

## **Relationship between abundance and morphology of benthic foraminifera**

### ***Epistominella exigua*: Paleoclimatic implications**

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### **Abstract**

The relationship between abundance (relative as well as absolute abundance) and morphology (size of the shell, number of chambers and proloculus size) of benthic foraminifera *Epistominella exigua* has been studied in a core to understand the influence of changing environmental conditions on its morphology and distribution. A total of 50 samples from the top 100 cm section of a gravity core collected from the southern Bay of Bengal Fan were used. The changes in abundance of *E. exigua* match well with variation in average proloculus size of *E. exigua*. An opposite relationship however, is observed between the abundance and size of *E. exigua* shells. The higher abundance corresponds with smaller *E. exigua* shells. Similarly, the increased *E. exigua* abundance matches with a decrease in the number of chambers. The increased abundance of *E. exigua* shows favourable conditions for its growth and survival. Thus the study indicates that during favourable conditions, while the number of chambers in the shells and the size of the shells of *E. exigua* decreases, more number of specimens have a larger proloculus. Since asexual reproduction results in megalospheric specimens with larger proloculus, smaller size and less number of chambers, it is inferred that *E. exigua* prefers an asexual mode of reproduction during favorable conditions. The findings can be used to apply morphological characteristics of *E. exigua* as a proxy to infer past climatic conditions.

**Keywords:** Benthic foraminifera, *Epistominella exigua*, abundance, morphology, reproduction

## **Introduction**

Foraminiferal characteristics are among one of the most often used proxies for paleoclimatic reconstruction (Gooday, 1994; 2003). Besides assemblage, isotopic and elemental composition, abundance and morphology of a few foraminiferal species vary with ambient conditions and are used as paleoclimatic proxy (Thiede, 1971; Prell, 1984; Nigam and Rao, 1987; 1989; Anderson and Prell, 1993; Nigam and Khare, 1999; Peeters *et al.*, 2002; Žarić *et al.*, 2005; Saraswat *et al.*, 2005a; 2005b). The abundance and morphology of benthic foraminifera is closely associated with the reproduction which depends on the ambient environmental conditions. Therefore, the changes in abundance and morphology of the benthic foraminifera should be evaluated in the perspective of changing mode of reproduction. However, except for the views expressed by Boltovskoy and Wright (1976) that under favourable conditions, the species prefer asexual mode of reproduction, not much attention has been paid to understand changing mode of reproduction (if any) of benthic foraminifera in response to changing environmental conditions. Recently, Dettmering *et al* (1998) and Lehmann *et al* (2006) explored various possibilities for the occurrence of morphologically distinct forms belonging to the same species based on laboratory culture studies. The presence of morphologically distinct forms within the same species is attributed to reproduction in foraminifera. Alternating sexual and asexual mode of reproduction, leading to two distinct forms, viz. microspheric and megalospheric is common in foraminifera (Boltovskoy and Wright, 1976). The asexual reproduction results in megalospheric individuals whereas sexual reproduction leads to microspheric individuals (Boltovskoy and Wright, 1976; Lee *et al.*, 1991; Lehmann *et al.*, 2006). Thus the relative abundance of megalospheric and microspheric forms can help to assess changing mode of reproduction (Nigam, 1986). The purpose of this study is to explore changes, if any, in the mode of reproduction of benthic foraminifera *Epistominella exigua* (Fig. 1), by studying the abundance and morphological characteristics of *E. exigua* in the sediments collected from the distal Bay of Bengal Fan.

## **Previous Studies on *Epistominella exigua* (Brady)**

*Epistominella exigua* is a trochospirally coiled, calcareous species with smooth surface (Murray, 1991). This taxon is epifaunal detritovore, usually associated with a pulsed supply of phytodetritus and elevated oxygen concentrations (Gooday, 1993; Mackensen *et al.*, 1995; Schmiedl *et al.*, 1997; Nees and Struck, 1999; Gupta and Thomas, 2003). Abundance of thin-walled *Epistominella exigua* has been noted to indicate slightly less carbonate-corrosive conditions. The increased abundance of *E. exigua* has also been correlated with seasonal pulses of food supply (Gooday, 1993). According to Fontanier *et al* (2003), the taxa *Epistominella exigua*, *Reophax guttiferus*, *Bolivina spathulata*, *Cassidulina carinata* and *Nuttallides pusillus* appear to respond to the arrival of labile organic matter. Boltovskoy and Lena (1969) showed

that in eutrophic shallow water environments, *E. exigua* has short reproductive cycle (about one month) and reproduces throughout the year. Peterson (1984) while studying the distribution of Recent benthic foraminifera from the deep eastern Indian Ocean region, reported that *E. exigua* is associated with more oxygenated Indian bottom water of the Wharton-Cocos Basin. Gupta and Thomas (2003) grouped *E. exigua* along with the species indicating cool, strongly pulsed, low to intermediate flux and high seasonality environment and applied the same to infer paleomonsoon pattern from the equatorial Indian Ocean region. Based on the down-core variation of abundance and average proloculus size of *E. exigua*, Saraswat *et al* (2005b) concluded that the conditions favourable for *E. exigua*, mainly represented by increased seasonality in the organic matter production persisted at ~7 kyr BP, ~22 kyr BP and ~33 kyr BP and ~46 kyr BP in the distal Bay of Bengal fan.

## Materials and Methods

A total of 50 samples from the top 100 cm section of a gravity core collected during the 157<sup>th</sup> cruise of ORV *Sagar Kanya*, under the then Department of Ocean Development (now Ministry of Earth Sciences) funded project were used. The core was collected at 4.6° N latitude, 85.4°E longitude from a water depth of 3439 m (Fig. 2). The sediment samples were processed following the standard procedure for foraminiferal studies.

Five to ten gram of sediment from each sample was dried overnight at 45°C. Dried sample was weighed and soaked with distilled water and subsequently treated with 5-10 ml of 10% sodium hexametaphosphate to dissociate clay particles followed by addition of 5 ml of 10% hydrogen peroxide to oxidize the organic matter. The treated samples were wet sieved through 63 µm size sieve. The sand residue retained over the sieve was transferred on weighed Whatman filter paper and dried (at ~45°C) to obtain weight of sand fraction. From an appropriate aliquot of sand fraction (varying from sample to sample, ~0.25-0.04 g), ~300 specimens of benthic foraminifera were picked and mounted in micropaleontological slides. Specimens of *E. exigua* were segregated from the benthic foraminiferal assemblage. In the samples where *E. exigua* is less in numbers in the total of 300 specimens, additional forms were picked from the remaining samples.

The proloculus size, number of chambers and average diameter of each specimen was measured by keeping the specimen in dorsal view under an Olympus SZX 12 stereozoom microscope, with a maximum magnification of 180x. A total of 872 *E. exigua* were studied for generating data points, and each data point is an average of ~20 specimens. In order to avoid minor variations to smoothen the down-core variation of all parameters, 2-point running average was calculated and plotted against the depth. However, higher level averaging (3 or 5 point) was avoided in view of coarse resolution of core and not to subdue important events. The age of the core was estimated by two Accelerator Mass

Spectrometer radiocarbon dates obtained on monospecific (*Globorotalia menardii*) planktic foraminiferal samples at 02-04 cm and 48-50 cm interval ( $3700\pm 25$  and  $22170\pm 130$  yr BP, respectively), calibrated by using Calib Rev 5.0.1 software (Stuiver *et al.*, 2005) and corrected for  $\Delta R$  (difference between the regional and global marine  $^{14}\text{C}$  age) (Dutta *et al.*, 2001).

## Results and Discussion

The relative abundance of *Epistominella exigua* shows large variation (varying from ~2 to ~10%). Abundance is comparatively high towards the bottom of the core but decreases sharply till ~42 kyr BP (Fig. 3). From ~42 kyr BP upwards, the abundance shows a fluctuating trend, with an increase till ~33 kyr BP. Above ~33 kyr BP, the abundance decreases sharply till ~27 kyr BP to increase again till ~25 kyr BP. From ~25 kyr BP upwards, the abundance decreases gradually till ~18 kyr BP and remains comparatively low till ~12 kyr BP. The relative abundance of *E. exigua* remains comparatively high (> ~5%) throughout the upper portion of the core till ~12 kyr BP and in the top sample the relative abundance of *E. exigua* is reported to be ~5% (Fig. 3).

Down-core variation in average proloculus size of *E. exigua*, in general, closely follows that of *E. exigua* relative abundance, except for a brief period (~35-37 kyr BP) towards the lower part of the core (Fig. 3). The average proloculus size is comparatively larger towards the bottom of the core section and remains high till ~32 kyr BP, with a fluctuating trend. Above ~32 kyr BP, the average proloculus size decreases till ~28 kyr BP. From ~28 kyr BP onwards the average proloculus size increases and remains comparatively large till ~18 kyr BP. Above ~18 kyr BP, the average proloculus size decreases slightly and remains smaller till ~10 kyr BP. From ~10 kyr BP upwards, the average proloculus size remains comparatively large till the top of the core. The lowest average proloculus size (~16  $\mu\text{m}$ ) is reported at ~28 kyr BP while the maximum (~27  $\mu\text{m}$ ) is reported at ~40 kyr BP. Though the general down-core variation trend of both abundance and average proloculus size of *E. exigua* is similar, as evident from the figure, the point to point correlation value is very low, probably due to slightly incoherent and non-linear response of both abundance and average proloculus size of *E. exigua*, to changing physico-chemical parameters.

A strong inverse relationship is observed between down-core variation of *E. exigua* abundance and average size as well as average number of chambers (Fig. 4). The average size of *E. exigua* remains comparatively low from core top till ~12 kyr BP, with minor peaks corresponding with minor troughs in abundance (Fig. 4). From ~12 kyr BP downward, average size of *E. exigua* increases sharply and remains comparatively large till ~18 kyr BP. Average size again shows a decreasing trend till ~27 kyr BP, below which average size is comparatively large till ~31 kyr BP. From ~31 kyr BP downward the average size of *E. exigua* again shows increasing trend almost upto the bottom of the core, decreasing slightly towards

the bottom most part of the core. The maximum average size (~241  $\mu\text{m}$ ) is reported at ~15 kyr BP whereas minimum average size (~179  $\mu\text{m}$ ) occurs at ~27 kyr BP. Though the average total number of chambers per specimen of *E. exigua* shows minor variation throughout the core, the trend is similar to that of down-core variation of average size of *E. exigua* (Fig. 5). The general down-core variation of various parameters does show direct or inverse relationship but the point-to-point correlation values are insignificant, probably due to incoherent response of various morphological characteristics and abundance of *E. exigua*, to changing physico-chemical parameters.

The degree of differences between megalospheric and microspheric specimens varies from species to species. The alternating mode of sexual and asexual reproduction has been cited as the factor responsible for the morphologically distinct forms (Lister, 1895). However, the megalospheric and microspheric forms of all the species have not been found to have distinctly different proloculus size (Schaudin, 1895). Therefore, it was suggested that the overall size of the test along with the number of chambers should also be considered to distinguish the specimens into megalospheric and microspheric forms (Boltovskoy and Wright, 1976). Interestingly, repeated occurrence of asexual reproduction was noted in number of specimens under normal conditions, whereas sexual reproduction was favoured only during harsh conditions (Hofker, 1930; Arnold, 1964). Therefore, if a relationship can be established between the relative abundance of microspheric and megalospheric specimens with the relative abundance of the species, it will provide an idea about the changing mode of reproduction in the species. The information can then be used as a proxy for paleoclimatic reconstruction. Here we have made an attempt to infer such relationship for the benthic foraminiferal species *Epistominella exigua*.

The direct relationship between the down-core abundance and average proloculus size of *E. exigua* indicates that under favorable conditions *E. exigua* specimens have more megalospheric shells. This conclusion is further supported by inverse relationship between average size of specimen as well as average number of chambers, and abundance and average proloculus size of *E. exigua*. Since asexual reproduction leads to megalospheric specimens with large proloculus, smaller size and comparatively less number of chambers, it is inferred that *E. exigua* prefers asexual mode of reproduction under favorable conditions leading to prolific growth of specimens. Boltovskoy and Wright (1976) expressed similar views about the benthic foraminifera in general while stating that under normal condition number of megalospheric specimens always outnumber the microspheric specimens. As the morphological variations of the test, as well as the variation in distribution of benthic foraminifera have previously been applied to infer past climatic variations from the west coast of India (Nigam and Rao, 1989; Nigam and Khare, 1992; Nigam and Khare, 1999) the present study suggests that morphologic variations of *E. exigua* can also be applied to infer paleoclimatic conditions.

## Conclusion

In this study we provide insight into the mode of reproduction in benthic foraminifera *Epistominella exigua*, in response to changing physico-chemical conditions from distal Bay of Bengal Fan sediments. Based on the relationship between abundance and morphologic characteristics of *E. exigua* from distal Bay of Bengal Fan sediments, we observe that increased abundance matches well with smaller specimens having larger proloculus and less number of chambers, characteristic of megalospheric forms resulting from the asexual reproduction. We suggest that *Epistominella exigua* prefers asexual mode of reproduction during favourable conditions. Since relative abundance of *E. exigua* has been correlated with changing food supply, we conclude that morphologic characteristics of *E. exigua* can be used to infer past physico-chemical conditions.

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## LEGEND TO FIGURES

- Figure 1: Digital camera micrographs of *Epistominella exigua* (Brady); A. Spiral view, B. Side view, C. Umbilical view (Scale Bar= 50  $\mu\text{m}$ )
- Figure 2: Core Location in the southern Bay of Bengal.
- Figure 3: Down-core variation of *E. exigua* abundances and average proloculus size.
- Figure 4: Relationship between down core variation mean diameter of *E. exigua* specimens, both relative and absolute abundances, and average number of chambers per specimen.
- Figure 5: Down-core variations of *E. exigua* mean diameter and average number of chambers per specimen.

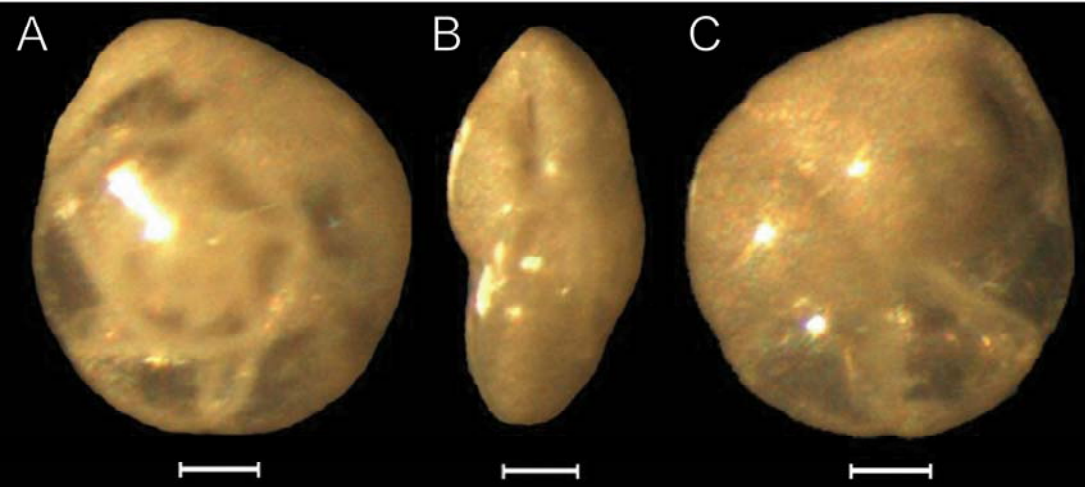


Figure 1

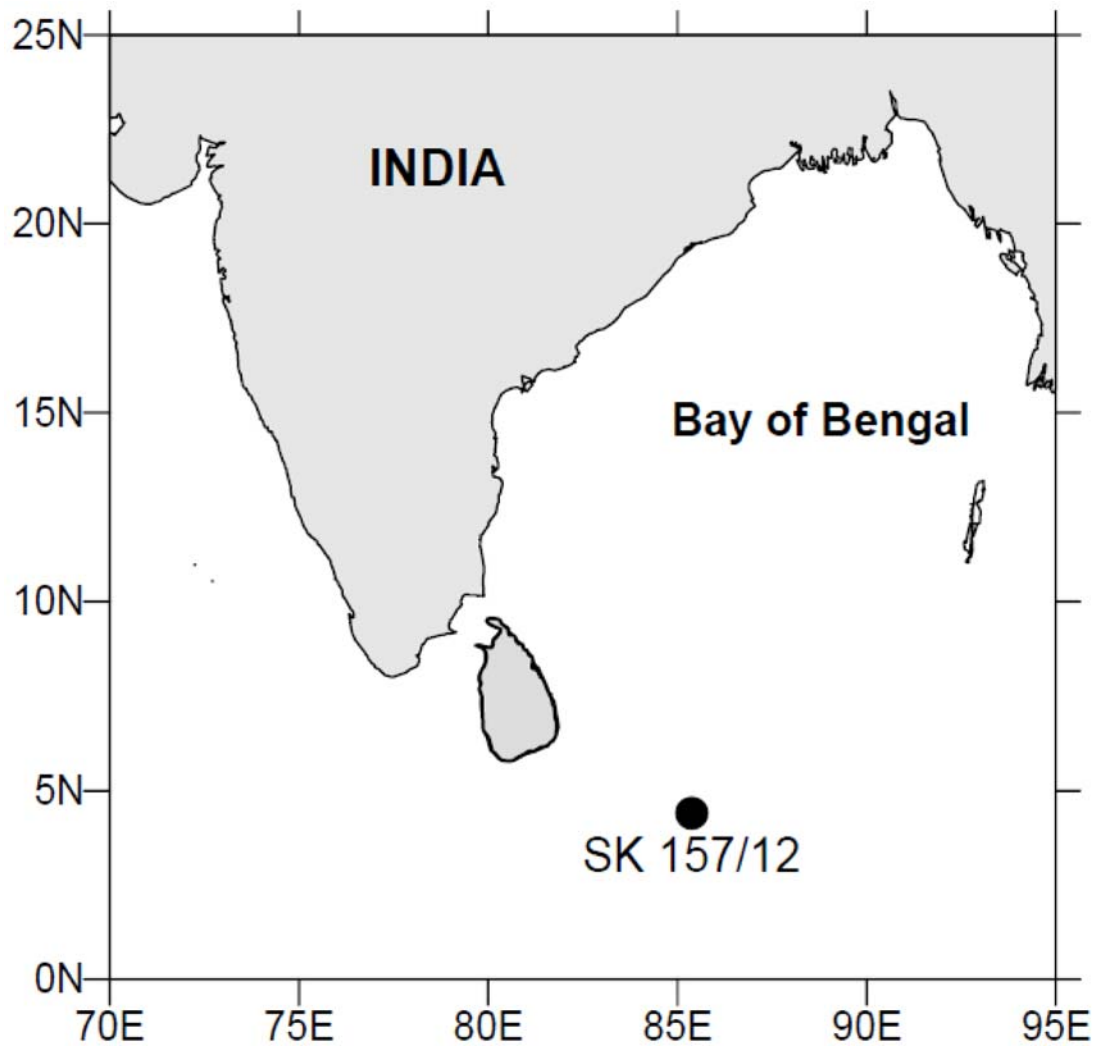


Figure 2

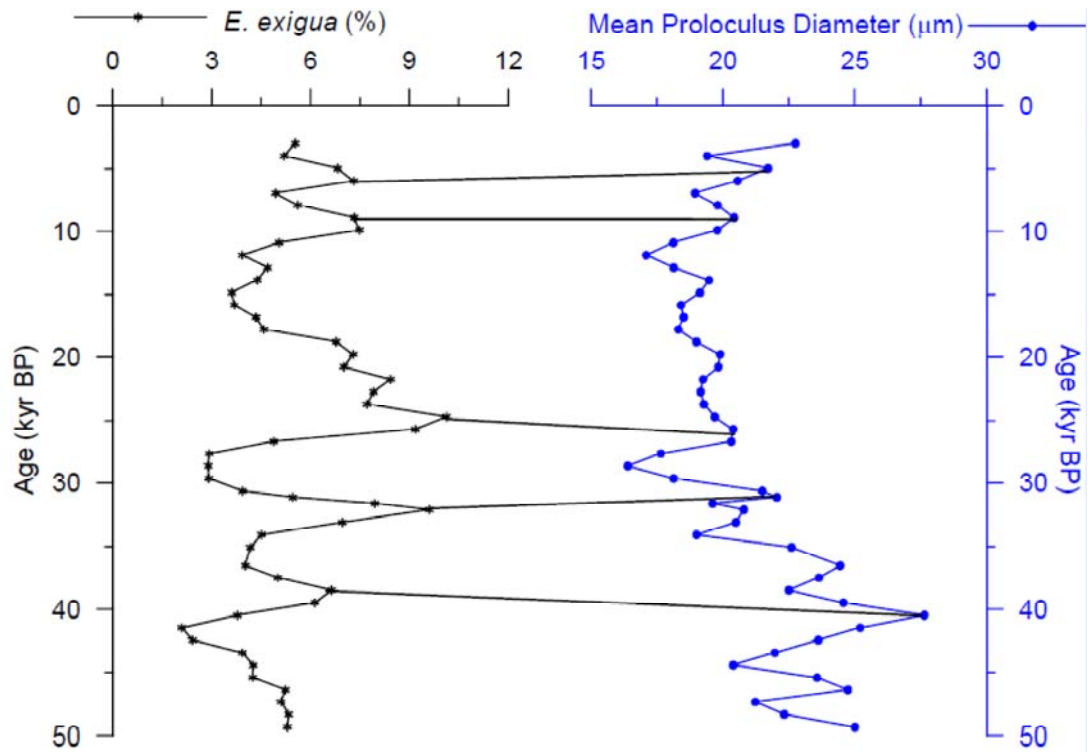


Figure 3

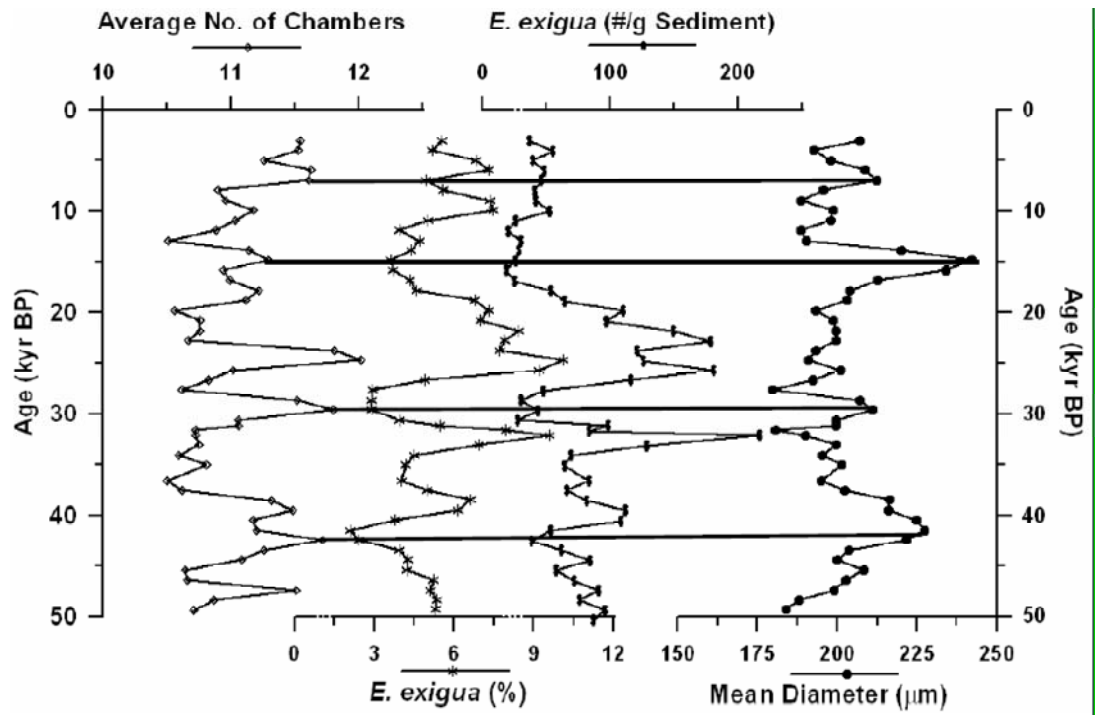


Figure 4

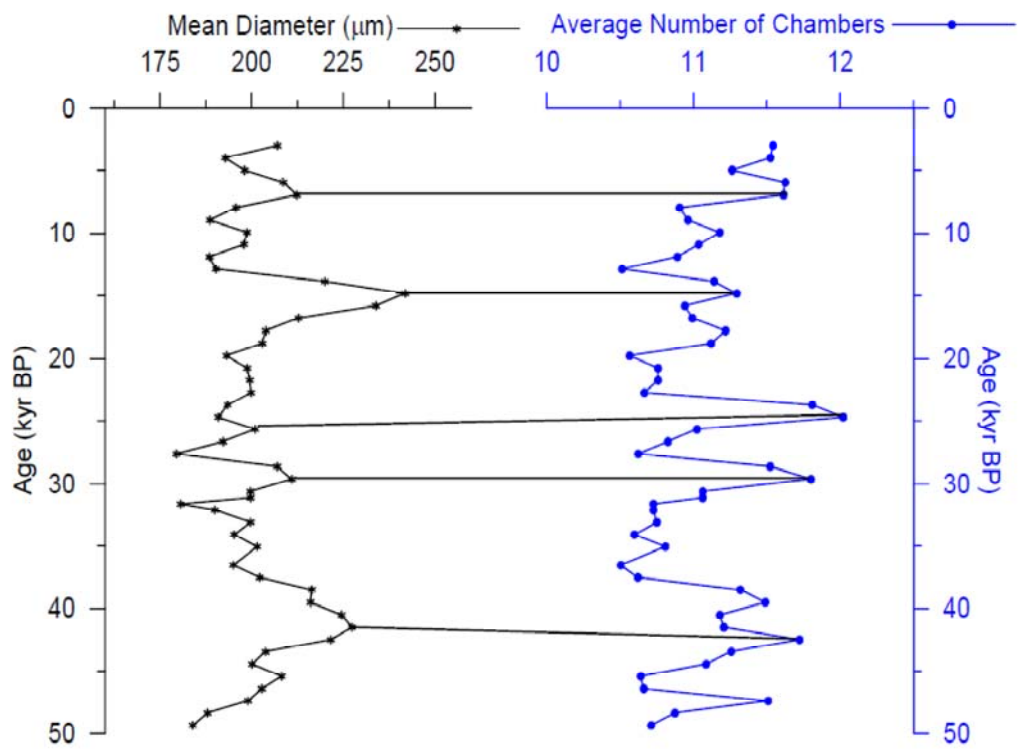


Figure 5