

***Asteriacites quinquefolius* – Asteroid Trace Maker from the Bhuj Formation (Lower Cretaceous) of the Mainland Kachchh, Western India**

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Abstract: Trace fossil of ichnospecies *Asteriacites quinquefolius* - QUENSTEDT 1876, of the pentamerous star fish is recorded for the first time from the Central Mainland Kachchh, Western India. It occurs in the lower part of Bhuj Formation, on thin slabs of fine grained sandstone that intercalate with siltstone, along with symmetrical ripple surface covered by mud drapes. Two different types of behavioural activities are found (i) solitary and isolated deep impression of the traces, on account of their resting structures and (ii) composite, overlain structure indicating the movement of arms for preying activities. The occurrence of *Asteriacites* traces in the Lower Bhuj Formation indicates tidal-subtidal condition in a fully marine environmental set up.

Keywords: *Asteriacites*, Asteroid (star-fish), Trace fossil, Marine environment, Bhuj Formation, Kachchh, Gujarat

INTRODUCTION

Asteriacites VON SCHLOTHEIN 1820, a resting trace produced by asterozoans/ophuroids (Seilacher, 1953) has been recorded from Cambrian to Recent, in shallow to deep marine facies. *A. quinquefolius* are very common in Lower Member of Bhuj Formation in shallow to marginal marine/intertidal deposits. The objective of this paper is (1) to describe the morphology of the *Asteriacites*, particularly *A. quinquefolius* in the Lower Member of Bhuj Formation, (2) to examine the mechanism of *A. quinquefolius* formation and identify its producer and (3) to discuss the environmental significance.

For this study 32 specimens were studied and all of them record the activities of Asteroids. Although ophiuroids as producers of *Asteriacites* have been repeatedly quoted in the literature, an overview shows that an asteroid trace maker is the most reliable interpretation in all cases/ species.

LOCATION AND STRATIGRAPHY

In Central Mainland Kachchh, Bhuj Formation (Biswas, 1977) comprises of Lower Member in the basal part (equivalent to Ghuner Member of western Kachchh). The trace fossil *Asteriacites quinquefolius* described here has been recorded from the top of reddish to brownish, thinly

bedded ferruginous feldspathic sandstone with alternate siltstone bands that constitute the Lower Member. These thinly bedded ferruginous feldspathic sandstones are 5 to 20 cm thick exposed in two different localities, one about 2 km WSW of Bhuj (23°14'30" N, 69°39'00" E) and another in the river section, about one km NNE of Bharapur village (23°8'20" N, 69°38'30" E). In both these places, the sequence is correlatable and occurrence of *A. quinquefolius* is at the same stratigraphic level, i.e. the lower part of the Bhuj Formation (Biswas, 1977), which is Lower Cretaceous in age. A total of twenty-five impressions of the star fish have been studied in the ferruginous ripple-marked sandstone of the Bhuj section. This section comprises of coarse to very coarse sandstones (subarenite, subarkose) showing herringbone structure, hard ferruginous gritty sandstone with mega ripples, followed by sandstones/siltstones containing symmetrical oscillation and interference ripples and parting lineations. At the top it is characterised by hard ripple-marked ferruginous sandstone. In the Bharapur section, seven impressions have been found, in predominantly arenaceous, red to brown, massive and current bedded sandstone, with hard ferruginous ripple-marked top having intercalations and alternations of shale and siltstone.

A marine origin of Bhuj sandstone was suggested based

on trace fossils by Casshyap et al (1983), on trace fossils and sedimentary structures by Krishna et al (1982, 1983) and Singh and Shukla (1991) and by Rai (2006) based on calcareous nannofossils Howard and Singh (1985) pointed out that the absence of marine body fossils in the Bhuj sandstone is due to leaching of shell material in the highly porous sandstone

SYSTEMATICS

Asteriacites von Schlotheim, 1820

Diagnosis Impression in the form of asteroids or ophiuroids, with transversely sculptured arms, striae produced by activity of digging tube feet, often intersected by traces of neighbouring animals (horizontal repetition) or (as reaction to rapid sedimentation) "vertical repetition", morphology dependent on preservation as convex hyporelief or concave epirelief

Asteriacites quinquefolius Quenstedt, 1876 (Fig 1a-i)

Diagnosis Conical, sub-conical or sub-cylindrical biogenic structures with pentameral symmetry, depression on sides, coarsely striated with double row of nodes or rounded radial grooves

Description The trace fossils of Kachchh identified as *Asteriacites quinquefolius* are star-like trace fossils consisting of five tapering arms (Fig 1) radiating outwards from the centre. These structures are showing pentameral symmetry in the form of asteroids, with transversely striated and sculptured arms with raised rims. They occur in the form of depression or concave epirelief on the casting medium, i.e. ripple-marked ferruginous sandstone. Arms are transversely striated and in some cases double rows of transverse grooves are present. All the specimens exhibit more or less similar morphology and uniform dimensions. Length across the structure is about 5 cm, diameter of the central knob is about 8 mm (Figs 1a, e, f) and length of the arm is 17 to 20 mm. Distance between the striae or the grooves is 1-2 mm. Impressions are 2-6 mm deep with raised rims on the entire margin of the arms. Lateral repetition (Fig 1i) is produced by the movement of the same animal as multiple, hazy or indistinct impression of the arms.

Discussion and Interpretation Four *Asteriacites* are recognised viz *Asteriacites stelliformis* Osgood, 1970, *A quinquefolius* Quenstedt, 1876, *A lumbricalis* von

Schlotheim, 1822 and *A aberensis* Crimes and Crossley, 1991. *A quinquefolius* Quenstedt, 1876 is larger with broader arms and a "shaggy" (zotting) appearance rather than with transverse striations, apparently made by tube feet of asteroids as they burrow in the sediments. *A lumbricalis* von Schlotheim, 1822, is generally smaller with narrow arms, showing transverse striations, apparently made by the tube feet of ophiuroids as they burrowed into the sediment. Seilacher (1953) experimentally showed *A quinquefolius* to be more likely the trace of asteroid, *Astropecten aurantiacus* rather than ophiuroids. *Asteriacites stelliformis* is characterized by arms showing a distinctive chevron-like sculpturing (Osgood, 1970), while *A aberensis* is represented by small, five-rayed impressions with a large central area compared to the length of the rays (Crimes and Crossley, 1991). A fifth species *A gugelhupf* Seilacher, 1983, is now better regarded as belonging to a different ichnogenus *Pentichnus gugelhupf* (Mangano et al 1999).

The Kachchh specimens occur repeatedly on sandstone partings, showing lateral movement over the bedding surface. They consist of a shallow depression of five arms with pentameral symmetry which shows features clearly indicative of their production by asteroids. The trace fossils from the Lower Bhuj Formation described here easily fit within Seilacher's (1953) original definition of *A quinquefolius*. They have relatively broad arms and a shaggy appearance. *A quinquefolius* in the Bhuj formation near Bhuj and Bharapur village are also consistent with Seilacher's description of their mode of burrowing, slightly raised rims on arms and lateral repetition of the whole structure representing movement of asterozoa star fishes.

The paleoenvironmental interpretation by Pemberton et al (1988) suggests that the *Asteriacites* represent a thixotropic muddy-sandy substrate of a lower tidal, infratidal regime, where fluctuation in the water level caused the animals to be stranded on the muddy-sand substrate. Markings made by the movement of arms in *Asteriacites* demonstrate some kind of activity of the organism which may be predatory.

Asteriacites are characterised by slightly raised rim on entire margin, intricate row of tubercle markings on both sides of the arms and slightly raised knob or bottom like, rounded to polygonal central part as peristome impression. Two specimens with shallow subsiding ray impressions on the sides of and in between star arms, as a result of movement of arms indicate their production by a living star fish. The impressions are in the form of Asteroids with transversely sculptured arms, where their striae is produced by the digging of the tube feet as reflected by the two

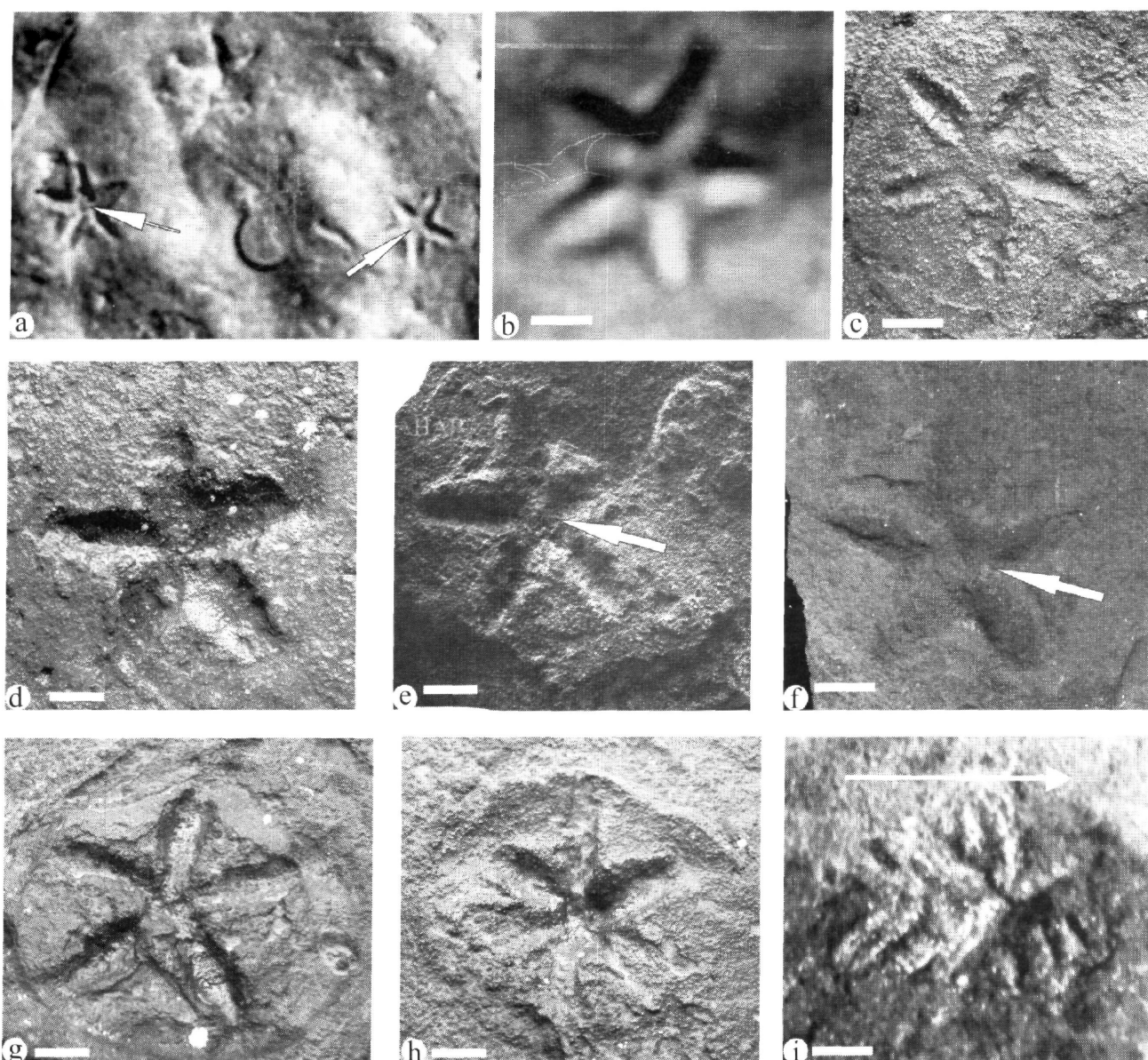


Fig.1. Morphological variation of *Asteriacites quinquefolius* Quenstedt, 1876, from Bhuj (23°14'30" N, 69°39'00"E). All specimens are preserved as negative epirelief on ripple marked ferruginous sandstone. Diameter of Coin in (a) = 2.5 cm, Scale bar = 1 cm for (b, c, f, i); Scale bar = 0.9 cm for (d, e, g, h). (a) Group of *A. quinquefolius* on ripple marked sandstone partings; two specimens on crest while one in trough. Note the central knob like impression (arrow) with well-developed pentagonal forms. (b) Enlarged view of Figure 1a, right hand specimen showing prominent knob like impression and weakly developed impression of two arms. (c) Well developed, slender, pentameral impression in negative epirelief. (d) Robust, pentameral specimen of *A. quinquefolius* with broad arms. (e & f) Central depression with pentameral symmetry of the asteroids. Note the presence of a shallow central depression (arrow), most likely formed by the mouth of the asteroid/tracemakers. (g) *A. quinquefolius* displaying variation in morphology with raised rims, indicating thixotrophic nature of sediment during the trace making activity. (h) *A. quinquefolius* indicating lateral movement of the trace maker. (i) Lateral movement of the trace maker (marked by arrow) recording horizontal repetition and overlapping of arm impression. Also note the predatory action of the trace maker produced by the arms movement on thixotrophic sediments.

specimens, intersected by traces of neighbouring animals (horizontal repetition) or as a reaction to rapid sedimentation (vertical repetition). All these characters correspond in shape

to the modern day star fish- *Astropecten* (Asteroids) and its resting/crawling traces on the clastic sediments of the intertidal and subtidal environments.

ENVIRONMENTAL SIGNIFICANCE OF *Asteriacites quinquefolius*

The star fish (Asteroids) is virtually a symbol of sea life since its inception during the Ordovician time. They are found more on hard rocky bottom or shelly bottom. However, the species that live more or less buried necessarily occur on the sandy bottom. Heddl (1967) documented *Astropecten irregularis* digging into a layer of sand in aquarium. When digging in to the substrate, the tube feet are protected and bent laterally outwards. Then they are withdrawn from the lateral position and the cycle is repeated. In some smaller animals, the movement markings of arms may have been formed due to increase in grip on the prey between the sediment and starfish, to prevent escape. Seilacher (1953) has discussed and concluded that the structures (resting activity) made by the modern asteroid *Astropecten aurantiacus* is comparable with *A. quinquefolius* from the Braun-Jura of Germany.

The latero-ventral morphology of the resting traces of

A. quinquefolius is identical to star fish- *Astropecten* (Asteroids) and repetitive arm movement intergrades with crawling traces. The animal is stranded on sandy sediments making an impression on sediments and departs from the same route during fluctuations of the water level conditions in tidal flat environment. The large size of the Bhuj Formation specimens may suggest normal marine salinity, especially as *Asteriacites* most commonly has been reported from shallow marine deposit of presumed normal marine salinity (Miller and Knox, 1985).

Occurrence of *A. quinquefolius* in the ferruginous rippled sandstone of the Lower Member of the Bhuj Formation is indicative of fully marine conditions, with normal marine salinity in the intertidal zone, which were subjected to repetitive fluctuation of water levels and exposed to the subareal conditions. The species that live more or less buried necessarily occur on the sandy bottom. The presence of *A. quinquefolius* in the Lower Member of the Bhuj Formation indicates that the star fish-*Astropecten* (asteroids) was living in the soft sandy sediments in tidal flat environment.

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