

λ depends slightly on the trajectory under focus. We then have to average over many different points on the same trajectory to get a true value of λ . After a time t , the discrepancy grows to

$$\|\lambda(t)\| = \|\lambda_0\|e^{\lambda t}.$$

Let a be the measure of our tolerance, i.e. if a prediction is within a of the true state, we consider it acceptable. Then our predictions become intolerable when

$$\|\delta(t)\| \geq a, \text{ occurring at a time}$$

$$t_{\text{horizon}} \sim 0\left(\frac{1}{\lambda} \ln \frac{a}{\|\lambda_0\|}\right).$$

Thus the landslide in the Ambootia Tea Estate may be an instance in point when

$$\|\delta(t)\| \text{ became } > a.$$

No matter how hard we work to reduce the errors in the initial measurement, we cannot predict the occurrence of the landslide at Ambootia longer than a few multiples of $1/\lambda$. It might explain the apparent regularity in the landslides of Ambootia. Obviously computer-aided analyses of the database collected would help enumerate the exact multiple of $1/\lambda$. The exercise has to be repeated every time after the landslide takes place. From the management point of view, therefore, the disaster management team may have enough time to prepare for the proposed response system to save human life and prevent other damages as much as possible.

Finally, it is pertinent to point out with reference to the model used, that the system discussed above being dissipative ($V_t = V_0 e^{-(\sigma+1+b)t}$), any phase volume will exponentially shrink fast. Quasiperiodicity is possible only on the phase space of a torus.

$$d\theta_1/dt = f_1(\theta_1, \theta_2),$$

$$d\theta_2/dt = f_2(\theta_1, \theta_2),$$

where f_1 and f_2 are periodic in both the arguments.

(A torus will be given by a simple model of a coupled oscillator:

$$d\theta_1/dt = w_1 + K_1 \sin(\theta_2 - \theta_1),$$

$$d\theta_2/dt = w_2 + K_2 \sin(\theta_1 - \theta_2),$$

where the symbols have the obvious meanings.)

The volume of the torus in a dissipative system will eventually become zero and quasiperiodicity is thus impossible.

1. Roeser, T., Chicago flood's lessons – Privatize. *Wall Street J.*, 28 May 1992, p. 38.
2. Burton, T. and Gibson, R., Repairing Mississippi levees to be costly but system is unlikely to improve. *Wall Street J.*, 26 July 1993, p. A3.
3. Miller, G., Debt management networks. *Public Adm. Rev.*, 1993, **53**, 50–58.
4. Mosekilde, E., Aracil, J. and Allen, P. M., Instabilities and chaos in non-linear dynamic systems. *Syst. Dyn. Rev.*, 1988, **4**, 14–55.
5. Priesmeyer, H. R., *Organisation and Chaos: Defining the Methods of Non-linear Management*, Quorum Books, Westport, Conn., 1992.
6. Rugina, A., Principia Methodologica 1: A bridge from economics to all other natural sciences – towards a methodological unification of all sciences. *Int. J. Soc. Econ.*, 1989, **16**, 3–76.
7. Mandelbrot, B. B., *The Fractal Geometry of Nature*, Freeman, New York, 1977.

Received 21 December 2006; revised accepted 28 December 2007

Fossil pteropods (Thecosomata, holoplanktonic Mollusca) from the Eocene of Assam–Arakan Basin, northeastern India

Kapasa Lokho and Kishor Kumar*

Wadia Institute of Himalayan Geology, 33 General Mahadeo Singh Road, Dehradun 248 001, India

A small collection of fossil pteropods, including some unidentified species, provisionally referable to the families Limacinidae, Creseidae, and Clioidae (?) is reported from the late Middle Eocene–Late Eocene beds of the Upper Disang Formation exposed near the town of Pfutsero, Phek District, South Central Nagaland (Assam–Arakan Basin, northeastern India). This is the first record of fossil pteropods from this part of India. Although based exclusively on juvenile or incompletely preserved adult shells, documentation of this collection is important from the viewpoint of biostratigraphy as well as palaeoecology. The occurrence of pteropods in the Upper Disang Formation indicates deposition in an open marine basin above the aragonite compensation depth. The combined assemblages of pteropods and previously reported uvigerinid foraminifers from the Upper Disang Formation indicate a palaeobathymetry of ~500 m, i.e. upper bathyal zone, and a tropical–subtropical climate.

Keywords: Assam–Arakan Basin, Disang Group, Eocene, Mollusca, pteropoda.

PTEROPODS or holoplanktonic gastropods (Mollusca), commonly referred to as sea-butterflies because of their parapodia, resembling wings or fins, are an extant group

*For correspondence. (e-mail: kumark@wihg.res.in)

of small-sized (range 1–40 mm), exclusively marine gastropods adapted to pelagic life^{1–3}. They are widespread in the present world oceans and seas, but fossil records of shelled pteropods are relatively poor, primarily because their thin and fragile aragonitic shells are more susceptible to chemical and mechanical damage in comparison to calcitic skeletal remains of other marine organisms like foraminifers². Pteropod remains are scarce in Palaeogene beds, though they have been recorded from the older Tertiary beds of Australia^{4,5}, Europe^{6–10}, North America^{11–13} and USSR^{14–16}. Their first occurrence as known to date is in the latest Palaeocene of Europe⁸ and North America¹⁷. In India, Tertiary pteropods were first noticed in the Eocene Anklesvar Formation (western India)¹⁸, but no further work was carried out. Most studies have been limited to the Quaternary and Recent sea bed sediments^{19–22}.

Here we report a small collection of fossil thecosomatus (shelled) pteropods from the Eocene sediments of the Assam–Arakan Basin, northeastern India. The fossil material consists of shells of limacinoids (juvenile) and cavolinioids (protoconchs and some incomplete adult shells). It was recovered from the late Middle Eocene–Late Eocene beds of the Upper Disang Formation exposed near the town of Pfutsero, Phek District of Nagaland (northeastern India). Prior to this, the only systematic report of Cenozoic pteropods from the Indian subcontinent was from the Ghazij shales (Eocene) of the Zinda Pir section in Pakistan²³. Whereas the material from Pakistan included only limacinoids, our collection from northeastern India is more diverse and is comprised of coiled and uncoiled pteropods (Limacinoidea and Cavolinoidea). This occurrence might be of importance for palaeoecological considerations because the distribution of pteropods is influenced by environmental factors such as water temperature, salinity, depth, oxygen content, etc.

Nagaland is part of the Assam–Arakan Basin, which is believed to have evolved through the collision of the Indian, Eurasian and Burmese plates. The Naga Schuppen Belt and the Kohima–Patkai folded zone are the major geotectonic units of Nagaland^{24,25}. The former is an imbricate thrust zone, predominantly consisting of Oligocene and younger sediments, whereas the latter comprises a huge pile of Eocene (Disang Group) and Oligocene (Barail Group) deposits²⁶. The Disang Group (>3000 m thick) is subdivided into two formations: the Lower Disang Formation consisting of dark grey argillaceous shales intercalated with thin bands of grey siltstone or fine-grained sandstone, and the Upper Disang Formation with arenaceous dark grey splintery shales intercalated with sandy shales and siltstones²⁷. The Disang Group shows a gradual transition into the overlying Barail Group²⁵. Based on planktic foraminifers, the Upper Disang Formation is considered to be of latest Middle Eocene to Late Eocene age²⁸.

The pteropods recorded here were recovered from test samples taken from outcrops at three localities, namely

Leshemi (25°32'10"E, 94°14'05"N), Pfutsero (25°34'03"E, 94°17'43"N) and Chobama (25°33'43"E, 94°19'27"N), all situated in the Phek District (Figure 1). Pfutsero, the sub-divisional headquarter of Phek District, is situated about 70 km southeast of the state capital Kohima and about 150 km from the town of Phek. The fossiliferous, pteropod-bearing horizon is nodular/concretionary or silty shale in the Upper Disang Formation (Figure 2). The fossils were concentrated by disintegrating the shale by means of hydrogen peroxide and/or ammonia solution, followed by screen-washing. Other groups of fossils recovered together with the pteropods include foraminifers (planktic as well as benthic), benthic marine gastropods and bivalves.

The pteropod remains recovered so far from the Upper Disang Formation are fairly common, but represent exclusively juvenile and/or incomplete shells. Among the presently available specimens, two superfamilies can be distinguished, viz. Limacinoidea (family Limacinidae) with sinistrally coiled shells and Cavolinoidea (families Creseidae and Clioidae?) with straight, uncoiled shells. To identify Limacinoidea to species or even to genus level, adult specimens are essential, preserving their apertural morphology. For the Cavolinoidea adult specimens, preferably retaining their protoconch, are crucial for a generic or specific identification. The present material includes just juvenile limacinids. In the case of cavolinioids isolated protoconchs were found, and a number of adult specimens not preserving their larval shell-parts.

Therefore, identification of the present specimens beyond family level (Limacinidae sp., Creseidae sp. and Clioidae sp.?) is not possible. This can only be attempted when more complete fossils are recovered. Here we illustrate only the representative specimens and note their important features comparing them with closely similar taxa. All specimens referred to herein (WIMF/A) are housed in the Repository of the Wadia Institute of Himalayan Geology, Dehradun (India).

Superfamily Limacinoidea – Limacinidae spp. (1–12, Figure 3): Limacinid pteropods are characterized by their

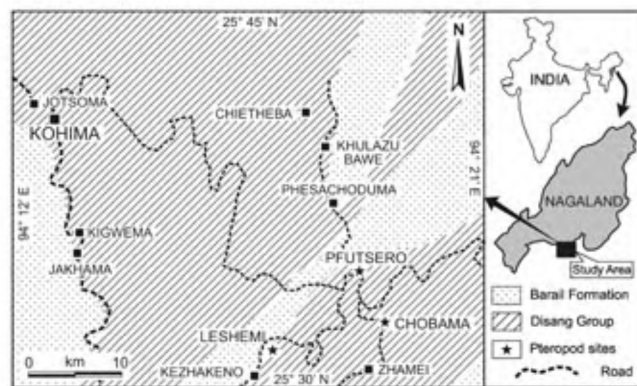


Figure 1. Geological map of the area around Pfutsero (Phek District, Nagaland, northeastern India) showing pteropod-yielding localities. (Modified after Ganju *et al.*²⁵).

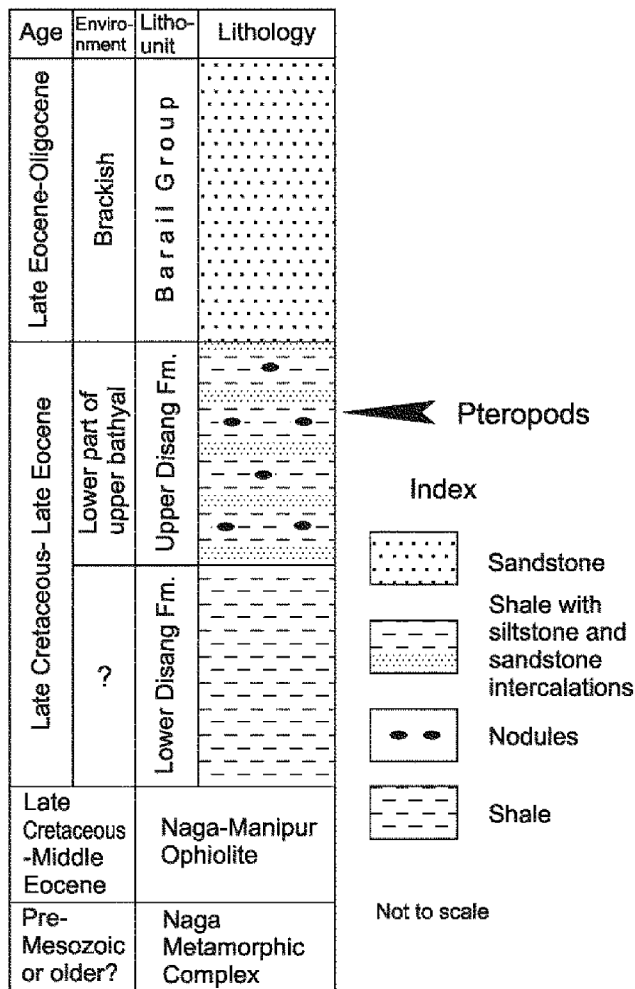


Figure 2. Generalized lithostratigraphy (not to scale) of South Central Nagaland showing approximate position of pteropod-yielding fossiliferous level in the Upper Disang Formation.

macroscopically smooth, sinistral shells, coiled in a spatial or planorboid spiral. A provisional subdivision in seven genera for the Limacinidae was presented by Janssen²⁹. In the present collection they seem to be represented by three juvenile, but morphologically distinct shell types that cannot be related to the existing genera. Therefore, they are referred here to as Limacinidae types 'A', 'B' and 'C'.

Type 'A' specimens (1–8, Figure 3) are depressed trochospiral, clearly wider than high, with two–three whorls, gradually increasing in diameter towards the aperture, and a narrow umbilicus. They seem to resemble a limacinid illustrated by Hodgkinson *et al.*¹² under the most certainly incorrect name, *Limacina pygmaea* (Lamarck, 1805), which is a species originally described from the Lutetian of the Paris Basin.

Type 'B' shells (9, Figure 3) are planispiral, with the apical whorls invisible in frontal view, and a narrow umbilicus. Like type 'A' shells, they are wider than high, with whorls gradually increasing in diameter but their spire is depressed, and just about as high as the body whorl.

Type 'B' shells are morphologically similar to a planorboid pteropod species, viz. the Palaeocene/Eocene western European *Heliconoides mercinensis* (Watelet and Lefèvre, 1885; see Curry⁶), but the preserved part of the body whorl in the present admittedly juvenile specimens is much less inflated. Another related species might be *Planorbis alienatus* Eames (1952), described from Eocene deposits (Upper Chocolate Clays, Rakhi Nala section) of Pakistan²³.

Type 'C' shells (10–12, Figure 3) are also planispiral, but coiled in a tighter spiral so that their body whorl is relatively larger and the umbilicus is wider. They have a depressed, concave apical plane, appearing as an apical 'umbilicus', as a result of which the shell looks more or less the same in apical as well as in umbilical views.

Type 'C' shells are comparable with planispiral pteropods, such as the Miocene–Recent *Heliconoides inflata* (d'Orbigny, 1836), which at present has a worldwide distribution in tropical and subtropical seas (see Janssen³⁰), and numerous further planorboid limacinids, such as *Heliconoides tertiaria* (Tate, 1887), described from the Australian Miocene⁴, but also occurring during the Miocene in the Mediterranean and the eastern North Atlantic (see Janssen⁵). These two species, however, have a distinctly wider apical spiral. More closely related might be the Eocene *Skaptotion spirale* Hodgkinson, described from Eocene deposits in USA and Canada¹², which also has a tight apical spire.

Superfamily Cavolinioidea – Creseidae spp. (13–24, Figure 3): Creseids are characterized by their uncoiled, conically tapering shells. At least three morphologically distinct shell types occurring in our collection are thought to represent this family and are referred here to as Creseidae types 'A', 'B' and 'C'.

Creseidae type 'A' shells (13–16, Figure 3) are long-conical, straight or almost straight, more or less needle-shaped with a circular transverse section. Since all specimens lack an embryonal part (protoconch), it cannot be made out with certainty if they really represent pteropods of the creseid family. It cannot be excluded that they belong to other fossil groups, such as scaphopods, or even annelids.

Creseidae type 'B' shells (17, Figure 3) are cylindrical, but have a slight inflation which makes them resemble some species of the Cuvierinidae: slightly inflated in the middle and tapering posteriorly. The apertural part widens slightly. Species of *Cuvierina* appear in the Late Oligocene, and are markedly larger than the present material.

Creseidae type 'C' shells (18–24, Figure 3) are the smallest uncoiled shells in the collection, and obviously represent larval specimens (protoconchs). They are straight, with a circular transverse section and characterized by their rounded, frequently slightly swollen apical parts (protoconch-1) and a distinctly inflated younger shell part (protoconch-2). The connecting 'neck' between these two shell parts usually shows concave sidelines.

Morphologically and meristically these protoconchs are similar to various *Creseis* spp., as for instance the Recent *Creseis chierchiai* Boas, 1886 (see Richter³¹), or the

European Miocene (Langhian) *C. spina* (Reuss, 1867) (see Zorn³²). These two species, however, have a less distinct separation between protoconchs 1 and 2.

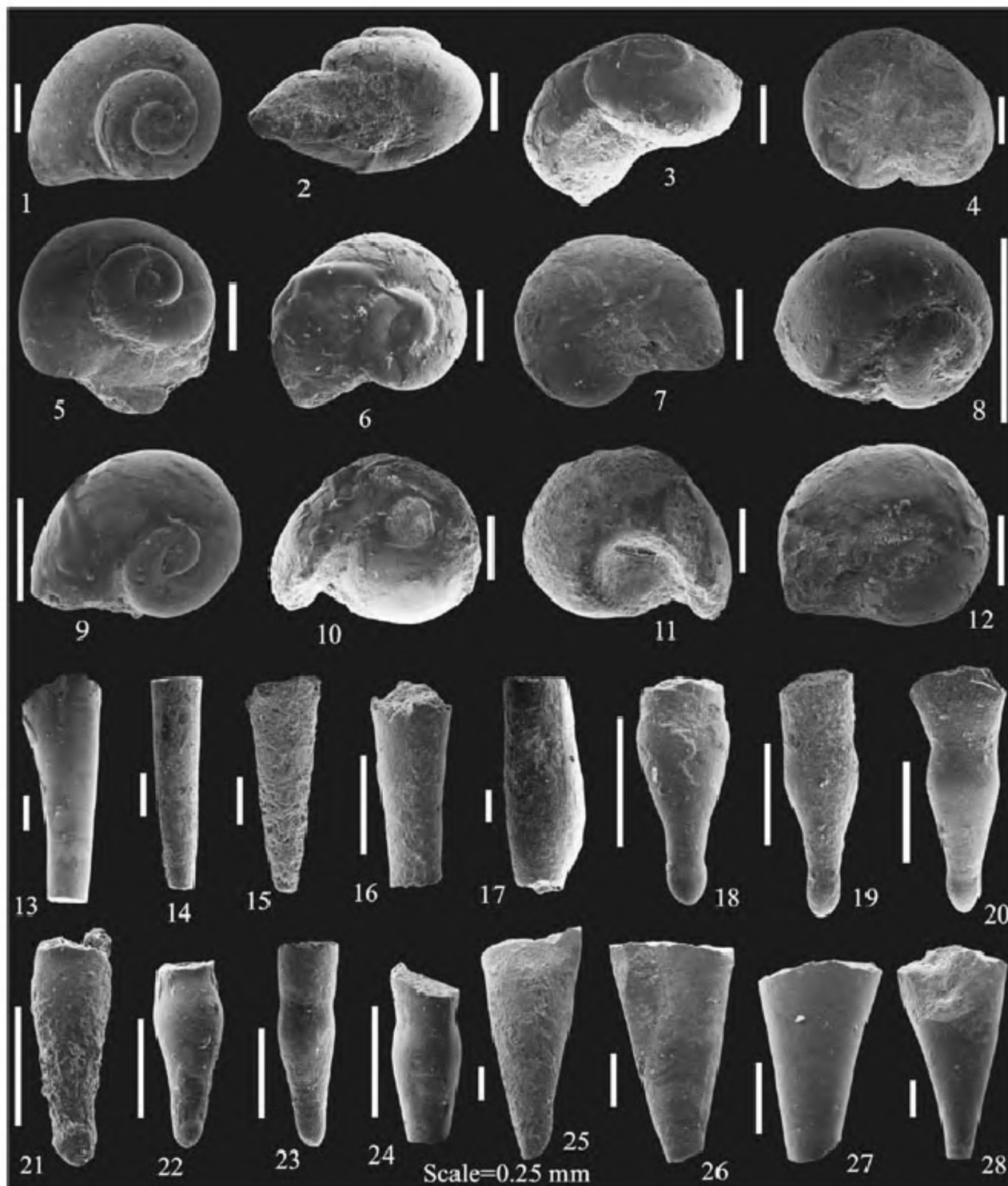


Figure 3. Fossil pteropods from the Upper Disang Formation, Phek District, Nagaland. 1–12, Limacinidae spp. 1, 2, WIMF/A 2241; 3, 4, 2242; 5, 2243; 6, 7, 2244; 8, 2245, type 'A' shells in apical (1, 5, 6, 8), apertural (2, 3) and umbilical (4, 7) views; 9, 2246, type 'B' shell in apical view; 10, 11, 2247; 12, 2248, type 'C' shells in apical (10, 12) and umbilical (11) views. 13–24, Creseidae spp. shells in side view. 13, 2210; 14, 2209; 15, 2211; 16, 2205; type 'A'; 17, 2207, type 'B'; 18, 2239; 19, 2234; 20, 2235; 21, 2238; 22, 2236; 23, 2237; 24, 2240, type 'C'. 25–28, Cliidae sp.? shells in dorsal or ventral view. 25, 2215; 26, 2214; 27, 2216; 28, 2213.

Type 'C' creseids in the present material demonstrate two morphotypes – one (18–21, Figure 3) with a distinct bulbous protoconch-1 and a short conical connection to protoconch-2 (18–21, Figure 3) and the second morphotype protoconch-1 that is not swollen, but just shows a rounded tip, whereas the connection with protoconch-2 is more slender (22–24, Figure 3). Whether or not these two variants represent distinct species is not known, but similar differences are seen in several Eocene North American species (see Collins¹¹), such as *C. hastata* (Meyer, 1886), *C. corpulenta* (Meyer, 1886), or even *Bovicornu gracile* (Meyer, 1886) or *B. eocenense* (Meyer, 1886). Also, species in the genus *Euchilotheca*, such as the Eocene (Lu-tetian) Paris Basin *E. succincta* (Defrance, 1828) have generally similar protoconchs (see Collins¹¹), among which the same differences can be seen.

Creseidae types B and C might well represent the protoconchs of Creseidae type A or of the supposed Clioidae, described below.

Clioidae sp.? (25–28, Figure 3): The Clioidae family comprises pteropods characterized by their uncoiled, conical, bilaterally symmetrical shells that are straight or slightly curved, usually (but not always) demonstrating lateral carinae. In the present collection they are represented by several specimens that have become flattened and triangular due to postmortem deformation. They might represent Clioidae species, although lateral carinae are not seen. In all specimens both the anterior and posterior ends are broken, making identification nearly impossible. The preserved part of all shells is straight, but curvature of the posterior part in complete specimens is not ruled out. Their transverse section is elliptical. Size-wise these are among the largest conical shells in the collection, and it is possible that they represent more adult parts of Creseidae. Their apical angle is wider and they are adaperturally more compressed than in the other conical shells. Due to deformation some specimens show a longitudinal crack near the aperture, which could be mistaken for lateral carinae as seen in *Clio*.

The age of the pteropod-yielding Upper Disang Formation is constrained by the occurrence, in the same beds, of certain index planktic foraminifers belonging to the *Globigerinatheka semiinvoluta* – Biozone (Zone P14 of Berggren *et al.*³³), *Cribohantkenina inflata* (P15) and *Turborotalia cerroazulensis* (P16), which are equivalent to the tropical planktic foraminiferal zones E14 to E16 (in part) of Berggren and Pearson³⁴ and indicate a Bartonian (Late Middle Eocene) to Priabonian (Late Eocene) age³⁵.

Various views on the palaeoenvironment of the Disang Group were published, with one group regarding it as a deep water geosynclinal facies³⁶ and another considering it a shallow distal shelf to deltaic facies^{24,37}. Recent reports on well-preserved uvigerinid foraminifers from the same horizons and localities that yielded the pteropods described here, have provided definitive evidence on the depositional environment of the Upper Disang Forma-

tion²⁸. The uvigerinid assemblage, comprising *Uvigerina coccaensis*, *U. continuosa*, *U. cf. eoacena*, *U. glabrans*, *U. jacksonensis*, *U. longa*, *U. moravia*, *U. cf. steyeri* and *U. vicksburgensis*, suggests a deep marine anoxic environment (lower part of the upper bathyal zone) for the fossiliferous horizons of the Upper Disang Formation²⁸. The interpretation as an anoxic set up was based on the morphology of some cosmopolitan uvigerinids and their dominance in Nagaland.

Pteropods have a restricted tolerance with regard to variations in water temperature, salinity, depth, oxygen content, etc. and are therefore useful proxies of past environments^{38,39}. Their presence in a microfaunal assemblage indicates deposition in an open marine basin above the aragonite compensation depth (ACD)^{39–41}, which is higher in the water column than the calcite compensation depth. Pteropods generally get preserved above the ACD only. In present-day oceans and seas, pteropods predominantly occupy the uppermost 500 m of the water column in tropical and subtropical warm waters; the number of species decreases rapidly in cold-temperate and polar regions^{2,42}.

The combined evidence of uvigerinid foraminifers and pteropods suggests a palaeobathymetry of ~500 m for the Upper Disang Formation. Benthic microgastropods, bivalves and larger foraminifers, including simple radiate *Nummulites* (*N. chavannesii* and *N. pengaronensis*) that also occur in the pteropod-yielding samples, may have been transported into the bathyal zone from near-coastal shallow marine areas. *N. chavannesii* and *N. pengaronensis* are morphologically similar to *N. venosus*, which lives in present-day oceans between 15 and 80 m depth⁴³, with maximum accumulation at 50 m.

1. van der Spoel, S., Euthecosomata, a group with remarkable development stages (Gastropoda, Pteropoda). Gorinchem (J. Noor-duijn), Thesis, University of Amsterdam, 1967, p. 375.
2. Herman, Y., Pteropods. In *Introduction to Marine Micropaleontology* (eds Haq, B. U. and Boersma, A.), Elsevier–North Holland, NY, 1978, pp. 151–159.
3. Lalli, C. M. and Gilmer, R. W., *Pelagic Snails. The Biology of Holoplanktonic Gastropod Molluscs*, Stanford University Press, Stanford, 1989, pp. 1–259.
4. Tate, R., The pteropods of the older Tertiary of Australia. *R. Soc. Aust., Trans.*, 1887, **9**, 194–196.
5. Janssen, A. W., Pteropoda (Gastropoda, Euthecosomata) from the Australian Cainozoic. *Scr. Geol.*, 1990, **91**, 1–76.
6. Curry, D., The English Palaeogene pteropods. *Proc. Malacol. Soc. London*, 1965, **36**, 357–371.
7. Curry, D., Ptéropodes éocènes de la tuilerie de Gan (Pyrénées-Atlantiques) et de quelques autres localités du SW de la France. *Cah. Micropaléontol.*, 1981, **4**, 35–44.
8. Janssen, A. W. and King, C., Planktonic molluscs (pteropods). *Geol. Jahrb. (A)* 1988, **100**, 356–368.
9. Janssen, A. W., Pteropod species (Mollusca, Gastropoda, Euthecosomata) from the Late Oligocene of Mogenstrup, Jylland, Denmark. *Contrib. Tert. Quat. Geol.*, 1990, **27**, 83–91.
10. Bohn-Havas, M. and Zorn, I., Biostratigraphic studies on planktonic gastropods from the Tertiary of the Central Paratethys. *Scr. Geol. Spec. Issue*, 1993, **2**, 57–66.

11. Collins, R. L., A monograph of the American Tertiary pteropod molluscs. *Johns Hopkins Univ. Stud. Geol.*, 1934, **1**, 137–234.
12. Hodgkinson, K. A., Garvie, C. L. and Bé, A. W. H., Eocene euthecosomatous Pteropoda (Gastropoda) of the Gulf and eastern coasts of North America. *Bull. Am. Paleontol.*, 1992, **103**, 5–62.
13. Squires, R. L., Pteropods (Mollusca: Gastropoda) from Tertiary formations of Washington and Oregon. *J. Paleontol.*, 1989, **63**, 433–438.
14. Korobkov, I. A., Krylonogie (Mollusca: Pteropoda) Paleogenovykh otlozhenij juga S.S.S.R. *Vopr. Paleontol.*, 1966, **5**, 71–92.
15. Korobkov, I. A. and Makarova, R. K., A new pteropod mollusk from the Upper Eocene deposits in the USSR. *Paleontol. Zh.*, 1962, **4**, 83–87.
16. Bielokrys, L. S., Pteropod gastropods from the Eocene of Ukraine. *Paleontol. Zh.*, 1997, **4**, 14–21.
17. Janssen, A. W., Schnetler, K. I. and Heilmann-Clausen, C., Notes on the systematics, morphology and biostratigraphy of fossil holoplanktonic Mollusca, 19. Pteropods (Gastropoda, Euthecosomata) from the Eocene Lillebaelt Clay Formation (Denmark, Jylland). *Basteria* (in press).
18. Pandey, J., Stratigraphy of Indian petroliferous basins of India, Presidential Address. In *XVI Indian Colloquium on Micropaleontology and Stratigraphy*, NIO, Goa, 1998, p. 284.
19. Singh, A. D., Rajaram, K. N., Ramachandran, K. K., Suchindan, G. K. and Samsuddin, M., Pteropods as bathometers: A case study from the continental shelf off Kerala coast, India. *Curr. Sci.*, 1998, **75**, 620–623.
20. Singh, A. D., Nisha, N. R. and Joydas, T. V., Distribution patterns of Recent pteropods in surface sediments of the western continental shelf of India. *J. Micropaleontol.*, 2005, **24**, 39–54.
21. Bhattacharjee, D., Taxonomic study of pteropods from the seabed sediments in the Carlsberg Ridge and its significance. *J. Palaeontol. Soc. India*, 2000, **45**, 79–89.
22. Mohan, R., Verma, K., Mergulhao, L. P., Sinha, D. K., Shanvas, S. and Guptha, M. V. S., Seasonal variation of pteropods from the western Arabian Sea sediment trap. *Geo.-Mar. Lett.*, 2006, **26**, 265–273.
23. Eames, E. E., A contribution to the study of the Eocene in western Pakistan and western India. C. The description of the Scaphopoda and Gastropoda from standard sections in the Rakhi Nala and Zinda Pir areas of the western Punjab and in the Kohat District. *Philos. Trans. R. Soc. London, Ser. B*, 1952, **236**, 1–168.
24. Ranga Rao, A., Geology and hydrocarbon potential of a part of Assam–Arakan Basin and its adjacent region. *Pet. Asia J.*, 1983, **6**, 127–158.
25. Ganju, J. L., Khar, B. M. and Chaturvedi, J. G., Geology and hydrocarbon prospects of Naga Hills south of 27°N latitude. *Bull. Oil Nat. Gas Comm.*, 1986, **23**, 127–145.
26. Mallet, F. R., On the coalfields of the Naga Hills bordering the Lakhimpur and Sibsagar Districts, Assam. *Mem. Geol. Surv. India*, 1876, **12**, 269–363.
27. Sinha, N. K. and Chatterjee, B. P., Notes on the Disang Group in parts of Nagaland and its fossil fauna. *Rec. Geol. Surv. India*, 1982, **112**, 50–52.
28. Lokho, K., Venkatchalapathy, R. and Raju, D. S. N., Uvigerinids and associated foraminifera, their value as direct evidence for shelf and deep marine palaeoenvironments during Upper Disang of Nagaland, Eastern Himalaya and its implications in hydrocarbon exploration. *Indian J. Pet. Geol.*, 2005, **13**, 79–96.
29. Janssen, A. W., Notes on the systematics, morphology and biostratigraphy of fossil holoplanktonic Mollusca, 13. Considerations on a subdivision of Thecosomata, with the emphasis on genus group classification of Limacinidae. *Cainozoic Res.*, 2003, **2**, 163–170.
30. Janssen, A. W., Holoplanktonic molluscan assemblages (Gastropoda, Heteropoda, Thecosomata) from the Pliocene of Estepona (Spain, Málaga). *Palaeontos*, 2004, **5**, 103–131.
31. Richter, G., *Creseis chierchiae* Boas, eigene Art oder Jugendstadium von *Hyalocylis striata* (Rang)? *Arch. Molluskenkd.*, 1976, **107**, 145–148.
32. Zorn, I., Gastropoda tertiaria, Pteropoda (Thecosomata, Gastropoda). *Cat. Fossil. Austriae*, 1991, **VIc/3c**, 1–69.
33. Berggren, W. A., Kent, D. V., Aubry, M. P. and Hardenbole, J., Geochronology, timescales and global stratigraphic correlation. *Soc. Sediment. Geol. Spec. Publ.*, 1995, **54**, 129–212.
34. Berggren, W. A. and Pearson, P. N., A revised tropical to subtropical planktonic foraminiferal zonation of the Eocene and Oligocene. *J. Foram. Res.*, 2005, **35**, 279–298.
35. Pearson, P. N., Olsson, R. K., Huber, B. T., Hemleben, C. and Berggren, W. A. (eds) In *Atlas of Eocene Planktonic Foraminifera*, Cushman Foundation for Foraminiferal Research, Special Publication, 2006, No. 41, p. 513.
36. Mathur, L. P. and Evans, P., Oil in India. In *International Geology Congress, 22nd Session, New Delhi, 1964*, p. 85.
37. Acharyya, S. K., Roy, D. K. and Mitra, N. D., Stratigraphy and palaeontology of the Naga Hills Ophiolite belt. *Mem. Geol. Surv. India*, 1986, **119**, 64–74.
38. Herman, Y. and Rosenberg, P. E., Pteropods as sea level indicators. In *Études sur le Quaternaire dans le monde. VIIIe Congrès INQUA, Paris 1969* (ed. Ters, M.), 1971, vol. 1, pp. 187–190.
39. Berger, W. H., Deep-sea carbonate and deglaciation preservation spike in pteropods and foraminifera. *Nature*, 1977, **269**, 301–304.
40. Berger, W. H., Deep-sea carbonate: Pteropod distribution and the aragonite compensation depth. *Deep-Sea Res. Part A*, 1978, **25**, 447–452.
41. Biekart, J. W., Euthecosomatous pteropods as paleohydrological and paleoecological indicators in a Tyrrhenian deep-sea core. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 1989, **71**, 205–224.
42. Bé, A. W. H. and Gilmer, R. W., A zoogeographic and taxonomic review of euthecosomatous Pteropoda. In *Oceanic Micropaleontology* (ed. Ramsey, A. T. S.), Academic Press, London, 1977, vol. 1, pp. 733–808.
43. Hohenegger, J., Depth coenoclines and environmental considerations of western Pacific larger foraminifera. *J. Foram. Res.*, 2004, **34**, 9–33.

ACKNOWLEDGEMENTS. We are grateful to Arie W. Janssen (Gozo, Malta) for help in identifying the fossils, reviewing the text, and providing the relevant literature. Thanks are also due to Dr D. S. N. Raju, ONGC, Dehradun for suggestions and Dr Rahul Mohan, NCAOR, Goa for providing important literature.

Received 10 August 2007; accepted 27 November 2007