# Eocene agglutinated foraminifera at NE Atlantic DSDP Site 550: assemblage turnover across hyperthermal events

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## Abstract

The early Paleogene was characterised by the occurrence of several short and extreme warming events, known as hyperthermals, superimposed on a greenhouse climate. The most extreme of these events was the Paleocene-Eocene Thermal Maximum (PETM), which was associated with a severe extinction of benthic foraminifera. Consequently, major peaks of agglutinated taxa has been registered in several sites during the PETM. Nonetheless, the response of this taxa to smaller hyperthermal events is not well known.

We analysed the evolution of agglutinated taxa across the ETM2 and H2 events at DSDP Site 550 (NE Atlantic Ocean), where the most abundant species are *Repmanina charoides*, *Rhizammina* spp. and *Ammobaculites* sp. During the events, *R. charoides*, *Glomospirella* sp. and *Glomospira* sp. markedly increased in abundance, reflecting their opportunistic and/or disaster behavior under perturbed environments.

## INTRODUCTION

A long term global warming trend was registered during the early Paleogene, and peaked with the Early Eocene Climatic Optimum (Miller *et al*., 1987a; Zachos *et al*., 2001). This trend was punctuated by several short and extreme warming events called hyperthermals (Thomas & Zachos, 2000). These events have been associated with the repeated emission of large masses of $^{13}$C-depleted carbon into the ocean-atmosphere system, reflected in the sedimentary record as negative carbon isotope excursions (CIEs) (Cramer *et al*., 2003). Additionally, the hyperthermal events were also characterised by increased $CaCO_3$ dissolution in oceans (reflecting an increase in ocean acidification), perturbations of the hydrological cycle and increased continental erosion (e.g., Zachos *et al*., 2005; Nicolo *et al*., 2007; Leon-Rodriguez & Dickens, 2010; Stap *et al*., 2010).

Severe faunal changes in land and oceans occurred during the Paleocene-Eocene Thermal Maximum (PETM, 55.5 Ma), the most severe of these events. Among the marine biota, the deep-sea benthic foraminifera suffered their major extinction of the Cenozoic, disappearing between the 35-55% of the species (e.g., Tjalsma & Lohmann, 1983; Miller *et al*., 1987b; Katz & Miller, 1991; Thomas, 2007; Alegret *et al*., 2009a, b). According to Thomas (1998), postextinction faunas were dominated by thin-walled calcareous or agglutinated taxa. The increase in abundance of agglutinated taxa has been registered in several sites across the PETM (e.g., Alegret *et al*., 2009a, b; Giusberti *et al.,* 2009). Thus, increased $CaCO_3$ dissolution has been proposed as the main cause of the benthic foraminiferal extinction (Thomas, 2012). Nonetheless since the extinction was global, the cause should be global too, and there are some regions where the percentage of $CaCO_3$ not decreased or even increased, hence Alegret *et al*. (2010) suggest that ocean acidification was not the only cause of the extinction. In these sense, dissolution experiments carried on agglutinated benthic foraminifera has been demonstrated that even some species resistant to dissolution, became extinct during the PETM; so indeed, in addition to ocean acidification (i.e. carbonate dissolution), the interaction of other factors may contribute to the perturbation of benthic foraminifera (Arreguín-Rodríguez & Alegret, 2015).

Unlike the PETM, quantitative studies analysing the benthic foraminiferal response to smaller hyperthermal events has been less developed. These few studies has registered a low abundance of agglutinated taxa (D'haenens *et al*., 2012; Arreguín-Rodríguez *et al*., 2016; Arreguín-Rodríguez &

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Alegret, 2016), and consequently their reaction to less intense hyperthermals is not known. Therefore, we present the evolution of the agglutinated taxa at DSDP Site 550 (NE Atlantic Ocean) during the early Eocene and across smaller hyperthermal events such as the ETM2 and H2.

## STUDY MATERIAL

The early Eocene sediments from the Deep Sea Drilling Program Site 550, located in the northeast Atlantic Ocean (48°30.91´N, 13°26.37´W, ~43.72°N palaeolatitude; McInerney & Wing, 2011) (Figure 1), consist of brownish and grayish marly nannofossil chalk. The studied interval comprise 7.87 m thick of Core 29-R (363.95 – 356.08 mbsf), where three hyperthermal events have been documented, the ETM2, H2 and I1. These events were recognised by D'haenens *et al.* (2014) based on the record of negative CIEs, coinciding with a decrease in percentage of $CaCO_3$.

The total benthic foraminiferal assemblage across this interval has been already documented by Arreguín-Rodríguez & Alegret (2016). In such study, the authors described assemblages moderately diverse and strongly dominated by calcareous taxa, with a mixed of infaunal and epifaunal morphogroups. Among infaunal taxa, the most abundant species are *Bolivinoides decoratus*, *Quadrimorphina profunda*, *Globocassidulina subglobosa* and *Oridorsalis umbonatus,* while *Nuttallides truempyi*, *Osangularia* sp. 1 and *Gyroidinoides depressus* are the most abundant epifaunal species. Agglutinated taxa represent less than 5% of the total assemblage composition throughout the studied interval, and they make up to 8-10 % of the assemblages in coincidence with the ETM2 and H2 events, coinciding with very low % $CaCO_3$ values (Figure 2).

Since the total benthic foraminiferal assemblage during the early Eocene at DSDP Site 550 are dominated by calcareous taxa, it is necessary to evaluate the agglutinated fraction separately in order to understand how they reacted to the ETM2 and H2. The I1 event is not considered in this study due to the low sampling resolution across it, and because its recovery interval is not represented in our study interval.

## METHODS

A total of 44 samples were studied from the Core 550-29R. Samples were soaked in water with detergent and washed over a 63 µm sieve. Approximately 300 benthic foraminifera specimens were picked from the >63 µm residues in each sample, although two of them, 550-29-5, 72-74 cm (362.72 mbsf) and 550-29-5, 85-87cm (362.85 mbsf), had insufficient specimens (<50 specimens), and correspond to an interval of severe carbonate dissolution across the ETM2 (D'haenens *et al.,* 2014).

The picked specimens correspond to 147 species including calcareous and agglutinated taxa, but only 18 are agglutinated species. Thus, the percentages of relative abundances were recalculated excluding the calcareous taxa (Figures 2-4), and absolute abundances were also calculated, based on the number of agglutinated benthic foraminifera per gram of bulk sediment (ABF/g).

## RESULTS

*Repmanina charoides* is the most abundant agglutinated species, and makes up more than 40% of the agglutinated assemblage. Other abundant taxa include *Rhizammina* spp.

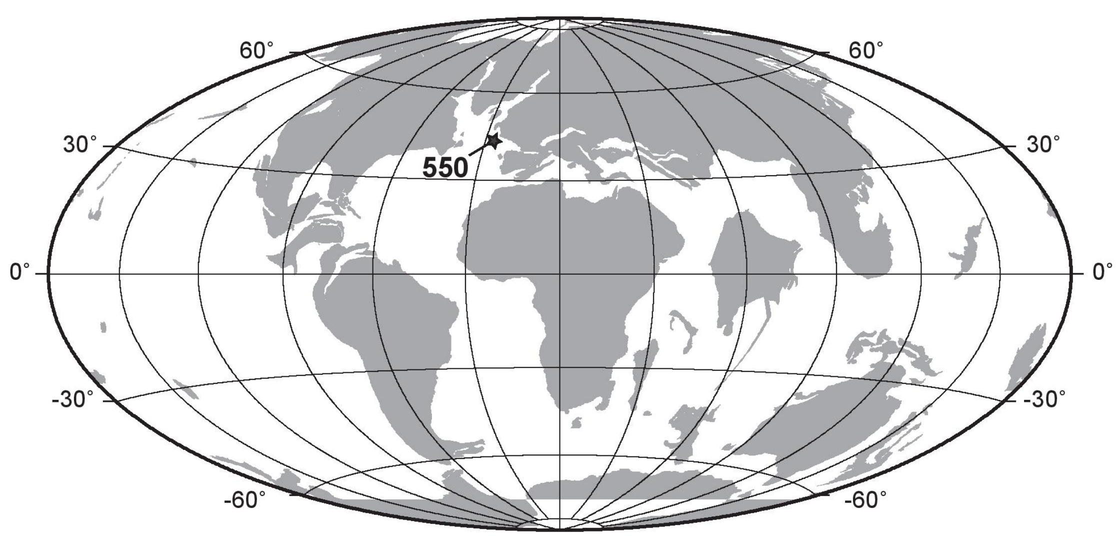


**Figure 1**. Palaeogeographic reconstruction (~53 Ma) showing the location of the DSDP Site 550. Modified from Hay *et al.* (1999).

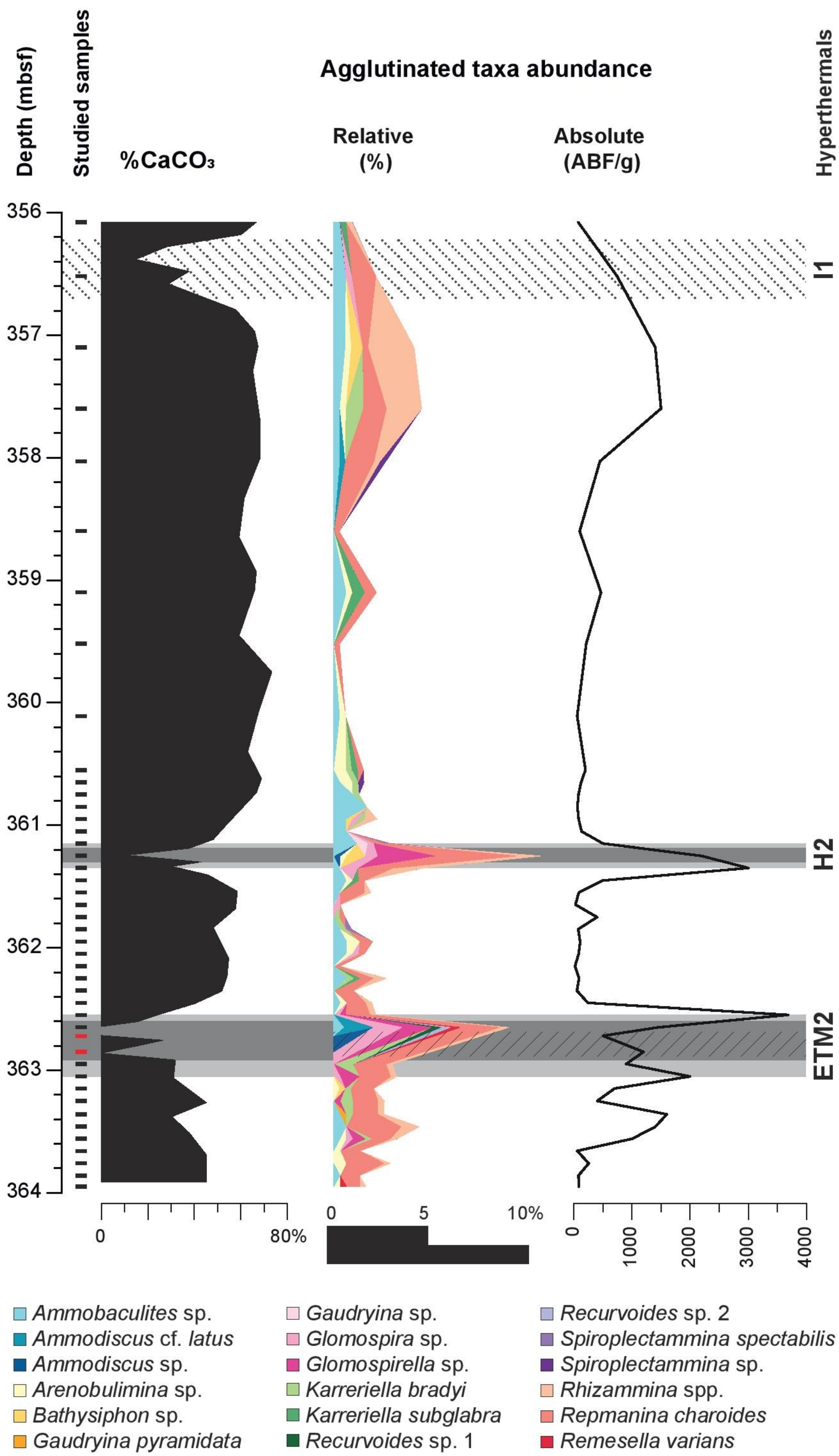


**Figure 2**. Cumulative plot of % agglutinated species, and absolute abundance of agglutinated taxa (number of specimens per gram of bulk sediment) across the studied interval at DSDP Site 550. Dark grey areas indicate the core of the ETM2 and H2 events. Percentage of $CaCO_3$ data from D'haenens *et al*. (2014)

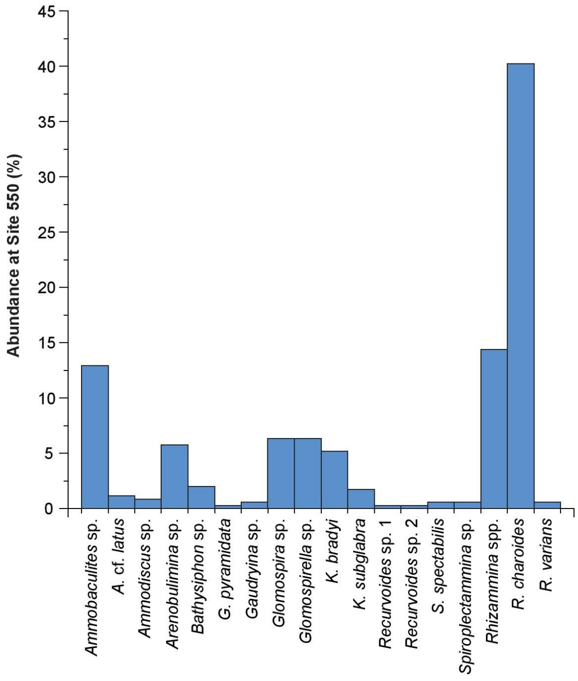


**Figure 3**. Species composition of agglutinated assemblages at DSDP Site 550. Average percentages of taxa show their relative abundance within the agglutinated assemblages only.

(>14%) and *Ammobaculites* sp. (>12%). *Arenobulimina* sp., *Glomospira* sp., *Glomospirella* sp. and *Karreriella bradyi* are common species (Figure 3).

A peak in relative and absolute abundance of agglutinated taxa (number of agglutinated foraminifera per gram of bulk sediment, ABF/g) is recorded towards the upper part of ETM2, coinciding with $CaCO_3$ values of 0% (Figure 2). Agglutinated species make up ~8% of the total (calcareous + agglutinated) assemblage, and their absolute abundance is > 3500 specimens per gram of bulk sediment. The increase in relative abundance of agglutinated taxa across the ETM2 interval mainly consists of increased percentages of *R. charoides*, *Glomospira* sp., *Glomospirella* sp. and *Ammodiscus* cf. *latus* (Figures 2 and 4), and species like *Glomospira* sp., *Glomospirella* sp., *Rhizammina* spp. and *R. charoides* also shown absolute peaks of abundance during the ETM2 (Figure 4).

Foraminifera are scarce at the interval with insufficient specimens (i.e., samples located within the core of ETM2 with less than 50 specimens each one), and are not considered as representatives. However, agglutinated taxa slightly dominate the entire assemblage over the calcareous taxa in these two samples (>51% and 58%). At this interval, *R. charoides*, *Rhizammina* sp., *Glomospira* sp., *Glomospirella* sp. and *Ammodiscus* sp. are the most abundant species.

Higher up in the core, a second peak in relative abundance of agglutinated taxa is recorded across the H2 event, where they represent ~10% of the total assemblage. This peak mainly consists of increased percentages of *R. charoides*, *Glomospira* sp. and *Rhizammina* spp. (Figures 2 and 4), and it occurred across an interval where the %$CaCO_3$ content dropped down to ~11%. These same species integrate the absolute abundance peak during the H2 event (Figure 4).

## INTERPRETATION

Some of the most abundant species across the studied interval and particularly during the hyperthermal events at DSDP Site 550 are *R. charoides*, *Glomospira* sp. and *Glomospirella* sp. These species have been included into the "*Glomospira* group", which proliferation has been related with perturbed ecosystems during the Cretaceous and Paleogene (e.g., Kuhnt & Kaminski, 1989; Kuhnt *et al*., 1989; Kaminski *et al*., 1992). Due to the fact that this group of species bloomed at many global sites during the widespread rise of the carbonate compensation depth related to the PETM and that they have non-calcareous test, it has been suggested that the increased abundance of these species is a result of the dissolution of calcareous taxa (Galeotti *et al*., 2004; Kaminski & Gradstein, 2005). But recent studies suggest that this bloom seems to be related with increased influx of refractory organic matter, which may represent an alternative food source (Arreguín-Rodríguez *et al.,* 2013, 2014). According to Arreguín-Rodríguez & Alegret (2016), the benthic foraminiferal assemblages (including both calcareous and agglutinated taxa) indicate a decline in effective food supply to the seafloor and increase in carbonate corrosivity during both hyperthermal events (ETM2 and H2); however, during the H2 some opportunistic species (like *Globocassidulina subglobosa* and *Osangularia* sp. 1) peak in abundance suggesting pulsed food inputs thru this event. Therefore, it may be possible that such pulses of food gave an advantage to the species of the *Glomospira* group (over other agglutinated taxa), and thus the relative abundance peaks of these species are higher during the H2 than during the ETM2. On the other hand, the markedly dominance of this group, respect to the agglutinated assemblage, across the studied interval, but mostly at intervals close to hyperthermal events, may be related with the opportunistic and/or disaster behavior of these species, reflecting the perturbation of the ecosystem.

In spite of the proximity between the studied site (DSDP Site 550) and DSDP Site 401, the composition of the agglutinated assemblages across the hyperthemal events is different. D'haenens *et al.* (2012) reported scarce agglutinated taxa represented by species like *Eggerella* sp., *Karrierella*

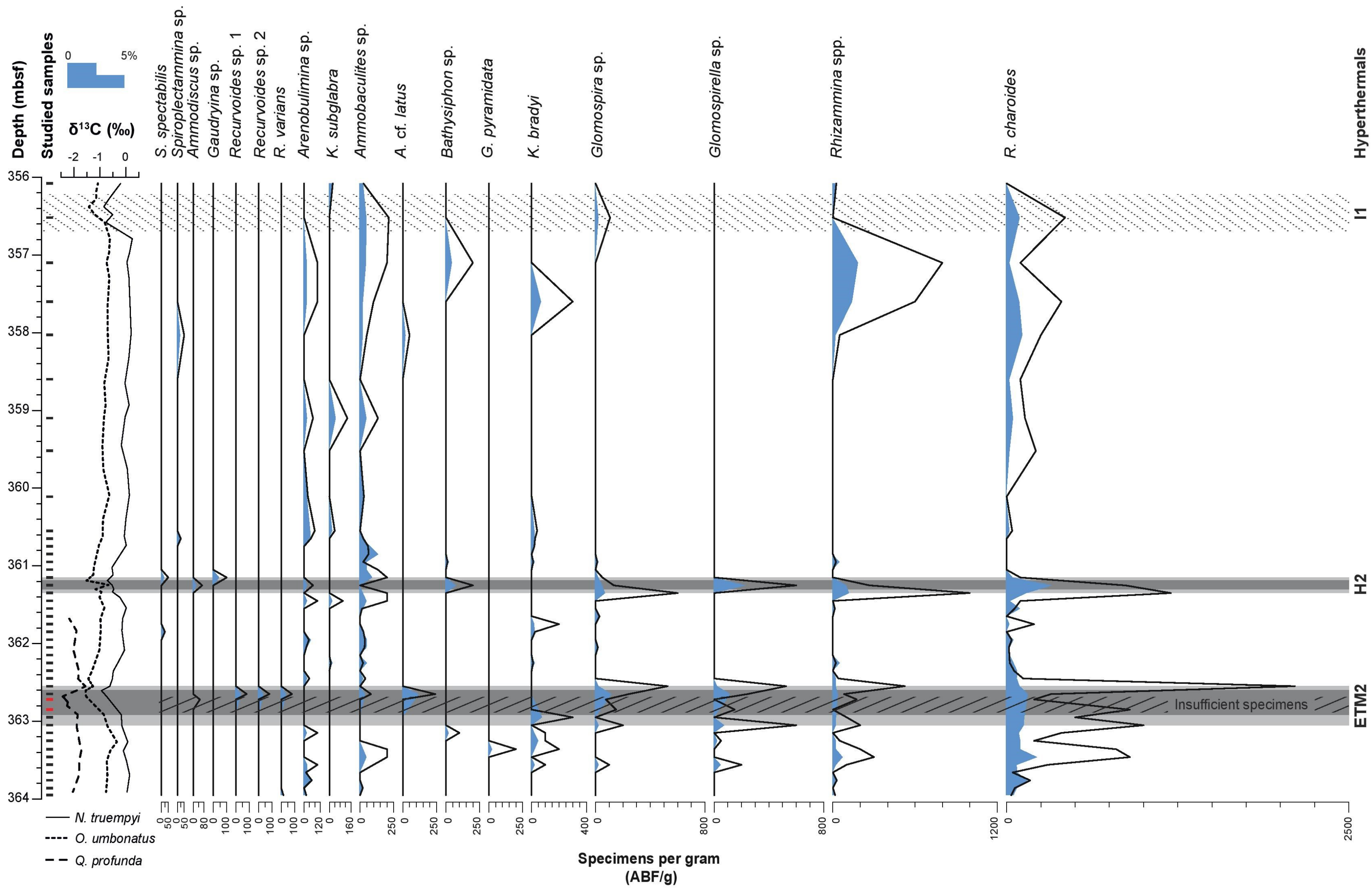


Figure 4. Distribution of agglutinated taxa across the studied interval. Blue areas represent the percentage of taxa within the agglutinated assemblage, and black lines show the absolute abundance of taxa (number of specimens per gram of bulk sediment). Dark grey areas indicate the core of the ETM2 and H2 events. δ13C data from D'haenens et al. (2014).

sp., *Spiroplectammina spectabilis* and *Vulvulina mexicana* across an interval that includes the ETM2 (which they called it level *δ*), and no changes in their abundance during the event are mentioned. Additionally, other studies of benthic foraminiferal during early Eocene hyperthermals do not include quantitative analysis, therefore we are not able to compare our agglutinated assemblage with other locations, in order to evaluate if the composition and changes reported in our study is a common feature during these hyperthermals, or if the response of the agglutinated taxa at this site is controlled by local conditions.

## CONCLUSIONS

Agglutinated benthic foraminifera are not abundant compared with calcareous taxa at DSDP Site 550 during the early Eocene. However, they show a slight increase in abundance across the ETM2 and H2 events.

The most abundant taxa of the agglutinated assemblage is *R. charoides*, and other species from the *Glomospira* group are also common across the studied interval, and these same species mostly composed the abundance peaks during both hyperthermal events. Therefore, the dominance of these species probably reflects the opportunistic and/or disaster behavior of these taxa under perturbed environments.

## ACKNOWLEDGEMENTS

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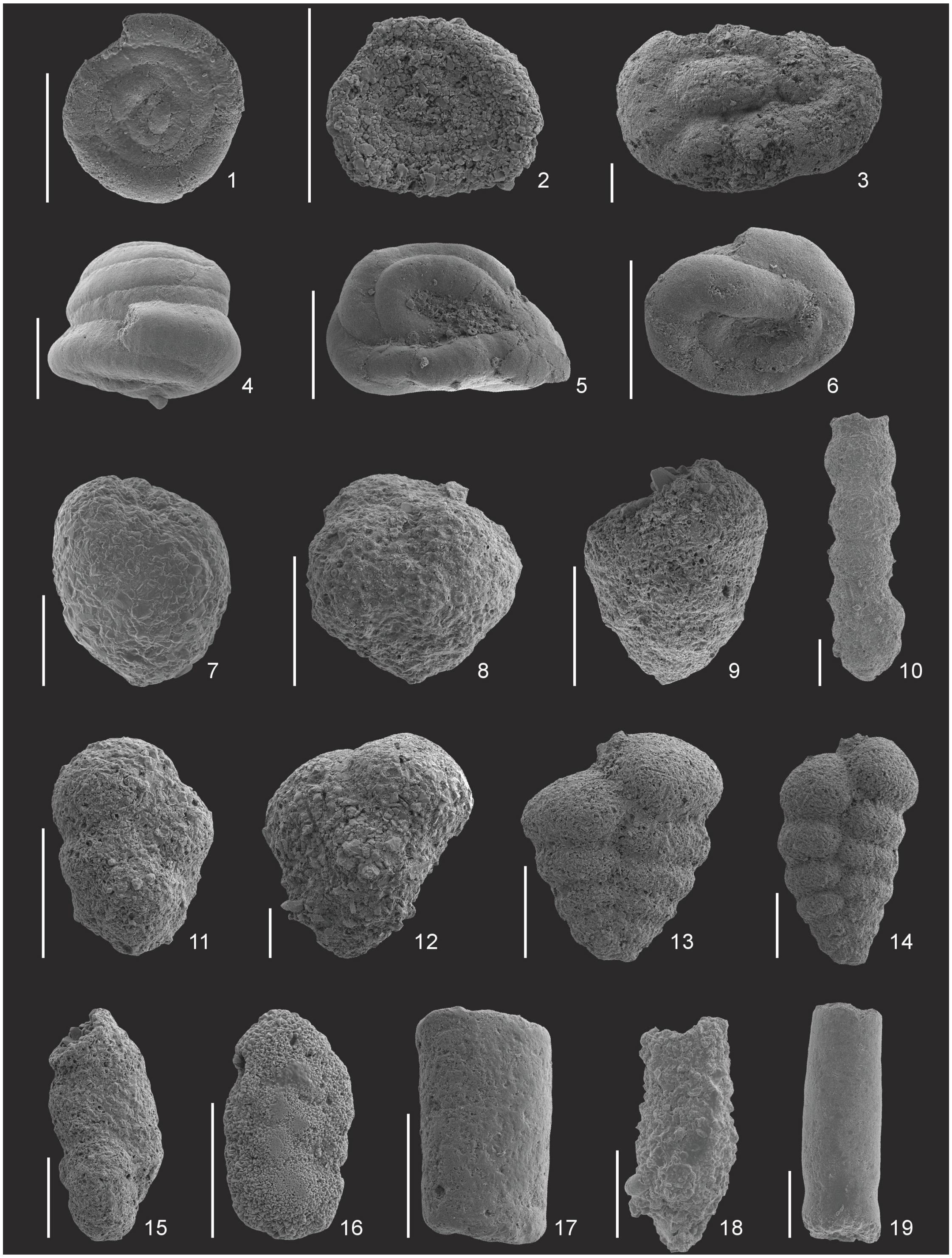


**Plate 1.** Scanning electron micrographs of early Eocene agglutinated benthic foraminiferal species at DSDP Site 550. All scale-bars represent 100 µm. 1, *Ammodiscus* cf. *latus* (sample 550-29-5, 65-67 cm, depth 362.65 mbsf); 2, *Ammodiscus* sp. (sample 550-29-4, 75-77 cm, depth 361.25 mbsf); 3, *Recurvoides* sp. 1 (sample 550-29-5, 65-67 cm, depth 362.65 mbsf); 4, *Repmanina charoides* (sample 550-29-5, 85-87 cm, 362.85 mbsf); 5, *Glomospira* sp. (sample 550-29-4, 85-87 cm, depth 361.35 mbsf); 6, *Glomospirella* sp. (sample 550-29-5, 105-107 cm, depth 363.05 mbsf); 7, *Arenobulimina* sp. (sample 550-29-4, 5-7 cm, depth 360.55 mbsf); 8, *Recurvoides* sp. 2 (sample 550-29-5, 65-67 cm, depth 362.65 mbsf); 9, *Remessella varians* (sample 550-29-6, 61-63 cm, depth 363.95 mbsf); 10, *Ammobaculites* sp. (sample 550-29-4, 35-37 cm, depth 360.85 mbsf); 11, *Gaudryina* sp. (sample 550-29-4, 65-67 cm, depth 361.15 mbsf); 12, *Gaudryina pyramidata* (sample 550-29-6, 2-4 cm, depth 363.36 mbsf); 13, *Karreriella bradyi* (sample 550-29-4, 135-137 cm, depth 361.85 mbsf); 14, *Karreriella subglabra* (sample 550-29-3, 10-12 cm, depth 359.10 mbsf); 15, *Spiroplectammina* sp. (sample 550-29-2, 53-55 cm, depth 358.03 mbsf); 16, *Spiroplectammina spectabilis* (sample 550-29-4, 135-137 cm, depth 361.85 mbsf); 17, Bathysiphon sp. (sample 550-29-4, 75-77 cm, depth 361.25 mbsf); 18, *Rhizammina* spp. (sample 550-29-1, 110-112 cm, depth 357.10 mbsf); 19, *Rhizammina* spp. (sample 550-29-1, 110-112 cm, depth 357.10 mbsf).