Introducing some echinoderms from the Tirgan Formation, Kopeh-Dagh Basin, NE of Iran

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Abstract

A stratigraphic section from the Tirgan Formation was selected in Arkan village nearby Bojnourd city in order to study echinoderm fauna systematically. Many specimens of echinoderms, especially toxasteridae which is associated with brachiopods were collected and studied systematically in this paper. Microscopie slides were also prepared and studied. All slides contain benthic foraminifers and calcareous algae as well as gastropod and coral fragments. Based upon diagnostic micro and macro fossils, a Barremian-Aptian age is assigned to the Tirgan Formation which suggests Urgonien facies type indicating shallow water of open marine environment.

Keywords: *Tirgan Formation; Echinodermata; Kopeh-Dagh; Barremian-Aptian; Urgonien facies type.*

Introduction

The Urgonien is named after the village with this name in the east of Tarascon, France. This facies type is characteristic of shallow-water carbonate facies which was accumulated along the Tethys northern shelf from the Barremian to the late Albian. The facies consists of hard, white-gray limestones which contains *Orbitolina* (foraminifers) and transitional sediments – detrital or siliceous limestones (Foury, 1968). Characteristic fossils of the Urgonien facies type are bivalves, corals, bryozoans and algae as well as small and large foraminifers (Krobicki *et al.,* 2005). So far, this sedimentary facies type has reported from different parts of Iran (e.g. Seyed-Emami 1997; Aryaei *et al.,* 1999; Parvaneh Nejad Shirazi 2004). The Tirgan Formation includes of micro and macro-fossils which are very similar to the Urgonien facies in Europe. Therefore, this formation is correlatable with Europe from the palaeontological and lithological point of view.

Geological setting

The NE active fold belt of Iran, Kopeh-Dagh, formed on Hercynian metamorphosed basement at the SW margin of the Turan Platform (Fig. 1).
The Kopeh-Dagh region of Northeast Iran exposes rather complete Jurassic sections, which reach thicknesses of about 3000 m.

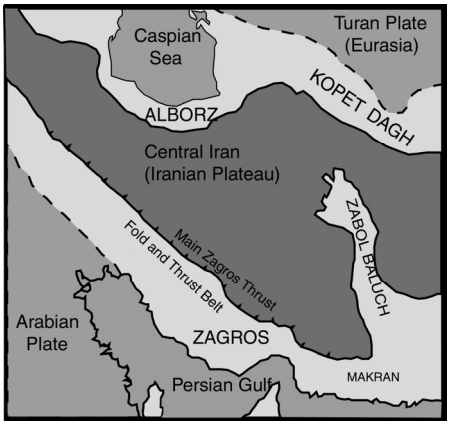


Figure 1: Structural Units of Iran (After Berberian &King, 1981).

The belt is composed of about 10 km of Mesozoic and Tertiary sediments (mostly carbonates) and like the Zagros, was folded into long linear NW-SE trending folds during the last phase of the Alpine Orogeny, in the Plio-Pleistocene time. No igneous rocks are exposed in Kopeh-Dagh except for those in the basement in Aghdarband tectonic window (Stocklin & Setudehnia, 1991).
The Bojnourd area is part of the Kopeh-Dagh sedimentary basin which is located in Northern Khorasan province. The Shurijeh, Tirgan, Sarcheshmeh, Sanganeh and Abderaz formations are well-exposed in the studied area. The Tirgan

Formation has Early Cretaceous age in the type-section which is located 39 km southeast of Dargaz city. This formation is mainly consists of medium-thick bedded grey fossiliferous limestones (Afshar-Harb, 1994)

The Arkan section is located 19 km southwest of Bojnourd, heading for Esfarayen (37 24' 64" N and 57 06' 74" E) (Fig. 2 , 3). In this section, the Tirgan Formation is 195 thick and rests on the sandstones and limestones of the Shurijeh Formation (Fig.4). The Tirgan Formation is overlain by the Sarcheshmeh Formation. The Tirgan Formation mainly consists of oolithic limestones, fossiliferous limestones, marly limestones and shaly limestones. The Orbitolinid limestones are the most important characteristic for separation of this formation from underlying and overlying roch units.

For micropaleontological studies, 85 samples were taken from which 108 thin-sections were prepared. In field and thin-section studies, we could identify some lithologies such as micrite limestones, thick layers of biomicrite limestones, shaly limestones, marly limestones etc. which are correlatable with the Tirgan Formation reference section. In the study area, the general striking of the beds is approximately E-W with a dipping of 15-35°. In micropaleontological studies, done on the thick limestone layers of this formation, we could identify some foraminiferas such as *Balkhania balkhanica, Charentia cuvillieri, Commaliama* sp.*, Cuneolina pavonia, Derventina filipescui, Dictyoconus arabicus, Iraqia simplex, Lenticulina* sp.*, Miliolidea, Nautiloculina oolithica, Orbitolina* spp.*, Pseudocyclaminna littus, Torinosuella peneropliformis, Trocholina* sp.*, Vercorsella* sp. and Calcareous algae such as *Actinoporella* sp.*, Boueina* sp.*, Cayeuxia* sp.*, Cylindroporella* spp.*, Macroporella* sp.,and *Salpingoporella* sp.

According to these, the Barremian-Aptian age for this sedimentary unit is suggested. Also, the echinoderms recorded from its marls and marly limestones canfirm the Barremian-Aptian age for this sedimentary unit.

Previous studies in the Middle East

In the Kopeh-Dagh region, the first studies on the echinoderms of the Abderaz Formation (Turonian-Coniacian age) was carried out (Vahidinia & Aryaei, 2000) and those of the Tirgan Formation (Hashemian *et al*., 2007). Likewise, a study on the early Cretaceous echinoderms of central Iran was carried out by Yaghoubi *et al.,* (2008).

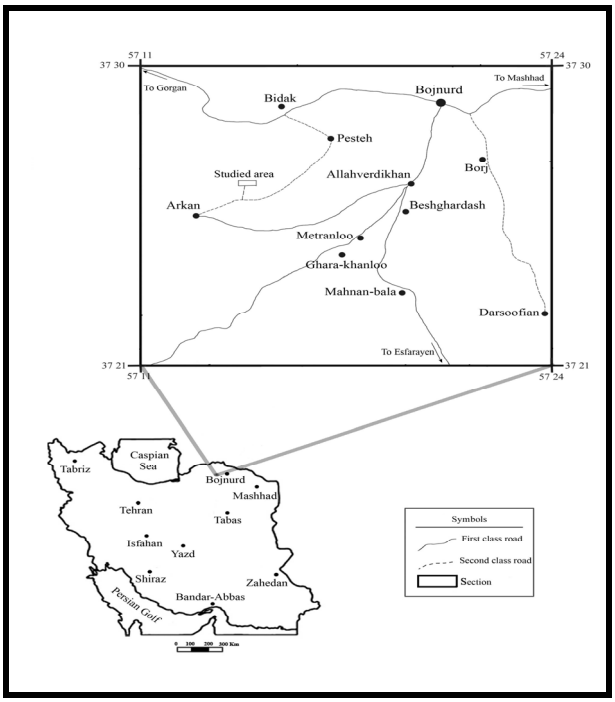


Figure 2: The studied area.

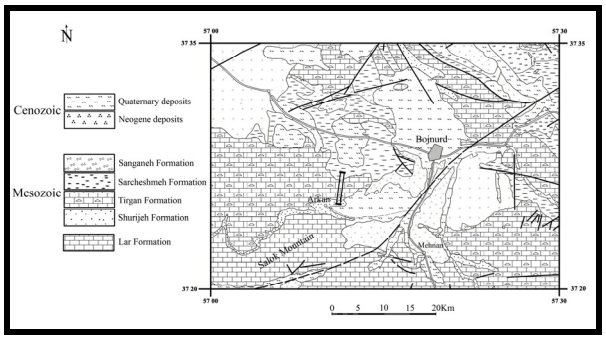


Figure 3. Index geological map showing the location of the studied section.

Meanwhile, from elsewhere some species such as *Heteraster musandamensis* (Aptian age) and *Heteraster* aff. *couloni* (index for Hauterivian-Barremian age) are reported from upper Musandam limestone (Hudson & Chatton, 1959), *Heteraster oblongus* of the Early Aptian (Dunnington *et al.,* 1959), in the United Arab Emirates. *Toxaster radula, Toxaster lamberti, Toxaster dieneri* and *Toxaster collegnoi* have been reported from the Aptian age from Risan Aneiza Formation (Abdelhamid, 2003) in Egypt, *Heteraster oblongus* is reported from the Barremian age from Qishn

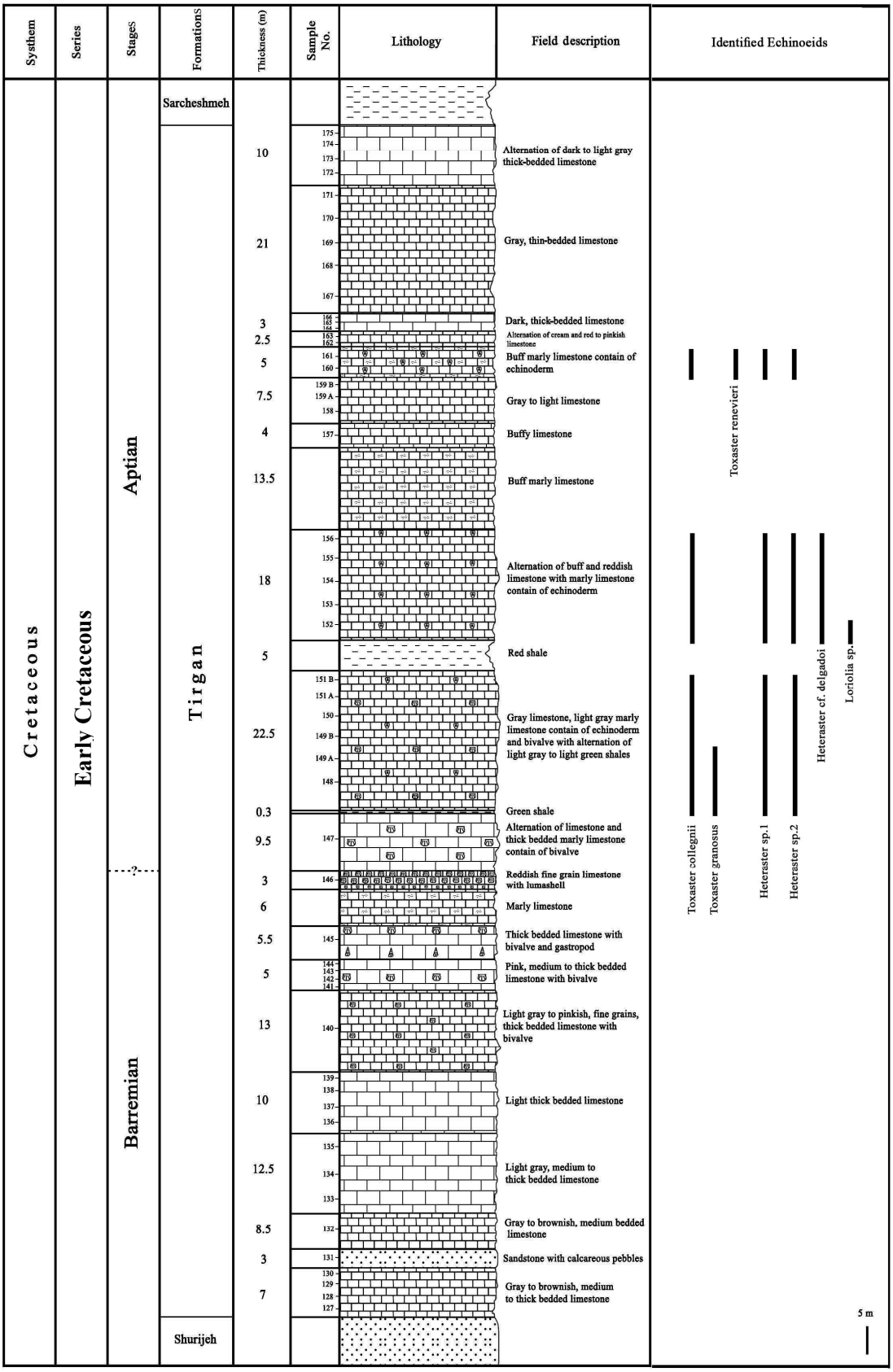


Figure 4: Stratigraphic column of the Arkan section.

Formation (Howarth *et al.,* 1998) in Yemen. *Heteraster oblongus* from Sarmord Formation in North Iraq, *Toxaster retusus* from Turkmenistan (Cecca *et al.,* 1999), *Heteratser delgadoi* from the Palmyrides chain in Central Syria (Mouty *et al*., 2003) and *Heteraster renngarteni* from Central Syria (Villier *et al.*, 2005) are reported. The stratigraphic distributions of above-mentioned genera has summerized in table 1.

Table 1: List of previous studies in the Middle East.

	Ira	UAE	Ira	Yemen	Turkmenistan	Egyp	Syri
Toxaster	*	-	-	-	*	*	-
Heteraste	-	*	*	*	*	-	*
Loriolia	-	-	-	-	-	-	-

Material and Methods

Echinoderms are marine, solitary and usually benthic animals. They were diverse in shapes (in ambulacra, genital plates and etc) in this phylum from the Early Paleozoic. Echinoderms are characterized by the presence of an ambulacral system. This organ helps the animal for obtaining food, the vascular system, the respiratory system, as well as organs for locomotion. The system starts at the surface with an opening known as the hydropore, or with a perforated calcareous madrepore plate.

Water which circulates through the ambulacral system not only provides the organism with oxygen, but also moves microscopic particles of food towards the mouth. Water penetrates this to the water vascular system, gradually passing into the radial canal to be taken to every part of the body. Echinoderms developed an internal calcareous skeleton, the so-called theca, which consist of fixed plates or plates of $CaCO_3$ connected by joints. The name of this entire phylum is based on the fact that there are usually numerous spines sticking through the skin and covers the calcareous skeleton to appear on the surface. Living representatives of the echinoderms are subdivided into five classes and of these the subphyla Blastozoa, Crinozoa and Echinozoa are particularly important for paleontology (Ivanov *et al.,* 2005). Fifteen genera of Spatangoida appeared during the Early Cretaceous and the Early Cenomanian and they are distributed within five families such as Toxasteridae, Hemiasteridae, Micrasteridae, Palaeostomatidae and Schizasteridae according to the classification of Fischer (1966). Some of the diagnostic genera in the Early Cretaceous are listed in table 2 (Villier *et al.,* 2004).

From the whole thickness of the Tirgan Formation more than 30 specimens of echinoderms were collected from marl and marly limestone horizons. In primary identity, it was clear that the specimens are different species of Toxaster and Heteraster genera (by owning of diffrent shape in their ambulacra and also distribution of their tubercles) and a genus of Hemicidaroida order. Among the Toxaster genera, there were some specimens which were different from the others and transferred to the laboratory for more research works.

Table 2: List of spatangoid genera cited from the Early Cretaceous (Villier *et al*., 2004).

Genus	Stratigraphic range
Aphelaster Lambert, 1920	Valanginian
Douvillaster Lambert, 1917	Aptian – Turonian
Epiaster d'Orbigny, 1854	Aptian – Senonian
Hemiaster Desor, 1847	Aptian – Recent
Heteraster d'Orbigny, 1853	Hauterivian – Cenomanian
Macraster Roemer, 1888	Aptian – Cenomanian
Palhemiaster Lambert, 1916	Aptian – Cenomanian
Toxaster Lambert, 1920	Berriasian – Cenomanian

Systematic Paleontology

Materials (rock samples and fossils thin-sections) are housed in the department of geology, Islamic Azad University, Mashhad branch with prefix of TIAUM. The specimens use in this article with their prefixes are as follow**:**

Ti 3, TIAUM 6, TIAUM 7, TIAUM 10, TIAUM 12, TIAUM 15, TIAUM 17

Diagnostic features of Toxaster (Agassiz, 1840)

Phylum **Echinodermata** Klein 1754
Class **Echinoidea** Leske 1778
Family **Toxasteridae** Lambert 1920
Genus ***Toxaster*** Agassiz 1840

The shell of the genus Toxaster is heart-shaped. The anterior ambulacrum is in the deep groove which runs from the top to the anterior edge, where it partly extends as far as the oral side. Posterior face obliquely truncates. The anterior ambulacra are twice the posterior ambulacra. The ambulacra are narrow and the rows of pores almost touch on the aboral side of the shell. Paired ambulacra petaloid; petals flush; No fasciola have developed in this genus. Periproct is small and located towards the top of posterior truncated face. Peristome is small, subcircular and inclined slightly towards the front.

The countless small tubercles are perforated and serrated on the circumference (Ivanov *et al*., 2005). They are infaunal animals.
Important remarks; Toxaster differs from Epiaster in having laterally elongate pore-pairs in the anterior ambulacrum aborally that resemble those in the paired ambulacra. It also differs from Heteraster in having the two columns of pore-pairs equally developed in the paired petals.

Toxaster renevieri Wright
Sample No. TIAUM 17
(Pl. 1, Fig. 1; Pl. 3, figs. 1,5)

Description: The anterior ambulacra are twice the posterior. The anterior ambulacra (the right and left one) are curved but this formation is so weak in the posterior ones. The interambulacral plates are almost preserved in this specimen. The anal opening is clear in the posterior side. In anterior part, the right lobe is upper than the left lobe and this is the most important character in recoganization of this spices. Its length is about 2.5 cm. Two specimens of this species were found.
Age: Early Cretaceous.
Occurences: TA-160 & TA-161.

Toxaster collegnii Sismonda 1843
Sample No. TIAUM 7
(Pl. 2; Fig. 1)

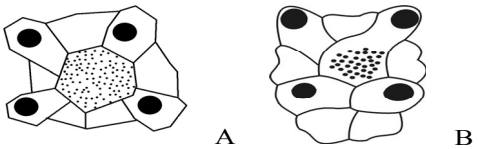
Description: The anterior ambulacra are twice the posterior. The curvedness of anterior ambulacra is clear. There are big tubercles in oral and aboral sides of this specimen. Labrum is clear in it. The species's length is about 3.5 cm.
Age: Index for Aptian.
Occurences: TA-148 – TA-151B & TA-152 – TA-156.

Toxaster granosus d'Orbigny 1853
Sample No. TIAUM 3
(Pl. 1, Fig. 3; Pl. 3, Fig. 3)

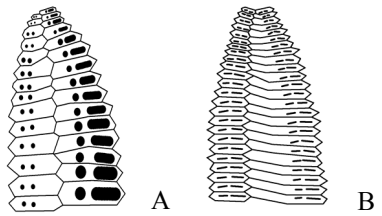
Description: The anterior ambulacra are twice the posterior ambulacra. The right and left ambulacra curve in anterior part is weak and tends to be straight. The anal opening is clear in posterior part of the specimen. There are big tubercles in oral and aboral sides. The species's length is about 3 cm.
Age: Valanginian.
Occurences: TA-148 – TA-151B.

Phylum **Echinodermata** Klein 1754
Class **Echinoidea** Leske 1778
Family **Toxasteridae** Lambert 1920
Genus ***Heteraster*** d'Orbigny 1853

The test is ovate with shallow but distinct anterior sulcus. Test is sub-quadrate in outline, longer than wide. The posterior face is truncate. Apical disc is ethmophract with four gonopores. Anterior ambulacrum sunken from apex to peristome. Pore-pairs are heterogeneous and formed of a mixture of elongate 'petal-type' pores and smaller circumflexed pore-pairs. Other ambulacra are petaloid and flush. Anterior petals are flexed forwards. Peristome is subcircular and facing downwards. Aboral tubercles are small, scattered and set in a groundmass of fine granules.
Important remarks; Heteraster differs from Toxaster in having pores in the frontal ambulacrum a mixture of wide and narrow forms as it described before. Also the anterior petals have fewer plates in the anterior column than the posterior column. This last character it shares with Washitaster, which differs only in having the apical disc more towards the posterior and the frontal ambulacrum more excavated and enlarged. Washitaster is therefore treated as a subgenus of Heteraster (Villier *et al*, 2001).



Text-Fig. 1: Architectural types of the apical system. A, apical system in *Heteraster* cf.*delgadoi* (drawing by Taherpour, M.). B, apical system in *Toxaster retusus* (drawing by NHM).



Text-Fig. 2: Architectural types of the ambulacra and the position of pair-pores. A, ambulacra and pair-pores in *Heteraster*. B, ambulacra and pair-pores in *Toxaster*. (drawing by Taherpour, M.).

Heteraster sp. 1
Sample No. TIAUM 6
(Pl. 1, Fig. 2; Pl. 3, figs. 2,6)

Description: The anterior ambulacra are twice the posterior. The anterior and posterior ambulacra are thicker than the ones in other species. The anal opening is not clear. The interambulacral plates are almost preserved in this specimen. There are big tubercles in oral side while the ones in aboral side are mainly wasted. The species's length is about 3 cm.
Age: Barremian-Aptian.
Occurences: TA-148 – TA-151B & TA-152 – TA-156.

Heteraster sp. 2
Sample No. TIAUM 12
(Pl. 1, Fig. 4; Pl. 3, figs. 4,7,8; Pl. 4, Fig. 1)

Description: The anterior ambulacra are twice the posterior. The anterior ambulacrum is shallow. The anal opening and interambulacral plates are not preserved in this specimen. There are big tubercles in oral side while the ones in aboral side are mainly wasted. Apical system with all parts is preserved as well. The species's length is about 3 cm.
Age: Barremian-Aptian.
Occurences: TA-148 – TA-151B & TA-152 – TA-156.

Heteraster cf. *delgadoi* de Loriol 1888
Sample No. TIAUM 15
(Pl. 2, Fig. 2; Pl. 4, Fig. 2)

Description: The anterior ambulacra are twice the posterior. Posterior ambulacra are curved. Pore pairs are visible in arterior ambulacra. There are primary and secondary tubercles in oral and aboral sides of this specimen. Apical system with all parts is preserved as well.
Age: Early Cretaceous (index for Urgonien).
Occurences: TA-152 – TA-156.

Phylum Echinodermata Klein 1754
Class Echinoidea Leske 1778
Family Hemicidaroida Beurlen 1937
Genus Loriolia Neumayr 1881

Its test is depressed, flattened above and below and rounded. The apical disc is large and in pentagonal shape. The ambulacra are straight. There are primary and secondary tubercles on the test. Interambulacral plates are wider and there are primary tubercles on it. The areoles are large. Ambulacral and interambulacral tubercles are similar in size, perforate and crenulate. They are epifaunal animals.
Important remarks; Loriolia distinguished from Polydiadema by its lack of phyllodes. It means that in Polydiadema there is adoral crowding of pore-pairs and the peristome is less sunken, whereas in Loriola the peristome is strongly sunken and pore-pairs remain uniserial to the edge. Furthermore in Loriola the apical disc is pentagonal and projects strongly into the posterior interambulacrum whereas in Polydiadema the apical disc is more or less circular. Finally in Polydiadema the apical disc is obviously smaller than the peristome, whereas in Loriola the apical disc is larger than the peristome.

Loriolia sp. Neumayr 1881
Sample No. TIAUM 10
(Pl. 2, Fig. 3; Pl. 4, figs. 3-6)

Description: The ambulacral and interambulacral plates are preserved distinctly in this specimen. The primary and secondary tubercles are visible. The anal and mouth opening are covered by sediments. The species's length is about 2 cm.
Age: Early Cretaceous (specially Neocomian-Aptian).
Occurences: TA-152.

Conclusion

Our investigations on the echinoderm fauna of the Tirgan Formation of the Arkan village nearby Bojnourd city was resulted in echinoderm species such as *Toxaster granosus*, *Toxaster collegnii*, *Toxaster renevieri*, *Heteraster* cf. *delgadoi*, *Heteraster* sp. 1., *Heteraster* sp. 2. and *Loriolia* sp.
Some of the above-mentioned taxa (*Toxaster renevieri*, *Heteraster* cf. *delgadoi, Heteraster* sp. and *Loriolia* sp.) are recorded from Kopeh-Dagh region, northeastern Iran for the first time. Based on the stratigraphic distribution of the above-mentioned echinodem species a Barremian-Aptian age is assigned to the Tirgan Formation. Moreover, comparison of lithofacies and biofacies of the

Tirgan Formation of the study area with the Urgonien facies in Europe, suggests a close relationship.

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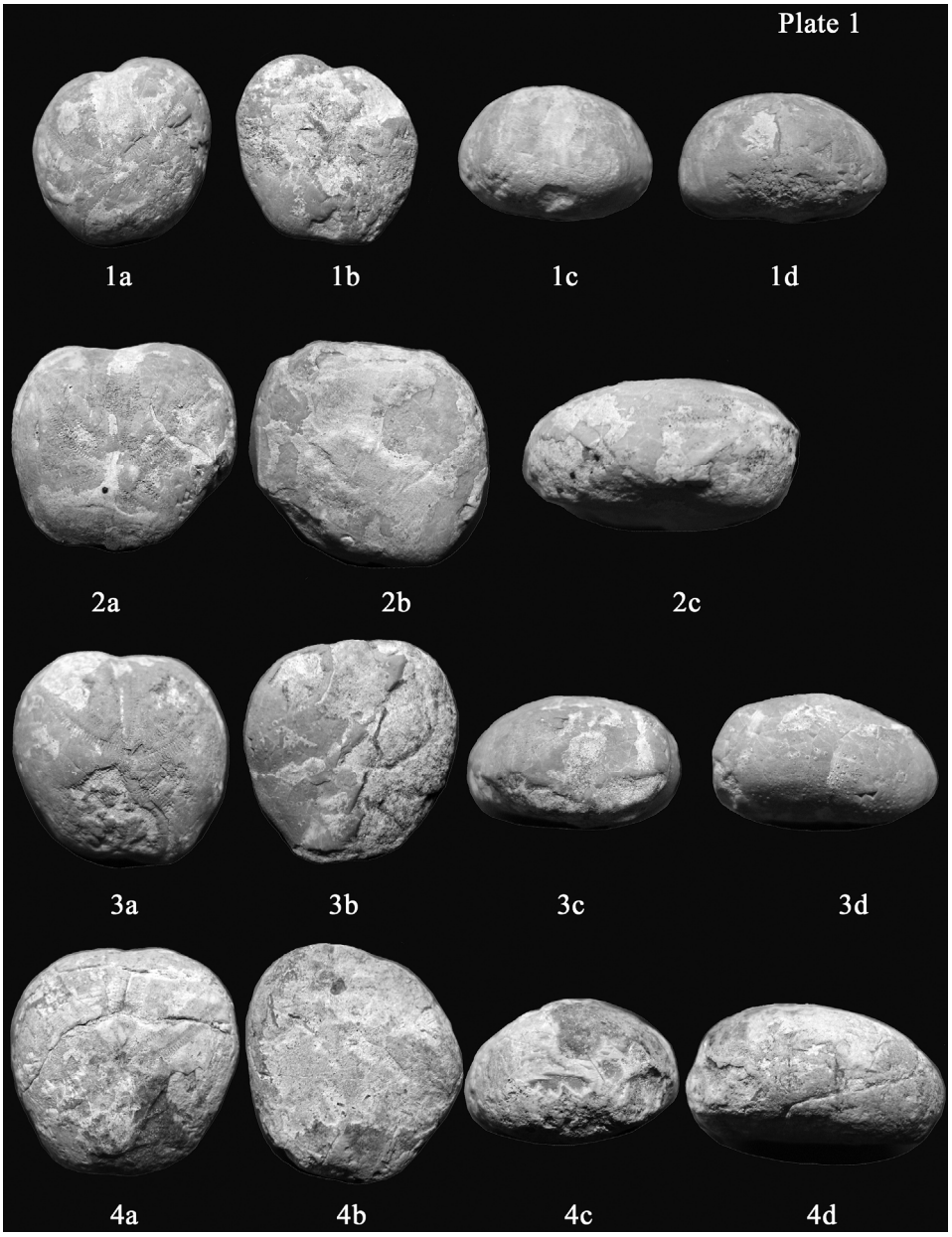

Plate 1: 1. *Toxaster renevieri* (Wright), A: Aboral view, B: Oral view, C: Posterior view, D: Lateral view (1.2X). 2. *Heteraster* sp. 1., A: Aboral view, B: Oral view, C: Lateral view (1X). 3. *Toxaster granosus* (d'Orbigny), A: Aboral view, B: Oral view, C: Posterior view, D: Lateral view (1X). 4. *Heteraster* sp. 2., A: Aboral view, B: Oral view, C: Posterior view, D: Lateral view (1X).

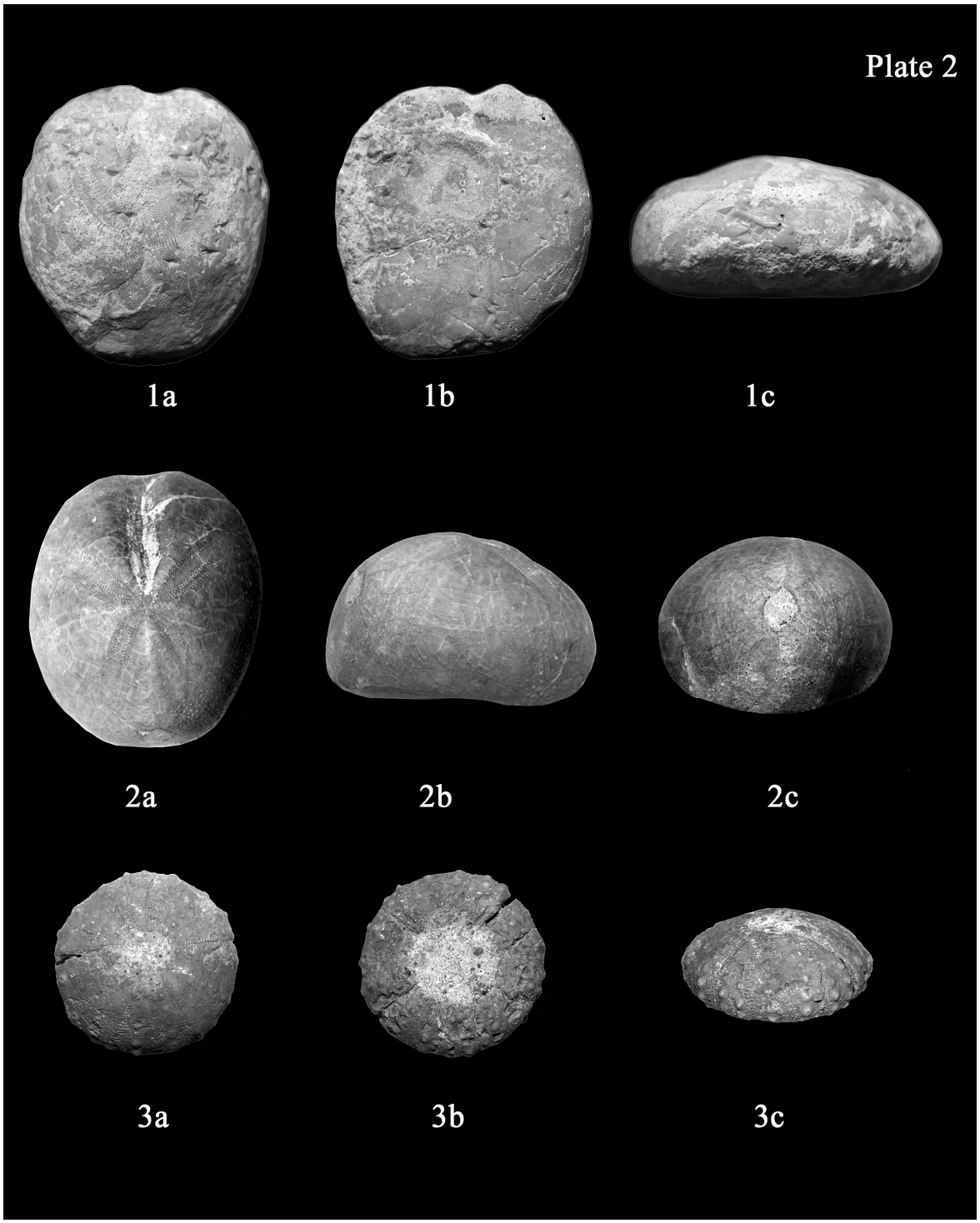

Plate 2: 1. ***Toxaster collegnoii*** **(Sismonda), A: Aboral view, B: Oral view, C: Lateral view (1.2X). 2.** ***Heteraster*** **cf.** ***delgadoi*** **(de Loriol), A: Aboral view, B: Lateral view, C: Posterior view (1.2X). 3.** ***Loriolia*** **sp. (Neumayr), A: Aboral view, B: Oral view, C: Lateral view (2X).**

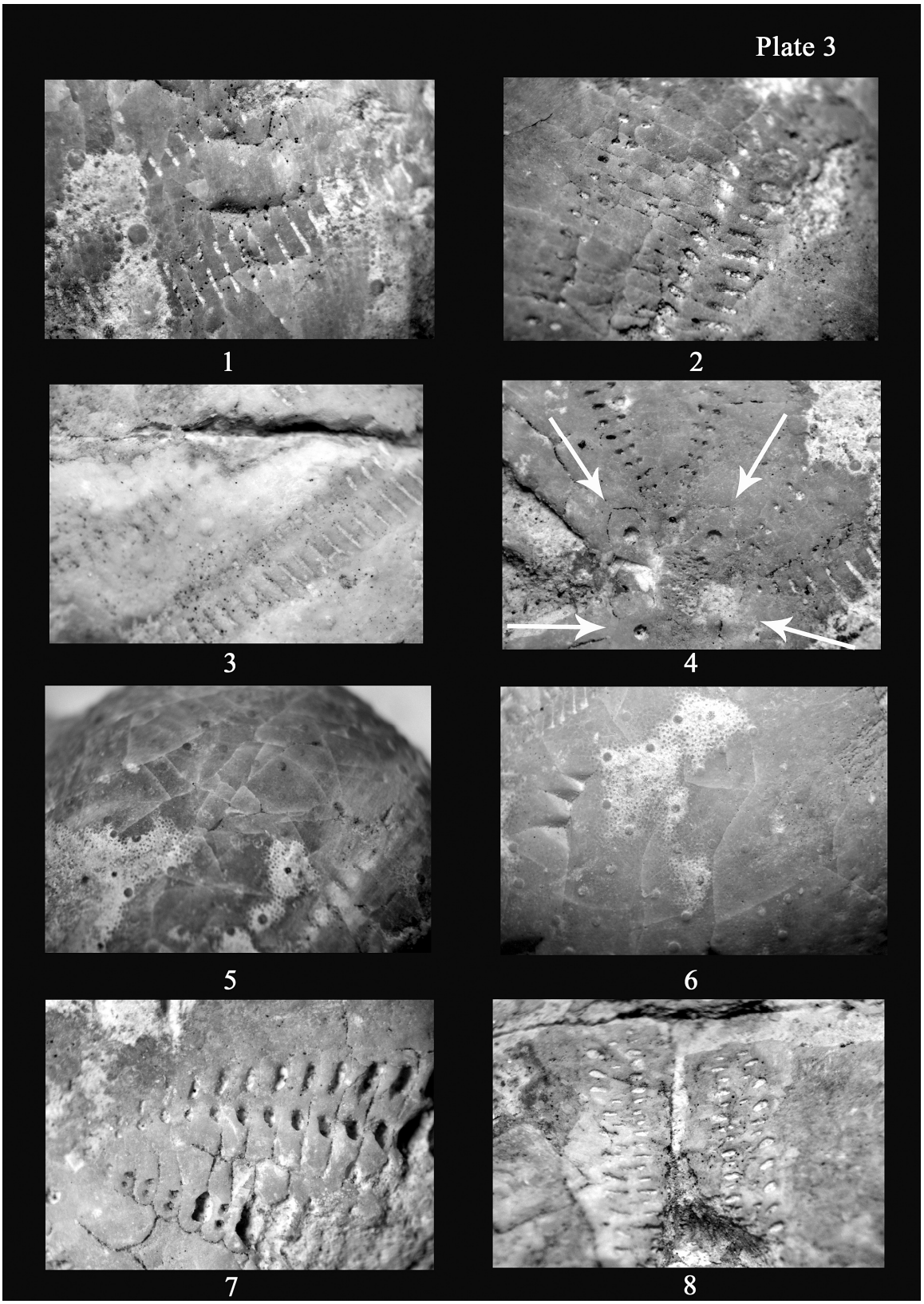

Plate 3: 1. Ambulacrum shape in *Toxaster renevieri* (25X). 2. Ambulacrum shape in *Heteraster* sp. 1. (25X). 3. Ambulacrum shape in *Toxaster granosus* (25X). 4. Preserved apical system in *Heteraster* sp. 2. (25X). 5. Tubercles distribution on Aboral surface in *Toxaster renevieri* (25X). 6. Tubercles distribution on Aboral surface in *Heteraster* sp. 1. (25X). 7. Ambulacrum shape in *Heteraster* sp. 2. (25X). 8. Position of pore-pairs in *Heteraster* sp. 2. (25X).

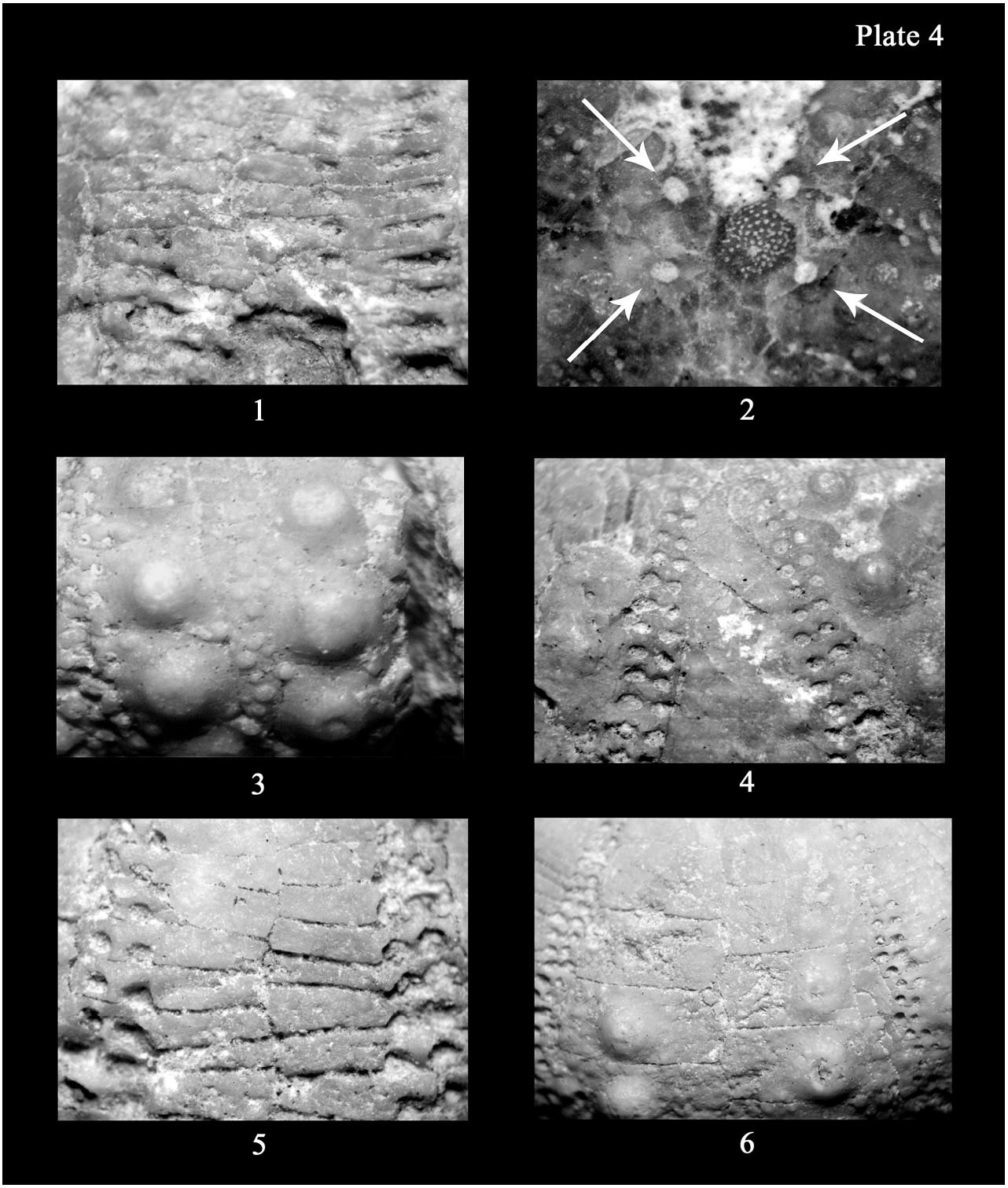

Plate 4: 1. Ambulacral plates in *Heteraster* sp. 2. (another view) (25X). 2. Preserved apical system in *Heteraster* cf. *delgadoi* (25X). 3. Primary and secondary tubercles in *Loriolia* sp. (25X). 4. Ambulacrum shape in *Loriolia* sp. (25X). 5. Ambulacral plates in *Loriolia* sp. (25X). 6. Interambulacral plates and primary tubercles in *Loriolia* sp. (25X).

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