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TURONIAN (LATE CRETACEOUS) LIMIDS (BIVALVE) FROM THE BAGH GROUP, CENTRAL INDIA

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ABSTRACT

The Turonian (Late Cretaceous) in the Bagh Group of central India is represented by the Nodular Limestone Formation. Four limid species namely *Acesta (Acesta) obliquistriata* (Forbes), *Pseudolimea interplicosa* (Stoliczka)*, Lima* cf. *granulicostata* Chiplonkar and Badve and *Lima scaberrima* (Stoliczka) have been recorded from this interval and systematically described. *Acesta (Acesta) obliquistriata* (Forbes), *Pseudolimea interplicosa* (Stoliczka) and *Lima scaberrima* (Stoliczka) have been reported here for the first time from the Narmada Basin. The status of subclass Pteriomorphia, with special reference to superfamily Limacea, has also been reviewed in brief. The functional morphology and the usefulness of these limids in the palaeoecological interpretation have also been briefly discussed.

Keywords: Pteriomorphs, Limid bivalve, Turonian, Late Cretaceous, Bagh Group, central India.

INTRODUCTION

The pteriomorph bivalves account for about 20% population of the class Bivalvia (Combosch and Giribet, 2016). These are assorted group of quite distinct morphology and ecology, dwelled in a variety of marine environments. Their diversity may be due to their variety of adaptive radiations and different shell forms (Motsumoto, 2003). .Although most of the bivalve experts believed in its monophyletic origin but internal morphological attributes posed a major problem. Some of the bivalve experts like Campbell *et al.* (1998); Waller (1998); Carter *et al.* (2000); Giribet (2008); Bieler *et al.* (2014); González *et al.* (2015) and Combosch and Giribet (2016) have made a good effort to resolve this issue by using mostly the internal morphological characters of the modern representatives for the higher bivalve lineages and clades. However, amongst the all bivalve subclasses, subclass Pteriomorphia has least uncertainty in their monophyletic origin which has been inferred on the basis of anatomical uniqueness (Purchon, 1987) and the progression of ligament (Waller, 1990, 1998).

These pteriomorphs contain mostly epifaunal bivalves with byssal threads like oysters, scallops, mussels and arks and fit into orders Arcoida, Limopsoida, Mytiloida, Modiomorphoida, Limoida, Pectinoida, Pinnoida*,* Pterioida, Anomioida and Ostreoida. Ark shells are amongst the oldest bivalve lineages, reaching back to the Early Ordovician (Morton *et al*., 1998). At the superfamily level, Anomioidea, Limoidea, and Pectinoidea are charactertised by typical calcite prismatic outer layer underlain by crossed lamellar aragonite layer (Taylor *et al.,* 1969). However, the assignment of the order Limoida or even superfamily Limoidea to subclass Pteriomorphia has been tricky (Gilmour, 1990; Mikkelsen and Bieler, 2003) due to some deviating diagnostic features like reduced hinge teeth, monomyarian adductor scar and perceptible 180^0 rotation of foot with respect to the shell.

Limidae has monophyletic clad within Pteriomorphia and consists of 21 genera and 17 subgenera in which *Aviculolima, Gryphellina and Roncania* have been doubtfully placed (Coan *et al*., 2000, p. 203). Limidae has 10 living genera and about half of them have a fossil record dating back into the Mesozoic (Harasewych and Tëmkin, 2015).

An attempt has been made to look into the recent development in the taxonomy of the Superfamily Limacea Rafinesque, 1815 and accordingly four taxa have been described here from the Nodular Limestone Formation. Their functional aspects and interaction within the shallow marine environment have been briefly discussed. The present study is based on the collection of bivalves from Nodular Limestone Formation exposed in Sitapuri and Chakrur localities of the Narmada Basin (Figs. 1, 2).

GEOLOGICAL SETTING

Narmada Basin of central India is an intracratonic rift basin between the longitude 72º32′ E to 81º32′ E and latitude 21º20′ N to 23º45′ N (Biswas, 1987; Acharya and Lahiri, 1991; Tripathi, 2006). The origin of this basin in the Early Cretaceous is accredited to the reactivation of fault along the Narmada-Son lineament (Kumar *et al*., 1999; Racey *et al*., 2016).

These Late Cretaceous sediments occur as isolated outcrops in the basin, stratigraphically overlie the Precambrian crystalline rocks and underlie the Deccan Trap in the central and western sector of peninsular India (Tripathi, 2006; Racey *et al*., 2016). The published stratigraphic frameworks in the basin are baffling and restrain many inconsistencies in terms of fundamental basic lithostratigraphic stages (Group, Formation, Member and Beds), age, environment and terminologies. In previous literatures, the terms 'Bagh Beds' and 'Lameta Beds' were popular for the Cretaceous sedimentary successions exposed in the Narmada Basin. In succeeding works, 'Lameta Beds' have gained the status of Lameta Formation/Lameta Group (Akhtar and Khan, 1997). The name 'Bagh Beds' was given after Bagh Town by Blanford (1869) and redesignated as Bagh Group (Akhtar and Khan, 1997; Tripathi, 2006; Jaitly and Ajane, 2013; Jaitly *et al*., 2015) which includes major part of the Cretaceous sediments excluding Lameta Group. These marine Cretaceous sediments of Bagh Group is exposed in the Bagh area, situated in Dhar district of Madhya Pradesh, in the western sector of Narmada Basin, Central India (Fig. 1).

LITHOSTRATIGRAPHIC REMARKS

Numerous schemes of classification of the Late Cretaceous sediments of the Lameta Basin have been proposed by different workers since the time of of Blanford (1869). However, the present authors have followed the classification given by Jaitly and Ajane (2013) which is also widely in usage. Jaitly and Ajane (2013) formally organized the marine Cretaceous succession and revised the lithostratigraphic framework of the Bagh area by keeping whole of the pre-Lametas sediments into the Bagh Group. They further subdivided the Bagh Group into Nimar Sandstone, Nodular Limestone (inclusive of Deola-Chirakhan Marl) and Coralline Limestone formations in ascending order (Table 1).

The sedimentation in the Narmada Basin commences with a conglomeratic horizon followed by the sediments of the Nimar Sandstone Formation (Fig. 2). It is primarily composed of non-marine thickly bedded, red, ferruginous sandstones, with occasional inter- beds of conglomerates and siltstones in the lower part. The upper part of the Nimar Sandstone Formation embraces marine succession of coarse to medium or even fine grained sandstones, with few levels of glauconitic sandstone and siltstone interbeds. Cross-bedding, lenticular bedding and ripples are common sedimentary features in these sandstones. The next younger unit in the basin is Nodular Limestone Formation which conformably overlies the Nimar Sandstone Formation. It is marine and mainly comprised of fossiliferous limestone beds rich in macroinvertebrates (bivalves, ammonoids, gastropods etc.). It has been further differentiated into Karondia and Chirakhan members in the order of superposition, separated by a distinct hardground. Lithologically, the Karondia Member represents the thinly bedded, whitish grey, nodular limestones intercalated with frequent relatively thin marly bands yielding bivalves, ammonoids, gastropods and echinoids. The lower part of this member consists planner-bedded, laminated, moderately fossiliferous limestones while the upper part is poorly bedded and highly fossiliferous. A distinct hardground separates these two divisions of the Karondia Member. The Chirakhan Member is characterized by having purple to light brown marl/siltstones alternating with nodular limestone/ bioturbated limestone beds. Physically, it is distinguished from the underlying Karondia Member through the distinct presence of relatively much thicker, friable, argillaceous marly beds and relatively highly fossiliferous horizons. The youngest unit of the Bagh Group is Coralline Limestone Formation, named after coral-like appearance, not due to abundance of corals. This marine succession occupies its stratigraphic position above the Nodular Limestone Formation and lies either below Lameta Group or Deccan volcanics. It is a hard, yellow, yellowish green to reddish brown, fossiliferous motled limestones/fine grained calcareous sandstones. It has yielded the diverse macrofauna (echinoids, gastropods, oysters, bivalves, brachiopods, serpulid

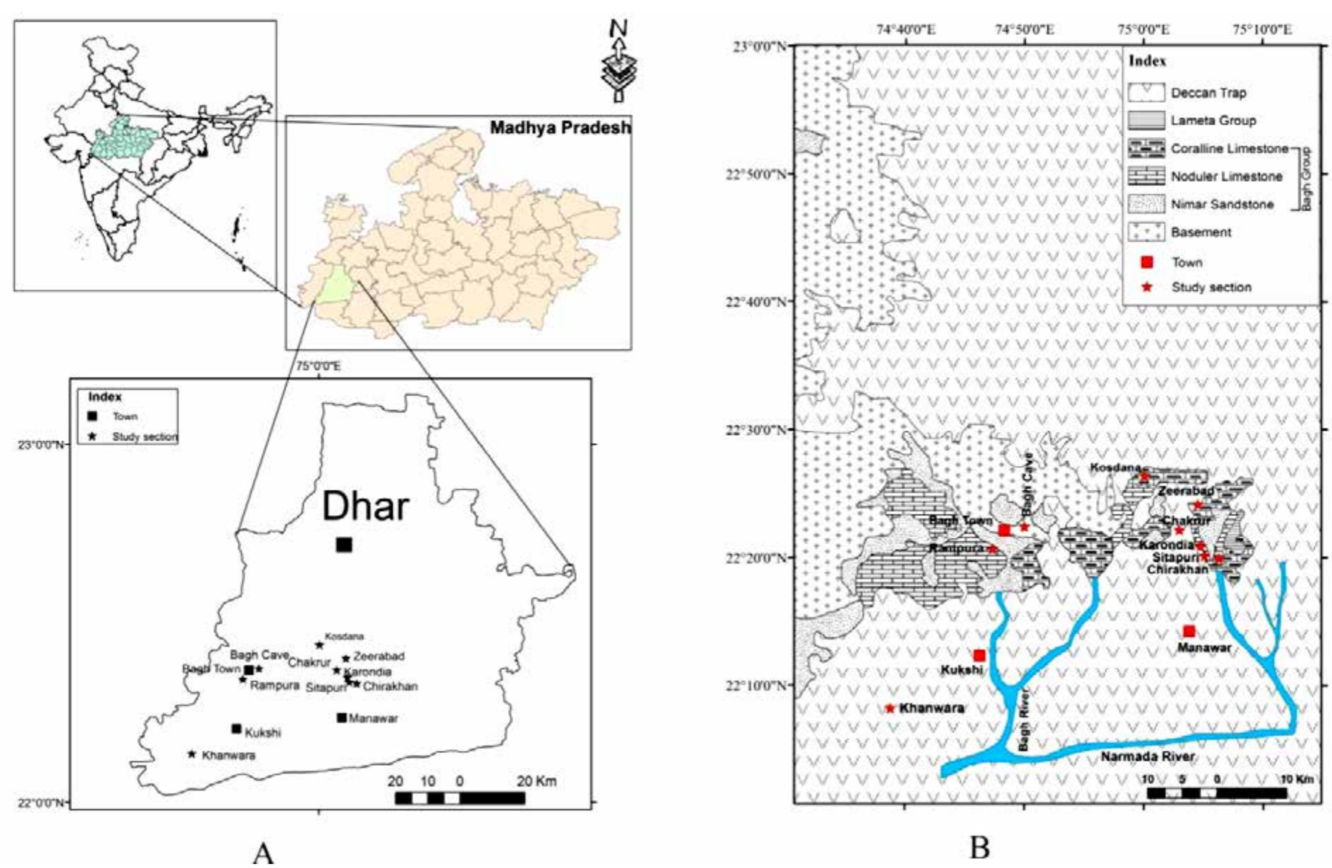

Fig. 1.A. Location of the studied sections in Narmada Basin, central India, B. Geological Map of the Bagh area, Dhar district, Madhya Pradesh (Modified after Jaitly and Ajane, 2013).

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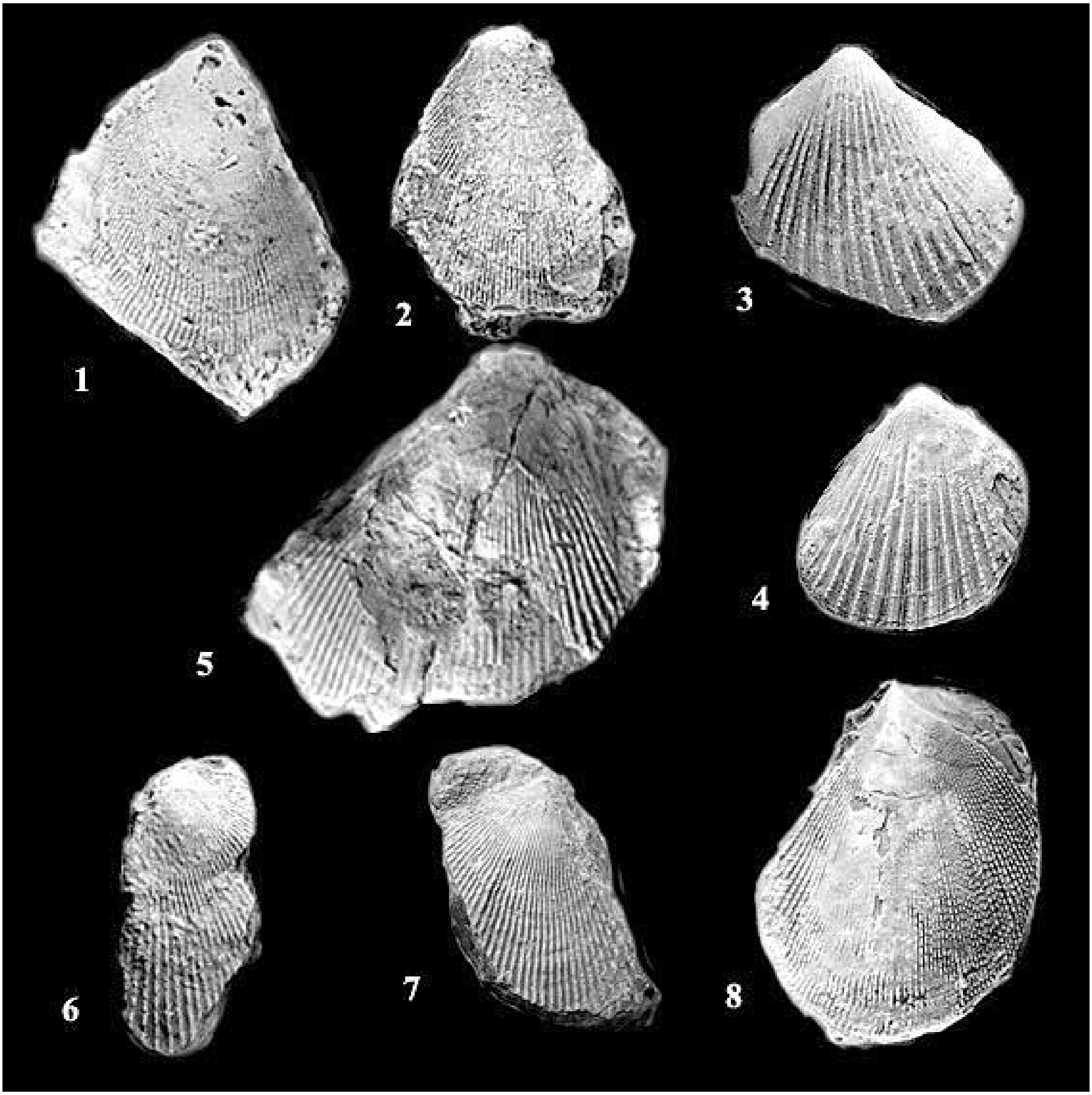
Plate I



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EXPLANATION OF PLATE I

Figs. 1, 2. ***Acesta (Acesta) obliquistriata*** (Forbes, 1846), 1 - (BHU2014/Si4/4) x 1.5, External view of right valve, 2- (BHU2014/Sn3/59) x 1, External view of rightt valve, lower part of Chirakhan Member, Nodular Limestone Formation, Sitapuri, Narmada Basin, central India. Figs. 3,4. ***Pseudolimea interplicosa*** (Stoliczka, 1871), 3- (BHU2014/ Ck2/15) x 2.5, External view of right valve; 4- (BHU2014/ Ck1/59) x2.5, External view of left valve, upper part of Karondia Member and Chirakhan Member, Nodular Limestone Formation, Chakrur, Narmada Basin, central India. Figs. 5-7. ***Lima* cf. *granulicostata*** (Chiplonkar and Badve, 1972), 5- (BHU2014/Sn2/1) x0.6, External view of left valve, 6- (BHU2014/Si5/9) x 0.6, External view of right valve, 7- External view of left valve, upper part of Karondia Member, Nodular Limestone Formation, Sitapuri, Narmada Basin, central India. Fig.8. ***Lima scaberrima*** **(**Stoliczka, 1871), (BHU2014/Sn3/28) x 1.5, External view of left valve upper part of Karondia Member, Nodular Limestone Formation, Sitapuri, Narmada Basin, central India.

Table 1. Lithostratigraphic framework of the Bagh Group in the Narmada Basin, central India (modified after Jaitly and Ajane, 2013)

Lameta Group and Deccan Traps			
Group	**Formation**	**Member**	**Age**
Bagh	Coralline Limestone		Coniacian
	Nodular Limestone	Chirakhan	Late Turonian
		Karondia	Middle Turonian
			Early Turonian
	Nimar Sandstone		Cenomanian
Crystalline rocks			

worms and shark teeth) but is overwhelmingly dominated by the bryozoans.

SYSTEMATIC PALAEONTOLOGY

Order **Pterioida** Newell, 1965
Superfamily **Limacea** Rafinesque, 1815
Family **Limidae** Refinesque, 1815
Genus ***Lima*** Braguiere, 1797
Type species *Lima alba* Cuvier, 1797

Lima cf. *granulicostata* Chiplonkar and Badve
(Pl. I, figs. 5 - 7)

cf. *Lima granulicostata* Chiplonkar and Badve, 1972, p. 87, pl. 2, fig. 10

Material: Two specimens (BHU2013/Si - 5/9, Sn2/1)

Horizon and locality: Nodular Limestone Formation (Turonian) from Bed No. 9 of Sitapuri, Dhar, M.P.

Description: The present specimens are broken along the ventral margin. Umbo is prominent, appears to be submesial in position. The apical angle is obtuse. The anterior margin is long and straight, while posterior one is small and also straight. The auricles are not preserved. The surface is ornamented with radial ribs which are almost straight in dorsal half but becoming undulatory in ventral half. The radial ribs are rounded and separated by evenly concave interspaces which are narrower in dorsal half and gradually becoming wider in ventral half (almost of equal width as of radial ribs). The radial ribs are scaly with almost smooth interspaces and crossed by irregularly distributed faint concentric growth lines.

Dimensions:

S.No	**Specimen No.**	**Height (mm)**	**Length (mm)**	**Inflation (mm)**
1	BHU2013/ Si5/9	70	65	30 (Both Valves)
2	BHU2013/ Sn2/1	88	65	30 (Both Valves)

Remarks: In the available characters, the specimens from Bagh Bed are comparable to the *Lima scabrissima* Woods (1904, p. 7, pl. 2,figs. 8 and 9) and *Lima granulicostata* Chiplonkar and Badve (1972, p. 87, pl. 2, fig. 10) from the Turonian of Bagh Group. Chiplonkar and Badve (1972) separated *L. granulicostata* from the English species due to the absence of perceptive growth lines and densely crowded scales/granules. In the present fragmentary specimens, surface features are adequately preserved but it does not show presence of any secondary (as intercalations) ribs or punctate/transverse threads in the interspaces. These differences refrain the direct assignment of the present specimens to *L. granulicostata* and recorded here as *L.* cf. *granulicostata* Chiplonkar and Badve.

Lima scaberrima (Stoliczka)
(Pl. I, fig. 8)

Radula (?Ctenoides) *scaberrima* Stoliczka, 1871, p. 421, pl. 30, fig. 1

Material: One specimen (BHU2014/Sn3/28)

*Horizon and locality***:** Nodular Limestone Formation (Turonian) from Bed No. 9 of Sitapuri, Dhar, M.P.

Dimensions:

S. No	**Specimen No.**	**Height (mm)**	**Length (mm)**	**Inflation (mm)**	**Apical Angle**
1	BHU2014/ Sn3/28	30	22	4 (Left Valve)	70^0

Description: This lone specimen is broken along the postero-dorsal margin but is apparently subovate in outline and poorly inflated. Height is appreciably greater than length. Umbo small, prosogyrous and slightly protruding above the dorsal margin. Antero - dorsal margin long and nearly straight, anterior margin short and merging with ventral margin in obtuse curve. The rounded postero-dorsal, posterior and symmetrically rounded ventral margins form an uninterrupted semicircle.

Surface ornamentation consists of numerous narrow, rounded, scabrous and undulating ribs separated by grooves which are narrower or almost of equal width. In the ventral half these primaries are intercalated by secondary ribs of similar nature. The radial ribs are crossed by concentric growth line and bear scales or minute lappet like projections at the point of intersection. In the grooves these scales appear as lamellar projections. These radials become sharper and separated by wider grooves on the anterior region.

Remarks: This lone specimen shows adequately preserved surface features and quite similar to *Radula* (?Ctenoides) *scaberrima,* a new species of Stoliczka (1871) from the Ariyalur Group, South India. *L. scaberrima* is almost identical to *L. scabrissima* Woods (1904, p. 7, pl. 2, figs. 8a - b, 9a - b), in surface features, scrabous (ribs with numerous concentrically displaced scales) radials, however, *L. scabrissima* Woods is broadly ovate with greater apical angle (92^0).

Genus **Acesta** Adams and Adams, 1858
Type species: *Ostrea excavata* Fabricius, 1779

Generic remarks: There is minor difference in the shell outline of *Acesta* Adams and Adams and some of the other limid genera like *Lima* Bruguiere, *Antiquilima* Cox, *Plagiostoma* J. Sowerby etc. The genus *Antiquilima* ranges in Early to Middle Jurassic, *Plagiostoma* Middle Triassic – Late Cretaceous, while Acesta and *Lima* range from the Jurassic to Recent. *Acesta* can be readily distinguished by its typical surface character in having strong radials in the anterior and posterior part which grades into fine striae on the median part. Beasides the genus *Acesta* is characterized by the presence of prosocline ligament pit, acute umbo and H:L >1 (Jaitly *et al*., 1995).

Acesta (Acesta) obliquistriata (Forbes)
(Pl. I, figs. 1, 2)
Lima obliquistriata Forbes, 1846, p. 154, pl. 18, fig. 13.

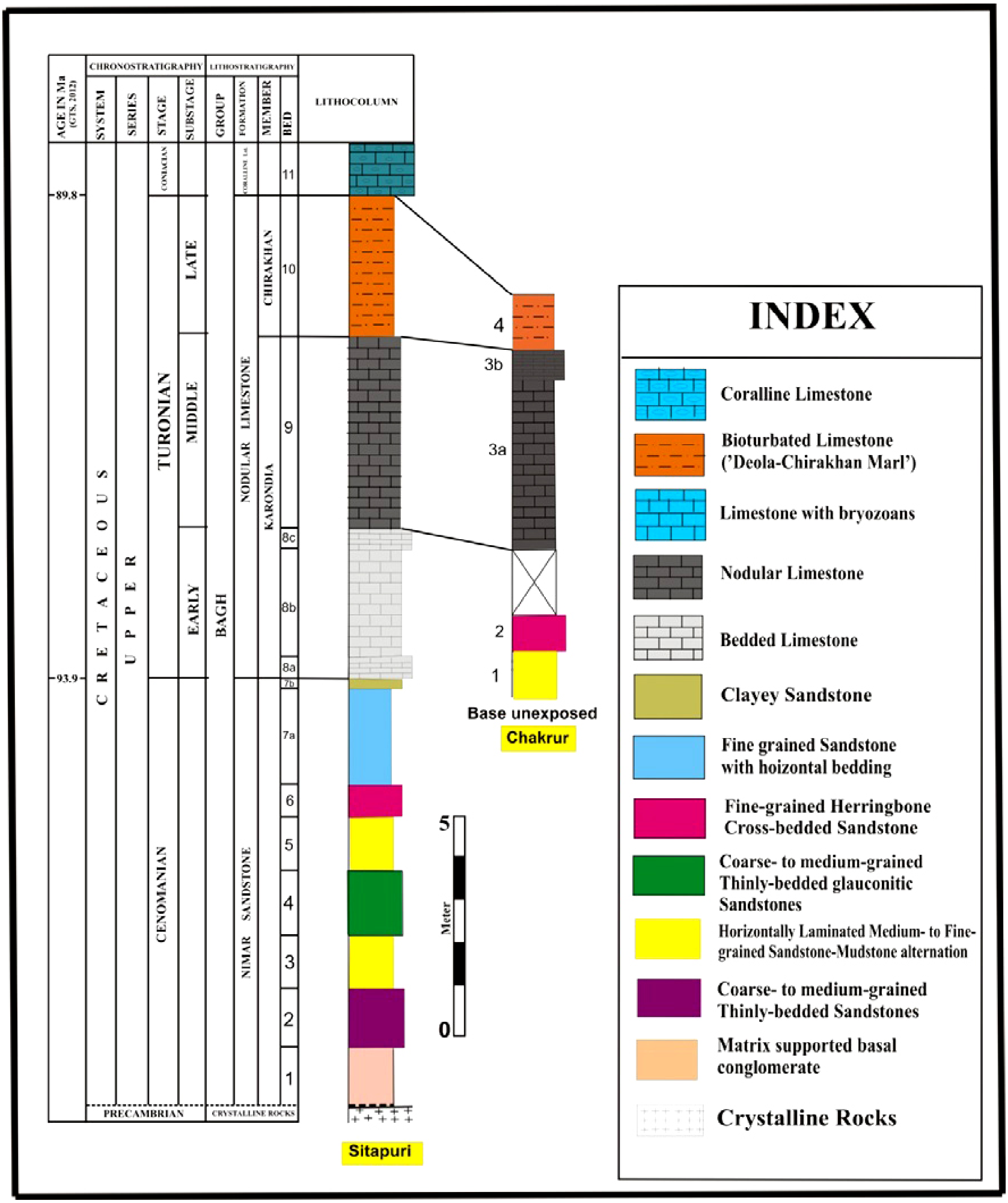

Fig.2. Lithocolumn of the Nodular Limestone Formation at Sitapuri and Chakrur localities of the Narmada Basin.

Redula (*Acesta*) *obliquistriata* Forbes: Stoliczka, 1871, p. 693, pl. 30, fig. 2 - 5, 13.

Redula (*Acesta*) *obliquistriata* Forbes: Rennie, 1930, p.183, pl.19, figs. 7, 8.

Lima obliquistriata Forbes: Schneegans, 1932, p. 220.

Redula (*Acesta*) cf. *obliquistriata* Forbes: Tavani, 1948, p.103, pl. 2, fig.12.

Lima (*Acesta*) *obliquistriata* Forbes: Dertvelle and Freneix, 1957, p. 99, pl. 12, fig 12 - 13; pl.14, fig.13.

Material: Two specimens (BHU2014/Si4/4, BHU2014/Sn3/59)

Horizon and locality: Nodular Limestone Formation (Turonian), Bed No. 9 of Sitapuri, Dhar, M.P.

Description: The specimens thin shelled, subovate, antero -ventrally elongated, poorly inflated and without anterior umbonal carina. Umbo pointed, anteriorly placed with umbonal angle of about 68^0. Anterior margin obliquely elongated; posterior margin gently rounded making almost semi circle with the symmetrically rounded ventral margin. The shell has maximum inflation along the dorsal half region from where it slopes steeply to create more or less flat margins. The shell surface is ornamented with numerous radial riblets altering in to finer striae in the mid - shell region. These riblets are separated by narrower interspaces, which gradually become wider towards the ventral margin. The radials are crossed by several irregularly spaced growth lines throughout the surface. Near ventral margin the radials are squamose in nature. There are some remnants of spinose scales near the ventral margin.

Measurements:

S. No	Specimen No.	Height (mm)	Length (mm)	Inflation (mm)
1	BHU2014/ Si4/4	30	25	5 (Right valve)
2	BHU2014/ Sn3/59	36	27	6 (Right valve)

Remarks: In all the available characters these Bagh specimens compare well to *Lima obliquistriata* Forbes (1846). This species is also known from the Late Cretaceous of the Tiruchirappalli Sub-basin of South India and recorded as *Radula (Acesta) obliquistriata* by Stoliczka (1871, pl. 30, figs. 2 - 5). Dertvelle and Freneix (1957, p. 99, pl. 12, fig 12-13; pl.14, fig.13) have described this species from Central Africa under the genus *Lima* Bruguiére, as the genus *Radula* has been considered a junior synonym to *Lima* (Newell, 1969). However, the species *Acesta obliquistriata* certainly belongs to *Acesta s.s*, owing to thin and ventricose shell having peculiar surface features of pronounced radial ribs on anterior and posterior parts, both grading into striae on the mid-shell region.

Genus ***Pseudolimea*** Arkell
(in Douglas and Arkell, 1932)

Type species *Plagistoma duplicate* Sowerby, 1827

Remarks: Newell (1969, p. N391) assigned such limids to the genus *Pseudolimea* Arkell in Douglas and Arkell (1932), which are small in size, gibbose to orbicular with ill defined anterior umbonal ridge and angular radial ribs with threads in interspaces on the surface. Genus *Radula* Mörch is now considered a junior synonym of *Lima* Braguiére. The most of the species of the genus *Pseudolimea* have been earlier described either under *Radula* (Stoliczka, 1871) or *Lima* Braguiére.

Pseudolimea interplicosa (Stoliczka)
(Pl. I, figs. 3, 4)

Radula interplicosa Stoliczka, 1871, p. 418, pl.30, figs. 10 - 11

Lima blecheri Thomas and Peron, 1889, p. 220, pl. 27, fig. 11 - 12

Lima blecheri Thomas and Peron: Pervinquire, 1912, p. 147, pl. 9, fig. 11a - c

Lima (*Mantellum*) sp. Rennie, 1929, p.22, pl.4, fig. 11.

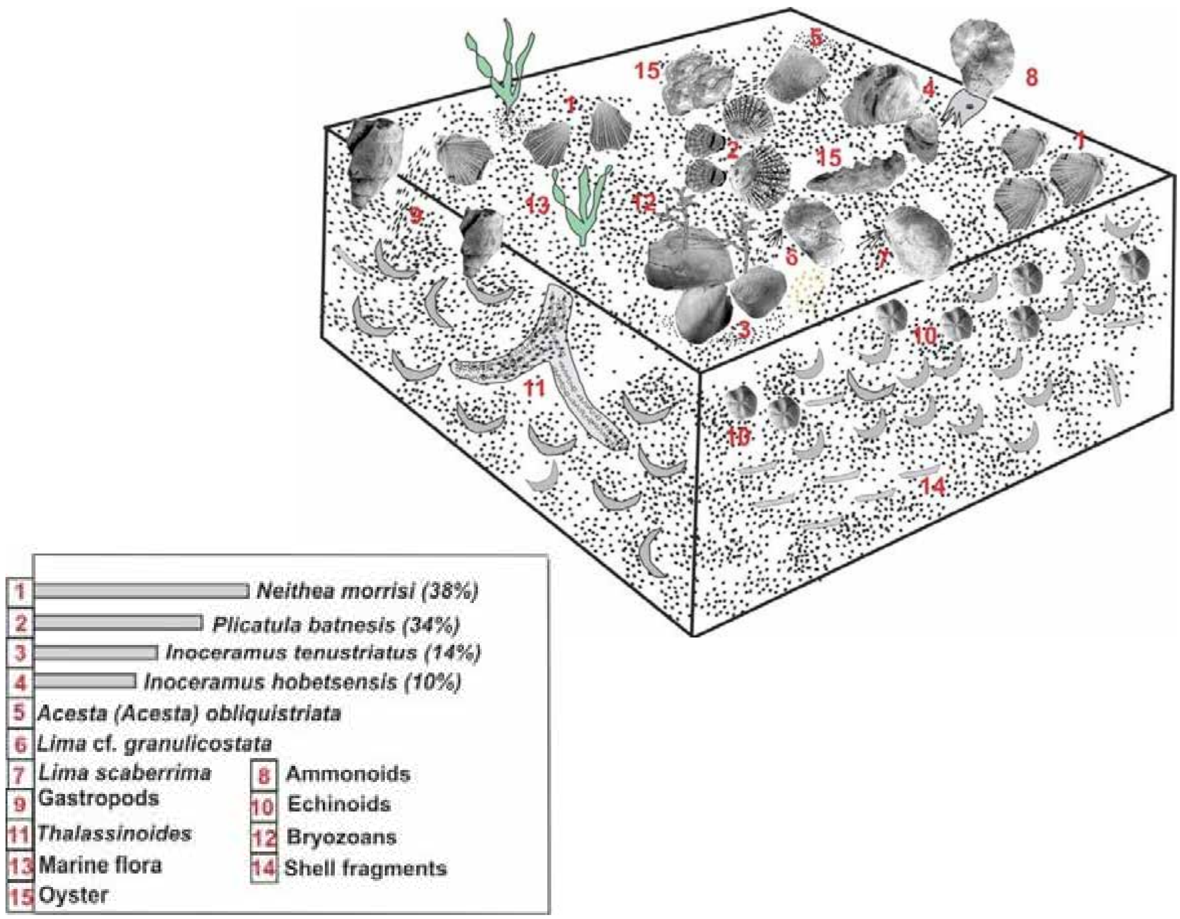

Fig. 3. The occurrence of limids and other associated fauna during Turonian in the area.

Lima itieriana Pictate and Roux: Babet, 1929, p. 85, pl. 15, fig. 2

Lima cf. itieriana Pictate and Roux: Lombard, 1930, p. 305

Lima mexicana Bose: Schneegans, 1932, p. 221

Pseudolimea interplicosa (Stoliczka): Dartevelle and freneix, 1957, p. 103, pl. 14, figs. 1-4

Material: Seven specimens (BHU2014/Ck1/59, BHU2014/Ck2/15, BHU2014/Si 5/7, BHU2014/Ck1/91, BHU2014/Sn3/71, BHU2014/ Sn3/19, BHU2014/Sn3/75)

Horizon and locality: Nodular Limestone Formation (Turonian) from Bed No. 9 of Sitapuri and Bed No 3a of Chakrur, Dhar, M.P.

Description: The specimens are subovate in outline, highly inequilateral, height slightly greater than length and moderately inflated. Antero–dorsal margin long and straight, postero - dorsal feebly curved and the rest of the margins merging each other smoothly to form a semicircular outline. Umbones small, mesial, pointed, prosogyrous and protruding slightly above the dorsal margin. Apical angle is 73^0. Anterior area small, bordered by an ill defined anterior umbonal ridge. Auricles are small and subequal. Ornamentation of the auricles has been worn out. Surface covered throughout with numerous radial ribs, which are having subrounded crest. The interspaces of the ribs are narrower then the thickness of ribs near the dorsal margin and becoming gradually wider towards ventral margin. 2 - 3 secondary riblets are present in the interspaces. Both primary and secondary ribs are grooved at regular intervals to give a knotted appearance. These are crossed by few concentric growth lines, which are more prominent in the ventral - half. Only one of the specimens (BHU2014/Ck1/59) is showing some internal character with moderately arched hinge plate and small, triangular ligament pit.

Mesurements:

S. No	Specimen No.	Height (mm)	Length (mm)	Inflation (mm)
1	BHU2014/Ck1/59	14	12	6 (Left Valve)
2	BHU2014/ Ck2/15	15	15	8 (Right Valve)
3	BHU2014/Si 5/7	20	15	8 (Right Valve)
4	BHU2014/Ck1/91	9	13	7 (Left Valve)
5	BHU2014/Sn3/71	18	14	9 (Right Valve)
6	BHU2014/Sn3/19	10	6	6 (Left Valve)
7	BHU2014/Sn3/75	13	9	4 (Left Valve)

Remarks: In light of the morphological features discussed above, these Bagh specimens are identical to *Radula interplicosa* recorded by Stoliczka (1871) from the Ariyalur Group (Campanian - Maastrichtian), Tiruchirappalli Sub-basin, South India. Dartevelle and Freneix (1957, p. 103, pl. 14, figs. 1-4) recorded this species from the Santonian of Tunisia while the present record is from Turonian. So that the range *Pseudolimea interplicosa* is revised here as Turonian to Maastrichtian. *Lima (Plagiostoma) cretacea* Woods (1904, p. 22, pl. 4, figs. 13, 14 a - c, 15, pl. 5, figs. 1a, b, 2, 3, 4a, b) from the Cretaceous of England is small, gibbose and inequilateral shell bearing radial ribs intercalated with radial threads on the entire surface, is actually a *Pseudolimea* and closely comparable to *P. interplicosa.*

REPOSITORY

All the described bivalve specimens are housed in the Stratigraphy and Invertebrate Palaeontology Laboratory, Department of Geology, Banaras Hindu University, Varanasi.

FUNCTIONAL MORPHOLOGY AND PALAEOECOLOGICAL REMARKS

The limids are exemplified by its inequilateral, equivalve or subequivalve shells with ovate, triangular and orbicular outline; some of them also bear small auricles with squamiform riblets and corrugations in the interspaces. All the Cretaceous limid genera have long, straight to slightly rounded anterior margins (except for the genus *Ctenostreon* Eichwald). Broadly these are firm substrate epifuana and own both nestler and free living life habits. The byssate, epifaunal nestlers inhabit near shore environments, pre-dominently at depth less than 35 m. The nestling is preferential in crevices and similar depressions in the firm substrate, which are further exposed on the surface for their attachment. Some species possess the ability to swim and while others are able to move using their foot and byssus (Mikkelsen and Bieler, 2007). The swimmer limids have almost rounded shells and behave like pectinids. These can swim by clapping of both valves, so that they move in the direction opposite to the direction of propelling water current. Such swimming behavior has also been observed in the recent limids, which are largely homoeomorphic (Jefferies, 1960). The broadly rounded shell maintains a stable horizontal stance in the water and once the energy for movement is generated by the clapping of valves the animal use to swim along expediently within the water current. However, some limids with similar rounded outline are also byssate fissure dwellers which may be due to their secondary adaption for defense strategy (Walz *et al*., 2014). Such mode of life has also been evidenced in the modern limids which occur in variable depth in the sea (Allen, 2004). These are basically suspension feeders, byssally attached to the sediments, shells and even to marine plants. In case the hard substrate proves unsuitable for byssal attachment, the mucus and byssus threads enable them to form 'nests' (Merrill and Turner, 1963). Phylogenetically limids show a series of consequential features like reduction in hinge teeth and monomyarian muscle scar (Yong,1953). Unlike other monomyarian bivalves, limids are not pleurothetic but adjust their commissure perpendicular to the substrate (Mikkelsen and Bieler, 2007).

Acesta (*Acesta*) *obliquistriata* (Forbes) has sub-ovate shell with feeble inflation which does not warrant an epifaunal cemented life habit. The lamellar growth lines and concavity on the anterior margin near the umbo support the epifaunal byssate life habit (Walz *et al*., 2014). *Pseudolimea interplicosa* (Stoliczka) and *Lima scaberrima* (Stoliczka) are almost orbicular and much inflated. The anterior marginal ridge is obtusely rounded and two small subequal auricles evidently promote the epifaunal nestler habit. However, *Lima scaberrima* (Stoliczka), has radial ribs which bear concentrically arranged scales or lappet like projections, crossed by concentric growth lines, is significantly adaptable for epifaunal nestler life habit and which also act as protecting cover in saving from predators. *Lima* cf. *granulicostata* Chiplonkar and Badve has relatively larger, inflated shells and almost straight anterior margin to ease the epifaunal, free resting life habit. It has been supported by an apparent lip like structure near the umbo, which provided extra strength for stability.

The limids *Acesta (A.) obliquistriata* (Forbes), *Pseudolimea interplicosa* (Stoliczka), *Pseudolimea interplicosa* (Stoliczka), *Lima scaberrima* (Stoliczka) and *Lima* cf. *granulicostata* Chiplonkar and Badve co-occur together. The other co-existing associated species are *Plicatula batnesis* Coquand*, Inoceramus hobetsensis* Nagao and Matsumoto and *Inoceramus tenuistriatus* Nagao and Matsumoto (Fig. 3). As per the life habits, in this population, the epifauna free resting dominates with a few epifauna cemented, epifaunal byssate and epifaunal nestlers. These limids are basically low level suspension feeders with a few high level suspension feeder individuals. The richness and evenness of the limids increase from biosparite to biomicrite and to marly substrates. Overall the dominance of suspension feeders points toward sufficient availability of the particulate organic material, which is usually a characteristic of photic zone.These thin shelled epifaunal nestlers, epifaunal free living and epifaunal byssate limids found in the firm substrate amicably adapted a protected lagoonal to sutidal environment. The water depth may be maximum up to 15 m as also observed by Cataldo *et al*. (2013) for the recent analogue of the above environmental setting.

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REFERENCES

Acharyya, S. K. and Lahiri, T. C. 1991. Cretaceous palaeogeogrphy of the Indian sub- continent; a review. *Cretaceous Research*, **12**: 3-26.

Akhtar, K. and Khan, D. A. 1997. A tidal island model for carbonate sedimentation: Karondia Limestone of Cretaceous Narmada basin. *Journal of Geological Society of India,* **50:** 481-490.

Allen, J. A. 2004. The Recent species of the genera Limatula and Limea (Bivalvia, Limacea) present in the Atlantic with particular reference to those in deep water. *Journal of Natural History,* **38** (20): 2591-2653.

Babet, V. 1929. Etude géologique de la zone du chemin de fer Congo - Océan et de la région minière du Niari et du Djoué, Paris. *Carte Géol.*, 1-176.

Beurlen, K. 1944. Beiträge zur Stammesgeschichte der Muscheln. *Mathematisch-Naturwissenschaftlichen Abteilung der Bayerischen Akademie der Wissenschaften zu München, Sitzungsberichte*, **1-2**:133-145.

Beiträge Zur stammesgeschichte der Muschelu-Naturwissensehaftlichen Abteilung der Bayerischen Akademie der Willsseuch after Zu Muchen, Sitzungsberichte, 1-2: 133-145.

Bieler, R., Mikkelsen, P. M., Collins, T. M., Glover, E. A. and González, V. L. 2014. Investigating the Bivalve Tree of Life - An exemplar-based approach combining molecular and novel morphological characters. *Invertebrate Systematics,* **28:** 32-115.

Biswas, S.K. 1987. Regional tectonic framework structure and evolution of western marginal basins of India. *Tectonophysics*, **135:** 307-327.

Blanford, W. T. 1869. On the geology of Tapti and lower Narbada Valley and some adjoining districts. *Memoir of Geological Survey of India*, **6** (3): 163-384.

Bose, P. N. 1884. Geology of the Lower Narbada Valley between Nimawar and Kawant. *Memoir of Geological Survey of India,* **21:** 1-72.

Campbell, A. Harbo, R. M. and Hand, C. M. 1998. Harvesting and distribution of Pacific geoduck clams, Panopea abrupta, in British Columbia, p. 349–358. In: *Proceedings of the North Pacific Symposium on Invertebrate Stock Assessment and Management.* (Eds. Jamieson, G. S. and Campbell, A.), Canadian Special Publication of Fisheries and Aquatic Sciences 125. Ottawa, Canada: NRC Research Press.

Campbell, D. C. 2000. Molecular evidence on the evolution of the Bivalvia, p. 31–46. In: *The Evolutionary Biology of the Bivalvia* (Eds. Harper, E. M. Taylor, J. D. and Crame, J. A.), The Geological Society of London, Special Publication*,* **177**.

Carter, J. G., Campbell, D. C. and Campbell, M. R. 2000. Cladistic perspectives on early bivalve evolution, p., 47–79. In: *The Evolutionary Biology of the Bivalvia* (Eds. Harper, E. M., Taylor, J. D. and Crame, J. A.), Geological Society Special Publication, **177**.

Cataldo, C. S., Lazo, D. G., Tunik, M. A. and Aguirre-Urreta, M. B. 2013. Taphonomy and Palaeoecology of Hautervian-Barremian nerineoid shell beds from the Neuquen Basin, West-Central Argentina. *Lathaia*, **46**: 114-126.

Chiplonkar, G. W. and Badve, R. M. 1972. Palaeontology of the Bagh Beds: I - Bivalvia (excluding Inoceramidae and Ostreacee). *Journal of the Palaeontological Society of India*, **17:** 67-114.

Coan, E. V., Scott, P. V. and Bernard, F. R. 2000. Bivalve seashells of Western North America. Marine bivalve molluscs from Arctic Alaska to Baja California. *Santa Barbara Museum of Natural History Monographs,* **2:** 764p.

Combosch, D. J. and Giribet, G. 2016. Clarifying phylogenitic relationships and the evolutionary history of the bivalve order Arcida (Mollusca: Bivalvia: Pteromorphia). *Molecular Phylogenitics and evolution,* **94:** 298-312.

Cox, L. R. Nuttall, C. P. and Trueman, E. R. 1969. General features of Bivalvia. In: *Treatise on invertebrate paleontology* (Ed. Moore, R. C.), Part N. Mollusca 6, Bivalvia, Geological Society of America, New York, and University of Kansas, Lawrence, N2–N129.

Dartevelle, E. and Freneix, S. 1957. Mollusques fossils du Crétacé de la côte occidentale d'Afrique du Cameroun l'Angola II- Lamellibranches. *Sciences géologiques*, **20:**1-271.

Douglas, J. A. and Arkell, W. J. 1932. The stratigraphical distribution of the cornbrash: II.The north-eastern area. *Quarterly Journal of Geological Society,* **88**: 112-170.

Forbes, E. 1846. Report on the fossils Invertebrate from the Southern India, collected by M.M. Kaye and Cunliffe. *Transection Geological Society of London*, **7** (2): 97-174.

Gilmour, T. H. J. 1990. The adaptive significance of foot reversal in Limoida, p. 247-263. In: *The Bivalvia Proceedings of Memorial symposium in honour of sir Charls Maurice Young, Edinburg* (Ed. Morton, B. S.), Hong-Kong University press, Hong-Kong.

Giribet, G. and Distel, D. L. 2003. Bivalve phylogeny and molecular data, p. 45–90. In: *Molecular Systematics and Phylogeography of Mollusks, no. 3.* (Eds Lydeard, C. and Lindberg, D. R.), Smithsonian Books. Washington, D.C. and London.

Giribet, G. and Wheeler, W. 2002. On bivalve phylogeny: A high-level analysis of the Bivalvia (Mollusca) based on combined morphology and DNA sequence data. *Invertebrate Biology*, **121** (2): 271–324.

González, V. L., Andrade, S. C. S., Bieler, R., Collins, T. M., Dunn, C. W., Mikkelsen, P.M. Taylor, J. D. and Giribet, G. 2015. A phylogenetic backbone for Bivalvia: an RNA-seq approach. *Proceedings of the Royal Society of London B: Biological Sciences* **282:** 2014-2332.

Hammer, Ø. Harper, D. A. T. and Ryan, P. D. 2001. PAST: Paleontological statistics software package for education and data analysis, *Palaeontologia Electronica,* **4**(1): 1-9, http://palaeo-electronica.org/2001_1/past/issue1_01.htm.

Harasewych, M. G. and Tëmkin, I. 2015. The Miocene genus Mantellina (Bivalvia: Limidae) discovered living on the deep reefs off Curaçao, with the description of a new species. *Journal of Molluscan studies,* **81** (4): 442-454.

Jaitly, A. K. and Ajane, R. 2013. Comments on *Placenticeras mintoi* (Vredenburg, 1906) from the Bagh Beds (Late Cretaceous), Central India with special reference to Turonian Nodular Limestone Horizon. *Journal Geological Society of India*, **81**: 565-574.

Jaitly, A. K., Fürsich, F. T. and Heinze, M. 1995. Contributions to the Jurassic of Kachchh, western India. IV. The bivalve fauna. Part I.

Subclasses Palaeotaxodonta, Pteriomorphia, and Isofilibranchia. *Beringeria,* 16: 147-257.

Jaitly, A.K., Kumar, S. and Pandey, B. 2015. First record of *Pressastarte* Zakharov and *Pinguiastarte* Kelly (mollusca: bivalvia) from the Turonian (Upper Cretaceous) of the Bagh Beds, Central India. *Journal of the Palaeontological Society of India*, **60** (2)**:**21-26.

Jefferies, R. P. S. 1960. Photonegative young in the Triassic lamellibranch *Lima Lineate* (Schlotheim). *Palaeontology,* **3:** 362-369.

Kumar, S., Singh, M. P. and Mohabey, D. M. 1999. *Lameta and Bagh Beds, Central India, Field Guide. Journal of the Palaeontological Society of India*, 48p.

Lombard, J. 1930. Céphalopodes et Lamellibranches crétacés du Congo français. *Bulletin de la Société géologique de France,* **30** (4): 277-322.

Matsumoto, M. 2003. Phylogenetic analysis of the subclass Pteriomorphia (Bivalvia) from mtDNA COI sequences. *Molecular Phylogenetic Evolution,* **27:** 429–440.

Merril, A. S. and Turner, R. D. 1963. Nest building in the bivalve genera *Musculus* and *Lima*. *Veliger,* **6:** 55-59.

Mikkelsen, P. M. and Bieler, R. 2003. Systematic revision of the Western file clams, Lima and Ctenoides (Bivalvia: Limoida: Limidae. *Invertebrate Systematics,* **17:** 667-710.

Mikkelsen, P. M. and Bieler, R. 2007. *Seashells of Southern Florida: Living Marine Mollusks of the Florida Keys and Adjacent Regions. Bivalves*. Princeton University Press, Princeton, New Jersey, 503p.

Moore, H. J. 1971. The structure of the latero-frontal cirri on the gills of certain lamellibranch molluscs and their role in suspension feeding. *Marine Biology,* **11:** 23-27.

Moore, R. C. 1969. Treatise on invertebrate paleontology N. Mollusca. *The Geological Society of America and University of Kansas press, Lawerance*, **6:** N1-951.

Morton, B. S., Prezant, R. S. and Wilson, B. 1998. Class Bivalvia, p. 195–234. In: *Mollusca: The Southern Synthesis. Fauna of Australia* (Eds. Beesley, P. L., Ross, G. J. B. and Wells, A.), CSIRO Publishing, Melbourne, **5**.

Newell, N. D. 1969. Classification of Bivalvia. In: *Treatise on Invertebrate Paleontology, Part N, Mollusca 6. vol.1, Bivalvia* (Ed. Moore, R.), Geological Society of America and University of Kansas, Boulder-Lawrence, N205–N400.

Pervinquiere, L. 1912. Etudes de paleontologie tunisienne: II. Gasteropodes et Lamellibranches des terrains cretaces, Direction generale des travaux publics. *Carte geologique de la Tunisie*, Paris, 338p.

Purchon, R. D. 1987. The stomach in the bivalvia. *Philosphical Transactions of the Royal Society London,* **316** (B): 183–276.

Racey, R., Fisher, J., Bailey, H. and Roy, S. K. 2016. The value of fieldwork in making connections between onshore outcrops and offshore models: an example from India. In: *The Value of Outcrop Studies in Reducing Subsurface Uncertainty and Risk in Hydrocarbon Exploration and Production.* (Eds. Bowman, M., Smyth, H. R., Good, T. R., Passey, S. R., Hirst, J. P. P. and Jordan, C. J.), Geological Society London, special Publications 436, http://doi.org/10.1144/SP436.9.

Rennie, J. V. L. 1929. Cretaceous fossils from Angola (Lamellibranchia and Gastropoda). *Annals of the South African Museum,* **28:** 1-54.

Rennie, J. V. L. 1930. New Lamellibranchia and Gastropoda from the Upper Cretaceous of Pondoland (with an appendix on some species from the Cretaceous of Zululand). *Annals of the South African Museum,* **28:** 159-260.

Schneegans, D. 1932. La faune des couches sénoniennes du bassin du Moyen-Congo entre Pointe Noire et M'Vassa (A.E.F.). *Bulletin de la Société géologique de France,* **16:** 220-222.

Stoliczka, F. 1871. Cretaceous fauna of southern India. The Pelecypoda, with a review of all known genera of this class, fossil and recent. *Memoir Geological Survey of India, Palaentologica Indica,* **3**(6): 1-537.

Tavani, G. 1948. Fauna Malacologica cretacea della Somalia e dell'Ogaden. *Palaeontographica italica*, **43**: 83-153.

Taylor, J. D., Kennedy, W. J. and Hall, A. 1969. The shell structure and mineralogy of the Bivalvia (Nuculacea — Trigonacea). *Bulletin British Musium natural History of Zoology, Supply,* **3:** 125.

Taylor, J. D., Glover, E. A. and Williams, S. T. 2005. Another bloody bivalve: anatomy and relationships of Eucrassatella donacina from south western Australia (Mollusca: Bivalvia: Crassatellidae), p. 261–288. In: *The Marine Flora and Fauna of Esperance* (Eds. Wells, F. E., Walker, D. I. and Kendrick, G. A.), Western Australia. Western Australian Museum, Perth.

Thomas, P. and Peron, A. 1889. Description des mollusques fossiles des terrains crétacés de la région sud des hauts-plateaux de la Tunisie recueillis en 1885 et 1886 par M. Philippe Thomas... : / par Alphonse Péron : Partie 1, Paris, Imprimerie nationale, coll. *Exploration scientifique de la Tunisie,* XII-327p.

Tripathi, S. C. 2006. Geology and evolution of the Cretaceous Infratreppean basins of Lower Narmada Valley, Western India; 459-468.

Wallar, T. 1990. The evolution of ligament system in the bivalvia, p. 47-51. In: *The Bivalvia Proceedings of a memorial symposium in honor of sir Charls Maurice Yong Edinburg* (Ed. Morton, B.), Hong-Kong University Press, Hong-Kong.

Waller, T. R. 1998. Origin of the molluscan class Bivalvia and a phylogeny of major groups, p. 1–45. In: *Bivalves: An Eon of Evolution – Palaeobiological Studies Honoring Norman D. Newell* (Eds. Johnston, P. A. and Haggart, J. W), University of Calgary Press, Calgary.

Walz, K. R., Clague, D. A., Barry, J. P. and Vrijenhoek, R. C. 2014. First records and range extensions for two Acesta clam species (Bivalvia: Limidae) in the Gulf of California, Mexico. *Marine Biodiversity Records*, **7**: 1–7.

Williams, S. T., Taylor, J. D. and Glover, E. A. 2004. Molecular phylogeny of the Lucinoidea (Bivalvia): non-monophyly and separate acquisition of bacterial chemosymbiosis. *Journal of Molluscan Studies*, **70:** 187-202.

Woods, H. 1904. A Monograph of the Cretaceous Lamellibranchia. *Palaeontographical Society [Monograph]- 1*, **2** (2): 1-56.

Yong, C. M. 1953. Formand habit in *Pinna carnia* Gmelin. *Philosophical transactions of the Royal Society of London,* **237** (B): 335-374.

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