to 14 genera are recognized and described. The Kabir Kuh section yielded two regular echinoid taxa: *Salenia nutrix* and *Goniopygus superbus*, one holoctypoid taxa: *Coptodiscus noemiae*, two conulid taxa: *Conulus douvillei* and *Globator bleicheri*, six cassiduloid taxa: *Parapygus longior*, *Parapygus declivis*, *Parapygus inflatus*, *Parapygus vassilini*, *Vologesia tataosi* and *Pygurostoma morgani*, one holasteroid species: *Hemipneustes persicus* and nine spatangoid taxa: *Iraniaster douvillei*, *I. morgani*, *I. nodulosus*, *Hemiaster noemiae*, *Hemiaster opimus*, *Mecaster kanepanensis*, *Mecaster longus*, *Proraster morgani* and *Epiaster lamberti*. The taxon association indicates a Campanian age. Some of the taxa are known from the similar Campanian age in Saudi Arabia such as: *Coptodiscus noemiae*. Some specimens are reported also from Campanian deposits of Afghanistan such as: *Hemiaster noemiae*, *H. opimus* and *Parapygus vassilini*. *Globator bleicheri* and *Salenia nutrix* are recorded from Maastrichtian deposits of UAE and Oman.

**Keywords:** Campanian, Echinoid, Kabir Kuh, Seymareh member, Southwest Iran.

### Introduction

Echinoids are among the most conspicuous and diverse elements of the Late Cretaceous marine invertebrate fauna of Iran. However, there have been few studies published on the paleontology and systematic of the Iranian Cretaceous echinoids. After (Cotteau and Gauthier, 1895) and (Gauthier, 1902), that could be out forward as the most outstanding works in the Crataceous strata of the Zagros Basin, unfortunately there have not been any index study carried out on Echinoid fauna of this area, specially on Campanian deposits. Their studies chiefly focused on the initial exploration and general and primary description of the Iranian Cretaceous echinoid fauna. Recent works focused on remarkable Cretaceous echinoid specimens of the Zagros Basin, such as: (Balmaki *et al.*, 2010 & 2012) (Campanian-Maastrichtian fauna); (Kamyabi Shadan *et al.*, 2014) (Albian fauna); (Yavari *et al.*, 2016) (Barremian and Aptian fauna) and (Kamyabi Shadan & Dashtban, 2017) (Santonian fauna). (Balmaki *et al.*, 2012) briefly studied on some specimen of the Campanian strata in Kabir Kuh section. The aim of present work is to revise the echinoid forms paleontologically and systematically, that was collected newly from the Campanian strata of different sections of the Kabir Kuh Anticline, Zagros Basin, southwest of Iran. The Campanian fauna of the Seymareh Member from the Gurpi Formation is rich, including Saleniidae,

Acropeltidae, Holoctypidae, Conulidae, Cassiduloida, Holasteroid and Spatangoida.

### Geological Setting and Stratigraphy Framework

Kabir Kuh Anticline is part of the Zagros fold belt in southwest of Iran. The studied sections are located on the North flank of Kabir Kuh anticline (approximately 80 to 130 km Southeast of Ilam city and about 15 km SW of Darreh Shahr city (at latitude 33° 06' 12.51" N and longitude 47° 20' 25.20" E), 15 km SW of Zarangush village (at latitude 33° 11' 56.40" N and longitude 47° 11' 40.46" E), 15 km SW of Badreh city (at latitude 33° 16' 25.33" N and longitude 47° 00' 04. 6" E) and 10 km SW of Valiasr town at (at latitude 33° 18' 19.24" N and longitude 46° 56' 42.13" E) (Fig.1).

Echinoid specimen sampled from the Seymareh (Lopha Limestone) Member, Gurpi Formation, which is 20 m thick in the Kabir Kuh section, resting on the light gray and soft marls of Gurpi Formation and being overlain by the light gray and marly limestone rocks of the Imam Hassan Member (Fig. 2). The dominant rock facies are hard, silty and gray to light brown marly limestones (Lopha Boundstone). The general striking of the beds is NW-SE with a dipping of about 40°. In 1970 detailed stratigraphy of the Late Cretaceous deposit of the studied section has been revealed in Brien, Nasr, Zavieh, and Khosravi Said and revised

by Setudehnia (drawing stratigraphical sections). In this study, age of the Seymareh Member determined

Campanian (supported by the micropaleontological studies).

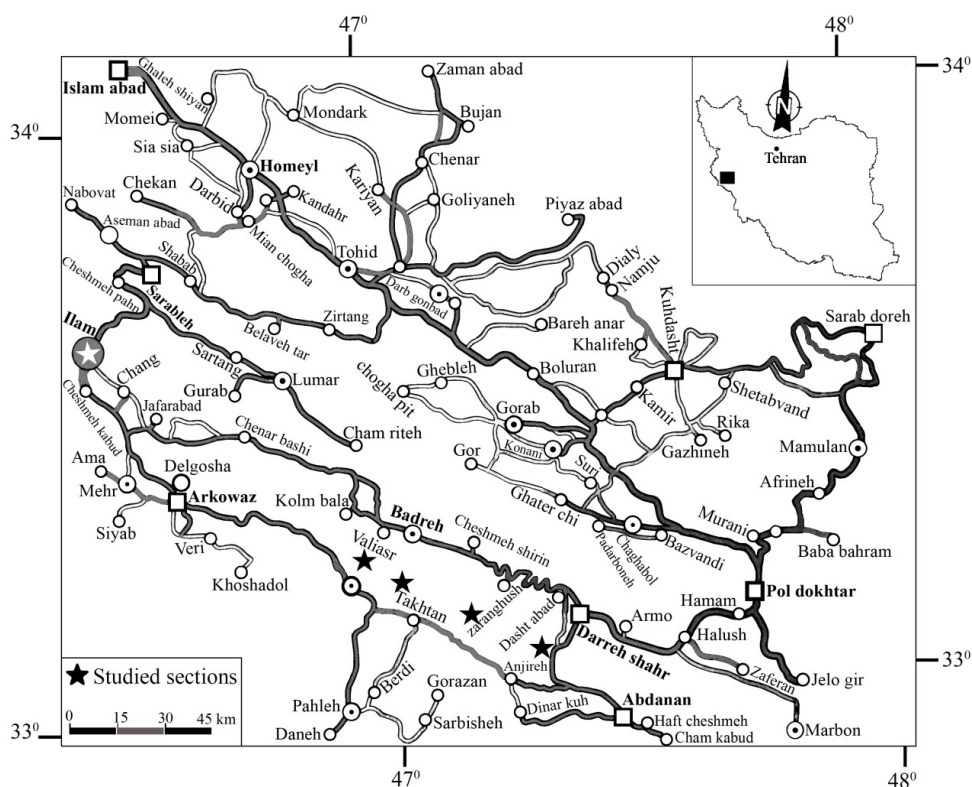


Figure 1. Location map of studied sections.

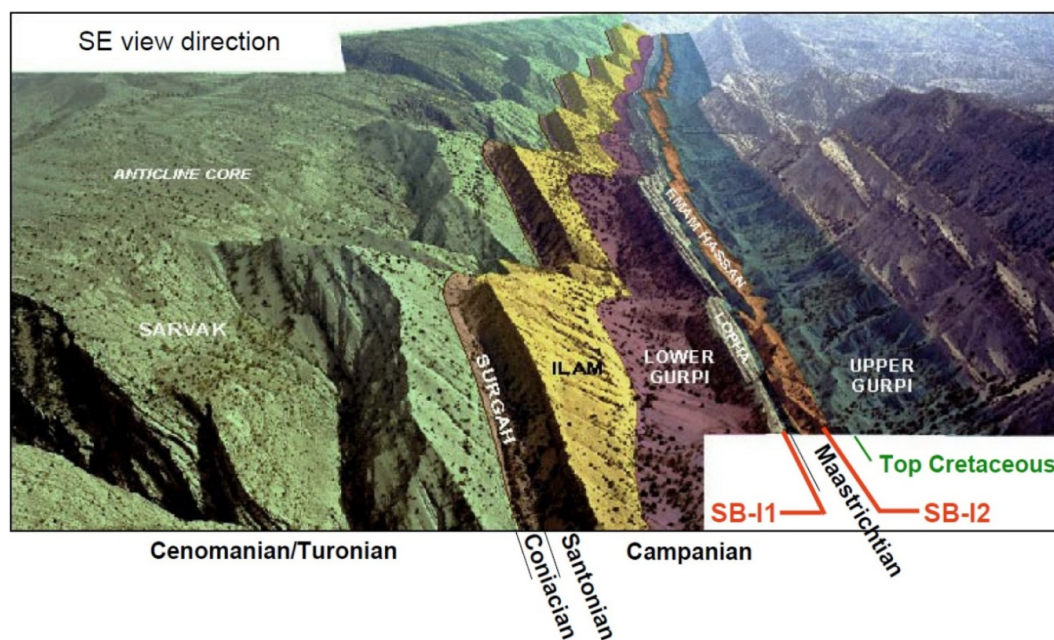


Figure 2. A long view from Kabir Kuh Anticline. Loph or Seymareh Member resting on the soft marls of lower Gurpi and being overlain by the marly limestone rocks of the Imam Hassan Member. Seymareh Member is dated here of Campanian age (Van Buchem *et al.*, 2006).

The Biostratigraphy and Micropaleontological studies of the Kabir Kuh section (Kalantari, 1972), Qaleh Darreh section about 65 km NW of study section and Tange Salmani section about 20 km of NW Kabir Kuh section (Bahrami & Darvish Zadeh,

1994) and Delgosha section in SW flank of Kabir Kuh about 70 km NW of Darreh Shahr section (Van buchem *et al.*, 2006) confirmed the Campanian age for the Lopha Member (Figs. 2 & 3).

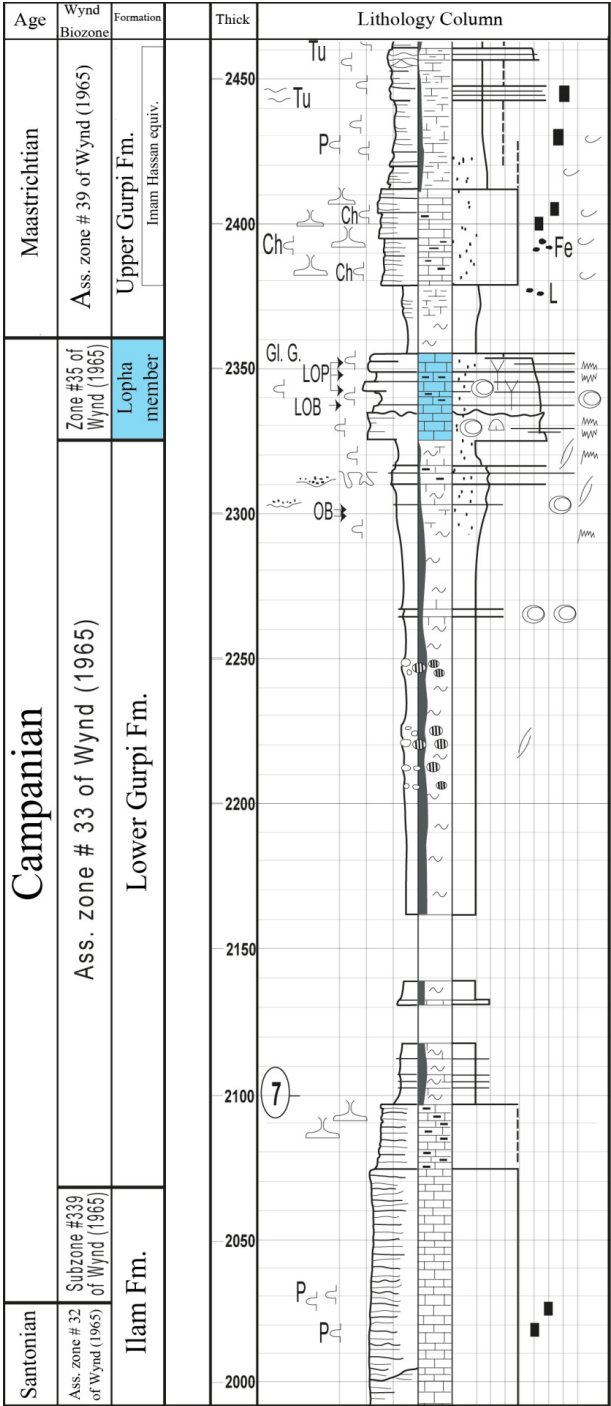


Figure 3. Stratigraphical column of Gurpi Formation and Lopha Member in Kabir Kuh section. Study of this section revealed micropaleontological assemblages of Campanian age in the Lopha Member (Van Buchem *et al.*, 2006). (Vertical Scale in meter, showed the left side of lithology column).

### Systematic Paleontology

The systematic classification follows the classification of (Kroh and Smith, 2010) complemented by (Smith & Wright 1990) for Calycina; (Smith & Wright 1993) for Arbacioida, (Smith & Wright 2000) for Cassiduloids, (Smith & Wright 2003) for Holasteroida, and (Smith & Wright 2008) for Spatangoida. All linear measurements are given in millimeters (taken with Vernier Caliper).

### Abbreviations

D: test diameter of regular echinoids; dp: peristome diameter of regular echinoids; L: test length; W: test width; H: test height;  $L_{ap}$ : Length of the apical disc;  $W_{ap}$ : width of the apical disc;  $L_I$ : length of the posterior paired petals (ambulacrum I or V);  $L_{II}$ : length of the anterior paired petals (ambulacrum II or IV);  $L_{III}$ : length of ambulacrum III up to ambitus;  $L_{pc}$ : length of the periproct;  $W_{pc}$ : width of the periproct;  $L_{pr}$ : length of the peristome;  $W_{pr}$ : width of the peristome;  $W_a$ : Width of ambulacrum III at the ambitus;  $W_i$ : Width of intrambulacrum III at the ambitus.

Phylum Echinodermata Klein, 1734  
 Subphylum Echinozoa Haeckel in Zittel, 1895  
 Class Echinoidea Leske, 1778  
 Cohort Echinacea Claus, 1876  
 Superorder Stirodonta Jackson, 1912  
 Order Calycina Gregory, 1900  
 Synonym Salenioida Delage & Hérouard, 1903  
 Family Saleniidae Agassiz, 1838  
 Subfamily Saleniinae Agassiz, 1838  
 Tribe Saleniini Agassiz, 1838  
 Genus *Salenia* Gray, 1835 Synonym *Cidarelle* (vernacular) Des Moulins, 1837  
 Type species: by monotypy; *Cidarites scutigera* Goldfuss, 1829, [= *Echinus petaliferus* Desmarest in DeFrance, 1825]  
 Subgenus *Salenia* (*Salenia*) Gray, 1835  
 Synonym *Trisalenia* Lambert, 1895  
 Type species: *Salenia scutigera* Goldfuss, 1829 by monotypy [= *Echinus petaliferus*]  
 Diagnosis: Saleniinae with relatively broad

ambulacra with primary, secondary and miliary tuberculation differentiated. Apical disc outline is circular or pentagonal, smooth or granular and with sutural pits at triple suture junctions. It derived from *S. (Bathysalenia)* by change in position of the gonopores. In *Salenia* gonopores are relatively centrally positioned while they are marginal in *Bathysalenia*. *S. (Salenia)* differs from *S. (Pleurosalenia)* by having bigeminate ambulacral plating. *Pleurosalenia* has unigeminate ambulacral plating.

Occurrence: *S. (Salenia)* is recorded from the Barremian to Burdigalian, Worldwide distribution.

*Salenia (Salenia) nutrix* Cotteau, Peron and Gauthier, 1881

Plate 1, Figs. A- F

1881 *Salenia nutrix* Peron & Gauthier, p. 167, pl. 18, figs. 4-10.

1895 *Salenia cossiaea* Cotteau & Gauthier, p. 83, pl. XIII, figs. 13-19.

2012 *Salenia nutrix* Balmaki et al., p. 22, pl. 2, figs. 3a-3c.

Material: 3 well preserved and measurable specimens from Kabir Kuh section (DCSK Sn1-3), Seymareh Membr, Gurpi Formation.

Measurement: In Table 1.

Diagnosis: A small to moderate size *Salenia*. The test is relatively inflated in shape with slightly flattened and subpentagonal apical disc ornamented by weakly deep subrounded pits and with a large and subpentagonal to roughly circular periproct with a distinct lip.

Description: The test is inflated in shape, circular in outline, relatively high (the height of test is 70% of test diameter) and flattened adapically and adorally. The apical disc is dicyclic, thin, subcircular and flat (somewhat very slightly inflated) and forms about 42% to 50% of test diameter (Fig. 4A; Table 1). Genital plates are large, squat, broad and do not project as much as the oculars. The genital pores are about large with distinct lip and located subcentrally (slightly toward genital plates margin) (Fig. 4B).

Table 1. Quantitative description of the test shape variations in *Salenia (Salenia) nutrix*.

Taxa name / Parameter	Sample No.	D	H	H/D	$D_{ap}$	$D_{ap}/D$	$D_{pc}$	$D_{su}$	$D_{su}/D_{pc}$	$D_{pe}/D_{ap}$	$D_{pe}/D$	$D_{pr}$	$D_{pr}/D$	$W_{am}$	$W_{int}$	$W_{am}/W_{int}$	$W_{am}/D$	$W_{int}/D$
<i>S. (Salenia) nutrix</i>	DCSKSn1	24.8	17.5	0.71	10.4	0.42	3.9	3.5	0.90	0.38	0.16	11.1	0.45	3.5	10.8	0.32	0.14	0.44
	DCSKSn2	22.75	15.6	0.69	11.2	0.49	4	3.7	0.93	0.36	0.18	11.25	0.49	3	9.1	0.33	0.13	0.40
	DCSKSn3	20.70	15.1	0.73	10.3	0.50	3.5	3.2	0.91	0.34	0.17	10.20	0.49	2.8	8.8	0.32	0.14	0.43

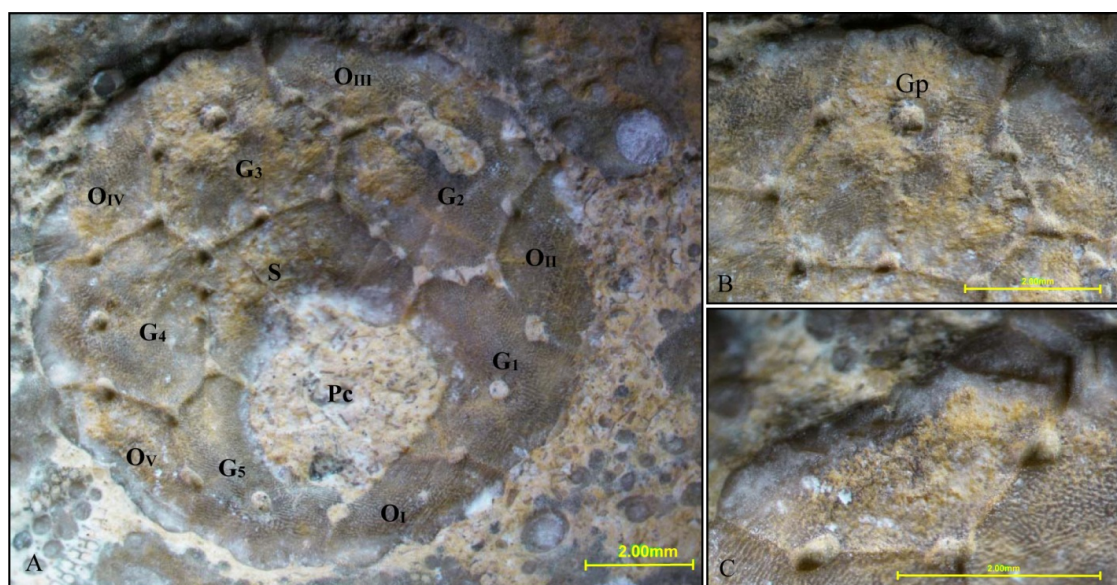


Figure 4. Apical disc of *S. (Salenia) nutrix*. A. Apical disc plating in specimen DCSKGn2. B. Genital plate 3, with a subcentral gonopore; C. Ocular plate V, with weakly concave outer margin. (G: Genital plate, O: Ocular plate, Pc: Periproct, S: Suranal plate, Gp: Gonopore or Genital pores).

The ocular plates are grossly heart shaped with weakly concave outer margin (Fig. 4C). The suranal plate is very large as large as the genital plates (about equal in size with periproct) and has a distinct rim with periproct (Fig. 2A). Periproct is large and subpentagonal in shape, positioned toward the right posterior side and has a prominent lip. Periproct diameter represents about 30% of test diameter. Sutural pores (pits) at ocular and genital plates are rounded and at genital/suranal plates are nail like.

Ambulacra are bigeminate, broad, about 12% of test diameter in width and with a distinct sinuous trajectory, especially near to apical disc. The central ambulacral tuberculate zone is raised distinctly and represent about 60% of ambulacral width. Primary tubercles are bead Shape, about the same size throughout, and contiguous vertically. The two rows of primary tubercles are separated by a band of small tubercles perradially. Pore pairs located below the primaries, are oblique and arranged biserially (Fig. 5).

The interambulacral plates have five plates in each column. Primary tubercles are well developed ambitally and supra-ambitally and are surrounded by a scrobicular ring of five widely spaced scrobicular tubercles (Fig. 6).

Areoles of primary tubercles confluent. There are two sizes of tubercles (secondary tubercles with distinct mamelon and miliary tubercles) in the

interradial zone (outside the scrobicular tubercles) that are smaller than primaries. The peristome is the same diameter as the apical disc (52% of test diameter) and weakly depressed.

Remarks: It very similar and synonym to the Campanian species *Salenia cossiaea* Cotteau & Gauthier, 1895. Many of the European species such as *S. (Salenia) neocominsis* Cotteau, 1861 (Barremian-Early Aptian), *S. (Salenia) rugosa* d'Archiac, 1847 (Cenomanian), *S. (Salenia) petalifera* Defrance, in Desmarest, 1825 (Cenomanian), *S. (Salenia) wilmingttonensis* Smith & Wright, 1990 (Cenomanian), *S. (Salenia) baylissi* Smith & Wright, 1990 (Cenomanian), *S. (Salenia) geometrica* Agassiz, 1838 (Coniacian or Santonian), *S. (Salenia) magnifera* Wright, 1872 (Campanian), *S. (Salenia) sigillata* Schlüter, 1892 (Maastrichtian) differ from *S. (Salenia) nutrix* by having thick and slightly higher apical disc, slightly conical to conical profile and subtriangular periproct. The swedish species *Trisalenia (Salenia) loveni* Cotteau, 1888, is similar to *S. (Salenia) nutrix* by having flattened apical disc but differs from it by having very small periproct (much smaller than suranal plate) and a widely spaced ring of seven scrobicular tubercles around the primaries. Occurrence: In studied section, *Salenia (Salenia) nutrix* is known from the Campanian deposits of the Seymareh (Lopha limestone) Member, Gurpi Formation.

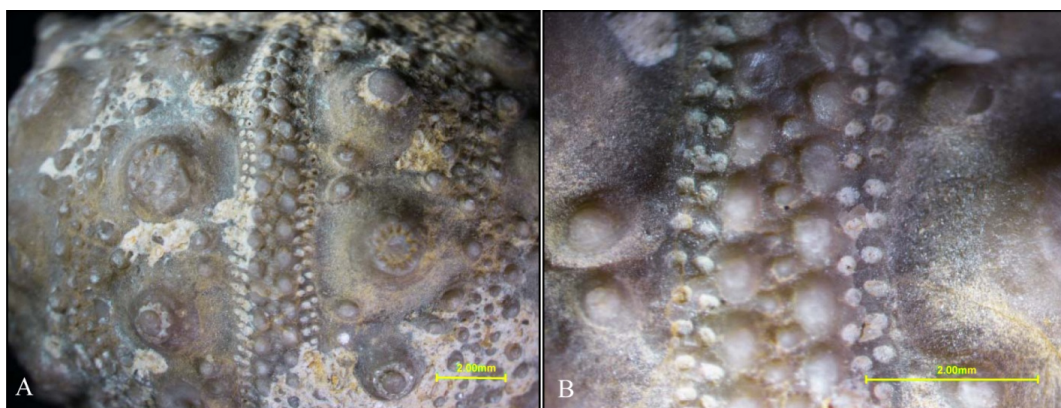


Figure 5. Ambulacral tuberculation and plating in *S. (Salenia) nutrix*. A. slightly sinuous ambulacrum I in specimen DCSKSn2. B. Ambital ambulacral plating and tuberculation (with biserially arranged primary tubercles) in ambulacrum V, specimen DCSKSn 2.



Figure 6. Intrambulacral tuberculation and plating in *S. (Salenia) nutrix*. A. Intrambulacral tuberculation in interambulacrum 5 with large primary tubercles and two size of military tubercles, specimen DCSKSn2. B. Primary tubercle in inter-ambulacrum 5 with five widely spaced scrobicular tubercles, specimen DCSKSn2.

*S. (S.) nutrix* is also reported in Campanian strata, Badra Formation in Gafsa region, Tunisia (Gallemí & Abdallah, 2010), Late Campanian-Early Maastrichtian (Dordonién Inférieur) deposits of Algeria (Cotteau, Peron & Gauthier, 1881), Maastrichtian strata, Simsim Formation in UAE and Oman (Boukhary *et al.*, 1999), Maastrichtian deposits of southeastern Netherlands and northeastern Belgium, Cuba, Libya, Turkey and Kazakhstan (Jagt *et al.*, 1999).

Order Arbacioida Gregory, 1900  
Family Acropeltidae Smith & Wright, 1993

Genus *Goniopygus* Agassiz, 1838

Synonyms: *Cyphopygus* Pomel, 1883;  
*Polygoniopygus* Valette, 1906; *Heteropodia* de Loriol in White, 1887.

Type species: *Goniopygus peltatus* Agassiz, 1838  
Diagnosis: Acropeltids with smooth, unornamented and dicyclic apical disc plates, ambulacra with one occluded plate in each triad, and a single sunken

tubercle on the periproctal rim of genital plates.

Occurrence: Upper Jurassic (Tithonian) to Palaeocene, Europe, North Africa, North and South America, Iran and Arabian Peninsula.

*Goniopygus superbis* Cotteau & Gauthier, 1895  
Plate 1, Figs. G-L

1895 *Goniopygus superbis* Cotteau & Gauthier, p. 101, pl. XVI, figs. 5-10.

2017 *Goniopygus superbis* Valls, p. 58.

Material: 6 well preserved and measurable specimens (DCSK GS1-6), from Kabir Kuh section, Seymareh Member, Gurpi Formation.

Measurement: In Table 2.

Diagnosis: A *Goniopygus* with a subcircular to subpentagonal periproct with 5 perianal tubercles, apical disc is dicyclic and including small ocular plate above each ambulacrum and a pointed genital plate centred toward each interambulacrum. Genital and ocular plates are about equal in size.

Description: The lower test surface is flattened and

the upper face is slightly convex to flat at the apical disc. The apical disc is thick and forming raised platform, dicyclic and consist of a pointed genital plates centred toward each interambulacrum and small ocular plates above each ambulacrum. Gonopores at outer interradian point, bounded by interambulacral zones. Ocular plates are small, square, with slightly concave outer margin, and projecting strongly beyond the genital plates. A single tubercle develops on the inner edge of genital

plates which is sunken. There are 5 perianal tubercles on the periproctal margin (Figs. 7 A & B). Ambulacra are straight. They have small and non-conjugate pore-paires, uniserially. Ambulacra expanded into phyllodes orally (Fig. 8A).

Interambulacral plates are wider than tall, with a large imperforate primary tubercle on each and there are 2 or 3 irregular rows of minute tubercles interradianly (3 at ambitus) (Fig. 8B).

Table 2. Quantitative description of the test shape variations in *Goniopygus superbus*.

Taxa name/ Parameter	Sample No.	D	H	H/D	Dap	Dap/D	Dpc	Dpc/Dap	Dpe/D	Dpr	Dpr/D	Wam	Wint	Wam/Wint	Wam/D	Wint/D
<i>Goniopygus superbus</i>	DCSKGs1	33.6	18.85	0.56	13.3	0.40	5.2	0.39	0.15	15.0	0.45	6.1	14.1	0.43	0.18	0.42
	DCSKGs2	37.1	19.0	0.51	14.9	0.40	6.0	0.40	0.16	15.8	0.43	6.6	15.6	0.42	0.18	0.42
	DCSKGs3	22.7	10.5	0.46	10.1	0.44	3.8	0.38	0.17	10.2	0.45	3.5	9.2	0.38	0.15	0.41
	DCSKGs4	38.3	22.2	0.58	14.9	0.39	5.6	0.38	0.15	16.1	0.42	6.3	15.1	0.42	0.16	0.39
	DCSKGs5	29.4	15.6	0.53	13.0	0.44	5.2	0.40	0.18	13.3	0.45	5.1	11.9	0.43	0.17	0.40
	DCSKGs6	23.2	12.8	0.55	10.2	0.44	4.0	0.39	0.17	-	-	3.8	9.0	0.42	0.16	0.39

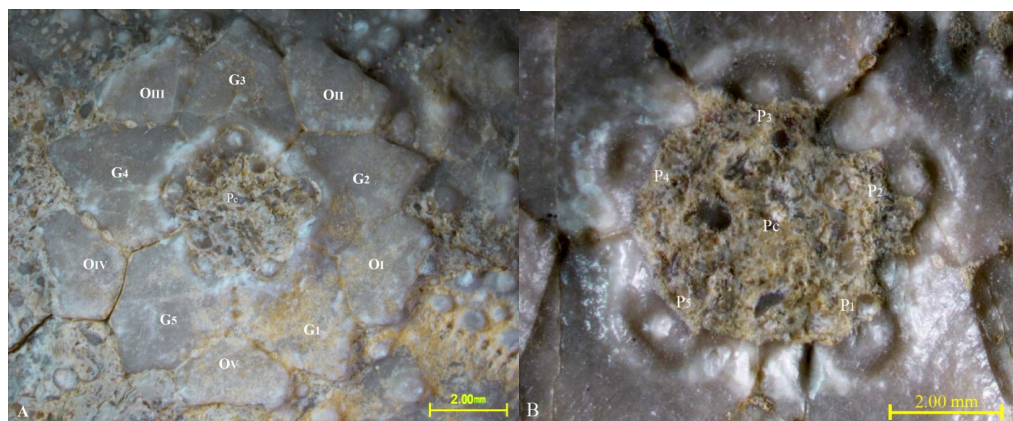


Figure 7. Apical disc plating in *Goniopygus superbus*. A: Dicyclic apical disc with pointing margin genital plates and weakly concave margin ocular plates, specimen DCSKGs3. B: Periproct bordered with five perianal tubercles, specimen DCSKGs2 (Pc: Periproct, G: Genital plate, O: Ocular plate, P: Perianal tubercle).

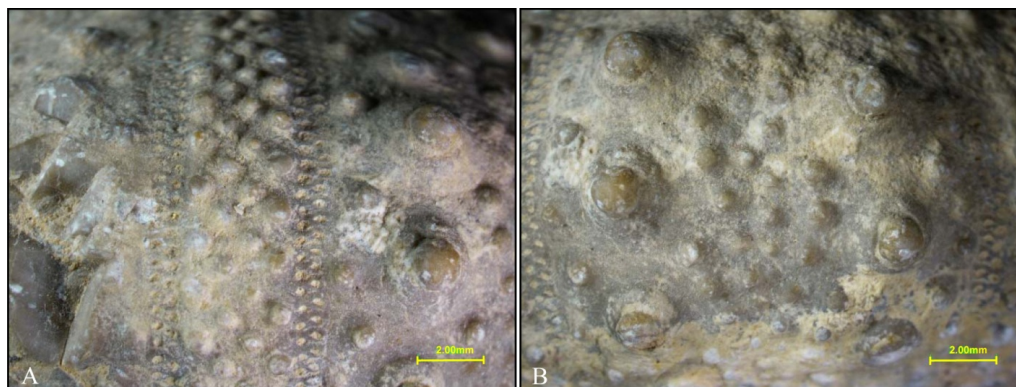


Figure 8. Tuberculation and plating in *Goniopygus superbus*. A: Straight ambulacrum with small pore-pairs in ambulacrum, 5 in specimen DCSKGs1. B: Intrambulacral tuberculation with large primary tubercles and three irregular rows of minute tubercles interradianly in interambulacrum 2, specimen DCSKGs1.

Largest tubercles located suprambitally. Tubercles with no surrounding platform. The periproct is subcircular to subpentagonal. The peristome is large, subcircular and slightly sunken. Remarks: Smith (1995) assumed *G. superbus* described in Iran to be distinct from the forms found in the Arabic Peninsula, for which he erected a new species *Goniopygus arabicus*. *Goniopygus superbus* is similar to *Goniopygus arabicus* Smith, 1995, in the development of genital plates with sharp distal protrusions, but it distinguishes by having the subcircular periproct and 5 perianal tubercles (in *G. arabicus* periproct is roughly triangular with 3 perianal tubercles). The European species *Goniopygus delphinensis* Gras, 1848, and *Goniopygus menardi* Desmarest, 1825, distinguished from *G. superbus* by having a small triangular periproct with 2 or 3 perianal tubercles and only a single irregular row of minute tubercles interradially.

Occurrence: This species occurs in the Campanian of the studied sections. *G. superbus* is also reported in Campanian strata, Lower Aruma Formation in Saudi Arabia (Kier, 1972), and Maastrichtian deposits of Simsim Formation in Oman and UAE (Ali, 1989).

Cohort Irregularia Latreille, 1825  
Order Holcypoida Duncan, 1889 Suborder  
Holcypina Duncan, 1889  
Family Holcypidae Lambert, 1900

Subfamily Coenholcypinae Smith & Wright, 1999

Genus *Coptodiscus* Cotteau & Gauthier, 1895

Type species: *Coptodiscus noemiae* Cotteau & Gauthier, 1895

Diagnosis: Holcypids with five perforated genital plates in apical disc, aboral plating highly ornamented with sutural pits and inframarginal periproct.

Occurrence: Late Cretaceous (Cenomanian-Maastrichtian); Spain and the Middle East

*Coptodiscus noemiae* Cotteau & Gauthier, 1895

Plate 2, Figs. A- C

1895 *Coptodiscus noemiae* Cotteau & Gauthier, p. 76, pl. XII, figs. 8-14.

2012 *Coptodiscus noemiae* Balmaki et al., p. 22, figs. 5c-d.

Material: 2 well preserved and measurable specimens (DCSK Cn1-2), from Kabir Kuh section, Seymareh Membr, Gurpi Formation.

Measurement: In Table 3.

Diagnosis: In this species, aboral plating ornamented with sutural pits and the apical disc has five genital pores.

Description: The test is circular in outline and flattened in profile (upper surface gently convex), with rounded margins. The apical disc is compact with five genital pores in central position of the genital plates (Fig. 9A). Aboral plating ornamented with sutural pits.

Table 3. Quantitative description of the test shape variations in *Coptodiscus noemiae*.

Taxa name/ Parameter	Sample No.	D	H	H/D	Dap	Dap/D	Lpc	Wpc	Dpr	Dpr/D	Wam	Wint	Wam/Wint	Wam/D	Wint/D
<i>Coptodiscus noemiae</i>	DCSKCn1	22.8	7.90	0.35	2.4	0.1	4.4	2.9	10.3	0.45	6.5	7.1	0.92	0.29	0.31
	DCSKCn2	23.6	7.6	0.32	-	-	3.6	2.6	9.8	0.42	-	-	-	-	-

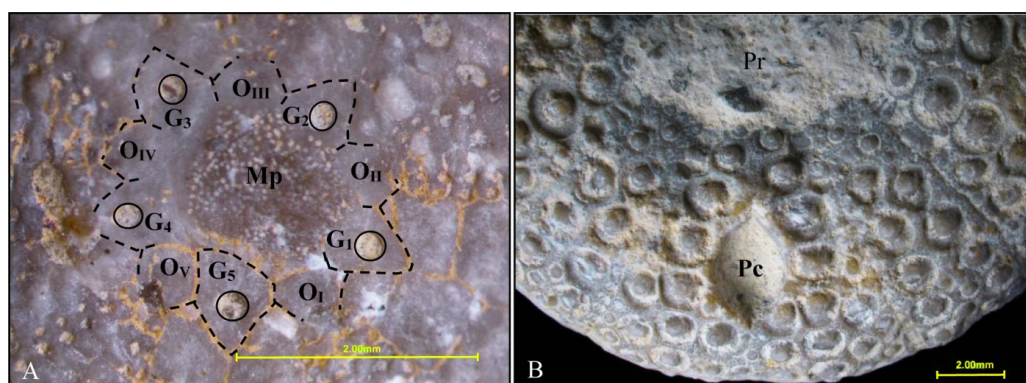


Figure 9. Apical disc and oral face in *Coptodiscus noemiae*. A. Apical disc plating with five gonopore, in specimen DCSKCn1. B. Periproct position at oral face, in specimen DCSKCn2 (Pc: Periproct, G: Genital plate, O: Ocular plate, Pr: Peristome, Mp: Madreporite).

Single primary tubercle placed on each aboral interambulacral plate centrally, but multiple tubercles placed on adoral interambulacral plates. Periproct is ovate, relatively small, situated on oral surface, between peristome and posterior margin (Fig. 9B). Ambulacra narrower than interambulacra (about 1/3) at the ambitus.

Remarks: The Spanish species *Coptodiscus mengaudi* Lambert, 1919, easily distinguished from *Coptodiscus noemiae*, by having much more conical in aboral surface.

Occurrence: In studied sections, *Coptodiscus noemiae* is known from the Campanian deposits. In Saudi Arabia it is found in Lower Aruma Formation, of Campanian age (Kier, 1972; Néraudeau *et al.*, 1995).

Order Echinoneoidea Clark, 1925

Superfamily Conuloidea Lambert, 1911

Family Conulidae Lambert, 1911

Genus *Conulus* Leske, 1778

Type species: *Conulus albogalerus* Leske, 1778

Diagnosis: Conulids with tetrabasal apical disc and pyrinoid adoral ambulacral plating.

Occurrence: Upper Jurassic (Oxfordian) to Lower Eocene, Europe, Russia, Central Asia, North Africa, Pakistan, Tibet and the Middle East.

*Conulus douvillei* Cotteau & Gauthier, 1895

Plate 2, Figs. D- G; L-N

1895 *Echinoconus douvillei* Cotteau & Gauthier, p. 70, pl. XI, figs. 9-13.

1989 *Globator mortenseni* Ali, p. 403, figs. 4, (6-7).

1995 *Conulus douvillei* (Cotteau & Gauthier); Smith, p.188, pl. 19, figs. 8-11; pl. 20, figs. 11- 16; text figs. 46, 47c- e, 48B.

2012 *Conulus douvillei* Balmaki *et al.*, p. 23, pl. 1, figs. 4a-c.

Material: 43 well preserved and measurable specimens (DCSK CD1-43), Kabir Kuh section, Seymareh Member, Gurpi Formation.

Measurement: In table 4.

Diagnosis: a rather subpentagonal *Conulus* with hemispherical profile; slightly carinate in the ambulacra, and slightly concave in intrambulacra.

Description: Test is subpentagonal in outline, hemispherical in profile, and flattened adorally with

rounded margins. The test surface is slightly carinate in the ambulacral area and slightly concave in intrambulacral area. The peristomial area slightly depressed. The apical disc is tetrabasal, centrally in position, compact with four genital pores and genital plates in contact together. Ambulacra straight, without differentiated petals. Pore-pairs are small, uniserial, simple and narrow in aboral surface. Ambulacral plating is pyrinoid with every third element small and confined to adradial margin. No buccal pores present. Interambulacra are wide. Periproct is ovate, relatively small and inframarginal to marginal in position. Tuberculation consists of small uniform primary tubercles with slightly sunken areoles scattered over plates covered otherwise by dense uniform granules. Peristome is subcircular in shape, subcentral in position and slightly depressed.

Remarks: The post-Cretaceous species *Conulus raulini* Cotteau, 1863, distinguished from *Conulus douvillei* by having pore pairs that remain weakly offset in triads towards the peristome and do not form phyllodes. The Arabian species *Conulus triadis* Lees, 1928, specified from *C. douvillei* by having the high aboral surface with straight vertical sides for about half the height, the upper half being hemispherical and coarser tuberculation in lower surface. It differs from the *Conulus albogalerus* Leske, 1778, by having hemispherical upper surface (*C. albogalerus* has a subconical and higher aboral surface).

Occurrence: In studied section, *Conulus douvillei* is known from the Campanian deposits. *Conulus douvillei* is also reported in the Maastrichtian strata of Simsim Formation in UAE and Oman (Ali, 1989 and Boukhary *et al.*, 1999), Campanian deposits of Lower Aruma Formation in Saudi Arabia (Kier, 1972), Maastrichtian strata of Libya (Checchia-Rispoli, 1932) and Baluchistan, India and Tibet (Neumann *et al.*, 2002).

Order Echinoneoidea Clark, 1925

Superfamily Conuloidea Lambert, 1911

Family Conulidae Lambert, 1911

Genus *Conulus* Leske, 1778

Type species: *Conulus albogalerus* Leske, 1778

Table 4. Quantitative description of the test shape variations in *Conulus douvillei*

	n=43	L	W	H	W/L	H/L	L <sub>ap</sub>	W <sub>ap</sub>	L <sub>I</sub>	L <sub>II</sub>	L <sub>III</sub>	L <sub>pc</sub>	W <sub>pc</sub>	L <sub>pr</sub>	W <sub>pr</sub>	W <sub>a</sub>	W <sub>i</sub>
<i>Conulus douvillei</i>	Range	18.8-38.3	17.1-33.7	12.5-26.4	0.86-0.91	0.64-0.76	2-3.5	2.2-3.7	12.7-29.1	11.6-28.1	12.3-28.3	4-7.7	3.8-6	3.8-6.9	3.3-6.5	2.7-5.3	7.5-15.7
	Mean	27.51	24.56	19.05	0.895	0.69	2.62	2.93	19.7	18.96	19.68	6.62	4.72	5.06	4.1	3.94	11.25

Diagnosis: Conulids with tetrabasal apical disc and pyrinoid adoral ambulacral plating.

Occurrence: Upper Jurassic (Oxfordian) to Lower Eocene, Europe, Russia, Central Asia, North Africa, Pakistan, Tibet and the Middle East.

Genus *Globator* Agassiz, 1840

Type species: *Globator nucleus* Agassiz, in Desor, 1842

Diagnosis: Conulids with central and tetrabasal apical disc with genital plates all in contact, ambulacra relatively narrow with uniserial pore-pairs aborally, wide interambulacra and subcentral, weakly to strongly oblique and a little depressed peristome.

Occurrence: Cretaceous (Aptian-Maastrichtian), America, Europe, North Africa, Middle East, India.

*Globator bleicheri* Gauthier, 1889

Plate 2, Figs. H- K

1889 *Pyrina bleicheri* Gauthier, p. 51, pl. 3 figs. 15-18.

1895 *Pyrina orientalis* Cotteau & Gauthier, p. 68, pl. XI, figs. 1-3.

1995 *Globator bleicheri* Smith, p. 186, pl. 20 figs. 1-10, text. figs. 46, 47, 47A, B, F-I, 48A. 2010. *Globator bleicheri* Balmaki et al., p. 2108, pl. 1, figs. 1a-1c.

Material: 34 well preserved and measurable specimens (DCSK Gb1-34), Kabir Kuh section, Seymareh Member, Gurpi Formation.

Measurement: In Table 5.

Diagnosis: The periproct is large and longitudinally elongate and the peristome is strongly oblique.

Description: The test is ovate longitudinally elongated, almost as tall as wide, with rounded margins and flattened adoral side. The apical disc is central, compact and tetrabasal with four genital pores. All genital plates are in contact together (genital 2 is the largest of the apical disc with hydropores in central part). The ambulacra are narrow and they hold uniserial pore-pairs aborally and ambitally that becoming offset in triads adorally. Ambulacral plating is pyrinoid. Periproct is large and marginal to supramarginal in position and longitudinally elongated and pointed in shape, adapically. Interambulacra are wide. Tuberculation consists of small uniform primary tubercles with slightly sunken areoles scattered over plates and a uniform, dense granulation in between. The

peristome is subcentral, ovate irregularly, strongly oblique and slightly depressed.

Remarks: Distinguished from the *Conulus* Leske, 1778, by having large and marginal periproct and strongly oblique peristome. *Pseudopyrina darderi* Lambert, 1935 has a taller test and a more cylindrical outline than *G. bleicheri*. The Lower Cretaceous species *Globator vionneti* Desor, 1857 (= *Conulopyrina anomala* Hawkins, 1921) differs from *G. bleicheri* only in being strongly developed phyllodes. The European species *Globator nucleus* Agassiz, in Desor, 1842, distinguished from *G. bleicheri* by having circular outline and hemispherical and higher aboral surface. *Nucleopyrina cylindrica* Gras, 1848, marked has a wider test and a less oblique peristome than *G. bleicheri*. In the Hauterivian species *Globator incisa* Agassiz in Desor, 1842, periproct is supramarginal and located on aboral surface and closer to apical disc than *G. bleicheri*.

Occurrence: Campanian of studied section., *G. bleicheri* is reported from the Maastrichtian deposits of the Simsim Formation in UAE and Oman (Ali, 1989; Smith, 1995 and Boukhary et al., 1999), and from the Campanian strata, Badra Formation, of Tunisia (Gauthier, 1889 and Gallemini & Abdallah, 2010).

Superorder Neognathostomata Smith, 1981

Order Cassiduloida Claus, 1880

Family Gitolampadidae

Genus *Parapygus* Pomel, 1883

Type species: *Botriopygus cotteauanus* d'Orbigny, 1856

(= *Pseudocatopygus* Cotteau & Gauthier 1895,

Type species: *Pseudocatopygus longior* Cotteau & Gauthier, 1895)

Diagnosis: Medium sized Cassiduloid with tetrabasal apical disc, short petals equally, longitudinally elongate periproct marginal, bourrelet with bulging walls near peristome and single pored phyllodes.

Remarks: *Pseudocatopygus* is a junior subjective synonym of *Parapygus* (Lambert & Thiery, 1909-1925, p. 352) and (Mortensen 1948, p. 143) considered that the *Pseudocatopygus longior* Cotteau & Gauthier, 1895, the type species to *Pseudocatopygus*, to be congeneric with *Parapygus cotteauanus* (d'Orbigny, 1856).

Table 5. Quantitative description of the test shape variations in *Globator bleicheri*.

	n=34	L	W	H	W/L	H/L	L <sub>ap</sub>	W <sub>ap</sub>	L <sub>I</sub>	L <sub>II</sub>	L <sub>III</sub>	L <sub>pc</sub>	W <sub>pc</sub>	L <sub>pr</sub>	W <sub>pr</sub>	W <sub>a</sub>	W <sub>i</sub>
<i>Globator bleicheri</i>	Range	14.9-31.1	12.8-26.9	10.1-20.5	0.85-0.91	0.63-0.74	1.8-2.7	2-2.8	9.0- 20	9.0- 19.8	9.5-20.9	4.4-7.6	2.9-5.2	4.3-7.2	3.3-5.1	2-4.5	5.2-11.8
	Mean	25.41	22	16.84	0.87	0.67	2.32	2.6	16.25	15.2	16	6.56	4.55	5.67	4.24	3.67	9.77

Occurrence: Upper Cretaceous (Senonian), Iran.

*Parapygus longior* (Cotteau & Gauthier, 1895)

Plate 3, Figs. K-O

1895 *Pseudocatopygus longior* Cotteau & Gauthier, p. 64, pl. X figs. 1- 4.

Material: 3 well preserved and measurable specimens (HD.15330a, HD.15331b & DCSK pl.1), Kabir Kuh section, Seymareh Member, Gurpi Formation.

Measurement: In Table 6.

Diagnosis: The periproct is marginal and longitudinally elongate. The petals are short and of equal lengths.

Description: The test is ovate in ambital outline, longitudinally elongated, almost as tall as wide, with rounded margins, and slightly flattened adorally. The apical disc is tetrabasal with 4 gonopores, and it is slightly anterior. The ambulacra are petaloids. Petals are short, equal in size, tapering distally but open and their pore-pairs are conjugate. Pores of the inner series are round and those of the outer series are slightly elongate (Fig. 10A). The interporiferous zones are wide and almost twice the width of poriferous zones. The poriferous zones in the same petal are equal in width. The periproct is small, marginal in position and longitudinally elongate (pointed adapically) (Fig.10). The peristome is pentagonal and positioned anteriorly. Phyllodes are short, single pored, wide and each half-ambulacrum has two

series of pores. The tuberculation includes crowded fine tubercles uniformly on upper and lower surfaces.

Remarks: Lambert & Thiery (1909-1925, p. 352) and Mortensen (1948, p. 143) considered *Pseudocatopygus longior* Cotteau & Gauthier, 1895 congeneric with *Parapygus cotteauanus* d'Orbigny 1856, thus synonymizing *Pseudocatopygus* as a junior subjective synonym of *Parapygus*. Kier (1962, p. 104) agreed with Mortensen's conclusion, despite that the phyllodes have fewer pores in *Pseudocatopygus longior*. Meanwhile the position of the periproct is also distinct, slightly inframarginal in *Parapygus*, and marginal in *Pseudocatopygus*.

*Parapygus declivis* Cotteau & Gauthier, 1895, differs from *P. longior* by having lower test, narrower poriferous zones, slightly larger periproct and with posterior paired petals longer than the anterior ones (in *P. longior* the posterior and anterior paired petals are equal in size).

Occurrence: Campanian of studied sections.

*Parapygus declivis* Cotteau & Gauthier, 1895

Plate 3, Figs. A-F

1895 *Pseudocatopygus declivis* Cotteau & Gauthier, p. 63, pl. IX, figs. 13-17.

1958 *Botriopygus declivis* de Renzy, p. 97, figs. 13-17.

Table 6. Quantitative description of the test shape variations in *Parapygus longior*

Taxa name/ Parameter	Sample No.	L	W	H	W/L	H/L	L <sub>I</sub>	L <sub>II</sub>	L <sub>III</sub>	L <sub>I</sub> /L <sub>II</sub>	L <sub>pr</sub>	W <sub>pr</sub>	L <sub>pc</sub>	W <sub>pc</sub>	L <sub>ap</sub>	W <sub>ap</sub>
<i>Parapygus cotteauanus</i>	DCSK PL1	31	24.7	19.2	0.79	0.62	-	8.1	-	-	-	-	3.9	2.3	-	-
	HD- 15331b	23.95	18.4	15.2	0.77	0.63	6.7	5.8	6.2	1.13	2.0	2.6	4.8	2.6	1.3	1.4
	HD- 15330a	24.05	18.3	14.8	0.76	0.62	6.7	5.9	6.0	1.15	-	-	-	-	1.3	1.3

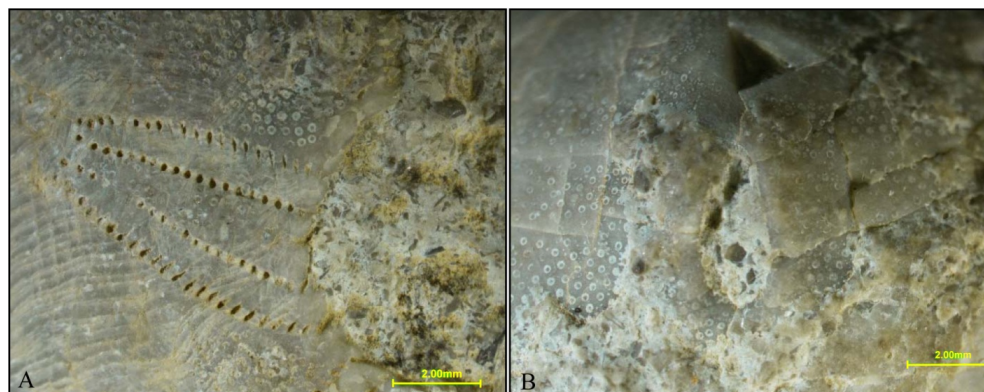


Figure 10. Ambulacra and periproct in *Parapygus longior*. A. Petal IV short and tapering distally with a wide poriferous zones with small pore-pairs. Pores of the inner series rounded and those of the outer series are slightly elongate., in specimen DCSKPL1; B. Periproct small, longitudinally ovate and marginally in position, specimen DCSKPL1.

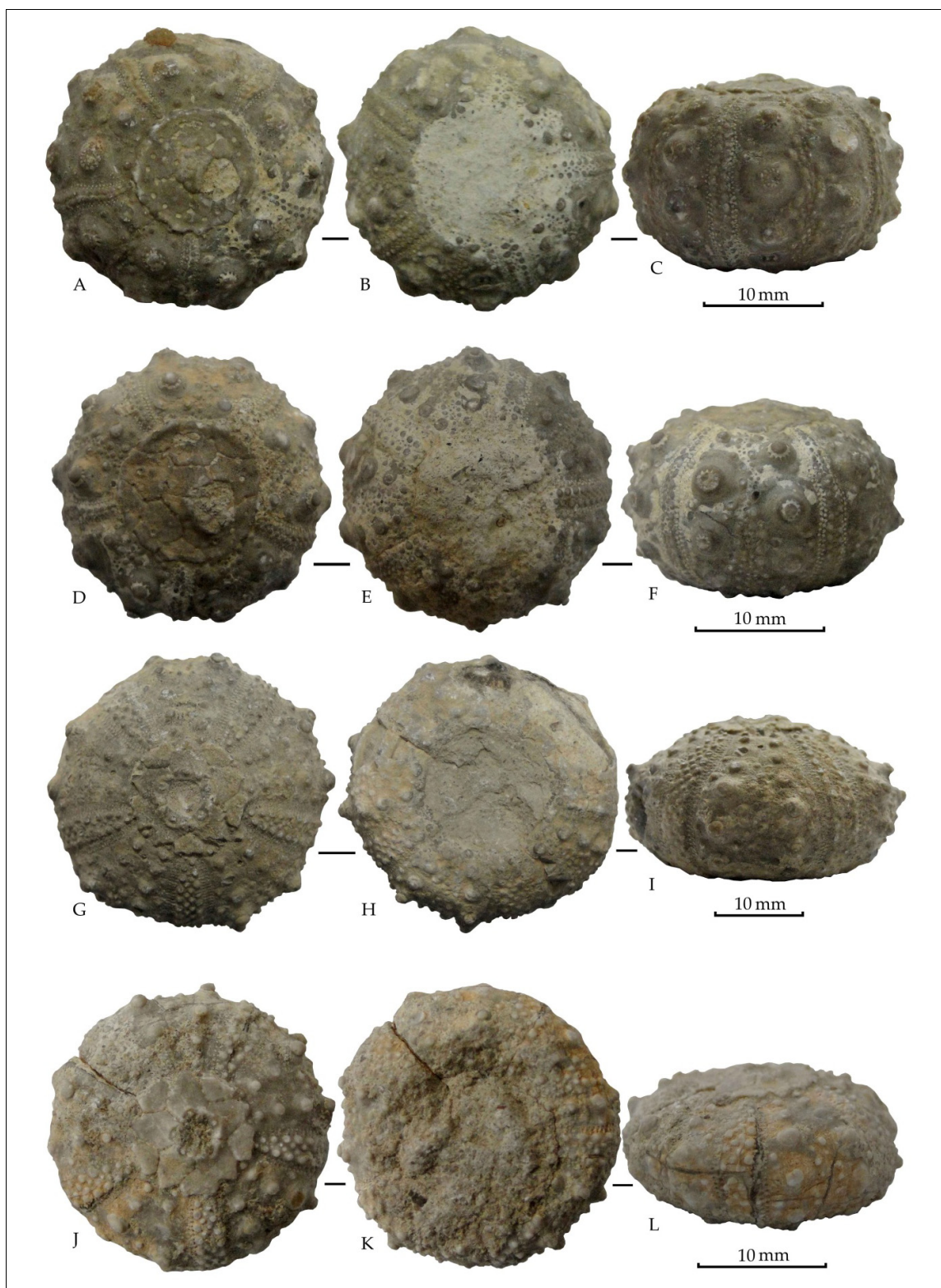


Plate 1. *Salenia (Salenia) nutrix*. A-C: specimen DSCK Sn-1; A: Apical view, B: Oral view, C: Lateral view. D-F: specimen DSCK Sn-2; D: Apical view, E: Oral view, F: Lateral view. *Goniopygus superbus*. G-I: specimen DSCK Gs-1; G: Apical view, H: Oral view, I: Lateral view. J-L: DSCK Gs-2; J: Apical view, K: Oral view, L: Lateral view.

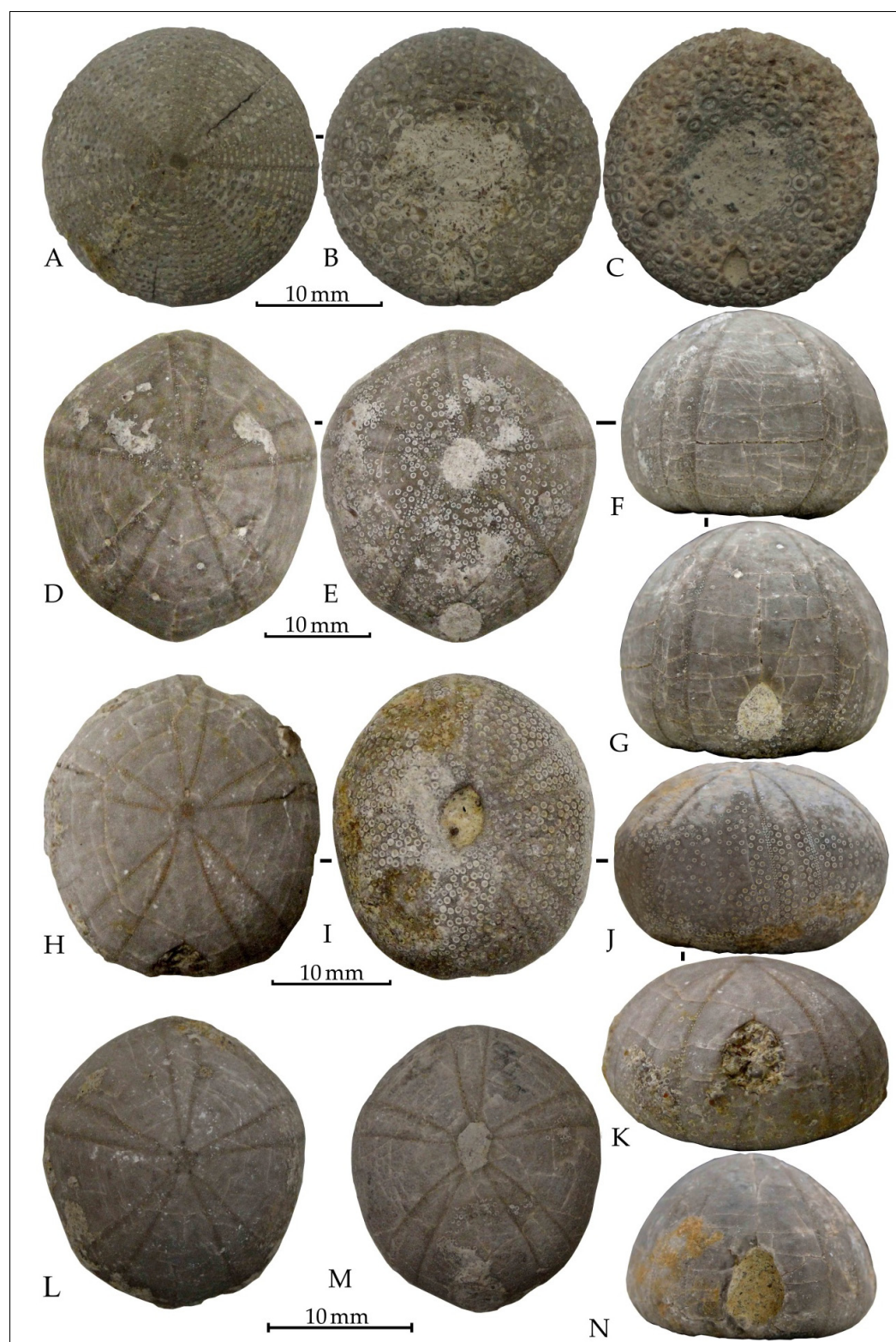


Plate 2. *Coptodiscus noemiae*. A-B: specimen DSCK Cn-1, A: Apical view, B: Oral view. C: specimen DSCK Cn-2, C: Oral view. *Conulus douvillei*. D-G: specimen DSCK Cd-2. D: Apical view, E: Oral view, F: Lateral view, G: Posterior view. L: specimen DSCK Cd-38, Apical view. M: specimen DSCK Cd-8, Oral view. N: specimen DSCK Cd-37, Posterior view. *Globator bleicheri*. H, K: specimen DSCK Gb-14; H: Apical view, K: Posterior view. I, J: specimen DSCK Gb-11; I: Oral view, J: Lateral view.



Plate 3. *Parapygus declivis*. A-C: specimen DCSK Pd-15331a; A: Apical view, B: Lateral view, C: Posterior view). D: specimen DCSK Pd-15331-a, Oral view. E-F: specimen DCSK Pd-1, E: Apical view, F: Lateral view. *Parapygus inflatus*. G-J: specimen DCSK Pi-15334a. G: Apical view, H: Oral view, I: Lateral view. *Parapygus longior*. K: specimen DCSK PL1; Apical view. L-O: DCSK PL-15330a; L: Apical view, M: Oral view, N: Lateral view, O: Posterior view. *Parapygus vassilini*. P-R: specimen DCSK Pv 15332-1; P: Apical view, Q: Oral view, R: Lateral view.

**Material:** 4 well preserved and measurable specimens (DCSK-Pd1&2; HD.15331a; HD.15330b), Kabir Kuh section, Seymareh Member, Gurpi Formation.

**Measurement:** In Table 7.

**Diagnosis:** In this species the periproct is marginal and ovate, elongated in the antero-posterior axis. The petals are short, slightly unequally (the posterior paired petals longer). Narrow poriferous and wide interporiferous zones in the petals.

**Description:** The test is ovate in shape, with rounded margins and slightly flattened adorally (weakly depressed toward peristome). The apical disc is tetrabasal, slightly anterior in position, compact with four genital pores. The genital 2 is the largest plate of the apical disc and forms the

madreporite (Fig. 11).

Petals are short and unequal in size, tapering but open distally (terminal part of each petal are parallel together). The pore pairs are conjugate. Inner series of pores are round and the outer series are slightly elongate (Figs. 12 A & B). The periproct is relatively large, positioned marginally, ovate elongated in the antero-posterior axis. Interambulacra are wide. Tuberculation consist of small uniform tubercles with slightly sunken areoles scattered over plates. The peristome is subcentral, slightly anteriorly placed, pentagonal in shape, depressed, slightly wider than long, with vertically walled margins. Phyllodes are single pored, parallel sided and slightly wide. Each half-ambulacrum has two series of pores (Figs. 13 A & B).

Table 7. Quantitative description of the test shape variations in *Parapygus declivis*

Taxa name/ Parameter	Sample No.	L	W	H	W/L	H/L	L <sub>i</sub>	L <sub>ii</sub>	L <sub>iii</sub>	L <sub>i</sub> /L <sub>ii</sub>	L <sub>pr</sub>	W <sub>pr</sub>	L <sub>pc</sub>	W <sub>pc</sub>	L <sub>ap</sub>	W <sub>ap</sub>
<i>Parapygus declivis</i>	DCSK-Pd1	28.9	24.2	14.3	0.84	0.49	10.2	9.1	8.8	1.12	-	-	4.6	2.8	2.3	2.0
	DCSK-Pd2	41.3	37.6	12.3	0.91	0.35	13.8	11.9	11.8	1.16	-	-	4.9	3	2.7	2.4
	HD- 15330b	29.67	24.57	17.04	0.88	0.57	9.45	9.19	7.49	1.168	3.95	4.31	3.83	1.77	2.22	1.98
	HD- 15331a	25.58	21.91	11.61	0.86	0.45	9.59	7.97	7.85	1.2	-	-	4.53	2.54	2.21	2.05

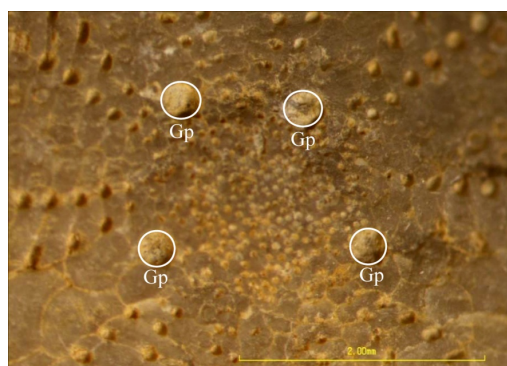


Figure 11. Apical disc in *Parapygus declivis*. Apical disc plating with four gonopores and large genital plate 2, specimen HD- 15331a (Gp: Genital pores).

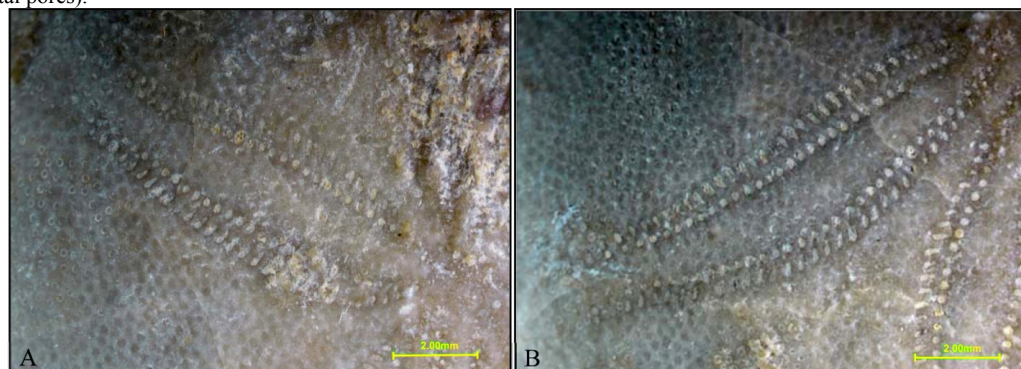


Figure 12. Petaloid ambulacra in *Parapygus declivis*. A. Anterior paired Petal IV short, tapering and open distally, with small pore-pairs. Pores of the inner series are round and those of the outer series are slightly elongate. There is a narrow poriferous zones and wide interporiferous zones, specimen DCSKPd1. B. Posterior paired Petal V short and open with small pore-pairs and wide interporiferous zones, specimen DCSKPd1.

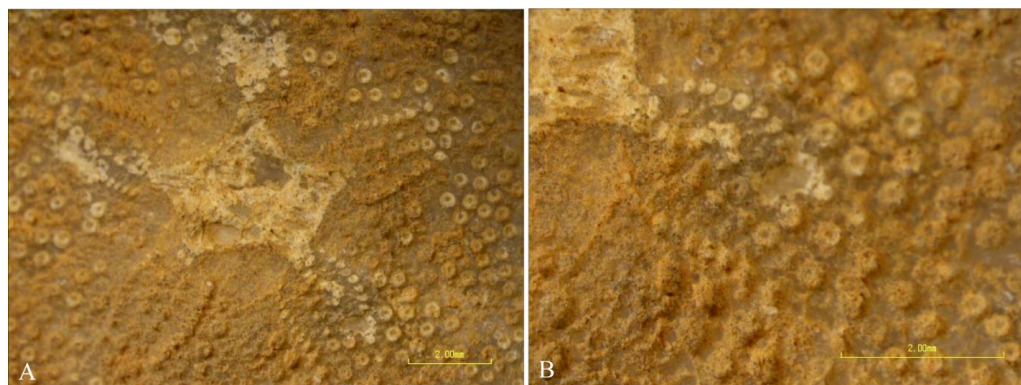


Figure 13. Phyllodes in *Parapygus declivis*. A. Parallel sided and wide phyllodes, specimen HD-15330b. B. Phyllode I with single pore and two series of pores in each half-ambulacrum, specimen HD-15330b.

Bourrelets are weak but distinct and buccal pores are present. Tuberculation includes uniform fine tubercles.

Remarks: *P. declivis* distinguishes from *P. longior* and *P. inflatus* by having lower test, narrower poriferous zones, slightly larger periproct and unequal paired petals. *Parapygus petalodes* Cotteau & Gauthier, 1895, differs from *P. declivis* by having the asymmetry in anterior and posterior columns of each petal in posterior paired petals. *Parapygus coquandi* Cotteau, 1866 from the Santonian deposits of Algeria, similar to *P. declivis* in shape and outline, is distinct in having equal paired petals.

Occurrence: Campanian of the Kabir Kuh section.

*Parapygus inflatus* Cotteau & Gauthier, 1895

Plate 3, Figs. G-J

1895 *Parapygus inflatus* Cotteau & Gauthier, p. 55, pl. VIII, figs. 6-9.

1958 *Botriopygus inflatus* de Renzy, p. 97, figs. 6-9.

Material: 1 well preserved and specimen (DSCK- Pi 15334a), from Kabir Kuh section.

Measurement: In Table 8.

Diagnosis: In this species, the apex is pointed and the greatest height is found at apical system. The anterior paired petals are shorter than the posterior ones and the posteriors are slightly diverging outwardly from the middle parts.

Description: Test is of moderate size, ovate in outline with rounded margins, and slightly pointing anteriorly. The test is inflated in profile, slightly convex and weakly depressed toward the peristome adorally. Apex pointed. Highest point positioned at the apical disc and widest point positioned at the posterior. Apical disc is tetrabasal and compact with four genital pores and slightly anterior in position. Adapically the ambulacra are petaloid. Petals are

flush, unequal in size and tapering distally, but open. The petals hold conjugate pore pairs. Inner series of pores are round, and pores of the outer series are elongate. The posterior paired petals are longer than the anterior ones. The anterior paired petals extending about 72% of the corresponding test radius and the posterior ones 76%. The anterior column of each posterior petals is bowed in the proximal part of the petal, and the inner column of each posterior petal are bowed in middle part of the petals. The anterior petal (III) and anterior paired petals (II & IV) are straight. The inner columns of petals are parallel sided and the outer ones are slightly bowed. Poriferous and interporiferous zones in posterior and anterior paired petals are equal in width. The periproct is ovate, elongated vertically, marginal, and positioned in the posterior face. The peristome is pentagonal, with vertical margins, and positioned centrally. Phyllodes are single pored, parallel sided, with two series of pores in each half-ambulacrum. The phyllode I and V longer than the others, the III being the shortest (Figs. 14 A & B). Tuberculation consist of fine uniform tubercles with weakly sunken areoles, that scattered over plates adoral and adapically. Bourrelets is distinct and moderately developed and buccal pores are present.

Remarks: *Parapygus inflatus* easily distinguished from the other species of *Parapygus* by having the pointed apex, a higher profile and more developed bourrelets.

Occurrence: This species found in the Campanian deposits of the Kabir Kuh section.

*Parapygus vassilini* Cotteau & Gauthier, 1895

Plate 3, Figs. P- R

1895 *Parapygus vassilini* Cotteau & Gauthier, p. 56, pl. VIII figs. 10-12.

Table 8. Quantitative description of the test shape variations in *Parapygus inflatus*

Taxa name/ Parameter	Sample No.	L	W	H	W/L	H/L	L <sub>I</sub>	L <sub>II</sub>	L <sub>III</sub>	L <sub>I</sub> /L <sub>II</sub>	L <sub>pr</sub>	W <sub>pr</sub>	L <sub>pc</sub>	W <sub>pc</sub>	L <sub>ap</sub>	W <sub>ap</sub>
<i>Parapygus inflatus</i>	DSCK- Pi 15334a	28.14	23.06	19	0.82	0.67	9.72	8.51	8.61	1.14	3.21	3.1	3.71	2.73	3.1	2.85

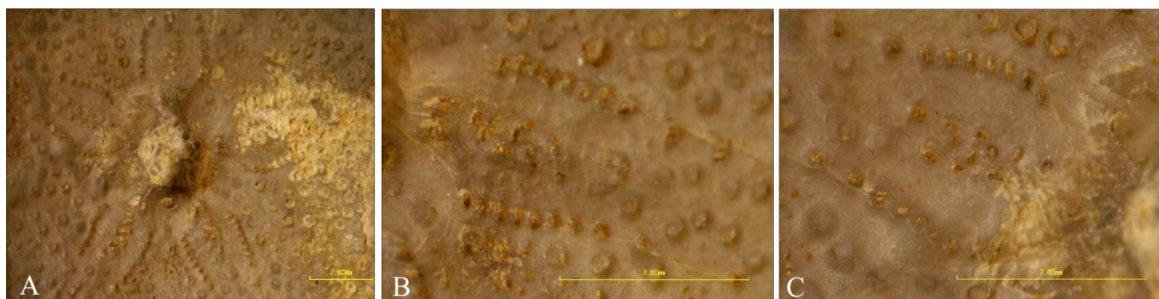


Figure 14. Phyllodes in *Parapygus inflatus*. A. Parallel sided, short and wide phyllodes, specimen DSCK- Pi 15334a. B. Phyllode I with single pore and two series of pores in each half-ambulacrum, specimen DSCK- Pi 15334a. C. Phyllode IV with single pore and two series of pores in each half-ambulacrum, specimen DSCK- Pi 15334a.

1958 *Botriopygus vassilini* de Renzy, p. 97, figs. 10-12.

Material: 3 well preserved and measurable specimens (DC SKPv-1, HD. 15332-1 & 2), from Kabir Kuh section.

Measurement: In Table 9.

Diagnosis: Test is of equal width and length. Anterior and posterior paired petals are equal in size. The anterior petal (III) is parallel sided and narrower than the other petals.

Description: Test is ovate in outline, with rounded margins, flattened aborally, and weakly depressed toward peristome adorally. Test is broad with its maximum width on the posterior side. The apical disc is tetrabasal, compact, lying towards the anterior and with four genital pores. The ambulacra are petaloid. The petals are relatively long, flush and equal in size. The anterior petal is narrow, straight with parallel sides, and is narrower than the other petals. Paired petals are straight, tapering distally but open. The pores of the inner series are round and those of the outer series are elongate. Poriferous zones are narrow. Interporiferous zones are wide and triple the width of poriferous zones. The periproct is ovate in shape and marginal in position (positioned on the posterior face). The peristome is pentagonal, with vertical-walled margins and positioned slightly anteriorly. Phyllodes are single pored with two series of pores in each half-ambulacrum. Phyllodes II, III and IV is short petaloid, I and V longer than the others and with parallel sided at the end parts (Figs. 15 A & B). Tuberculation includes fine tubercles with weakly sunken areoles uniformly scattered over

plates adorally and adapically. Bourrelets is weakly inflated but distinct and buccal pores are present.

Remarks: *Parapygus vassilini* differs from *P. declivis* and *P. longior* by having a wider test. *P. vassilini* and *P. inflatus* both have a broad test. *P. declivis* and *P. inflatus* have unequal paired petals (posterior paired petals longer than the anterior ones), but in *P. vassilini* anterior and posterior paired petals are similar in size. Also, *P. inflatus* has a pointed apex.

Occurrence: This species found in Campanian deposits of the Kabir Kuh section. *P. vassilini* also reported from Campanian deposits of Kabul block, Afghanistan (Montenat, 2009).

Family Echinolampadidae Gray, 1851

Genus *Vologesia* Cotteau & Gauthier, 1895

Type species: *Vologesia tataosi* Cotteau & Gauthier, 1895

Diagnosis: An Echinolampadid with Moderate to large sized test, ovate in outline and very flattened adorally. The apical disc is tetrabasal with four gonopores. Petals are long, subequal in size, open distally and broad. The periproct is inframarginal. There are well developed bourrelets and broad phyllodes.

Occurrence: Upper Cretaceous (Campanian-Maastrichtian), Iran, UAE and Oman.

*Vologesia tataosi* Cotteau & Gauthier, 1895

Plate 4, Figs. A- G

1895 *Vologesia tataosi* Cotteau & Gauthier, p. 66, pl. X, figs. 5-8.

1958 *Vologesia tataosi* de Renzy, p. 108, figs. 5-8

Table 9. Quantitative description of the test shape variations in *Parapygus vassilini*

Taxa name/ Parameter	Sample No.	L	W	H	W/L	H/L	L <sub>I</sub>	L <sub>II</sub>	L <sub>III</sub>	L <sub>I</sub> /L <sub>II</sub>	L <sub>pr</sub>	W <sub>pr</sub>	L <sub>pc</sub>	W <sub>pc</sub>	L <sub>ap</sub>	W <sub>ap</sub>
<i>Parapygus vassilini</i>	DC SKPv-1	35	31.2	-	0.89	-	10.9	11	11.1	0.99	3.6	3.7	5.2	2.9	-	-
	HD- 15332-1	35.2	30.7	18.1	0.87	0.51	10.92	11.08	11.2	0.985	-	-	-	-	2.1	2.2
	HD- 15332-2	34.4	30.17	17.5	0.87	0.51	11.92	12.05	14.51	0.99	4.41	4.6	-	-	2.7	2.8

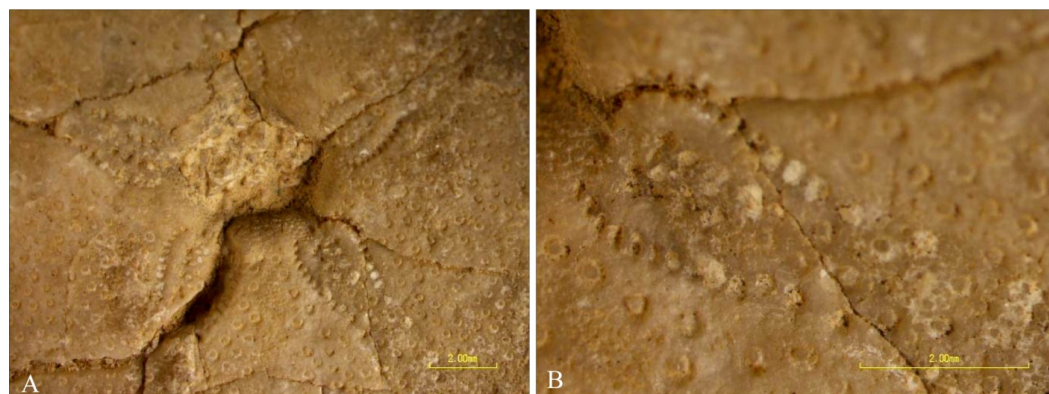


Figure 15. Peristome and phyllodes in *Parapygus vassilini*. A. Pentagonal peristome with vertical-walled margins. Phyllodes with parallel sides in its distal part, specimen HD-15332-2. B. Phyllode I with single pore and two series of pores in each half-ambulacrum, specimen HD-15332-2.

**Material:** 3 well preserved and measurable specimens (DCSK Vt-1; HD. 15333-1 & 2), from Kabir Kuh section, Seymareh Member, Gurpi Formation.

**Measurement:** In Table 10.

**Diagnosis:** This species has a flattened lower surface and a domed upper surface. The periproct located in margin of the oral surface. Bourrelets are not swollen and flush with the test.

**Description:** The test is moderate in size, ovate in outline, with rounded margins. It is domed aborally, very flattened adorally and slightly pointed posteriorly. The apical disc is tetrabasal, compact, with four genital pores and slightly anterior in position (Fig. 16 A). The genital 2 (madreporite) is larger than the other genitals. All of ambulacra are petaloid, subequal in length, and open distally (Fig. 16B). The pore columns of the anterior petal (III) are bowed equally. The posterior columns are more bowed than the anterior columns in the paired petals. Posterior paired petals are slightly longer than the anterior ones. Pore pairs are conjugate in the petals. The pores of the outer series are elongated transversely, slit-like, and those of the inner series of pores are rounded. Ambulacral plates beyond petals have single pores (Figs. 16 C & D).

The periproct lies inframarginally on the very posterior end of the test. It is ovate and elongated longitudinally. The peristome is pentagonal, transversely elongated, and lies anterior of the

center. Phyllodes are broad, single pored, with three series of pores in each half-ambulacrum. Bourrelets not swollen. Narrow and naked interradianal zones are present in oral surface between the peristome and the periproct.

**Remarks:** The Arabian species *Vologesia rawdahensis* Ali, 1989, is fairly similar to *V. tataosi* but it can be distinguished from test shape and petal development. *V. rawdahensis* is taller than the *V. tataosi*. The paired petals are asymmetrical in *V. rawdahensis*. The anterior column of anterior paired petals is straight and the posterior column are bowed. In the posterior paired petals, the anterior column of each petal are bowed and the posterior column are straight.

**Occurrence:** Campanian deposits of Kabir Kuh section.

Family Faujasiidae Lambert, 1905

Subfamily Faujasiinae Lambert, 1905

Genus *Pygurostoma* Cotteau & Gauthier, 1895

Type species: *Pygurostoma morgani* Cotteau & Gauthier, 1895

**Diagnosis:** A faujasiinae with moderate to large size, ovate in outline, elongate and low test. The test is slightly depressed towards the peristome, adorally. A tetrabasal apical disc with four gonopores. Petals are long and broad, the anterior and posterior pairs of equal length. Peristome is pentagonal.

Table 10. Quantitative description of the test shape variations in *Vologesia tataosi*

Taxa name/ Parameter	Sample No.	L	W	H	W/L	H/L	L <sub>I</sub>	L <sub>II</sub>	L <sub>III</sub>	W <sub>Pz</sub> /W <sub>Ipz</sub>	L <sub>pr</sub>	W <sub>pr</sub>	L <sub>pc</sub>	W <sub>pc</sub>	L <sub>ap</sub>	W <sub>ap</sub>
<i>Vologesia tataosi</i>	DCSKVt-15333-1	29.7	23.9	14.8	0.80	0.50	13.5	11.2	10.1	0.41	3.1	3.9	2.7	3.3	1.9	1.9
	DCSKVt-15333-2	23.5	20.5	10.6	0.87	0.45	9.7	8.0	7.1	0.33	2.7	3.5	-	-	1.3	1.4
	DCSKVt-1	24.4	21.0	13.2	0.86	0.54	10.8	8.4	8.1	0.42	-	-	2.7	2.3	1.5	1.6

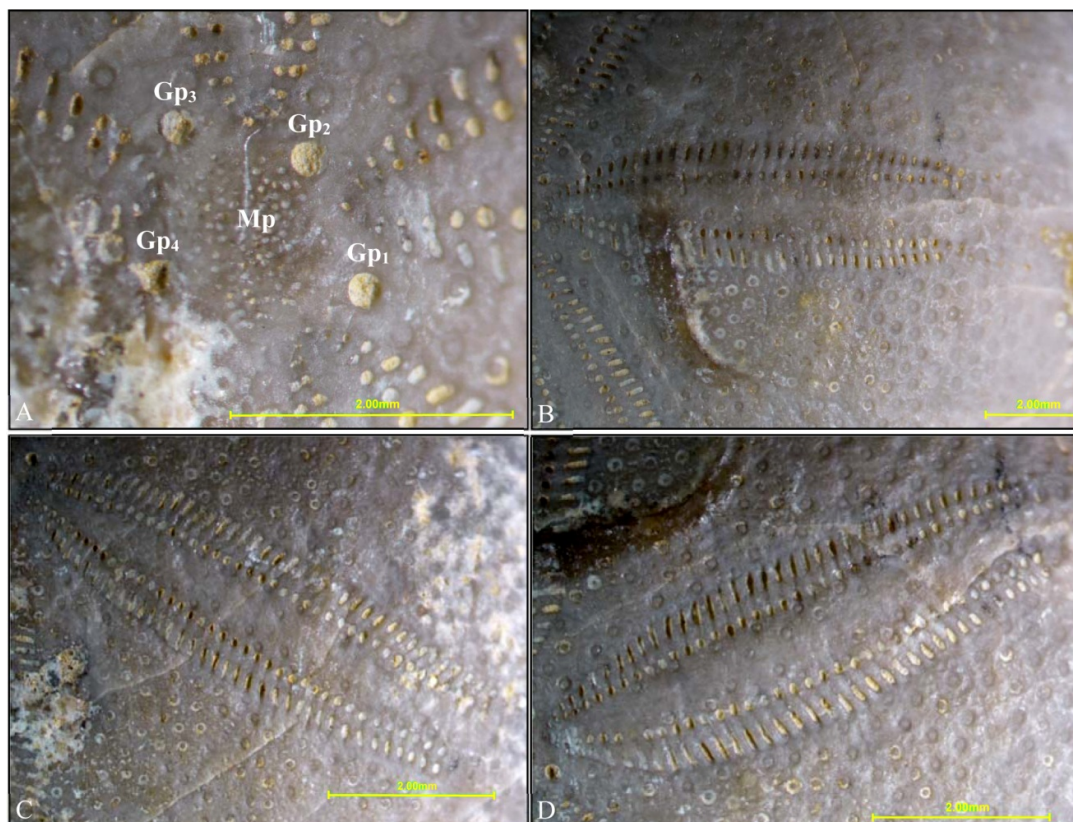


Figure 16. Apical disc and ambulacra in *Vologesia tataosi*. A. Apical disc plating with four gonopores, specimen DCSKVt1. B. Anterior petaloid ambulacrum III, in specimen DCSKVt1. C. Posterior paired petal I with narrow poriferous zones, wide interporiferous zones, small pore-pairs in inner series and elongate pore-pairs in outer series, specimen DCSKVt1. D. Anterior paired petal II, specimen DCSKVt1 (Gp: Genital pores, Mp: Madreporite).

Periproct is inframarginal and longitudinally elongated. Well developed bourrelets and broad phyllodes.

Occurrence: Upper Cretaceous (Senonian-Maastrichtian) of Iran, United Arab Emirates and possibly Central America.

*Pygurostoma morgani* Cotteau & Gauthier, 1895  
Plate 4, Figs. H-N

1895 *Pygurostoma morgani* Cotteau and Gauthier, p. 52, pl. VIII, figs. 1-5.

1958 *Pygurostoma morgani* de Renzy, J., p. 105, figs. 1-5.

1962 *Pygurostoma morgani* Kier, p. 135, Fig. 117, pl. 19, figs. 1-3.

1972 *Pygurostoma morgani* Kier, p. 73, pl. 46, figs. 1-4.

Material: 7 well-preserved and measurable specimens (DCSKPym1-4 & DCSKPym-13701, 15327a & b), from Kabir Kuh section, Seymareh Member, Gurpi Formation.

Measurement: In Table 11.

Diagnosis: This species has tooth-like and blunt bourrelets. Phyllodes broad with a distinct outer and inner series of pores in each half-ambulacrum, plus a broad space with scattered pores in between.

Description: The test is ovate and elongate in shape, and medium to large in size. Test is low with rounded margins. The greatest width of test positioned at the posterior. The apical system is

tetrabasal, compact, with four genital pores and becomes slightly eccentric towards the anterior part of the test (Fig. 17A).

All of ambulacra are petaloid. The petals are long, flush, slightly broad, tapering distally but not closed and equal to subequal in size. The interporiferous zones are slightly wider in petals II and IV than the others (Figs. 17B, C & D). The petals hold conjugate pore pairs but the ambulacral plates have single pores, beyond petals.

The periproct is ovate, elongated longitudinally in shape and is in a marginal- inframarginal position (Fig. 18A). The peristome is pentagonal, transverse. The phyllodes are broad with well-defined inner and outer series of pores in each half-ambulacrum,

several pores being scattered in between the series (Fig. 18B). There are blunt and tooth-like bourrelets and rudimentary and very small buccal pores (Figs. 18 C & D). Narrow and smooth tubercle-free granular zones are present on the oral surface.

Remarks: *Pygurostoma morgani* is very similar to *Pygurostoma passionensis* Cooke, 1949 from the Campanian of Guatemala, but it distinguishes mainly by the larger tubercles on the lower surface. *Pygurostoma passionensis* has a parallel, open-ended ended petals, such as the genus *Clypeolampas*. *Pygurostoma morgani* is distinct from other faujasiids due to densely pored phyllodes and differs from *Stigmatopygus* in position of periproct.

Table 11. Quantitative description of the test shape variations in *Pygurostoma morgani*

Taxa name/Parameter	Sample No.	L	W	H	W/L	H/L	L <sub>I</sub>	L <sub>II</sub>	L <sub>III</sub>	L <sub>I</sub> /L <sub>II</sub>	L <sub>pr</sub>	W <sub>pr</sub>	L <sub>pe</sub>	W <sub>pe</sub>	L <sub>ap</sub>	W <sub>ap</sub>
<i>Pygurostoma morgani</i>	DCSKPym-13701	43.6	40.1	20.2	0.92	0.46	18.1	14.2	16.7	1.27	4.0	4.8	-	-	2.8	2.8
	DCSKPym-15327a	43.3	36.4	-	0.84	-	18.2	14.8	17.6	1.23	-	-	5.1	3.4	3.0	3.1
	DCSKPym-15327b	44.5	34.9	20.1	0.78	0.45	-	14.1	15.6	-	3.0	4.1	-	-	2.8	2.9
	DCSKPym-1	63.4	52.9	21.2	0.83	0.33	21.3	21.1	21.3	1.01	4.4	4.9	5.4	3.6	3.7	3.5
	DCSKPym-2	60.4	-	18.9	-	0.31	22.5	18.5	22.4	1.22	-	-	7.3	4.2	3.8	3.5
	DCSKPym-3	52.1	42.2	-	0.81	-	18.8	14.3	15.4	1.31	-	-	-	-	2.7	2.5
	DCSKPym-4	54.2	46.3	13.5	0.85	0.25	19.5	17.4	18.3	1.12	3.6	4.3	4.9	2.9	3.1	3.2

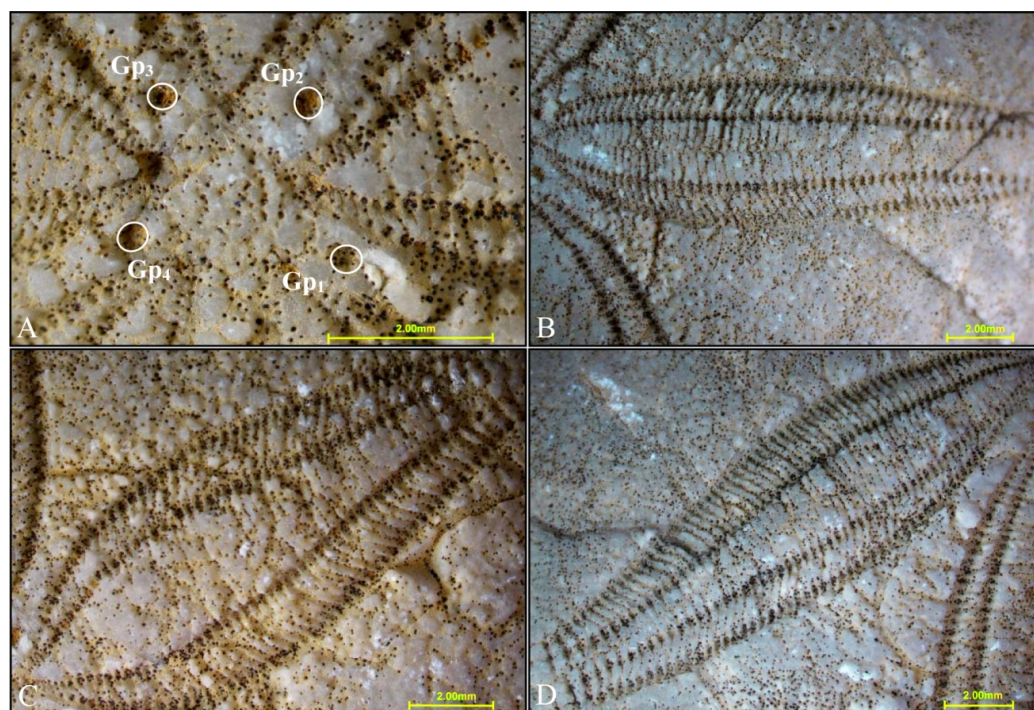


Figure 17. Apical disc and petals in *Pygurostoma morgani*, specimen DCSKPym-15327-1; A. Apical disc with four gonopores. B. Anterior petaloid ambulacrum III. C. Anterior paired petal II with small pore-pairs in inner series and elongate pore-pairs in outer series. D. Posterior paired petal V, (Gp: Genital pores).

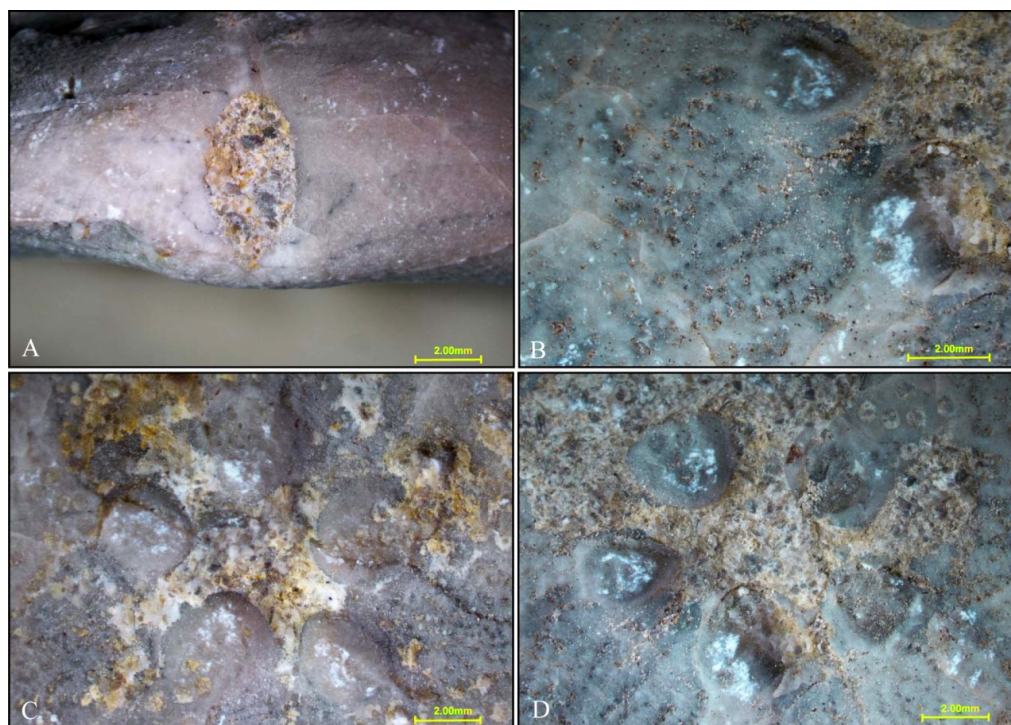


Figure 18. Periproct, Phyllode, and bourrelets in *Pygurostoma morgani*. A. Marginal and ovate periproct, specimen DCSKPym3. B. Phyllode V, specimen DCSKPym1. C, D. Bourrelets structure in specimens DCSKPym3 and DCSKPym1.

**Occurrence:** The species occurs in the Campanian of the studied sections. In Saudi Arabia it has been recorded from the Campanian strata of the Lower Aruma Formation (Kier, 1972). *P. morgani* is also reported from Maastrichtian strata, Simsim Formation, in Oman and UAE (Smith, 1995).

Order Holasteroida Durham & Melville, 1957

Family Hemipneustidae Lambert, 1917

Genus *Hemipneustes* Claus, 1876

Type species: *Spatangus striato-radiatus* Leske, 1778

**Diagnosis:** Moderate to large holasteroid with a domed-shape test, narrow anterior sulcus and long apical disc with four gonopores. The paired ambulacra rather strongly flexed and with columns markedly unequal. The periproct is inframarginal in position. There is no any fascioles.

**Occurrence:** Upper Cretaceous (Campanian-Maastrichtian), Europe, North Africa, Middle East, Iran and India.

Order Holasteroida Durham & Melville, 1957

Family Hemipneustidae Lambert, 1917

Genus *Hemipneustes* Claus, 1876

Type species: *Spatangus striato-radiatus* Leske, 1778

*Hemipneustes persicus* Cotteau & Gauthier, 1895

Plate 5, Figs. A-K

1895 *Hemipneustes persicus* Cotteau and Gauthier, p.15, pl. II, figs. 1-6.

1958 *Hemipneustes persicus* de Renzy, p 116, figs. 1-6.

2009 *Hemipneustes* cf. *persicus* Montenat, p. 186.

**Material:** 6 well preserved and measurable specimens (DCSK Hp1-3; BCSK Hp1-2 & DCSK Hm1), from studied section, Seymareh Member, Gurpi Formation.

**Measurement:** In Table 12.

**Diagnosis:** The test has an ovate outline and a deep anterior sulcus with sharp carina. The posterior face is weakly truncated and concave, so that periproct positioned at the formed depression. No fascioles present. In paired ambulacrum, the anterior columns of each half-ambulacrum consist of small and rounded pore pairs, and the posteriors ones consist of pore pairs with slit like and elongate pores in the outer series and less elongate pores in the inner series.

**Description:** Test is ovate in shape and moderate in size. Test profile is low, vaulted, with distinct anterior sulcus and sharp carina. The apical disc is central and long with four genital pores. (Fig. 19A).

Table 12. Quantitative description of the test shape variations in *Hemipneustes persicus*

Taxa name/Parameter	Sample no.	L	W	H	W/L	H/L	L <sub>I</sub>	L <sub>II</sub>	L <sub>III</sub>	L <sub>I</sub> /L <sub>II</sub>	L <sub>pr</sub>	W <sub>pr</sub>	L <sub>pc</sub>	W <sub>pc</sub>	L <sub>ap</sub>	W <sub>ap</sub>
<i>Hemipneustes persicus</i>	DCSK Hp1	39.6	34.2	19.2	0.86	0.48	14.3	18.6	11.5	0.77	4.1	8.6	7.8	7.1	5.4	2.9
	DCSK Hp2	50.2	43.7	21.8	0.87	0.43	16.6	23.6	-	0.70	4.8	-	-	-	5.8	3.0
	DCSK Hp3	75.8	64.7	30.1	0.85	0.40	25.6	33.1	-	0.77	-	-	14.3	7.6	-	-
	BCSK Hp1	67.2	56.4	26.8	0.84	0.40	23.2	31.0	19.2	0.75	-	-	12.2	6.5	6.5	3.6
	BCSK Hp2	70.1	62.5	30.2	0.89	0.43	24.1	32.2	19.5	0.75	-	-	-	-	6.6	3.5
	DCSK Hm1	35.0	33.8	15.2	0.97	0.43	9.1	14.9	15.6	0.61	-	-	9.9	7.8	4.3	2.4

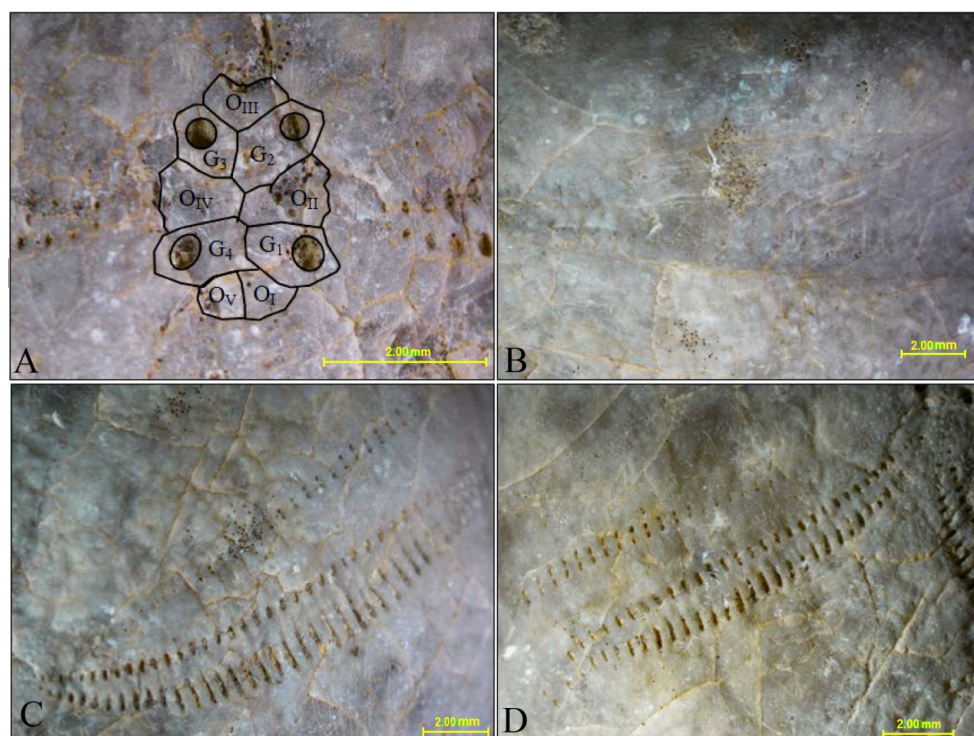


Figure 19. Apical disc and ambulacral plating in *Hemipneustes persicus*. A. Apical disc plating, specimen DCSK Hp1. B. Anterior ambulacrum III with simple, small and rudimentary pore pairs, specimen DCSK Hp1. C. Anterior paired petal II with unequal columns, pore pairs in posterior columns are elongate whereas they are small or rudimentary in the anterior columns, specimen DCSK Hp1. D. Posterior paired petal V with unequal columns, specimen DCSK Hp1. (G: Genital plate, O: Ocular plate).

Paired petals are strongly flexed in the apical region and become rather straight on the lateral sides of the test. The posterior paired ambulacra are diverging posteriorly to form an angle of grossly 90°. Paired ambulacra have markedly unequal columns. The pore pairs of the posterior columns are conjugate and elongate, whereas those of the anterior columns are small or rudimentary, especially in upper surface (Figs. 19 C & D).

The anterior sulcus is continuous from apex to peristome. The peristome is covered by the labral plate, partially. The periproct is ovate in shape, and is marginal in position. It situated at concave part of the posterior, slightly truncated face. The peristome is transversally elongated, and positioned anteriorly. Remarks: *H. striatoradiatus* Leske, 1778, differs

from *H. persicus* in a more rounded outline and a hemispherical upper surface. *H. pyrenaicus* Hebert, 1875 distinguishes from *H. persicus* by a more heart shaped outline, a narrower frontal groove, and a subconical upper surface. *H. arabicus* Ali, 1989 differs from *H. persicus* in a higher test, a narrower frontal groove and a slightly posterior apex. The European specis *H. oculatus* Cotteau, 1892, distinguished from *H. persicus* by a highly conical upper surface, a deeper anterior sulcus and a slightly posterior apex.

Occurrence: This species occurs in the Campanian of the studied sections. *H. persicus* is also Reported from Maastrichtian strata, Simsim Formation, Oman and UAE (Smith, 1995) and Senonian deposits of Belouch range, Kabul block,

Afghanistan (Montenat, 2009).

Order Spatangoida Claus, 1876

Suborder Hemiasterina Fischer, 1966

Family Somaliasteridae Wagner & Durham, 1966

Genus *Iraniaster* Cotteau & Gauthier, 1895

Type species: *Iraniaster morgani* Cotteau & Gauthier, 1895

(=*Somaliaster* Hawkins, 1935, Type species: *Somaliaster magniventer* Hawkins, 1920)

Diagnosis: A hemiasterina with ovate test and distinct anterior sulcus. The apical disc is ethmophract with four gonopores. The petals are weakly depressed. The periproct is marginal in position. There is distinct peripetalous fascioles. In plastron, labral plate separated from sternal plate by the second ambulacral plates.

Occurrence: Upper Cretaceous (Campanian-Maastrichtian), East Africa, Middle East, Iran.

Remark: *Iraniaster* shares with other Somaliasteridae a discontinuous plastron plating. The plastron plating is continuous in *Somaliaster* Hawkins, 1935 but the two genera are considered as synonym. The apical disc of *Iraniaster* exhibits 4 gonopores, whereas there are only two gonopores on the posterior genital

plates in *Leviechinus* and *brightonia*.

*Iraniaster douvillei* Cotteau & Gauthier, 1895

Plate 6, Figs. A-G

1895 *Iraniaster douvillei* Cotteau and Gauthier, p. 30, pl. V, figs 1-6.

1935 *Somaliaster magniventer* Hawkins, p. 53, text-figs. 8-14, pl. 7, figs 2-3.

1999. *Iraniaster douvillei* Jeffery, p 1030, text-fig. 3. Material: 22 well preserved and measurable specimens (DCSK SD1-10; DCSK SPn1-4; DCSK SCn1-6 & DCSKPv-15341-1 & 2), from Kabir Kuh section, Seymareh Member, Gurpi Formation.

Measurement: In Table 13.

Diagnosis: The test is ovate with a very shallow sulcus, inflated aborally and slightly convex adorally. Paired ambulacra are petaloid and flush with the test. Interporiferous zones are slightly sunken.

Description: Test is ovate in shape and medium in size. The test is inflated aborally, slightly convex adorally (raised plastron), and without marked frontal depression. There is only a very shallow sulcus near the ambitus. The apical system is ethmophract and compact.

Table 13. Quantitative description of the test shape variations in *Iraniaster douvillei*

Taxa name/Parameter	Sample no.	L	W	H	W/L	H/L	LI	LII	LIII	LI/LII	Lpr	Wpr	Lpc	Wpc	Lap	Wap
<i>Iraniaster douvillei</i>	DCSKPv-15341-1	38.5	34.2	27.2	0.89	0.71	16.2	16.4	13.1	0.98	2.7	3.3	4.5	4.6	2.6	2.3
	DCSKPv-15341-2	30.8	28.4	21.4	0.92	0.69	14.8	14.5	12.1	1.02	2.8	3.1	3.7	3.9	2.0	2.0
	DCSK SD1	35.6	33.1	24.2	0.93	0.68	12.3	13.7	12	0.90	3.6	5.9	4.6	4.9	2.4	2.5
	DCSK SD2	48.9	45.9	31.2	0.94	0.64	22.2	25.3	19.2	0.88	-	-	4.8	-	2.2	2.5
	DCSK SD3	32.9	29.6	21.6	0.90	0.66	13.3	13.8	10.4	0.96	2.6	3.7	4	4.6	1.7	2
	DCSK SD4	42.3	38.1	29.1	0.90	0.69	14.7	15.3	13.7	0.96	3.3	4.4	-	-	2.6	2.8
	DCSK SD5	38	34.9	27	0.92	0.71	13.8	16.1	-	0.86	2.6	-	3.9	4.4	2.3	2.6
	DCSK SD6	36.9	34.1	26.3	0.92	0.71	15.1	16.1	14.6	0.94	3.7	4.4	5	5.2	2.2	2.5
	DCSK SD7	38.4	34.7	23.5	0.90	0.61	14.3	14.8	14.1	0.97	-	-	4.7	4.8	2.8	3.0
	DCSK SD8	39.5	36.4	25	0.92	0.63	14.6	16.8	12.3	0.87	3.9	4.5	4.8	4.5	3.2	3.4
	DCSK SD9	37.1	33.6	26.5	0.91	0.71	14.8	16.1	13.4	0.92	4.3	5.8	3.8	-	2.8	3.1
	DCSK SD10	-	34.2	26.8	-	-	13.5	15.3	-	0.88	2.9	3.7	-	-	2.1	2.3
	DCSK SPn 1	37.9	33.8	21.6	0.89	0.57	13.0	14.7	14.2	0.88	4.8	5.0	3.3	-	2.4	2.7
	DCSK SPn 2	36.3	32.8	20.3	0.90	0.56	14.1	14.5	13.2	0.97	5.0	5.1	3.5	4.5	2.8	3.0
	DCSK SPn 3	32.1	29.5	20.6	0.92	0.64	12.6	13.3	-	0.95	-	-	3.6	3.9	2.7	2.9
	DCSK SPn 4	41.0	37.8	22.1	0.92	0.54	16.8	17.6	16.9	0.95	4.9	4.9	-	-	2.7	3.0
	DCSK SCn 1	39.6	38.3	24.4	0.97	0.62	14.3	14.8	13.8	0.96	3.3	4.8	3.7	3.8	2.7	3.0
	DCSK SCn 2	39.5	38.6	25.7	0.98	0.65	15.5	15.8	14.5	0.98	-	-	-	-	2.5	2.9
	DCSK SCn 3	43.9	41.2	27.3	0.94	0.62	17.4	17.7	18.3	0.98	-	-	4.8	4.0	2.6	3.0
	DCSK SCn 4	36.7	35.9	21.0	0.98	0.57	13.0	13.2	-	0.98	3.4	4.5	5.2	3.7	2.6	2.8
	DCSK SCn 5	38.8	37.6	25.5	0.97	0.66	14.2	15.2	15.6	0.93	-	-	7.0	5.4	2.4	2.7
	DCSK SCn 6	47.3	44.9	25.0	0.95	-	16.9	17.4	-	0.97	3.0	3.9	-	-	2.3	2.9

It is central in position, with four gonopores. Genital plate 2 separates the posterior genital plates (Figs. 20 A & B).

The anterior ambulacrum weakly depressed. It holds minute size and rounded pore-pairs that arranged in single series (Figs. 21 A & B). The peristome is small, circular and close to anterior margin. The periproct is subcircular in shape, relatively large in size and positioned on short posterior truncated face. The peripetalous fasciole present and passes around the base of the petals. The labral plate is small and longitudinally

elongated and has a broad contact with a single sternal plate.

Remarks: *Iraniaster douvillei* is similar to *Iraniaster morgani* Cotteau & Gauthier, 1895, but distinguished by having a broad contact between the labral plate and a sternal plate (in *Iraniaster morgani*, labral plate are usually separated from sternal plate by the second ambulacral plates). *Somaliaster magniventer* var. *Checchiai* Maccagno, 1941, may be distinct from *I. douvillei* because of a lower test and sunken paired petals.

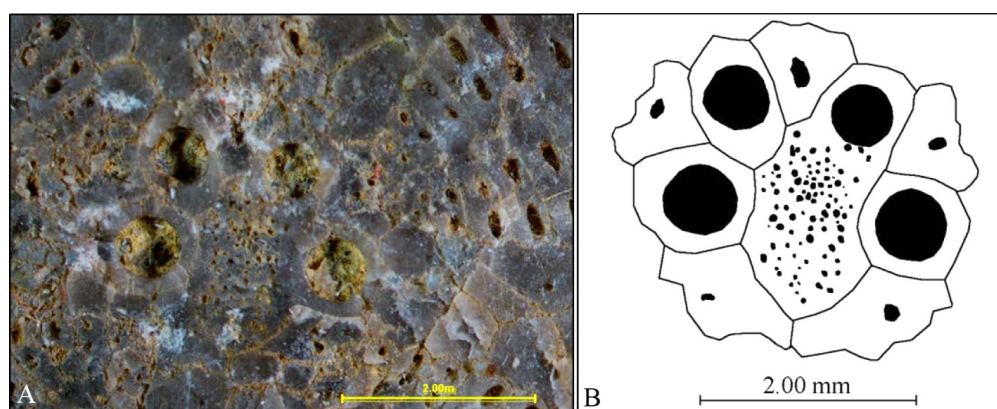


Figure 20. Apical disc plating in *Iraniaster douvillei*. A. Apical disc plating with four gonopores, specimen DCSKSD4. B. Camera lucida drawing from Apical disc plating in specimen DCSKSD4.

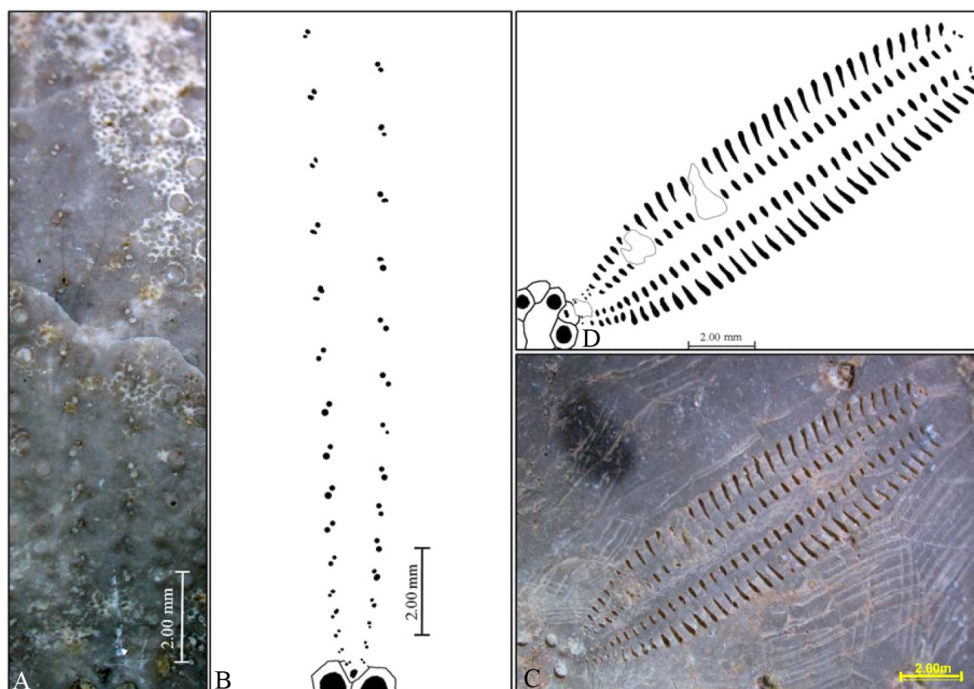


Figure 21. Anterior ambulacrum and anterior paired petal in *Iraniaster douvillei*. A. Anterior ambulacrum III, specimen DCSKSD7. B. Camera lucida drawing of anterior ambulacrum III, specimen DCSKSD7. C. Anterior paired petal II; outer series of pore pairs are slit like and wider than the inner series, specimen DCSKSD7. D. Camera lucida drawing of anterior paired petal II, specimen DCSKSD7.

Occurrence: Campanian of the studied sections. Also *I. douvillei* is reported from the Senonian strata of Somalia (Hawkins, 1935; Maccagno, 1941).

*Iraniaster morgani* Cotteau & Gauthier, 1895

Plate 6, Figs. H-N

1895 *Iraniaster morgani* Cotteau and Gauthier, p. 28, pl. IV, figs. 1-12.

1999 *Iraniaster morgani* Jeffery, p 1030, text- fig. 2, pl. 1, figs. 1-3.

Material: 9 well preserved and measurable specimens (HD.Ir.mg.15297-302 & HD.Ir.mg.15303-1 & 2, HD.Ir.mg. 6304), from study section, Seymareh Member, Gurpi Formation.

Measurement: In Table 14.

Diagnosis: A somaliasterid with ovate shape, a distinct anterior sulcus and a short, truncated, posterior face. The anterior ambulacrum is weakly depressed and pore pairs are minute size and arranged in single series. The paired petals are

weakly depressed. Plastron plating is discontinuous, with a small labral plate separated from sternal plate by the third ambulacral plates.

Description: The test is ovate in outline, vaulted in profile and weakly convex adorally. There is a distinct sulcus in anterior face and a short truncated part in posterior face. The apical disc is compact, ethmophract with four gonopores and is central in position (Figs. 22 A & B).

The anterior ambulacrum weakly depressed from apex to peristome. Pores are minute size and arranged in single series (Figs. 23 A & B). The paired ambulacra are petaloid. The petals are straight and slightly sunken. They are open distally, with narrow interporiferous zones and extending most of the way to the ambitus. The outer series of pore pairs are slit like and wider than the pores of the inner series (Figs. 23 C & D).

The peristome is subcircular and close to anterior margin, and facing towards the frontal groove.

Table 14. Quantitative description of the test shape variations in *Iraniaster morgani*

Taxa name/ Parameter	Sample No.	L	W	H	L/H	W/H	LI	LII	LIII	LI/ LII	Lpr	Wpr	Lpc	Wpc	Lap	Wap
<i>Iraniaster morgani</i>	HD.Ir.mg.15297	52.1	48.9	33.1	1.07	1.48	25.4	25.8	22.3	0.98	4.1	4.6	4.5	6.0	3.2	3.0
	HD.Ir.mg.15298	64.4	57	-	1.13	-	25.4	25.6	22.4	0.99	-	-	4.2	5.8	4.1	31
	HD.Ir.mg.15299	53.2	50.3	31.9	1.06	1.58	22.1	24.6	19.7	0.9	4	4.8	5.1	5.3	3.5	3.2
	HD.Ir.mg.15300	48.6	46.1	30.3	1.05	1.52	23.2	23.8	21	0.97	4	4.4	4.6	4.2	3.1	2.9
	HD.Ir.mg.15301	47.1	42.8	21.8	1.10	1.96	18.5	19.7	18.3	0.94	-	-	3	-	3.0	2.6
	HD.Ir.mg.15302	70.6	65.2	34	1.08	1.92	28	29.1	27.2	0.96	-	-	5.8	6.9	4.3	4.0
	HD.Ir.mg.15303-1	43.2	40.3	24.9	1.07	1.62	18.1	18.9	16.3	0.96	4.6	4.9	4.2	4.5	2.8	2.6
	HD.Ir.mg.15303-2	35.2	31.4	21.4	1.12	1.47	14.1	14.6	13.5	0.96	3	3.1	3.7	4.1	2.4	2.2
	HD.Ir.mg.6304	40.7	38.4	23.2	1.06	1.66	17.3	18.2	16.7	0.95	2.7	2.8	3.4	3.3	2.6	2.4

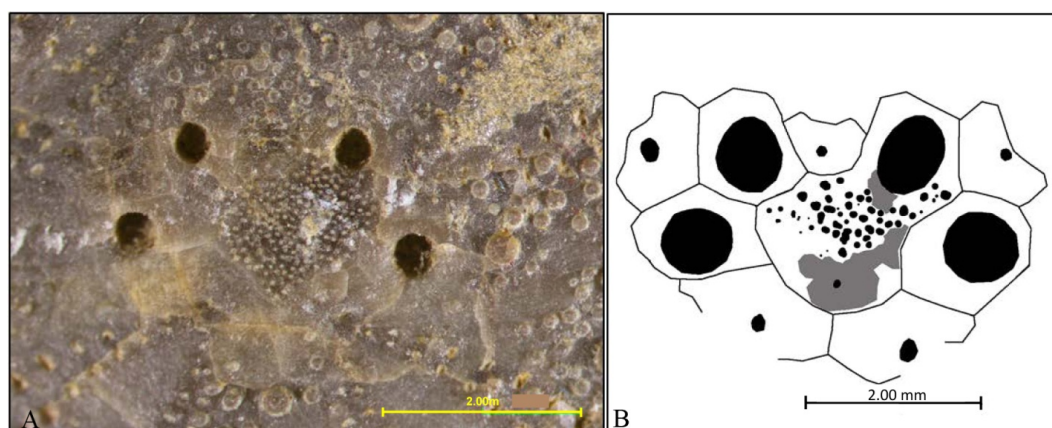


Figure 22. Apical disc in *Iraniaster morgani*. A. Apical disc plating with four gonopores, specimen HD. Ir.mg.15303-1. B. Camera lucida drawing of apical disc, specimen HD.Ir.mg.15301.

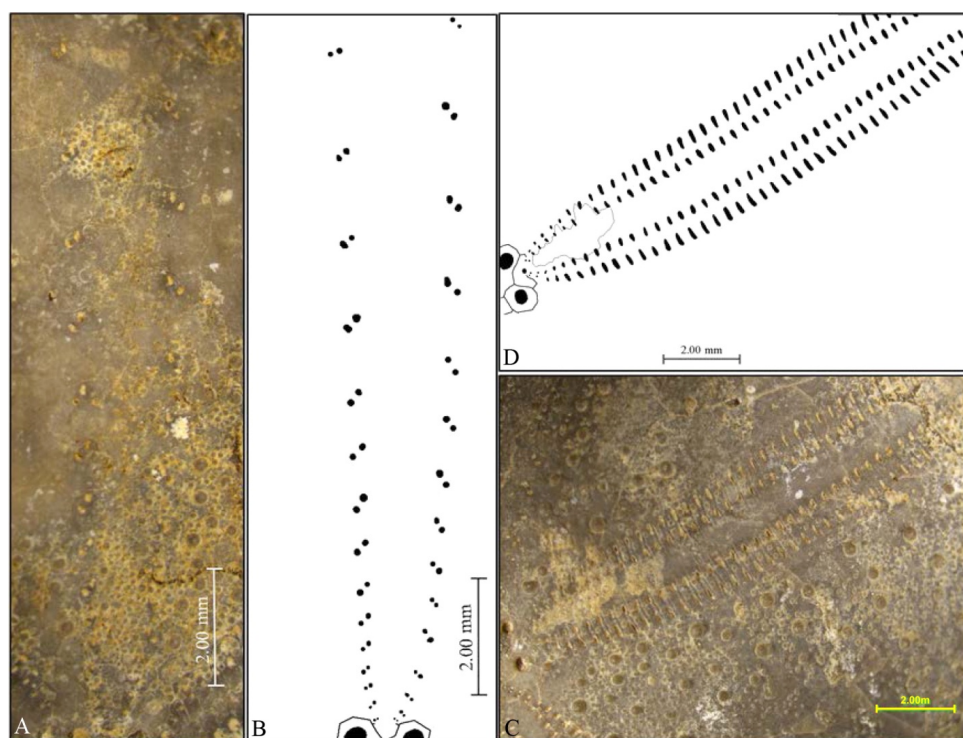


Figure 23. Anterior ambulacrum and anterior paired petal II in *Iraniaster morgani*. A. Anterior ambulacrum III, specimen HD.Ir.mg.15301. B. Camera lucida drawing from Anterior ambulacrum III, specimen HD.Ir.mg.15301. C. Anterior paired petal II; pore of the outer series are slit like and wider than those of the inner series, specimen HD.Ir.mg.15303-1. D. Camera lucida from Anterior paired petal II, specimen HD.Ir.mg.15303-1.

The periproct is circular or weakly oval in out; inner, marginal, and located on short, posterior, truncated face. Peripetalous fasciole is present.

The labral plate is small, elongated longitudinally, extending to the third ambulacral plate that separated the labral from sternal plate 5. b. 2. The sternal plate 5.b.2 is larger and anterior to the plate 5. a. 2. Episternal plates arranged biserially.

Remarks: *Iraniaster morgani* differs from the Arabian species *Iraniaster affinemorgani* Kier, 1972, *Iraniaster bowersi* Kier, 1972 and *Iraniaster affinidouvillei* Kier, 1972 by having less sunken paired petals, and longer and straighter posterior paired petals. The aboral surface of *I. bowersi* is subconical in profile.

Occurrence: It is found from the Campanian deposits (Seymareh Member) of Kabir Kuh section.

*Iraniaster nodulosus* Gauthier, 1902

Plate 6, Figs O-R

1902 *Iraniaster nodulosus* Gauthier, p. 122, pl. XVIII figs. 4-5.

1958 *Iraniaster nodulosus* de Renzy, p. 21, figs. 4-5.

1999 *Iraniaster nodulosus* Jeffery, p. 1029.

Material: One specimen well preserved and

measurable specimens (DCSK IN1), from Kabir Kuh section, Seymareh Member, Gurpi Formation.

Measurement: In Table 15.

Diagnosis: Test is ovate to subquadrate with very wide, and shallow anterior sulcus. Posterior face short, truncated. Anterior ambulacrum is weakly depressed. Pore pairs are minute size and arranged in single series. Paired petals are weakly depressed. Description: The test is ovate to subquadrate in outline, weakly convex adoral and adapically with a shallow and wide anterior sulcus, and a short truncate at posterior face. Length and width of the test are about equal. The apical disc is ethmophract, with four genital pores and positioned centrally (Fig. 24A). Anterior ambulacrum weakly but continuously depressed from apex to peristome. Pore-pairs are minute size and arranged in single series (Fig. 24B).

The paired petals are straight, slightly sunken and and with narrow interporiferous zones. It is open distally and extending most of the way to the ambitus. The pores of the outer series are slit like and wider than the inner series. The anterior paired petals are slightly longer than the posterior ones (Figs. 24 C & D).

Table 15. Quantitative description of the test shape variations in *Iraniaster nodulosus*

Taxa name/Parameter	Sample no.	L	W	H	W/L	H/L	L <sub>I</sub>	L <sub>II</sub>	L <sub>III</sub>	L <sub>I</sub> /L <sub>II</sub>	L <sub>pr</sub>	W <sub>pr</sub>	L <sub>pc</sub>	W <sub>pc</sub>	L <sub>ap</sub>	W <sub>ap</sub>
<i>Iraniaster nodulosus</i>	DCSK IN1	41.3	41.1	23.7	0.99	0.57	15.7	17.5	15.3	0.89	2.7	3.5	-	-	2.7	3.1

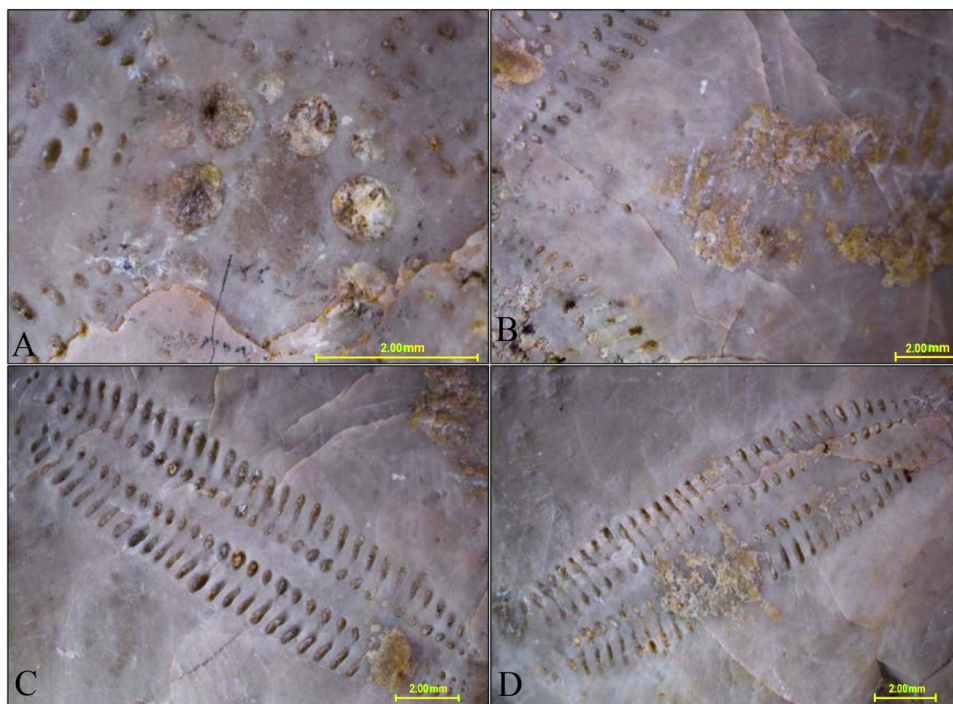


Figure 24. Apical disc and ambulacra plating in *Iraniaster nodulosus*. A. Apical disc with 4 gonopores, specimen DCSK IN1. B. Anterior ambulacrum III, specimen DCSK IN1. C. Anterior paired petal IV; pores of the outer series are slit like and wider than those of the inner series, specimen DCSK IN1. D. Posterior paired petal (V), in specimen DCSK IN1.

The peristome is located close to anterior margin, subcircular in shape and facing towards frontal groove. The periproct and plastron plating is unknown. Peripetalous fasciole is present.

Remarks: *Iraniaster nodulosus* distinguishes from the other species of *Iraniaster* by having transversly ovate to subquadrate outline and a wide, shallow anterior sulcus.

Occurrence: Seymareh Member, Campanian strata of the Kabir Kuh section.

Family Hemiasteridae H. L. Clark, 1917

Genus *Hemiaster* Desor, in Agassiz & Desor, 1847

Type species: *Spatangus bufo* Brongniart, 1822

Diagnosis: Hemiasterina with ovate outline and weak distinct anterior sulcus. Apical disc is ethmophract with four gonopores and positioned centrally. Petals are depressed and closing distally. Anterior petals are around twice the length of posterior petals. Periproct is marginal in position and high on posterior truncate face. There is a peripetalous fasciole and the peristome is D-shape.

Occurrence: Albian to Late Cretaceous (Campanian-Maastrichtian), Worldwide.

*Hemiaster noemiae* Cotteau & Gauthier, 1895

Plate 7, Figs. A-H

1895 *Hemiaster noemiae* Cotteau and Gauthier, p. 35, pl. VI, figs. 1-7.

1902 *Hemiaster noemiae* var. *Gulgulensis* Gauthier, p. 140, pl. XIX, figs. 8-9.

1958 *Hemiaster noemiae* de Renzy, p. 134, figs. 2-4.

2012 *Hemiaster noemiae* Balmaki *et al.*, p. 22, pl. 1, figs. 2a-2c.

Material: 6 preserved and measurable specimens (DCSKHn1, 2 & 3, DCSK Hn-15354-1&2, DCSK Hn-15356-1), from studied section, Seymareh Member, Gurpi Formation.

Measurement: In Table 16.

Diagnosis: A relatively moderate *Hemiaster* with an ovate outline and distinct anterior sulcus. Apical disc plating is ethmophract. Paired petals are aslightly sunken and the anteriors are about twice as long as the posterior ones. A thin peripetalous

fasciole is present. Some nodular swelling scattered on test aborally.

Description: The test is mostly medium in size, ovate in outline vaulted aborally and slightly convex adorally (plastron raised). A distinct anterior sulcus, and a short truncate posterior face are differentiated. The highest point of test is positioned posteriorly, the test looks wedge shaped in lateral profile.

The apical disc is ethmophract, compact, with four gonopores and positioned centrally. Gonopores 1 and 4 larger than 2 and 3 (Figs. 25A).

The frontal ambulacrum is weakly but rather distinctly sunken from apex to peristome and forms a shallow but distinct notch at the anterior margin. The pore pairs of the frontal ambulacrum are

enlarged and two pores of each pore-pairs are separated by a prominent interpore knob (Fig. 25 B). The paired petals are sunken, bowed and near to closed distally. The posterior petals are about 1/2 the length of anterior ones (53 to 58%). The pores are large, and equal in width (Figs 25 C & D).

The peristome is D shaped, slightly sunken and facing the anterior side and opens about 1/4 of the test length from the anterior margin. The periproct is small, circular to slightly ovate in outline, and lies towards the top of the steeply sloping posterior face. Peripetalous fasciole is well defined but slightly narrow. Aboral tuberculation consists of the fine, dense and not sunken tubercles. Some scattered nodular are swelling on test aborally.

Table 16. Quantitative description of the test shape variations in *Hemiasiter noemiae*.

Taxa name/Parameter	Sample No.	L	W	H	W/L	H/L	L <sub>I</sub>	L <sub>II</sub>	L <sub>III</sub>	L <sub>I</sub> /L <sub>II</sub>	L <sub>pr</sub>	W <sub>pr</sub>	L <sub>pc</sub>	W <sub>pc</sub>	L <sub>ap</sub>	W <sub>ap</sub>
<i>Hemiasiter noemiae</i>	DCSKHn-15354-1	30.5	27.2	20.4	0.89	0.67	5.3	9.1	11.9	0.58	-	-	-	-	2.2	2.3
	DCSKHn-15354-2	28.3	25.3	19.1	0.89	0.67	6.1	11.2	12.2	0.54	2.9	3.4	4.1	3.4	2.0	2.2
	DCSKHn-15356-1	39.7	35.3	25.9	0.89	0.65	-	-	15.8	-	3.4	4.3	3.5	3.1	-	-
	DCSKHn-1	32.9	29.7	21.6	0.90	0.66	6.4	12.1	13.9	0.53	3.1	3.2	3.9	3.1	2.4	-
	DCSKHn-2	34.3	30.1	-	0.88	-	5.6	10.1	13.2	0.55	-	-	-	-	2.3	2.3
	DCSKHn-3	30.0	26.1	19.7	0.87	0.66	6.0	10.7	12.8	0.56	-	-	3.3	2.7	2.4	2.5

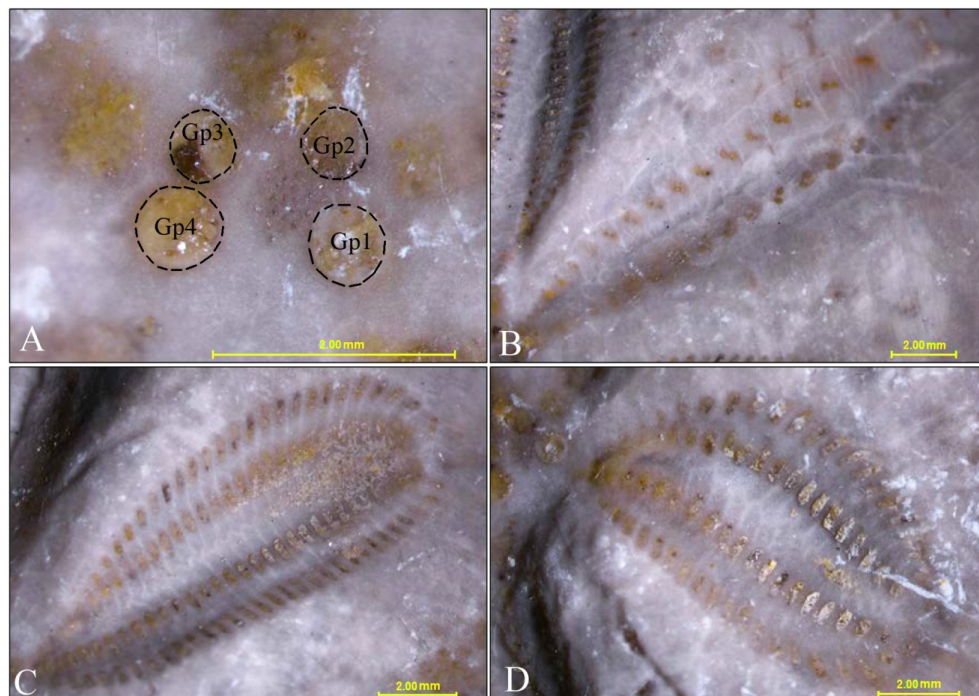


Figure 25. Apical disc and ambulacra plating in *Hemiasiter noemiae*. A. Apical disc with 4 gonopores, specimen DCSKHn-1. B. Anterior ambulacrum III, specimen DCSKHn-1. C. Anterior paired petal IV, with slightly wide pore pairs and equal in width, in specimen DCSKHn-1; D. Posterior paired petal (I), in specimen DCSKHn-1. (Gp: Gonopore or Genital pores).



Plate 4. *Vologesia tataosi*. A-D: specimen DCSK Vt-15333-1; A: Apical view, B: Oral view, C & D: Lateral view. E-G: specimen DCSK Cn-1; E: Apical view, F: Oral view, G: Lateral view. *Pygurostoma morgani*. H-J: DCSK Pym-1; H: Apical view, I: Oral view, J: Lateral view. K: specimen DCSKPym-15327-1; Apical view. L-N: specimen DCSKPym-4; L: Oral view, M: Apical view, N: Lateral.



Plate 5. *Hemipneustes persicus*. A-D: specimen DCSKHm1; A: Apical view, B: Oral view, C: Lateral view, D: Posterior view. E-H: DCSKHp1; E: Apical view, F: Oral view, G: Lateral view, H: Anterior view. I-J: BCSK Hp2; I: Apical view, J: Oral view. K: BCSK Hp1; K: Apical view. *Epiaster lamberti*. L-O: DCSKEL 15351; L: Apical view, M: Oral view, N: Lateral view, O: Anterior view.



Plate 6. *Iraniaster douvillei*. A-D: specimen DCSKpV-15341-1; A: Apical view, B: Oral view, C: Lateral view, D: Posterior view. E-G: specimen DCSK SPn1; E: Apical view, F: Oral view, G: Lateral view. *Iraniaster morgani*. H-L: specimen HD.Ir.mg.15300; H: Apical view, I: Oral view, J: Lateral view, K: Anterior view, L: Posterior view. M-N: specimen HD.Ir.mg.15301; M: Apical view, N: Oral view. *Iraniaster nodulosus*. O-R: specimen DCSK IN1; O: Apical view, P: Oral view, Q: Anterior view, R: Lateral view.

Remarks: *Hemiaster noemiae* distinguishes from *H. opimus* Cotteau & Gauthier, 1895 and *H. bufo* Brongniart 1822, by having an ovate outline (in *H. opimus* and *H. bufo* outline is more circular). It differs from the Iranian species *Mecaster longus* Cotteau & Gauthier, 1895, by having a lower profile and an ethmophract apical disc. The African species *Hemiaster forbesii* Bailey, 1855, distinguished from *H. noemiae* by having heart shaped outline and more sunken and wider anterior ambulacrum and paired petals. The European species (related to Cenomanian) *H. morrissi* Woodward, 1856, distinguished from *H. noemiae* by having more circular outline and an apical disc shifted posteriorly.

Occurrence: *Hemiaster noemiae* is known from the Campanian deposits of the studied section. Also, *Hemiaster noemiae* is known from Senonian deposits of Afghanistan, Beloutch range, Kabul block (Montenat, 2009).

*Hemiaster opimus* Cotteau and Gauthier, 1895

Plate 7, Figs. I-Q

1895 *Hemiaster opimus* Cotteau and Gauthier, p. 38, pl. VI, figs. 8-11.

1958 *Hemiaster opimus* de Renzy, p. 134, figs. 8-11.

2009 *Hemiaster opimus* Montenat, p. 177.

Material: 5 well preserved and measurable specimens (DCSKHo-15355-1&2; DCSKH0-15356-2; DCSKH0-1 &2), from studied section, Seymareh Member, Gurpi Formation.

Measurement: In Table 17.

Diagnosis: *Hemiaster opimus* has a rounded or circular outline, with shallow but distinct anterior sulcus. Posterior paired petals are shorter and about 2/3 of the anterior ones.

Description: The test is circular in outline, wedge shaped in profile and with a distinct and slightly shallow anterior sulcus but there is no distinct frontal notch and in some specimen there is a shallow indentation at the anterior. Test is vaulted aborally and slightly flattened adorally. It has a

short truncated and steeply sloping posterior face. The highest point of test positioned at the posterior.

The apical disc is compact, ethmophract, with four gonopores and located centrally. Anterior ambulacrum slightly sunken adapically. In each pore pairs of the anterior ambulacrum, the two pores are separated by a interporal knob. The paired petals sunken, slightly bowed and near to closed distally. Posterior petals are about 2/3 the length of posterior petals (62 to 67%). Pore pairs are large and equal in width. The paired petals end at the fasciole abruptly.

The peristome is D shaped, slightly sunken, facing the anterior side and opens approximately 1/4 of the test length from the anterior ambitus. The periproct is small, ovate and situated at top of posterior truncated face. The narrow peripetalous fasciole is present. Aboral tuberculation consist of the fine, dense and not sunken tubercles.

Remarks: *H. opimus* easily distinguishes from other species of *Hemiaster* found in Upper Cretaceous series of Iran by having a more circular outline. *H. noemiae* differs from *H. opimus* by having ovate outline. The overall shape of *Hemiaster opimus* is fairly similar to *Hemiaster bufo* Brongniart, 1822, *H. stella* Morton, 1834 and *H. parastatus* Morton, 1833. It differs from *H. bufo* by having slightly shallower petals, lower aboral face and a more central position of the apical disc. *H. stella* distinguished from *H. opimus* by having shorter posterior paired petals and deeper paired petals and anterior ambulacrum. *H. parastatus* differs from *H. opimus* by having wider and shorter paired petals.

Occurrence: The species occurs commonly in the Campanian deposits (Seymareh Member) of studied section. This species is recorded also from the Campanian deposits of Afghanistan, Kabul block (Montenat, 2009).

Genus *Mecaster* Pomel, 1883

Type species: *Hemiasterourneli* Agassiz & Desor 1847.

Table 17. Quantitative description of the test shape variations in *Hemiaster opimus*

Taxa name/Parameter	Sample No.	L	W	H	W/L	H/L	L <sub>i</sub>	L <sub>ii</sub>	L <sub>iii</sub>	L <sub>i</sub> /L <sub>ii</sub>	L <sub>pr</sub>	W <sub>pr</sub>	L <sub>pe</sub>	W <sub>pe</sub>	L <sub>ap</sub>	W <sub>ap</sub>
<i>Hemiaster opimus</i>	DCSKHo-15356-2	33.6	33.4	25.1	0.99	0.75	-	-	-	-	2.8	3.8	3.5	2.9	-	-
	DCSKHo-1	36.5	35.6	27.6	0.98	0.76	7.9	12.8	14.4	0.62	-	-	3.7	2.6	2.3	2.8
	DCSKHo-2	30.2	29.3	21.9	0.97	0.73	6.1	11.4	12.9	0.63	-	-	-	-	-	-
	DCSKHo-15355-1	21.1	20.6	15.3	0.98	0.73	-	-	10.0	-	1.5	2.7	2.3	2.0	-	-
	DCSKHo-15355-2	20.8	20.1	14.8	0.97	0.71	3.5	5.8	8.9	0.67	1.4	2.6	2.8	2.0	1.7	2.1



Plate 7. *Hemiaster noemiae*. A-D: specimen DCSKHn-15354-1; A: Apical view, B: Oral view, C: Lateral view, D: Posterior view. E-H: specimen DCSKHn-15354-1; E: Apical view, F: Oral view, G: Lateral view, H: Anterior view. *Hemiaster opimus*. I-M: specimen DCSKHo-15355-2; I: Apical view, J: Oral view, K: Lateral view, L: Posterior view, M: Anterior view. N-Q: specimen DCSKHo-1; N: Apical view, O: Oral view, P: Posterior view, Q: Anterior view.

Diagnosis: Hemiasterina with an ovate test, a distinct anterior sulcus, a central apical disc with four gonopores, and a semi-ethmolytic to ethmolytic structure. The petals are sunken and closed distally. The posterior petals are about half to two-thirds length of anterior petals. The periproct is marginal and located at the top of a posterior truncated face. Peripetalous fasciole is present. Peristome is pentagonal.

Occurrence: Cretaceous (Late Cenomanian to Maastrichtian), Europe, former SSU, Africa, North and South America and Middle East.

*Mecaster kanepanensis* Cotteau & Gauthier, 1895  
Plate 8, Figs. A-H

1895 *Hemiaster kanepanensis* Cotteau and Gauthier, p. 133, pl XIX, figs. 5-6

1958 *Hemiaster kanepanensis* de Renzy, p. 134, figs. 5-6.

Material: 4 well preserved and measurable specimens (DCSK Mk1-4), from studied section, Seymareh Member, Gurpi Formation.

Measurement: In Table 18.

Diagnosis: *Mecaster kanepanensis* has an ovate outline, semiethmolytic apical disc and with distinct anterior sulcus. Paired petals are long, open distally and sunken. Anterior and posterior paired petals are about equal in length. It has a distinct horizontal

sulcus at anterior of test adorally (along the peristome).

Description: The test is ovate in outline with distinct anterior sulcus. The test is short truncate in posterior face, vaulted aborally and flattened adorally. The apical disc is semiethmolytic, with four gonopores, compact and becomes slightly eccentric towards the anterior part of the test, (Fig. 26A). The anterior ambulacrum sunken from apex to peristome (deepest aborally) and pore pairs are rounded, small and arranged slightly oblique and have a prominent interporal partition (Fig. 26B). The paired ambulacra are petaloid. The petals are deeply sunken, slightly straight and open distally. The posterior and anterior paired petals are about equally in length. Pore pairs are slightly wide and equal in width. The peristome is about pentagonal transversely, slightly sunken, towards anterior boarder and opens approximately 20% of the test length from the anterior margin. There is a distinct horizontal sulcus along the peristome to ambitus. The periproct is slightly large, ovate longitudinally (pointed adapically) and situated at posterior truncate face. Peripetalous fasciole is present.

Remarks: It differs from *Mecaster longus* Cotteau & Gauthier, 1895, by having a wider test and with paired petals equally in length.

Table 18. Quantitative description of the test shape variations in *Mecaster kanepanensis*.

Taxa name/Parameter	Sample No.	L	W	H	W/L	H/L	L <sub>I</sub>	L <sub>II</sub>	L <sub>III</sub>	L <sub>I</sub> /L <sub>II</sub>	L <sub>pr</sub>	W <sub>pr</sub>	L <sub>pc</sub>	W <sub>pc</sub>	L <sub>ap</sub>	W <sub>ap</sub>
<i>Mecaster kanepanensis</i>	DCSK Mk1	56.5	50.4	29	0.89	0.51	24.0	23.8	17.9	1.008	5.7	10.6	8.6	5.3	2.6	2.7
	DCSK Mk2	56.0	50.2	25.6	0.90	0.46	22.5	22.2	16.5	1.013	5.6	9.3	9.5	-	2.7	2.9
	DCSK M k3	59.6	-	27.3	-	0.46	25.3	25.1	17.3	1.007	-	-	-	-	3.0	3.2
	DCSK M k4	58.9	51.9	28.5	0.88	0.48	22.6	22.9	-	0.986	5.8	-	9.6	-	-	-

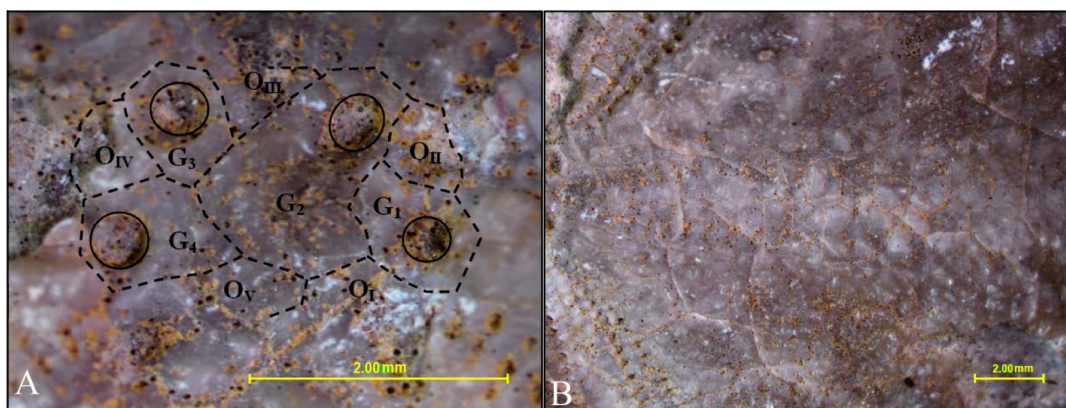


Figure 26. Apical disc and ambulacra plating in *Mecaster kanepanensis*. A. Semiethmolytic apical disc with 4 gonopores, specimen DCSK Mk2. B. Anterior ambulacrum III, in specimen DCSK Mk2. (G: Genital plate, O: Ocular plate).

*M. cubicus* Desor, in Agassiz and Desor, 1847, and *M.ourneli* Agassiz & Desor, 1847, distinguished from *M. kanepanensis* by having the higher test and with flexed paired petals (anterior paired petals flexed anteriorly and the posterior paired flexed posteriorly), also *M.ourneli* has ethmolytic apical disc. *M.ourneli*, *M. syriacus* Conrad in Lynch 1852, *M. batnensis* Coquand, 1862 and *M. gabrielis* Peron & Gauthier, 1878 have unequal petals (posterior paired petals shorter than the anterior). In the Algerian species *M. obliquetruncatus* Peron & Gauthier, 1880, the posterior petals longer than the anteriors, apical disc positioned anterior to center and poriferous and interporiferous zones in paired petals and interporiferous zone in anterior ambulacrum wider than the *M. kanepanensis*.

Occurrence: It found from the Campanian deposits (Seymareh Member) of studied sections.

*Mecaster longus* Cotteau & Gauthier, 1895

Plate 8, Figs. I-O

1895 *Hemiaster longus* Cotteau and Gauthier, p. 40, pl. VII, figs. 1-5.

1958 *Hemiaster longus* de Renzy, p. 134, figs. 1-5.

Material: 4 well preserved and measurable

specimens (DCSK ML1-3 and DCSKMI-15347), from Kabir Kuh section, Seymareh Member, Gurpi Formation.

Measurement: In Table 19.

Diagnosis: *Mecaster longus* has an elongate outline, and a semiethmolytic apical disc. The labral plate is short and subquadrate. There is a well defined peripetalous fasciole.

Description: Test is ovate, elongated longitudinally, vaulted aborally and weakly convex adorally. It has a distinct anterior sulcus. Posterior face is short truncated. The apical disc is semiethmolytic, compact, centrally in position, with four gonopores and the genital plate 2 separating the posterior genital plates but not the posterior ocular plates (Fig. 27).

The anterior ambulacrum is sunken from the apex to the peristome. The pore-pairs are partitioned by a prominent interporal ridge. The paired petals are deeply sunken, bowed proximally, closed distally and posterior petals about half to two-thirds the length of the anterior petals. The peristome is pentagonal and located close to the anterior margin. The periproct is ovate in shape, small in size and situated at the top of truncated posterior face. The peripetalous fasciole is present.

Table 19. Quantitative description of the test shape variations in *Mecaster longus*.

Taxa name/Parameter	Sample No.	L	W	H	W/L	H/L	L <sub>I</sub>	L <sub>II</sub>	L <sub>III</sub>	L <sub>I</sub> /L <sub>II</sub>	L <sub>pr</sub>	W <sub>pr</sub>	L <sub>pc</sub>	W <sub>pc</sub>	L <sub>ap</sub>	W <sub>ap</sub>
<i>Mecaster longus</i>	DCSKMI-15347	33.4	28.1	24.4	0.84	0.73	7.4	12.6	14.2	0.587	3.3	3.6	4.0	2.5	1.6	1.7
	DCSKMI-1	39.3	30.2	22.9	0.77	0.58	7.7	13.1	16.7	0.587	-	-	-	-	1.9	2.1
	DCSKMI-2	31.95	24.9	16.8	0.78	0.53	5.4	11.1	13.8	0.51	2.9	-	3.6	2.2	-	-
	DCSKMI-3	35.7	28.1	20.6	0.79	0.58	-	12.5	15.7	-	-	-	-	-	1.8	2.0

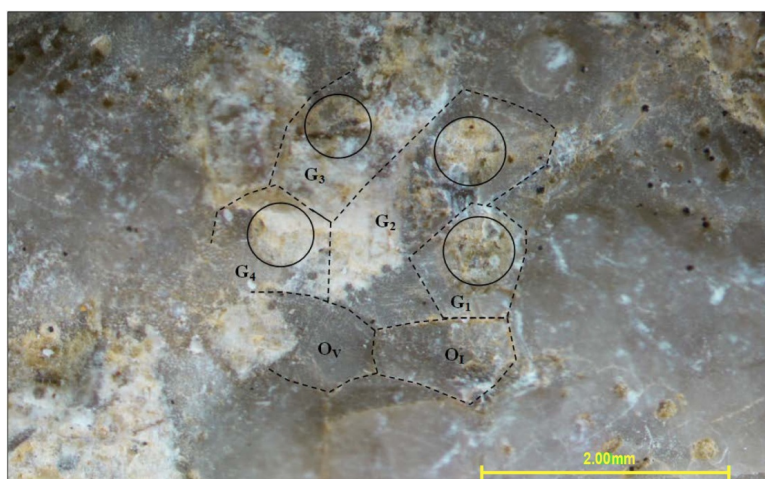


Figure 27. Apical disc and ambulacra plating in *Mecaster longus*. A. Semiethmolytic apical disc with 4 gonopores, specimen DCSK MI1. (G: Genital plate, O: Ocular plate).

Remarks: *M. longus* differs from typical *Hemiaster* and *Mecaster* by its elongated shape, its semi-ethmolytic apical disc, and its short, subquadrate labral plate.

Occurrence: The species was found in the Seymareh Member of Kabir Kuh section, of Campanian age.

Genus *Proraster* Lambert, 1895

(=*Sanfilippaster* Checchia-Rispoli, 1932, p. 313; Type species: *Proraster geayi* Cottreau, 1908)

Type species: *Proraster geayi* Cottreau, 1908

Diagnosis: Hemiasterina with low and ovate test. Very deep distinct anterior sulcus. Apical disc is semiethmolytic with four gonopores and positioned posteriorly. Ambulacrum III is deeply sunken aborally. Petals are sunken strongly assymetrical. Periproct is marginal, and positioned at the posterior truncate face. Peripetalous fascioles. Peristome close to anterior border.

Remarks: The deeply sunken frontal groove and flexed anterior petals make *Proraster* looking like *Brisaster* Gray, 1855 or *Paraster* Pomel, 1869, two genera of Shizasterids, but *Proraster* distinguishes from both by its ethmophract apical disc and absence of a latero-anal fasciole.

Occurrence: Cenomanian to Maastrichtian, Europe, Mangyshlak, Kazakhstan, North Africa and Middle East.

*Proraster morgani* Cotteau & Gauthier, 1895

Plate 9, Figs. A-P

1895 *Opissaster morgani* Cotteau and Gauthier, p. 43, pl. VII, figs. 6-9, 18.

1958 *Opissaster morgani* de Renzy, p 135, figs. 6-9 & 18.

Material: 9 well preserved and measurable specimens (DCSKPm-15294-1 & 2; 15295-1, 2 & 3 and 15296-1, 2, 4 & 5), from Kabir Kuh section,

Seymareh Member, Gurpi Formation.

Measurement: In Table 20.

Diagnosis: *Proraster morgani* has a deep and broad anterior sulcus. Apical disc is semiethmolytic with 4 gonopores, located close to the the posterior margin of the test. Anterior petals are long and flexed anteriorly. Posterior petals are less than half the length of the anterior petals and highly divergent.

Description: The test is low, ovate with rounded margins and a wedge-shaped profile. The posterior face is truncated. The apical disc is semiethmolytic with four gonopores, and very close to posterior boarder in position (Fig. 28A).

Anterior ambulacrum settled in a deeply sunken, long, and wide anterior sulcus bordered by vertical walls, and running from the apex to the peristome. The anterior sulcus marks a constriction at the ambitus. Pore-pairs of the anterior ambulacrum are uniserial. In anterior ambulacrum, each pore-pairs, the two pores are separated by a prominenet interporal knob. (Fig. 28B). Paired ambulacra are petaloid. The anterior paired petals are long and flexed anteriorly. Posterior paired petals are less than half the length of the anterior petals, widely divergent, and only weakly depressed.

The peristome is close to the anterior test border and faces the frontal groove. The labrum projects to partially cover peristome. The periproct is small, ovate, slightly taller than wide and situated at the top of the posterior truncated face. The narrow peripetalous fasciole is present.

Remarks: *P. morgani* differs from the type species *Proraster geayi* Cottreau, 1908, and the Iranian species *Proraster douvillei* Gauthier, 1902, in being its roughly circular outline and wider and shallower anterior sulcus with lower vertical walls (in *S. geayi* and *P. douvillei* outline is ovate longitudinally and the anterior sulcus is deeper and narrower with higher vertical walls.

Table 20. Quantitative description of the test shape variations in *Proraster morgani*.

Taxa name/Parameter	Sample No.	L	W	H	W/L	H/L	L <sub>I</sub>	L <sub>II</sub>	L <sub>III</sub>	L <sub>I</sub> /L <sub>II</sub>	L <sub>pr</sub>	W <sub>pr</sub>	L <sub>pc</sub>	W <sub>pc</sub>	L <sub>ap</sub>	W <sub>ap</sub>
<i>Proraster morgani</i>	DCSKPm-15294-1	33.4	33.0	21.4	0.99	0.64	4.7	15.9	18.95	0.295	2.8	3.1	3.6	2.9	-	-
	DCSKPm-15294-2	28.7	27.8	19.0	0.97	0.66	4.1	14.0	16.1	0.292	2.6	2.7	3.7	2.7	1.4	1.8
	DCSKPm-15295-1	25.6	24.5	16.0	0.96	0.63	3.6	11.5	-	0.313	-	-	3.3	2.7	-	-
	DCSKPm-15295-2	22.3	21.3	14.8	0.96	0.66	2.7	10.0	13.3	0.270	2.3	2.5	2.9	2.3	1.7	1.9
	DCSKPm-15295-3	19.5	18.9	12.9	0.97	0.66	2.9	9.4	10.1	0.308	-	-	2.8	2.2	1.6	1.8
	DCSKPm-15296-1	16.9	16.5	11.4	0.98	0.67	2.9	8.8	9.6	0.329	1.7	2.0	2.6	2.1	1.1	1.3
	DCSKPm-15296-2	16.0	15.4	10.1	0.96	0.63	2.1	7.1	8.2	0.295	1.6	1.9	-	-	1.1	1.4
	DCSKPm-15296-4	14.1	13.95	9.6	0.99	0.68	1.7	6.3	7.3	0.270	2.2	2.0	2.4	1.8	1.1	1.4
	DCSKPm-15296-5	13.7	13.5	9.3	0.99	0.68	1.8	6.2	7.8	0.290	1.8	1.7	1.7	1.4	0.9	1.1

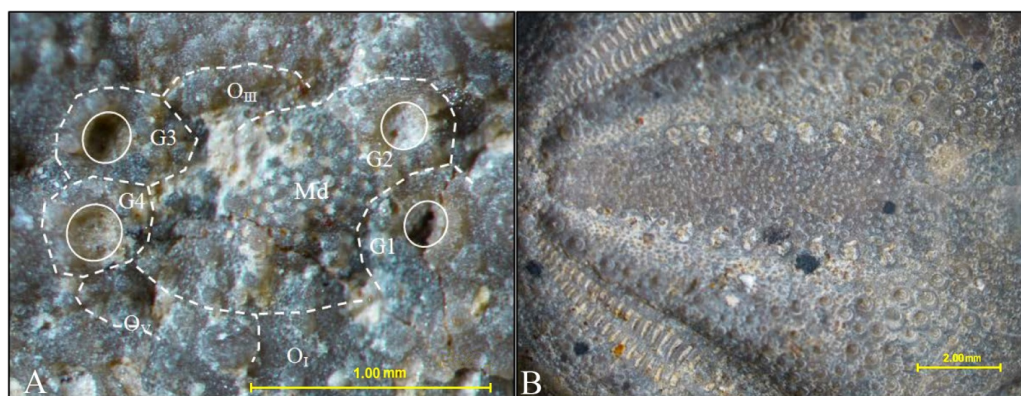


Figure 28. Apical disc and anterior ambulacrum in *Proraster morgani*. A. Semiethmolytic apical disc with 4 gonopores, specimen DCSKpm-15296-1. B. Anterior ambulacrum III, specimen DCSKpm-15296-1. (G: Genital plate, O: Ocular plate).

It differs from *P. centrosus* Cotteau & Gauthier, 1895, in being lower test and apical disc position posteriorly (in *P. centrosus* test is higher and apical disc position is near to center). *Proraster granti* Kier, 1972, distinguished from *P. morgani* by having less sunken and shorter anterior ambulacrum and shorter posterior paired petals.

Occurrence: *P. morgani* is found in the Seymareh Member of Kabir Kuh section (Campanian age).

Suborder Micrasterina, Fischer, 1966

Genus *Epiaster* d'Orbigny, 1853

Type species: *Spatangus crassissimus* Defrance, 1827

*Epiaster* has previously been included in the Toxasteridae because of its lack of fascioles. It is recognized from phylogenetic analysis as a stem Micrasterina (Villier *et al.*, 2004). *Epiaster* differs from early *Micraster* species only in lacking a subanal fasciole (Pomel, 1883; Lambert, 1901; Smith and Wright, 2008). It is very similar to *Micraster* in tuberculation, petal structure, and plating arrangement. *Epiaster* and *Micraster* share the same derived pattern of scattered primary tubercles set in a dense matrix of granules aborally, which distinguishes early micrasterid from *Pliotoxaster* and *Macraster*.

Diagnosis: A basal Micrasterine genus with heart shaped outline and with shallow anterior sulcus and posterior face obliquely truncated. The apical disc is is ethmophract, with four gonopores. Paired ambulacra petaloid and straight, more or less closed

distally. No fascioles present.

Occurrence: Aptian-Senonian, Europe and Middle East.

*Epiaster lamberti* Gauthier, 1902

Plate 5, Figs. L-O

1902 *Epiaster lamberti* Gauthier, pl. XIX, figs. 1-2.

1958 *Epiaster lamberti* de Renzy, p. 127, figs. 1-2.

Material: One well preserved and measurable specimens (DCSK EL15351), from Kabir Kuh section, Seymareh Member, Gurpi Formation.

Measurement: In Table 21.

Diagnosis: Test is heart shaped outline, inflated adapically, with a relatively shallow anterior sulcus. Petals are long and straight. Posterior and anterior paired petals are about equal in length.

Description: The test is cordiform, inflated adapically, and flattened adorally, with rounded margins, a shallow anterior sulcus, and an obliquely truncated posterior face. The apical disc damaged but it has 4 gonopores and located centrally. The anterior ambulacrum weakly sunken from apex to peristome, with rounded and simple pore pairs. Paired ambulacra are petaloid. The petals are long, straight, sunken and open distally. The posterior and anterior paired petals are equal in length and outer and inner series of pore pairs are elongate, and slit like. The peristome is pentagonal, near to anterior border and opens approximately 1/5 of the test length from the anterior margin. The periproct is small, ovate, longitudinally elongated and situated at the top of the short posterior truncated face. There is no any fascioles.

Table 21. Quantitative description of the test shape variations in *Epiaster lamberti*.

Taxa name/ Parameter	Sample No.	L	W	H	W/L	H/L	L <sub>I</sub>	L <sub>II</sub>	L <sub>III</sub>	L <sub>I</sub> /L <sub>II</sub>	L <sub>pr</sub>	W <sub>pr</sub>	L <sub>pc</sub>	W <sub>pc</sub>	L <sub>ap</sub>	W <sub>ap</sub>
<i>Epiaster lamberti</i>	DCSKEL 15351	25.6	23.9	16.1	0.93	0.63	10.5	11.7	10.6	0.897	2.6	3.3	2.6	2.2	2.1	2.0

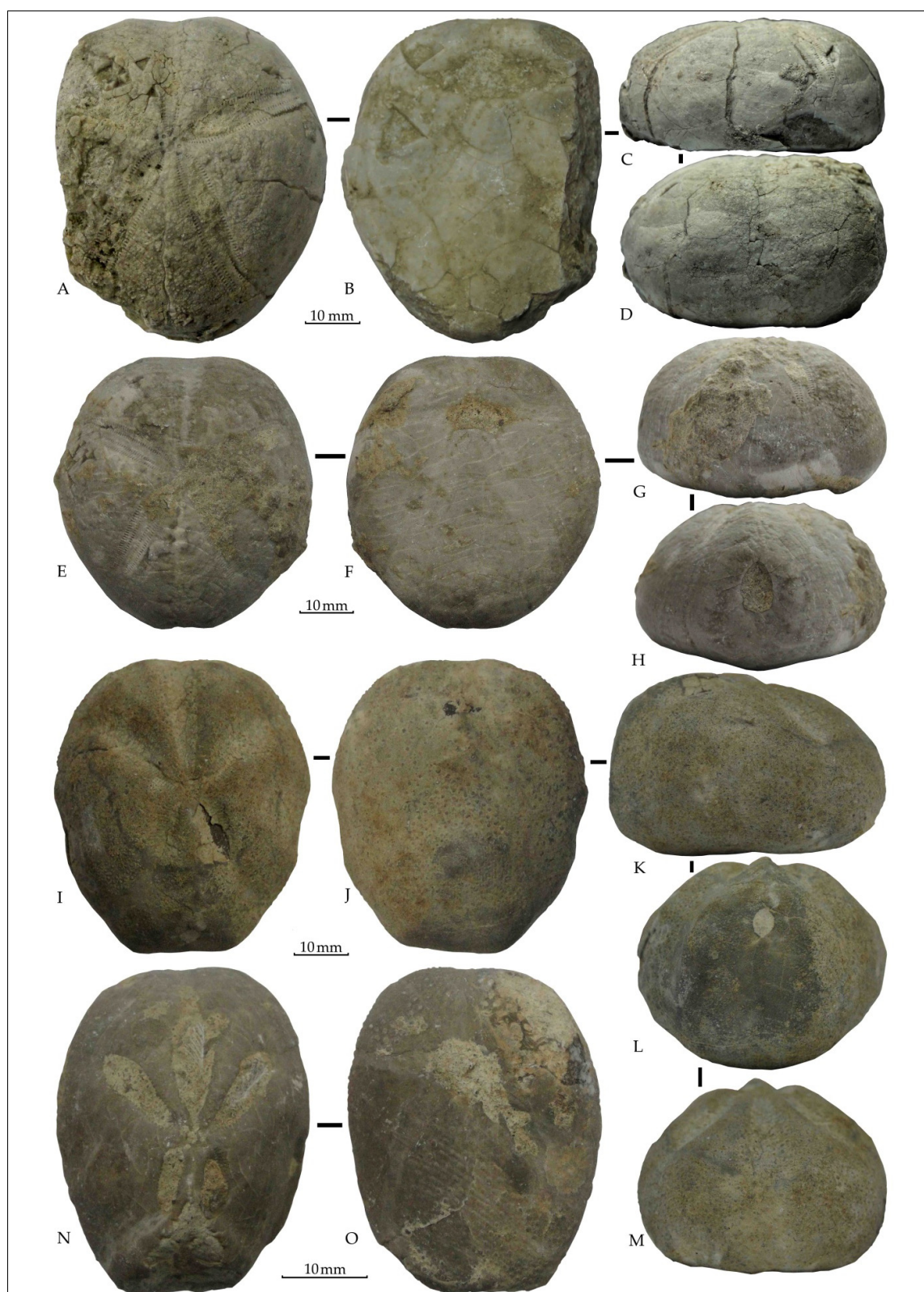


Plate 8. *Mecaster kanepanensis*. A-D: specimen DCSK M k3; A: Apical view, B: Oral view, C: Lateral view, D: Anterior view. E-H: specimen DCSK SPn1; E: Apical view, F: Oral view, G: Lateral view, H: Posterior view. *Mecaster longus*. I-M: specimen DCSKML-15347; I: Apical view, J: Oral view, K: Lateral view, L: Anterior view, M: Posterior view.

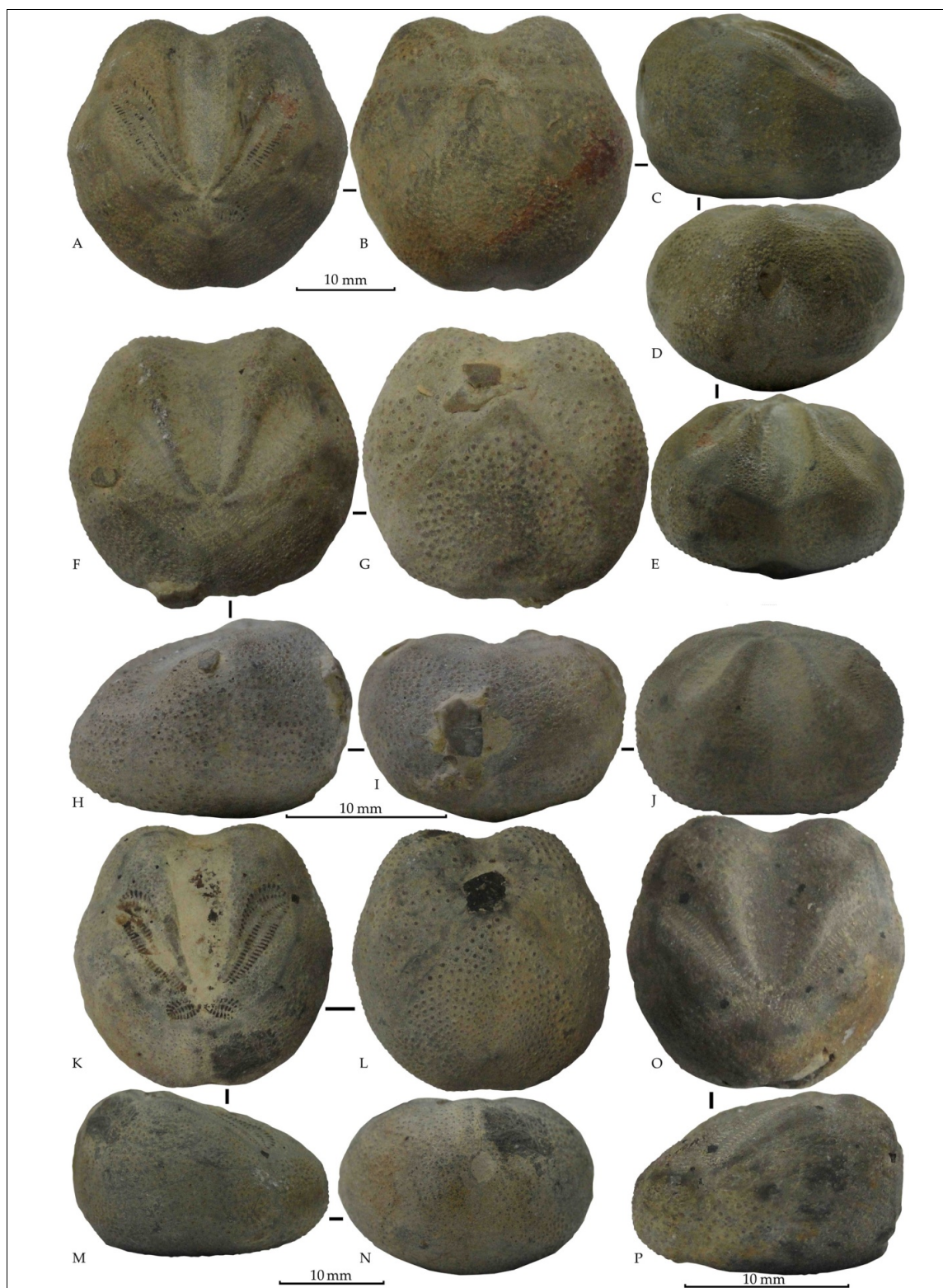


Plate 9. *Proraster morgani*. A-E: specimen DCSKpm-15294-2; A: Apical view, B: Oral view, C: Lateral view, D: Posterior view, E: Anterior view. F-J: specimen DCSKpm-15295-3; F: Apical view, G: Oral view, H: Lateral view, I: Posterior view, J: Anterior view. K-N: specimen DCSKpm-15295-1; K: Apical view, L: Oral view, M: Lateral view, N: Posterior view. O-P: specimen DCSKpm-15296-1; O: Apical view, P: Lateral view. Scale bar: 10mm

Remarks: *Epiaster lamberti* easily distinguishes from Hemiasterids and Somaliasterids by the lack of fascioles. *E. crassissimus* Defrance, 1827 differs from *E. lamberti* in being pointed posterior face and in having flexed posterior paired petals. *E. trigonalis* Desor, 1847 differs from *E. lamberti* by a pointed posterior face and posterior paired petals shorter than the anterior ones.

*Epiaster lamberti* distinguished from *E. distinctus* Agassiz in Agassiz & Desor 1847 and *E. henrici* Cotteau, Peron & Gauthier, 1878, by having posterior and anterior paired petals equal in length and a shallow anterior sulcus. In *E. distinctus* and *E. henrici* posterior paired petals are shorter than the anterior ones and the anterior sulcus are deeper than that of *E. lamberti*. *E. incisus* differs from *E. lamberti* in being more truncated posteriorly and by relatively shorter posterior paired petals.

Occurrence: Seymareh Member, Gurpi Formation of Kabir Kuh section (Campanian age).

### Discussions

The Seymareh Member, as a member of the Gurpi Formation extends just in the Luristan region, western part of Zagros Basin and northeasternmost part of the Arabian plate. The member has a richest echinoids fauna during the Campanian in Arabian plate, while in Maastrichtian, the rich- echinoid fauna extends in southern part of the plate, in UAE and Oman border region (Boukhary et al., 1999; Smith & Gale, 2005).

During the Late Cretaceous, specially in the Campanian, there were two different rich- echinoid territories in Iran (Fig. 29):

- Southwest of Iran (Luristan zone of Zagros

Basin) as a part of south margin of Tethys and near the 15 degrees' north paleo-latitude, that determined by abundance of Hemiasterid spatangoid (*Mecaster*, *Proraster* and fewer *Hemiaster*), Somaliasterid spatangoid (*Iraniaster*), Conulid echinoneoid (*Conulus* and *Globator*), Cassidulid (*Parapygus*, *Pygurostoma* and fewer *Vologesia*), Holasteroid (*Hemipneustes*) and Regular echinoid (*Salenia* and *Goniopygus*).

- North, northeast and north center of Iran, related to Alborz (K3 unit), Koppeh-Dagh (Abtalkh Formation) and Central Iran (Farokhi Formation) Basins respectively, as a part of north margin of Tethys and north European province and near the 30 degrees north paleo-latitude, (Tröger, 1989) (Fig. 30). This territory determined by abundance of Micrasterid spatangoid (*Micraster*, *Gibbaster* and *Isomicraster*), Holasteroid (*Echinocorys*, *Offaster*, and fewer *Galeola*, *Cardiaster* and *Sternotaxis*) and conulid (*Conulus*) (Allameh & Taherpour, 2014; Kamyabi Shadan et al., 2015; Abdollahi, 2019).

There was only one common taxon in both territory, *Conulus douvillei*, that reported from the K3 unit in Alborz Basin (Abdollahi, 2019). Some of Campanian echinoid taxa of studied sections are similar by Maastrichtian fauna of UAE and Oman regions. Ali (1989), Boukhary et al., (1999) and Smith & Gale (2005), reported *Globator bleicheri*, *Conulus douvillei* and *Salenia nutrix* in Maastrichtian carbonates of the Simsim Formation from the north of Oman and border region of UAE, that we could see them in the Campanian deposits of studied sections.

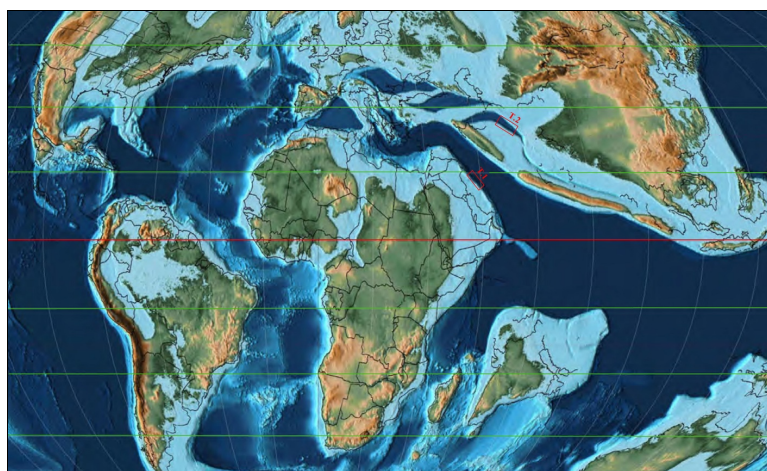


Figure 29. Paleogeographic map of Campanian, that shows location of the Territories of Echinoid fauna in Iran (T.1 and T.2) (based on Scotese, 2014).

Also, Kier (1972) reported *Coptodiscus noemiae*, *Conulus douvillei*, *Goniopygus superbus* and 3 different species of *Iraniaster* (*I. affindouvillei*, *I. affinimorgani* and *I. bowersi*) in Campanian sediments of the Lower Aruma Formation from the east of Saudi Arabia. In Senonian sediments of Afghanistan, (Montenat, 2009) reported the same taxa with Iranian Campanian species such as: *Hemiasiter opimus*, *Hemipneustes persicus* and *Parapygus vassilini*.

A total of 21 echinoid species were found from the Kabir Kuh section, none of which is new. Of these, ten species are endemic taxa, included: *Parapygus declivis*, *P. inflatus*, *P. longior*, *Vologesia tataosi*, *Hemiasiter noemiae*, *Iraniaster morgani*, *Mecaster kanepanensis*, *Mecaster longus*, *Proraster morgani* and *Epiaster lamberti*.

Seymareh Member has different lithologies in 4 studied sections in Kabir Kuh Anticline, from north to south, respectively included: Valiasr, Badreh,

Zarangush and Darreh Shahr, so depending on the lithology, it has different assemblages of echinoid taxa (Table. 22).

In the northernmost section, west of the Valiasr Town, lithology of the Seymareh Member included calcareous Shale and marly Limestone that we found somaliasterid and hemiasterid spatangoid (*Iraniaster morgani*, *Proraster morgani*, *Mecaster kanepanensis*) and large holasteroid form, *Hemipneustes*, in it. The regular's taxa *Salenia* and *Goniopygus*, somaliasterid spatangoid (*Iraniaster douvillei*), hemipneustid holasteroid form, *Hemipneustes persicus* and the flat-based cassiduloid form, *Vologesia tataosi* were found in marly limestones to calcareous marls of the Badreh section. Cassiduloid taxa such as: *Pygurostoma morgani*, *Parapygus vassilini*, *P. declivis* and *P. inflatus* came from sandy marl with intercalation of sandy-marly limestones of the Zarangush section.

Table 22. List of species in the present work and their relative habitat and sections.

Sections	Lithology (Seymareh Member)	Echinoid taxa
Valiasr	calcareous Shale, marly Limestone	<i>Iraniaster morgani</i> , <i>Proraster morgani</i> , <i>Hemipneustes persicus</i> , <i>Mecaster kanepanensis</i>
Badreh	marly Limestone to calcareous Marl	<i>Salenia nutrix</i> , <i>Goniopygus superbus</i> , <i>Iraniaster douvillei</i> , <i>Conulus douvillei</i> , <i>Vologesia tataosi</i> , <i>Hemipneustes persicus</i>
Zarangush	Sandy Marl, intercalation of sandy-marly Limestone	<i>Pygurostoma morgani</i> , <i>Parapygus vassilini</i> , <i>P. declivis</i> , <i>P. inflatus</i>
Darreh-Shahr	Marl, intercalation of marly Limestone	<i>Conulus douvillei</i> , <i>Globator bleicheri</i> , <i>Iraniaster douvillei</i> , <i>I. nodulosus</i> , <i>Hemiasiter noemiae</i> , <i>H. opimus</i> , <i>Mecaster longus</i> , <i>Goniopygus superbus</i> , <i>Epiaster lamberti</i> , <i>Coptodiscus noemiae</i> , <i>Parapygus longior</i>

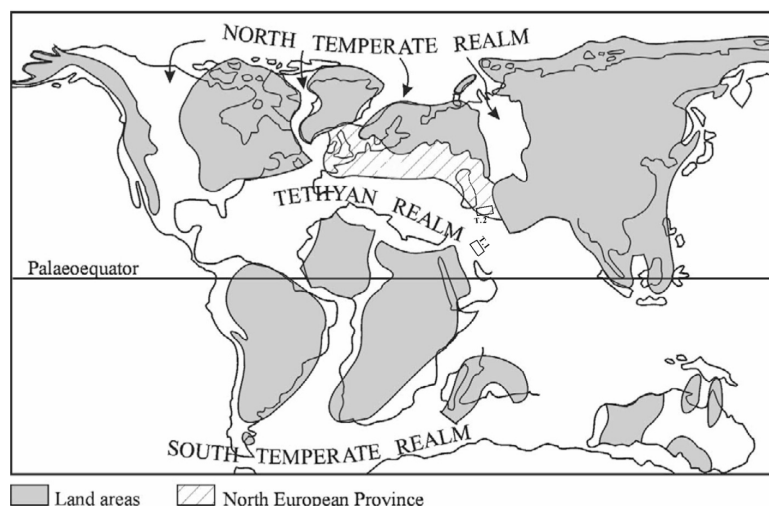


Figure 30. Location of Echnoid territories in the south Tethyan Realm (T.1) and north European Province (T.2) (after Tröger, 1989).

Lithology of the Seymareh Member, in the southernmost section, near the Darreh Shahr City, is composed of marl with intercalation of marly limestone that included many echinoid taxa such as: Conulid (*Conulus douvillei*, *Globator bleicheri*), Somaliasterid (*Iraniaster douvillei*, *I. nodulosus*), Hemiasterid (*Hemiaster noemiae*, *H. opimus*, *Mecaster longus*), Holoctypoid (*Coptodiscus noemiae*) and only one species of Micrasterid spatangoid, *Epiaster lamberti*.

### Conclusions

The rich echinoid fauna of the Kabir Kuh section allowed the description of 21 species belonging to 14 genera, 12 families and 7 orders. The order Salenoida is represented by *Salenia* (*Salenia*) *nutrix*, a species previously recorded from the Maastrichtian of Algeria (Peron & Gauthier, 1881) and upper Senonian (usually equivalent to Campanian) of Iran (Cotteau & Gauthier, 1895). *S. (S.) nutrix* is the latest known species of the genus in Iran. It is a widespread species, recorded previously in the Campanian-Maastrichtian of Oman, UAE, Algeria, Tunisia, Libya, The Netherlands, Belgium, and Cuba. The order Arbacioida is represented in the Kabir Kuh section by *Goniopygus superbus*, a species reported from Campanian strata of Saudi Arabia and Oman.

The order Holoctypoida is represented by *Coptodiscus noemiae*, a species also recorded in Campanian deposits of Saudi Arabia (Kier, 1972).

The conulid Echinoneoida is represented by two species *Conulus douvillei* and *Globator bleicheri*. *C. douvillei* was previously reported from Campanian deposits of Saudi Arabia (Kier, 1972), Maastrichtian strata of Libya (Checchia-Rispoli, 1932), India, and Tibet (Neumann et al., 2002). *Globator bleicheri* was previously recorded from the Campanian strata of Tunisia (Gauthier, 1889; Gallemi & Abdallah, 2010) and Maastrichtian deposits of Oman and UAE (Ali, 1989; Smith, 1995; Boukhary et al., 1999). *Globator bleicheri* is the latest known species of the genus in Iran.

The order Cassiduloida is represented by 6 species, *Parapygus longior*, *Parapygus declivis*,

*Parapygus inflatus*, *Parapygus vassilini*, *Vologesia tataosi* and *Pygurostoma morgani*, that belonging to to 3 families: Gitolampadidae, Echinolampadidae and Faujasiidae. All of this species appeared in Campanian, *Parapygus declivis*, *P. inflatus*, *P. longior* and *Vologesia tataosi* are Iranian endemic species.

The order Holasteroida is represented in the Campanian strata of Kabir Kuh section by *Hemipneustes persicus*, that was previously recorded from the Campanian of Afghanistan (Montenat, 2009) and the Maastrichtian deposits of UAE (Smith, 1995).

The order Spatangoida is represented by 9 species in 3 families: *Iraniaster douvillei*, *I. morgani* and *I. nodulosus* belonging to Somaliasteridae, *Hemiaster noemiae*, *H. opimus*, *Mecaster kanepanensis*, *M. longus* and *Proraster morgani* belonging to Hemiasteridae and *Epiaster lamberti* belonging to Micrasteridae. Seven of the occurring species of spatangoids are endemic to Iran. *Iraniaster douvillei* and *Hemiaster opimus* are recorded in Senonian deposits of Somalia (Hawkins, 1935) and Afghanistan (Montenat, 2009), respectively.

Previous studies of the echinoid fauna from Zagros area such as Cotteau and Gauthier (1895), Balmaki et al., (2010, 2012), did not recognize the Campanian age for the Seymareh Member, which was dated to the Senonian and the Campanian-Maastrichtian stages, respectively. The present work in addition to micropaleontological studies (Bahrami and Darvish zadeh, 1994) or sequence stratigraphy (Van buchem et al., 2006) reveal the Campanian age for the Seymareh Member in the Kabir Kuh Anticline.

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