Global Calcareous Nannoplankton Trends Across the Middle Miocene Transition: A Statical Study

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Abstract

Calcareous nannoplankton, a group of calcifying phytoplankton that includes Coccolithophores, are vulnerable to changes in Earth's climate and ocean acidification. Calcareous nannoplankton records are documented at several sites worldwide. This group has a long fossil history recorded in marine sediments, which can provide information on how these organisms coped with climate change in the geologic past. The middle Miocene transition (~ 15 to 13.8 million years ago) was marked by a major increase in the Eastern Antarctic Ice Sheet, global cooling, a shift in the global carbon cycle, and changes in ocean circulation patterns. This cooling phenomenon transformed communities at all latitudes, though compositional differences in the fossil assemblage were retained in the Atlantic Ocean suggesting that provinciality is an important factor to consider. Regardless of the compositional differences, there may be similarities among global localities that can be identified and provide information on the impact of global cooling to the entire nannoplankton community.

In order to determine whether there is a similar global community response, calcareous nannoplankton datasets are compared from ocean drilling sites in the the North, South, and equatorial Atlantic Oceans to those from the equatorial Pacific Ocean using diversity metrics and multivariate statistical analyses. Our results show that nannoplankton populations from the equatorial Pacific Ocean are quite different from those in the Atlantic Ocean basins and the differences appear to be independent of temperature and climatic disturbances.

Introduction and Background

During the middle Miocene transition (~ 15 to 13.8 million years ago) the climate on Earth began to phase from a warmer to a a relatively cooler climate (Holburn et al., 2014). This transition is characteristic of major expansion of ice sheets on East Antarctica and changes in ocean circulation. The two predominant datasets used during this project are from Site U1338 and the other obtained from Henderiks et al., 2020.

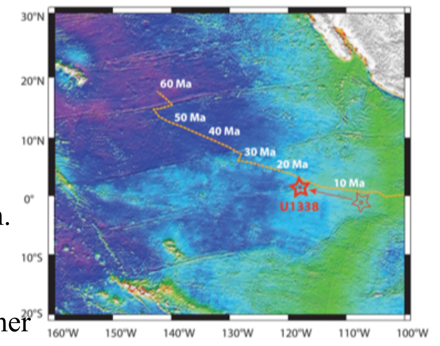

Figure 1 – Illustrating the location of Site U1338 (Holburn et al., 2014)

The objectives of this project are to:

- Compare calcareous nannoplankton datasets using diversity metrics and multivariate statistics
- Interpret and analyze plots made in RStudio
- Determine possible influences in nannoplankton communities at a regional scale

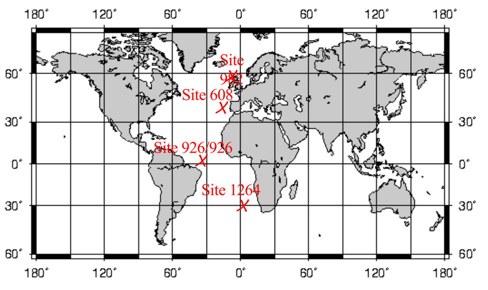

Figure 2 – Demonstrating the various sites used from (Hendriks et al., 2020) dataset

Methods

Shannon's Diversity Metrics

Calculated Shannon's diversity metrics through RStudio processes, which included downloading the package "vegan." Shannon's diversity was utilized since it is a measure of both species' richness and evenness.

Cluster Analysis

Executed cluster analysis in RStudio by using the packages "vegdist" and "cluster." Next, the dataset was standardized by row total, removed taxa less than 2% in order to reduce noise, multiplied the matrix by 100, added 1 to the matrix, and completed log transform. Followed by transposing the matrix, applying the distance measure (Bray Curtis), and applying the linkage method (Group Averaging and Hclust). Cluster analysis was conducted in order to interpret how the genera are most closely associated based on samples such as environment or ecology with the intent to learn more about the global community.

Non-Metric Multidimensional Scaling Analysis

Utilized the package "vegan" and standardized by row total, applied the distance measure (Bray Curtis) set code to run at 3 axes. NMS analysis was used to better understand what environmental factors such as temperature or nutrients were influencing the fossil assemblage.

Sea Surface Temperature and Chlorophyll Concentration

Researched the monthly sea surface temperatures for the summer months of 2020, while considering the summer months of the Southern hemisphere, for every site using a Columbia University database and continued a similar process for chlorophyll concentration using a NASA database.

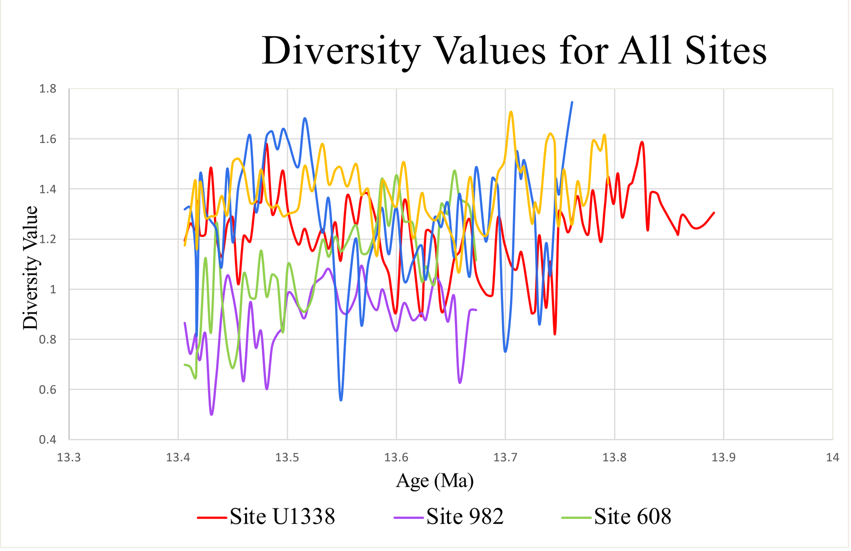

Figure 3 – Plot demonstrating Diversity values for all sites

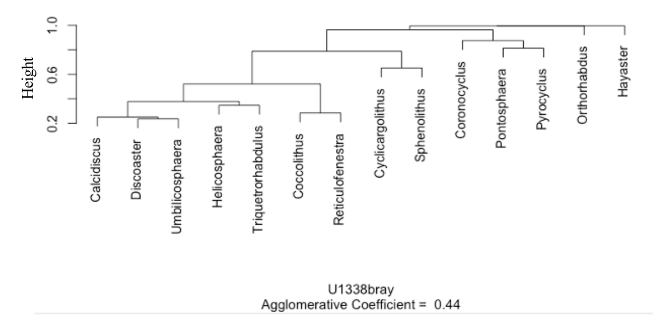

Figure 4 – Dendrogram depicting Site U1338 genera and genera from (Henderiks et al., 2020) dataset

Results and Discussion

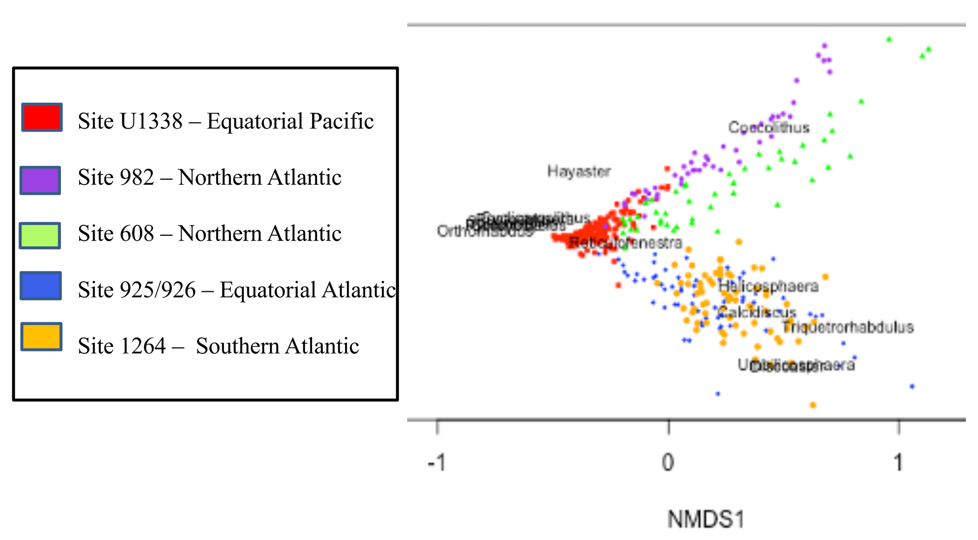

Figure 5 - U1338 Genera and Henderik's Genera

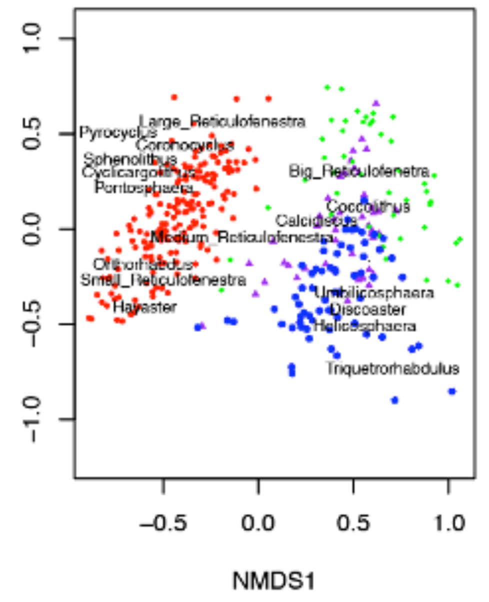

Figure 6 – NMS Analysis using the dataset "Reticulofenestra Separated by Size"

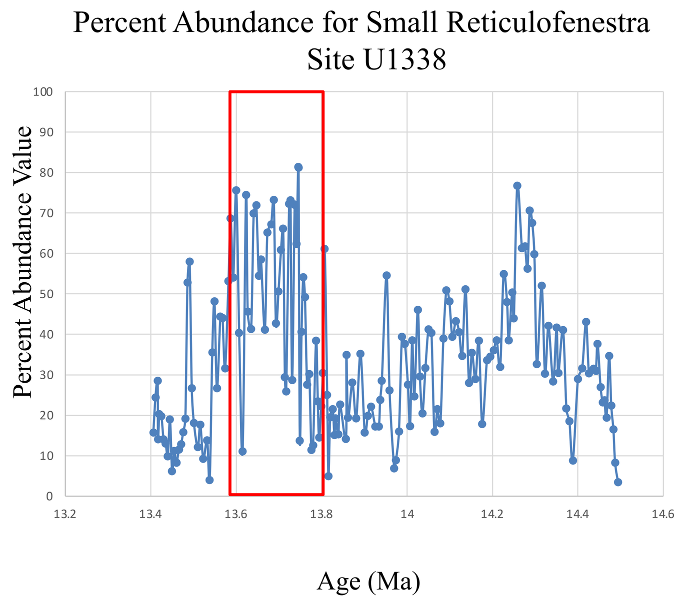

Figure 7 – Plot demonstrating percent abundance of small reticulofenestra over time

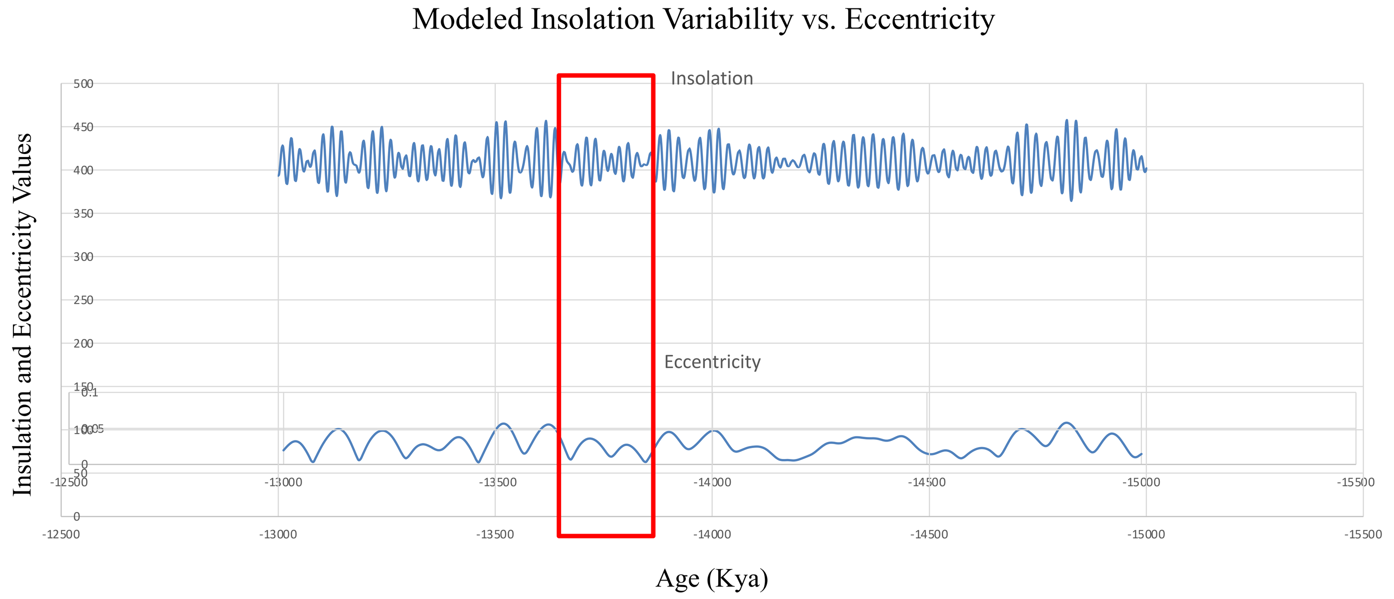

Figure 8– Demonstrating how solar insolation and eccentricity correlate

As shown in Figure 5, the genera are differentiated by the Atlantic and Pacific ocean basin with the Pacific sites to the left side and the Atlantic to the right. The equatorial Pacific data points appear to cluster more closely together, while the Atlantic points display a wider range of distribution. The reticulofenestra genus acts as a linkage between both ocean basins, since it is plotting near the origin. Due to the nature of all sites having reticulofenestra as the common factor Figure 6 has focused on reticulofenestra .

In Figure 6, the reticulofenestra is separated into size fractions to further investigate patterns. Looking at Figure 6, Axis 1 is separated by the Atlantic and Pacific ocean basin with the Pacific site on the far left and while the Atlantic sites are to the right. Furthermore, the Atlantic sites differentiate by colder climate species vs. warmer climate species. Based on the distribution in this figure, there seems to be a pattern related to net primary productivity. However, when comparing modern sea surface temperatures and chlorophyll concentrations not one of these environmental factors relate to either axis in Figure 6.

Looking at Figure 7, the percent abundance of small reticulofenestra experiences an acme roughly around 13.6 to 13.8 ma. In (Beltran et al., 2014) it was proposed that small reticulofenestra abundance increased during a period of low eccentricity since low eccentricity allowed for a longer growing day near the equator. Furthermore, (Beltran et al., 2014) confirms how nutrients nor temperature are negligible factors. According to (Rickaby et al., 2007), high oceanic primary productivity inversely correlates with low eccentricity and low insolation variability. Lastly in Figure 7, where small reticulofenestra displays a higher percentage abundance, the same time period in Figure 8 demonstrates a lower eccentricity and lower insolation variability value.

Conclusions

- NMS axes do not appear to be dependent on temperature nor chlorophyll concentrations
- High reticulofenestra productivity inversely correlates to low eccentricity and low insolation variability
- Reticulofenestra is driving the variants for Figure 5
- Based on (Beltran et al., 2014) and (Rickaby et al., 2007) in Figure 6 there appears to be a productivity signal, but chlorophyll concentrations don't support this conclusion
- Further comparison and analysis is recommended for future validation

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