

Late Paleocene larger conical Agglutinated Foraminifera of the Cauvery Basin, South India

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Abstract

A 35 m-thick section of limestone and marls encountered in the subsurface in an onland well drilled in the southern part of Cauvery Basin, South India, revealed a rich larger foraminiferal assemblage. The presence of well-preserved conical agglutinated genus *Fallotella* Mangin as matrix free specimens has enabled the study of the architectural details through oriented axial sections. Taking into account the scanty and intermittent record of this agglutinated conical genus, possibly due to restricted environmental living conditions, its presence in this basin is considered to be significant. Three species of *Fallotella* are described and illustrated: *F. alavensis*, *F. kochanskae* and a new species *F. cauveryensis*. The record of *Fallotella alavensis* is associated with *Glomalveolina primaeva* Reichel, a zonal index taxon of SBZ-3, and it indicates a Thanetian (late Paleocene) age for this carbonate section. Carbonate sediments were likely deposited in very shallow, warm open marine waters not exceeding 30–40 m water depth during a regressive phase. This is the only confirmed record of *Fallotella* in the southern rim of the eastern Tethys at a palaeolatitude of 15°S. All other reports are from the northern rim of the western Tethys, above palaeolatitude 30°N. In addition to *Fallotella* species, casts of calcareous cemented agglutinated conical specimens with chambers showing buttresses/ vertical partitions are described under a new genus, named *Neovoloshinoides* n.gen.

INTRODUCTION

Several micropalaeontological studies dealing with planktonic foraminifera and larger and smaller benthonic foraminifera are available from Upper Cretaceous and lower Paleogene sediments of the Cauvery Basin, South India. Both agglutinated and calcareous foraminifera are abundant and well represented in the Upper Cretaceous and lower Paleogene fine clastic sediments in this basin. These deep-water agglutinants have been extensively reported from the Tethyan region, and mostly belong to tubular, planispiral and trochospiral groups. A detailed study on these taxa has been recently published (Govindan, 2015). Another group of high conical, uniserial/multiserial agglutinated benthonics is reported exclusively from the Upper Cretaceous – lower Paleogene shallow water carbonates. Their fossil record is intermittent and scanty due to their limited ecological preferences. A chance discovery of large sized high conical agglutinated foraminifera in a carbonate section of late Paleocene age from an exploratory well (Well-A, Fig. 1) in the southeastern part of Cauvery Basin was instrumental for this study. This group has not been previously recorded from this part of the Tethys Ocean. The purpose of this contribution is to describe and illustrate these agglutinated conical specimens belonging to the genus *Fallotella* Mangin and to interpret their age, environmental affinities, and palaeobiogeographical significance.

MATERIALS AND METHODS

The studied exploratory well A (Fig. 1) is in the southern part of the Nagapattinam sub-basin on an inter-basinal high in the southeastern part of the Cauvery Basin. The lower Paleogene, Eocene–Paleocene subsurface section was encountered between 750 and 1920 m at this site. This section chiefly consists of well sorted, clean, calcareous sand, occasionally silty, interstratified in places with carbonate beds of variable thickness at depths of 750 m, 970 m, 1400 m, 1635 m and 1755 m. This sequence yielded calcareous larger benthic foraminifers for biostratigraphic study. The appearance of light greenish to grayish shale, silty shales, and siltstones further down at 1920 m marks the top of the Upper Cretaceous section at this site.

A nearly 35 m-thick carbonate section of pink and white limestone and marls/clays recovered from a measured depth of 1755 m studied through cutting samples is the basis for this study. The studied section lies 165 m above the appearance of Upper Cretaceous sediments at this site. Conventional methods were employed for disintegrating samples. The samples were moderately fossiliferous with well preserved microfauna. Large conical organic-walled agglutinated foraminifers were obtained as free specimens. Other common taxa include *Nummulites*, *Discocyclina*, *Orbitocypeus*, *Nemkovella*, and *Alveolina*.

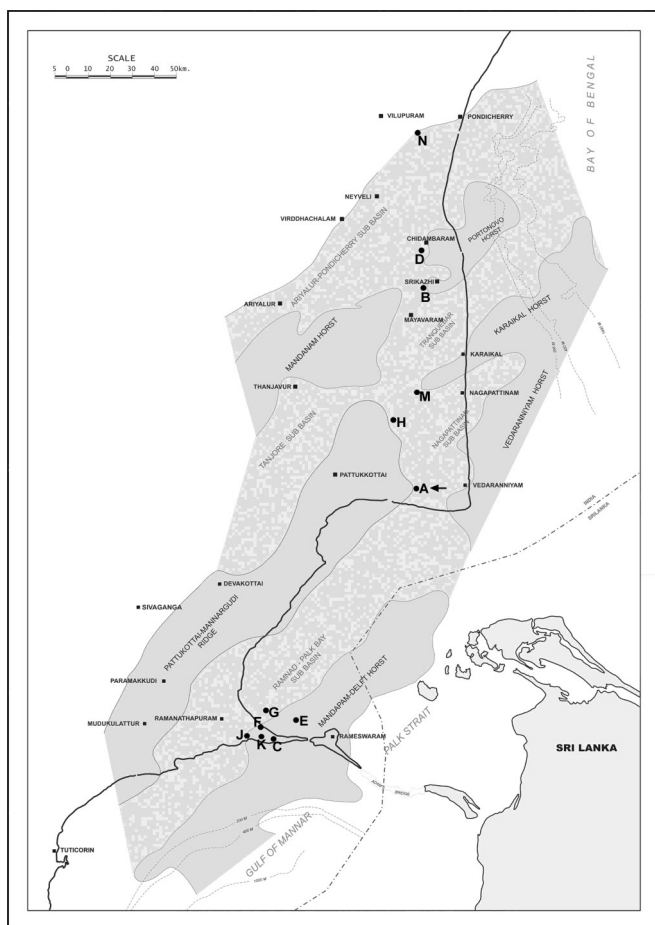


Figure 1. Location map showing well 'A' containing the genus *Fallotella* in the Cauvery Basin, south India.

As these conical taxa were recovered as free specimens, inner details were studied in oriented sections obtained with a fine abrasive in water on a glass plate. Closer to the axial line, the half-cut specimen is mounted on a glass slide for further rubbing with periodical assessment under the microscope. Some broken fragments revealed oblique section details and 'tablet' like fragments from the basal part also revealed further details. The internal structural elements that are visible in the half-cut conical specimens along the axial plane could not be reproduced in thin sections, possibly due to diagenesis. Measurements were made through a calibrated eyepiece.

The described specimens are housed in the collections of Reg. Geol. Lab ONGC, Chennai with the prefix ONGC/RGL/CB/12/16-24; another set is deposited in the author's collection.

Previous Studies on Paleocene Foraminifera of the Cauvery Basin

Rajagopalan (1965) detailed the litho- and biostratigraphic

framework of the exposed Paleocene sediments of Pondicherry area in a standard planktonic foraminiferal scheme. Gowda (1964) published a checklist of planktonic and benthonic foraminifera species from the outcropping Upper Cretaceous – Paleocene sediments of this basin. A detailed account on the larger benthonic foraminifera and planktonic foraminifera from the outcropping sediments of the Pondicherry area was presented and illustrated by Samanta (1967, 1970, 1980). The presence of a few planktonics and benthic foraminifera of late Paleocene age from the exposed carbonates of Tiruchirappoly area was reported by Malarkodi & Nagaraj (1998).

RESULTS

Agglutinated Conical Larger Foraminifera

This groups includes finely agglutinated tests of high conical shape, extending from a trochospiral nepionic stage that grows rapidly into uniserial adult stage with saucer cup-shaped chambers and a flat/convex base. These specimens were identified in thin sections of Upper Cretaceous and lower Palaeogene carbonate sediments. An in-depth study on the architecture of these agglutinated conical specimens for generic/species placement was published by Hottinger & Drobne (1980) and subsequently by Veechio & Hottinger (2007).

The structural details on the conical agglutinants were mainly observed in random thin sections of hard cemented limestone. However, a thin section study without taking into account orientation of the section with respect to the cone mantel line could be misleading (Veechio & Hottinger, 2007). Since the conical agglutinated tests were recovered as free specimens from the limestones and marls, these were examined in oriented axial section. They revealed exoskeleton elements as long radial partitions (beams), short restricted intercalary beams and horizontal partitions (rafters). The endoskeleton exhibits pillars alternating in position and the axial plane passes through the pillars. The megalosphere is centrally positioned close to the apex. Chambers are arranged in a high trochospire in the nepionic growth stage, followed by saucer-shaped uniserial chambers in the adult stage. A thin intercameral foramenal plate with an irregular primary aperture and subcircular secondary apertures communicating between lumen of consecutive chambers was observed. These conical agglutinants are placed in the genus *Fallotella* Mangin.

The conical specimens are restricted to clay/mud-rich, light pink limestones (wackestones), attributed to very shallow marine, warm water conditions, at less than 30–40 metres water depth. The algae reported from the outcropping upper Paleocene carbonates of the Cauvery Basin indicate algal

vegetation cover (Rao & Pia, 1936; Mishra *et al.*, 2001). This suggests that these conical agglutinants had algal symbionts.

In a recent compilation, twenty suspected species belonging to eleven conical agglutinated genera have been listed from the Paleogene of the Tethyan realm by Drobne & Cosovic (2010). Among these, genera *Fallotella* Mangin, 1954, *Karsella* Sirel, 2004, *Coskinon*, Hottinger & Drobne, 1980 are confined to the late Paleocene. The genus *Dictyoconus* Blanckenhorn, 1900 ranges from late Paleocene to Eocene. Each of these genera is represented by a single species. *Fallotella* alone is represented by two species and one subspecies.

Loeblich & Tappan (1987) grouped these agglutinated conicals in the superfamily Orbitolinacea, subfamily Orbitolinidae, which is further subdivided into subfamilies Dictyoconinae and Orbitolininae. The subdivision is based on the embryonic apparatus configuration. In the Dictyoconinae, a simple embryonic configuration with a protoconch and deuteroconch is observed. A more complex embryonic configuration is seen in the Orbitolininae. According to Hottinger (op. cit), the arbitrary subdivision did not give due emphasis to progressive morphological development from a possible ancestor, besides the structural changes in the conical agglutinants.

Associated with *Fallotella*, moderately preserved casts of finely cemented calcareous agglutinated conicals, showing chambers with rows of buttresses/ vertical partitions are mentioned as the new genus *Neovoloshinoides* in this study.

DISCUSSION

This study is the first report on the conical agglutinated larger foraminiferal genus *Fallotella* Mangin, 1954 from the upper Paleocene limestones and marls in the Cauvery Basin. The age of this carbonate subsurface section is late Paleocene (Thanetian), correlatable to *Glomalveolina primaeva* biozone and to standard biozone SBZ-3 of Serra-Kiel *et al.* (1998) (Table 1). This is deduced from the associated taxa *Glomalveolina primaeva* Reichel, *Glomalveolina levis* Hottinger, *Discocyclus seunesi* Douville, *Orbitoclypeus ramaraoi* (Samanta) and *Nemkovella stockari* Less. Deposition of late Paleocene carbonate sediments in shallow restricted conditions is inferred. In a depositional gradient from very shallow to deeper waters, the agglutinated conicals are the first large benthonic assemblage to occur at very shallow depths (Veechio & Hottinger, 2007). An assemblage of agglutinated conicals of Thanetian age from several localities in Slovenia was documented in detail by Hottinger & Drobne (1980). Since then, this conical assemblage has attracted

the attention of micropaleontologists. The species such as *Fallotella alavensis* Mangin, *F. kochanskae* Hottinger & Drobne, *Glomalveolina primaeva* Reichel and *Discocyclus seunesi* Douville reported from Slovenia are present in the limestones and marls in Cauvery Basin at a corresponding age.

In the Shiraz section of the Zagros mountain range, Iran, Rahaghi (1983) reported *Fallotella alavensis*, *F. kochanskae* besides *Glomalveolina primaeva* and *Discocyclus seunesi* from the upper Paleocene carbonates. This fauna is similar to that of the Cauvery Basin record. A striking resemblance in the fauna between these two regions is the presence of *Spirolina* (Pl. 2, fig. 11, in this study) though rare in the studied samples. Hence the depositional conditions seem to be less restricted, with an intermittent access to open marine shallow waters with an increase in oligotrophic conditions at this level.

A checklist of species inclusive of larger agglutinated conicals such as *Karsella hottingeri* Sirel, *Fallotella kochanskae persica* Hottinger & Drobne (later re-designated as *Dictyoconus baskilensis* Sirel, 2008), besides *Discocyclus seunesi* Douville, *Glomalveolina primaeva* Reichel, *Miscellanea yvettiae* Leppig and several new genera/species such as *Haymanella paleocenica* Sirel, *Orduella sphaerica* Sirel, *Kayseriella decostroi* Sirel and *Elazigella altiners* Sirel, were reported by Sirel (1998, 1999, 2009) from the Paleocene carbonates of Turkey. Sirel's (op.cit) study is based mainly on thin section details of hard cemented limestone from different sections. Except for few age diagnostic species such as *Glomalveolina primaeva* and *Discocyclus seunesi* of this region, the rest of the species could not be recognised from the Cauvery Basin.

While studying several sections in Apulian and Preapulan platform from central southern Turkey and Ionian Islands Greece, larger foraminiferal assemblage of SBZ-3 and 4 of late Paleocene age represented by *Fallotella kochanskae*, *Glomalveolina primaeva*, *Idalina sinjarica*, *Fallotella alavensis* and *Orbitoclypeus ramaraoi* were reported by Pignatti *et al.* (2008). This assemblage closely corresponds with that of the Cauvery Basin. The carbonate facies and associated assemblage containing conical agglutinants and other taxa indicates a less restricted very shallow warm open marine water in a regressive phase in the studied site.

Afzal *et al.* (2010) reported *Fallotella alavensis*, *Coskinon rajkae*, *Vania anatolica*, *Miscellanea juliettae* and other forms from Indus Basin in Dungan Formation. Many species recorded through thin section details from the suspected upper Paleocene carbonates could not be recognised in the Cauvery Basin.

Table 1. Distribution of shallow benthics in SBZ-3 (Serra-Kiel et al. 1998)

Foraminifera	Turkey Sirel (2009)	Italy Pignatti and others (2008)	Slovenia Hottinger and Drobne (1980)	Iran Shiraz Area Rahaghi (1983)	Cauvery Basin, South India Present Study
<i>Glomalveolina primaeva</i>	•	•		•	•
<i>Nummulites heberti</i>	•				
<i>Ranikothalia bermudezi</i>	•				
<i>Discocyclus seunesi</i>	•			•	•
<i>Discocyclus tenuis</i>					
<i>Orbitocyclus schopeni ramaraoui</i>		•			•
<i>Cribobulimina carniolica</i>			•		
<i>Coskinon rajkae</i>		•	•		
<i>Fallotella alavensis</i>		•	•	•	•
<i>Vania anatolica</i>	•	•			
<i>Vania labyrinthica</i>					
<i>Globoflarina sphaeroidea</i>	•			•	
<i>Pseudononion. sopadensis</i>					
<i>Helenaalveolina rahaghi</i>					
<i>Periloculina slovenica</i>					
<i>Pseudolacazina oeztemueri</i>	•				
<i>Idarina sinjarica</i>		•			•
<i>Redmondina hennigtoni</i>					
<i>Thalmanita madrugensis</i>	•				
<i>Cuvillerina sireli</i>	•				
<i>Pseudomiscellanea primitiva</i>				•	
<i>Miscellanea yvettae</i>	•				•
<i>Lockhartia haimei</i>					•
<i>Kathina subsphaerica</i>					
<i>Fallotella kochanskae*</i>		•	•	•	•
<i>Dictyoconus turriculus*</i>			•	•	

* Not in Serra-Keil table

Late Palaeocene – Early Eocene Tethyan Carbonate Platform

In a synthesis of late Paleocene – early Eocene Tethyan carbonate platform evolution, three stages were distinguished based on the palaeobiogeographical distribution of carbonate platform builders such as corals and larger foraminifera (Scheibner & Speizer, 2008). The stages are: (1) coral algal reef stage in the late Paleocene at low palaeolatitudes less than 20° S, (2) a transitional stage with coralgal reefs at mid latitudes (20° – 30°S), while larger foraminifera shoals dominate in at low latitudes during the latest Paleocene, and (3) a final evolution stage coinciding with the proliferation of nummulitids and alveolinids in the Tethys in the earliest Eocene at middle palaeolatitudes above 30°S. The reported carbonate platforms of middle palaeolatitudes

are all along the northern rim of the Tethys, while those from the intermediate (30°S – 20°S) and low (20° – 0°S) palaeolatitudes are on the southern rim of the Tethys.

The reported occurrences of *Fallotella alavensis*, a marker species of SBZ-3 of Thanetian age are all in the northern rim of the Tethys in the coral algal reef stage. The present report of *F. alavensis* in the Cauvery Basin, is the only record at a low palaeolatitude of about 15°S in the southern rim of this part of the Tethys (Fig. 2). The fossiliferous, mud- and clay-rich limestone (wackestone) encountered in the subsurface at the studied location probably represents the inner margin of the late Paleocene carbonate ramp at a time interval coinciding with the prominent sea level fall in the late Paleocene (Haq *et al.* 1987). The upper Paleocene carbonates exposed as disconnected outcrops in the western

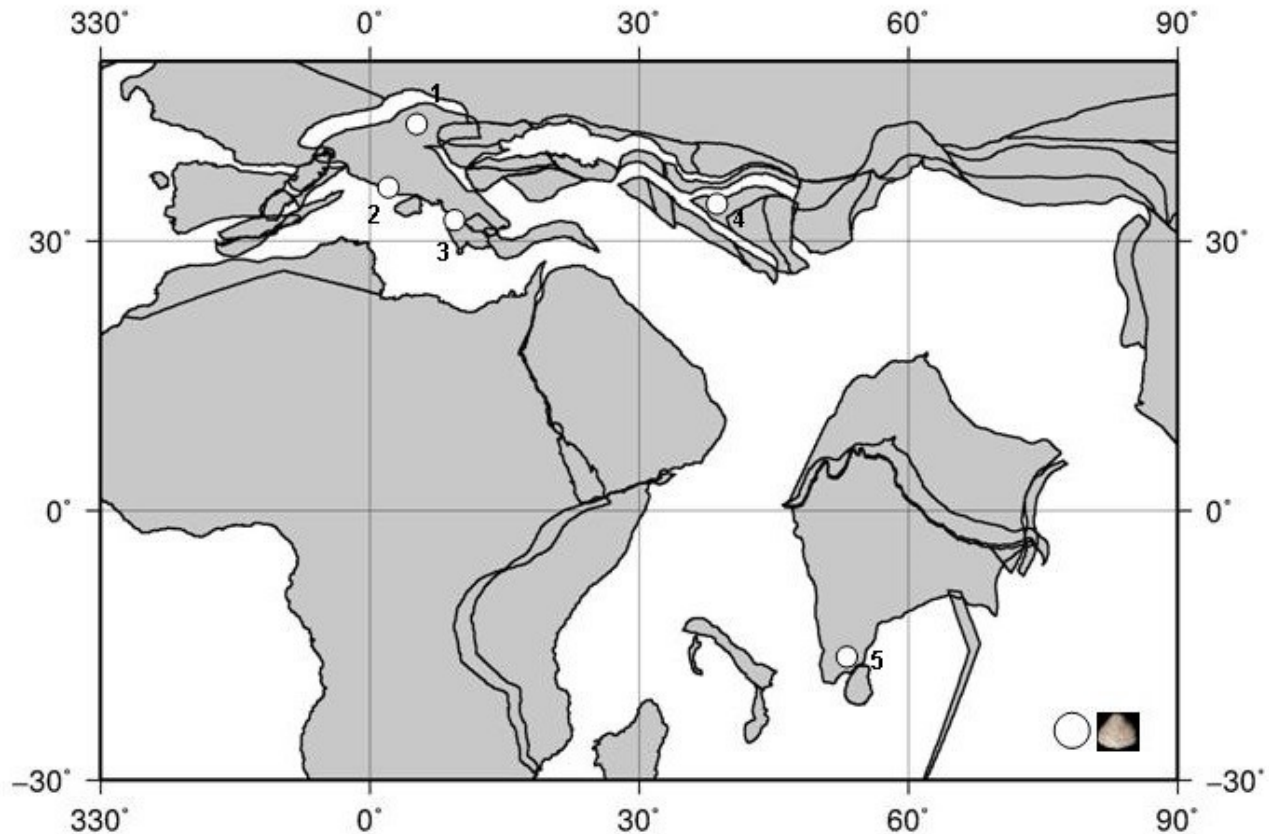


Figure 2. Distribution of the agglutinated conical foraminiferal genus *Fallotella* in the Thanetian (late Paleocene) in the 55 Ma Paleomap constructed (<http://www.ods.de/ods/services/paleomap/paleomap.html>) 1. Slovenia (Hottinger & Drobne 1980), 2. Maiella Platform, Italy (Pignatti *et al.* 2008), 3. Greece (Di Carlo *et al.* 2010), 4. Iran (Rahaghi, 1983) 5. Cauvery Basin, India (this report) source: Scheibner & Speijer (2008).

margin of the Cauvery Basin are characterised by encrusting coralline algae as the main contributor for reefs bio-construction (Misra *et al.* 2002). The contributions from the corals seem to be minimal in this basin. It is likely that some areas in the basin witnessed corallgal bioherms in late Paleocene. These were drowned probably towards the end of the Paleocene and subsequently covered by hemipelagic marls containing planktonic foraminifers and discocyclinids as recorded in the Pondicherry area in this basin (Samanta, 1967, 1970).

SUMMARY

Limestone and marls from a 35 m-thick subsurface section in an onshore well (Fig. 1, Well A) from the southern part of Cauvery Basin revealed the presence of the conical agglutinated genus *Fallotella* as matrix-free specimens. These were studied in oriented axial section. The species *Fallotella alavensis*, *Fallotella kochanskae*, a new species *Fallotella cauveryensis* and a new conical agglutinant genus *Neovoloshinoides* with type species *Neovoloshinoides lukasi* are described and illustrated. Reports on these forms were not previously known beyond the Mediterranean region, Zagros

Mountains of Iran, and the Indus Basin, Pakistan. Considering their scanty and intermittent record due to their limited ecological preferences, this find is significant. In addition to agglutinated conicals, the other taxa present include *Glomalveolina primaeva*, *G. levis*, *Discocyclina seunesi*, *Orbitoclypeus ramaraoui*, *Nemkovella stockari*, *Nummulites globulus*, *Miscellanea* sp. aff. *M. yvetteae*, *Lockhartia haimeii*, *Idalina sinjarica*, *Sphaerogypsina globulus*, *Spirolina* sp. and *Assilina* sp. (Govindan, 2013). The precise age of this carbonate section deduced by the occurrence of *Fallotella alavensis* Mangin, *Fallotella kochanskae* Hottinger & Drobne, *Glomalveolina primaeva* Reichel, *Glomalveolina levis* Hottinger, and *Discocyclina seunesi* Douville is Thanetian (late Paleocene) correlatable to biozone SBZ-3 of Serra-Kiel *et al.* (1998) and to standard Planktonic Zone P4. The presence of these conical agglutinants and associated taxa suggests that these carbonates were deposited in shallow, less restricted, warm open marine waters not exceeding 30 – 40 m water depth in a shelf setting under regressive conditions. The presence of a few forms of *Spirolina* with larger agglutinated conicals in this section also indicates a restricted shallow marine carbonate environment (Vecchio

& Hottinger, 2007). The occurrence of the genus *Fallotella*, a late Paleocene conical foraminifer, in the carbonates of this basin is the only record on the southern rim of the eastern Tethys at a palaeolatitude of about 15°S. The other reports are mostly from the northern rim of the western Tethys above 30°N. The limestones containing the agglutinated conical specimens and other benthic foraminifera were possibly deposited at the inner margin of a carbonate ramp running parallel to the palaeo-coastline in this part of the basin during the late Paleocene-Eocene.

SYSTEMATIC PALEONTOLOGY

Order FORAMINIFERIDA Eichwald, 1830

Superfamily ORBITOLINACEA Martin, 1890

Family ORBITOLINIDAE Martin, 1890

Subfamily ORBITOLININAE Martin, 1890

Genus *Fallotella* Mangin, 1954

Type species. *Fallotella alavensis*, Mangin, 1954

Fallotella alavensis Mangin, 1954

Plate 1, figs 8–9, 10a,b; Plate 2, Fig. 4

Fallotella alavensis MANGIN, 1954, p. 209, pl. 3, figs 1–6, text-figs 1–3. – HOTTINGER & DROBNE, 1980, p. 50, pl. 2, figs 1–3, pl. 14, figs 1–27, text figs. 2, 5. – RAHAGHI, 1983, p. 28, pl. 2, figs 1–5.

Description. Tests are of moderate size, high conical, subcylindrical with finely agglutinated outer wall. Chambers are trochospiral in the initial stage with a spherical protoconch, hemispherical deutoconch, followed by 4 to 5 hemispherical chambers. Later, chambers are uniserial, saucer shaped about 7–8 chambers per mm in the axial cone length with a maximum of 18–20 chambers in the axial length. Exoskeleton is simple with short radial partitions (beams) approximately as thick as that of marginal wall. There are 28 to 32 alternating radial partitions in a cone of 3 mm diameter. Intercalated vertical partitions are short confining to the base of the chamber. The apertural face at the base is flat to gently convex. Horizontal partitions (rafters) are in the middle of the chamber as thick epiderm. Endoskeleton consists of pillars seen as rounded mounds at the base of the chamber. These are irregular in shape in the horizontal section. Wall finely agglutinated with minute silica as outer coating over the thick carbonate layer. There are 6–8 marginal subcircular apertures.

Basal diameter ranges between 2.0 – 3.0 mm and maximum height in the axial cone ranges from 2.5 – 4.3 mm. The apical angle close to the apex is about 10°. The ratio between the axial cone length and basal diameter is 5:4.

Remarks. *Fallotella alavensis*, originally reported from Slovenia, has been widely recognised as a marker species of the late Paleocene. It has been recorded from Iran, Spain, Slovenia and Greece. It is restricted to *Glomalveolina primaeva* zone as a marker species for the SBZ-3 biozone (Serra-Kiel *et al.* 1998) in the western Tethys. The present report from the Cauvery Basin, South India confirms its wider geographical existence in this part of the Tethys. Generally, all specimen observed in this study are well developed adult forms larger than those reported elsewhere.

Fallotella kochanskae Hottinger & Drobne, 1980

Plate 1, figs 1–5; Plate 2, figs 5a-b

Fallotella kochanskae HOTTINGER & DROBNE, 1980, p. 238, pl. 2, fig. 4, pl. 15, figs 1–14, text fig. 2. – RAHAGHI, 1983, p. 29, pl. 2, figs 6–9.

Description. Tests are of moderate size, high conical with finely agglutinated wall. Chambers initially close to the apex are trochospiral with a spherical protoconch and hemispherical deutoconch followed by 5 to 6 chambers in a high spiral. Later chambers are saucer shaped, uniserially arranged 7–8 per mm in the axial cone length. Sutures faintly depressed to nearly flush with the surface. The exoskeleton consists of simple radial partitions in alternation (beams) of about 7 to 8 per quadrant at the base in a cone of 3.1 mm diameter. Secondary partitions are short at the base of the marginal chamber cavity. Several vertical partitions (rafters) together with the radial partitions (beams) divide the marginal chamber cavity into alveolar compartments. The endoskeleton consists of pillars alternating in position from one chamber to another. Behind the minute sand grain coated thin agglutinated wall a thick imperforate calcareous layer is observed.

Basal diameter ranges between 3.1 and 4 mm and the height of the cone from apex to middle of the base is 3.5 – 4.5 mm. The ratio between the axial length and the basal diameter is 7:6. The apical angle close to the apex ranges between 15° – 20°.

Remarks. This species is originally reported from Slovenia from the middle Paleocene in *Glomalveolina primaeva* Zone. The structural elements are somewhat closely spaced in *F. kochanskae* in contrast to *F. alavensis*. Furthermore, the subcylindrical cone outline of *F. alavensis* distinguishes it from the broadly subconical test of *F. kochanskae*.

Originally reported from the Golez section, Slovenia, and subsequently reported from the Mediterranean region and in the Shiraz section, Zagros Mountains, Iran. The present

wider geographical existence in this part of the Tethys. Generally, all specimen observed in this study are well developed adult forms larger than those reported elsewhere.

***Fallotella kochanskae* Hottinger & Drobne, 1980**

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Originally reported from the Golez section, Slovenia, and subsequently reported from the Mediterranean region and in the Shiraz section, Zagros Mountains, Iran. The present report from the Cauvery Basin, South India, confirms its wider geographical presence beyond the western Tethys. All studied specimen are larger than those reported elsewhere.

***Fallotella cauveryensis* Govindan n.sp.**

Plate 1, figs 6a–c, 7; Plate 2, figs 1a–c, 2, 3

Derivation of Name. Named after the holy river Cauvery

flowing through this basin.

Description. Tests are of moderate large size, high conical with finely agglutinated thin outer wall and imperforate thick calcareous inner wall. Megalosphere is centrally positioned at the apex. In the initial growth stage chambers are trochospiral consisting of large spherical protoconch and nearly hemispherical deutoconch followed by 8–9 hemispherical chambers in 1½ – 2 whorls. In the later stage the chambers are saucer shaped, uniserially arranged extending from the center towards the periphery. Chambers are mostly continuous and rarely discontinuous at some places. There are 16 – 20 uniserial chambers at the axial cone length. Sutures flush to faintly depressed. In the exoskeleton the main partitions (beams) are 7 – 8 per quadrant at the base in a cone of 4.0 mm diameter. Secondary partitions are as long as in primary partitions at the basal part of the marginal chamber cavity perpendicular to the chamber septum subdividing it into alveolar compartments. The endoskeleton consists of pillars alternating in position from one chamber to another. In the axial section the plane is passing through 8 – 10 pillars in a test of about 4 mm diameter. A thin intercameral foramen plate with primary “tuning fork” like aperture and 6 – 8 circular secondary apertures are present providing intercommunication between lumina of consecutive chambers (see Pl. 2 fig. 5). It is evident during sectioning.

Basal diameter ranges between 4.1 and 4.5 mm and the height of the cone from apex to middle of the base is from 3.5 to 4 mm. The ratio between the axial length and basal diameter is 7 : 8. The apical angle close to the apex between 30° and 35°.

Remarks. This species differs from *F. avalensis* and *F. kochanskae*, in the high trochospiral megalosphere, in less number of septa in axial cone length, in revealing of an off centred primary irregular foramen and 6–8 circular secondary foramina for inter communication across chamber lumen and in the greater basal cone diameter to that of axial cone length. Further the greater apical angle of 30° to 35° at the apex is also a distinguishing feature.

The test is well represented as matrix free specimens in the studied samples. It is seen in association with *F. alavensis*, *Glomalveolina primaeva*, *G. levis* and *Discocyliina seunesi* which favours firmly placing it in the Thanetian (late Paleocene) in the SBZ-3 biozone of Serra-Kiel *et al.* (1998).

Type locality. Subsurface well sample at a measured depth of 1775 m in an onland well ‘A’ in the Cauvery Basin, South India.

Type Level. Late Paleocene.

Holotype. Pl 1. Figs. 6a-c ONG/RGL/CB/012/16.

Paratype. Pl. 2. Fig. 1a-c ONG/RGL/CB/012/17.

CONICALS IN CASTS

Superfamily LITUOLACEA de Blanville, 1825

Family ATAXOPHRAGMIIDAE Schwager, 1877

Subfamily PERNERININAE Loeblich & Tappan, 1984

Neovoloshinoides Govindan, n.gen.

Plate 2, figs 6, 7a-b; Text-fig. 1a-b.

Type Species. *Neovoloshinoides lukasi* Govindan n.sp.

Derivation of Name. Since this suspected genus evolved from the upper Cretaceous ancestor *Voloshinoides*, designated its record in the Paleocene as *Neovoloshinoides*.

Description. Test high conical, subcylindrical, finely agglutinated. Chambers trochospirally enrolled in the initial end, probably quadriserial, with 3–4 chambers in the later whorls. Intercameral sutures distinct, depressed, oblique to the axis of growth in the last 4–5 whorls. Chambers distinct, broad and low in the adult stage and indistinct in the early stage. Surface with a row of elongated buttresses/ partitions giving rise to chamberlets. Aperture a broad low narrow arch, interiomarginal, at the base of the flat apertural face.

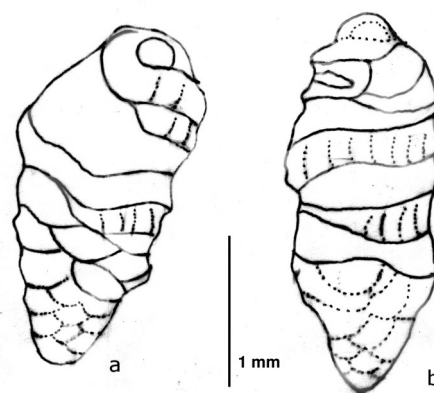
Remarks. This form differs from the closely similar genus *Voloshinoides* Barnard & Banner in its size, in the nearly conical subcylindrical shape, in the presence of a row of buttresses/partitions and in the broad low arch like interiomarginal aperture at the base of the flat apertural face. The presence of buttresses/ partitions in a row extending from the floor upward towards the roof of the chambers in this conical subcylindrical agglutinated cast places this taxon in the subfamily Pernerininae in the family Ataxophragmiidae. The stratigraphic range of this conical form in the studied sample is late Paleocene.

Neovoloshinoides lukasi Govindan, n.gen. n.sp.

Plate 2, figs 6, 7a-b; Text-fig. 1a-b.

Derivation of Name. The species name is dedicated to Dr. Lukas Hottinger in recognition of his fundamental contributions to foraminiferal research.

Description. The cast is of moderate size, elongate with a tapering end. It is nearly subcylindrical with a marginal



Text-Fig. 1a-b. *Neovoloshinoides lukasi* n.gen. n.sp. Camera lucida drawing of external shape of abraded specimen showing internal partitions and chamberlets.

increase in breadth near the apertural end. It is subcircular in cross section with a faintly lobulate periphery. Initially chambers are indistinct, trochospirally enrolled and probably quadriserial. There are 3 to 4 chambers in the final 4 to 5 whorls. These are broad and low, faintly raised, progressively increasing in size with growth. Intercameral sutures are distinct, depressed at oblique angle to the axis of coiling. Wall is finely agglutinated with a more calcareous cement and test less hard. The surface covered with a row of buttresses/ partitions at the base of the chamber extending upward towards the roof. Even if the buttresses were lost due to abrasion, its presence is still felt by the subparallel vertical partitions on the surface dividing the chamber into chamberlets. In the abraded specimen (Pl. 2, fig. 7) the subparallel vertical partitions are distinct. The aperture is a broad low arch interiomarginal at the base of the last chamber. The length of the specimen ranges from 2.1 to 2.8 mm; breadth between 1 and 1.5 mm

Remarks. These conical forms, though in casts, are of taxonomic significance as these are seen in the late Paleocene. On the other hand the genus *Voloshinoides* is found to be restricted to the Upper Cretaceous. It suggests the genus *Voloshinoides* is the direct ancestor from which this species evolved in the Paleocene. No other conical agglutinated taxa having buttresses/ partitions have yet been reported from the Paleocene. A certain possibility exists to come across these forms in tests/ shells later in this basin and elsewhere at this stratigraphic level.

Type locality. Subsurface sample at 1800 m in an onland well A (Fig. 1) in the Cauvery Basin, Tamil Nadu, South India.

Type Level. Late Paleocene *Glomalveolina primaeva* zone – SBZ-3 Biozone.

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Plate 1

- Figs. 1 – 5. *Fallotella kochanskae* Hottinger & Drobne
- Figs 1. Half cut megalosphere test external surface under incident light. Note convex cone base; initial trochospiral coil nepiont; septum distinct at distal end marginal apertures and pillars irregular diagonal, x12.
- Figs. 2 – 4. Oriented axial sections showing exoskeleton and endoskeleton structural elements (beam) short horizontal partitions (rafters) and pillars, x12.
- Figs. 5. Slightly oblique external view of the test showing basal radial partition (beam), rafter, marginal apertures, pillars, convex cone base, x12. ONG/RGL/CB/012/17
- Fig. 6 – 7. *Fallotella cauveryensis* n.sp.
- Figs. 6a-c. External (6a), cone base (6b) and apical view (6c) of the test; Note low conical shape, high trochospiral initial nepiont, uniserial adult chambers, markedly increasing in circumference, convex cone base, beam and pillars and marginal apertures, x7. ONG/RGL/CB/12/17
- Figs. 7. Half cut axial section view of the test. Note concentric rows of saucer shaped uniserial chambers, thick septum, irregular beams, short pillars, marginal apertures, x8.
- Figs. 8 – 10. *Fallotella alavensis* Mangin
- Fig. 8. Axial section; high conical shape, initial nepiont missing, pillars irregular subcircular marginal apertures, x12.
- Fig. 9. External view of the test; megalosphere is centrally positioned at the apex, radial beam in alternation, pillars irregularly aligned sub parallel, thick septum, uniserial chambers in the adult stage, x11.
- Figs. 10a-b. Slightly oblique external inner view close to the base (10a) and external outer view of the same (10b), x22.

Plate 2

- Figs. 1–3. *Fallotella cauveryensis* n.sp.
- Figs 1a-c. External (1a), basal (1b) and apical (1c) views; High trochospiral initial chambers in 1 ½ to 2 whorls, chambers uniserial, septum thick concentric, mostly continuous, beams and pillars, radial partitions and marginal apertures. x12. ONG/RGL/CB/12/16
- Figs 2. External view of the cone base showing exoskeletal and endoskeletal structural elements. x30.
- Figs. 3. Thin section close to the base, Note large irregular ‘tuning fork’ like primary foramen and scattered circular secondary foramina for intercommunication across lumen. x11.
- Fig. 4. *Fallotella alavensis* Mangin
- External view of a fragment of longitudinal oblique test. Note pillars, beam, intercalary beams, thick septum. x15.
- Fig. 5a-b. *Fallotella kochanskae* Hottinger & Drobne
- Inner view of the test cut along Axial line (5a) and other side view of the same (5b) showing structural elements. x12
- Figs. 6 – 7. *Neovoloshinoides lukasi* n.gen. n.sp.
- Fig 6. Holotype ONG/RGL/CB/12/18 Fig 7. Paratype, ONG/RGL/CB/12/19 7a-b side views. High conical subcylindrical agglutinated cast, low interiomarginal aperture. Interchamberal suture oblique to the growth axis. Slightly raised buttresses, sub parallel vertical partitions on the broad low chambers distinct in abraded surface, apertural end slightly broken. Fig 6. x20, Fig. 7. x25.
- Figs. 8-10. *Glomalveolina primaeva* Reichel
- Fig. 8. External view of nearly spherical tests. index of elongation 1 to 1.1. x9. ONG/RGL/CB/011/12 and 13
- Fig. 9. Equatorial section x12. ONG/RGL/CB/011/14
- Fig. 10. Axial section x12.
- Fig. 11. *Spirolina* sp. x12. ONG/RGL/CB/011/11

