



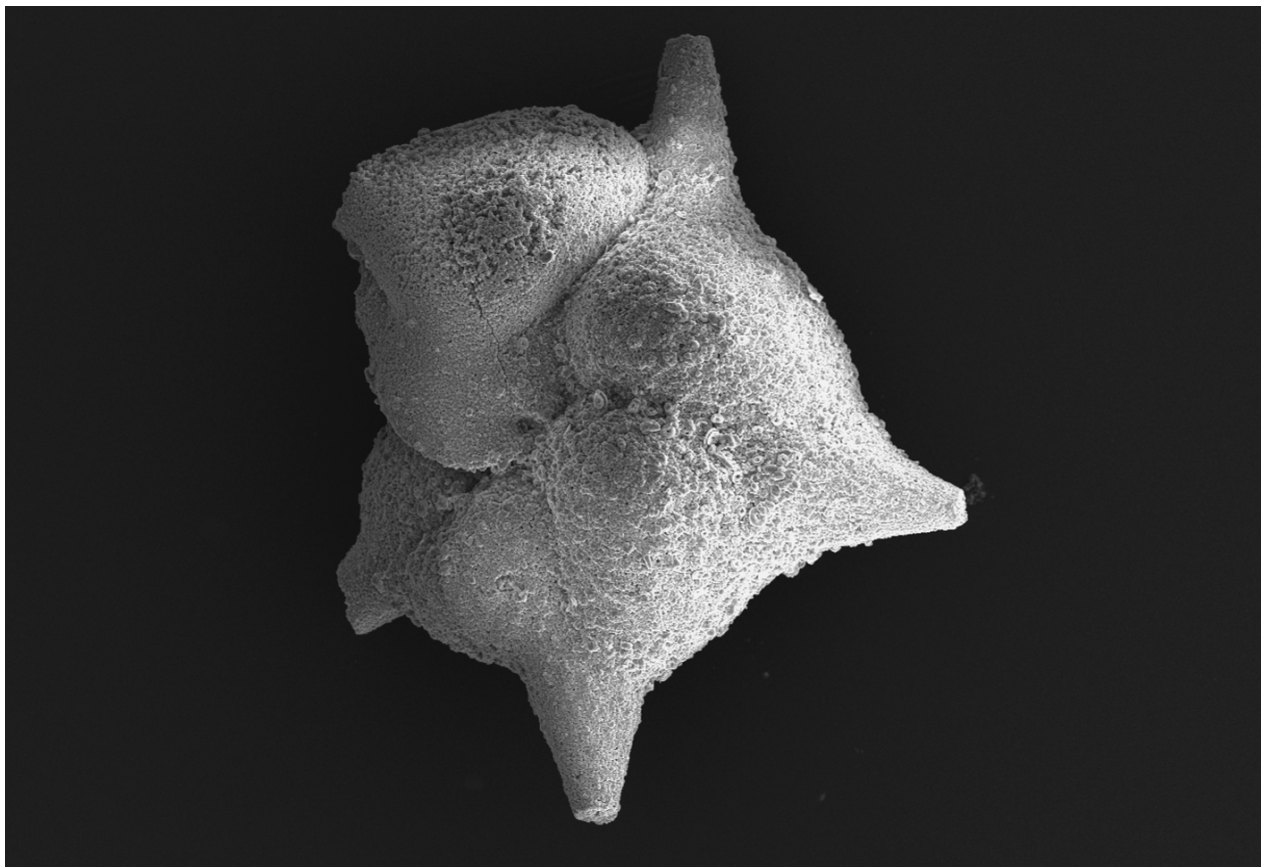
Stockholm
University

Bachelor Thesis

Degree Project in
Marine Geology 15 hp

The *Hantkenina* extinction and Eocene-Oligocene climate change at ODP Site 757, Ninetyeast Ridge, Southern Indian Ocean

Tomas Schedwin



Stockholm 2014

Department of Geological Sciences
Stockholm University
SE-106 91 Stockholm

The *Hantkenina* extinction and Eocene-Oligocene climate change at ODP Site 757, Ninetyeast Ridge, Southern Indian Ocean

Tomas Schedwin

Abstract.

This is a bachelor project at Stockholm's university with the aim of correlating the extinction of the planktonic foraminifera family *Hantkeninidea* and other key marker species of planktonic foraminifera at ODP Site 757 in the tropical Indian Ocean with climate change associated with the Eocene Oligocene boundary. The Eocene Oligocene transition is associated with the change in climate from a greenhouse world to icehouse conditions with a glaciated Antarctica. This transition is divided into a number of steps, EOT-1 and Oi-1 followed by the EOGM. The Eocene Oligocene boundary that is defined by extinction of hantkeninids have been shown to that fall in between EOT-1 and Oi-1 during an intermediate plateau in the $\delta^{18}\text{O}$ isotopic record. 29 samples from site 757B were visually examined for a number of key marker species in the late Eocene and early Oligocene of site 757. Two last occurrences (LO) were found at the site, hantkeninids at 120,36mbsf and *Globigerinatheka index* at 121,9mbsf. Two age models with the LO combined with published bioevents of calcareous nannofossils found at the site was created and the age model gave ages of extinction to 33,65Ma for hantkeninids and 34,6Ma for *Globigerinatheka index* which is close to calibrated ages for the extinctions. With the age model-1 the sedimentation rate was calculated to 2,90m/Ma. The age of hantkeninids were compared to benthic stable isotope data at the site and it showed that the hantkeninids extinction occurs in between EOT-1 and Oi-1, where the climate started to change but before large increase in benthic stable isotope associated with the Oi-1. The timing of the extinction of hantkeninids indicates that changes in seawater temperature is an important factor.

Abstract	1
Introduction.....	4
Background.....	4
Geological background.....	5
Purpose	6
Method.....	7
Sample preparation.....	7
Scanning electron microscope.	7
Biostratigraphic analysis.....	8
Taxonomy.....	8
<i>Globigerinatheka index</i> (Finlay, 1939).....	9
Hantkeninidea (Cushman, 1924).....	9
<i>Pseudohastigerina</i> spp (Banner and Blow, 1959).....	9
<i>Turborotalia cocoaensis</i> (Cushman, 1928)	10
<i>Chiloguembelina cubensis</i> (Glaessner, 1937)	10
<i>Subbotina</i> spp (Brotzen and Pozaryska 1961)	10
<i>Dentoglobigerina</i> spp (Blow, 1979).....	11
Age model	11
Results	12
Site 757 planktonic foraminifera assembles and calcite preservation.....	12
Examined samples.....	12
Plate 1	14
Plate 2.....	15
Plate 3.....	16
Relative abundance of planktonic foraminifera.....	17
Age-model	20
Age vs depth plot.....	20
Sedimentation rate.....	22
Comparison with isotope data	22

Discussion	23
Robustness of the Site 757B age model	23
Planktonic foraminifera turnover	23
Conclusion	24
Acknowledgements	24
References	24
Appendix	26

Introduction

Background

The Eocene Oligocene transition (EOT) is the change in earth's climate that occurred 34 million years ago (Ma) when the climate changed from an ice-free greenhouse world to a glaciated icehouse climate. This is believed to have taken around 500 000 years and occurs in the boundary between the Eocene and the Oligocene (EO) epochs (Coxall & Pearson, 2007).

The causes of the major transition in the climate are still unclear but are believed to have involved (i) changes in the ocean circulation due to the separation of Antarctica from Australia and South America that isolates Antarctica, (ii) lowering carbon dioxide in the atmosphere past threshold level for glaciation (Coxall & Pearson, 2007; Zachos et al. 1996) and (iii) changes in earth's orbital pattern that encourage ice growth (Coxall et al. 2005). The effects on the EOT can be seen in different systems of the earth for example in isotope records in the shells of benthic foraminifera and a big evolutionary turnover in the planktonic foraminifera (Coxall & Pearson, 2007).

From a biostratigraphic perspective the E/O is marked by the extinction of one family of foraminifera, the Hantkeninidea (Nocchi et al. 1988) here after referred to as hantkeninids. This distinctive family characterized by tubospines, disappeared from the stratigraphy 33,7Ma (Wade et al. 2011). The last occurrence of hantkeninids defines the stratigraphic marker, or the golden spike at Massignano in Italy (Nocchi et al. 1988). Before the E/O-boundary 5 species of the hantkeninids was present (Pearson et al. 2006), all of which disappeared at the E/O-boundary.

Planktonic foraminifera at and close to the E/O underwent a large biotic turnover that left many niches available for other species to fill (Coxall and Pearson, 2007). Some of the important planktonic foraminifera events other than the extinction of hantkeninids that are closely related to the E/O are: (i) the extinction of *Globigerinatheka index* (Nocchi et al. 1988) at 34.5Ma (Wade et al. 2011), (ii) the last occurrence of *Turborotalia cerrazulensis* and (iii) the disappearance of larger individuals of *Pseudohastigerina micra* (Nocchi et al. 1988; Coxall & Pearson, 2007). The abundance of the genus *Pseudohastigerina* was also declining at the E/O (Wade & Pearson, 2008).

The $\delta^{18}\text{O}$ isotope record in benthic foraminifera can be seen as an important proxy for recording the changes the EOT had in the climate. The $\delta^{18}\text{O}$ in the benthic foraminifera reflect seawater temperature and the initial $\delta^{18}\text{O}$ of the seawater. Ice growth and ice melting affect the amount of $\delta^{18}\text{O}$ in seawater (Coxall & Pearson, 2007).

It is in the benthic isotopes that evidence that the EOT had a distinctive stepped structure could be found. The transition is divided into steps that are clearly visible in the stable isotope record. The first step it called the Eocene Oligocene transition 1 (EOT-1). EOT-1 occurred 33,8Ma and characterized by a 0,9‰ increase in the $\delta^{18}\text{O}$ stable isotope record. The cooling of this event is estimated to 2,5°C (Katz et al.

2008). The second event is called the Oligocene ice event (Oi-1). This step occurs 33,5Ma and the rise in stable isotopes is estimated to 1.0‰ and the water masses cooled with 2°C. During Oi-1 was when the largest expansion of ice sheets on Antarctica is thought to have occurs (Katz et al. 2008). The time that follows the Oi-1 is called the Eocene Oligocene Glacial Maximum (EOGM) where the isotope records are highest before they decrease (Coxall & Pearson, 2007).

The few existing records having both stable isotopes and hantkeninids extinction (Coxall & Pearson, 2007; Wade & Pearson, 2008) the extinction of hantkeninids is occurring during an intermediate plateau in the $\delta^{18}\text{O}$ isotopic record where there is little shifts in the isotopes just before the sudden increase in the isotope associated with the Oi-1 event (Figure 1). It is important for this study to be able to distinguish these events and their relationship with climatic events indicated by, in the benthic stable isotope records.

Previous studies on the E/O where both $\delta^{18}\text{O}$ and hantkeninids occur are few. The most detailed study is by Pearson et al, (2008) in Tanzania 2008 that hantkeninids went extinct during the intermediate plateau between EOT-1 and Oi-1 (Figure 1). This study will help to fill the gap in knowledge concerning whether this is robust, in example if hantkeninids goes extinct at the same time globally and if it occurs on the plateau in the $\delta^{18}\text{O}$ isotopic record.

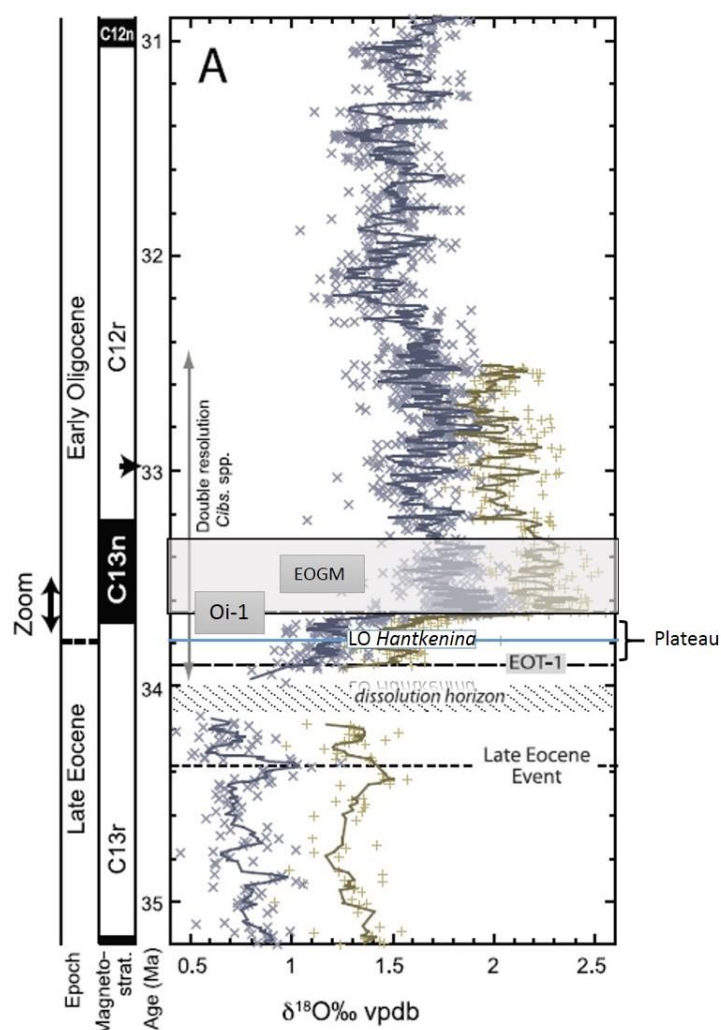


FIGURE 1 SHOW A MODIFIED BENTHIC $\Delta^{18}\text{O}$ RECORD FROM COXALL AND WILSON 2011 WITH LAST OCCURRENCE OF *HANTKENINA*, THE PLATEAU IN BETWEEN EOT-1 AND OI-1 AND THE EOGM FROM SITE 1218 IN THE PACIFIC OCEAN.

Geological background

Nintyeast ridge is a bathymetric high located in the Indian Ocean (figure 2). The ridge is approximately 5000 km long and stretches from 34°S to 10°N with a height from 1500 to 3000 m above the sea floor and 100km to 200km wide (Shipboard Scientific Party, 1989). The ridge is believed to have been formed from by the Kerguelen/Nineyeast hot spot that is located on the Indian plate before the Keroguelen plateau and the Indian plate was separated in the middle of Eocene. The basement of the ridge contains basalts with a geochemistry similar to lavas from other oceanic islands (Shipboard Scientific Party, 1989).

Out of the three holes that were drilled at Site 757, hole 757B turned out to be the best to do paleontological study on, because of the continuous core down to a total depth of 374,8mbsf and sequence of calcareous ooze from the Holocene to Paleocene until the basaltic basement was hit (Shipboard Scientific Party, 1989). Out of the 374,8mbsf 271,94m of core was recovered giving a total core recovery of 72%. The total water depth at the site was measured to be 1652,1m measured using the drill-pipe (Shipboard Scientific Party, 1989). The sediments recovered at site 757 is dominated by carbonate sediments with a carbonate content of 90% down to 210mbsf (van Eijden & Smit, 1991) and contains planktonic foraminifera and calcareous nanofossils that are dated as early Eocene to Holocene. Benthic foraminifera is present but not as abundant as planktonic foraminifera (Shipboard Scientific Party, 1989). Below 210mbsf in the Paleocene the carbonate content drops drastically down to 10% and contains mostly of volcanogenic material (van Eijden & Smit, 1991). Dissolution could be a factor controlling the amount of foraminifera in the sample (van Eijden & Smit, 1991). The depth of the water of the early Eocene was around 1500m. The assemblage of the planktonic foraminifera at site 757B is species that thrives in tropical to subtropical environments (Shipboard Scientific Party, 1989).

Purpose

The primary objective of this project is to calibrate the extinction of the hantkeninids to benthic foraminifera stable isotope record at ODP Site 757 on the Ninetyeastridge in the Indian Ocean, relate extinction and changes in morphology in important key marker species to the climatic changes at the Eocene Oligocene boundary.

The secondary objective was to generate a biostratigraphic age model for the site using the planktonic foraminifera data and published nannofossil events at Site 757. These data were compared to other locations that have stable isotope record.

To do this the taxonomy of hantkeninids and other important late Eocene to early Oligocene planktonic foraminifera marker species was required.

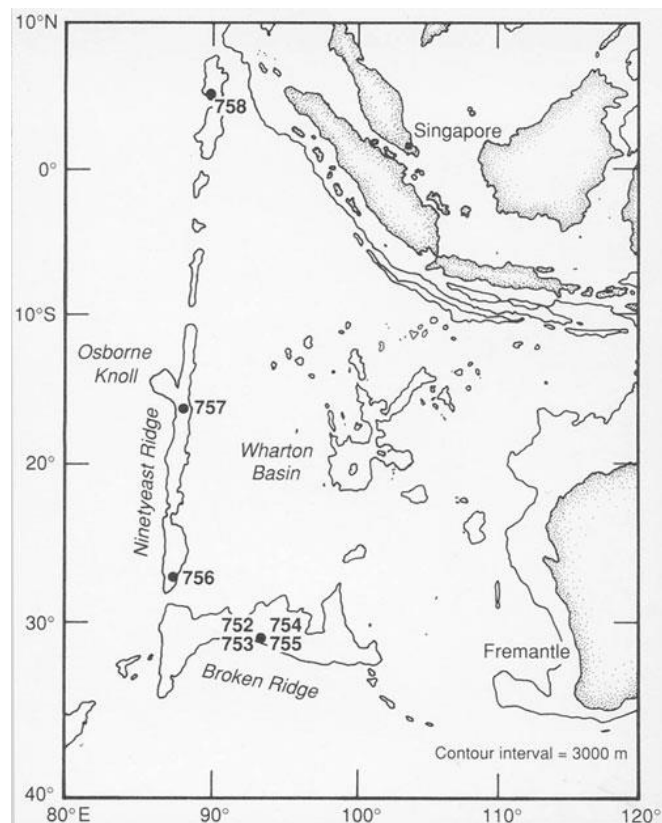


FIGURE 2 SHOWS THE LOCATION OF NINETYEAST RIDGE
[HTTP://WWW-ODP.TAMU.EDU/PUBLICATIONS/121_IR/IMAGES/121_MAP.JPG](http://www-odp.tamu.edu/publications/121_IR/images/121_map.jpg)

Method

Sample preparation

Prior to the project the samples from site 757 had been washed and sieved with a fraction of 63 μ m and larger. In order to gain knowledge on how to prepare unwashed samples preparation from two different sites was done. The sites for this preparation were VAT 12 from Lake Vättern and ODP site 1406C.

The method for preparing the samples was given by lab-technician Klara Hajnal.

The samples were frozen one day before the samples could be freeze-dried. To freeze-dry the samples the plastic bags containing the samples was cut open and placed in an exicator for three days.

After three days the samples were taken out of the freeze dryer and cut up into smaller parts to make them disaggregate more easily. Some of the sample from site 1406C was saved if other method of preparation was needed.

In order to document the right sample weight the Erlenmeyer flasks (E-flasks) were numbered and weighed. The samples were transferred into the pre- weighed E-flasks and the sample plus E-flask was weight. 100 to 150 ml deionized water was added to E-flasks and the E-flasks was put into a shaker table for at least 60 minutes or more to suspend the sediment.

The solution was poured into numbered sieves with fraction of 63 μ m and to wash away the clay component (<63 μ m) with deionized water until the liquid leaving the sieve was clear. The sieving process was controlled using a light microscope to see that all the clay was washed away.

For samples where there was clay left the sieves was put into a sonicator in order to dissolve the clay. This process was repeated in some cases. Samples that contained a great amount of clay was dried overnight and washed again to get rid of the cohesive forces in the clay and make it easier to wash away the clay.

When the sample has been washed it was placed in a drying cabinet with a temperature of 49,5C to dry overnight to be transferred into vials. The vials were weighed before and after the sample was transferred into the vial to get the total weight of the samples.

Scanning electron microscope.

In order to document the morphology of the important biostratigraphic markers and other important species present in the assemblage, and to examine the quality of preservation of the planktonic foraminifera images were taken using the scanning electron microscope (SEM) at Stockholm University (Philips XL-30-ESEM-FEG).

To prepare the samples for the SEM the best-looking specimens of each species that needed to be examined were chosen. Ideally three specimens of each species in three different diagnostic views, as shown by Pearson et al. (2011) are required. The specimens selected were manually placed on steel stubs that are designed to fit into the SEM. The surfaces of the stubs were coated with gold so that the specimens do not get charged, and so that the electrons bounce of the surface of the foraminifera. The stub is imaged under high vacuum of >10⁵ mbar with a voltage of 15,00kV.

Biostratigraphic analysis

A primary goal of this study was to use planktonic foraminifera biostratigraphy to provide a chronologic framework of the EOT at Site 757. Biostratigraphy is an indirect method to reconstruct climatic change and changes in the ocean using fossils. Observations are made in fossil assemblage composition of the sediments, changes in morphology (size) and extinctions of a species or genera.

The first stage in this process was to document the stratigraphic range of hantkeninids and other important late Eocene to early Oligocene key species. This information was recorded in a range chart using a binocular light microscope. The key marker species were relatively rare, therefore samples were separated in three different fractions (>250µm, 150-250µm and 63-150µm), which helped the process of systematic scanning.

The Abundance of a certain species in a sample was determined in a qualitative sense. The abundance was divided into four different categories, Not observed (.) which means that there was no individual of that species present in the sample, Observed (O), that there was a few specimens present. Rare (R) means that individuals were present in the sample but not many. Common (C), that there are a lot of that certain species in the sample and Very common (V), that the sample is dominated by that certain species. A blank cell means that the abundance of the species was not recorded.

Counts were not made with these samples because it is a very time-consuming process and therefore not possible in the short timeframe of this project.

Taxonomy

The taxonomy used to determine the different species of foraminifera was the Atlas of Eocene planktonic foraminifera (Pearson et al. 2006).

Nine key-species was examined and sought after, *Globigerinatheka index*, *Hantkenina spp.*, *Cribohantkenina inflata*, *Pseudohastigerina micra*, *Pseudohastigerina naguwichiensis*, *Turborotalia cocoaensis*, *Chiloguembelina cubensis*, *Subbotina spp.* and *Dentoglobigerina spp.*, whose evolution have been incorporated into existing biostratigraphic biozonation schemes

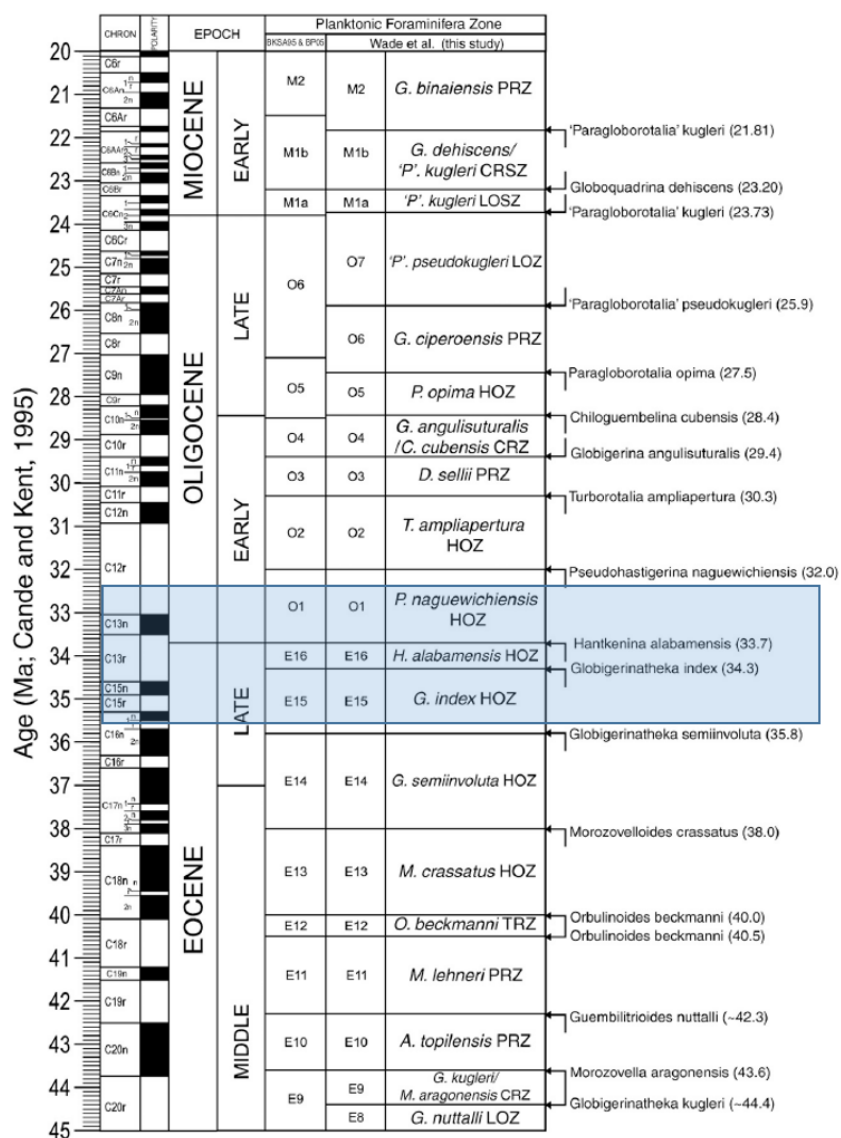


FIGURE 3 SHOW MODIFIED VERSION OF BIOZONATION SCHEME FROM WADE ET AL. (2011) WITH THE INTERVAL OF INTEREST HIGHLIGHTED.

(Wade et al. 2011). The planktonic foraminifera event is shown in Cande and Kent (1995) (CK95) polarity timescale (Figure 3).

Using the Atlas of Eocene planktonic foraminifera (Pearson *et al.* 2006) the differences between species could be determined.

Species list and taxonomic notes.

Globigerinatheka index (Finlay, 1939)

Finlay, H.J., 1939, New Zealand foraminifera: Key species in stratigraphy – No. 2: Royal Society New Zealand, Transactions Proc., v. 69, pt. 1, p. 89-128. Plate 1, Figures 4-6.

Rounded but slightly elongated and a very compact outline. It got 3 chambers in the final whirl with distinct and visible sutures. The final chamber is larger than the two previous ones. They consists of one to three apertures but most commonly two that is located in-between the three final chambers and directly above the suture. The aperture is commonly large and arched. *Globigerinatheka index* went extinct in the late Eocene around 34.3Ma (Wade et al 2011).

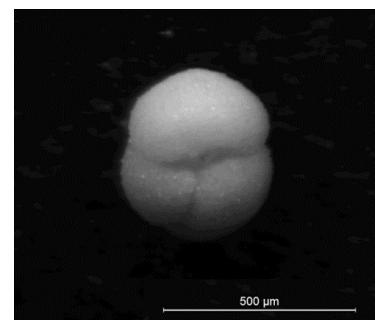


IMAGE 1 SHOW A
GLOBIGERINATHEKA INDEX
UNDER THE LIGHT MICROSCOPE.

Hantkeninidea (Cushman, 1924)

Cushman, J.A., 1924, A new genus of Eocene foraminifera: Proceedings of the U.S. National Museum, v. 66, p. 1-4. Plate 2, Figure 1-8.

Hantkeninids are recognized by tubulospines that grow from the chambers in the final whirl. Hantkeninids are planispiral and have 4 to 7 chambers in the final whirl. Sutures are visible making the chambers visible. Broken off spines of hantkeninids have hollow canals and can be distinguished by this feature. Genus *Cribrohantkenina* is distinguished from *Hantkenina* spp. by the presence of one or more additional apertures on the final chamber while *Hantkenina* spp. has only one arched aperture on the final chamber. Size of the genus is maximum 0,75mm in diameter including the spines (Pearson et al. 2006) The hantkeninids went extinct around 33.7Ma (Wade et al. 2011) and is the marker of the boundary between Eocene and Oligocene (Nocchi et al. 1988).

Pseudohastigerina spp (Banner and Blow, 1959)

Banner, F. T., Blow, W. H., 1959, The classification and stratigraphical distribution of the Globigerinacea: Palaeontology, v. 2, p. 1-27. Plate 3, Figure 1-4.

Pseudohastigerina spp. is rounded and planispiral. It got five to six chambers in the final whirl and an aperture on the final chamber. Specimen is most commonly found in the 63 to 150µm fraction but some can be found in the 150 to 250µm fraction where they are less abundant.

Distinguishing features between *Pseudohastigerina naguewichiensis* (Plate 3, Figure 1-2) and *Pseudohastigerina micra* (Plate 3, Figure 3-4) are that *P. naguewichiensis* has a lower chamber rate expansion, the final chamber is smaller compared to the penultimate, while on *P. micra* the final chamber is much larger compared to the earlier chambers. *P. micra* also appear to be taller and less compact than *P. naguewichiensis*. To distinguish the two species apart is difficult in the light microscope due to their similar appearance and small size. *P. naguewichiensis* went extinct 32,0Ma (Wade et al. 2011). Extinction of *P. micra* is somewhat unknown and Pearson et al. (2006) does not give a precise age of extinction.

Turborotalia cocoaensis (Cushman, 1928)

Cushman, J.A., 1928, Additional foraminifera from the Upper Eocene of Alabama: Contributions from the Cushman Laboratory for Foraminiferal Research, v. 4, p. 73-79.

Plate 1, Figure 1-3.

Turborotalia cocoaensis has a trochospiral test with four to five chambers in the final whirl visible on the spiral side. Sutures are poorly visible. On the umbilical side the chambers and sutures are more visible and in the center of the umbilical side it has a chamber that often is eroded into a depression. Aperture appears on the edge view and is large and arched. In a side view *Turborotalia* is flat on the umbilical side and rounded on the spiral side. *Turborotalia cocoaensis* went extinct around 35,8Ma (Pearson et al. 2006).

Chiloguembelina cubensis (Glaessner, 1937)

Glaessner, M.F., 1937, Studien über foraminiferen aus der Kreide und dem Tertiär des Kaukasus. I. Die foraminiferen der ältesten Tertiärschichten des Nordwest-Kaukasus: Problemy Paleontologii, Paleontologicheskay Laboratoriya Moskovskogo Gosudarstvennogo Universiteta, v. 2-3, p. 349-410.

Plate 3, Figure 5-7.

Chiloguembelina cubensis is elongated, triangular shaped with 12 to 14 chambers growing in a bispiral fashion. The chambers are rounded and increase in size through ontogeny. The aperture is arched and located in the center of the final chamber. Specimens are planispiral and are commonly found in the 63 to 150µm fraction although some specimens can be found in the 150 to 250µm fraction though it is much less common. *Chiloguembelina cubensis* continues through in the range of interest.

Subbotina spp (Brotzen and Pozaryska 1961)

Brotzen, F., Pozaryska, K., 1961, Foraminifères du Paléocène et de l'Eocène inférieur en Pologne septentrionale; remarques paléogéographiques: Revue de Micropaléontologie, v. 4, p.155-166.

Plate 1, Figure 10-12.

Subbotina spp. has 3 to 4 spherical chambers in the final whirl arranged in a trochospiral fashion. The chambers are usually heavily inflated and are easily distinguished from *Globigerinatheka index* due to this. Aperture got an umbilical position and is in most specimens arched. Most *Subbotina* spp. species has either a lip or a tooth in the chamber above the aperture.

Subbotina spp. is found in all fractions of the samples from site 757 though they can be hard to distinguish from *Dentoglobigerina* spp. in the smallest fraction.

Dentoglobigerina spp (Blow, 1979)

Blow, W. H., 1979, The Cainozoic Globigerinida: E.J. Brill, Leiden, 1413p.

Plate 1, Figure 7-9.

The features of *Dentoglobigerina* spp. has a similar appearance as *Subbotina* spp. except that the chambers are not as inflated as in *Subbotina* spp. *Dentoglobigerina* spp. at Site 757 have 4 chambers in the final whirl and visible sutures. The aperture is commonly large and arched placed above the middle chamber. The final chamber is larger than the other chambers and the final chamber can have a tooth like structure above the aperture.

Dentoglobigerina spp. is present in most of the samples at site 757 all though they can be confused with *Subbotina* spp. in the smaller fractions.

Age model

Using the range chart (as described above) first and last occurrences and depth in the core (mbsf) of the key species were recorded together with their calibrated age in a datum table. To strengthen the age model, the planktonic foraminifera first and last occurrences were combined with biostratigraphic data based on bioevent of calcareous nannofossils from the Initial Report of Site 757 (Shipboard Scientific Party, 1989).

An age model was created by plotting the calibrated ages against the depth in the core for the FO and LO in an x-y scatter chart using Excel. The ages were calculated by adding a linear trend line (Age model-1). The sedimentation rate was calculated by the slope of the linear trend line added to the chart. An alternative age model was produced using a second order polynomial trend line (Age model-2).

Using the formula for the straight line ($y=mx+c$) the sedimentation rate could be seen as m in the formula (age model-1). The inverse of m was calculated in this case because of the style of the plot. To strengthen the sedimentation rate form the equation the change in the depth was divided with change in the calculated age below.

$$Sedrate = \frac{\Delta d}{\Delta t}$$

Results

Site 757 planktonic foraminifera assembles and calcite preservation.

The Site 757 assemblage can be divided into two types, Eocene and Oligocene. In samples from 120,22mbsf to 129,54mbsf the assemblage were dominated by Eocene related species of foraminifera. *Globerginatheka index* is present in most of the samples and fragments, spines or whole specimens of hantkeninids occur in many of the samples. *Dentoglobigerina* spp. and *Subbotina* spp. are present in most of the samples.

From 119,56mbsf to the top sample 110,55mbsf the assemblage changes and the species associated with Eocene has disappeared. The remaining species such as *Dentoglobigerina* spp. and *Subbotina* spp. make up most of the assemblage in the larger fraction while in the smallest fraction *Pseudohastigerina* spp. and *Chiloguembelina cubensis* is still present.

Preservation of the planktonic foraminifera is generally poor. The foraminifera are heavily recrystallized in some cases until it is hard to tell the species apart. This problem was especially common in small species such as *Pseudohastigerina* spp. Fragments of broken foraminifera were common in the smallest fraction in most of the samples. Some samples had visible signs of secondary recrystallization and showed a various amount of pyrite in the test.

Under the SEM the recrystallization was clearly visible as extrusive micro scale granular textures.

In the <250 µm whole specimens were common and easily identifiable to species level, with only a few fragments of broken foraminifera. 150-250 µm fragments were more common even though whole specimens were present. Certain species were particularly sensitive to fragmentation, including hantkeninids, which were in some samples identifiable only by detached spines in the fine fraction, and *Turborotalia*, which often shown peeling of the outer wall layer. Fragments of broken foraminifera dominated the lowest fraction 63-150 µm and only a few species that is generally smaller in size was preserved whole.

Examined samples

Out of 65 samples (Appendix A) that were given by Stephen Bohaty 29 was examined and the abundance of the key marker species was registered. Table 1 shows a list of the examined samples.

The samples chosen for examination were based on where the E/O might be. Samples above and below the suspected boundary were studied in order to record the first and last occurrences of the marker species.

Hole	Core	Section	Type	Top	Bottom	Depth
757B	13	H	1	5	7	110,55
757B	13	H	1	65	67	111,15
757B	13	H	1	89	91	111,39
757B	13	H	3	15	17	113,65
757B	13	H	3	136	138	114,86

757B	13	H	5	15	17	116,65
757B	13	H	5	111	113	117,61
757B	13	H	6	18	20	118,18
757B	13	H	6	48	50	118,48
757B	13	H	6	77	79	118,77
757B	13	H	6	108	110	119,08
757B	13	H	6	136	138	119,36
757B	13	H	7	6	8	119,56
757B	14	h	1	12	14	120,22
757B	14	H	1	44	46	120,54
757B	14	H	1	66	68	120,76
757B	14	H	1	110	112	121,2
757B	14	H	1	135	137	121,45
757B	14	H	2	15	17	121,75
757B	14	H	2	45	47	122,05
757B	14	H	2	78	80	122,38
757B	14	H	2	105	107	122,65
757B	14	H	2	137	139	122,97
757B	14	H	3	15	17	123,25
757B	14	H	3	45	47	123,55
757B	14	H	4	15	17	124,75
757B	14	H	4	105	107	125,65
757B	14	H	5	15	17	126,25
757B	14	H	6	75	77	128,35
757B	14	H	CC	6	8	129,54

TABLE 1 SHOWS THE SITE 757 EXAMINED SAMPLES WITH DEPTH (MBSF).

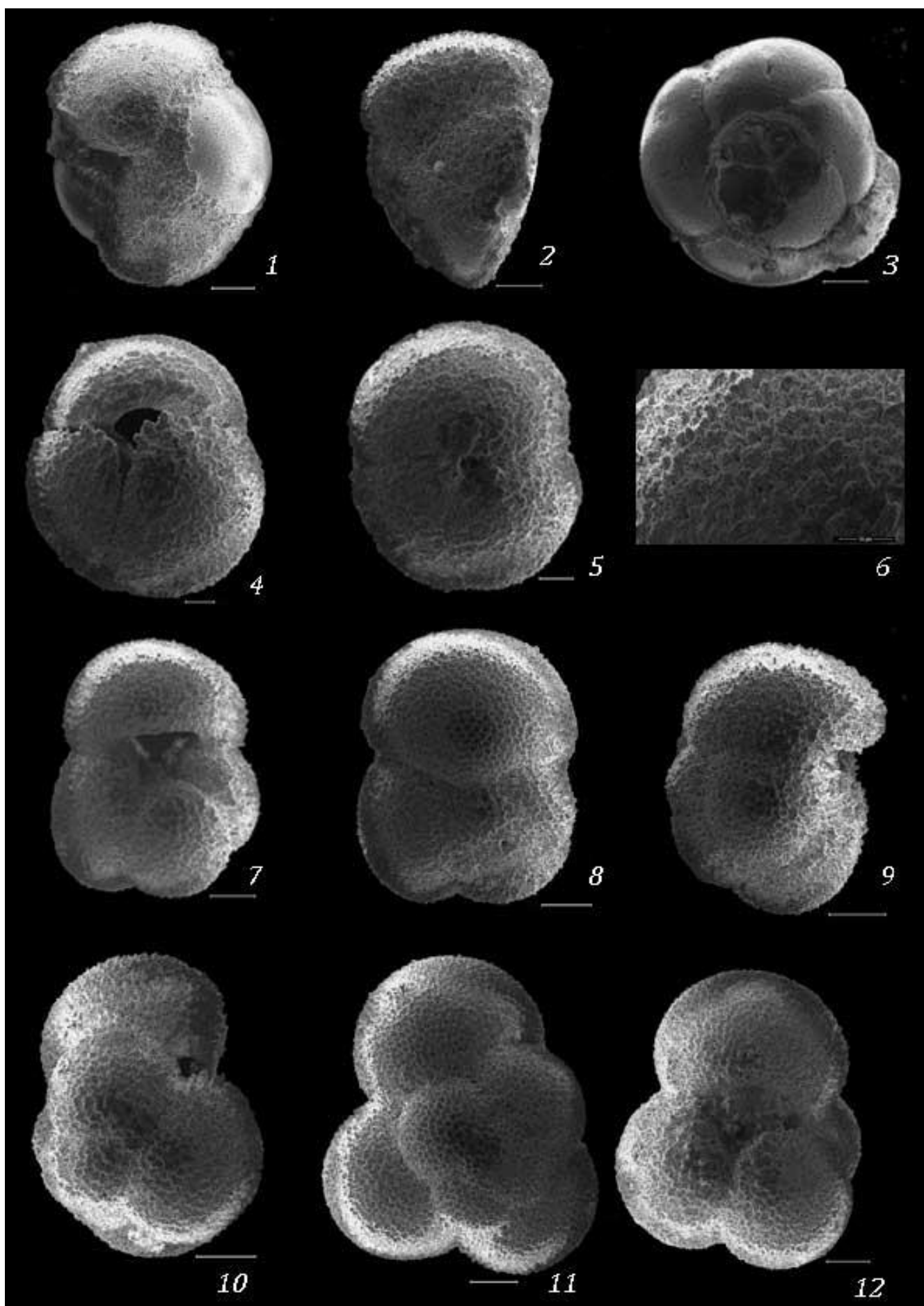


PLATE 1: 1-3 *TURBOROTALIA COCOAENSIS*, 4-6 *GLOBIGERINATHEKA INDEX*, 7-9 *DENTOGLOBIGERINA* SP., 10-12 *SUBBOTINA* SP. SCLAE BARS IS 100µM EXCEPT FOR 6 THAT IS 50µM.

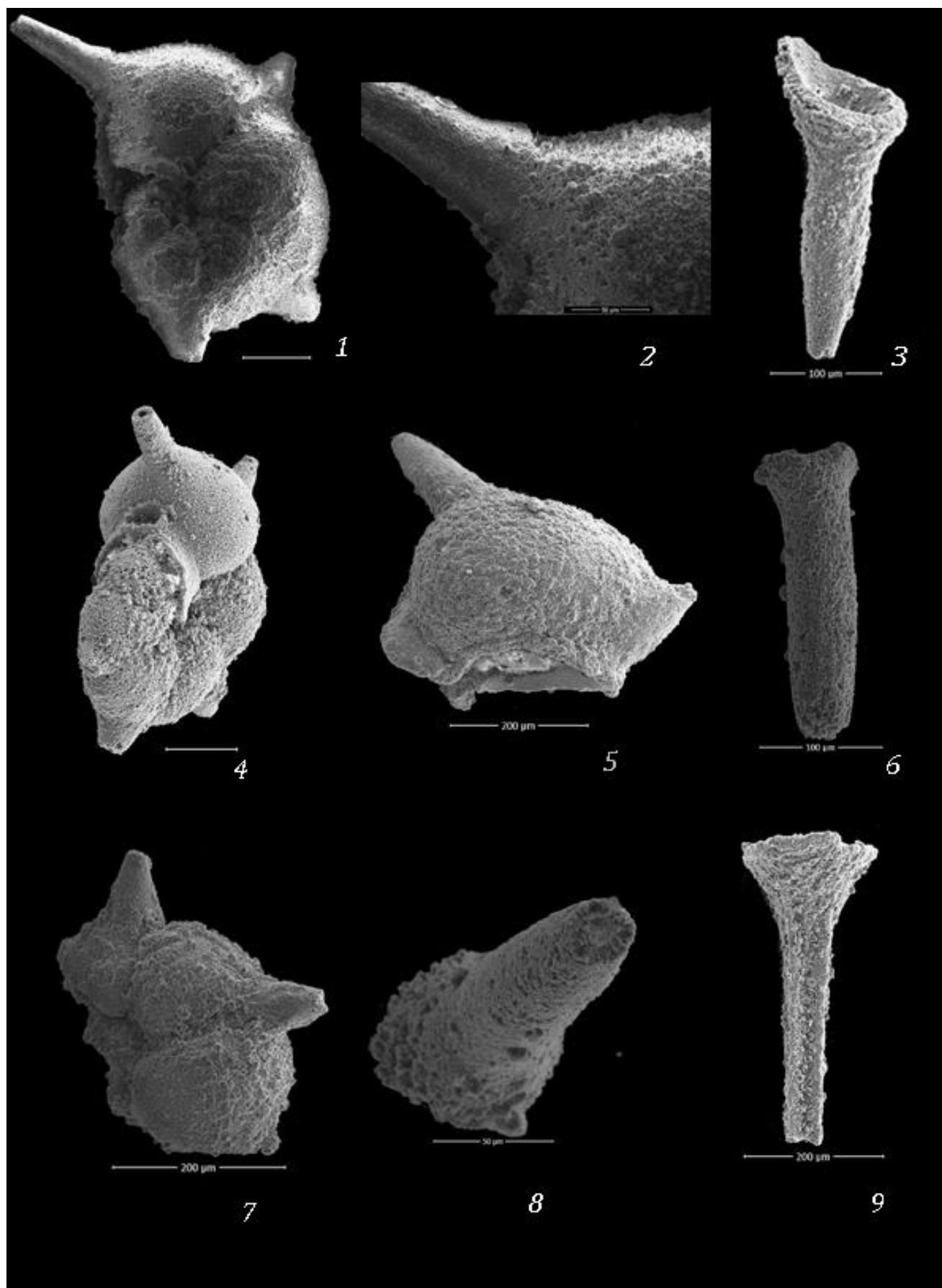


PLATE 2: 1-2 SHOW WHOLE SPECIMEN OF *HANTKENINA* SP. 3, 6 AND 8 SHOW DETACHED TURBULOSPINES. 4 SHOW *CHIBROHANTKENINA INFLATA* WITH THE HOLLOW SPINE VISIBLE. 5 AND 7 SHOW FRAGMENTS OF *HANTKENINA* SP. 9 SHOW A SUSPECT *HANTKENINA* SPINE. SCALE BARS ARE 100 μ M IF NOTHING ELSE IS STATED.

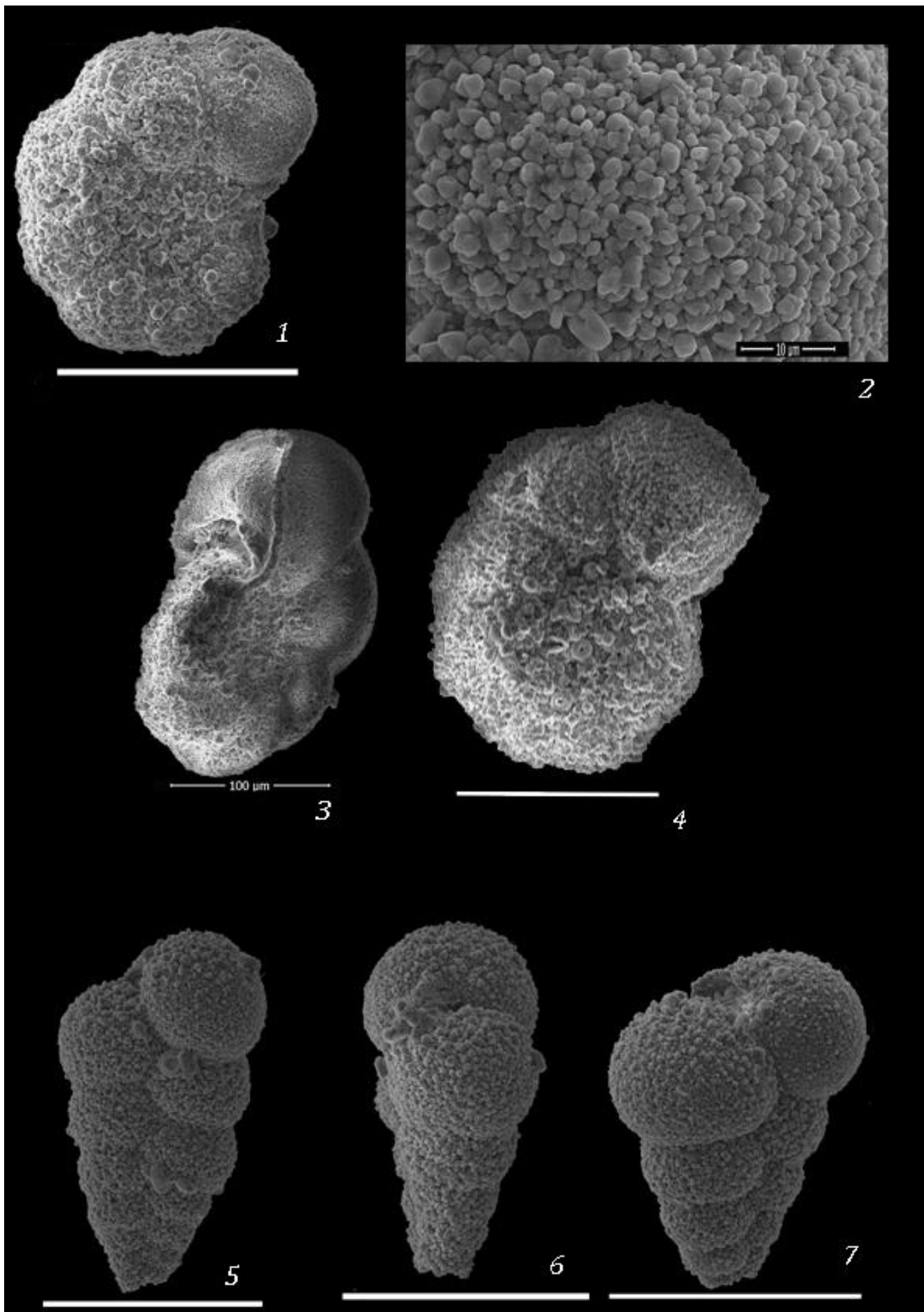


PLATE 3: 1 SHOW *PSEUDOHASTIGERINA NAGUEWICHIENSIS*. 2 SHOW WALL VIEW OF RECRYSTALLIZATION ON A *PSEUDOHASTIGERINA NAGUEWICHIENSIS*. 3-4 SHOW *PSEUDOHASTIGERINA MICRA*. 5-7 SHOW *CHILOGUEMBELINA CUBENSIS*. SCALE BARS ARE 100 μ M EXCEPT FOR 2 THAT IS 10 μ M.

Relative abundance of planktonic foraminifera

In Site 757 the hantkeninids were poorly preserved. However, there is a consistent record of them that allowed constraining the range in the most poorly preserved samples. Detached spines and fragments such as the final chamber with a spine visible could be used to identify the family. Spines could be easily determined as hantkeninid tubulospines because of their distinctive hollow center and the change in texture from the top of the spine to the area where it had been broken off from the parent chamber. Whole specimens were very rare except in some samples where preservation was generally better. Spines could be found in the 63-150 μm and fragments and whole specimens could be found in both 150-250 μm and <250 μm fraction. The last occurrence of hantkeninids were in sample 757B-14H-1-44-46 at 120,54mbsf making this the last suspected sample of Eocene age. A spine-like feature was found in a sample (Plate 2, Figure 9) above the suspected Eocene Oligocene boundary but further inspection under the SEM showed that it was not a hantkeninid tubulospine since it was not hollow and had different texture than the other spines found. Due to the poor preservation of the planktonic foraminifera in the samples it was difficult to identify species of hantkeninids. Instead only the genus was identified. *Cribohanktenina sp.* was found in sample 757B-14H-2-137-139 at 122,97mbsf. This specimen was identified as *Cribohanktenina inflata* under the SEM where the extra apertures were visible.

Another marker species in the late Eocene that was abundant in the lower samples was *Globigerinatheka index*. In the samples at Site 757 they could easily be distinguished from other species with similar appearances such as *Subbotina spp.* and *Dentoglobigerina spp.* by being very compact, more rounded and heavily recrystallized to a yellow/brown color. Whole specimens of this species were abundant in the late Eocene samples until it disappeared in sample 757B-14H-245-47 at 122,05mbsf. Before disappearance the species appeared in the <250 μm fraction but could be found in the 150-250 μm fraction as well. 2 specimens were found further up in the stratigraphy in sample 757B-14H-1-44-46 at 120,54mbsf.

Both species of *Pseudohastigerina* are present in most of the samples in the studied interval. They appear in the 63-150 μm fraction except in a few samples where it could be found in the 150-250 μm fraction.

Turborotalia cocoaensis were least common. Occurring only in 2 of the samples (757B-14H-5-15-17 at 126,25mbsf and 757B-14H-6-75-77 at 128,35mbsf) and in those samples the specimens were rare. In the samples where it occurred they were found in the largest size fraction (<250 μm). The specimens found were distinct compared to the other species due to the flat umbilical side and large aperture on the side. Under the SEM it was visible that the aperture had recrystallized shut. Table 2 show the samples where they were present. The low abundance of the *Turborotalia cocoaensis* at site 757 means these taxa, which have useful biostratigraphic potential in this interval (Wade et al. 2011) could not be used.

Chiloguembelina cubensis like *Pseudohastigerina spp.* was present in most of the samples studied and in most of the samples they were common in the smallest size fraction, but could be found in the 150-250 μm fractions. Their distinctive appearance made them easy to distinguish.

Subbotina spp. is common in the studied range. They were common in all fractions but can be hard to separate from *Dentoglobigerina spp.* in the smallest fraction. Preservation of this family is better the further up in the stratigraphy. In the Eocene samples they co-occur with *Globigerinatheka index* and

Dentibloberigina spp., the most abundant taxa. Up in the section in the Oligocene samples *Subbotina* spp. becomes more common.

Dentoglobigerina spp. at the site as previously mentioned, is together with *Globigerinatheka index* and *Subbotina* spp. the most common species in the Eocene and together with *Subbotina* spp., the most common in the Oligocene. They can be found in most of the samples in the studied range and are present in all the fractions. In the samples *Dentigloberina* spp. is generally well preserved but most of the specimens is missing the tooth that is characteristics for some of the species in the genus. The abundance of *Dentigloberina* spp. and *Subbotina* spp. was not recorded in all the samples in the selected range.

Sample	Depth	<i>Globigerinatheka index.</i>		<i>Hantkeninia spp.</i>		<i>Cibrohantkeninia inflata</i>	<i>Pseudohastigerina micra</i>	<i>Pseudohastigerina naguiewichiensis</i>	<i>Turborotalia cacaensis</i>	<i>Chiloguembina cubensis</i>	<i>Subbotina spp.</i>	<i>Dentoglobigerina spp.</i>
		Spines	Whole	Spines	Whole							
757B-13H-1-5-7	110,55	.	.	.	.	R	R	.	V	R	R	
757B-13H-1-65-67	111,15	.	.	.	.	R	R	.	C	C	C	
757B-13H-1-89-91	111,39	.	.	.	.	.	.	.	R	C	C	
757B-13H-3-15-17	113,65	.	.	.	.	R	R	.	C			
757B-13H-3-136-138	114,86	.	.	.	.	R	R	.	C	C	R	
757B-13H-5-15-17	116,65	.	.	.	.	.	.	.	C	C	C	
757B-13H-5-111-113	117,61	.	.	.	.	.	R	.	C	C	C	
757B-13H-6-18-20	118,18	.	.	.	.	R	C	.	C			
757B-13H-6-48-50	118,48	.	.	.	.	C	C	.	C			
757B-13H-6-77-79	118,77	.	.	.	.	.	.	.	C			
757B-13H-6-108-110	119,08	.	.	.	.	O	C	.	C			
757B-13H-6-136-138	119,36	.	.	.	.	C	C	.	C			
757B-13H-7-6-8	119,56	.	.	.	.	C	R	.	C			
757B-14h-1-12-14	120,22	.	.	.	.	C	C	.	C			
757B-14H-1-44-46	120,54	O	R	.	.	R	C	.	C			
757B-14H-1-66-68	120,76	.	R	R	.	C	.	.	R			
757B-14H-1-110-112	121,2	.	R	R	.	R	.	.	R			
757B-14H-1-135-137	121,45	.	.	.	.	R	.	.	C			
757B-14H-2-15-17	121,75	.	.	C	.	C	.	.	C			
757B-14H-2-45-47	122,05	R	.	R	.	C	.	.	R	C	R	
757B-14H-2-78-80	122,38	C	R	.	O	C	.	.	O	C	C	
757B-14H-2-105-107	122,65	R	C	R	.	C	C	.	R	O	O	
757B-14H-2-137-139	122,97	C	R	O	.	R	R	.	.	C	C	
757B-14H-3-15-17	123,25	C	R	R	.	O	O	.	R			
757B-14H-3-45-47	123,55	V	R	R	.	O	O	.	.	C	C	
757B-14H-4-15-17	124,75	C	.	R	.	.	.	.	O	R	R	
757B-14H-4-105-107	125,65	V	R	O	.	O	.	.	O	C	C	
757B-14H-5-15-17	126,25	C	R	O	.	.	.	R	R	O	O	
757B-14H-6-75-77	128,35	C	R	.	.	R	.	O	.			
757B-14H-CC-6-8	129,54	C	.	.	.	O	.	.	.			

TABLE 2 SITE 757 PLANKTONIC FORAMINIFERA RANGE CHART SHOWING THE STRATIGRAPHIC RANGE OF BIOSTRATIGRAPHIC IMPORTANT AND OTHER COMMON TAXA DURING THE LATE EOCENE AND EARLY OLILOCENE. THE BLANK SPACE MEANS THAT THE ABUNDANCE OF THAT SPECIES WAS NOT RECORDED.

Age-model

Table 3 shows the depth and calibrated ages of the two key species that disappear in our study intervals and which are useful for planktonic foraminifera biostratigraphy. Table 4 shows the nannofossil bioevent from the initial report. The ages are plotted into a spreadsheet and new calibrated ages were calculated from the linear trend line (Figure 4) and the polynomial (Figure 5).

Planktonic foraminifera event name	Depth top (mbsf)	Depth bottom (mbsf)	Midpoint (mbsf)	Calibrated age (Ma) (Wade et al. 2011) (CK95)
LO Hantkeninidea	120,54	120,22	120,38	33,7
LO Globigerinatheka index	122,05	121,75	121,9	34,5

TABLE 3 SHOW THE TOP AND BOTTOM SAMPLE WHERE THE BIOMARKERS WERE FOUND, THE MEAN DEPTH OF SAMPLES AND CALIBRATED AGES FROM WADE ET AL. (2011).

Nannofossil event name	Depth top (mbsf)	Depth bottom (mbsf)	Midpoint (mbsf)	Age (Ma) (CK95)
FO Sphenolithus ciperoensis	106,8	105,3	106,05	28,1
FO Sphenolithus distentus	112	110,5	111,25	30,4
LO Reticulofenestra umbilica	116,5	115	115,75	31,7
LO Coccolithus formosus	120,1	119,5	119,8	33,27
LO Discoaster saipanensis	124,6	123,1	123,85	34,28
FO Isthmolithus recurvus	129,8	129,1	129,45	36,6
LO Chiasmolithus grandis	133,3	131,1	132,2	37,1

TABLE 4 SHOW NANNOFOSSIL DATUM TABLES USED IN CONSTRUCTION OF THE OF SITE 757 AGE MOSEL. AGES IN CK95 TIMESCALE.

Age vs depth plot

In age model-1 as seen in Figure 4 the extinction of hantkeninids and *Globeriginetheka index* does not fall on the linear trend line but slightly below. This indicates that they are younger than the calibrated ages (Table 5).

In age model-2 (Figure 5) using the polynomial curve the data produces a different result (Table 5) more close to the calibrated age of the E/O (Wade et al. 2011).

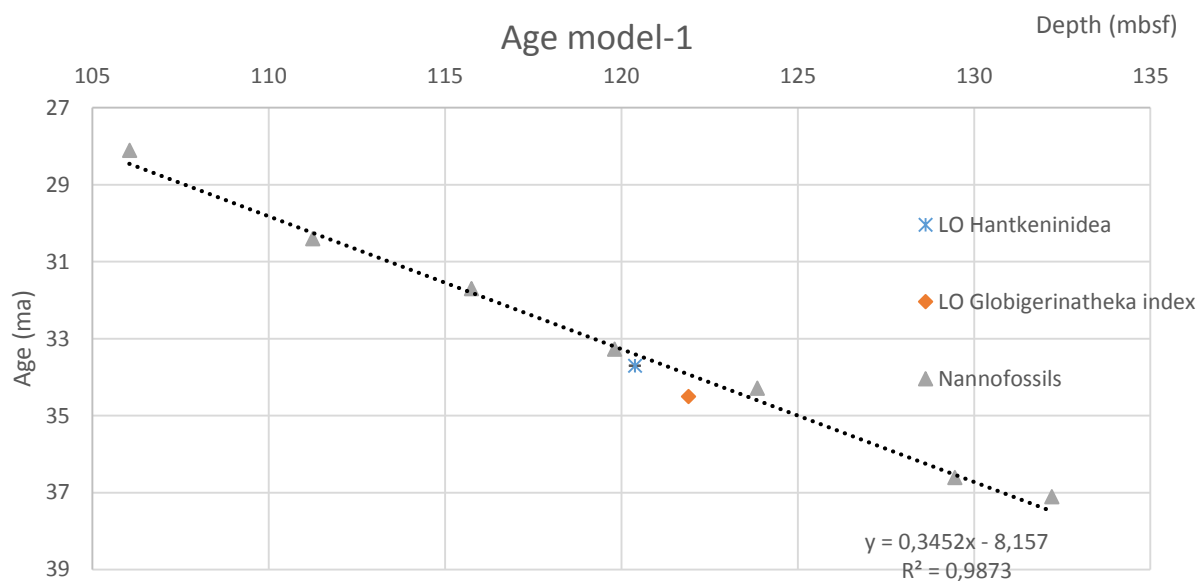


FIGURE 4 SHOW THE AGE MODEL-1 GENERATED FROM TABLE 3 AND 4 USING A LINEAR TREND LINE.

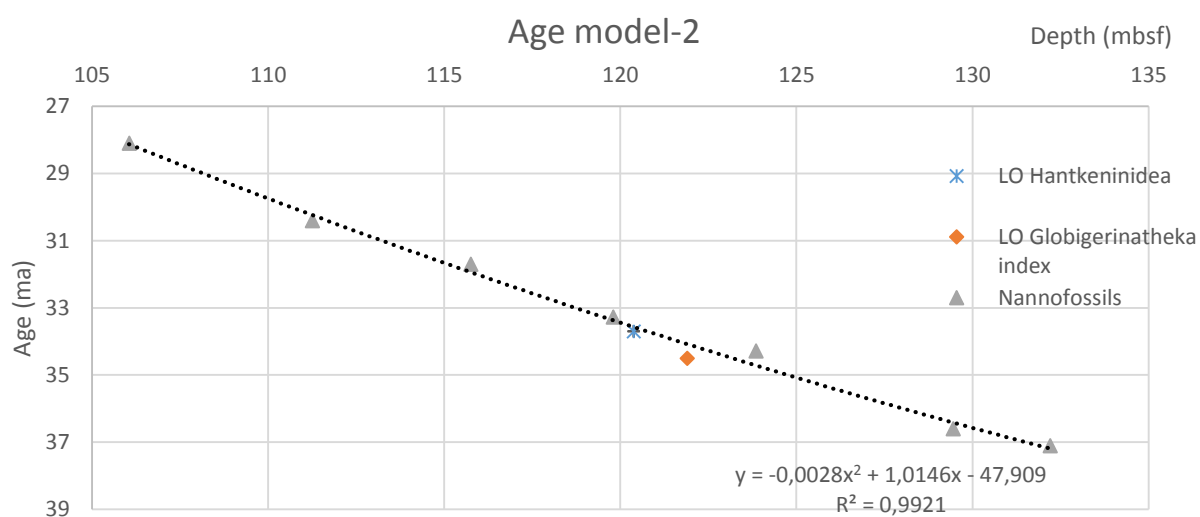


FIGURE 5 SHOW SITE 757 AGE MODEL-2 GENERATED FROM TABLE 3 AND 4 USING A SECOND ORDER POLYNOMIAL TREND LINE.

Event name	Midpoint (mbsf)	Calibrated age (ma) (Wade et al. 2011)(CK95)	Site 757 age model-1 age (Ma)	Site 757 age model-2 age (Ma)
Planktonic foraminifera				
LO Hantkeninidea	120,38	33,70	33,40	33,65
LO Globigerinatheka index	121,90	34,50	33,92	34,16

TABLE 5 SHOW MIDPOINT DEPTHS, THE CALIBRATED AGE (CK95) AND THE CALCULATED AGES USING AGE MODEL-1 AND AGE MODEL-2.

Sedimentation rate

The slope of the linear regression of curve fit in age model-1 is 0,3452, and the inverse of the value was 2,90m/ma. To double check this value the change in depth divided with age that confirmed the sedimentation rate as 2,90m/ma.

Comparison with isotope data

In order to calibrate the hantkeninids datum with respect to isotopically defined ocean climate events the biostratigraphic datum were compared to new Site 757 benthic $\delta^{18}\text{O}$ isotope data from a study made by Max Holmström (2014).

The benthic $\delta^{18}\text{O}$ data from Holmström (2014) was provided in meters below seafloor (mbsf). It has been converted into ages using the formula from the polynomial age vs depth plot (age model-2). This shows better agreements of the calibrated age of hantkeninids extinction (Wade et al. 2011) with the new Site 757 data. An interpretation of the two steps, EOT-1 and Oi-1 and the EOT was made (Figure 6).

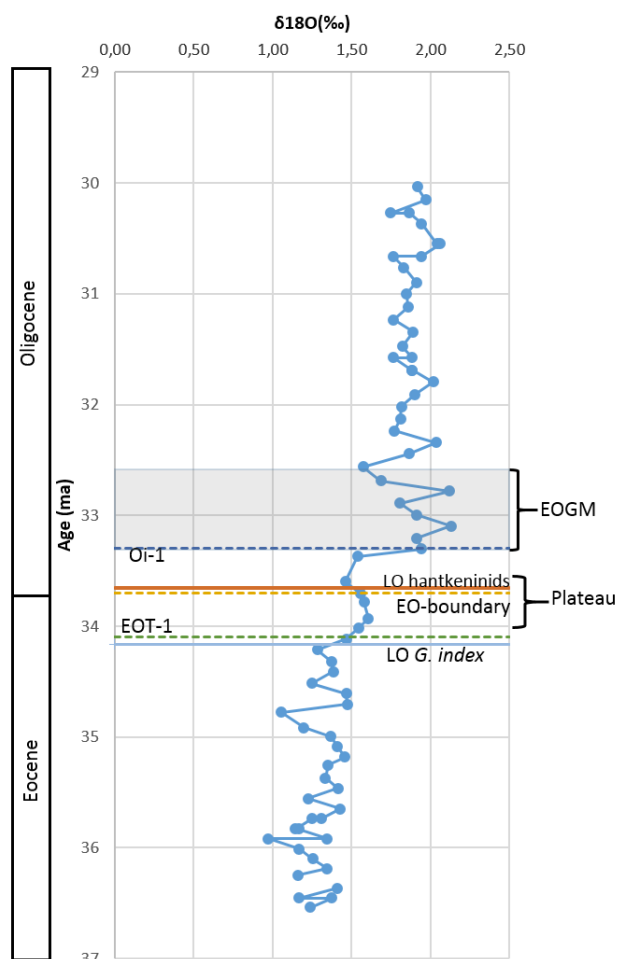


FIGURE 6 SHOW BENTHIC STABLE ISOTOPE DATA WITH THE LO OF HANTKENINIDS AND GLOBIGERINATHEKA INDEX, THE CALIBRATED AGE OF E/O-BOUNDARY (WADE ET AL. 2011), A INTERPRETATION WHERE THE EOT-1, Oi-1 AND EOGM IS AND THE INTERMEDIATE PLATEAU WHERE HANTKENINIDS WENT EXTINCT.

Discussion

Robustness of the Site 757B age model

Errors in the study could be because of the low abundance of first and last occurrence of the marker key species and extensive calcite dissolution that removes key species giving the impression they are not present. With more biostratigraphic first and last occurrences the age model could have been more accurate. The fact that the bioevents of the planktonic foraminifera marker species at the interval of interest at Site 757B do not correlate with the trend line (age model-1) added using nannofossil at the site makes the age model questionable. The polynomial trend line (age model-2) gives a closer fit of the Site 757 hantkeninids and *Globigerinatheka index* event ages and is therefore considered more suitable for calculating ages for other sample in this study.

Error in the taxonomic interpretation of the key marker species hantkeninids and *Globigerinatheka index* was considered low because of their distinct appearance compared to other species at Site 757. Errors in separating the two species of the genus *Pseudohastigerina* are considered possible because of their similar appearance and the poor preservation. This error might also occur when separating *Subbotina* spp. and *Dentoglobigerina* spp. The appearance of those two families can be similar to each other, especially in the lower fractions. However these latter taxa are not relevant to this age model.

Calculating the sedimentation rate assumes that the sedimentation rate is constant over the E/O which is not likely.

Planktonic foraminifera turnover.

The extinction of *Globigerinatheka index* that is supposed to occur at 34,3Ma (Wade et al. 2011) occurs according to the generated age model using the polynomial trend line at 34,16Ma.

The find of *Globigerinatheka index* further up in the stratigraphic column was interpreted as reworking of the sediments since no specimens were found neither above nor below this find.

Dwarfing of *Pseudohastigerina micra* at the E/O (Nocchi et al. 1988; Coxall & Pearson, 2007) is not as drastic as described, but the result in the abundance spreadsheet with separated fractions show a lower abundance of the genus in the 150-250 μ m fractions (Appendix B).

As can be seen in Figure 6 and Table 5 the extinction of hantkeninids occur slightly above the Wade et al. (2011) set E/O at 33,7Ma with the polynomial trend line. One reason for this difference in the age can be the resolution of the samples. Although the resolution is relatively high, around 30cm between the samples, we do not know exactly where the hantkeninids extinction occurs in between the samples. The extinction of hantkeninids in relation to the oxygen isotope record at site 757B shows that the extinction occurs when the isotopic values of $\delta^{18}\text{O}$ started increasing and occurs in between the EOT-1 and the Oi-1. This tells us that the extinction occurred after the start of the transition to a colder climate but before the sudden increase in isotope values that is related to the Oi-1 and EOGM. The Coxall and Pearson (2007) theory that the hantkeninids extinction occurs on a plateau right before the increase into Oi-1 could be seen in the benthic stable isotope data at site 757, as can be seen in other sites in the world such as Tanzania Drilling Project (TDP) (Pearson et al. 2008). This indicates that the extinction on the intermediate plateau might be global. The extinction occurs before the Oi-1 that is associated with the increase in ice volume on Antarctica (Katz et al. 2008). Therefore with the timing of the extinction I suggested that changes in the seawater temperature before the expansion of Antarctic ice might be an important factor. According to Wade & Pearson (2008) the extinction of hantkeninids are related to changes in thermal structures in the water column due to high latitude climatic change.

What the thermal structure of the water column at site 757 looks like cannot be seen in the benthic stable

isotopic record. A stable isotope record of the planktonic foraminifera could fill this gap of knowledge, although the preservation of the quality of planktonic foraminifera at site 757 is too poor. The extinction of *Globigerinatheka index* occurs before EOT-1 indicates that they went extinct before the climate started to shift.

The timing of the E/O and the extinction of hantkeninids and the decrease in size of *Pseudohastigerina micra* indicates that they could cope with the change in climate and the decrease in temperature of 2,5°C associated with EO-1 (Katz et al. 2008) over a short period of time but did not evolve to adapt in the long term and therefore went extinct. Other genera such as *Subbotina*, *Dentoglobigerina* and *Chiloguibelina* that continues to be present in the biostratigraphy might have been better adapted to the changes in the climate and continue to thrive and might have filled the niches that the late Eocene species left open.

Conclusion

The biostratigraphic analysis shows that the extinction of hantkeninids is at site 757 located at 120,38mbsf and 33,65Ma using the generated age model (age model-2), which is close to the calibrated age of the boundary 33,7Ma. The extinction of hantkeninids in relation to benthic stable isotopes at site 757 after the climate started to change but before the large leap in stable isotopes associated with Oi-1 and EOGM and that the extinction occurred on the intermediate plateau that could be seen in other sites in the world.

Acknowledgements

A special thanks to my supervisor Helen Coxall for her guidance, help and inspiration.

Thanks to:

Max Holmström for the isotopic data at the site and for guidance and help during the project.

Anna Nyberg for help with the taxonomy.

Jonas Nilsson for his expertise in Excel.

References

- Cande, S. C., and Kent, D. V., 1995, Revised calibration of the geomagnetic polarity timescale for the Late Cretaceous and Cenozoic: *Journal of Geophysical Research*, v. 100, p. 6093–6095.
- Coxall, H. K., & Pearson, P. N., 2007, The Eocene-Oligocene transition, in Williams, M., Hayward, A., Gregory, J., and Schmidt, D. N., eds., *Deep time perspectives on climate change: Marrying the signal from computer models and biological proxies*: London, *Geological Society Special Publication*, p. 351-387.
- Coxall, H. K., & Pearson, P. N., 2011, Early Oligocene glaciation and productivity in the eastern equatorial Pacific: Insights into global carbon cycling, *Paleoceanography*, Vol. 26.
- Coxall, H. K., Wilson, P. A., Pälike, H., Lear, C. H., & Backman J. (2005). Rapid stepwise onset of Antarctic glaciation and deeper calcite compensation in the Pacific Ocean. *Nature* 433, 53–57.

Katz, E., Miriam, Miller, G., Kenneth, Wright, D., James, Wade, S., Bridget, Browning, V., James, Cramer, S., Benjamin, Rosenthal, Yair, 2008, Stepwise transistion from Eocene greenhouse to the Oligocene icehouse, *Nature*, Vol. 1, 2008.

Nocchi, M., Monechi, S., Coccioni, R., Madile, M., Monaco, P., Orlando, M., Parisi, G., and Premoli Silva, I., 1988, The extinction of Hantkeninidae as a marker for defining the Eocene/Oligocene boundary: A proposal., in Premoli Silva, I., Coccioni, R., and Montanari, A., eds., International Union of Geological Sciences Commission on Stratigraphy, The International Subcommission of Paleogene Stratigraphy: The Eocene/Oligocene boundary in the Marche-Umbria basin (Italy): Ancona, Monte Cònero, p. 249-252.

Pearson, P. N., Olsson, R. K., Hemleben, C., Huber, B. T., and Berggren, W. A., 2006, Atlas of Eocene planktonic foraminifera, Cushman Foundation of Foraminiferal Research, Special Publication, Volume 41: Lawrence, Kansas, Allen Press, p. 513.

Pearson, N., Paul, McMillian, K., Ian, Wade, S., Bridget, Jones, Dunkley, Tom, Coxall, K., Helen, Brown, R., Paul, Lear, H., Caroline, 2008, Extinction and environmental change across the Eocene-Oligocene boundary in Tanzania, *Geology* 2008:36, p 179-182.

Shipboard Scientific Party, 1989. Site 757. In Peirce, J., Weissel, J., et al., *Proc. ODP, Init. Repts.*, 121: College Station, TX (Ocean Drilling Program),

Wade, S. Bridget, Pearson, N. Paul, 2008, Planktonic foraminiferal turnover, diversity fluctuations and geochemical signal across the Eocene/Oligocene boundary in Tanzania: *Marine micropaleontology*, 68, p 244-255.

Wade, S. Bridget, Pearson, N. Paul, Berggren, A., William, Pälike, Heiko, 2011, Review and revision of Cenozoic tropical foraminiferal biostratigraphy and calibration to the geomagnetic polarity and astronomical time scale, *Earth-science Reviews*, 104, p 111-142.

van Eijden, A.J.M, Smith, J., 1991, Eastern Indian ocean cretaceous and paleogene quantitative biostratigraphy, *Proceedings of Ocean Drilling Program, Scientific Results*, Vol. 121.

Zachos, J. C., Pagani, M., Sloan, L. C., Thomas, E., & Billups, K., 2001, Trends, rhythms, and aberrations in global climate 65 Ma to present: *Science*, v. 292, no. 5513, p. 686-693.

Zachos, J. C., Rea, D. K., Seto, K., Nomura, R., & Niitsuma, N., 1992, Paleogene and Early Neogene Deep Water Paleoceanography of the Indian Ocean as Determined from Benthic Foraminifer Stable Carbon and Oxygen Isotope Records, in Duncan, R. A., Rea, D. K., Kidd, R. B., von Rad, U., & Weissel, J. K., eds., *Synthesis of Results from Scientific Drilling in the Indian Ocean: Washington, D. C., American Geophysical Union.*

Appendix

Appendix A – List of samples.

Hole	Core	Section	Type	Top (cm)	Bottom (cm)	Depth
757B	13	H	1	5	7	110,55
757B	13	H	1	35	37	110,85
757B	13	H	1	65	67	111,15
757B	13	H	1	89	91	111,39
757B	13	H	1	136	138	111,86
757B	13	H	2	15	17	112,15
757B	13	H	2	42	44	112,42
757B	13	H	2	77	79	112,77
757B	13	H	2	103	105	113,03
757B	13	H	2	135	137	113,35
757B	13	H	3	15	17	113,65
757B	13	H	3	44	46	113,94
757B	13	H	3	79	81	114,29
757B	13	H	3	106	108	114,56
757B	13	H	3	136	138	114,86
757B	13	H	4	15	17	115,15
757B	13	H	4	46	48	115,46
757B	13	H	4	75	77	115,75
757B	13	H	4	105	107	116,05
757B	13	H	4	135	137	116,35
757B	13	H	5	15	17	116,65
757B	13	H	5	43	45	116,93
757B	13	H	5	75	77	117,25
757B	13	H	5	111	113	117,61
757B	13	H	5	137	139	117,87
757B	13	H	6	18	20	118,18
757B	13	H	6	48	50	118,48
757B	13	H	6	77	79	118,77
757B	13	H	6	108	110	119,08
757B	13	H	6	136	138	119,36
757B	13	H	7	6	8	119,56
757B	14	H	1	12	14	120,22
757B	14	H	1	44	46	120,54

757B	14	H	1	66	68	120,76
757B	14	H	1	110	112	121,2
757B	14	H	1	135	137	121,45
757B	14	H	2	15	17	121,75
757B	14	H	2	45	47	122,05
757B	14	H	2	78	80	122,38
757B	14	H	2	105	107	122,65
757B	14	H	2	137	139	122,97
757B	14	H	3	15	17	123,25
757B	14	H	3	45	47	123,55
757B	14	H	3	68	70	123,78
757B	14	H	3	111	113	124,21
757B	14	H	3	136	138	124,46
757B	14	H	4	15	17	124,75
757B	14	H	4	45	47	125,05
757B	14	H	4	67	69	125,27
757B	14	H	4	105	107	125,65
757B	14	H	4	135	137	125,95
757B	14	H	5	15	17	126,25
757B	14	H	5	45	47	126,55
757B	14	H	5	75	77	126,85
757B	14	H	5	105	107	127,15
757B	14	H	5	135	137	127,45
757B	14	H	6	15	17	127,75
757B	14	H	6	45	47	128,05
757B	14	H	6	75	77	128,35
757B	14	H	6	95	97	128,55
757B	14	H	6	135	137	128,95
757B	14	H	7	15	17	129,25
757B	14	H	CC	6	8	129,54

<i>Pseudohastigerina</i>				<i>Turborotalia</i>			<i>Chiliqueberina</i>			<i>Subbotini</i>			<i>Dentigloberina</i>				
<i>micra</i>		<i>naigueviensis</i>		<i>sp.</i>			<i>cubensis</i>			<i>sp.</i>			<i>sp.</i>				
63#	150#	>250	63#	150#	>250	63#	150#	>250	63#	150#	>250	63#	150#	>250	63#	150#	>250
R	.	.	R	.	.	R	.	.	R	.	.	R	.	.	R	.	.
.	.	.	R	.	.	V	.	.	C	.	.	R	.	.	R	.	.
R	O	.	R	.	.	R	O	.	R	C	.	R	C	.	R	C	.
R	.	.	R	.	.	C	.	.	C	C	.	C	C	.	C	C	.
.	.	.	.	.	.	C	.	.	.	.	.	R	C	.	R	C	.
R	.	.	R	.	.	C	.	.	R	C	.	C	C	.	R	C	.
C	.	.	C	.	.	C	.	.	.	.	.	C	C	.	C	C	.
O	.	.	O	.	.	C	.	.	.	.	.	C	C	.	R	C	.
O	.	.	C	.	.	C	.	.	.	.	.	C	C	.	.	.	.
C	.	.	C	.	.	C	.	.	.	.	.	C	C	.	.	.	.
C	O	.	R	.	.	C	.	.	R	C	.	C	C	.	O	C	.
R	X	.	C	.	.	C	.	.	.	.	.	O	C	.	O	C	.
C	C	.	C	C	.	C	R	.	.	.	.	C	C	.	O	C	.
C	C	.	C	.	.	R	.	.	.	.	.	O	C	.	O	C	.
C	O	.	C	O	.	O	.	.	.	.	.	C	C	.	O	C	.
R	O	.	R	.	.	R	.	.	.	.	.	O	C	.	O	C	.
O	O	.	O	O	.	R	.	.	.	.	.	C	C	.	O	C	.
O	O	.	O	O	.	O	.	.	.	.	.	C	C	.	C	C	.
R	O	.	.	.	.	R	.	.	.	.	.	R	C	.	R	C	.
O	O	.	.	.	.	O	.	.	.	.	.	O	C	.	O	C	.