overlying Pink Clays. As such, although our collection from the Boulder Conglomerate horizon of the Central Narmada basin elsewhere is very rich in Early as well as Middle Acheulian tools, yet the Narmada Man at Hathnora could be associated with the Late Acheulian culture on the evidence available at present.

The cultural, biostratigraphic and absolute chronology of the Narmada Man at Hathnora is, however, debatable. The appearance of Acheulian culture in India is considered an event of earlier to 0.4 million years[10] BP on $Th^{230}/U^{234}$ dating. The mammalian fauna in our collection from the Boulder Conglomerate horizon include cranial, dental and postcranial material belonging to *Bubalus palaeindicus, Bos namadicus, Equus namadicus, Elephas namadicus, Stegodon* sp., *Hexaprotodon palaeindicus, Cervus duvauceli*, etc. These are indicative of a Middle/late Middle to early Upper Pleistocene age, as also inferred by other workers. Coupled with the biostratigraphic and cultural evidence, the youngest Toba Ash horizon (ca. 75000 yrs BP) in the Narmada basin provides an estimate of 0.2 to 0.3 Myr[11] for the Hathnora Man. But considering the upper age limit of 0.7 Myr[12] for the Narmada sequence based on palaeomagnetic dates, the current opinion on Hathnora Man's dating is of an age above half a million years BP. This now seems reasonable in view of a K–Ar date of $0.67 \pm 0.03$ Myr[13] for the Early Acheulian culture at Bori, Pune.

Our detailed Narmada Report would attempt reassessment of the evolutionary relationships of the Narmada Man in a global framework.


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# The mode of epibiont attachment on molluscs in Chandipur Beach, Orissa and its palaeontological implications

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**Epibionts attach themselves on hard parts of other organisms so as to complete their own life cycles. Host organisms may be dead or alive during the attachment time. Chandipur coast in Orissa, offers to study various types of marine epibiont attachments on other animals, particularly on molluscs. The nature of attachments provides clues to deduce life modes of the host molluscs and timing of attachments. Its paleontological implications are also explored.**

EPIBIONTS attach themselves on live or dead shells of other organisms. The host may be sessile or mobile. Even in rock records there are numerous examples where epibionts are attached to diverse groups of host animals. The relationship between them is usually symbiotic or may be, in some cases, parasitic. In any case, it is possible to deduce the life habit and timing of attachment from the nature of attachment. By drawing analogy from the recent epibiont attachment we can have better insight into the problems encountered in the rock records.

The present study concerns observations on various epibiont attachments on different kinds of host organisms which help in determining the life habit of the latter and the timing of attachment, i.e. whether host was alive or dead during the epibiont infestation.

The Chandipur coast in Balasore district, Orissa (Figure 1) is characterized by very wide (~4 km) tidal flat fringed by a narrow beach on the northern side. The Buribalam river and its emerged terrace now covered with marsh is on the east; southward beyond the tidal flat and shoreface of the Balasore shelf is planer[1]. The beach is skirted by aeolian dunes beyond which, further landward lies recent alluvium bordered by Nilgiri hills which are situated about 40 km from the studied coastline[2]. The coastal zone is presently undergoing intense

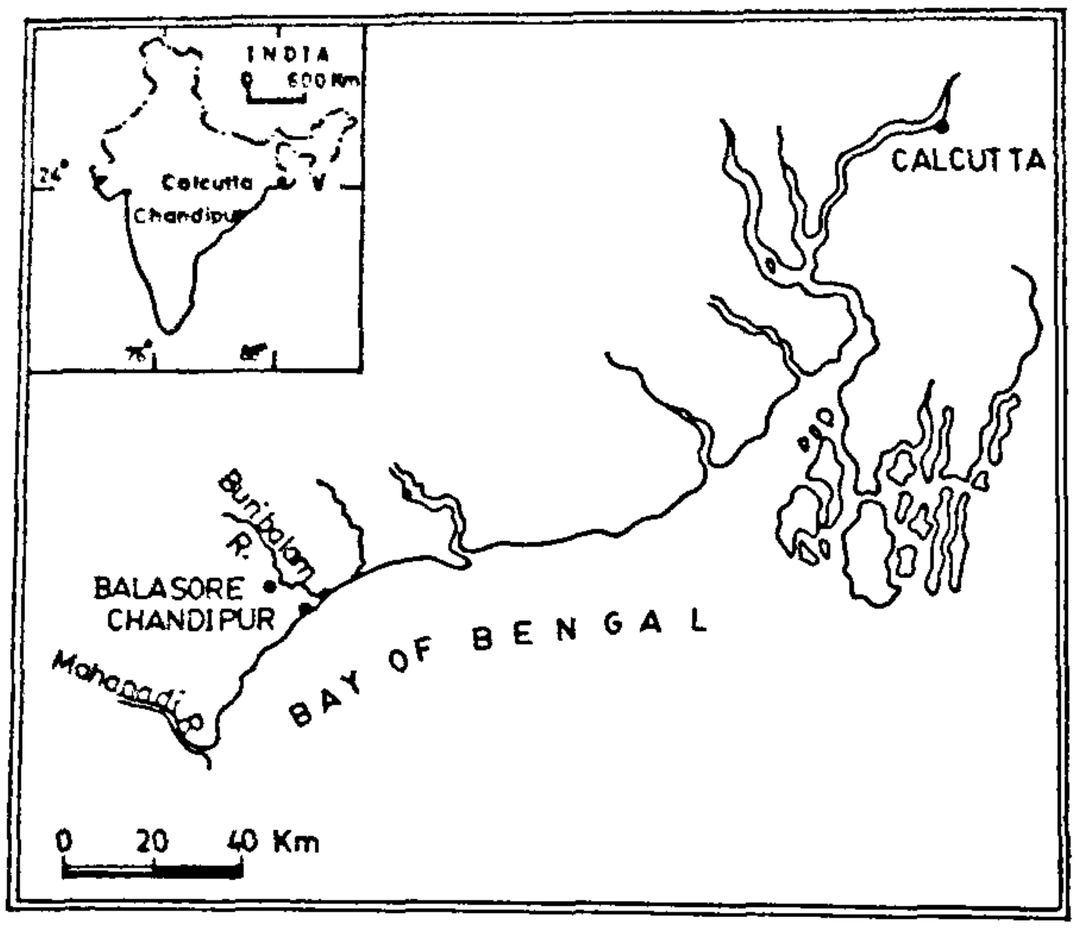


**Figure 1.** Location map of Chandipur beach.

erosion due to encroachment of sea. None of the geomorphic components is in equilibrium with the wave dynamics prevailing at present. The shoreline in this sector is trending in a NE–SW direction.

Chandipur coast supports diverse marine life, of which molluscs are predominant. Both bivalves and gastropods are equally abundant. They have various ways of life and are found in different modes of preservation. Live animals are rarely found. Bivalves are mostly disarticulated and fragmented, and are found mostly as wave lags aligned parallel to the shoreline. The vast array of morphologic types of this area is a biological storehouse providing information of different life modes of molluscs.

The epibionts include both epizoans and epiphytes. Epizoans are mainly oysters, i.e. *Crassostera* cf. *cuttackensis* (Newton & Smith) and *Saccostrea cucullata* (Born) and barnacles (*Balanus* sp.), a crustacean. The epiphytes include green-coloured algae whose specific identification could not be made. Both the barnacles and oysters are cemented to any object which provide hard substrate for cementation. Many organisms, mainly molluscs, are found to be attached by these epibionts. In case of gastropod hosts, which are both abundant and diverse along the beach sediments, epibionts attach themselves on both live and dead shells. In case of dead host, the attachment is random, all around, even on the apertural region (Figure 2 *a*, *b*).

The closing of aperture would be fatal for live animals and it is no wonder that not a single live gastropod is seen to have epibiont attachment near aperture or on the lower surface. Lower surface lying in direct contact with the substrate in case of live animals is not available to any epibionts. Therefore, live hosts as a rule carry epibionts on the upper surface (Figure 2 *c*). *Barnea candida* (Linnaeus) is a bivalve belonging to the family Pholadiadae. The genus has been reported from various parts of the world[3]. They are extremely thin-shelled, cylindrical and streamlined with both the pedal and siphonal gapes and have ornamentation on the external surface. They are known as borer into stiff clay or weathered rocks[3]. Some species of *Barnea* also burrow into soft sediments[4]. The Indian species, i.e. *Barnea candida* inhabits intertidal zone and is found all along the East coast, i.e. in Chandipur, Gangasagar and Bakkhali. In all these regions, the species is never found alive or even intact shells are also rare. The shells are mostly disarticulated and scattered in distribution. The nature of preservation and rarity of live individuals suggests sublittoral zone as their native habitat. Therefore, no direct observation could be made with respect to their mode of living. It is even presumed that they are deep infauna[5] and accumulation of disarticulated valves results from the transportation by waves after being posthumously exhumed. But epibiont attachment on disarticulated valves provides clues to their actual life mode. The epibionts, mainly barnacles and algae, are invariably attached on the posterior side of the valves (Figure 2 *d*). This clearly signifies the preexhumation attachment. The mode of attachment indicates that host organisms, i.e. *B. candida* have semi-infaunal life mode with posterior part exposed above the substrate. But it remains uncertain whether the host animal was alive or dead during attachment. The following case study provides much stronger ground for timing of attachment.

Extensive ancient marsh all along the Eastern coast is locally exposed from below a thin veneer of beach sands[6,7] during recent beach erosion. The ancient marsh constitutes stiff black mud which supported typical tidal mangrove and monotypic bivalve community characterized by *Glauconome sculpta* (Sowerby) of estuarine facies. The bivalve is thin-shelled, elongated and streamlined with external surface ornamented with concentric costae. These bivalves are numerous and colonized the whole stretch of low-water mark of the ancient marsh (Figure 2 *e*). The marsh has been radiometrically dated as being around 3000 years old[6]. During exhumation of marsh in recent times, the bivalves are locally reworked and get admixed with modern beach fauna indicating extensive time-averging[8]. These bivalves are semi-infaunally positioned within the sediments, indicating their life mode. Their posterior ends are always exposed above the surface and thus provide hard substrate for epibiont attachment. Epibionts are marine – small oysters or barnacles of very recent origin. Bardhan *et al.* showed that around 3000 years ago, the Indian eastern coastline was rapidly transgressed so that beach environments prograded directly over the marsh of estuarine facies.

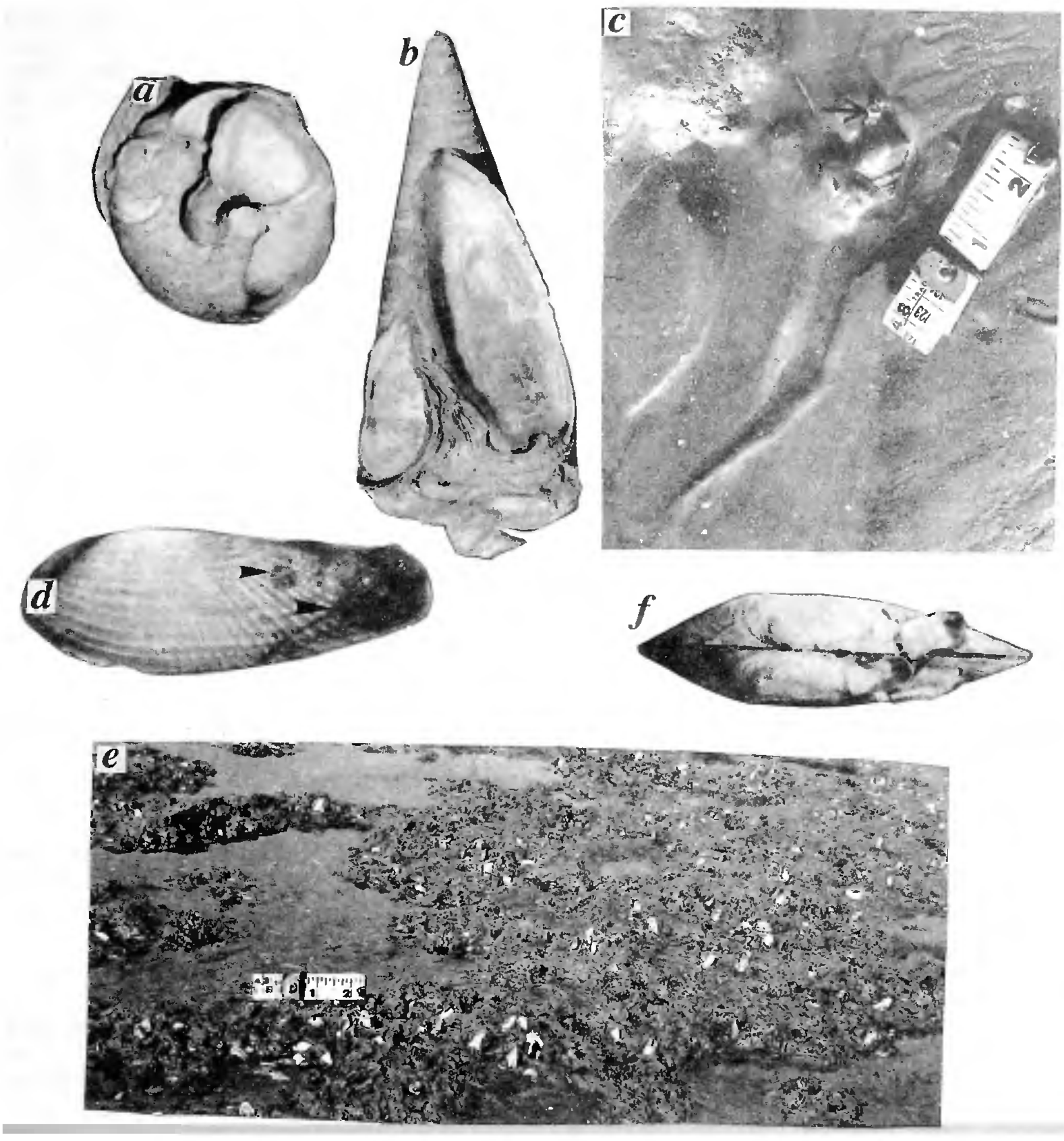


**Figure 2.** All around epibiont (*Saccostera cucullata*) attachment on a gastropod (*Telescopium telescopium*) host indicating post-mortal infestation. *a*, Apertural view × 0.75. *b*, Upper view × 1. *c*, A live gastropod (*Thais lacera*) carrying a Balanus epibiont on its upper side. Note the trail left by the gastropod and the epibiont sitting just above the aperture (see arrow). *d*, *Barnea candida*. Note epibionts (both algae and Balanus) attachment on the posterior part. External view of right valve × 1. *e*, Numerous Glauconome sculpta shells are semiinfaunally positioned in their life attitudes within the muddy marsh sediment, Chandipur. *f*, Oysters sitting on the dorsal commissure of *G. sculpta* shell indicating the post-moral infestation × 1.

Therefore it appears that epibiont attachment takes place on hosts which are of different environments, thus indicating allochthonous time-averaging[9,10]. That epibiont attachment is a postmortal infestation becomes apparent when oysters are even found sitting on the top of the dorsal commissure of *G. sculpta* shell (Figure 2 *f*)

The organisms are rarely preserved in their life positions in the rock record. Various taphonomic processes are involved in determining the ultimate disposition. The information loss in between may even amount to complete obliteration of palaeoecologic data. There are many fossil species which are nondescript and lack typical functional morphologic traits and thus provide almost no clue to their life mode. This is particularly true for organisms inhabiting between two ecological boundaries and hence are not optimally adapted, displaying wide range of intraspecific variation. For example, *Mactra meritriciformis* (Deshayes) living as shallow burrowers in intertidal area and *G. sculpta* having semi-infaunal way of life in swamp, give hardly any clue to their specific ecologic niche when they are exhumed. Epibiont attachment may occasionally compensate the information lost in the subsequent process of fossilization.

The buoyancy control in one ammonite genus *Buchiceras* (Hyatt, 1875) came into light through the study of epizoic oysters on it[11]. Previously, Seilacher[12] had shown this overgrowth of oysters took place when the ammonite was alive and capable of remaining afloat with the increasing weight of the oysters. In another example from Cretaceous Bagh-beds (MP), many specimens of *Placenticeras* (Meek, 1870) ammonites have oyster attachments on their internal moulds. Ammonite shells, being originally aragonitic, are very unstable during diagenesis and original shells are mostly recrystallized to calcite or undergo dissolution leaving only internal moulds. Now, overgrowth of oysters on internal moulds clearly implies that the timing of attachment must have involved some complex taphonomic processes. Organisms were buried, the original shell was dissolved during early diagenesis, leaving only indurated internal mould Specimens are reported from a hard-ground horizon which facilitates early lithification (pers commun.). These internal moulds were subsequently reworked and provided hard substrate for oyster attachment.

Raup and Stanley[13] described the Devonian bivalve, *Modiomorpha concentrica* (Conrad) with epibionts encrusting in the posterior part. Because of this preferential encrustation they concluded that the host bivalve species was alive and the animal had semi-infaunal life mode. While the present author fully agrees with their interpretation with regard to the way of life of the host animal on the basis of the evidence of epibiont attachment, the timing of attachment may not, however, be always the same.

In the present study of *G. sculpta*, it has been demonstrated that infestation was a post-mortal event since organisms show ecologic incompatibility and time-averaging. No wonder that telescoping of organisms of different environments in a single horizon has also been observed in fossil records. Fursich and Kauffman[14] for example, described freshwater unionids in life position amidst brackish water molluscs from the Albian sequence of Wyoming

*Barnea* is a highly variable pholadid genus belonging to the family Pholadiadae. It is usually described as a boring organism into different substrata such as stiff clay, weathered rocks, etc. and to our knowledge not a single species is known to have semi-infaunal life mode. *B. candida*, the common Indian species, is axiomatically considered as deep burrowing organism[5]. But evidence such as preferential encrustation of different epibionts along the posterior region suggests that the Indian species perhaps evolved to adapt a semi-infaunal life within stiff clay sediments without sacrificing its streamlined shape and other features which may otherwise indicate deep boring form when considered in isolation.

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# Evidence of Middle to Late Holocene neotectonic activity in the Ganga Plain

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**We report here the development of fracture planes, bending and tilting of the beds, and block movement in cliff section of the Sengar river, a tributary of the Yamuna river.**

FORELAND basins are characterized by syndepositional activity, which is more pronounced along the orogenward as well as cratonward margins. The Ganga Plain is an active foreland basin where effects of active tectonics are evident[1]. Lately, several studies have documented evidences of active tectonics which has controlled the development of geomorphic features and the alignment of river courses in the Ganga Plain[2–10]. Based on the pattern of tectonic activity, three major zones are identified in the Ganga Plain, namely the Piedmont zone, Central alluvial plain, and Marginal alluvial plain[7,11].

The Marginal alluvial plain and the southern part of the Central alluvial plain show evidences of vertical upliftment causing deep incision of the river system[1,11,12]. In this paper, we report development of fracture planes, bending and tilting of the beds, and block movement in cliff section of the Sengar river, a tributary