Paläontol Z
DOI 10.1007/s12542-009-0025-5

REVIEW ARTICLE

Oligocene and Early Miocene gastropods from Kutch (NW India) document an early biogeographic switch from Western Tethys to Indo-Pacific

Mathias Harzhauser · Markus Reuter · Werner E. Piller · Björn Berning · Andreas Kroh · Oleg Mandic

Received: 9 May 2009 / Accepted: 12 May 2009

Abstract Shallow marine gastropod assemblages from Chattian, Aquitanian and Burdigalian sections in the Indian Kutch Basin are described. They provide insight into the composition and biogeographic relations of the gastropod assemblages at this junction between the Western Tethys and Proto-Indo-Pacific Ocean. For the first time, an improved biostratigraphy allows a clear separation of the assemblages, especially for the hitherto undifferentiated Early Miocene faunas. Throughout the Oligocene, about one-third of the species are also frequently found in the Western Tethys, documenting a passable Tethyan Seaway for nearshore molluscs. A considerable provincialism is evident as well. The expected turnover during the Early Miocene, due to the closing of the Tethyan Seaway, is reflected in the Miocene assemblages. Surprisingly, however, the cut appears very early, i.e. already during the Aquitanian, when the West–East interrelation drops to zero despite the passage having been open during this interval. In contrast, the Burdigalian assemblages witness a minor re-appearance of Western Tethys taxa, suggesting the re-establishment of rather ineffective migration pathways prior to the final closure of the Tethyan Seaway. *Cerithium bermotiense* and *Lyria* (*Indolyria*) *maniyaraensis* are introduced as new species.

Keywords Gastropoda · India · Biogeography · Oligocene · Miocene

Zusammenfassung Seicht marine Gastropodenvergesellschaftungen aus dem Chattium, Aquitanium und Burdigalium des indischen Kutch Beckens werden beschrieben. Sie erlauben Einblicke in die Zusammensetzung und die biogeographischen Beziehungen der Gastropodenfaunen an dieser Schnittstelle zwischen West-Tethys und Proto-Indo-Pazifik. Erstmals können insbesondere die bisher ungetrennten frühmiozänen Faunen aufgrund einer verbesserten Biostratigraphie gut separiert werden. Während des gesamten Oligozäns deutet ein Anteil von ca. 30% West-Tethys Arten an der Gesamtfauna auf eine gut passierbare Tethys Verbindung. Ein hohes Maß an Provinzialismus ist ebenso evident. Der in Folge der Tethys-Schließung erwartete Umschwung im frühen Miozän wird durch die Faunen deutlich belegt. Überraschend ist jedoch der sehr frühe biogeographische Schnitt, da die faunistischen West-Ost Beziehungen bereits im Aquitanium zusammenbrechen. Ein sehr geringer Anteil an West-Tethys Arten im Burdigalium dürfte auf eine Wiederherstellung eines relativ uneffektiven Migrationsweges vor der finalen Tethys-Schließung hinweisen. *Cerithium bermotiense* und

M. Harzhauser (✉) · A. Kroh · O. Mandic
Natural History Museum Vienna, Burgring 7,
1010 Vienna, Austria
e-mail: mathias.harzhauser@nhm-wien.ac.at

A. Kroh
e-mail: andreas.kroh@nhm-wien.ac.at

O. Mandic
e-mail: oleg.mandic@nhm-wien.ac.at

M. Reuter · W. E. Piller
Institute of Earth Sciences, Geology and Palaeontology,
Graz University, Heinrichstrasse 26, 8010 Graz, Austria
e-mail: markus.reuter@uni-graz.at

W. E. Piller
e-mail: werner.piller@uni-graz.at

B. Berning
Upper Austrian State Museum, Welserstr. 20,
4060 Linz-Leonding, Austria
e-mail: b.berning@landesmuseum.at

Published online: 06 June 2009

Lyria (*Indolyria*) *maniyaraensis* werden als neue Arten eingeführt.

Schlüsselwörter Gastropoda · Indien · Biogeographie · Oligozän · Miozän

Introduction

First studies of the fauna of the Kutch Basin go back to Sowerby (1840). Unfortunately, he provides only locality names without describing the exact positions. Nevertheless, in respect to the limited outcrop areas, we suggest that Sowerby had received material more or less from the same localities as studied herein. Sowerby's material and additional fossils from the Kutch Basin were described in detail by Vredenburg (1925, 1928), who provided coordinates of the localities. Thereafter, only geological investigations have been published on the area, usually neglecting the paleontological data of Sowerby (1840) and Vredenburg (1925, 1928). In these papers (e.g. Biswas 1982, 1987, 1992) the fossil content of Oligocene and Miocene strata of the Kutch Basin was treated only on a very rough genus or family level. Nevertheless, the mollusc assemblages of the Kutch Basin, together with coeval assemblages from Pakistan (d'Archiac and Haime 1853; Fedden 1880), were frequently used for biogeographic considerations concerning the closure of the Tethyan Seaway (Vredenburg 1925; Vlerk 1931; Sahni and Mitra 1980; Piccoli 1984; Piccoli et al. 1991; Harzhauser et al. 2002, 2007). These considerations, however, suffered strongly from the mixing of faunas of different stratigraphic levels. Herein, we will present for the first time a clear separation of the gastropod faunas into Rupelian, Chattian, Aquitanian and Burdigalian ones. This will serve as a base for new estimations on faunistic interrelations of the NW-Indian and Pakistanian Oligocene and Early Miocene faunas with coeval Western Tethyan and Proto-Indo-Polynesian ones. These comparisons are largely based on our own fieldwork in Oman, Tanzania and South India within the frame of the Austrian Science Foundation: Biogeographic Differentiation and Biotic Gradients in the Western Indo-Pacific during the Late Oligocene to Early Miocene.

Localities and geological setting

The Kutch Basin is a peri-cratonic rift basin at the western passive continental margin of the Indian craton (Biswas 1982). Extending ca. 200 km east into the inland, the basin is bounded by the SW–NE striking Kathiawar Uplift to the south, the E-W striking Nangar Parkar Ridge to the north and the NNW–SSE striking Radhanpur–Bamer Arch to the west (Biswas 1991) (Fig. 1).

The basin started to open during the Late Triassic-Early Jurassic as a result of the break-up of the Gondwana supercontinent, and because of the subsequent counter-clockwise rotation and northward drift of the separated Indian subcontinent since the Middle Jurassic (Biswas 1982, 1987; Ali and Aitchison 2008). Until the Early Cretaceous it was filled with 3,000 m of predominantly siliciclastic sediments deposited in shallow shelf and deltaic environments (Biswas 1982, 1992). Effusive volcanism, forming the Deccan Traps, occurred during the Late

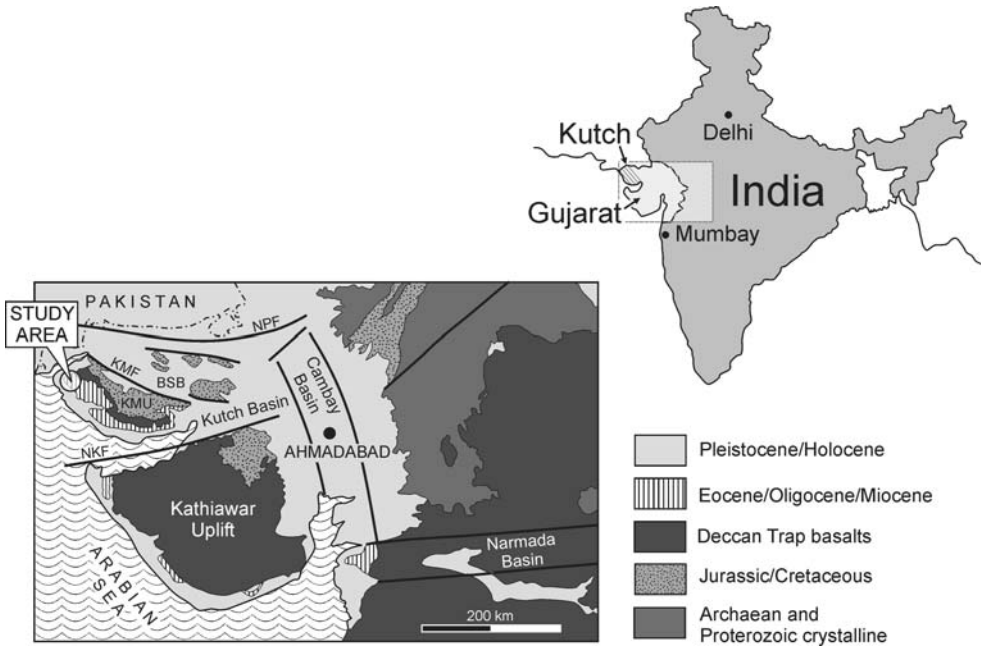


Fig. 1 Geological map of the Kutch Basin (modified after Biswas 1987); KMU = Kutch Mainland Uplift, KMF = Kutch Mainland Fault, BSB = Banni Subbasin, NPF = Nangar Parkar Fault, NKF = North Kathiawar Fault

Cretaceous to Paleocene, and coeval with the beginning collision of the Indian subcontinent with Eurasia, which sealed the Mesozoic siliciclastic rocks beneath basalt flows (Biswas and Deshpande 1973). The final architecture of the Kutch Basin developed during the early Cenozoic because of enduring plate collision. The Cenozoic sedimentary succession was deposited in a complex system of consecutively staged, northwest–southeast trending half grabens (Biswas 1987). With only 300 m, the Cenozoic basin fill has a low thickness compared to the Mesozoic depositional succession, caused by a minor subsidence rate and many sedimentary discontinuities (Biswas 1992). Today, Cenozoic rocks crop out in the western Kutch Basin in the surroundings of uplifts composed of Mesozoic sediments and Deccan Trap basalts. These uplifts are the highest elevated areas of tilted tectonic blocks and form the highlands within the present day basin (Biswas 1987). The physiography of these fault blocks is that of a gently inclined ramp formed by the tilted surface of the block, dipping away from a steep scarp. The studied outcrops are located on a 5–10° SW inclined dip-slope ramp situated northwest of the Kutch Mainland Uplift. Kutch Mainland is a northwest–southeast extending highland approximately 150 km in length, and is composed of Jurassic and Early Cretaceous siliciclastics as well as of Deccan Trap basalts. To the north it is bounded by the Banni Sub-basin, stretching along the Kutch Mainland Fault (Biswas 1987).

Studied localities

The studied Oligocene/Miocene successions comprise shallow-marine carbonates of Oligocene age (Maniyara Fort Formation) and siliciclastics of Early Miocene age (Khari Nadi Formation, Chasra Formation). The Rupelian/Chattian boundary is exposed at the type section of the Maniyara Fort Formation along the Bermoti River in the surrounding area of the village Bermoti (Maniyara Fort, MF locality, N 23°27′45″, E 68°36′07″) (Biswas and Raju 1971; Biswas 1992). The studied sedimentary succession at the MF locality is 27 m thick. Its lower, 6-m-thick segment belongs to the upper Rupelian Coral Limestone Member of the Maniyara Fort Formation. The larger foraminifera *Eulepidina dilatata* and *Nummulites fichteli* in the Coral Limestone Member indicate a Rupelian age (Biswas 1992). This unit is dominated by argillaceous, pelletoidal limestones with intercalated coral patch reefs. Nummulitid limestones occur subordinately. Some beds are dolomitic. The contact to the overlying Bermoti Member (8 m thick), which has a Chattian age (Biswas 1992), is characterised by metre-thick dolomite and sandstone deposits. The stacking of meter-scale depositional cycles is typical for the sedimentary architecture of the Bermoti Member. Such a depositional cycle starts with argillaceous, pelletoidal limestone that differs from that of the Coral Limestone Member by the absence of reef-building corals. Up-section, argillaceous limestones pass gradually in shell concentration-limestones composed of irregular echinoids, pectinids, solitary corals and gastropods. These biota also occur in the argillaceous, pelletoidal limestones, but in much lower numbers. The caps of depositional cycles in the Bermoti Member are increasingly affected by dolomitization towards the top.

The Oligocene/Miocene transition is characterised by a drastic change in sedimentation, and the carbonate environments became smothered by siliciclastic sediments. Siliciclastic sedimentation started with the shallow-marine Aquitanian Khari Nadi Formation, which is dated to the Aquitanian by the occurrence of *Miogysina* (*Myogypsina*) *tani* in its middle and upper part (Biswas and Raju 1971; Biswas 1992). At the MF locality the Oligocene carbonates are truncated by deltaic conglomerates and sandstones of the Khari Nadi Formation, which does not contain any mollusc fauna. Therefore, we have chosen an outcrop at the waterside of the Khari Nadi River at N 23°23′04.2″, E 68°43′17.7″ for the study of Aquitanian gastropod faunas (Khari Nadi KN locality). This location exposes two fossiliferous beds of sandy shell concentration limestone, which are intercalated with thick marl deposits of the Khari Nadi Formation. The lower shell bed is 1.5 m thick and separated by a 0.4-m-thick marl package from the upper 0.65-m-thick shell bed. Both shell concentrations are dominated by the gastropod *Zaria angulata*. Additionally, bivalves (oysters, pectinids), cupuladriid bryozoans, regular and irregular echinoids, larger foraminifera (lepidocyclinids), as well as isolated fragments of branching (acroporids) and massive corals contribute to the fauna.

During the Burdigalian, when the Chasra Formation was deposited (Biswas 1992), shallow-marine siliciclastic sedimentation continued. The Burdigalian age is indicated by the miogypsinidae assemblage with *Lepidosemicyclina excentrica*, *L. droogeri, Miogypsina globulina*, *Miogypsinoides dehartii* and *M. indica* (Biswas 1992).

Representative for the Burdigalian, we studied two outcrops along the Kankawati River near the village Vinjhan. Outcrop KW is situated at the southern waterside of the river, 2.1 km SE of Vinjhan at N 23°05′37.5″, E 69°02′57.2″. It is 6 m high and documents a succession of siltstones, claystones and sandstones. Intercalated are three 0.5–1.0-m-thick beds of sandy shell concentration limestone composed of gastropods, bivalves (e.g., *Periglypta*, *Placuna*, pectinids, *Kuphus*, *Solen*), echinoids (*Clypeaster*) and solitary corals. The shell concentrations have irregular bases with *Thalassinoides* galleries and are laterally continuous over hundreds of metres without a change in facies or thickness.

The stratigraphic higher outcrop VJ is situated 1.8 km downstream and 0.5 km south of Vinjhan at the northern waterside of Kankawati River (N 12°05′35″, E 69°01′46″). Here, a 20-m-thick sedimentary sequence of predominantly laminated siltstones is exposed that is part of the Upper Siltstone Member (upper Chasra Formation). Intercalated are sandstones and claystones. Some sandstone beds exhibit ripple-scale cross-beds or contain leaf imprints and fine phytoclastic debris. A stromatolite and two shell concentrations are also intercalated. These shell concentrations are mainly composed of disarticulated oyster valves, which were colonised by balanids and unilaminar encrusting bryozoans after their deposition, forming flat (10–15 cm thick), laterally extensive (several tens of metres) lenses.

Repository: The material is stored in the collections of the Natural History Museum Vienna (NHMW).

Systematic paleontology

The systematic arrangement of higher taxa largely follows the proposal of Bouchet and Rocroi (2005).

Class Gastropoda Cuvier, 1797
Subclass Orthogastropoda Ponder & Lindberg, 1996
Superorder Vetigastropoda Salvini-Plawen & Haszprunar, 1987
Superfamily Trochoidea Rafinesque, 1815
Family Trochidae Rafinesque, 1815
Subfamily Trochinae Rafinesque, 1815
Genus *Tectus* Montfort, 1810
Type species: *Trochus mauritianus* Gmelin, 1791. Recent, Indo-Pacific.

***Tectus cognatus* (Sowerby,** 1840)

Fig. 2a

* 1840 *Trochus cognatus* Sowerby: explanation of plates (no page number), pl. 26 fig. 6
1928 *Trochus* (*Tectus*) *affinis* Sowerby.—Vredenburg: 407
1961 *Trochus* (*Tectus*) *cognatus* Sowerby.—Dey: 51, pl. 5 fig. 27
non 1853 *Trochus cognatus* Sowerby.—d'Archiac & Haime: 290, pl. 26 fig. 18 [= *Tectus loryi* (d'Archiac & Haime, 1853)]

Material: 1 specimen (silicone mould), NHMW 2008z0257/0001.
Measurements: height: 38 mm, diameter: 38 mm.
Locality: Vinjhan, Kankawati River (KW locality).
Lithostratigraphy: Chasra Formation.
Age: Burdigalian.

Fig. 2 Gastropods of the Kutch Basin. **a** *Tectus cognatus* (Sowerby, 1840), NHMW 2008z0257/0001, Vinjhan. **b** *Globularia* cf. *sanctistephani* (Cossmann & Peyrot, 1919), NHMW 2008z0255/0001, Bermoti. **c**, **d** *Globularia carlei* (Finlay, 1927), NHMW 2008z0255/0002, Vinjhan. **e** *Ampullinopsis crassatina* (Lamarck, 1804), NHMW 2008z0255/0002, Bermoti. **f** *Phasianella* aff. *variegata* Lamarck, 1822, NHMW 2008z0257/0011, Vinjhan. **g**, **h** *Pachycrommium harrisi* (Pannekoek, 1936), NHMW 2008z0257/0003, Vinjhan. **i** *Cerithium bermotiense* Harzhauser nov. sp. silicone mould of the holotype, NHMW 2008z0255/0010a, Bermoti. **j–l** *Cerithium rude* Sowerby, 1840, NHMW 2008z0257/0004, Vinjhan. **m** *Cerithium* cf. *pseudocorrugatum* d'Orbigny, 1852, NHMW 2008z0257/0005, Vinjhan. **n** *Tenagodus granti* (Sowerby, 1840), NHMW 2008z0255/0003, Bermoti River. **o**, **p** *Varicospira subrimosa* (d'Orbigny, 1852), NHMW 2008z0257/0012, Vinjhan. **q**, **r** *Natica obscura* Sowerby, 1840, NHMW 2008z0257/0014, Vinjhan. Scale bar = 5 mm

Remarks: Only a quite worn specimen is available, but natural casts of this species are very common in the outcrop area. The high, cyrtoconoid shell has distinctly incised sutures and a slightly protruding rim of nodes along the lower suture, agreeing fully with the type of Sowerby (1840). Its much smaller nodes distinguish *Tectus cognatus* from the Oligocene to Early Miocene *Tectus loryi* (d'Archiac and Haime 1853), which was frequently intermingled with that species (see Harzhauser 2007 for discussion). The Late Miocene *Tectus tjilonganensis* (Martin 1905), which was treated as a synonym of *Tectus cognatus* by Vredenburg (1928), is now considered to be a subspecies of the extant *Tectus pyramis* (Born 1778) (Beets 1981; Hoek Ostende et al. 2002).

Distribution: *Tectus cognatus* is known so far only from the Burdigalian of the Kutch Basin and from the Burdigalian of South India and Sri Lanka (Wayland and Davies 1923; Dey 1961).

Superfamily Turbinoidea Rafinesque, 1815
Family Phasianellidae Swainson, 1840
Genus *Phasianella* Lamarck, 1804

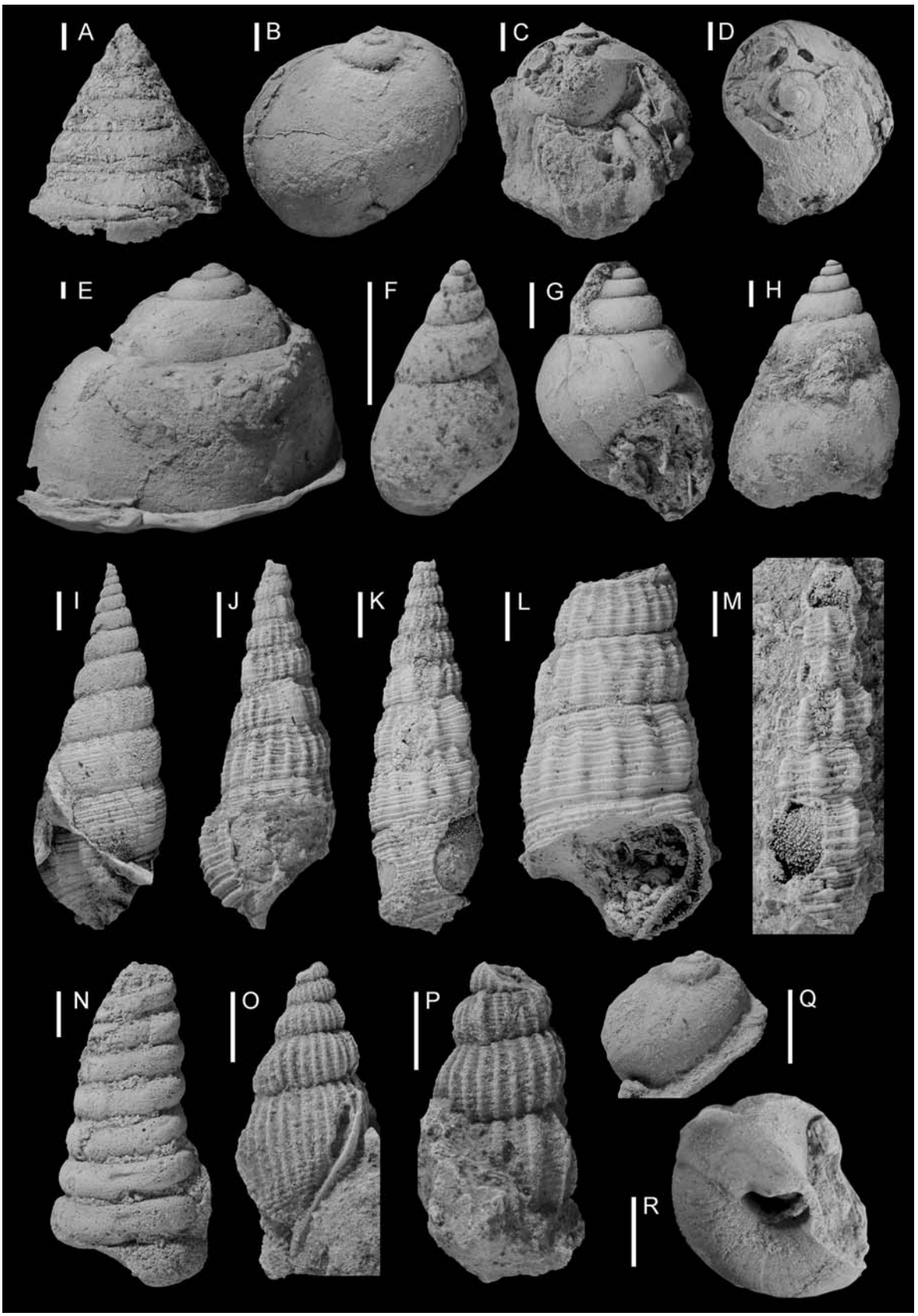
Type species: *Buccinum australe* Gmelin, 1791. Recent, Australia.

***Phasianella* aff. *variegata* Lamarck,** 1822

Fig. 2f

* 1822 *Phasianella variegata* Lamarck: 53
1961 *Phasianella variegata* Lamarck.—Dey: 49

Material: 1 specimen, NHMW 2008z0257/0011.
Measurements: height: 19 mm, diameter: 5.5 mm.
Locality: Vinjhan, Kankawati River (KW locality).
Lithostratigraphy: Chasra Formation.
Age: Burdigalian.
Description: Turbinate shell consisting of ca. two strongly convex protoconch whorls and four moderately convex teleoconch whorls producing an angle of ca. 55°. Shell surface is nearly smooth with an indistinct spiral band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close to the adapical suture. Traces of very delicate spiral threads in the upper part of the spire whorls are largely obscured by the corrosion of the shell surface. The last whorl displays a strong convexity at the periphery but lacks an angulation.

Remarks: Only a single specimen with sediment-covered aperture is available. There are hardly any representative Phasianellidae described from the Early and Middle Miocene of the Indo-Pacific area. *Phasianella teschi* Martin, 1916 (treated as a synonym of the extant *Phasianella aethiopica* Philippi, 1853 by Hoek Ostende et al., 2002) from the Early Miocene of Java differs clearly in its higher spire and the strongly convex spire whorls. Two *Phasianella* opercula from the Miocene of Eniwetok described by Ladd (1966) are incomparable with the Indian material.

Distribution: This species was also recorded from the Burdigalian of Kerala in South India (Dey 1961).

Superorder Caenogastropoda Cox, 1960
Order Architaenioglossa Haller, 1892
Superfamily Ampullinoidea Cossmann, 1918
Family Ampullinidae Cossmann, 1918
Genus *Globularia* Swainson, 1840

Type species: *Ampullaria sigaretina* Lamarck, 1804. Eocene, Paris Basin.

***Globularia carlei* (Finlay, 1927)**

Fig. 2c, d

1840	*Natica callosa* Sowerby: explanation of plates (no page number), pl. 26 fig. 3 [non *Natica callosa* Scopoli, 1777]
* 1927	*Natica carlei* Finlay: 498
1928	*Ampullina* (*Cernina*) *callosa* Sowerby.—Vredenburg: 400
1961	*Globularia* (*Cerntna* [sic!]) *carlei* (Finlay).—Dey: 54, pl. 5 figs. 3, 5
non 1895	*Natica callosa* Sowerby.—Noetling: 23, pl. 5 fig. 8
non 1901	*Natica callosa* Sowerby.—Noetling: 283, pl. 18 figs. 24–25, pl. 19 fig. 1
? 1930	*Cernina callosa* (Sowerby).—Cox: 107, pl. 12 figs. 11a–b
non 1953	*Natica callosa* Sowerby.—King: 76

Material: 5 specimens, NHMW 2008z0255/0002.
Measurements: diameter: 31–44 mm.
Locality: Vinjhan, Kankawati River (KW locality).
Lithostratigraphy: Chasra Formation.
Age: Burdigalian.

Remarks: This globulariid is characterised by a huge last whorl and a depressed spherical outline. The adapical part of the aperture reaches close to the spire, enveloping most of the preceding whorl. These features allow a distinct separation from the Aquitanian to Burdigalian *Globularia vredenburgi* Cox, 1927 (Cox, 1927, Harzhauser, 2009). The taxon, described by Noetling (1895, 1901) as *Natica callosa* from the Miocene of Burma, is clearly distinguished from *Globularia carlei* by its pointed spire and flat posterior part of the last whorl; it is a naticid and unrelated with the Indian fossil. Consequently, the South African Miocene record mentioned by King (1953) does not represent *Globularia callosa* as King (1953) refers to the illustrations in Noetling (1901). Cox (1930) describes a *Globularia* from the Miocene of Kenya as *Cernina callosa*. This shell differs from the Indian type by its stepped spire. Moreover, it lacks the regular convexity of the last whorl that characterises the depressed spherical *Globularia carlei*.

Distribution: *Globularia carlei* (Finlay 1927) is known so far only from the Burdigalian of the Kutch Basin and Kerala in South India (Dey 1961).

***Globularia* cf. *sanctistephani* (Cossmann & Peyrot, 1919)**

Fig. 2b

* 1919	*Ampullina Sancti-Stephani* Cossmann & Peyrot: 449, pl. 12, figs. 30–33
1973	*Globularia gibberosa sanctistephani* (Cossmann & Peyrot).—Baldi: 276, pl. 32 figs. 4–5

Material: 1 specimen (cast and silicone mould of the same specimen), NHMW 2008z0255/0001.
Measurements: height: 39 mm, diameter: 40 mm.
Locality: Bermoti village, MF section.
Lithostratigraphy: Maniyara Fort Formation, Bermoti Member.
Age: Chattian.

Remarks: The huge aperture, the concave columella, and the relatively low and compressed last spire whorl indicate a relation to *Globularia sanctistephani*. This species was frequently intermingled with *Globularia gibberosa* (Grateloup 1847), and references citing *G. gibberosa* from the Oligocene of Pakistan might also concern *G. sanctistephani* (e.g. Vredenburg 1928; Iqbal 1980). *Globularia gibberosa* differs especially by its straight columella and the less depressed outline. Poor preservation of the numerous internal moulds from the Kutch Basin limits the identification, and several specimens might also represent *G. gibberosa*.

Distribution: *Globularia sanctistephani* is known from the Oligocene of France and Hungary. Further occurrences might have been simply overlooked due to the intermingling with *G. gibberosa*. Both taxa seem to be present in the Chattian of the Kutch Basin.

Genus *Ampullinopsis* Conrad, 1865

Type species: *Natica mississippiensis* Conrad, 1848. Oligocene, Louisiana.

***Ampullinopsis crassatina* (Lamarck, 1804)**

Fig. 2e

* 1804 *Natica crassatina* Lamarck: 33, pl. 61 fig. 8
1922 *Ampullina* (*Megatylotus*) *crassatina* Lamarck.—Vredenburg: 36, pl. 27 fig. 27, pl. 28 fig. 5–6
1928 *Ampullina* (*Megatylotus*) *crassatina* (Lamarck).—Vredenburg: 400
2004 *Ampullinopsis crassatina* (Lamarck).—Harzhauser: 110, pl. 13 figs. 4–7, cum syn

Material: 1 specimen (silicone mould), NHMW 2008z0255/0002.
Measurements: diameter: > 86 mm (last whorl is missing).
Locality: Bermoti village, MF section.
Lithostratigraphy: Maniyara Fort Formation, Bermoti Member.
Age: Chattian.
Distribution: *Ampullinopsis crassatina* is a very widespread Oligocene species, known from the North Sea Basin, the Mainz Basin, France, Italy, Greece, Turkey, Hungary, Romania, Bulgaria, Armenia, Iran and Pakistan (Harzhauser 2004). Now, its easternmost occurrence is documented from the Kutch Basin where it is found as a rare element in the Chattian Bermoti Member. No South Indian occurrence is documented, probably due to the lack of Oligocene deposits. Further to the east it is replaced by the more elongate *Ampullinopsis birmanica* (Vredenburg 1922).

Genus *Pachycrommium* Woodring, 1928

Type species: *Amaura guppyi* Gabb, 1873. Miocene, Santo Domingo.

***Pachycrommium harrisi* (Pannekoek, 1936)**

Fig. 2g, h

? 1928 *Ampullospira* (*Euspirocrommium*) *oweni* d'Archiac & Haime.—Vredenburg: 400 [non *Phasianella Oweni* d'Archiac & Haime, 1853]
* 1936 *Ampullina* (*Ampullospira*) *harrisi* Pannekoek: 58, pl. 3 figs. 38–39
1948 *Pachycrommium harrisi* (Pannekoek).—Cox: 19, pl. 1 figs. 4a–b
? 1980 *Euspirocrommium* cf. *oweni* (Archiac & Haime).—Iqbal: 44, pl. 32 fig. 4
? 1989 *Pachycrommium harrisi* (Pannekoek).—Majima: 30, pl. 1 figs. 6–9 (non. text-fig. 16)
2007 *Pachycrommium harrisi* (Pannekoek).—Harzhauser: 87, pl. 6 fig. 6

Material: 5 specimens, NHMW 2008z0257/0003.
Measurements: height: 47 mm, diameter: 30 mm.
Locality: Vinjhan, Kankawati River (KW locality).
Lithostratigraphy: Chasra Formation.
Age: Burdigalian.
Remarks: This species is reminiscent of *Pachycrommium oweni* (d'Archiac & Haime, 1853) from the Eocene of Pakistan, which differs mainly in its less incised suture and the more convex spire whorls. *Pachycrommium oweni* is, however, a poorly defined species from Pakistan, based on two specimens, which obviously represent two different species (Oppenheim 1896, 1901). This species is unrecorded from post-Eocene sediments, and occurrences mentioned by Vredenburg (1928) and Harzhauser (2007) have to be rejected. European Eocene shells identified as *Pachycrommium oweni* have already been recognised by Vredenburg (1928) to be different from the Pakistani species. Biogeographic interpretations intermingling these different species are thus incorrect (e.g. Piccoli et al. 1991). *Pachycrommium martini* (Beets 1941) has a similar outline but differs from the Indian shell in its strongly canaliculate suture.
Distribution: *Pachycrommium harrisi* occurs during the Early Miocene in Oman, India and Java (Pannekoek 1936; Harzhauser 2007). A record of "*Phasianella oweni*" from the Early Miocene of Sri Lanka in Wayland and Davies (1923) might also refer to this species. During the Middle and Late Miocene it is reported from Borneo and Japan (Cox 1948; Majima 1989). Parts of the mentioned Japanese Middle Miocene records in Majima (1989), however, seem to represent a separate species, which is characterised by a shorter spire, canaliculate sutures and a large last whorl (Majima 1989: Text-fig. 16).

Family Campanilidae Douvillé, 1904
Genus *Campanile* Fischer, 1884

Type species: *Cerithium giganteum* Lamarck, 1804. Eocene, Paris Basin.

***Campanile pseudoobeliscus* (Grateloup, 1832)**

* 1832 *Cerithium pseudo-obeliscus* Grateloup: 282
1847 *Cerithium pseudo-obeliscus* Grateloup, pl. 17, fig. 12
2007 *Campanile pseudoobeliscus* (Grateloup).—Harzhauser: 88, pl. 2, figs. 5–7 (cum syn.)

Material: 1 specimen (field identification).
Measurements: height: >90 mm.
Locality: Bermoti village, MF section.
Lithostratigraphy: Maniyara Fort Formation, Bermoti Member.

Age: Chattian.

Remarks: The only specimen observed was destroyed in the field during preparation. A reliable identification, however, is warranted due to the highly characteristic morphology of that species.

Distribution: This is a Western Tethyan species, which is known from the Late Oligocene of France, Northern Italy, Bulgaria, Iran, Pakistan and the Kutch Basin. During the Aquitanian it occurs in France, Italy and the Iranian Esfahan-Sirjan Basin (Harzhauser 2007).

Order Sorbeoconcha Ponder & Lindberg, 1997
Superfamily Cerithioidea Fleming, 1822
Family Cerithiidae Fleming, 1822
Subfamily Cerithiinae Fleming, 1822

Genus *Cerithium* Bruguière, 1789

Type species: *Cerithium adansonii* Bruguière, 1792. Recent, Indo-Pacific.

***Cerithium rude* Sowerby, 1840**

Fig. 2j–l

* 1840 *Cerithium rude* Sowerby: explanation of plates (no page number), pl. 26 fig. 10
1978 *Cerithium* (*Ptychocerithium*) *rude* Sowerby.—Shuto: 147, pl. 17 figs. 11a–11b
2007 *Cerithium rude* Sowerby.—Harzhauser: 91, pl. 3 figs. 10–12 (cum syn.)

Material: 3 specimens, NHMW 2008z0257/0004.
Measurements: height: 48 mm, diameter: 15 mm.
Locality: Vinjhan, Kankawati River (KW locality).
Lithostratigraphy: Chasra Formation.
Age: Burdigalian.

Remarks: *Cerithium rude* was described in detail by Vredenburg (1928) and Harzhauser (2007).

Distribution: This cerithiid is one of the most widespread gastropods of the Proto-Indo-Polynesian Province. It appears already during the Chattian on the Arabian shelf (Harzhauser 2007) and becomes a common species during the Early Miocene, being documented from coastal Tanzania, Oman, Pakistan, northwestern India, southern India and Java (Vredenburg 1928; Pannekoek 1936; Dey 1961; Harzhauser 2007, 2009). From Borneo it is recorded also from Upper Miocene formations (Beets 1986).

***Cerithium* cf. *pseudocorrugatum* d'Orbigny, 1852**

Fig. 2m

1840 *Cerithium corrugatum* Sowerby: explanation of plates (no page number), pl. 26 fig. 11 [non *Cerithium corrugatum* Brongniart, 1823]
* 1852 *Cerithium pseudocorrugatum* d'Orbigny: 83
1928 *Cerithium* (*Ptychocerithium*) *pseudocorrugatum* d'Orbigny.—Vredenburg: 355
non 1853 *Cerithium pseudocorrugatum* var. a—d'Archiac & Haime: 299 (partim), pl. 28 fig. 6 [= *Cerithium rude* Sowerby, 1840]
non 1992 *Cerithium pseudocorrugatum* d'Orbigny.—Platel, et al.: 65 [= *Cerithium rude* Sowerby, 1840]

Material: 1 specimen, NHMW 2008z0257/0005.
Measurements: height: 43 mm, diameter: 14 mm.
Locality: Vinjhan, Kankawati River (KW locality).
Lithostratigraphy: Chasra Formation.
Age: Burdigalian.

Remarks: *Cerithium pseudocorrugatum* is a poorly defined species, which is documented so far only by the incomplete holotype. A second specimen, described by Vredenburg (1928), was lost. The new specimen from Vinjhan differs from Sowerby's type in the fewer axial ribs. These are more prominent and lack the rounded cross-section of the type specimen.

The Indian shell bears some similarities with *Cerithium markusreuteri* Harzhauser (2007) from the Oligocene of Oman. The separation of both species is warranted by the stout shape and two predominating spiral ribs of the Omanian species. *Cerithium haimei* Vredenburg, 1928 from the Oligocene of Pakistan develops wide-spaced axial ribs like the Indian species but has lower whorls and an adsutural cord.

Distribution: *Cerithium pseudocorrugatum* is documented only from the Early Miocene of the Kutch Basin.

***Cerithium bermotiense* Harzhauser nov. sp.**

Fig. 2i

Material: 4 specimens (casts in original sediment and the corresponding silicone moulds), NHMW 2008z0255/0010.

Holotype: Fig. 2i, NHMW 2008z0255/0010a, height: 47 mm, diameter: 17 mm (cast in sediment and silicone mould).

Paratype: NHMW 2008z0255/0010b, height: 54 mm, diameter: 20 mm.

Stratum typicum: marly limestones of the Maniyara Fort Formation, Bermoti Member.

Type locality: Bermoti River, MF section.

Age: Chattian.

Name: referring to the type locality.

Description: Stocky cerithiid consisting of 11 low and convex teleoconch whorls with narrow and indistinct sutures. The first 7–8 whorls bear blunt, opisthocyrt axial ribs, separated by narrow interspaces (the exact number cannot be given due to the preservation). Numerous spiral threads cross the axial ribs. These become differentiated

into primary spiral threads and only slightly weaker secondary ones on later whorls. One of the primaries coincides with a slight angulation in the adapical part of the whorl and separates a narrow subsutural ramp with 3–4 secondary threads. The axial sculpture becomes strongly reduced on the last 4–5 teleoconch whorls and consists mainly of the upper tips of the axial ribs covering the narrow ramp. Similarly, the spiral threads become reduced in the middle part of the whorls on late spire whorls. On the last whorl and on the base, the spiral threads tend to form pairs, which are separated by somewhat deeper spiral grooves. Each whorl bears one varix; on spire whorls the varices are only developed in the adapical half of the whorls and reach across the suture up to the preceding whorl. On the last whorl the varix is most prominent, broad, and reaches down to the base. The aperture is probably ovate but was largely destroyed in all specimens. Columella are concave with a thick callus and well-defined inner lip that becomes detached from the base.

Remarks: There is no other species that unites this set of characters. A superficial similarity may be stated for *Cerithium sindiense* Vredenburg, 1928 from the Oligocene of Pakistan. Similarities are the predominating spiral sculpture, the tendency to reduce the axial ribs close below the suture and the development of a subsutural ramp. Differences, however, are the weaker convexity of the whorls, the spiny nodes along the shoulder and the sculpture of the base, bearing three strong axial ribs in *Cerithium sindiense*. *Cerithium subnudum* (d'Archiac and Haime 1853) from the Eocene or Oligocene of Pakistan bears similarities concerning the opisthocyrt axial ribs on early whorls and the tendency to reduce these to an adapical rest on later whorls, but is very slender and develops flat whorls.

Distribution: Only known from the Oligocene of the Kutch Basin.

Family Turritellidae Lovén, 1847
Subfamily Turritellinae Lovén, 1847
Genus *Turritella* Lamarck, 1799

Type species: *Turbo terebra* Linnaeus, 1758. Recent, Indo-Pacific.

***Turritella assimilis* Sowerby,** 1840

Fig. 3j–n

* 1840 *Turritella assimilis* Sowerby: explanation of plates (no page number), pl. 26 fig. 8
1928 *Turritella assimilis* Sowerby.—Vredenburg: 377 (partim)

Material: 8 specimens, NHMW 2008z0257/0006.

Measurements: largest fragment: height: 25 mm, diameter: 8 mm.

Locality: Vinjhan, Kankawati River (KW locality).

Lithostratigraphy: Chasra Formation.

Age: Burdigalian.

Re-description: Small- to moderate-sized shells; early teleoconch whorls bear three prominent primary ribs of nearly equal strength, separated by concave interspaces. The whorls are flat in profile but separated by deep sutures causing a distinct constriction of the whorls. Soon, a weak secondary rib appears close to the lower suture. This rib attains nearly the dimension of the primary ribs within the first 4–5 teleoconch whorls. Later, another secondary rib appears close to the lower suture and a third one appears close to the first primary rib along the adapical suture. A faint spiral thread may occur between each pair of the primary and secondary ribs on late teleoconch whorls, which are now slightly convex.

Remarks: Although Vredenburg (1928) treats *Zaria javana* (Martin, 1883) as a synonym of *Turritella affinis*, it differs considerably from the Indian species by its size and angulated whorls. The Pliocene records of *Turritella affinis* mentioned by Vredenburg (1928) should thus be excluded. Similarly, *Turritella affinis* is definitely no synonym of *Zaria angulata* (Sowerby, 1840) as suggested by d'Archiac and Haime (1854). Specimens of the latter species from Vinjhan (in the same size category as *T. affinis*) differ in their obtuse spire angle and the prominent angulation.

Distribution: This species is known only from the Burdigalian of the Kutch Basin.

***Turritella kachhensis* Vredenburg,** 1928

Figs. 3g–i, 5l

* 1928 *Turritella heberti kachhensis* Vredenburg: 381

Material: 3 specimens, 2008z0257/0007.

Measurements: fragment: height: 12 mm, diameter: 4 mm.

Locality: Vinjhan, Kankawati River (KW locality).

Lithostratigraphy: Chasra Formation.

Age: Burdigalian.

Re-description: Very small and slender shells: the whorls are separated by channel-like grooves formed by a concave sutural ramp, which passes via the incised suture into the concave anterior-most part of the preceding whorl. The whorls display two raised spiral ribs accentuating the deep sutural channel. Between these adsutural ribs, the whorls are concave and bear two weak secondary ribs with faint tertiary intercalations. The two primary ribs are duplicated. In both cases, the rib closer to the suture is slightly less prominent.

Remarks: Vredenburg (1928) introduced this taxon as a subspecies of *Turritella heberti* d'Archiac & Haime, 1853, which was originally described from Pakistan. Vredenburg (1928) reports an Early Miocene age for the Pakistani

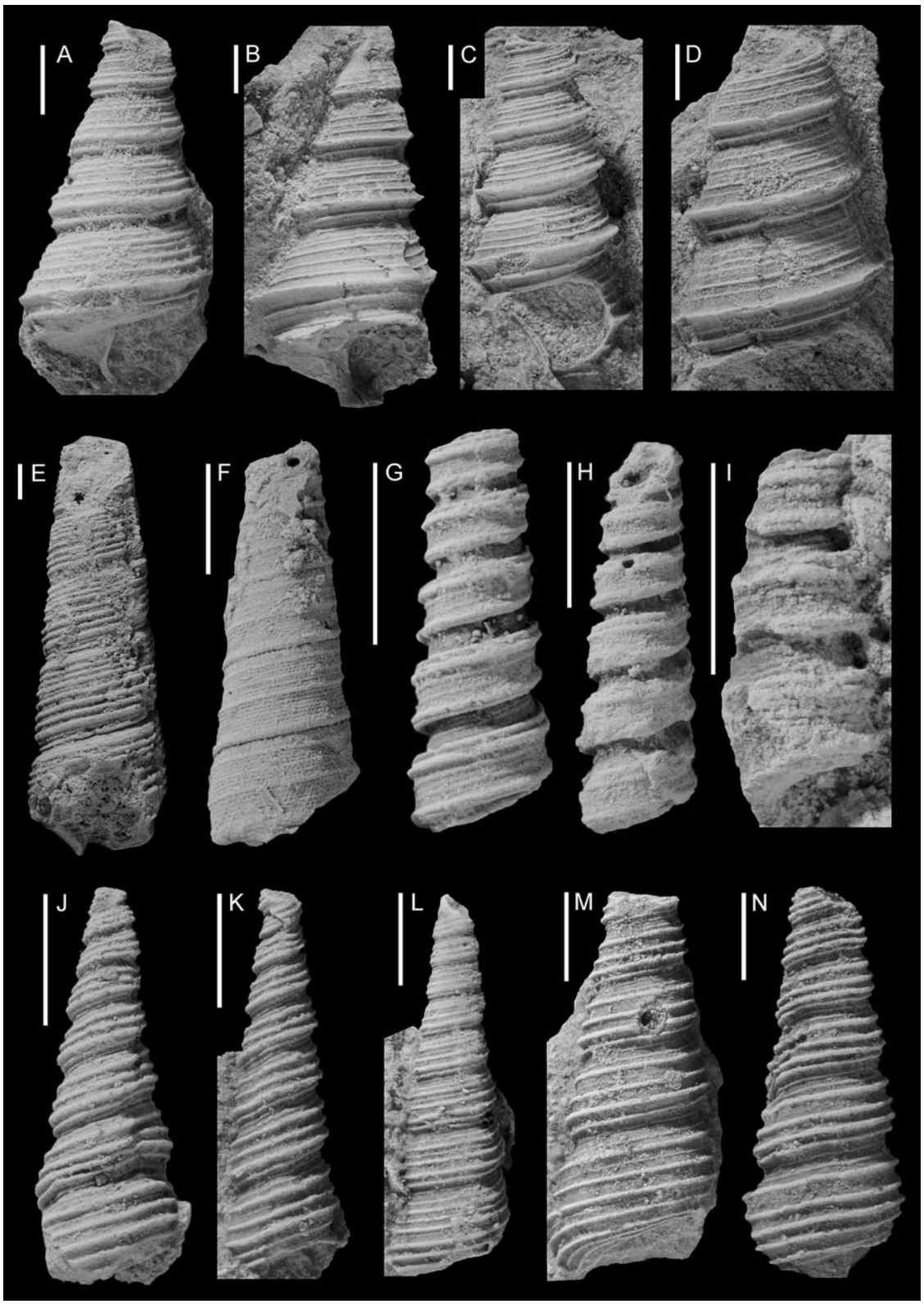


Fig. 3 Turritellids of the Kutch Basin. **a–d** *Zaria angulata* (Sowerby, 1840), NHMW 2008z0256/0002, Khari Nadi River. **e** *Protoma deshayesi* (d'Archiac, 1850), NHMW 2008z0256/0001, Khari Nadi River. **f** *Haustator tauroperturritus* Sacco, 1895, NHMW 2008z0257/0008, Vinjhan. **g–i** *Turritella kachhensis* Vredenburg, 1928, 2008z0257/0007, Vinjhan. **j–n** *Turritella assimilis* Sowerby, 1840, NHMW 2008z0257/0006, Vinjhan. Scale bar = 5 mm

species, which is not fully clear from the original description in d'Archiac & Haime (1853), and which may also be of Eocene age. In any case, the Pakistani species, although similar in size and shape, differs considerably from *Turritella kachhensis* in its sculpture. *T. heberti* lacks the duplicate primary rib along the posterior suture, and the anterior primary rib has a higher position. Moreover, the concave middle part of the shell develops a prominent secondary spiral rib, and the groove separating the whorls is indistinct because the primary ribs are less elevated. In contrast, the description of Vredenburg (1928), referring to Early Miocene specimens from the Kutch Basin, agrees fully with the shells from Vinjhan.

The specimens described by Beets (1983, 1986) from the Late Miocene of Borneo as *Turritella heberti* are not identical with *Turritella heberti* d'Archiac & Haime, 1853, and are also different from *T. kachhensis*. Differences are the larger size, the distinctly less slender outline and the completely different sculpture consisting of two adsutural spiral swellings, separated by a much broader and weakly ornamented middle part of the whorl.

Distribution: *Turritella kachhensis* is known only from the Early Miocene of the Kutch Basin. A further occurrence may be documented from the Early Miocene of the Garo Hills in northeast India (= *Turritella heberti garoensis* Mukerjee, 1939).

Genus *Haustator* Montfort, 1810

Type species: *Haustator gallicus* Montfort, 1810 (= *Turritella imbricataria* Lamarck, 1804). Eocene, Paris Basin.

***Haustator tauroperturritus* Sacco,** 1895

Fig. 3f

* 1895 *Haustator tauroperturritus* Sacco: 20, pl. 2 fig. 8
1904 *Haustator tauroperturritus* Sacco.—Sacco: 125, pl. 25 figs. 22–23
1984 *Haustator tauroperturritus* Sacco.—Ferrero Mortara et al.: 232, pl. 41 figs. 5a–b

Material: 3 specimens, NHMW 2008z0257/0008.
Measurements: fragment: height: 17 mm, diameter: 6 mm.
Locality: Vinjhan, Kankawati River (KW locality).
Lithostratigraphy: Chasra Formation.
Age: Burdigalian.
Re-description: Small and slender shells with an apical angle of 12°, flat whorls and weak sutures. The sculpture consists of a single, slightly granulated primary rib close to the lower suture and a weaker, also faintly granulated secondary rib in the middle of the whorls. Two tertiary ribs appear in the adapical part above the median rib, separated by 2–3 faint spiral threads. In the lower part of the whorl (between the median rib and the adsutural primary rib) an additional 5 spiral threads occur. The interspaces between the spiral ribs and threads display tiny pits.

Remarks: There are no resembling species described from the Miocene of the Proto-Indo-Pacific. *Haustator sedanensis* (Martin, 1905) from the Early Miocene of Indonesia is superficially similar, but lacks the median rib and develops 5 spiral ribs of equal strength. The Late Miocene to Pliocene Indonesian *Haustator subulata* (Martin, 1884) lacks the raised spiral rib along the lower suture, and its spirals lack the granulation.

Distribution: Shape and ornamentation of these specimens agree with the single available specimen of *Haustator tauroperturritus* Sacco, 1895, from the Burdigalian of Italy. Nevertheless, it is surprising that a Burdigalian Western Tethyan element occurs in coeval deposits of the Kutch Basin. Thus, the possibility remains that the Indian shells are not conspecific with *H. tauroperturritus*, but represent a striking example of parallel evolution. A geographically connecting occurrence, however, is recorded from the Burdigalian part of the Qom Formation in Iran (Harzhauser et al. 2002). These Iranian specimens correspond fully to the Indian ones and document the occurrence of that species west and east of the Burdigalian *Gomphotherium* landbridge (Rögl 1998; Harzhauser et al. 2007).

Genus *Zaria* Gray, 1847

Type species: *Turbo duplicatus* Linnaeus, 1758. Recent, Indo-Pacific.

***Zaria angulata* (Sowerby,** 1840)

Fig. 3a–d

* 1840 *Turritella angulata* Sowerby: explanation of plates (no page number), pl. 26 fig. 7
1853 *Turritella angulata* Sowerby.—d'Archiac & Haime: 294, pl. 27 figs. 6–9
1928 *Turritella angulata* Sowerby.—Vredenburg: 378
non 1909 *Turritella angulata* Sowerby.—Cossmann & Pissarro: 59, pl. 6, figs. 3–5 [= *Turritella ranikoti* Vredenburg, 1920]

Material: 10 specimens, NHMW 2008z0256/0002.
Measurements: maximum diameter: 12 mm.
Locality: Khari Nadi River (KN locality).
Lithostratigraphy: Khari Nadi Formation.
Age: Aquitanian.
Material: 12 specimens, NHMW 2008z0257/0009.
Measurements: maximum diameter: 24 mm.
Locality: Vinjhan, Kankawati River (KW locality), Chasra Formation.
Age: Burdigalian.

Remarks: The species is frequently reported from the Late Miocene to Pliocene of Iran, Burma and Indonesia (e.g. Cox 1936; Noetling 1901; Shuto 1974). These younger representatives are also treated as subspecies [e.g. *Zaria angulata djadjariensis* (Martin, 1905) in Hoek Ostende et al. (2002)]. In contrast, Shuto (1974) separates *Zaria acuticarinata* (Dunker, 1847), *Z. martini* (Cossmann, 1913) and *Z. djadjariensis* (Martin, 1905) from *Z. angulata* based on the growth lines. This feature is not preserved in the material from the Kutch Basin, and therefore we refrain from uniting the species group based solely on similarities in sculpture. Moreover, Indonesian Late Miocene shells in the collection of the NHM differ from the Indian shells in their convex early teleoconch whorls and the larger size. A separation at least on the subspecies level might thus be justified. Eocene occurrences are clear misidentifications (Vredenburg 1920).

Distribution: The typical *Zaria angulata* (Sowerby, 1840) is documented from the Aquitanian and Burdigalian of the Kutch Basin and the Sindh region in Pakistan. The westernmost occurrence is known from the Aquitanian of the Qom Basin (Harzhauser et al. 2002). The closely related *Zaria djadjariensis* species complex is ubiquitous in the Late Miocene and Pliocene of Iran, Pakistan, Burma and Indonesia.

Subfamily Protominae Marwick, 1957

Genus *Protoma* Baird, 1870

Type species: *Turritella cathedralis* Brongniart, 1823. Early Miocene, Italy.

***Protoma deshayesi* (d'Archiac,** 1850**)**

Fig. 3e

* 1850 *Turritella Deshayesi* d'Archiac: 285
1853 *Turritella Deshayesi* d'Archiac.—d'Archiac & Haime: 295, pl. 27 figs. 16–19
1928 *Protoma deshayesi* d'Archiac.—Vredenburg: 386 (partim)

Material: 1 specimen, NHMW 2008z0256/0001.
Measurements: fragment: height: 58 mm, diameter: 20 mm.
Locality: Khari Nadi River (KN locality).
Lithostratigraphy: Khari Nadi Formation.
Age: Aquitanian.
Remarks: A highly characteristic shell with flat whorls, poorly incised sutures, and 10–11 prominent spiral ribs separated by deep grooves. Prosocline axial threads cross the spiral ribs and form delicate axial bridges between the spiral ribs.

Protoma deshayesi belongs to a species group that is represented in the Oligocene of Pakistan by *Protoma renevieri* (d'Archiac & Haime, 1853) and *Protoma subrenevieri* Vredenburg, 1928. Both may be distinguished from *P. deshayesi* by the absence of any axial sculpture. *P. renevieri* develops very regular spiral ribs, whereas *P. deshayesi* displays some variability of the strength of the ribs. *P. subrenevieri* has higher whorls with more than 10 ribs.

Distribution: *Protoma deshayesi* was described so far only from the Oligocene of Pakistan and is now recorded also from the Aquitanian of the Kutch Basin.

Family Siliquariidae Anton, 1838

Genus *Tenagodus* Guettard, 1770

Type species: *Serpula anguina* Linnaeus, 1758. Recent, Indo-Pacific.

***Tenagodus granti* (Sowerby,** 1840**)**

Fig. 2n

* 1840 *Siliquaria Grantii* Sowerby: explanation of plates (no page number), pl. 25 fig. 2
1853 *Siliquaria Granti* Sowerby.—d'Archiac & Haime: 285, pl. 26 figs. 6–7
1928 *Siliquaria granti* Sowerby.—Vredenburg: 391
? 1961 *Siliquaria granti* Sowerby.—Dey: 60

Material: 1 specimen, NHMW 2008z0255/0003.
Measurements: height: 37 mm, diameter: 18 mm.
Locality: Bermoti River, MF section.
Lithostratigraphy: Maniyara Fort Formation, Bermoti Member.
Age: Chattian.
Remarks: The generally small size and small diameter of the whorls of *Tenagodus granti* and its slit, which is formed of a series of pores, characterises this species. These features distinguish it from the Oligocene to Miocene *Tenagodus terbellus* (Lamarck, 1818) from Europe and from *Tenagodus obtusiformis* Martin, 1905 from the Early Miocene of Indonesia. The generic affiliation (*Tenagodus* versus *Siliquaria*) follows Bieler (2004).

Distribution: *Tenagodus granti* is recorded from the Rupelian of Pakistan (Eames, 1950) and the Chattian of the Kutch Basin (this study). It is unclear from the original description if the type specimen described by Sowerby (1840) also derives from Oligocene deposits or from Lower Miocene ones as suggested by Eames (1950). The youngest record is mentioned by Dey (1961) from the Early Miocene of Qulion (South India). An illustration and description are missing, and therefore this identification is doubtful.

Suborder Hypsogastropoda Ponder & Lindberg, 1997
Infraordo Littorinimorpha Golikov & Starobogatov, 1975
Superfamily Naticoidea Guilding, 1834
Family Naticidae Guilding, 1834
Genus *Natica* Scopoli, 1777

Type species: *Natica vitellus* Linnaeus, 1758. Recent, western Pacific.

***Natica obscura* Sowerby, 1840**

Fig. 2q, r

* 1840 *Natica obscura* Sowerby: explanation of plates (no page number), pl. 26 fig. 2
1928 *Natica obscura* Sowerby.—Vredenburg: 397
non 1895 *Natica obscura* Sowerby.—Noetling: 22, pl. 5 figs. 6–7
non 1901 *Natica obscura* Sowerby.—Noetling: 284, pl. 19 figs. 2–3

Material: 3 specimens, NHMW 2008z0257/0014.
Measurements: diameter: 29 mm, height: 31 mm.
Locality: Vinjhan, Kankawati River (KW locality).
Lithostratigraphy: Chasra Formation.
Age: Burdigalian.

Remarks: The available material does not allow to settle the generic affiliation clearly. Nevertheless, this species seems to be closely related with the Miocene to Recent *Natica vitellus* Linnaeus, 1758. Fossil specimens of *Natica vitellus*, as described from Indonesia (Martin, 1905) and Japan (Majima, 1989), lack the sutural ramp and the stepped spire of *Natica obscura*. Another difference between both species is the clear separation between the funicle and the anterior lobe of the parietal callus in *N. obscura*. Similarities are the deeply incised suture, the umbilical features and the axial sculpture in the adapical part of the whorls. Specimens from the Miocene of Burma, referred to as *Natica obscura* by Noetling (1895, 1901), have little in common with the Indian species and differ e.g. by the elongate shape.

Distribution: This naticid is recorded only from the Burdigalian of the Kutch Basin.

Superfamily Stromboidea Rafinesque, 1815

Family Strombidae Rafinesque, 1815
Subfamily Rostellariinae Gabb, 1868

Genus *Varicospira* Eames, 1952

Type species: *Strombus cancellatus* Lamarck, 1822. Recent, Indo-Pacific.

***Varicospira subrimosa* (d'Orbigny, 1852)**

Fig. 2o, p

1840 *Rostellaria rimosa* Sowerby: explanation of plates (no page number), pl. 26 fig. 17 [non *Rostellaria rimosa* Solander in Brander, 1766]
* 1852 *Rostellaria subrimosa* d'Orbigny: 59
1925 *Rimella subrimosa* d'Orbigny.—Vredenburg, 320: pl. 6 figs. 7–10
1939 *Rimella subrimosa* d'Orbigny.—Mukerjee: 49, pl. 3 figs. 21–22
1961 *Dientomochilus* (*Varicospira*) *subrimosa* (d'Orbigny).—Dey: 67

Material: 6 specimens, 2008z0257/0012.
Measurements: height: 21 mm, diameter: 11 mm.
Locality: Vinjhan, Kankawati River (KW locality).
Lithostratigraphy: Chasra Formation.
Age: Burdigalian.

Remarks: The Oligocene shell from Iran, referred to as *Rimella subrimosa* by Harzhauser (2004), is too fragmentary to allow a clear identification and should rather be affiliated with the Oligocene *Varicospira narica* (Vredenburg, 1925). *Varicospira zuschini* Harzhauser, 2007 from the Oligocene of Oman is clearly distinguished from *V. subrimosa* by its globular last whorl, the larger size and the reduced axial ribs of the last whorl. *Varicospira mordax* (Martin, 1916) is similar in size and sculpture, but develops a broad inner lip.

Distribution: *Varicospira subrimosa* (d'Orbigny, 1852) is documented from the Burdigalian of the Kutch Basin, the Early Miocene of the Garo Hills in Assam (Mukerjee, 1939) and the Burdigalian of Kerala in South India (Dey, 1961).

Subfamily Strombinae Rafinesque, 1815

Genus *Dilatilabrum* Cossmann, 1904

Type species: *Strombus fortisii* Brongniart, 1823. Eocene, Italy.

***Dilatilabrum sublatissimum* (d'Orbigny, 1852)**

1847 *Strombus latissimus* Grateloup: suppl. pl. 1 fig. 3 (non *Strombus latissimus* Linnaeus, 1758)
* 1852 *Strombus sublatissimus* d'Orbigny: 11, nr. 177
2004 *Strombus* (*Tricornis*) *sublatissimus* d'Orbigny.—Harzhauser: 129, pl. 11 figs. 3–4, pl. 12 figs. 1–2
2007 *Dilatilabrum sublatissimus* (d'Orbigny).—Harzhauser: 101, pl. 4 figs. 12 a–b

Material: 1 specimen (field identification).
Measurements: diameter with wing: 180 mm.
Locality: Bermoti River, MF section.
Lithostratigraphy: Maniyara Fort Formation, Bermoti Member.
Age: Chattian.

Remarks: This highly characteristic giant strombid was unknown so far from India, but might have been misidentified by mapping geologists as "giant *Conus*" (e.g. Biswas, 1992).

Distribution: During the Oligocene it is distributed from France (Adour Basin) via Malta, Greece, Iran and the Kutch Basin. During the Aquitanian it is only reported from Iran and Oman (Harzhauser 2007). It represents a typical Western Tethys element that did not reach the Indonesian area.

Genus *Persististrombus* Kronenberg & Lee, 2007

Type species: *Strombus granulatus* Swainson, 1822. Recent, Western Atlantic.

Persististrombus depertitus (Sowerby, 1840)

Fig. 4f

* 1840 *Strombus depertitus* Sowerby: explanation of plates (no page number), pl. 26 fig. 19
1840 *Strombus nodosus* Sowerby: explanation of plates, pl. 26 fig. 20 [non *Strombus nodosus* Borson, 1820]
1853 *Strombus depertitus* Sowerby.—d'Archiac & Haime: 316, pl. 30 fig. 19
1853 *Strombus nodosus* Sowerby.—d'Archiac & Haime: 316, pl. 30 figs. 18, 20–21
1893 *Strombus exnodosus* Sacco: 5
1904 *Strombus sowerbyi* Cossmann: 7
1925 *Strombus* (*Gallinula*) *columba* Lamarck.—Vredenburg: 317 [non *Strombus columba* Lamarck, 1822]
1960 *Strombus depertitus* Sowerby.—Abbott: 92

Material: 6 specimens, NHMW 2008z0257/0013.

Measurements: diameter of largest fragment with wing: 25 mm.

Locality: Vinjhan, Kankawati River (KW locality).

Lithostratigraphy: Chasra Formation.

Age: Burdigalian.

Remarks: Vredenburg (1925) and Abbott (1960) discussed a close affinity with the extant *Dolomena plicatus columba* (Lamarck, 1822), which would require a placement within the genus *Dolomena* Wenz, 1940. This affiliation has to be rejected based on the absence of a posterior canal. The moderate size, fusiform shape and the distinct shoulder nodes on the last whorl point rather to a placement within *Persististrombus* Kronenberg & Lee, 2007. This placement is also supported by the spire sculpture of *P. depertitus*, which is highly reminiscent of that of the extant *Persististrombus granulatus* (which is the type species of the genus) as well as of that of Oligocene and Miocene representatives such as *P. radix* (Brongniart, 1823), *P. bonellii* (Brongniart, 1823) and *P. exbonellii* (Sacco, 1893) from the Western Tethys and the Paratethys.

A second lineage—characterised by a prominent sculpture—is represented by *Persististrombus bernielandaui* (Harzhauser, 2007) from the Oligocene of Oman, *P. gijskronenbergi* (Harzhauser, 2007) from the Aquitanian of Oman, *P. quilonensis* (Dey, 1961) from the Early or Middle Miocene of South India and *P. preoccupatus* (Finlay, 1927) from the Late Miocene of Borneo. Another closely related species is *P. kronenbergi* Harzhauser, 2009, from the Aquitanian of Tanzania, which has a broader last whorl and convex spire whorls, which lack the spiral sculpture and the nodes of *P. depertitus*.

Distribution: *Persististrombus depertitus* (Sowerby, 1840) is recorded from the Early Miocene of Pakistan and the Kutch Basin.

Persististrombus radix (Brongniart, 1823)

Fig. 4a–e

* 1823 *Pterocera radix* Brongniart: 74, pl. 4 fig. 9
1870 *Strombus radix* (Brongniart).—Fuchs: 149, pl. 4 fig. 3
1870 *Strombus vialensis* Fuchs: 172, pl. 4 figs. 4–5
1870 *Strombus rugifer* Fuchs: 173, pl. 3 fig. 26
1893 *Strombus radix* (Brongniart).—Sacco: 3, pl. 1 fig. 1
1893 *Strombus radix* var. *rugifera* Fuchs.—Sacco: 4
1893 *Strombus radix* var. *perrugifera* Sacco: 4, pl. 1 fig. 2
1893 *Strombus radix* var. *subnodosa* Sacco: 4, pl. 1 fig. 3
1904 *Strombus* (*Canarium*) *radix* var. *vialensis* Fuchs.—Sacco: 114, pl. 24 fig. 58
1964 *Canarium* (*Canarium*) *radix* (Brongniart).—Karagiuleva: 170, pl. 46 figs. 1–2
1969 *Strombus radix* (Brongniart).—Beneventi & Piccoli: 7, pl. 1 figs. 8–9
2004 *Strombus* (*Lentigo*) *radix* (Brongniart).—Harzhauser: 128, pl. 9 figs. 8–11

Material: 9 specimens (silicone moulds), NHMW 2008z0255/0004.

Measurements: height: 56 mm, diameter: 34 mm.

Locality: Bermoti River, MF section.

Lithostratigraphy: Maniyara Fort Formation, Bermoti Member.

Age: Chattian.

Re-description: A strongly sculptured and robust shell with coarse spiral cords covering the entire shell surface except for the shoulder area and the blunt nodes, where the axial ornament is reduced. The inner surface of the outer lip bears numerous plicae, which fade out towards the smooth, sharp rim of the outer lip. The plicae grade into irregular granulae behind and below the deeply incised notch. The inner lip is well defined and clearly demarcated. Its plicae correspond to the axial threads of the base in its middle part, but become oblique and granulated in the adapical part of the aperture. The adapical part of the

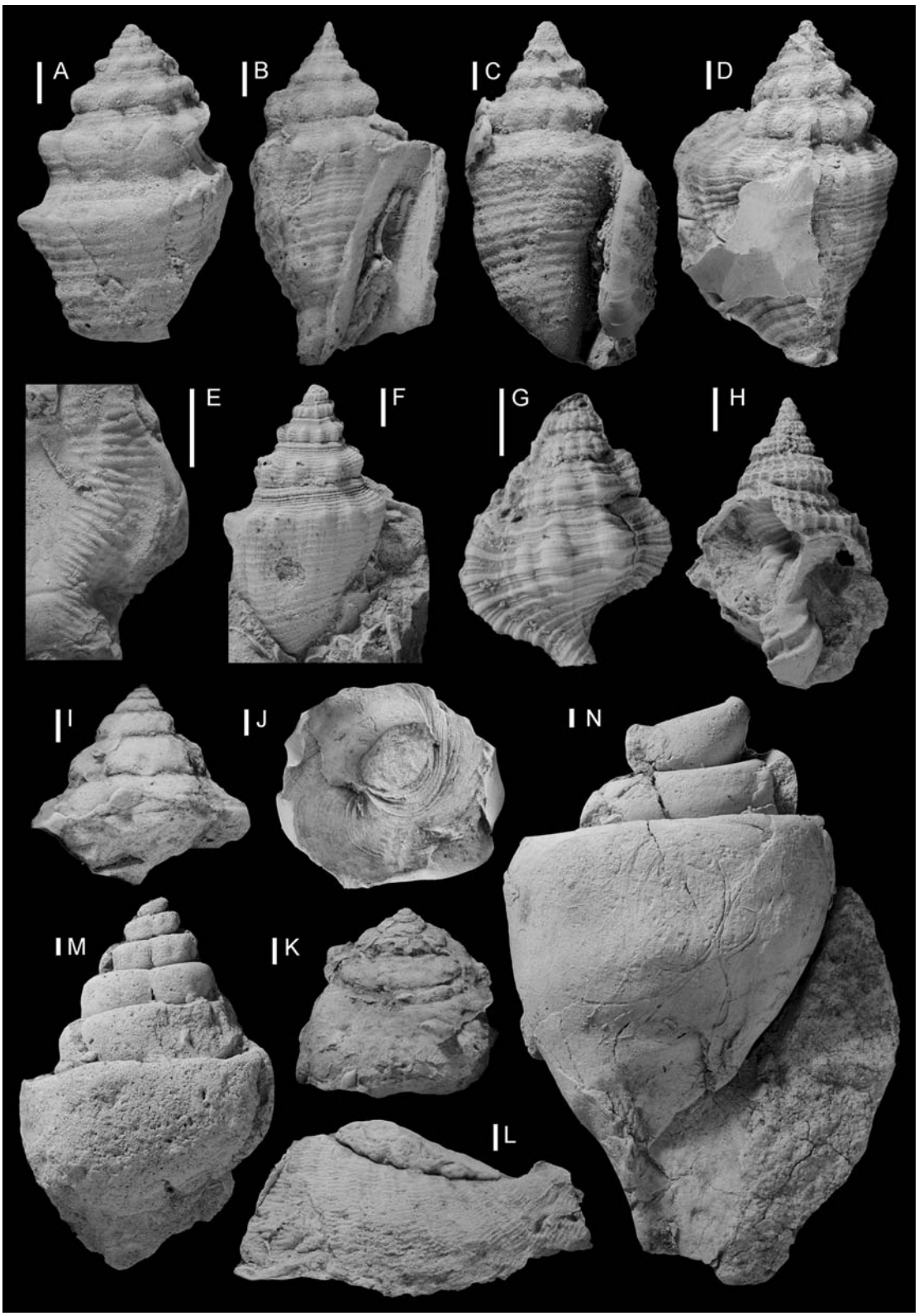


Fig. 4 Gastropods of the Kutch Basin. **a–e** *Persististrombus radix* (Brongniart, 1823), NHMW 2008z0255/0004, Bermoti. **f** *Persististrombus depertitus* (Sowerby, 1840), NHMW 2008z0257/0013. Vinjhan. **g** *Gyrineum bituberculare* (Lamarck, 1816), NHMW 2008z0257/0016, Vinjhan. **h** *Distorsio decipiens* (Reeve, 1844), NHMW 2008z0257/0015, Vinjhan. **i**, **j** *Xenophora* nov. sp., NHMW 2008z0255/0005, Bermoti. **k**, **l** *Stellaria* cf. *oligostriata* (Sacco, 1896), NHMW 2008z0255/0006, Bermoti. **m**, **n** *Clavellofusus* nov. sp., NHMW 2008z0255/0007, Bermoti. Scale bar = 5 mm

moderately expanding wing reaches up to the shoulder nodes of the preceding whorl; its tip may reach up to the suture. A very weak posterior canal groove may be present.

Remarks: Most shells represent a high-spired morphotype and correspond fully to the typical *P. radix*. Rarely, specimens with a depressed spire occur as well. These specimens represent morphotypes that were introduced as *Strombus vialensis* by Fuchs (1870). *Persististrombus depertitus* (Sowerby, 1840) might represent a close descendant of *P. radix*. Differences are the smaller size and the reduced spiral sculpture of *P. depertitus*. Spire fragments of both species from the Kutch Basin are difficult to distinguish.

The extremely elongate and high-spired Oligocene strombids from France (e.g.: Lozouet and Maestrati 1986: 12, figs. 1, E–G, H–I) might represent a distinct subspecies or species, which was not found in the Italian, Greek, Bulgarian, Iranian or Indian localities from where *P. radix* was described.

Distribution: *Persististrombus radix* is a very widespread Oligocene species, which is known from the Adour Basin in France in the west via the Western Tethys as far east as the Kutch Basin.

Superfamily Tonnoidea Suter, 1913
Family Personidae Gray, 1854

Genus *Distorsio* Röding, 1798

Type species: *Murex anus* Linnaeus, 1758. Recent, Indo-Pacific.

Distorsio decipiens (Reeve, 1844)

Fig. 4h

* 1844 *Triton decipiens* Reeve: pl. 20 fig. 102
1925 *Persona reticulata* var. *subclathrata* Vredenburg, p. 234 (pars)
? 1961 *Distorsio cancellinus* (Roissy).—Dey: 74
1969 *Distorsio* (*Distorsio*) *reticulatus decipiens* (Reeve).—Shuto: 89, pl. 7 figs. 7, 9
1994 *Distorsio decipiens* (Reeve).—Kronenberg: 72, pl. 3 fig. 3, Text-fig. 11
2005 *Distorsio decipiens* (Reeve).—Dharma: 358, pl. 144, figs. 2a–b
2005 *Distorsio decipiens* (Reeve).—Beu: 55, figs. 137–142 (cum syn.)

Material: 2 specimens, NHMW 2008z0257/0015.
Measurements: fragment: diameter: 20 mm; height: 31 mm.
Locality: Vinjhan, Kankawati River (KW locality).
Lithostratigraphy: Chasra Formation.

Fig. 5 Gastropods of the Kutch Basin. **a** *Turbinella affinis* (Sowerby, 1840), NHMW 2008z0257/0020, Vinjhan. **b**, **c** *Turbinella premekranica* Vredenburg, 1925, NHMW 2008z0256/0003, Khari Nadi River. **d**, **e** *Athleta* (*Volutospina*) *dentata* (Sowerby, 1840), NHMW 2008z0257/0022, Vinjhan. **f**, **g** *Lyria* (*Indolyria*) *maniyaraensis* Harzhauser nov. sp., silicone mould of the holotype, NHMW 2008z0255/0008, Bermoti. **h** *Lyria* (*Harpeola*) *jugosa* (Sowerby, 1840), NHMW 2008z0257/0021, Vinjhan. **I** *Hemipolygona* nov. sp., NHMW 2008z0257/0018, Vinjhan. **k** *Agaronia pupa* (Sowerby, 1840), NHMW 2008z0257/0023, Vinjhan. **l** *Agaronia pupa* (Sowerby, 1840) with *Turritella kachhensis* Vredenburg, 1928, NHMW 2008z0257/0023, Vinjhan. **m** *Pugilina eulactea* (Dey, 1961), NHMW 2008z0257/0019, Vinjhan. **n**, **o** *Architectonica affinis* (Sowerby, 1840), Vinjhan. **j** *Conus* (*Lithoconus*) *brevis* Sowerby, 1840, NHMW 2008z0257/0024, Vinjhan. **p** *Gemmula gajensis* Vredenburg, 1925, NHMW 2008z0257/0025, Vinjhan. **q** *Turricula spuria* (Hedley, 1922), 2008z0257/0026, Vinjhan. Scale bar = 5 mm ▶

Age: Burdigalian.

Remarks: This species was frequently confused with *Distorsio cancellina* (Lamarck, 1803) (= *Triton subclathratum* d'Orbigny, 1852), which was redefined by Landau et al. (2004) as a Miocene to Pliocene species, restricted to the Mediterranean Sea, the eastern Atlantic and the North Sea. The small size of the shells and the prominent spiral and axial sculpture separate the Indian specimens also from the Pliocene to Recent *Distorsio reticularis* (Linnaeus, 1758). Other features mentioned by Beu (2005) as criteria for a separation of these species, such as the aperture and the color, cannot be investigated in the Indian shells. Oligocene occurrences from Pakistan and India (Vredenburg 1925) represent a separate but still unnamed species, which seems to be closer related with *Distorsio cancellina* (see Landau et al. 2004; Harzhauser 2007).

Distribution: *Distorsio decipiens* appears during the Burdigalian (Kutch Basin, Sindh) and is probably also recorded from the Burdigalian of south India (Dey 1961). During the Middle and Late Miocene, it is frequently documented from Indonesia and the Philippines (Dharma 2005; Shuto 1969) and becomes an ubiquitous Indo-West Pacific species during the Pliocene and Pleistocene (Kronenberg 1994; Beu 2005).

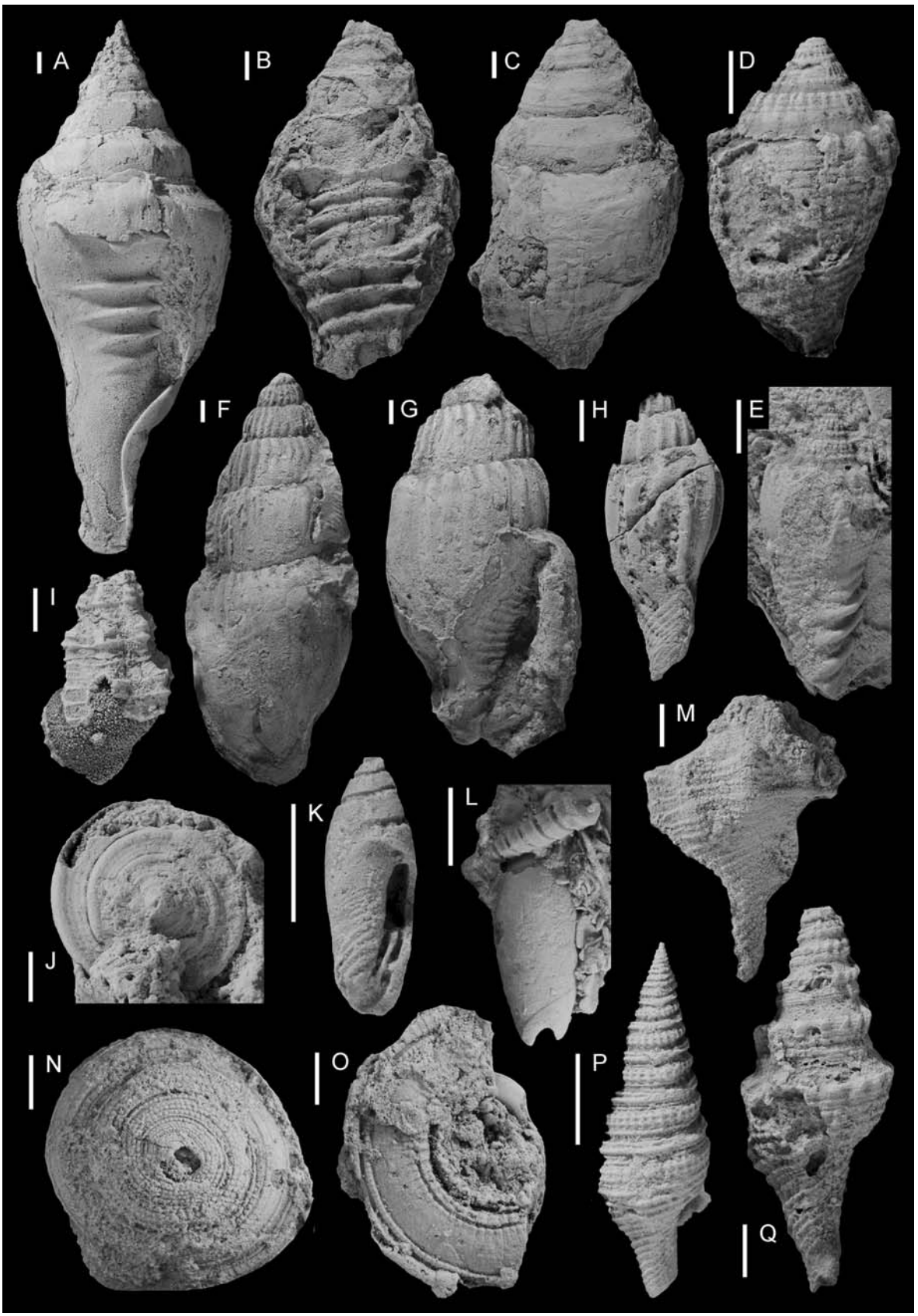
Family Ranellidae Gray, 1854
Subfamily Ranellinae Gray, 1854
Genus *Gyrineum* Link, 1807

Type species: *Gyrineum verrucosum* Link, 1807. Recent, Indo-West Pacific.

Gyrineum bituberculare (Lamarck, 1816)

Fig. 4g

* 1816 *Ranella bitubercularis* Lamarck: 412, fig. 6
1840 *Ranella Bufo* Sowerby: explanation of plates (no page number), pl. 26 fig. 16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1925 *Ranella bitubercularis* Lamarck.—Vredenburg: 255
1925 *Ranella* (*Biplex*) *bufo* Sowerby.—Vredenburg: 255 (pars)
1939 *Gyrineum bituberculatum* (Lamarck).—Mukerjee: 54
1961 *Argobuccinum* (*Biplex*) *bufo* (Sowerby).—Dey: 75, pl. 5 figs. 7, 12
2005 *Gyrineum bituberculare* (Lamarck).—Beu: 64, figs. 164–167 (cum syn.)
2005 *Gyrineum bituberculare* (Lamarck).—Dharma: 354, pl. 142 figs. 12a–c

Material: 2 specimens, NHMW 2008z0257/0016.
Measurements: height: 20 mm, diameter: 15 mm.
Locality: Vinjhan, Kankawati River (KW locality).
Lithostratigraphy: Chasra Formation.
Age: Burdigalian.
Remarks: Due to its variability a broad range of synonyms exists for fossil occurrences (Beu, 2005). Similarly, the Burdigalian specimens from the Kutch Basin have been introduced as *Ranella bufo* by Sowerby (1840) who already noticed the similarity with "*Ranella bituberculata*". Later, Vredenburg (1925) erroneously placed the Kutch specimens into *Biplex* Perry, 1810 referring to *Ranella pulchra* "Gray". This mistake was uncritically adopted by Cox (1948) and Eames (1950), who synonymised *Ranella pulchra* "Gray" with *Biplex perca* Perry, 1811. The available specimens from the Kutch Basin as well as the illustrated specimen in Sowerby (1840) are clearly unrelated with *Biplex perca*, based on the characteristic axial sculpture and the thick, blunt varices. Nevertheless, it cannot be excluded that Vredenburg (1925) had also true representatives of *Biplex* available as he describes "palmate"…"wing-shaped extensions of the varices".
Distribution: The extant *Gyrineum bituberculare* is a widespread species in the Proto-Indo-Polynesian Region where it appears during the Early and Middle Miocene in NW, S and NE India, Pakistan and Indonesia (Mukerjee 1939; Beets 1941; Dharma 2005).

Superfamily Xenophoroidea Troschel, 1852
Family Xenophoridae Troschel, 1852
Genus *Xenophora* Fischer von Waldheim, 1807

Type species: *Xenophora laevigata* Fischer von Waldheim, 1807 = *Trochus conchyliophorus* Born, 1780. Recent, Caribbean Sea.

***Xenophora* nov. sp**

Fig. 4i, j
Material: 2 specimens, NHMW 2008z0255/0005.
Measurements: specimen 1: diameter: 45 mm, specimen 2: diameter: 32 mm, height: c. 31 mm.
Locality: Bermoti River, MF section.
Lithostratigraphy: Maniyara Fort Formation, Bermoti Member.
Age: Chattian.
Description: This *Xenophora* is characterised by a very slender shell with an apical angle of ca. 54°. Teleoconch whorls are moderately convex with deep sutures. Only a few shell fragments are attached. These appear mainly at the suture but may also appear on the flanks of the whorls. The base is concave and ends in a very fragmentary preserved peripheral flange. Strongly curved and prominent collabral growth lines; spiral ornament is missing; umbilicus is closed.
Remarks: This species resembles the Miocene *Xenophora deshayesi* (Michelotti, 1847) in outline and general sculpture. Nevertheless, *X. deshasyesi* can be clearly distinguished from the Indian shell based on the less curved growth lines on the base. The absence of any spiral sculpture of the base, the slender outline and/or the sealed umbilicus distinguishes the Kutch shell clearly from the Oligocene to Miocene xenophorids described from the western Tethys and the Proto-Indo-Pacific (see Manganelli et al. 2004 for discussion and references). The material, however, is not sufficient to define a new species.

Genus *Stellaria* Möller, 1832

Type species: *Trochus solaris* Linnaeus, 1764. Recent, Gulf of Aden.

***Stellaria* cf. *oligostriata* (Sacco, 1896)**

Fig. 4k, l
1896 *Tugurium oligostriatum* Sacco: 26, pl. 4 fig. 2.
Material: 1 specimen, NHMW 2008z0255/0006.
Measurements: diameter: c. 80 mm, height: c. 47 mm.
Locality: Bermoti River, MF section.
Lithostratigraphy: Maniyara Fort Formation, Bermoti Member.
Age: Chattian.
Description: Large trochiform shell with teleoconch consisting of at least 8 whorls of decreasing convexity. Early whorls bear a continuous row of tiny fragments along the sutures; on later whorls, the fragments become scattered and seem to be absent on the suture of the last whorl. These whorls display a characteristic sculpture of very low angled opisthocline, delicate, vermiculate ribblets crossed by weak prosocline growth lines. The base and aperture are unknown.

Remarks: This rarely documented species was suggested by Sacco (1896) to be related with *Xenophora subextensa* d'Orbigny, 1852 (= *Trochus extensus*? Sow. in Nyst, 1845: 375). Vredenburg (1928) referred to the same species when describing Oligocene shells from Pakistan. *Xenophora subextensa*, however, is a North Sea species from the Paleogene of Belgium and differs considerably from the Indian and Italian shells in its low spire, the incised sutures and the style of agglutination. *Stellaria ornatoparva*, from the Oligocene of Italy, might be related, but displays several differences from the Indian shell such as the smaller size and the steeper angle of the opisthocyrt ribblets. The lack of conchological data of all these rare Oligocene species, however, does not allow a clear statement. According to Ponder (1983), these species are early representatives of *Stellaria* and may be ancestors of the Late Miocene Indonesian *Stellaria dunkeri* (Martin, 1879) and the Pliocene to Recent *Stellaria chinensis* (Philippi, 1841).

Distribution: Known so far only from the Oligocene of Italy and the Kutch Basin.

Infraorder Neogastropoda Wenz, 1938

Superfamily Buccinoidea Rafinesque, 1815
Family Fasciolariidae Gray, 1853
Subfamily Fasciolariinae Gray, 1853
Genus *Clavellofusus* Grabau, 1904

Type species: *Clavellofusus spiratus* Grabau, 1904. Eocene, France.

***Clavellofusus* nov. sp.**

Fig. 4n, m
Material: 2 specimens, NHMW 2008z0255/0007.
Measurements: diameter: c. 90 mm, height: >160 mm.
Locality: Bermoti village, MF section.
Lithostratigraphy: Maniyara Fort Formation, Bermoti Member
Age: Chattian
Remarks: A giant species that is very abundant in the section. The impressions on the internal casts of the early spire whorls suggest a prominent axial sculpture on the first 3–4 spire whorls. A broad sutural shelf seems to be developed on the last whorl, which contracts slowly into the base. Unfortunately, all specimens are preserved only as strongly deformed internal casts, and the surrounding sediment was too soft to take silicone moulds. No such giant representative of *Clavellofusus* has been mentioned so far from the Oligocene. The large Miocene *Clavellofusus fennemai* (Martin, 1906) differs from this shell by its subparallel flanks of the last whorl. The giant Oligocene gastropod *Turbinella episoma* (Michelotti, 1861) is somewhat reminiscent in shape, but bears strong columellar folds. The generic affiliation (*Clavilithes* vs. *Clavellofusus*) follows Snyder (1999).

Subfamily Peristerniinae Tryon, 1880
Genus *Hemipolygona* Rovereto, 1899

Type species: *Chascax maderensis* Watson, 1873. Recent, West Africa.

***Hemipolygona* nov. sp.**

Fig. 5i
Material: 1 specimen, NHMW 2008z0257/0018.
Measurements: height: 23 mm, diameter: 16 mm.
Locality: Vinjhan, Kankawati River (KW locality).
Lithostratigraphy: Chasra Formation.
Age: Burdigalian.
Description: Only a single fragment is available. The stout fusiform shell consists of the last three teleoconch whorls and lacks the base and the siphonal canal. The moderately convex whorls are separated by strongly wavy, narrow sutures and bear large swollen axial ribs (6 on last whorl), which are crossed by very prominent spiral ribs. A pair of weak secondary ribs occurs close to the suture on the sutural ramp. The two most prominent ribs mark the shoulder and a weak anterior angulation. A third primary rib coincides with the lower suture. Densely spaced, axial threads cover the interspaces between the spiral ribs on the sutural ramp and on the lower part of the whorls below the second predominating spiral rib. The interspace between the pair of primary ribs seems to be smooth.
Remarks: The fragment is not sufficient to serve as a holotype. Even its generic affiliation is hampered by the preservation. However, following the revision of Vermeij and Snyder (2006) the shape and ornamentation of the Indian shell suggests a relation with *Hemipolygona*. *Hemipolygona erinacea* (Peyrot, 1928) from the Middle Miocene of France displays some resemblance concerning sculpture, but develops secondary spiral threads between the primary ribs, and its whorls are more convex. Vredenburg (1924a, 1925) did not describe any related form from the Cenozoic deposits of India and Pakistan.

Family Melongenidae Gill, 1871

Genus *Pugilina* Schumacher, 1817

Type species: *Murex morio* Linnaeus, 1758. Recent, West Atlantic.

***Pugilina eulactea* (Dey,** 1961)

Fig. 5m

* 1961 *Hemifusus eulacteus* Dey: 84, pl. 4 figs. 9–10, pl. 9 fig. 3

Material: 1 silicone mould, NHMW 2008z0257/0019.
Measurements: height: 39 mm, diameter: 24 mm.

Locality: Vinjhan, Kankawati River (KW locality).
Lithostratigraphy: Chasra Formation.
Age: Burdigalian.
Remarks: The single fragment corresponds fully to the type from Kerala in South India. The sculpture of the base and the siphonal canal, consisting of oblique spiral ribs, reaches far into the aperture, pointing to a subadult stage of the specimen. The stout shape, the low angled shoulder, the rapid transition from base into siphonal canal and the sharp angulation of the whorls suggest a position within *Pugilina* Schumacher, 1817 rather than within *Hemifusus* Swainson, 1840, which is characterised by fusiform shells with a slowly contracting base.
Distribution: A rare species that was recorded so far only from the Burdigalian of south India (Dey, 1961).

Superfamily Muricoidea Rafinesque, 1815
Family Turbinellidae Swainson, 1835

Genus *Turbinella* Lamarck, 1799

Type species: *Voluta pyrum* Linnaeus, 1758. Recent, Indian Ocean.

Turbinella premekranica Vredenburg, 1925

Fig. 5b, c

1916 *Turbinella praeovoidea* Vredenburg: 122, nomen nudum
1924b *Turbinella premekranica* Vredenburg: 121, nomen nudum
* 1925 *Turbinella premekranica* Vredenburg: 174, pl. 11 figs. 1–5

Material: 4 specimens, NHMW 2008z0256/0003.
Measurements: incomplete height: 72 mm, diameter: 40 mm.
Locality: Khari Nadi River (KN locality).
Lithostratigraphy: Khari Nadi Formation.
Age: Aquitanian.
Remarks: This rather small-sized *Turbinella* was considered by Vredenburg (1924b) to be a link between the "lower Gáj" species *T. affinis* (Sowerby, 1840) and the Late Miocene *T. mekranica* Vredenburg, 1925. *T. affinis,* however, is found in Burdigalian strata in the Kutch Basin (see below), whereas *T. premekranica* occurs there in the Aquitanian Khari Nadi Formation. Therefore, the phylogenetic succession as drawn by Vredenburg (1924b) has to be rejected. *Turbinella rembangensis* (Pannekoek, 1936) from the Early Miocene of Java differs from *Turbinella premekranica* mainly in the nearly horizontal posterior columellar folds and the slightly more stocky shape. Considering the variability of extant *Turbinella* species, both taxa may be conspecific as well.
Distribution: Known so far only from the Burdigalian of Pakistan (Vredenburg 1924b, 1925).

Turbinella affinis (Sowerby, 1840)

Fig. 5a

* 1840 *Turbinellus affinis* Sowerby: explanation of plates (no page number), pl. 26 fig. 22
1853 *Turbinella affinis* Sowerby.—d'Archiac & Haime: 306
1925 *Turbinella affinis* Sowerby.—Vredenburg: 171
? 1961 *Xancus affinis* (Sowerby).—Dey: 83, pl. 5 fig. 1

Material: 4 specimens (silicone moulds), NHMW 2008z0257/0020.
Measurements: height: 126 mm, diameter: 59 mm.
Locality: Vinjhan, Kankawati River (KW locality).
Lithostratigraphy: Chasra Formation.
Age: Burdigalian.
Remarks: The specimen from the Burdigalian of Kerala described by Dey (1961) as *T. affinis* is a considerably sculptured juvenile shell with only 3 columellar folds. It is questionable if it is really conspecific with the material from the Kutch Basin, where the type of *T. affinis* derives from.
Distribution: *T. affinis* is documented from the Early Miocene of Pakistan and NW India.

Family Volutidae Rafinesque, 1815
Subfamily Volutinae Rafinesque, 1815

Genus *Lyria* Gray, 1847

Subgenus *Harpeola* Dall, 1907

Type species: *Voluta costata* Swainson, 1824 [= *Lyria* (*Harpeola*) *anna* Lesson, 1835]. Recent, Indo-Pacific.

Lyria (*Harpeola*) *jugosa* (Sowerby, 1840)

Fig. 5h

* 1840 *Voluta jugosa* Sowerby: explanation of plates (no page number), pl. 26 fig. 25
1853 *Voluta jugosa* Sowerby.—d'Archiac & Haime: 323, pl. 31 figs. 19–21
1853 *Voluta edwardsi* d'Archiac.—d'Archiac & Haime: 323, pl. 31 figs. 22–24
1925 *Lyria jugosa* (Sowerby).—Vredenburg: 138
1935 *Lyria jugosa* Sowerby.—Wanner & Hahn: 246, pl. 18 figs. 2–4
1941 *Lyria* (*Harpella*) *jugosa* (Sowerby).—Beets: 119, pl. 6 figs. 253–254

1948 *Lyria jugosa* (Sowerby).—Cox: 51, pl. 5 fig. 3
1961 *Lyria jugosa* (Sowerby).—Dey: 84, pl. 5 fig. 6

Material: 4 specimens, NHMW 2008z0257/0021.
Measurements: height: 38 mm, diameter: 17 mm.
Locality: Vinjhan, Kankawati River (KW locality).
Lithostratigraphy: Chasra Formation.
Age: Burdigalian.
Remarks: The channelled and coronated suture, the moderate size and the stepped spire suggest a placement within the subgenus *Harpeola* Dall, 1907. In the type area, the species is highly reminiscent of the extant IWP species *Lyria* (*Harpeola*) *anna* Lesson, 1835 concerning the strongly stepped spire and the right-angled drop of the shoulder at the suture. Both species seem to be closely related if not synonymous. A difference in shape is the more pronounced convexity of the middle part of the last whorl of the fossil species. Some of the Late Miocene specimens from Indonesia, treated as subspecies of *Lyria* (*Harpeola*) *jugosa* by Beets (1941), tend to develop higher spires, stockier last whorls and may develop an angulation of the last whorl below the suture. These specimens, thus, differ from the extant species and might represent a separate species.
Distribution: *Lyria* (*Harpeola*) *jugosa* is known from the Early Miocene of India and Pakistan and becomes ubiquitous during the Miocene in Madagascar and Indonesia. A Pliocene specimen from Indonesia (Dharma, 2005) might rather represent a separate species of smaller size with crowded axial ribs.

Subgenus *Indolyria* Bail & Poppe, 2001

Type species: *Mitra lyraeformis* Swainson, 1822. Recent, Indo-Pacific.

***Lyria* (*Indolyria*) *maniyaraensis* Harzhauser nov. sp**

Fig. 5f, g
Material: 1 specimen (cast and silicone mould).
Holotype: NHMW 2008z0255/0008, cast and the corresponding silicone mould, height. 94 mm, diameter: 44 mm.
Stratum typicum: marly limestones of the Maniyara Fort Formation, Bermoti Member.
Type locality: Bermoti River, MF section.
Age: Chattian.
Name: referring to the Maniyara Fort at the type locality.
Description: Large, solid, fusiform shell consisting of at least 6 moderately convex teleoconch whorls separated by shallow sutures. Sculpture consisting of 20–25 slightly sigmoidal, prominent axial ribs separated by narrower interspaces. The ribs are sharp and nearly carinate on early spire whorls and grade into broad bulgy ribs on the last and penultimate whorls. A broad varix occurs on the last whorl. Aperture ovate with thickened, seemingly smooth outer lip and incised, broad posterior canal. Columella bearing 12 prominent plicae; these are rather uniformly developed and equal-spaced except for the two anterior plicae, which are very strong and separated by a broad interspace. Inner lip thin and hardly separated from the base. Siphonal canal short, moderately incised and strongly deflected.
Remarks: The affiliation with *Indolyria* Bail & Poppe, 2001 is based on the large size, the thick shell and the high spire. Among the extant representatives of *Indolyria*, as described by Bail and Poppe (2004), only *Lyria* (*Indolyria*) *doutei* Bouchet & Bail, 1991 displays some resemblance with the fossil species. It differs in its fusiform outline and the distinct axial ribs on the last whorl. Even the bulgy varieties of *L.* (*I.*) *doutei* (e.g. Bail & Poppe, 2004: pl. 18) can be clearly separated from *L.* (*I.*) *maniyaraensis* by their fine plicae on the upper part of the columella. *Lyria* (*Indolyria*) *eodelessertiana* Dey, 1961, from the Early Miocene of Kerala in South India, is reminiscent of the Kutch species concerning the high spire and general outline, but differs considerably in its smaller size, the high number of narrow and crowded axial ribs (>25), and the stepped spire.

Subfamily Athletinae Pilsbry & Olsson, 1954

Genus *Athleta* Conrad, 1853
Subgenus *Volutospina* Newton, 1906
Type species: *Conus spinosus* Linnaeus, 1758. Eocene, England.

***Athleta* (*Volutospina*) *dentata* (Sowerby,** 1840)

Fig. 5d,e

* 1840 *Voluta dentata* Sowerby: explanation of plates (no page number), pl. 26 fig. 26
1853 *Voluta dentata* Sowerby.—d'Archiac & Haime: 324, pl. 32 figs. 2–2a
1853 *Voluta sykesi* d'Archiac & Haime: 324, pl. 32 figs. 3–3a
1925 *Athleta* (*Volutospina*) *dentata* Sowerby.—Vredenburg: 130
1925 *Athleta* (*Volutospina*) *dentata* var. *sykesi* d'Archiac & Haime.—Vredenburg: 133
non 1895 *Voluta dentata* Sowerby.—Noetling: 37, pl. 8 figs. 8–10 [= *Volutospina jacobsi* (Vredenburg, 1923)]
non 1901 *Voluta dentata* Sowerby.—Noetling: 324, pl. 21 figs. 14–15, pl. 22 figs. 1–3 [= *Volutospina jacobsi* (Vredenburg, 1923)]

Material: 3 specimens and 1 silicone mould, NHMW 2008z0257/0022.
Measurements: height: 36 mm, diameter: 18 mm.

Locality: Vinjhan, Kankawati River (KW locality).
Lithostratigraphy: Chasra Formation.
Age: Burdigalian.
Remarks: This species was described in great detail by Vredenburg (1925). It is characterised by its conspicuous coronate shoulder with spines pointing straight and parallel to the axis in posterior direction. One specimen exhibits 7 columellar folds, of which the two weak posterior plicae are followed by 3 very strong folds with a weak fold between the lower pair. The 7th most anterior fold is very weak. This species might be rooted in the Oligocene Western Tethys species *Athleta* (*Volutospina*) *multicostata* (Bellardi, 1890) and *A.* (*V.*) *subambigua* (d'Orbigny, 1852), which, however, lack the strong coronation.
Distribution: *Athleta* (*Volutospina*) *dentata* is only known from the Early Miocene of NW India and Pakistan.

Superfamily Olivoidea Latreille, 1825
Family Olivellidae Troschel, 1869
Genus *Agaronia* Gray, 1839

Type species: *Voluta hiatula* Gmelin, 1791. Recent, East Atlantic.

***Agaronia pupa* (Sowerby, 1840)**

Fig. 5k, l

* 1840 *Oliva pupa* Sowerby: explanation of plates (no page number), pl. 26 fig. 32
1853 *Oliva pupa* Sowerby.—d'Archiac & Haime: 336, pl. 34 fig. 1
1925 *Olivancillaria* (*Agaronia*) *nebulosa* Lamarck var. *pupa* Sowerby.—Vredenburg: 111
1961 *Olivancillaria* (*Agaronia*) *nebulosa* Lamarck var. *pupa* (Sowerby).—Dey: 88

Material: 4 specimens, NHMW 2008z0257/0023.
Measurements: height: 21 mm, diameter: 8 mm.
Locality: Vinjhan, Kankawati River (KW locality).
Lithostratigraphy: Chasra Formation.
Age: Burdigalian.
Distribution: *Agaronia pupa* (Sowerby, 1840) is known from the Burdigalian of NW India and South India (Dey, 1961). A close relation with the extant IWP species *Agaronia nebula* (Lamarck, 1811) as discussed by Vredenburg (1925) would significantly expand the stratigraphic and geographic distribution.

Superfamily Conoidea Fleming, 1822
Family Conidae Fleming, 1822
Subfamily Coninae Fleming, 1822

Genus *Conus* Linnaeus, 1758

Subgenus *Lithoconus* Mörch, 1852

Type species: *Conus millepunctatus* Lamarck, 1822. Recent, Indo-Pacific.

***Conus* (*Lithoconus*) *brevis* Sowerby, 1840**

Fig. 5j

* 1840 *Conus brevis* Sowerby: explanation of plates (no page number), pl. 26 fig. 33
1840 *Conus militaris* Sowerby: explanation of plates (no page number), pl. 26 fig. 34
1840 *Conus catenulatus* Sowerby: explanation of plates (no page number), pl. 26 fig. 35
1925 *Conus* (*Lithoconus*) *brevis* Sowerby. – Vredenburg: 89
1961 *Conus* (*Lithoconus*) *brevis* Sowerby.—Dey: 103
non 1877a *Conus brevis* Smith: 222

Material: 1 specimen, NHMW 2008z0256/0004.
Measurements: height: 39 mm, diameter: 22 mm
Locality: Khari Nadi River (KN locality).
Lithostratigraphy: Khari Nadi Formation.
Age: Aquitanian.
Material: 2 specimens, NHMW 2008z0257/0024.
Measurements: height: 27 mm, diameter: 17 mm
Locality: Vinjhan, Kankawati River (KW locality), Chasra Formation.
Age: Burdigalian
Remarks: Eocene records of *Conus brevis* are rejected by Vredenburg (1925) and united in *Conus blagravei* Vredenburg, 1925. The extant *Conus brevis* Smith, 1877a, is a junior primary homonym, but turned out to be a juvenile of *Conus caracteristicus* Fischer von Waldheim, 1807 (Coomans & Moolenbeek, 1982).
Distribution: *Conus brevis* is known from the Early Miocene of NW India, Kerala in South India and Sri Lanka (Wayland & Davies, 1923; Dey, 1961).

Family Turridae Adams & Adams, 1853
Subfamily Turrinae Adams & Adams, 1853

Genus *Gemmula* Weinkauff, 1875

Type species: *Gemmula hindsiana* Berry, 1958 [= *Pleurotoma gemmata* Reeve, 1843 (non Conrad, 1835]. Recent, Baja California.

***Gemmula gajensis* (Vredenburg, 1925)**

Fig. 5p

1925 *Pleurotoma* (*Gemmula*) *congener* variety *gajensis* Vredenburg: 57

Material: 1 specimen, NHMW 2008z0257/0025.
Neotype: NHMW 2008z0257/0025, diameter: 6 mm, height: 20 mm.
Type locality: Vinjhan, Kankawati River (KW locality).

Stratum typicum: marly limestones Chasra Formation.
Age: Burdigalian.

Emendated Description: Small, slender, fusiform shell of 8 teleoconch whorls. These bear a characteristic twofold spiral rib at the upper suture, of which the lower one protrudes most. Below follows a deep furrow with 2 indistinct spiral threads. This furrow is terminated by a massive peripheral keel, composed of two densely gemmate spiral ribs with vertically fused nodes. A narrow furrow, a single smooth spiral thread and a somewhat broader furrow follow below. In profile, the peripheral keel does hardly project above the twofold spiral along the upper suture. Last whorl short and rapidly contracting, decorated by 5 spiral ribs below the keel. The rather short, narrow siphonal canal bears about 9 weaker spiral threads.

Remarks: Vredenburg (1925) introduced the name *gajensis* as variety name for shells from the Kutch Basin, when discussing the Pliocene *Gemmula congener mekranica* (Vredenburg, 1925). His "one-sentence description", which mainly states the small size, is insufficient, but not a mere nomen nudum. Therefore, we present here an emendated description of a specimen from the type area. As the whereabouts of Vredenburg's type lot in Calcutta could not be clarified, we designate a neotype.

Indeed, this species is part of the Miocene to Recent *Gemmula congener* complex, but differs from the extant *Gemmula congener* (Smith, 1894) in its much smaller size, the slender outline and the less abruptly contracting base. Moreover, it occurs in very shallow marine sublittoral deposits, whereas *Gemmula congener* prefers deeper water environments below 80-m water depth (Powell, 1964). *Gemmula gajensis* might thus represent a rather small-sized Miocene offshoot of the *G. congener* complex, which settled shallow marine environments.

The Pliocene *Gemmula mekranica* (Vredenburg, 1925), which was discussed by Vredenburg (1925) to be very closely related to *Gemmula gajensis*, is larger and develops a broader spire and a shorter last whorl. *Gemmula sindiensis* (Vredenburg, 1925), from the Burdigalian of the Kutch Basin, differs from *Gemmula gajensis* in its higher spire and the unicarinate spiral cord. *Gemmula imitatrix* (Martin, 1916) from the Early Miocene of Java is characterised by a protruding gemmate keel as well as prominent growth lines, and by lacking the strong spirals at the suture. *Gemmula pilleri* Harzhauser, 2009 from the Aquitanian of Tanzania lacks the prominent twofold spiral rib along the upper suture, has a longer siphonal canal, and bears fewer spirals on the body whorl and the canal.

Distribution: Only documented from the Early Miocene of the Kutch Basin.

Family Clavatulidae Gray, 1853

Genus *Turricula* Schumacher, 1817

Type species: *Murex tornatus* Dillwyn, 1817. Recent, Indo-Pacific.

***Turricula spuria* (Hedley, 1922)**

Fig. 5q

* 1922 *Inquisitor spurius* Hedley: 245
1925 *Surcula tuberculata* Gray.—Vredenburg: 35
1948 *Turricula nelliae* (Smith).—Cox: 57, pl. 6 figs. 2a–c
1969 *Turricula nelliae spurius* (Hedley).—Powell: 238, pl. 197 figs. 2–7
2005 *Turricula nelliae spurius* (Hedley).—Dharma: 324, pl. 127 fig. 2

Material: 4 specimens, 2008z0257/0026.
Measurements: height. 42 mm, diameter: 18 mm; juvenile specimen: height: 18 mm, diameter: 8 mm.
Locality: Vinjhan, Kankawati River (KW locality).
Lithostratigraphy: Chasra Formation.
Age: Burdigalian.

Remarks and distribution: *Turricula spuria* is a very plastic extant species, which is distributed from the Persian Gulf to New Guinea and the Chinese Sea (Powell 1969). Fossil occurrences have been known so far only from the Late Miocene to Pleistocene of Persia, Indonesia and Japan (Vredenburg 1925; Cox 1948; Dharma 2005). Several very closely related species, such as *Turricula sethuramae* (Vredenburg, 1921) and *T. thangaensis* (Vredenburg, 1921), appear in Burma already during the Early Miocene. The specimens from the Burdigalian of the Kutch Basin differ from recent representatives only in their somewhat larger size and the stronger sculpture. They might represent a distinct subspecies, but may as well be only a large-sized morph. Powell (1969) treats *Turricula spuria* as subspecies of *T. nelliae* (Smith, 1877b), which is based on a single specimen lacking the characteristic granulations of *T. spuria*.

Superordo Heterobranchia J.E. Gray, 1840
Superfamily Architectonicoidea J.E. Gray in M.E. Gray, 1850
Family Architectonicidae J.E. Gray in M.E. Gray, 1850

Genus *Architectonica* Röding, 1798

Type species: *Trochus perspectives* Linnaeus, 1758. Recent, Indo-West Pacific.

***Architectonica affinis* (Sowerby, 1840)**

Fig. 5n, o

* 1840 *Solarium affine* Sowerby: explanation of plates (no page number), pl. 26 fig. 5

Table 1 A list of Rupelian, Chattian, Aquitanian and Burdigalian gastropod species from the Kutch Basin and the Sindh province in Pakistan (only Rupelian records), based on Vredenburg (1925, 1928) and this study

Taxa	Chattian—Kutch	Aquitanian—Kutch	Burdigalian—Kutch	Rupelian—Pakistan/Sind	Oligocene Oman	Oligocene Italy/France	Early Miocene Garo Hills Assam	Early/Middle Miocene Quilon (S-India)	Aquitanian—Oman	Early Miocene Tanzania	Early Miocene Indonesia	Early Miocene Italy/France
Tectus cognatus (Sowerby, 1840)	−	−	+	−	−	−	−	+	−	−	−	−
Tectus loryi (d'Archiac & Haime, 1853)	−	+	−	−	+	−	−	−	−	−	−	−
Tectus lucasianus (Brongniart, 1823)	−	−	−	+	−	+	−	−	−	−	−	−
Cantharus bucklandi (d'Archiac, 1850)	−	−	+	−	−	−	−	−	−	−	−	−
Turbo naricus Vredenburg (1928)	−	−	−	+	−	−	−	−	−	−	−	−
Turbo protocepoides (Vredenburg, 1928)	−	−	−	+	−	−	−	−	−	−	−	−
Turbo pseudoundulatus (Vredenburg, 1928)	−	−	−	+	−	−	−	−	−	−	−	−
Phasianella cf. variegata (Lamarck, 1822)	−	−	+	−	−	−	−	+	−	−	−	−
Globularia carlei (Finlay, 1927)	−	−	+	−	−	−	−	+	−	−	−	−
Globularia cf. *sanctistephani* (Cossmann & Peyrot, 1919)	+	−	−	+	−	+	−	−	−	−	−	−
Globularia gibberosa (Grateloup, 1847)	−	−	−	+	−	+	−	−	−	−	−	−
Ampullinopsis crassatina (Lamarck, 1804)	+	−	−	+	−	+	−	−	−	−	−	−
Ampullonatica angulifera (Sowerby, 1840)	−	−	+	−	−	−	−	−	−	−	−	−
Pachycrommium harrisi (Pannekoek, 1936)	−	−	+	−	−	−	−	−	+	−	+	−
Pachycrommium oweni (d'Archiac & Haime, 1853)	−	−	−	+	−	−	−	−	−	−	−	−

Table 1 continued

Taxa	Chattian—Kutch	Aquitanian—Kutch	Burdigalian—Kutch	Rupelian—Pakistan/Sind	Oligocene Oman	Oligocene Italy/France	Early Miocene Garo Hills Assam	Early/Middle Miocene Quilon (S-India)	Aquitanian—Oman	Early Miocene Tanzania	Early Miocene Indonesia	Early Miocene Italy/France
Campanile pseudoobeliscus (Grateloup, 1832)	+	−	−	−	+	+	−	−	+	+	−	+
Bellatara narica (Vredenburg, 1925)	−	−	−	+	−	−	−	−	−	−	−	−
Gourmya baluchistanensis (Vredenburg, 1928)	−	−	−	+	+	−	−	−	−	−	−	−
Vertagus kachhensis (Vredenburg, 1925)	−	−	+	−	−	−	−	−	−	−	−	−
Cerithium archiaci Vredenburg, 1928	−	−	+	−	+	−	−	−	−	+	−	−
Cerithium bermotiense Harzhauser nov. sp.	+	−	−	−	−	−	−	−	−	−	−	−
Cerithium bhagothorense Vredenburg, 1928	−	−	−	+	−	−	−	−	−	−	−	−
Cerithium haimei Vredenburg, 1928	−	−	−	+	−	−	−	−	−	−	−	−
Cerithium ighinai (Michelotti, 1861)	−	−	−	+	−	+	−	−	−	−	−	−
Cerithium perlamellosum Vredenburg, 1928	−	−	−	+	−	−	−	−	−	−	−	−
Cerithium pseudocorrugatum d'Orbigny, 1852	−	−	+	−	−	−	−	−	−	−	−	−
Cerithium rude Sowerby, 1840	−	+	+	−	+	−	−	+	+	+	+	−
Cerithium sindiensis Vredenburg, 1928	−	−	−	+	−	−	−	−	−	−	−	−
Cerithium tricingulatum Vredenburg, 1928	−	−	−	+	−	−	−	−	−	−	−	−
Tympanotonos laevis (Vredenburg, 1928)	−	−	−	+	−	−	−	−	−	−	−	−
Turritella asperula Brongniart, 1823	−	−	−	+	−	+	−	−	−	−	−	−

Table 1 continued

Taxa	Chattian—Kutch	Aquitanian—Kutch	Burdigalian—Kutch	Rupelian—Pakistan/Sind	Oligocene Oman	Oligocene Italy/France	Early Miocene Garo Hills Assam	Early/Middle Miocene Quilon (S-India)	Aquitanian—Oman	Early Miocene Tanzania	Early Miocene Indonesia	Early Miocene Italy/France
Turritella assimilis Sowerby, 1840	−	−	+	−	−	−	−	−	−	−	−	−
Turritella bhaothorensis Vredenburg, 1928	−	−	−	+	−	−	−	−	−	−	−	−
Turritella crassocingulata Vredenburg, 1928	−	−	−	+	−	−	−	−	−	−	−	−
Turritella desmarestina Basterot, 1825	−	−	−	+	−	+	−	−	−	−	−	−
Turritella kachhensis Vredenburg, 1928	−	−	+	−	−	−	−	−	−	−	−	−
Turritella narica Vredenburg, 1928	−	−	−	+	−	−	−	−	−	−	−	−
Turritella pseudotethis Vredenburg, 1928	−	−	−	+	−	−	−	−	−	−	−	−
Turritella strangulata Grateloup, 1847	−	−	−	+	−	+	−	−	−	−	−	−
Turritella tipperi Vredenburg, 1928	−	−	−	+	−	−	−	−	−	−	−	−
Haustator tauroperturritus Sacco, 1895	−	−	+	−	−	−	−	−	−	−	−	+
Haustellum naricum (Vredenburg, 1925)	−	−	−	+	−	−	−	−	−	−	−	−
Haustator conofasciata (Sacco, 1895)	−	−	−	+	+	+	−	−	−	−	−	−
Zaria angulata (Sowerby, 1840)	−	+	+	−	−	−	+	−	−	−	−	−
Protoma deshayesi (d'Archiac, 1850)	−	+	−	+	−	−	−	−	−	−	−	−
Protoma renevieri (d'Archiac & Haime, 1853)	−	−	−	+	−	−	−	−	−	−	−	−
Protoma retrodilatatum Vredenburg, 1928	−	−	−	+	−	−	−	−	−	−	−	−
Protoma subrenevieri Vredenburg, 1928	−	−	−	+	−	−	−	−	−	−	−	−

Table 1 continued

Taxa	Chattian—Kutch	Aquitanian—Kutch	Burdigalian—Kutch	Rupelian—Pakistan/Sind	Oligocene Oman	Oligocene Italy/France	Early Miocene Garo Hills Assam	Early/Middle Miocene Quilon (S-India)	Aquitanian—Oman	Early Miocene Tanzania	Early Miocene Indonesia	Early Miocene Italy/France
Tenagodus granti (Sowerby, 1840)	+	−	+	+	−	−	−	+	−	−	−	−
Natica obscura Sowerby, 1840	−	−	+	−	−	−	−	−	−	−	−	−
Sinum aquensis praecedens Sacco, 1891	−	−	+	−	−	+	−	−	−	−	−	−
Varicospira subrimosa (d'Orbigny, 1852)	−	−	+	−	−	−	−	+	−	−	−	−
Varicospira subrimosa narica (Vredenburg, 1925)	−	−	−	+	−	−	−	−	−	−	−	−
Varicospira? sindiensis (Vredenburg, 1925)	−	−	−	+	−	−	−	−	−	−	−	−
Strombus sedanensis Martin, 1899	−	−	+	−	−	−	−	−	−	−	+	−
Persististrombus depertitus (Sowerby, 1840)	−	−	+	−	−	−	−	+	−	−	−	−
Persististrombus radix (Brongniart, 1823)	+	−	−	+	−	+	−	−	−	−	−	−
Dilatilabrum sublatissimum (d'Orbigny, 1852)	+	−	−	−	−	+	−	−	+	−	−	−
Tibia protofusus (Vredenburg, 1928)	−	−	+	−	−	−	+	−	−	−	−	−
Seraphs naricus (Vredenburg, 1925)	−	−	−	+	−	−	−	−	−	−	−	−
Terebellum obtusum Sowerby, 1840	−	−	+	−	−	−	−	−	−	+	−	−
Calyptraea chinensis (Linnaeus, 1767)	−	−	+	−	−	+	−	−	−	−	−	+
Hipponyx narica Vredenburg, 1928	−	−	+	−	−	−	−	−	−	−	−	−
Xenophora nov. sp.	+	−	−	−	−	−	−	−	−	−	−	−
Stellaria cf. *oligostriata* (Sacco, 1896)	+	−	−	−	−	+	−	−	−	−	−	−

Table 1 continued

Taxa	Chattian—Kutch	Aquitanian—Kutch	Burdigalian—Kutch	Rupelian—Pakistan/Sind	Oligocene Oman	Oligocene Italy/France	Early Miocene Garo Hills Assam	Early/Middle Miocene Quilon (S-India)	Aquitanian—Oman	Early Miocene Tanzania	Early Miocene Indonesia	Early Miocene Italy/France
Cypraea humerosa Sowerby, 1840	−	−	+	−	−	−	−	−	−	−	−	−
Cypraea nasuta Sowerby, 1840	−	−	+	−	−	−	−	−	−	−	−	−
Cypraea prunum Sowerby, 1840	−	−	+	−	−	−	−	−	−	−	−	−
Cypraea sindiensis Vredenburg, 1925	−	−	−	+	−	−	−	−	−	−	−	−
Cypraea subexcisa Braun, 1850	−	−	−	+	−	+	−	−	−	−	−	−
Distorsio decipiens (Reeve, 1844)	−	−	+	−	−	−	−	+	−	−	+	−
Apollon morrisi (d'Archiac & Haime, 1853)	−	−	+	−	−	−	−	−	−	−	−	−
Biplex perca (Perry, 1811)	−	−	+	−	−	−	−	+	−	−	+	−
Gyrineum bituberculare (Lamarck, 1816)	−	−	+	−	−	−	+	+	−	−	+	−
Ranella tubercularis Noetling, 1895	−	−	−	+	−	−	−	−	−	−	−	−
Sassia indica (Vredenburg, 1925)	−	−	−	+	−	−	−	−	−	−	−	−
Cassis mamillaris Grateloup, 1847	−	−	−	+	−	+	−	−	−	−	−	−
Sconsia beyrichi (Michelotti, 1861)	−	−	−	+	−	+	−	−	−	−	−	−
Semicassis oligocalantica (Vredenburg, 1925)	−	−	−	+	−	−	−	−	−	−	−	−
Semicassis sculpta (Sowerby, 1840)	−	−	+	−	−	−	−	−	−	−	−	−
Eocithara narica (Vredenburg, 1925)	−	−	−	+	−	−	−	−	−	−	−	−
Ficus condita (Brongniart, 1823)	−	−	−	+	−	+	−	−	−	−	−	+
Ficus kachhensis (Vredenburg, 1925)	−	−	+	−	−	−	−	−	−	−	−	−

Table 1 continued

Taxa	Chattian—Kutch	Aquitanian—Kutch	Burdigalian—Kutch	Rupelian—Pakistan/Sind	Oligocene Oman	Oligocene Italy/France	Early Miocene Garo Hills Assam	Early/Middle Miocene Quilon (S-India)	Aquitanian—Oman	Early Miocene Tanzania	Early Miocene Indonesia	Early Miocene Italy/France
Muricantha ighinae (Bellardi, 1872)	−	−	−	+	−	+	−	−	−	−	−	−
Muricopsis exhexagonus Vredenburg, 1925	−	−	+	−	−	−	−	−	−	−	−	−
Fusinus nodulosus (Sowerby, 1840)	−	−	+	−	−	−	−	+	−	−	−	−
Fusinus reticulatus (Vredenburg, 1925) preoccupied!	−	−	−	+	−	−	−	−	−	−	−	−
Clavellofusus cf. *fennemai* (Martin, 1906)	−	−	+	−	−	−	−	−	−	−	+	−
Clavellofusus nov. sp.	+	−	−	−	−	−	−	−	−	−	−	−
Euthriofusus naricus Vredenburg, 1925	−	−	−	+	−	−	−	−	−	−	−	−
Euthriofusus subregularis (d'Archiac & Haime, 1853)	−	−	−	+	−	−	−	−	−	−	−	−
Nassaria bhagothorensis (Vredenburg, 1925)	−	−	−	+	−	−	−	−	−	−	−	−
Nassaria granosa (Sowerby, 1840)	−	−	+	−	−	−	−	−	−	−	−	−
Nassaria narica (Vredenburg, 1925)	−	−	−	+	−	−	−	−	−	−	−	−
Nassarius kachhensis (Vredenburg, 1925)	−	−	+	−	−	−	−	−	−	−	−	−
Melongena cornuta (Agassiz, 1843)	−	−	+	−	−	−	−	−	−	−	−	+
Melongena lainei (Basterot, 1825)	−	−	+	−	+	−	−	−	−	−	−	+
Pugilina eulactea (Dey, 1961)	−	−	+	−	−	−	−	+	−	−	−	−
Hemipolygona nov. sp.	−	−	+	−	−	−	−	−	−	−	−	−
Latirus sindiensis Vredenburg, 1925	−	−	−	+	−	−	−	−	−	−	−	−

Table 1 continued

Taxa	Chattian—Kutch	Aquitanian—Kutch	Burdigalian—Kutch	Rupelian—Pakistan/Sind	Oligocene Oman	Oligocene Italy/France	Early Miocene Garo Hills Assam	Early/Middle Miocene Quilon (S-India)	Aquitanian—Oman	Early Miocene Tanzania	Early Miocene Indonesia	Early Miocene Italy/France
Steptochetus pseudowaelii Vredenburg, 1925	−	−	−	+	−	−	−	−	−	−	−	−
Turbinella affinis (Sowerby, 1840)	−	−	+	−	−	−	−	+	−	−	−	−
Turbinella episoma (Michelotti, 1861)	−	−	−	+	−	+	−	−	−	−	−	−
Turbinella premekranica Vredenburg, 1925	−	+	−	−	−	−	−	−	−	−	−	−
Lyria (Harpeola) jugosa (Sowerby, 1840)	−	−	+	−	−	−	−	+	−	−	+	−
Lyria (Indolyria) maniyaraensis Harzhauser nov. sp.	+	−	−	−	−	−	−	−	−	−	−	−
Lyria anceps (Michelotti, 1861)	−	−	−	+	−	+	−	−	−	−	−	−
Athleta (Volutospina) dentata (Sowerby, 1840)	−	−	+	−	−	−	−	−	−	−	−	−
Athleta (Volutospina) sindiensis Vredenburg, 1925	−	−	−	+	−	−	−	−	−	−	−	−
Nebularia subscrobiculata (d'Orbigny, 1852)	−	−	+	−	−	−	−	−	−	−	−	−
Chrysame sowerbyi (d'Orbigny, 1852)	−	−	+	−	−	−	+	+	−	−	+	−
Ancilla indica Vredenburg, 1925	−	−	−	+	−	−	−	−	−	−	−	−
Agaronia pupa (Sowerby, 1840)	−	−	+	−	−	−	+	+	−	−	−	−
Oliva indica Vredenburg, 1925	−	−	+	−	−	−	+	+	−	−	−	−
Olivella elegantula Rovereto, 1900	−	−	−	+	−	+	−	−	−	−	−	−
Trigonostoma indicum (Vredenburg, 1925)	−	−	−	+	−	−	−	−	−	−	−	−

Table 1 continued

Taxa	Chattian—Kutch	Aquitanian—Kutch	Burdigalian—Kutch	Rupelian—Pakistan/Sind	Oligocene Oman	Oligocene Italy/France	Early Miocene Garo Hills Assam	Early/Middle Miocene Quilon (S-India)	Aquitanian—Oman	Early Miocene Tanzania	Early Miocene Indonesia	Early Miocene Italy/France
Uxia narica Vredenburg, 1925	−	−	−	+	−	−	−	−	−	−	−	−
Clathrus gajensis (Vredenburg, 1928)	−	−	+	−	−	−	−	−	−	−	−	−
Cominella annandalei Vredenburg, 1925	−	−	−	+	−	−	−	−	−	−	−	−
Terebra narica Vredenburg, 1925	−	−	−	+	−	−	−	−	−	−	−	−
Terebra perturrita Sacco, 1891	−	−	−	+	+	+	+	−	−	−	−	−
Myurella aiyengari (Dey, 1961)	−	−	+	−	−	−	−	+	−	−	−	−
Myurella katchhensis (Vredenburg, 1925)	−	−	+	−	−	−	−	−	−	−	−	−
Myurella quettensis (Vredenburg, 1925)	−	−	−	+	−	−	−	−	−	−	−	−
Myurella reticulata (Sowerby, 1840)	−	−	+	−	−	−	+	+	−	−	−	−
Conorbis bhagothorensis (Vredenburg, 1925)	−	−	−	+	−	−	−	−	−	−	−	−
Conorbis sindiensis (Vredenburg, 1925)	−	−	−	+	−	−	−	−	−	−	−	−
Conus (Leptoconus) marginatus Sowerby, 1840	−	−	+	−	−	−	−	−	−	−	−	−
Conus (Lithoconus) brevis Sowerby, 1840	−	+	+	−	−	−	+	+	−	−	−	−
Conus (Lithoconus) ineditus Michelotti, 1861	−	−	−	+	−	+	−	−	−	−	−	−
Conus (Lithoconus) odengensis Martin, 1895	−	−	+	−	−	−	+	+	−	−	+	−
Crassispira kachhensis (Vredenburg, 1925)	−	−	+	−	−	−	−	−	−	−	−	−
Turricula spuria (Hedley, 1922)	−	−	+	−	−	−	−	−	−	−	+	−

Table 1 continued

Taxa	Chattian—Kutch	Aquitanian—Kutch	Burdigalian—Kutch	Rupelian—Pakistan/Sind	Oligocene Oman	Oligocene Italy/France	Early Miocene Garo Hills Assam	Early/Middle Miocene Quilon (S-India)	Aquitanian—Oman	Early Miocene Tanzania	Early Miocene Indonesia	Early Miocene Italy/France
Gemmula gajensis (Vredenburg, 1925)	−	−	+	−	−	−	−	−	−	−	−	−
Gemmula sindiensis (Vredenburg, 1925)	−	−	−	+	−	−	+	−	−	−	−	−
Hemipleurotoma bhagothorensis (Vredenburg, 1925)	−	−	−	+	−	−	−	−	−	−	−	−
Hemipleurotoma bonneti (Cossmann, 1900)	−	−	+	−	−	−	−	−	−	−	+	−
Hemipleurotoma narica (Vredenburg, 1925)	−	−	−	+	−	−	−	−	−	−	−	−
Hemipleurotoma virginoides (Vredenburg, 1925)	−	−	+	−	−	−	−	−	−	−	−	−
Architectonica affinis (Sowerby, 1840)	−	+	+	−	−	−	−	+	−	−	−	−
Architectonica narica (Vredenburg, 1928)	−	−	−	+	−	−	−	−	−	−	−	−
Scaphander javanus (Martin, 1879)	−	−	+	−	−	−	−	+	−	−	+	−
Scaphander oligoturritus Sacco, 1897	−	−	−	+	−	+	−	−	−	−	−	−
Akera narica (Vredenburg, 1925)	−	−	−	+	−	−	−	−	−	−	−	−
Aliculastrum protocylindrica (Vredenburg, 1925)	+	−	+	−	−	−	−	−	−	−	−	−

Occurrences in adjacent bioprovinces are indicated as well (see text for references). Note that the generic affiliations of Vredenburg (1925, 1928) have been adopted

1853 *Solarium affine* Sowerby.—d'Archiac & Haime, pl. 26 fig. 13
1928 *Solarium affine* Sowerby.—Vredenburg: 393
1961 *Architectonica affinis* (Sowerby).—Dey: 53, pl. 1 fig. 1

Material: 1 specimen, NHMW 2008z0256/0005.
Measurements: fragment: height: 7 mm, diameter: 19 mm.
Locality: Khari Nadi River (KN locality).
Lithostratigraphy: Khari Nadi Formation.
Age: Aquitanian.
Material: 2 specimens, NHMW 2008z0257/0027.
Measurements: diameter: 24 mm.
Locality: Vinjhan, Kankawati River (KW locality), Chasra Formation.
Age: Burdigalian.
Remarks: As already discussed by Vredenburg (1925) and Dey (1961), this species belongs to the extant *Architectonica maxima*-group. Van Regteren Altena (1938) and Eames (1950) even united *Architectonica affinis* with *Architectonica maxima* (Philippi, 1849). This is rejected herein based on the distinctly smaller size, the depressed conical profile and the strongly nodose mid-ribs of *A. affinis* (see Bieler, 1993 for comparison with *A. maxima*).
Distribution: This species is recorded from Early Miocene deposits of Pakistan, NW India and Kerala in South India.

Ordo Opisthobranchia Milne-Edwards, 1848
Superfamily Haminoeoidea Pilsbry, 1895
Family Haminoeidae Pilsbry, 1895
Subfamily Atydinae Thiele, 1925
Genus *Aliculastrum* Pilsbry, 1895

Type species: *Bulla cylindrica* Helbling, 1779. Recent, Indo-West Pacific.

***Aliculastrum protocylindricum* (Vredenburg, 1925)**

* 1925 *Atys protocylindrica* Vredenburg: 11, pl. 5 figs. 1–2

Material: 1 specimen (silicone mould), NHMW 2008z0255/0009.
Measurements: height: 16 mm, diameter: 7 mm.
Locality: Bermoti River, MF section.
Lithostratigraphy: Maniyara Fort Formation, Bermoti Member.
Age: Chattian.
Remarks: This species was known so far only from the Early Miocene of the Kutch Basin, but appears already during the Chattian. In contrast to the small Miocene specimens, the Chattian representative attains a comparable size to the Recent *Aliculastrum cylindricum* (Helbling, 1779). Therefore, the type specimens might rather represent subadult shells.

Discussion and conclusions

The faunistic relations between Oligo-/Miocene faunas from India and those from France and Italy, as well as those from Indonesia, have been a matter of discussion in numerous papers (see Harzhauser et al. 2002 for references). A drastic drop of similarities between Western Tethys faunas and the Indian ones during the Early Miocene has already been recognised by Vredenburg (1925) and Martin (1931). Piccoli et al. (1991) and Harzhauser et al. (2002, 2008) tried to quantify these differences. All these studies, however, had to cope with the poor biostratigraphic resolution of the classical Sindh and Kutch faunas.

Now, a separation into four time slices is possible (Table 1): (1) Rupelian—based on the Sindh faunas in Pakistan (Vredenburg 1925, 1928). These have not been restudied herein and are used only as reference. (2) Chattian and (3) Aquitanian—both based on the Kutch Basin fauna in this study. (4) Burdigalian—based on the Kutch Basin fauna in this study and from Vredenburg (1925, 1928).

A broad Rupelian Tethyan Seaway is generally accepted by all paleogeographers (e.g. Rögl 1998). Thus, a faunistic relation between the study area and the Western Tethys can be expected. Indeed, the Pakistani Rupelian gastropod fauna bears 28% species in common with Western Tethyan faunas from Italy and France. Nevertheless, more than 70% of the taxa are so far known only from Pakistan, pointing to quite a distinct bioprovince. This pattern persists into the Chattian without major change. The Chattian of the herein studied Bermoti area yields a small assemblage of only 12 species. Four of these taxa are new, suggesting that the Chattian fauna of the Kutch Basin is still largely unknown. The remaining 8 species represent 6 gastropod taxa that are Western Tethyan elements [*Globularia* cf. *sanctistephani* (Cossmann & Peyrot, 1919), *Ampullinopsis crassatina* (Lamarck, 1804), *Persististrombus radix* (Brongniart, 1823), *Campanile pseudoobeliscus* (Grateloup, 1832), *Dilatilabrum sublatissimum* (d'Orbigny, 1852), *Stellaria ornatostriata* (Sacco, 1896)] and two that are so far unknown from western localities [*Tenagodus granti* (Sowerby, 1840), *Aliculastrum protocylindricum* (Vredenburg, 1925)].

Uniting all Oligocene records from Sindh and NW India raises the percentage of Western Tethyan species to 30% (Table 1; Fig. 6). In contrast, the faunas from Oman on the southern branch of the Tethys bear only 5% in common

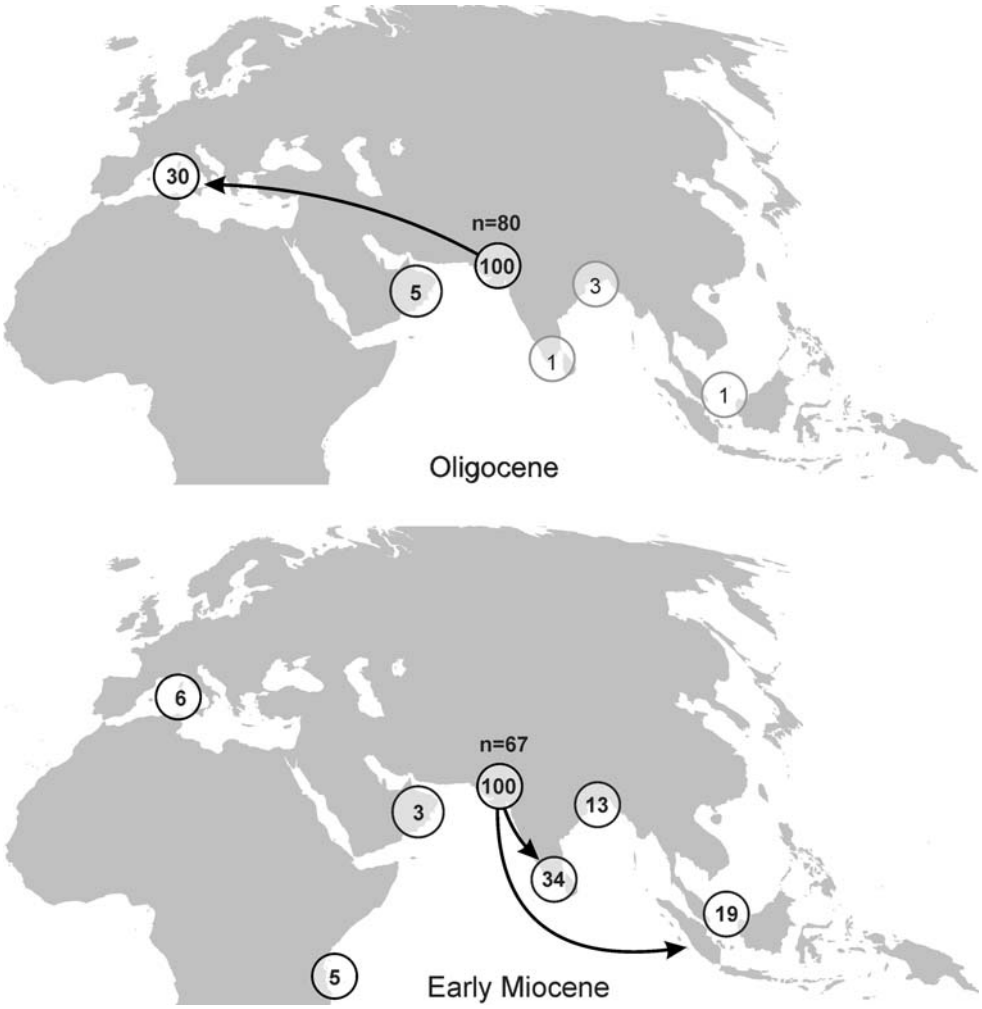

Fig. 6 Faunistic relations of the NW Indian and Pakistani gastropod assemblages with adjacent bioprovinces. Numbers in *circles* represent percentages of Indian and Pakistani species recorded in the various faunas. *Oligocene*: The fauna is based on the Rupelian assemblages from Sindh in Pakistan (Vredenburg 1925, 1928) and the newly described taxa from the Chattian of Kutch. Strong relations with the Western Tethys are indicated by at least 29% of species that occur also in French and Italian faunas. Relations with the rather proximate Oligocene faunas of the Arabian shelf are low. Comparisons with South Indian, NE Indian and Indonesian faunas are based on Early Miocene faunas and are thus less significant. *Early Miocene*: The fauna is based on the records from the Kutch Basin only (this paper and Vredenburg 1925, 1928). Clearly, the western relation dropped significantly, whereas a growing faunistic interrelation with the South Indian and Indonesian faunas is obvious

with the Indian ones. Thus, the interrelations along the northern Tethyan coast predominate. This poor relation with the Omanian assemblages is not understood yet, but may point to a peculiar current pattern. A comparison of these Oligocene faunas with the Indonesian ones is not possible as coeval faunas are unknown from that region. The relation to the Early Miocene Indonesian faunas, however, is extremely low (~1%) (Table 1; Fig. 6).

The Aquitanian fauna of the Kutch Basin are poorly known as well. Only 7 species are documented. Nevertheless, this small assemblage is important as it is the first record of Aquitanian faunas from that area, which usually have been shuffled together with Burdigalian ones. It is remarkable that none of the species is known from the Western Tethys. Only *Zaria angulata* (Sowerby, 1840) reaches as far west as the central Iranian basins (Harzhauser et al. 2002). All others are restricted to the NW-Indian-Pakistani area [*Turbinella premekranica* Vredenburg, 1925; *Protoma deshayesi* (d'Archiac, 1850)] or are widespread in the Proto-Indo-Polynesian province [*Tectus loryi* (d'Archiac & Haime, 1853); *Cerithium rude* Sowerby, 1840; *Zaria angulata* (Sowerby, 1840); *Conus* (*Lithoconus*) *brevis* Sowerby, 1840; *Architectonica affinis* (Sowerby, 1840)].

The sharp break indicates a first severe interruption of the Tethyan gateway, at least concerning the exchange potential of shallow marine molluscs. Simultaneously, the Omanian Aquitanian faunas document a loss of Western Tethys affinities and an opening towards the Proto-Indo-Polynesian Province (Harzhauser 2007).

This picture changes slightly for the Burdigalian. About 67 gastropod species are known from the Burdigalian of the Kutch Basin. Of these, about 6% are also documented from Western Tethyan localities in Italy or France. Closest affinities, however, are documented for South India (~35%) and Indonesia (~20%). Uniting all Early Miocene faunas of the Kutch Basin results in a very similar picture (Fig. 6) and documents a still surprisingly low

affinity with the faunas from Oman. This pattern corresponds to the biogeographic scheme of Harzhauser (2007) who proposes a distinct Western Indian Province (comprising the Sindh and Kutch faunas) that was separated from the Eastern African Arabian Province (comprising faunas from Oman and Somalia).

To conclude, the Chattian gastropod assemblage from the Kutch Basin may be considered as strongly influenced by the Western Tethys, but with a remarkable provincialism. A trans-Tethyan connection, however, was clearly still active and is documented for the Rupelian and Chattian. The faunistic relations are stronger along the northern Tethyan coast, but comparably low across the seaway, judged from the poor similarities with coeval Arabian faunas. The total breakdown of faunistic interrelations during the Aquitanian suggests a major biogeographic separation around ~22 Ma somewhere between Mesopotamia, Arabia and NW India (Harzhauser et al. 2002, 2007). This event predates the development of the so-called *Gomphotherium* landbridge (Rögl 1998) in the Burdigalian by 4–5 Ma and provides an example for biogeographic separation in the marine realm without formation of a continental barrier. Later, during the Burdigalian, the poor affinities with the Western Tethys point to a recurrent, but ineffective possibility for faunal exchange. The take-over by Proto-Indo-Polynesian faunas, however, eclipses the negligible Western Tethyan influence. Finally, the absence of any NW-Indian species in the European record clearly argues against "Indo-Pacific" migrations during the Early Miocene.

Acknowledgments We are greatly thankful to Bernard Landau (International Health Centres, Albufeira, Portugal) and Ronald Janssen (Senckenberg Museum, Frankfurt) for their constructive comments and thorough reviews. P.H. Bhatti (Bhuj) kindly provided the logistic and administrative support in Kutch. M. Stachowitsch (Vienna) checked the English. This study was granted by the FWF Project P-18189-N10: Biogeographic Differentiation and Biotic Gradients in the Western Indo-Pacific during the Late Oligocene to Early Miocene.

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