

Revision of *Keramosphaeropsis haydeni* (H. Douvillé), larger foraminifer (Miliolacea) from the Paleocene of southern Tibet (Tethys Himalaya)

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ABSTRACT - The original material of *Keramosphaeropsis haydeni* (H. Douvillé, 1916) was revised. This taxon showing a clear dimorphism is mainly characterized by the large, central proloculus of the megalospheric forms and by postembryonic chambers which are arranged in poorly defined concentric layers. *K. haydeni* cannot be regarded as a descendant of the Upper Cretaceous *keramosphaerinas*, but developed independently from an unknown miliolacean ancestor. On the base of the available bibliographic data, a Thanetian age is suggested for this species.

RIASSUNTO - [Revisione di *Keramosphaeropsis haydeni* (H. Douvillé, 1916), macroforaminifero (Miliolacea) del Paleocene del Tibet meridionale (Tetide Himalayana)] - E' stato revisionato il materiale originale di *Keramosphaeropsis haydeni* (H. Douvillé, 1916). Questo taxon, mostrando un chiaro dimorfismo, è caratterizzato nelle forme megalosferiche da un ampio proloculo in posizione centrale e da una serie di camere post-embryonali disposte secondo strati concentrici non ben definiti. *Keramosphaeropsis haydeni* non può essere considerato un discendente diretto delle *keramosphaerine* del Cretacico superiore, ma bensì come un taxon evolutosi in maniera indipendente da una forma ancestrale finora sconosciuta appartenente alle miliolacee. Sulla base dei dati bibliografici disponibili può essere suggerita per questa specie un'età thanetiana.

INTRODUCTION

In a monograph on Cretaceous and Tertiary fossils collected during the English expedition to Tibet (1903), H. Douvillé (1916) described under the name *Delheidia haydeni* n. sp. small globular fossils of few millimetres in diameter, abundantly occurring in the environs of the village Tüna (southern Tibet, Tethys Himalaya; Fig. 1) at the base of the "Gastropod Limestone" of alleged Eocene age (Hayden, 1907).

Douvillé compared this "organisme problématique" with the foraminiferal genus *Gypsina* and some hydrozoans (*Parkeria*, *Stoliczkania* and *Delheidia*). Because of the absence of perforate walls he excluded an affinity to *Gypsina* and took the view that these globular bodies showing an imperforate wall should be assigned to the hydrozoan genus *Delheidia*. Moreover, he observed in the centre of the bodies a small globular cavity which in his opinion could be the megalospheric embryonic chamber of a miliolid foraminifer serving as a substrate upon which the larval stage of *Delheidia* settled.

The genus *Delheidia* Dollfus, 1898 (type and only species: *Tubipora proxima* Delheid, 1898) was reported from the Rupelian of Belgium and Germany (Cherchi & Schroeder, 1989) and occurs probably also in the Aquitanian of SW France (Cahuzac & Gautret, 1993). The spherical colonies with a maximal circumference of 1.38 mm (!) (Delheid, 1899) are mainly characterized by radially directed bundles of slightly curved and septate tubes. A shell fragment of *Aturia* situated in the centre of the colony served as substrate of the larval stage of this organism, which was ascribed by different

authors to the anthozoans, hydrozoans or stromatoporates.

Silvestri (1923, 1924) and Parona (1928) regarded *Delheidia haydeni* as a synonym of *Bradya tergestina* Stache, 1889, a small spherical taxon of presumed Paleocene (in reality: Late Cretaceous) age, occurring in the Mediterranean region. According to Silvestri and Parona, *Bradya* and the recent *Keramosphaera* Brady, 1882 (type: *K. murrayi* Brady) are congeneric and belong to the class Hydrozoa. However, these two authors had overlooked the important publication of Stache (1913), who had stated that his genus *Bradya* was a homonym of the recent copepod genus *Bradya* Boek, 1872. Therefore, Stache established for the species *tergestina* the new genus *Keramosphaerina* which he placed among the foraminifers, regarding it, together with the recent *Keramosphaera murrayi* Brady, as representatives of the miliolid subfamily *Keramosphaerinae*.

In the following period, *K. tergestina* was regarded by numerous authors (e. g. Devoto, 1964; Steinhauser et al., 1970) as belonging to *Keramosphaera* Brady, whereas others (e. g. Pavlovec, 1971) assigned it to the genus *Keramosphaerina* Stache. Loeblich & Tappan mentioned this latter genus still in 1961 as a probable hydrocoralline among "generic names erroneously applied to Foraminiferida".

Subsequently, *Delheidia haydeni* has nearly fallen into oblivion. The pretended Paleocene age of the *keramosphaerids* of the Mediterranean realm was obviously the reason that numerous Chinese scientists (e. g. Ho et al., 1976; Sun & Zang, 1983; Wan, 1987, 1990) cited and figured the Paleocene Tibetan

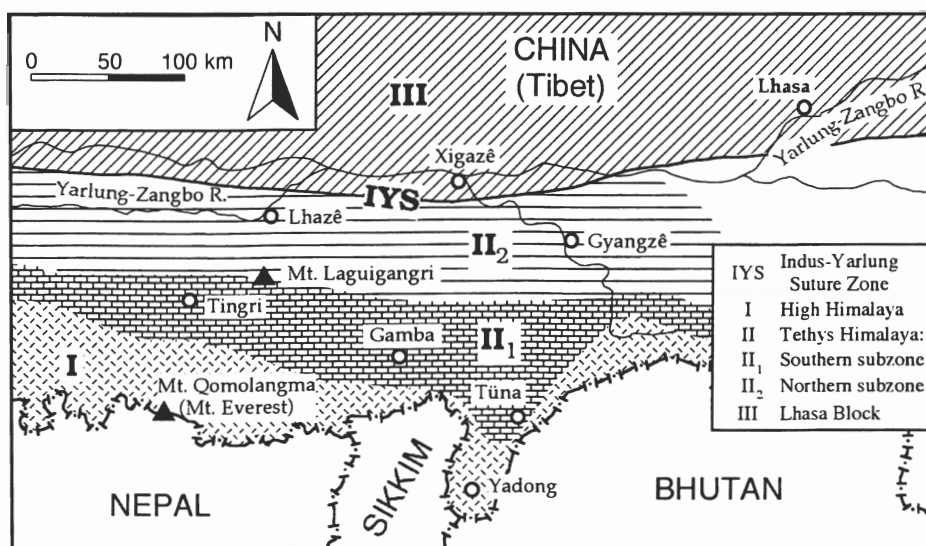


Fig. 1 - Location of the villages Tüna, Gamba and Tingri in the eastern part of the Tibetan Tethys Himalaya (from Willems et al., 1996, modified).

keramosphaerids during the last two decades under the name *Keramosphaera tergestina*, and Willems et al. (1996) established in the Tibetan Himalayas (Tingri area) a “*Keramosphaera* Assemblage Zone” (Thanetian), characterized by “*Keramosphaera tergestina* (Stache)”.

However, already Cherchi & Schroeder (1990) recognized that *Delheidia haydeni* belongs neither to the species *tergestina* nor unequivocally to the genus *Keramosphaerina*. These conclusions were based on a re-study of the original material of this species, which is presently stored in the collections of the Département des Sciences de la Terre of the University Claude Bernard (Lyon, France). In a preliminary report (Cherchi & Schroeder, 1997) we established for the species *haydeni* the new genus *Keramosphaerinopsis*.

STRATIGRAPHIC POSITION OF *KERAMOSPHAERINOPSIS HAYDENI*

The marine Cretaceous and Tertiary sediments of the Tibetan Tethys Himalaya, south of the Indus-Yarlung Suture Zone, were studied for the first time by Hayden (1907), who subdivided the upper part of the whole series (“Kampa [= Gamba] System”) into 8 lithologic units: (1) Ferruginous sandstone, (2) Gastropod limestone, (3) *Operculina* limestone, (4) *Spondylus* shales, (5) *Orbitolites* limestone, (6) Sandy shales, (7)

Alveolina limestone, (8) Dzongbuk shales, dating the unit (1) as Cretaceous and/or Tertiary, and the overlying units (2 to 8) as Eocene (Fig. 2).

On the basis of the study of the macrofossils and larger foraminifers, H. Douvillé (1916) took the view that the units 1 to 4 have to be dated as Danian, whereas only the units 5 to 8 could be assigned to the Eocene (Fig. 2).

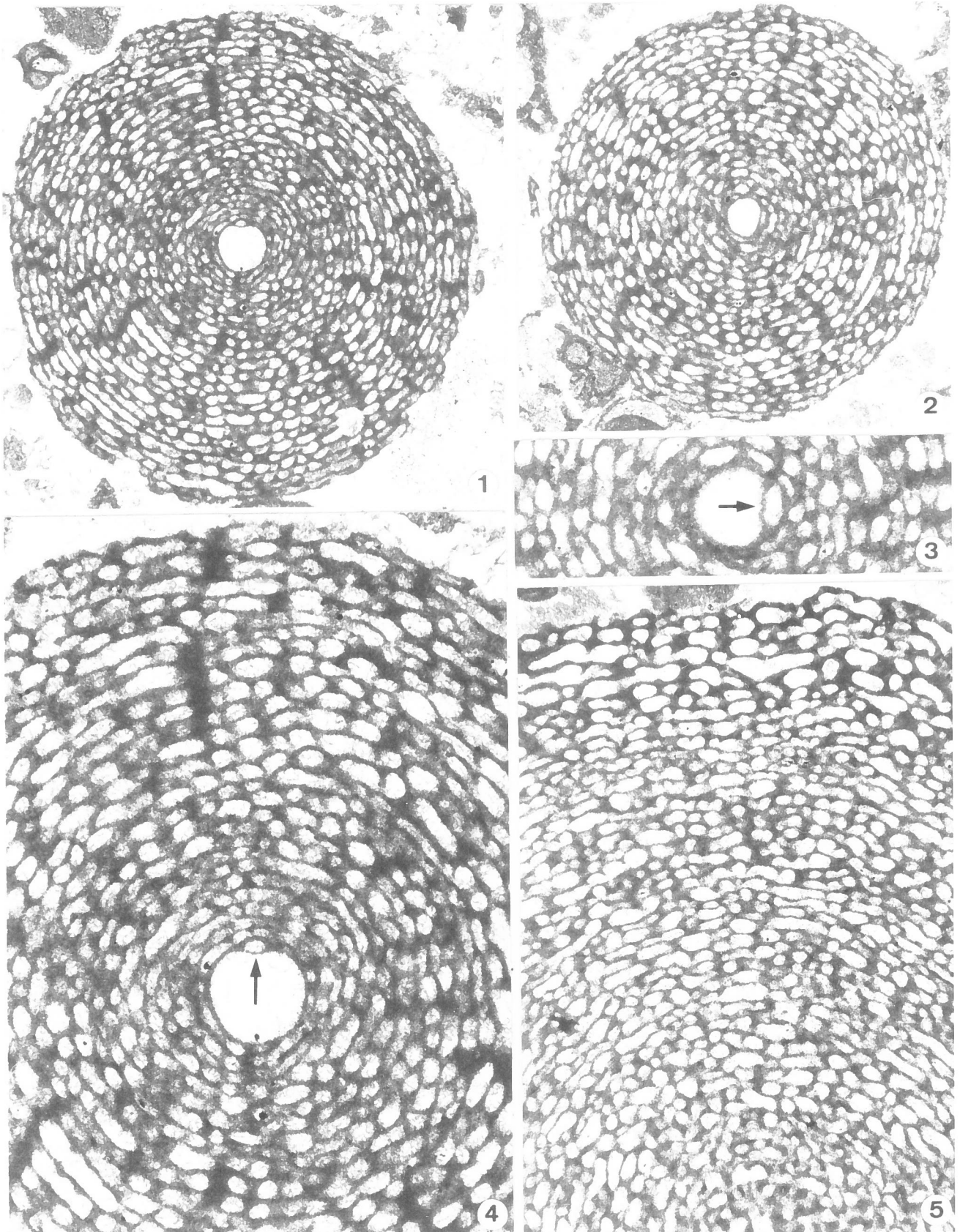
The sample with *Keramosphaerinopsis* (“*Delheidia*”) *haydeni* was taken by Hayden north-west of Tüna within the “Gastropod limestone” unit. It is a hard, grey very fossiliferous grainstone with some micritic intraclasts, mainly containing rotaliid and miliolid foraminifers, *Keramosphaerinopsis haydeni*, as well as dasyclads. Some sections of a small disc-shaped foraminifer show a structure similar to *Orbitolites*. A detailed study of the microfauna and -flora has yet to come.

A more precise dating of the beds containing *K. haydeni* is now possible on the basis of the stratigraphic studies made by Willems & Zhang (1993a) at Gamba (Fig. 3). According to these authors, the Jidula Formation, corresponding to the “Ferruginous sandstone” of Hayden (1907) and overlying Upper Maastrichtian beds with *Omphalocyclus*, shows in its middle part a limestone intercalation (Member II) with dasyclads and udoteacean algae, whose determination was, however, controversial. Nevertheless, these

EXPLANATION OF PLATE 1

Figs. 1-5 - *Keramosphaerinopsis haydeni* (H. Douvillé). North-west of Tüna, southern Tibet (Tethys Himalaya). Paleocene (?Thanetian).

- 1 - Centred section of a megalospheric form. EM 20318. x 40.
- 2 - Centred section of a megalospheric form. EM 20317. x 40.
- 3 - Centred section of a megalospheric form. Detail. The arrow points to the flexostyle. EM 20318. x 80.
- 4 - Detail of Fig. 1. The arrow points to the flexostyle. x 80.
- 5 - Almost centred section of a microspheric form. Detail. CM 20318. x 40.



Hayden (1907)		Douvillé (1916)	
Eocene	Dzongbuk shales	Eocène	Schistes et grès (Dzongbuk shales)
	<i>Alveolina</i> limestone		Calcaire à <i>Orbitolites</i>
	Sandy shale		
	<i>Orbitolites</i> limestone		
	<i>Spondylus</i> shales	Danien	Calcschistes à <i>Spondylus</i>
	<i>Operculina</i> limestone		Calcaires à <i>Operculines</i>
	Gastropod limestone		Calcaires à Gastropodes
Cretaceous and/or Tertiary	Ferruginous sandstone		Grès ferrugineux
uppermost Cretaceous	Tüna limestone	Maestrichtien	Tuna limestone

Fig. 2 - Subdivision and dating of the Lower Tertiary in the eastern part of the Tibetan Tethys Himalaya, proposed by Hayden (1907) and Douvillé (1916).

Zongpu Formation	V	Paleocene
	IV	
	III	
	III	
Jidula Formation	I	Late Maastrichtian
	III	
	II	
	I	

Fig. 3 - Subdivision of the uppermost Maastrichtian and Paleocene in the eastern part of the Tibetan Tethys Himalaya (Willems et al., 1993a).

authors suggest for the Jidula Formation a latest Maastrichtian to lower or middle Paleocene age. The overlying Zongpu Formation, comprising the stratigraphic interval "Gastropod limestone" to "*Alveolina* limestone" of Hayden (1907), was subdivided by Wen (1974) into five members (I to V). The 49 m thick Member I, approximately corresponding to the "Gastropod limestone" of Hayden (1907) and consisting of marls and well-bedded limestones, has yielded 5.5 m above its base "planktonic foraminifera of the *angulate* Zone" (Willems & Zhang, 1993a, p. 23). The *Morozovella angulata* Zone (P 3) comprises the lower part of the Selandian (early late Paleocene; Premoli Silva et al., 2003). The uppermost part (8.8 m) of Member I has yielded a larger foraminiferal fauna dominated above all by "rotaliids (*Lockhartia haimei* [Davies], *Daviesina*) and first *Miscellanea miscella* (d'Archiac & Haime), few *Ranikothalia*, *Discocyclina* and *Keramosphaera*" (Willems & Zhang, 1993a, p. 19). According to these authors, the first frequent occurrence of *Miscellanea miscella* at the top of Member I suggests a basal Thanetian age. However, *Lockhartia haimei* occurs in the Shallow Benthic Zones (SBZ) 3 and 4 (early-late Thanetian), whereas *Miscellanea miscella* s. l. is restricted to the Zones 4 and 5 (late Thanetian-early Ilerdian) (Serra-Kiel et al.,

1998). On the understanding that the determinations of the foraminifers by Willems & Zhang are correct, the age of the *Keramosphaerinopsis haydeni* horizon at Gamba should be late Thanetian.

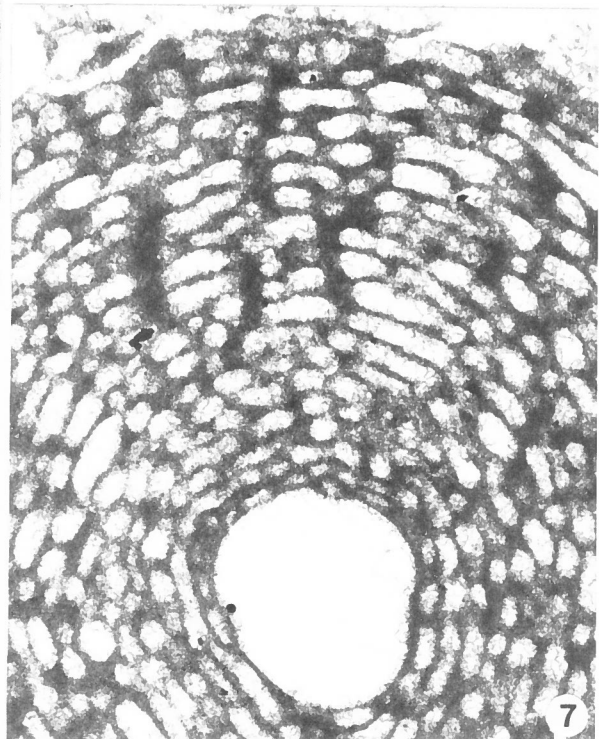
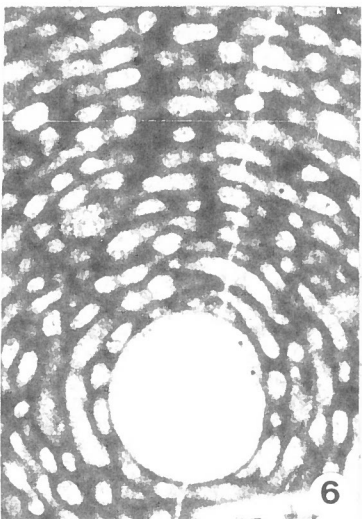
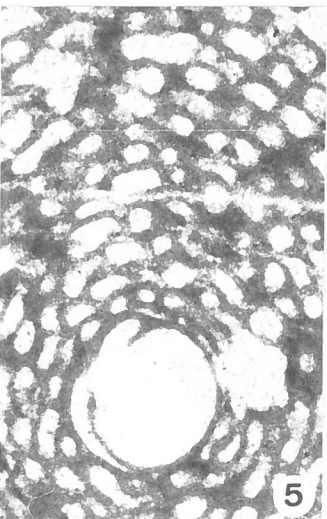
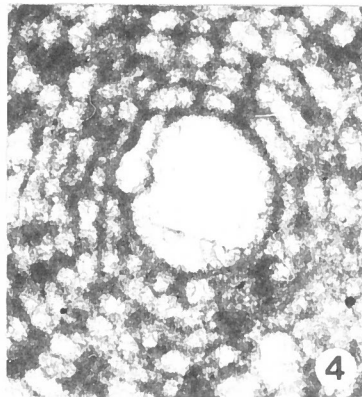
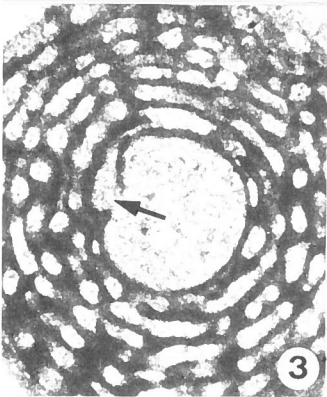
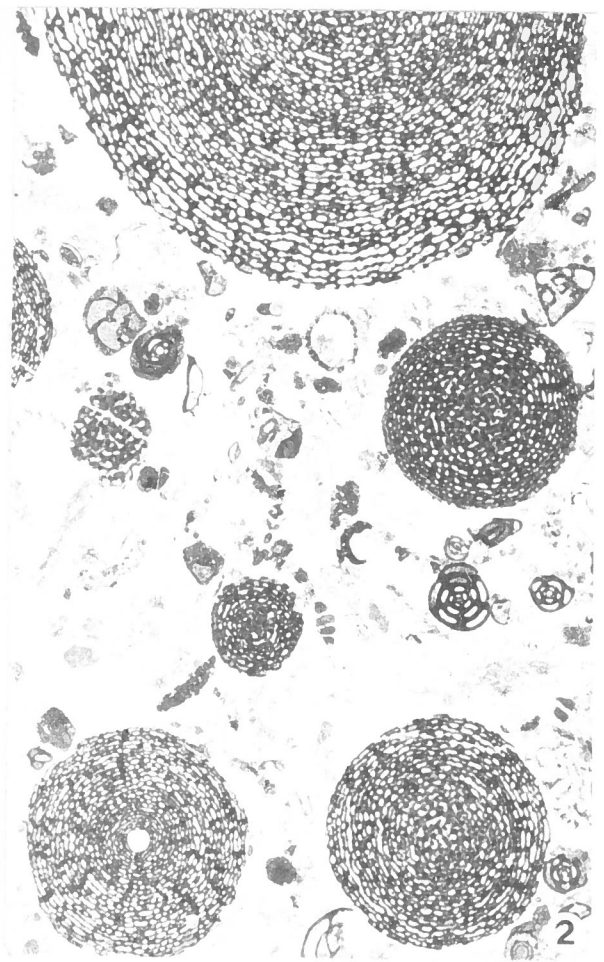
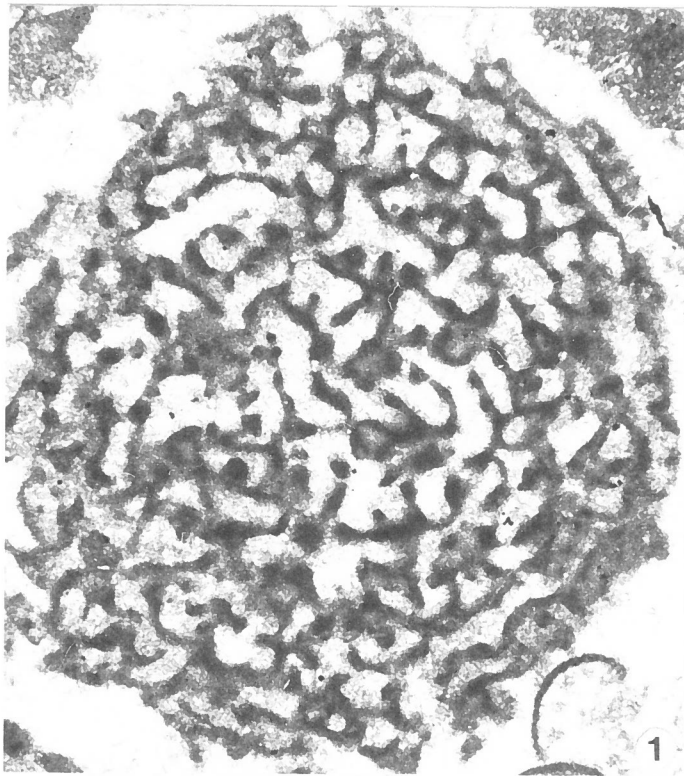
Due to lateral facies changes, the lithostratigraphic subdivision of the Paleocene in the environs of Gamba cannot be transferred to the Tingri region (Fig. 1), where the Zhepure Shan Formation comprises series of Lower Paleocene to Middle Eocene age (Willems & Zhang, 1993b). The first 20 metres of Member IV of this formation, consisting of nodular limestones and calcareous marls, are characterized by *Keramosphaerinopsis haydeni*. This species is associated, according to Willems et al. (1996), with *Lockhartia megapulata*, *L. hunti*, *Smoutina cruysi*, *Rotalia hensoni* and *R. dukhani* ("*Keramosphaera* Assemblage Zone") suggesting a Thanetian age. In the following 20 metres of Member IV, Willems & Zhang (1993b) reported *Miscellanea miscella*, *Ranikothalia* sp., *Operculina* sp. and *Discocyclina* sp.

Summing up, it may be said that on the basis of the available bibliographic data *Keramosphaerinopsis haydeni* from the Tibetan Himalaya could have a Thanetian age. However, this preliminary dating needs a confirmation by more detailed studies of the accompanying larger foraminifers.

EXPLANATION OF PLATE 2

Figs. 1-7 - *Keramosphaerinopsis haydeni* (H. Douvillé). North-west of Tüna, southern Tibet (Tethys Himalaya). Paleocene (?Thanetian).

- 1 - Tangential section. EM 20316. x 50.
- 2 - Rock section showing some megalospheric specimens and in the upper part a large microspheric form. EM 20318. x 14.
- 3 - Centred section of a megalospheric form. Lectotype. The arrow points to the flexostyle. EM 20317. x 80.
- 4 - Centred section of a megalospheric form. Detail. EM 20316. x 80.
- 5 - Centred section of a megalospheric form. Detail. EM 20317. x 80.
- 6 - Centred section of a megalospheric form. Detail. EM 20319. x 80.
- 7 - Centred section of a megalospheric form. Detail. EM 20318. x 80.



DESCRIPTION OF *KERAMOSPHAERINOPSIS* *HAYDENI*

Superfamily MILIOLACEA Ehrenberg, 1839
Family KERAMOSPHAERIDAE Brady, 1884
Subfamily KERAMOSPHAERIDAE Brady, 1884
Genus *Keramosphaerinopsis* Cherchi & Schroeder,
1997

Type species: *Delheidia haydeni* H. Douvillé, 1916

Keramosphaerinopsis haydeni (H. Douvillé, 1916)
Pl. 1, figs. 1-5; Pl. 2, figs. 1-7; Pl. 3, figs. 1-5

- 1916 *Delheidia haydeni*, nov. sp. - H. DOUVILLÉ, pp. 28-30, Pl. 10, figs. 1-6.
1976 *Keramosphaera tergestina* (Stache) - HO & ZHANG, p. 33, Pl. 11, figs. 1-6.
1987 *Keramosphaera tergestina* - WAN, Pl. 1, fig. 2.
1990 *Keramosphaerina* (?) *haydeni* (Douvillé) - CHERCHI & SCHROEDER, p. 1569, fig. 3.
1996 *Keramosphaera tergestina* (Stache) - WILLEMS ET AL., p. 746, fig. 160.
1997 *Keramosphaera* - ZHOU ET AL., Pl. 1, fig. 5.
1997 *Keramosphaerinopsis haydeni* (H. Douvillé) - CHERCHI & SCHROEDER, p. 646, figs. 1-5.

Material - Original rock sample (K9, 437), collected by Hayden (1903), studied by H. Douvillé (1916; thin sections 437 and 437-1) and stored in the collections of the Département des Sciences de la Terre, Université Claude Bernard (Lyon, France).

The specimens figured in this paper come from seven additional thin sections of the rock sample (EM 20314 to EM 20320), deposited in the same collections.

Lectotype - Centred section of a megalospheric specimen (EM 20317), illustrated in Pl. 2, fig. 3.

Type locality - North-west of Tüna, southern Tibet (Tethys Himalaya).

Type horizon - "Base des calcaires à Gastropodes" (Douvillé 1916), corresponding approximately to the basal part of Member I of the Zongpu Formation (Willems & Zhang, 1993a).

Age - Paleocene (? Thanetian).

Description - The following description is exclusively based upon random thin sections.

Shape - The specimens are of globular shape. Two size groups of tests can be differentiated (Pl. 2, fig. 2). The smaller ones with a diameter ranging from about 0.5 to 2.2 mm (max. 2.4 mm) and a large embryonic chamber correspond to the megalospheric generation, whereas the less frequent larger specimens with a diameter of 4.2 to 4.8 mm (max. 5.3 mm) are interpreted as microspheric forms.

Internal structures - The relatively large proloculus of the megalospheric forms with a diameter ranging from 0.14 to 0.25 mm (max. 0.34 mm) is situated exactly in the centre of the test. It is spherical to oviform and in one case (Pl. 2, fig. 7) slightly laced, suggesting perhaps an original subdivision into two chambers. The proloculus opens into a tubular flexostyle (Pl. 2, figs. 3-5), which has a flattened aspect in transversal section (Pl. 1, figs. 3-4), slightly bulging into the proloculus.

The microspheric initial stage is unknown, because it was never cut in random sections.

Tangential sections show that the postembryonic chambers are irregularly shaped in outline (Pl. 2, fig. 1), being elongate and vermiform, and developing more or less complex lateral ramifications. Their real extension should only be visible on the surface of isolated specimens. We suppose, however, that the externally visible pattern of chambers looks more or less like that which was observed by Stache (1889, Pl. 6, fig. 25d) on the surface of the Upper Cretaceous *Keramosphaerina tergestina*. Each chamber is provided with multiple apertures in form of simple, lateral openings (Pl. 2, fig. 1).

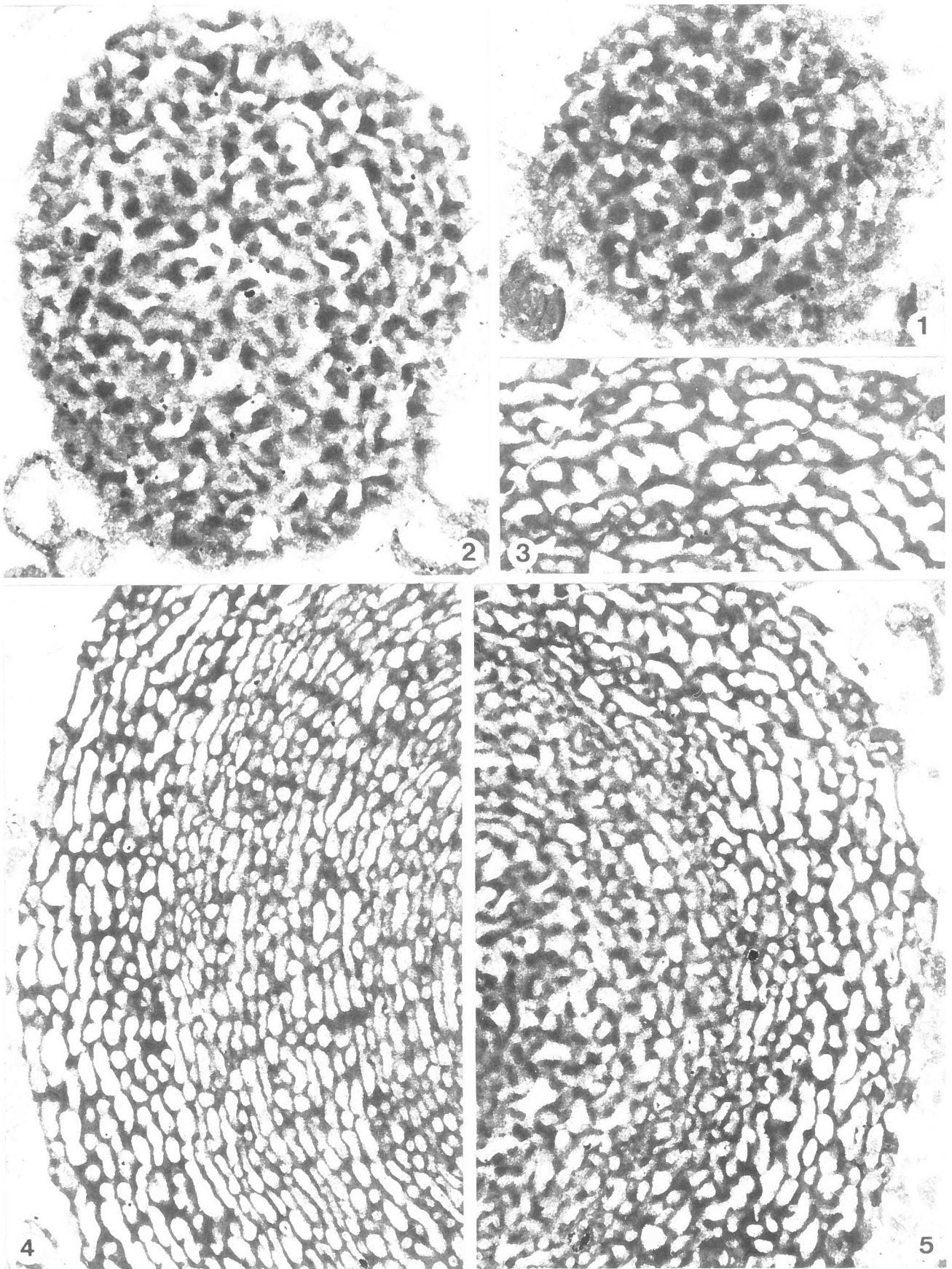
Central sections through the test show that the postembryonic chambers are arranged in poorly defined concentric "layers" (Pl. 1, figs. 1-2, 4; Pl. 3, fig. 4). Generally, these chambers irregularly alternate in position from one layer to the next, frequently tending to be organized in more or less developed radially directed stacks (Pl. 1, fig. 2). Neighbouring chamber stacks are separated by thickened lateral walls producing a pillar-like appearance in central sections (Pl. 2, figs. 6-7, upper halves).

Growth of the test is radial. The formation of new chambers took place during growth all over the surface of the test thus producing a spherical form.

EXPLANATION OF PLATE 3

Figs. 1-5 - *Keramosphaerinopsis haydeni* (H. Douvillé). North-west of Tüna, southern Tibet (Tethys Himalaya). Paleocene (?Thanetian).

- 1 - Tangential section. EM 20320. x 50.
- 2 - Tangential section. EM 20315. x 50.
- 3 - Almost centred section of a microspheric form. Detail. EM 20317. x 50.
- 4 - Almost centred section of a microspheric form. Detail. EM 20317. x 50.
- 5 - Microspheric form. Detail. EM 20317. x 40.



Comparison with other keramosphaerids - Based on the descriptions and figured specimens published by Devoto (1964), Drobne (1981) and Cherchi & Schroeder (1990), representatives of the genus *Keramosphaerina* Stache mainly differ from *Keramosphaerinopsis haydeni* by the streptospiral initial stage of their megalospheric forms. Moreover, the arrangement of the postembryonic chambers in radially directed stacks seems to be more regular in the Cretaceous forms than in *K. haydeni*. For further structural details we refer to a revision of *Keramosphaerina tergestina* in preparation.

The nature of the earliest stage of the recent *Keramosphaera murrayi* Brady, type species of the genus *Keramosphaera*, is unknown. The chambers of the adult stage are arranged in concentric spherical series, which are, however, less defined than in *K. haydeni* (Steinhauser et al., 1970, Pl. 2; Loeblich & Tappan, 1987, Pl. 426, fig. 9). Radially directed stacks of chambers as observed in *Keramosphaerina* and *Keramosphaerinopsis*, are completely lacking.

Keramosphaera allobrogensis Steinhauser et al., 1970, of Berriasian age and type species of the genus *Pavlovecina* Loeblich & Tappan, 1987, differs from *Keramosphaerinopsis haydeni* mainly by irregularly shaped, branching, flattened chambers distributed without definite arrangement and developing during growth all over the surface of the test. The proloculus and flexostyle are followed by a few chambers in quinqueloculine arrangement.

Keramosphaera iranica Rahaghi, 1983 from the "Upper Paleocene" of the Shiraz area (Iran) is like *Keramosphaerinopsis haydeni* a clearly dimorphic species. Diameter of the microspheric forms: up to 5 mm; diameter of the megalospheric forms: 1.1 mm. The proloculus of the latter form with a diameter of about 0.125 mm is followed by a flexostyle and a series of postembryonic chambers which seem to be arranged in a (?plan)spiral (Rahaghi, 1983, Pl. 19, fig. 9; Pl. 20, fig. 11). Postembryonic chambers of the microspheric forms are grouped in indistinctly defined concentric layers. A detailed comparison between this species and *Keramosphaerinopsis haydeni* is needed.

PHYLOGENETIC REMARKS

A comparison between the dimensions of different Upper Cretaceous keramosphaerids (Coniacian-Campanian, ?Maastrichtian) shows during this time interval a very clear increase of test diameter (Cherchi & Schroeder, 1990), which sometimes attains more than 25 mm in the Campanian - Maastrichtian (Brač "Marble" Formation of central Dalmatia; Gušić et al., 1988). In comparison with these last giant forms, the Paleocene *Keramosphaerinopsis haydeni* with a diameter of only approx. 5 mm (microspheric forms) is relatively small. This size difference indicates, that *Keramosphaerinopsis haydeni* cannot be regarded as a phylogenetic descendant of the Upper Cretaceous keramosphaerids. In our opinion, the family Keramosphaeridae Brady is a polyphyletic group; its genera *Pavlovecina* Loeblich & Tappan, 1988

(Berriasian), *Keramosphaerina* Stache, 1913 (Coniacian-?Maastrichtian), *Keramosphaerinopsis* Cherchi & Schroeder, 1997 (Paleocene) and *Keramosphaera* Brady, 1882 (Recent) developed independently from different ancestors.

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