CHAPTER-6

PALEONTOLOGY

6.1INTRODUCTION

The intertrappean succession of the Deccan Volcanic Provinces of India is a treasure of fossils and consists of a variety of vertebrates, invertebrates and microfossils. These successions are fascinating for their vertebrates, especially dinosaurian remains, (Rana, 1988; Prasad and Sahni, 1988; Prasad, 1989 and references therein; Khosla and Sahni, 1995; Arratia et al., 2004; Prasad and Rage, 2004; Samant et al., 2008; Keller et al., 2009) have been explored. The dinosaurian fossils are found namely, *Massospondylus rawesi*, *Megalosaurus* sp. (Sauropod), *Jainosaurus* cf. *septentrionalis, Indosuchus raptorius, Indosaurus matleyi, Laevisuchus indicus, Lametasaurus indicus, Hypselosaurus* (Prasad and Sahni, 2014)and also reported types of dinosaurian eggs, *Megaloolithus cylindricus, Megaloolithus jabalpurensis, Subtiliolithus kachchhensis, Fusioolithus baghensis, Subtiliolithus kachchhensis* (Khosla and Lucas, 2020) and other sauropod eggshells (Kapur and Khosla, 2019). Varied array of organisms flourished other than dinosaurs including ostracods, mollusks, fishes, frogs, turtles, lizards, snakes, crocodiles' spores, pollens and mammals.

The first detailed account of fossil fishes from the Bamanbor and Ninama Intertrappeans was given by Fedden (1884) where he recorded fragmentary fossil fish skeletons of *Horaclupea intertrappea* and *Paleopristolepis feddeni* along with *Perca* cf. *angusta* and a few percoid fish scales in the sediments of Ninama and Chotila intertrappeans. Later, Borkar (1973) had described two new genera *Horaclupea* and *Palaeopristolepis chiplonkari*. Chiplonkar and Badve (1976) reported the occurrence of trace fossil, identified as *Hirmeria khadluensis.* Borkar (1986) also reported the fossil fish scales from the intertrappean beds at Ninama. Arratia et al., (2004), reported a new taxon, *Indiaichthys bamanborensis* from the intertrappeans at Bamanbor and had discussed their systematic positions. Samant et. al. (2014), studied nine sections of the intertrappean beds of Saurashtra area for their palynology and reported the occurrence of *Neocouperipollis deccanii, Rhombipollis* sp. *Crototricolpites densus Pediastrum boryanum* etc. from the Ninama Intertrappean. During the present work, larger megafossils were also found from the Chotila Basin, the molluscan remains were reported from the Bamanbor Formation which includes freshwater bivalves and pulmonate gastropods.

Considering their significance, the freshwater bivalve fossils of these intertrappean succession are identified and described in details which has played a supportive role for interpreting the paleoecology, paleoclimate and paleogeography.

6.2 INTERTRAPPEAN BIVALVE STATUS

The Deccan Volcanic Province of the Indian Peninsula is characterised by a majority of freshwater intertrappean sequences which bear different types of unionids, essentially reported from the Nagpur and Gurmatkal, such as *Unio malcolmsoni*; *Unio deccanensis*, *Unio hunteri*, *Unio mamillatus*, *Unio imbricatus* and *Unio carteri* (Hislop, 1860); and one species of Sphaeriida, *Pisidium medlicottianum* from Goraha, Narmada Intertrappean beds of peninsular India (Hislop, 1860). *Pisidium medlicottianum* of Hislop (1860) was later redefined as a Unionoid, *Lamellidens vredenburgi* by Prashad, (1921). Hislop's (1860) descriptions were in Latin which hindered progress in molluscan research, they were later translated to English for potential usage by Hartman *et al.* (2008). The bivalve-bearing intertrappean sections described by Hislop were redefined and assigned the latest Cretaceous age based on the presence of dinosaurian and floral remains (Sahni *et al.*, 1984; Prasad and Khajuria, 1996; Hartman *et al.*, 2008; Samant *et al.*, 2020). Recently reported intertrappean unionids are *Lamellidens* from Rajindragram and Deori of Madhya Pradesh (Gangopadhyay *et al.*, 2011), *Unio deccanensis* from Topidhana of Madhya Pradesh (Srivastava and Kandwal 2013) and *Unio* from chertified limestone bed of the Cretaceous/Paleogene from Gurmatkal, Karnataka (Jalal *et al.,* 2020).

6.3 PRESERVATIONAL CONSTRAIN ON BIVALVE SHELLS

The bivalves are ubiquitous in aqueous environment and most of the freshwater bivalves secrete aragonitic calcium carbonate shell. The original aragonitic mineral composition is highly unstable and readily recrystallises to calcite (Casella *et al.*, 2017). The preserved materials are affected by taphonomic processes, where majority shells are disarticulated with insitu burial, or short distance transported and burial due to necrolysis or are severely affected by solution that led to the alteration of the original preserved shell material. The preservation of the shells is controlled by their own fragility, transportation, energy conditions, salinity and presence of the scavengers. The disarticulated young and adult shells are represented as either right or left valves, laying horizontally, due to postmortem

transportation. Few articulated shells are also observed either closed or open in butterfly position.

The textural and mineralogical composition of sediments has influenced and substituted the original materials, where original aragonitic shells are leached out and replaced either by fine grained clayey sediments or by ferruginous materials. It resulted in preservation of shells in the form of molds or casts and also influenced the crumbling of the shells during the retrieval. Even though, these altered shells, in some cases, show faithfully defined bivalve outlines and preserve delicate external or internal morphological features like impressions of cardinal characteristics. Occasionally, well preserved disarticulated, hard shells are also found, with diagenetic alteration of the original aragonitic material into more stable sparry to cleavable calcite (Casella *et al.*, 2017). The percolating rainwater has also caused severe alteration in the original composition, which has also compromised the recovery of the bivalve's specimens.

6.4 TAXONOMIC CONSTRAINS

The early nonmarine bivalve fossils record is sporadic and poor due to discontinuity in sedimentary record caused by ephemeral nature of most of the freshwater depositional systems of the continental realm. Hence, there is no systematic record available on nonmarine bivalve fossils which documents the lineage since their inception. The freshwater unionid ancestry possessed crucial weak point due to their allopatric nature which led to difficulty in recording their evolutionary pathway; and subsequently posed difficulty in assigning formal taxonomic categories for the older fossils (Chamberlain and Chamberlain, 2007).

The earliest recorded freshwater bivalve is based on a sole species, *Archanodon* from the Middle Devonian - Carboniferous, and its taxonomic status was debatable (Cox *et al.*, 1969) but, based on elongate, inequilateral shape and enlarged posterior region it is considered as earliest known member of the bivalve order Unionida even in absence of the soft parts (Chamberlain and Chamberlain, 2007). The status of the Upper Carboniferous nonmarine *Anthraconaia* and *Carbonicola* is confined to family Anthracosiidae of order Cardiida (Cox *et al.*, 1969) and the Permian widespread bivalve species *Palaeomutela* and *Palaeanodonta* are described under the order Actinodontida (Silantiev and Carter, 2015). The first recordof the nonmarine bivalve from the Permian Raniganj Formation (Indian Gondwana Coal Measures) records autobranchs namely, *Gondwanaiadites, Bakulia, Gangamya, Raniganjelia, Gondwanadontella*, and *Indonellina*, which is endemic in nature (Silantiev *et al.*, 2015). However, there is no link between the earliest form of nonmarine bivalves and the freshwater unionid bivalves of 230 m.yrs, i.e., the late

Triassic (Skawina and Dzik, 2011), which marks a long time gap in the records. But, the Triassic freshwater bivalves of Poland are to be considered as immediate ancestor of marine extent relative of the Australian *Neotrigonia* (Skawina and Dzik, 2011).

The earlier unionid bivalves evolved during the Late Triassic, in Pangea and subsequently disperse in all continents except Antarctica (Graf and Cummings, 2007). This group is well established in Triassic and subdivided into three suborders, Unionidina, Siluesunionidina and Hyriidina (Carter *et al.*, 2011) which bears distinct morphological features. The Unionidina and Siluesunionidina were separated based on gill structures, the former possess eulamellibranch gills while latter possess filibranch gills (Skawina and Dzik, 2011). Order Unionida is characterized by both, fossil and living forms and is further classified into number of superfamilies such as Silesunionoidea, Mullerioidea, Trigonioidoidea, Tamesnelloidea (Van Damme *et al.*, 2015), Unionoidea, Etherioidea and Hyrioidea (Carter *et al.*, 2011).

India also has evidence of unionid from the Late Triassic Pangea (Late Carnian or Early Norian), Maleri Formation of the Tihki region, Madhya Pradesh, India. This oldest described freshwater bivalve is poorly documented and represented by only a species belonging to Suborder Siluesunionina, Family Silesunionidae, *Tihkia corrugata* (Sahni and Tewari, 1958). The incompleteness of the freshwater bivalve record, particularly of Jurassic in the Indian continent poising the difficulty in establishing the relationship with older ancestor. Once again, these freshwater bivalves are recorded and described from the Upper Cretaceous intertrappean of Nagpur area and considered to belonging of the Superfamily Unionidea (Hislop, 1860). But there is no fossil record of freshwater bivalve from the intertrappean which can be considered as descendants of the Triassic suborder Siluesunionina.

The specimen described from the intertrappean of Saurashtra is difficult to make straightforward interpretation due to incomplete fossil record of the Indian continents as well as the freshwater bivalves shows the high degree of morphological disparities. To evaluate their evolutionary invention, major diagnostic characters are required in sequential manner in different geological epochs. Skawina and Dzik (2011) proposed filibranch versus eulamellibranch grades to diagnose paraphyletic units of suborder rank for the Late Triassic freshwater bivalves. The intertrappean specimens are not assigned suborder category due to lack of connecting link, poor preservation and unrecognizable gill structures and are kept open to inspect the well-preserved materials yet to be found.

At present five super families such as Silesunionoidea, Tamesnelloidea, Unionoidea, Etherioidea and Hyrioidea are described in suborder Unionina. The present material collected from the Deccan intertrappean shows characteristically distinct hinge structures and overall shape and ornamentation, which is a crucial character in bivalve taxonomy which are enabled to erect the new category at Superfamily level, Deccanoidea nov., based on new evidence, although still incomplete and tentative, should be included in concepts of high-rank unionid taxa. Although the specimens are limited, the analysis of the morphologic features reveals distinct characters, which has assisted in discriminating the species. This allopatric population is deemed to fit in to separate biological entity until more anatomical evidence on lacustrine unionids is made available.

6.5 TAXONOMY

A total of twenty-six specimens which are relatively well preserved in the fine-grained shaly sandstone of the Bamanbor Formation are studied for their morphological features which differentiate them into seven bivalve species. The detailed morphological analysis such as shape, size, ornamentation and dentition enabled to classify them into a superfamily, Deccanoidea, family Deccanoidae nov., divided into two subfamilies, Deccanoinae nov. and Chotiloinae nov. The former subfamily consisting of two genera, *Deccanoida* and *Bamanboria* which include four species, *Deccanoida conrugis* gen. et sp. nov., *Deccanoida aleta* gen. et sp. nov., *Deccanoida costaria* gen. et sp. nov. and *Bamanboria oblongis* gen. et sp. nov.; latter subfamily comprises of one genus *Chotilia* and three species, *Chotilia trappeansis* gen. et sp. nov., *Chotilia tuberculata gen.* et sp. nov. and *Chotilia deccansis gen.* et sp. nov.

These freshwater bivalves are described in accordance with the systematic classification of Unionida from (Carter *et al.*, 2011) and the Treatise on Invertebrate Paleontology, Part N, Volume 1, Mollusca 6, Bivalvia (Cox *et al.*, 1969).

Order Unionida, Gray, 1854

Superfamily Deccanoidea nov.

Diagnosis: Equivalve, inequilateral, elliptical to trapeziform, extremely prosogyrous umbones, flatly compressed unionids with prominent anterior muscle scar pit, 2-3 diverging cardinal teeth, one lateral teeth below the opisthodetic, parivincular ligament, and entirely corrugated commissure. The length of the shell ranges from 15mm to 60mm.

Remark: The defined superfamily from the Saurashtra Intertrappean described under the Order – Unionida, is a highly evolved paraphyletic group, owing to its allopatric nature and is assigned to a new category. The superfamily shows distinctly different shell morphological features as compared to unionid reported from other intertrappean of the Deccan Volcanic Province of India.

Family included: Deccanoidae nov.

Family Deccanoidae nov.

Diagnosis: Elongated, prosogyrous, opisthodetic unionid bivalves with anisomyrian muscle scars, one lateral and two to three cardinal teeth. Variable sizes, moderately inflated but with large capacious cavity below umbones. Ornamentation consists of growth lines, costae and prominent corrugations on the posterior-ventral margins. Shell is probably composed of aragonite and calcite with 1.0 to 1.5mm thickness with possible presence of innermost nacreous layer.

Subfamily included: **Deccanoinae nov. and Chotiloinae nov.**

Subfamily Deccanoinae nov.

Diagnosis: Elongated, inequivalve, equilateral to subequilateral bivalves, integripalliate, anisomyrian, heterodont with lateral tooth, prominent posterior wing, opisthodetic ligament and prominently developed ribs and corrugated commissures.

Genera included: Deccanoida **gen. nov. and** ***Bamanboria*** **gen. nov.**

Genus *Deccanoida* nov.

Type species: Deccanoida conrugis gen. et sp. nov.

Etymology: The genus name is derived from the Deccan Traps, a Large Igneous Province (LIP) of India where shells are intimately associated with the intertrappean.

Diagnosis: As per the type species.

Genus *Deccanoida conrugis* gen et sp. nov.

(Pl-6.1, Fig. a-k)

Material: Four left valves and two right valves with several broken ones are collected.

Etymology: The species name refers to the corrugated nature of the ventral margin (Latin conrugis, meaning corrugated)

Holotype: Geo/Mus/BF/I (Pl-6.1 Fig. a-b)

Paratype: Geo/Mus/BF/II, Geo/Mus/BF/III, Geo/Mus/BF/IV, Geo/Mus/BF/V, Geo/Mus/BF/VI (Pl-6.1, Fig. c-i)

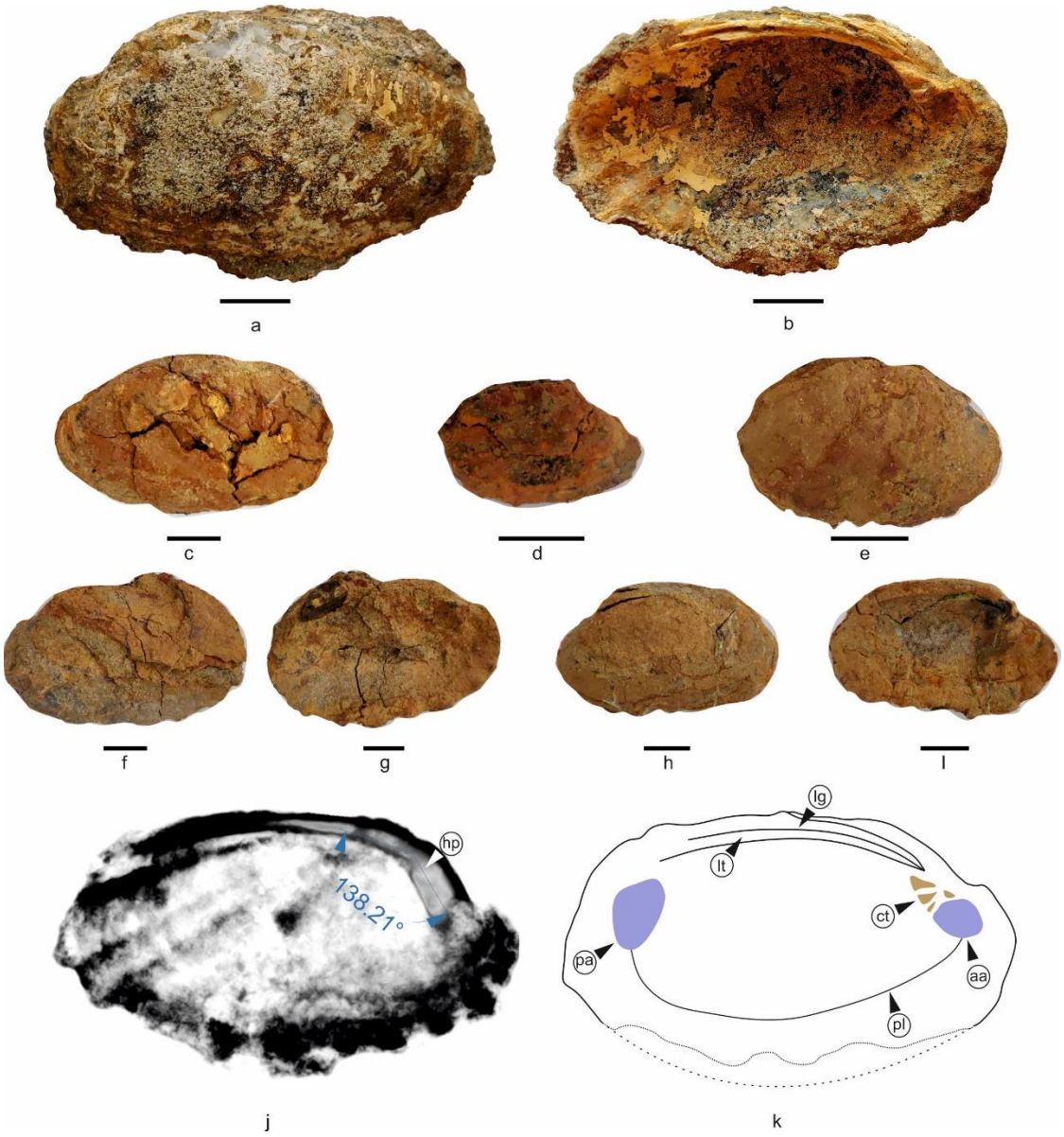

Plate 6.1 *Deccanoida conrugis* sp. nov. Fig. a, External view of holotype. Fig. b, Internal view of holotype. Fig. c-i, Paratypes of *D. conrugis*. Fig. j, X-ray image of the holotype showing umbonal angle and hinge plate (hp). Fig. k, Line drawing of the holotype shows internal morphology (ct-cardinal teeth, aa- anterior adductor muscle scar, lt-ligament tooth, lg-ligament, pl-pallial line, pa- posterior adductor muscle scar). All scale bars represent 1cm.

Diagnosis: Elliptical, compressed shell, with distinct corrugations towards the posterior margin and a small posterior dorsal wing.

Description: Shell thick, recrystallized and petrified, elongated, and elliptical in shape (Pl-6.1, Fig. a-b). The shell is long and inequilateral. The ornamentation on umbo is obscure whereas the entire shell shows prominent concentric growth lines (Pl-6.1, Fig. a). The anterio-ventral and posterio-ventral margin of the shell shows characteristic corrugation (Pl-6.1, Fig. a-b). The large and well-spaced radially broad costae in the central and lower part of the shell are typical and they either truncate or fade towards the umbo (Pl-6.1, Fig. a). The umbo and beak are subcentral towards anterior; beak is prosogyrous and umbonal angle is 138° (Pl-6.1, Fig. j). Small anterior and long posterior dorsal wings are noticeable. Parivincular ligament is distinct, low arched and well preserved. Three-four hinge teeth diverging towards the mantel cavity are discrete. One long lateral posterior tooth parallel to ligament is prominent. Anterior adductor muscle scar is definitive whereas posterior adductor muscle scar, posterior and anterior retractor muscle scars and pallial line are obscure. The commissure is corrugated (Pl-6.1, Fig. k).

Dimensions:

Specimen	**Length**	**Height**	**Width (single valve)**	**Hinge Length(l)**	**Umbonal angle**
Geo/Mus/BF/I (Pl-6.1, Fig. a-b)	6.9	4.2	0.6	3.3	138°
Geo/Mus/BF/II (Pl-6.1, Fig. c)	5.2	3	0.3	3.7	163°
Geo/Mus/BF/III (Pl-6.1, Fig. d)	2.3	1.7	0.2	1.3	-
Geo/Mus/BF/IV (Pl-6.1, Fig. e)	3.4	1.9	0.2	1.6	156°
Geo/Mus/BF/V (Pl-6.1, Fig. f-g)	5.6	2.9	0.7	3.5	175°
Geo/Mus/BF/VI (Pl-6.1, Fig. h-i)	4.8	2.8	0.6	3.3	167°

Remarks: Deccanoida conrugis gen. et sp. nov., is elliptical and inequilateral with prominent development of corrugations, and consists of 3-4 well preserved teeth, and prominent arcuate ligament. Comparative shell morphology of the present fossils is difficult due to inadequate records of freshwater bivalve from Paleogene intertrappean of India. The only resembling available record is of *Unio hunteri*, Hislop 1860, described from the Late

Cretaceous intertrappean beds of Nagpur, which is a smooth, sub quadrangular, inequilateral, posteriorly compressed, unionid bivalve with radiate-rugose apices. The overall morphology of the valves, their distinct dentition and shape, distinguishes them from the *U. hunteri*, and hence, considered as a new unionid species.

Type locality: Bamanbor, Chotila – Rajkot Highway, Gujarat, India

Type horizon: Bamanbor Formation

Genus *Deccanoida aleta* gen. et sp. nov.

(Pl-6.2, Fig. a-l)

Material: One complete specimen, five left valves and one right valve is preserved.

Etymology: The species name refers to the presence of prominent posterior wing in the specimen (Latin aleta, meaning wing).

Holotype: Geo/Mus/BF/VII (Pl-6.2, Fig. a-b).

Paratype: Geo/Mus/BF/VIII, Geo/Mus/BF/IX, Geo/Mus/BF/X, Geo/Mus/BF/XI, Geo/Mus/BF/XII, Geo/Mus/BF/XIII (Pl-6.2, Fig. c-j).

Diagnosis: Rhomboidal to sub rhomboidal shape, with a large prominent posterior wing and parivincular ligament.

Description: Elliptical to rhomboidal shape, posteriorly flattened shell, with faint growth lines (Pl-6.2, Fig. a-b). Characteristic ribs and folds on the commissure (Pl-6.2, Fig. a,b,e,f,i,j,l). The umbo is low, subcentral towards anterior with an angle of 147° (Pl-6.2, Fig. k). Three hinge teeth diverging towards the mantel cavity are discrete. A prominent high posterior dorsal wing, straight ligament and one lateral tooth are distinct. Anterior adductor muscle scar is small but deeply impressed, whereas the posterior muscle scar is large but faintly preserved with a small posterior retractor muscle scar; pallial line is distinct (Pl-2, Fig. a). The anterio-ventral and posterio-ventral margin of the shell also show characteristic corrugations. The posterior part is wider compared to the anterior (Pl-6.2, Fig. a-b). Ornamentation includes distinct growth lines.

Dimensions:

Specimen	**Length**	**Height**	**Width (single valve)**	**Hinge Length**	**Umbonal angle**
Geo/Mus/BF/VII (Pl-6.2, Fig. a-b)	4.3	2.7	1.1	2.3	147°
Geo/Mus/BF/VIII (Pl-6.2, Fig. c)	2.5	1.25	0.5	1.5	-
Geo/Mus/BF/IX (Pl-6.2, Fig. d-e)	4	2.1	0.4	2.7	139°

Geo/Mus/BF/X (Pl-6.2, Fig. f)	5.2	3.2	0.5	3.0	154°
Geo/Mus/BF/XI (Pl-6.2, Fig. g)	5.5	3.5	0.7	3.5	-
Geo/Mus/BF/XII (Pl-6.2, Fig. h-i)	5.5	3.3	0.2	3.4	152°
Geo/Mus/BF/XIII (Pl-6.2, Fig. j)	5.4	3.4	0.4	3.4	-

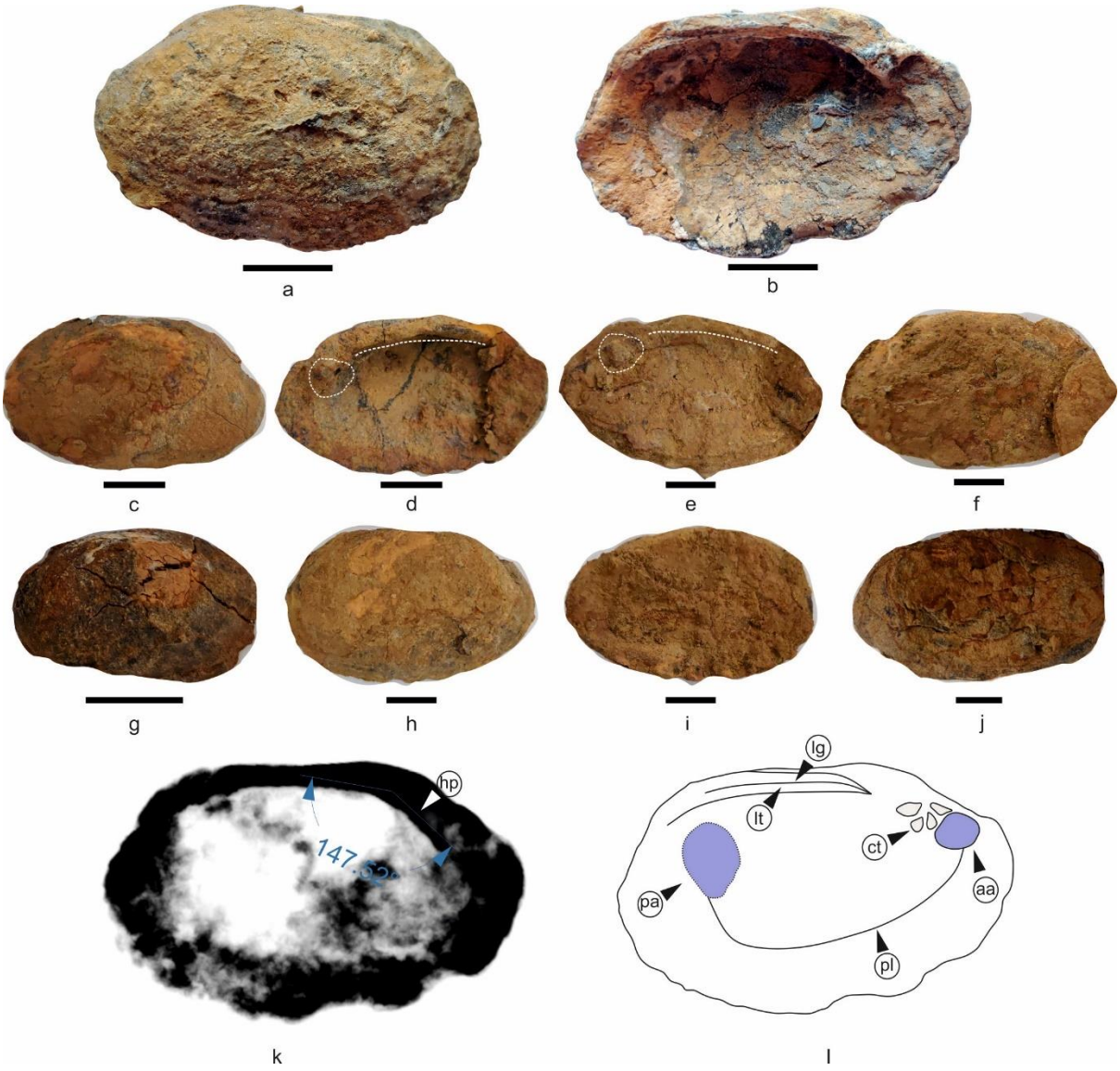

Plate 6.2 *Deccanoida aleta* sp. nov. Fig. a-b, holotype: Fig. a, External view; Fig. b, Internal view. Fig. c-j, Paratypes: Fig. c, External view and internal shell shows the dentition and ligament (Fig. d). Fig. e, Internal view shows the dentition and ligament. Fig. f-j, External view. Fig. k. X-ray of holotype with umbonal angle and hinge plate (hp), Fig. l, Internal shell morphology illustrated of holotype. (ct-cardinal teeth, aa-anterior adductor muscle scar, lt-ligament tooth, lg- ligament, pl-pallial line, pa-posterior adductor muscle scar). All scale bars represent 1cm.

Remarks: The shell morphology helps in designating the *Deccanoida aleta* gen. et. sp. nov. a new taxon and in differentiating it based on prominent posterior wing from the *Deccanoida conrugis* gen. et sp. nov. The nearest resembling unionid of Late Cretaceous is *Unio carteri* (Hislop, 1860) with smooth sub-elliptical shell, with prominent umbones; whereas *Deccanoida aleta gen. et. sp. nov.* is characterised by overall rhomboidal shape; discrete dentition with a prominent posterior wing.

Type locality: Bamanbor, Chotila – Rajkot Highway, Gujarat, India.

Type horizon: Bamanbor Formation.

Genus *Deccanoida costaria* gen. et sp. nov.

(Pl-6.3, Fig. a-f)

Material: Two complete specimens with both the valves closed are preserved.

Etymology: The species name refers to the presence of prominent ribs towards the ventral (Latin costae, meaning ribs).

Syntype: Geo/Mus/BF/XIV, Geo/Mus/BF/XV (Pl-6.3, Fig. a-d)

Diagnosis: Shell semicircular, moderate size, low to moderate posterior wing and prominent corrugations towards the posterior margin extending sub centrally.

Description: Equivalve, inequilateral, posteriorly compressed semicircular to rhomboidal in shape (Pl-6.3, Fig. a-d). Anteriorly placed umbo, prosogyre, ligament opisthodetic and parivincular with umbonal angle 154° (Pl-6.3, Fig. e). The posterior of the left and right valve shows prominent ribs and corrugations which continue till the subcentral anteriorly placed, low umbo (Pl-6.3, Fig. a-b). It has faint growth lines. The umbo is convex with concentric ornamentation. The growth lines are visible on the anterior dorsal wing of both the valves; a small posterior wing is present.

Dimensions:

Specimen	Length	Height	Width (single valve)	Hingle Length (l)	Umbonal angle
Geo/Mus/BF/XIV-L (Pl-6.3, Fig. a)	6.1	3.5	0.6	-	154°
Geo/Mus/BF/XIV-R (Pl-6.3, Fig. b)	6.4	3.2	0.6	-	154°
Geo/Mus/BF/XV (Pl-6.3, Fig. c-d)	5.7	3.8	0.5	3.5	158°

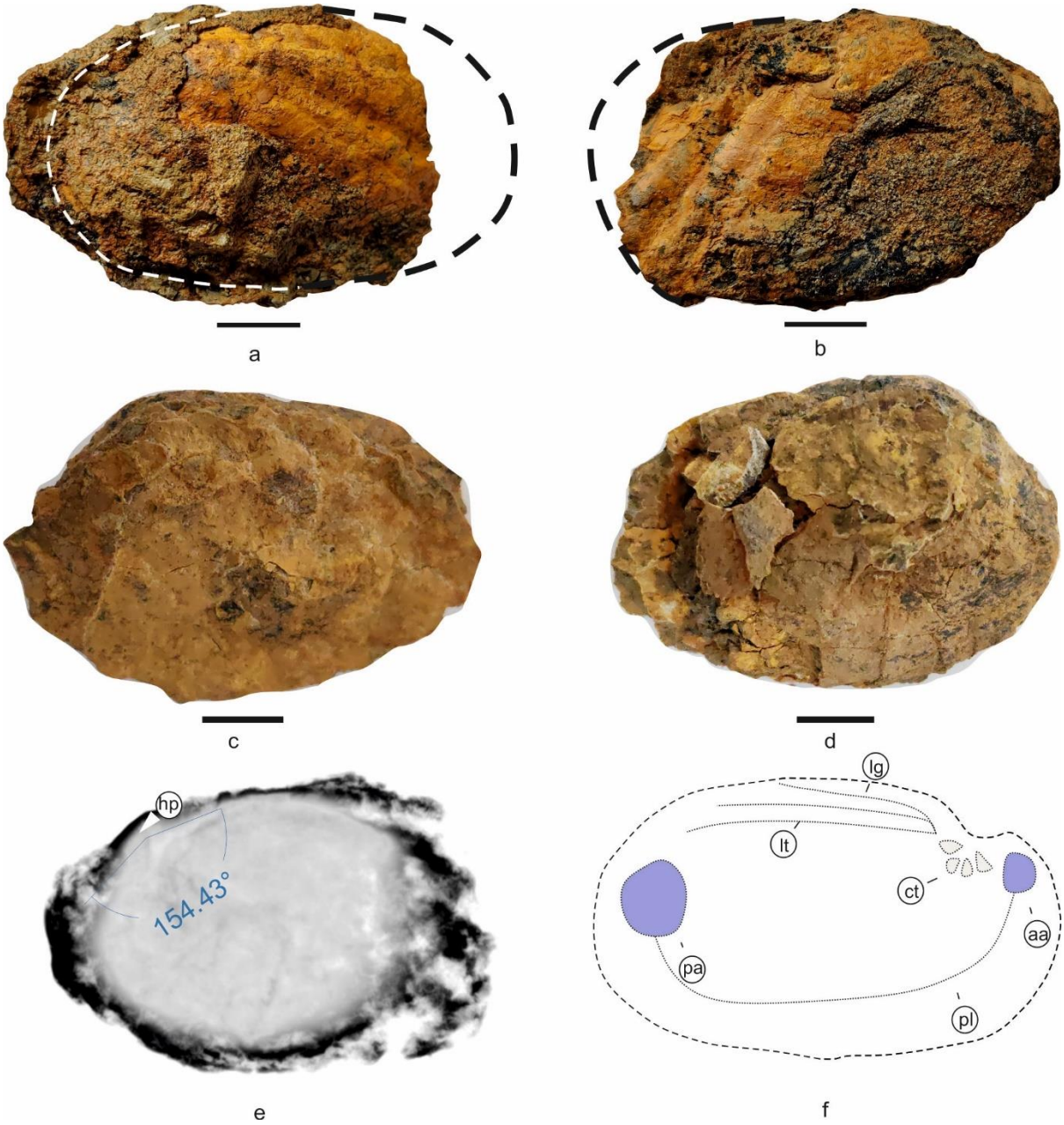

Plate 6.3 *Deccanoida costaria* sp. nov. Fig. a-b holotype: Fig. a, left external view; Fig. b, right external view. Fig. c-d Paratype: Fig. c, left external view; Fig. d, right external view. Fig. e. X-ray of holotype (left valve) with umbonal angle and hinge plate. Fig. f Line drawing of holotype illustrate the internal shell morphology. (ct-cardinal teeth, aa-anterior adductor muscle scar, lt-ligament tooth, lg-ligament, pl-pallial line, pa-posterior adductor muscle scar). All scale bars represent 1cm.

Remarks: Deccanoida costaria gen. et. sp. nov. is regarded as a new species due to its subrhomboidal to semicircular shape and prominent costae extending subcentrally towards the umbo. The external shell morphology is distinct from *Deccanoida conrugis* gen. et. sp. nov. and *Deccanoida aleta* gen. et. sp. nov. but articulated nature of the shells prevents the further

comparison on internal shell morphology. The complete species is redrawn that shows hinge structures, muscle scars and pallial line (Pl-6.3, Fig. f).

Type locality: Bamanbor, Chotila – Rajkot Highway, Gujarat, India

Type horizon: Bamanbor Formation

Genus *Bamanboria* nov.

Type species: Bamanboria oblongis gen. et sp. nov.

Etymology: The genus name refers to the geographic name of location wherein it was reported (Village - Bamanbor).

Diagnosis: As for the type species.

Genus *Bamanboria oblongis* gen. et sp. nov.

(Pl-6.4, Fig. a-k)

Material: Two right valves, one complete specimen and three molds are preserved.

Etymology: The species name refers to its elongated nature (Latin *oblongus*, meaning elongated, length is considerably more than width and thickness of the shell).

Holotype: Geo/Mus/BF/XVI (Pl-6.4, Fig. a-c)

Paratype: Geo/Mus/BF/XVII (internal mold), Geo/Mus/BF/XVIII (internal mold), Geo/Mus/BF/XIX (internal mold), Geo/Mus/BF/XX, Geo/Mus/BF/XXI, (Pl-6.4, Fig. d-i)
Diagnosis: Highly elongated with very wide hinge angle, >160°, one half height to length ratio, small posterior wing, and distinct corrugations towards the posterior margin.

Description: Equivalve, inequilateral, elliptical to oblong shell, length of the valves is nearly twice its height, shell thick but flattened (Pl-6.4, Fig. a, d-i). Umbo prominent, extremely anterior and bears two cardinal teeth, lateral teeth are long and extended quite to posterior margin (Pl-6.4, Fig. a, h). The ligament is long, extended up to 2/3 length of the valve, opisthodetic and parivincular ligament (Pl-6.4, Fig. a) with 175° umbonal angle (Pl-6.4, Fig. j). Anterior and posterior muscle scars are unequal and faintly preserved. Pallial line is straight and prominent. The shell shows allometric growth, on anterio- and posterior- dorsal margin, young shells are oblong (Pl-6.4, Fig. a-b) while adult is elliptical (Pl-6.4, Fig. g-h) in shape. The ventral outline of the shell has distinct corrugations with tubercles (Pl-6.4, Fig. a, c, g), size increase towards the posterior side. Small anterior and posterior wings are present in young shell (Pl-6.4, Fig. a-b). The valves have distinctly marked growth lines and the ventral margin is symmetrically corrugated (Pl-6.4, Fig. a-b, g-i).

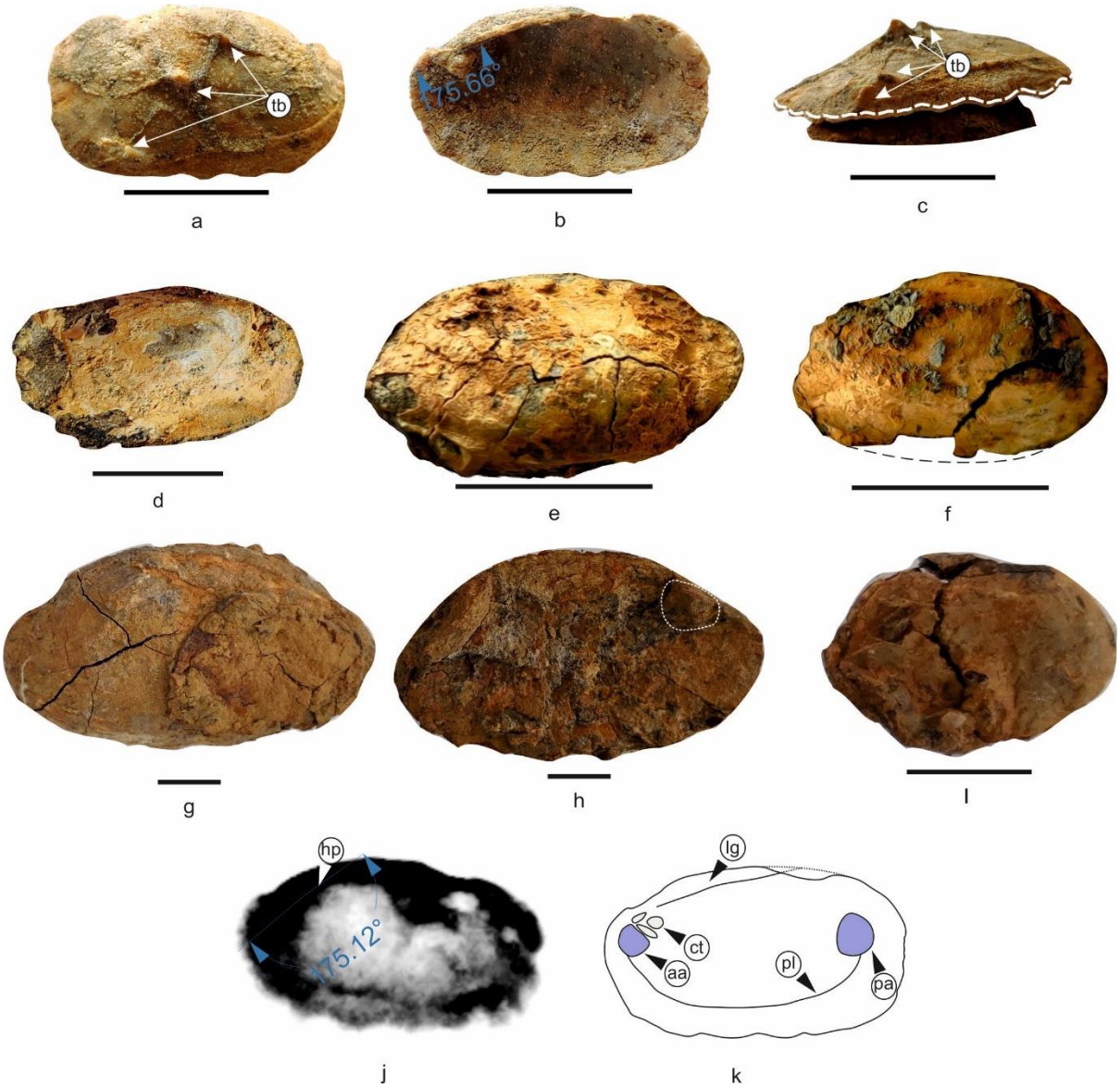

Plate 6.4 *Bamanboria oblongis* sp. nov. Fig. a-c, holotype: Fig. a, external view of right valve; Fig. b, internal of right view with umbonal angle; Fig. c, ventral view with highly corrugated commissure and tubercles. Fig. d-i, paratype: Fig. d-f, internal molds; Fig. g-h, external and internal view with cardinal teeth. Fig. i, external view. Fig. j, X-ray of holotype. Fig. k, internal shell morphology illustrated from the holotype. (ct-cardinal teeth, aa-anterior adductor muscle scar, lt-ligament tooth, lg-ligament, pl-pallial line, pa-posterior adductor muscle scar). All scale bars represent 1cm.

Dimensions:

Specimen	**Length**	**Height**	**Width (single valve)**	**Hinge Length (l)**	**Umbonal angle**
Geo/Mus/BF/XVI (Pl-6.4, Fig. a-c)	2	1.2	0.65	1	175°
Geo/Mus/BF/XVII (Pl-6.4, Fig. d)	2.2	1.2	0.45	-	-

Geo/Mus/BF/XVIII (Pl-6.4, Fig. e)	2	1	-	-	-
Geo/Mus/BF/XIX (Pl-6.4, Fig. f)	1.6	0.96	-	-	-
Geo/Mus/BF/XX (Pl-6.4, Fig. g-h)	5.9	3	0.4	3.4	167°
Geo/Mus/BF/XXI (Pl-6.4, Fig. i)	2.3	1.3	0.3	1.2	-

Remarks: Bamanboria oblongis gen. et. sp. nov. is characterized by its elliptical to oblong shape and a low posterior wing compared to *Deccanoida* nov. Number of internal molds are observed that shows faithful outline with identical ventral corrugations, for e.g., (i) Pl-6.4, Fig. d – left valve mold/nacreous layer which is elliptical/oblong in nature shows subcentral anteriorly placed umbo. The anterior adductor muscle scar and teeth impressions are distinct (Pl-6.4, Fig. b, d, k). The posterior part shows well preserved coarse corrugations; (ii) Pl-6.4, Fig. e – right valve mold/nacreous layer which is elliptical in nature shows anteriorly placed umbo and the internal mold is smooth; and (iii) Pl-6.4, Fig. f – the single left valve mold/nacreous layer which is elliptical in nature shows subcentral umbo. The internal mold is smooth.

Type locality: Bamanbor, Chotila – Rajkot Highway, Gujarat, India

Type horizon: Bamanbor Formation

Subfamily Chotiloinae nov.

Diagnosis: Trapezoidal to elliptical shape of specimens, with 2 diverging cardinal teeth and corrugated commissures.

Genera included: Chotilia gen. nov.

Genus *Chotilia* nov.

Type species: Chotilia trappeansis gen. et sp. nov.

Etymology: The genus name refers to the name of the geographic location where the type species was reported (Town - Chotila).

Diagnosis: As for the type species.

Genus *Chotilia trappeansis* gen. et sp. nov.

(Pl-6.5, Fig. a-f)

Material: Three specimens, one articulated; and two disarticulated shells, amongst one right valve and one left valve are preserved.

Etymology: The species name refers to the name of the sandwiched sedimentary sequences between two volcanic lava flows, deposited during the quiescence period of Deccan Volcanic activity (intertrappeans).

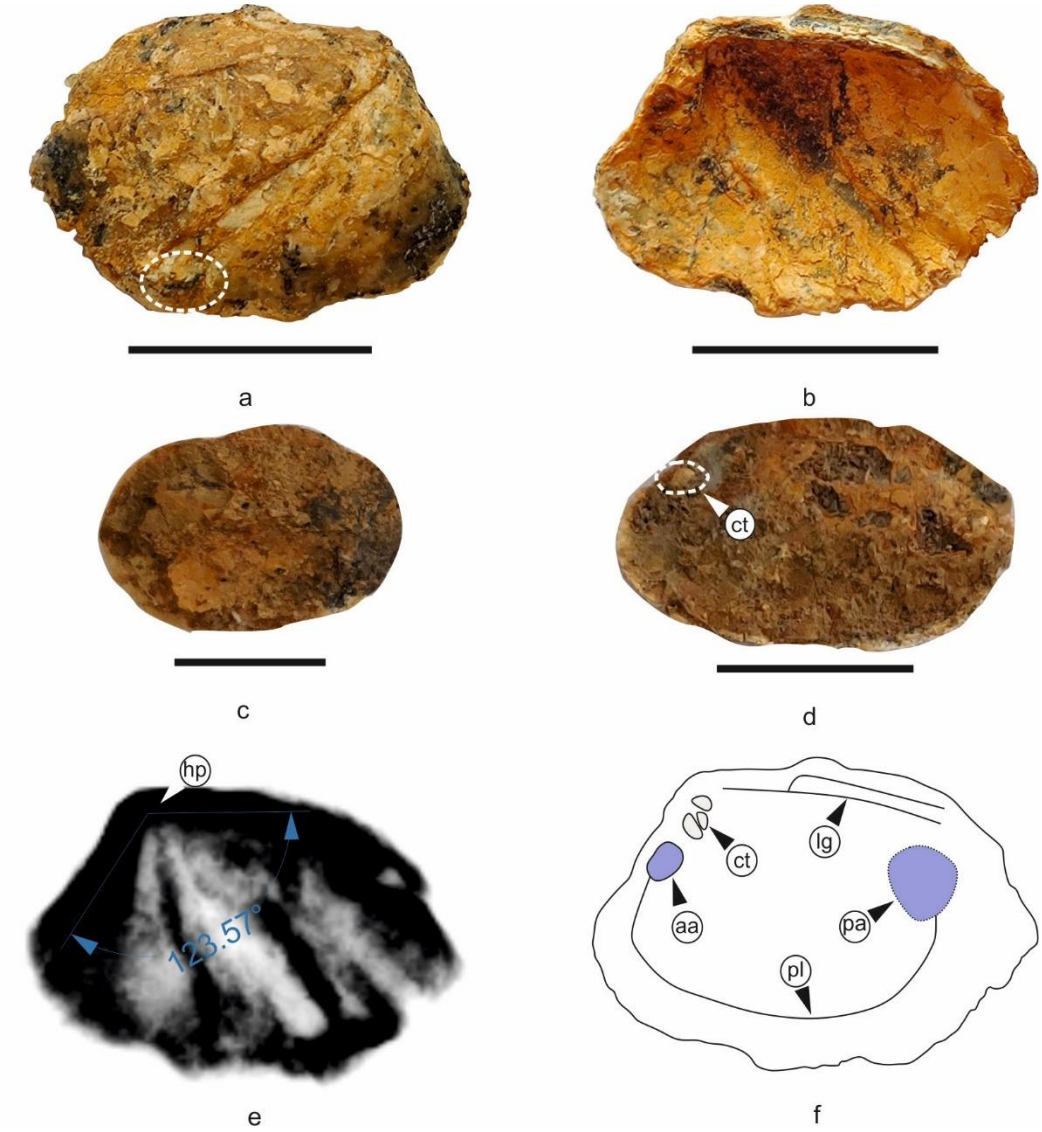

Plate 6.5 *Chotilia trappeansis* sp. nov. Fig. a-b, holotype: Fig. a, external view of right valve. Fig. b, internal view of right valve. Fig. c-d, paratype: Fig. c, left valve view; Fig. d, right valve view and also shows prominent cardinal teeth fused together. Fig. e, X-ray of holotype with umbonal angle and hinge plate. Fig. f, illustrated internal shell morphology of holotype. (ct-cardinal teeth, aa-anterior adductor muscle scar, lt-ligament tooth, lg-ligament, pl-pallial line, pa-posterior adductor muscle scar). All scale bars represent 1cm.

Holotype: Geo/Mus/BF/XXII (Pl-6.5, Fig. a-b)

Paratype: Geo/Mus/BF/XXIII, Geo/Mus/BF/XXIV (Pl-6.5, Fig. c-d)

Diagnosis: Trapezoidal shell, with low obtuse hinge angle, two prominent cardinals as well as one lateral teeth. The valves are uniquely characterised by the placement of single tubercle on posterior-ventral margin along with distinct corrugations and posterior wing.

Description: Trapezoidal, non-inflated and inequilateral, equivalve (Pl-6.5, Fig. a-b). The posterior wing is prominent and elevated, with a distinct opisthodetic parivincular ligament (Pl-6.5, Fig. b). Umbo is prominent, extremely anteriorly placed and has 123° umbonal angle (Pl-6.5, Fig. e); two cardinal and one lateral teeth on posterior side (Pl-6.5, Fig. b,d). Anterior muscle scar leaves a small depression with a faint pallial line. The posterior wing is distinct (Pl-6.5, Fig. b). One tubercle on posterior-ventral side with conspicuous wavy corrugated margin (Pl-6.5, Fig. a). Growth lines are broad, faint and distinct ventrally.

Dimensions:

Specimen	**Length**	**Height**	**Width (single valve)**	**Hinge Length (l)**	**Umbonal angle**
Geo/Mus/BF/XXII (Pl-6.5, Fig. a-b)	1.8	1.3	0.5	1.0	123°
Geo/Mus/BF/XXIII (Pl-6.5, Fig. c)	2	1.5	0.1	0.7	144°
Geo/Mus/BF/XXIV (Pl-6.5, Fig. d)	2	1.4	0.2	0.8	148°

Remarks: The trapeziform shape, distinct high perivincular opisthodetic ligament, and presence of tubercles in *Chotilia trappeansis* gen. et. sp. nov. is differentiates from the other species of the genus *Deccanoida* and *Bamanboria* of the Bamanbor Formation. The complete species is reconstructed with the internal features (Pl-6.5, Fig. f).

Type locality: Bamanbor, Chotila – Rajkot Highway, Gujarat, India

Type horizon: Bamanbor Formation

Genus *Chotilia tuberculata* gen. et sp. nov.

(Pl-6.6, Fig. a-e)

Material: Well, preserved articulated shell.

Etymology: The species name refers to the presence of single row tubercles (Latin tūberculum meaning lump) on both the valves.

Holotype: Geo/Mus/BF/XXV (Pl-6.6, Fig. a-b)

Diagnosis: Trapeziform to cuneiform bivalve with low obtuse hinge angle, and sub centrally placed umbo. Prominent tubercles at center of the valve in single row from umbo to the ventral margin. Moderately developed rostrum.

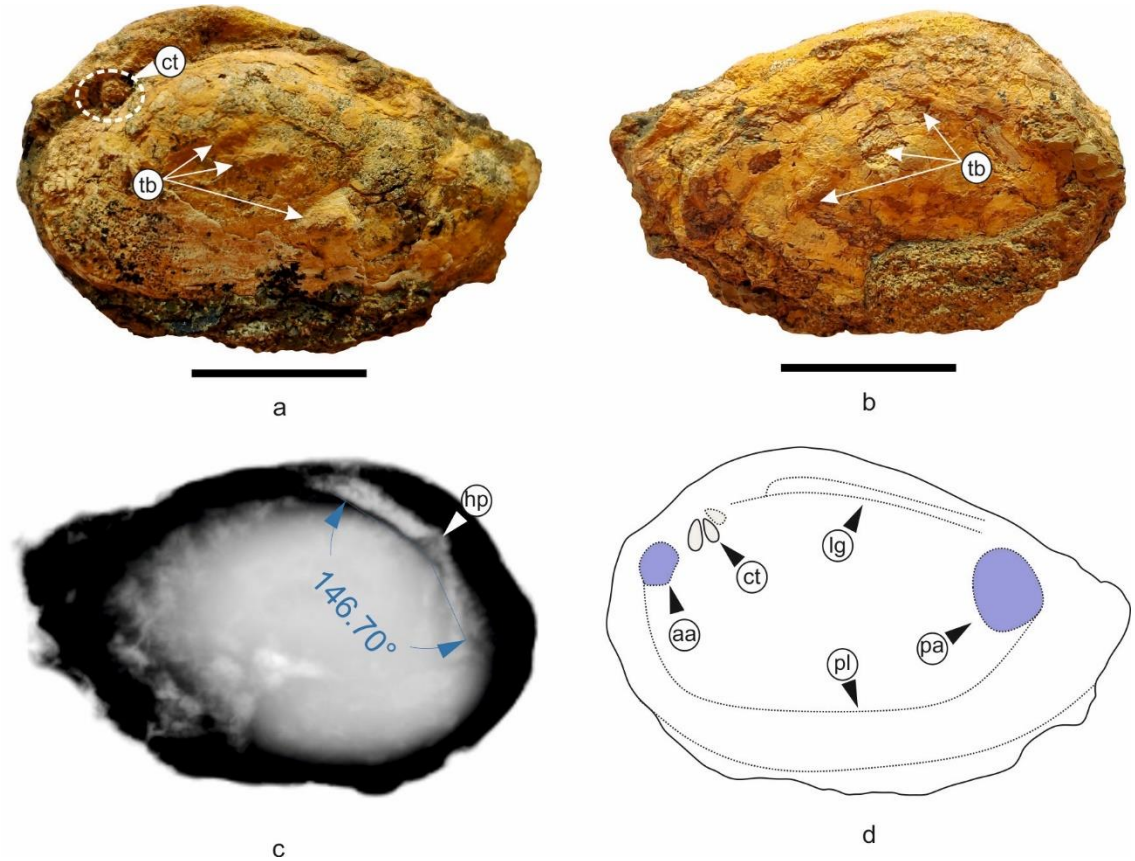

Plate 6.6 *Chotilia tuberculate* sp. nov. Fig. a-b, holotype: Fig. a, left valve external view showing prominent tubercles and cardinal teeth of right valve; Fig. b, external view of right valve. Fig. c. X-ray of holotype with hinge plate and umbonal angle. Fig. d. line drawing of the holotype shows the various internal morphological features. (ct-cardinal teeth, aa-anterior adductor muscle scar, lt-ligament tooth, lg-ligament, pl-pallial line, pa-posterior adductor muscle scar, tb-tubercle). All scale bars represent 1cm.

Description: It is a complete specimen, trapeziform to cuneiform in shape with inequilateral and equivalves (Pl-6.6, Fig. a-b). Valves are preserved in slightly displaced form. Umbo is high and ventricose, placed subcentrally on anterior side with 146° umbonal angle (Pl-6.6, Fig. c); and a slightly curved, opisthodetic ligament is present (Pl-6.6, Fig. a). Two faint cardinal teeth on the right valve are present (Pl-6.6, Fig. a). A posterior wing with moderately developed rostrum (Pl-6.6, Fig. a-b). The posterior end shows relics of ribs and corrugations. Corrugations are concentric towards the ventral margin. Tubercles are present in a single row on both the valves and their size gradually increases from umbo to ventral margin (Pl-6.6, Fig. a). Growth lines are distinct and present on entire valves. The redrawn figure 8-D from the X-ray (Pl-6.6, Fig. c) that shows the important internal features.

Dimensions:

Specimen	Length	Height	Width (single valve)	Hingle Length (l)	Umbonal angle
Geo/Mus/BF/XXV-L (Pl-6.6, Fig. a)	2.9	1.5	0.65	2	146°
Geo/Mus/BF/XXV-R (Pl-6.6, Fig. b)	2.8	1.7	0.4	2	130°

Remarks: Chotilia tuberculata gen. et. sp. nov. is compared with *Unio mammilatus*, Hislop, 1860 which is also a subcuneiform, inequilateral unionid with a single row of mamillae and elevated umbones. The presence of concentric growth lines on entire shell, tubercles on both the valves, highly corrugated margin of *Chotilia tuberculata* gen. et. sp. nov., is a distinguishing from *Unio mammilatus*, Hislop, 1860 and low posterior wing as compared to *Chotilia trappeansis* gen. et. sp. nov.

Type locality: Bamanbor, Chotila – Rajkot Highway, Gujarat, India

Type horizon: Bamanbor Formation

Genus *Chotilia deccansis* gen. et sp. nov.

(Pl-6.7, Fig. a-e)

Material: One right valve is preserved.

Etymology: The species name refers to the name of the Large Igneous Province (LIP) where it was reported (Deccan Traps).

Holotype: Geo/Mus/BF/XXVI (Pl-6.7, Fig. a-c)

Diagnosis: Elliptical shell, ventricose umbo placed low on anterodorsally margin with thick hinge plate. Distinct concentric corrugations, towards the posterior margin.

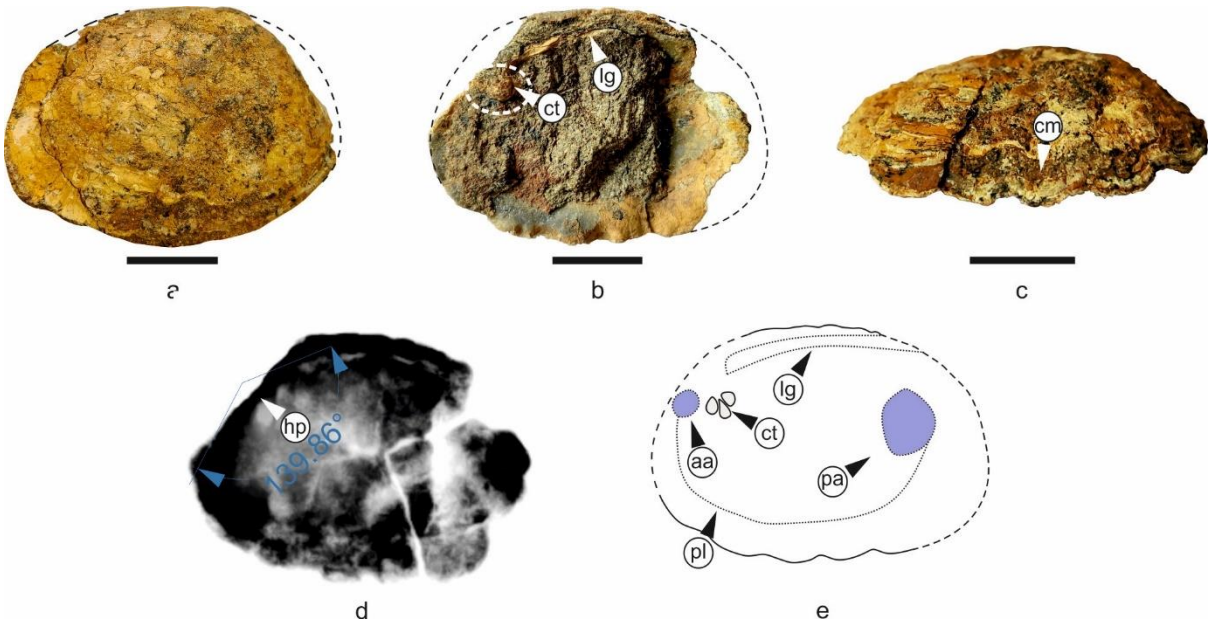

Plate 6.7 *Chotilia deccansis* sp. nov. Fig. a-e, holotype: Fig. a, external view of right valve; Fig. b, internal view of right valve with prominent cardinal teeth and opisthodetic parivincular ligament; Fig. c, ventral view with distinct coarsely corrugated commissure. Fig. d, X-ray image with umbonal angle and hinge plate Fig. e. Line drawing of the shell shows internal morphological features of holotype (ct-cardinal teeth, aa-anterior adductor muscle scar, lt-ligament tooth, lg-ligament, pl-pallial line, pa-posterior adductor muscle scar, cm-commissure). All scale bars represent 1cm.

Description: A thick right valve, elliptical in shape, probably equivalved but inequilateral (Pl-6.7, Fig. a). The umbo and beak are towards anterior side, but placed low (Pl-6.7, Fig. b) with 139° umbonal angle (Pl-6.7, Fig. d). Two cardinal and one lateral tooth are prominent with slightly curved parivinvular opisthiodetic ligament (Pl-6.7, Fig. b). Concentric growth lines are present on the entire valve (Pl-6.7, Fig. a). In ventral side it is folded with costae which are reflected as corrugation (Pl-6.7, Fig. c). The reconstructed species shows unequal adductor muscle scars with prominent pallial line (Pl-6.7, Fig. e).

Dimensions:

Specimen	**Length**	**Height**	**Width (single valve)**	**Hinge Length (l)**	**Umbonal angle**
Geo/Mus/BF/XXVI (Pl-6.7, Fig. a-c)	3.7	2.5	0.8	2	139°

Remarks: The unique elliptical shape is characteristic of *Chotilia deccansis* gen. et sp. nov which is differentiated from the *C. trappeansis* and *C. tuberculata*. It is also different from *Lamellidens vredenburgi*, Prashad, 1921, redescribed from the Hislop; and Hunter, 1855 collections of the intertrappeans of Goraha, Narbada (Narmada), which is an elongated subrhomboidal, uninod with narrow posterior wing and, rounded posterior and somewhat angulate anterior margin of the shell.

Type locality: Bamanbor, Chotila – Rajkot Highway, Gujarat, India

Type horizon: Bamanbor Formation

6.6 GATROPODA

Another important freshwater molluscan, the pulmonate gastropods, has also been recovered from Bamanbor Formation. These include the *Physa* (cf. *Physa prinsepii*) (Plate 6.8a) and *Valvata?* (Plate 6.8b).

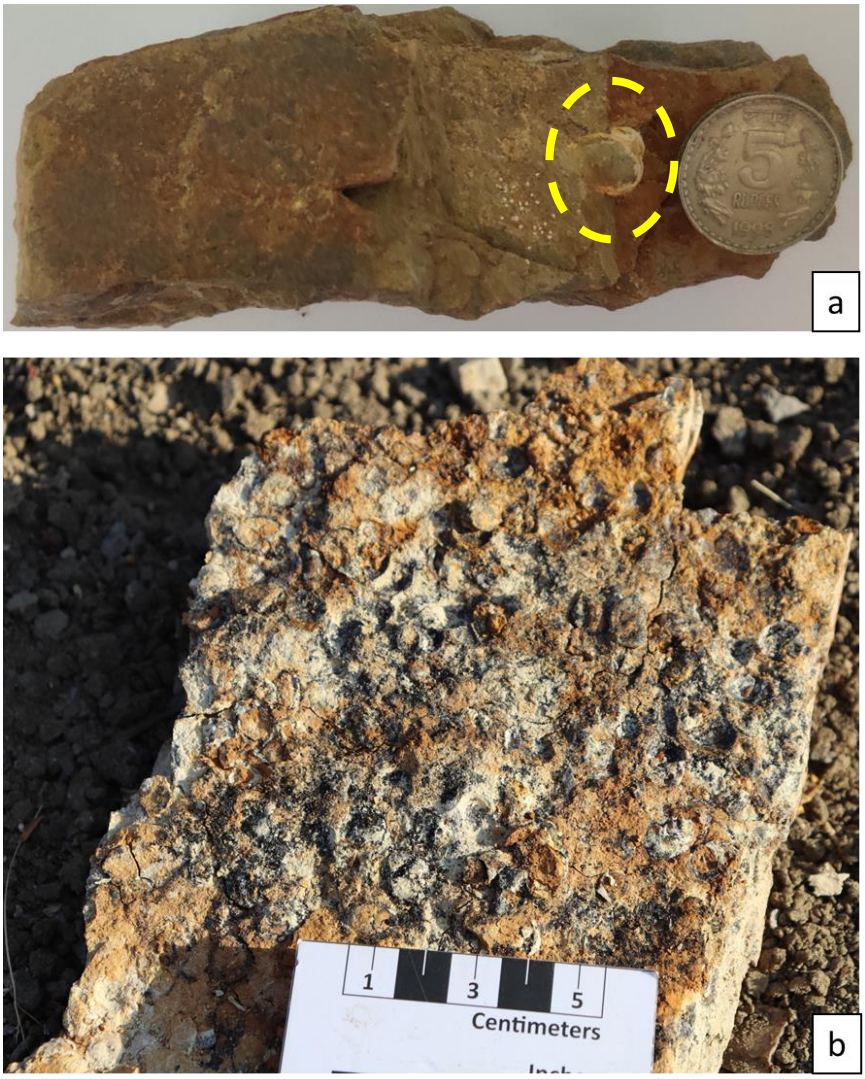

Plate 6.8 a. *Physa* from shaly sandstone, Bamanbor Formation, exposed at Bamanbor Roadcut section (Scale - 5₹ coin is 2.4 cm in diameter) b. *Valvata* from yellow mudstone, Bamanbor Formation, exposed at Rangpar GIDC section.

The *Physa* (Plate 6.8a) is observed near Bamanbor road cut section along with the bivalves. The shape of the *Physa* shell is ovate, with acute apex, three visible whorls with the last whorl larger than the spire and sinistral coiling. The yellow mudstone beds of the Bamanbor Formation, exposed at the Rangpur GIDC sections, hosts numerous planispirally coiled gastropods, *Valvata?* (Plate 6.8b). The shells are abundant, delicate and difficult to retrieve. They are found on junction of grey shales and yellow mudstone and preserved as internal molds. They are characterised by very small size of shell, discoidal and umbilicate shell, with three whorls and oval to rounded aperture.