Matthew Corbett is working on his Ph.D. degree at the University of Nebraska, under the guidance of Dr. David Watkins. He is studying mid-Cretaceous calcareous nannofossils. His dissertation is on the impact of OAE2 on nannofossil assemblages of the Western Interior and improving correlation to global records.

Abstract

The Cenomanian-Turonian (C/T) boundary is marked by a major period of global carbon burial known as Ocean Anoxic Event 2. Several major marine fossil groups (e.g. ammonites, inoceramids, foraminifera, calcareous nannofossils) were affected by the associated changes in atmospheric CO2 and paleoceanography. Calcareous nannofossil records show significant shifts in relative abundances across this boundary, which reflect change in sea-surface temperature and nutrient supply. Nannofossil records from the Tethyan realm have similar patterns of abundance to one another and are interpreted as evidence of enhanced productivity in oceanic surface waters. Sections from the central part of the Western Interior Seaway, however, have proven difficult to correlate with standard global zonations and suggest nannofossil assemblages were affected differently during OAE2.

An analysis of fossil material from new sites in the southern part of the seaway (west Texas) combined with reexamination of documented localities and incorporation of preexisting data sets is proposed. Quantitative biostratigraphy will improve correlation with global records and statistical analysis will allow for interpretations of regional paleoceanographic changes during OAE2 in the Western Interior.

Background

The mid-Cretaceous serves as an excellent record to study extreme global warming in a “super greenhouse” climate as major biological and oceanographic changes were occurring in the world’s oceans. Within this super greenhouse were several peak periods of warming, coincident with increased global carbon burial and positive excursions in carbon isotope records, known as Oceanic Anoxic Events (OAEs) (Erba, 2004). The Cenomanian-Turonian boundary corresponds to OAE2 and the warmest climate of the past 150 My. Calcareous nannofossil assemblages from this interval have been studied extensively for their potential to reveal paleobiological and paleoceanographic changes that can accompany major global warming (Watkins, 1986; Bralower, 1988; Bralower et al., 1997; Bralower and Bergen, 1998; Leckie et al., 2002; Erba, 2004; Hardas and Mutterlose, 2007; Melinte-Dobrinescu and Bojar, 2008; Linnert et al., 2010; and Fernando et al., 2010).

Increased submarine volcanism and formation of the Caribbean large igneous province coincides with the beginning of the Cenomanian carbon excursion and is thought to explain the ensuing greenhouse climate (Jones and Jenkyns, 2001, Wignall 2001, Erba 2004). Prior analysis of Tethyan (equatorial Atlantic and European) nannofossil assemblages suggests an increase in marine surface water productivity related to more nutrient availability possibly resulting from higher terrestrial runoff or break-down of water column stratification driven by global warming and volcanism from mid-ocean ridges or hydrothermal vents releasing greater amounts of biolimiting metals (Erba, 2004; Hardas and Mutterlose, 2007). Eutrophic conditions would explain the increased carbon burial and higher δ13C in marine fossil calcite, represented by a shift from about 2‰ to 5‰ (PDB), as more organic material rich in the lighter carbon isotope preferentially taken in by living organisms would reach the seafloor and be preserved. Oxidation and consummation of this organic material by bacteria, etc., would have lead to anoxia deeper in the water column.

Calcareous nannofossil fertility indicators Zeugrhabdotus, Watznaueria, and Biscutum (genera consisting of several species) have peculiar patterns of abundance across across the OAE2 interval in the Tethyan sections. Zeugrhabdotus and Biscutum are thought to be high productivity eutrophic surface water indicators, while Watznaueria is typically associated with low productivity oligotrophic conditions. High ratios of Zeugrhabdotus to Watznaueria indicate elevated primary productivity in the interval prior to and during OAE2, although Biscutum spp. do not always track with Zeugrhabdotids and may be representative of different levels of productivity (Erba, 2004; Hardas and Mutterlose, 2007; Melinte-Dobrinescu, 2008; and Tantawy, 2008). High fertility indicators drop off sharply in the later part of OAE2 while the cool-water Eprolithus floralis experiences several peaks in abundance, which may reflect paleoceanographic changes associated with an eventual “reverse greenhouse effect” (Clark and Jenkyns, 1999; Erba, 2004; Damste et al., 2010). Total nannofossil abundances are typically very low to nearly barren over an interval in these later portions of OAE2 or in the following succession.

The nannofossil records from the central part of the Western Interior Seaway are more complex and reflect oligotrophic conditions at the surface coincident with sediment anoxia (Watkins, 1986; Burns and Bralower, 1998; and Eleson and Bralower, 2005). High fertility indicators Zeugrhabdotus and Biscutum are less abundant through OAE2 in the Western Interior. Abundance changes and carbonate productivity here were likely tied to interactions between cool boreal and warm Tethyan currents and fresh-water runoff. The mixing of these water masses would have stratified the water column, enhancing sediment anoxia and bringing in nutrient depleted surface waters from the tropics (Watkins, 1986; Watkins, 1989; Burns and Bralower, 1998; and Eleson and Bralower, 2005).

The Tethyan sites are correlated biostratigraphically through the use of three global calcareous nannofossil zonation schemes, the CC zonation of Perch-Neilsen (1985), the UC zonation of Burnett (1998), and the integrated calcareous nannofossil and foraminiferan IC zonation developed by Bralower et al. (1995). The peak in greenhouse conditions and subsequent cooling across OAE2 resulted in significant turnover (i.e. extinctions and first occurrences) of calcareous nannofossil species (Erba 2004). These events serve as useful datums in the zonation schemes for the C/T boundary. Only a single lowest occurrence event (Quadrum gartneri) is used to mark the base of the Turonian in the CC zonation while the UC and IC zonations use several species (e.g., Eprolithus eptapetalis, Rhagodiscus asper, Axopodorhabdus albianus, Helenia chiastia, and Corolithion kennedyi) to bracket the C/T boundary.

Calcareous nannofossil records from the Western Interior Seaway are difficult to correlate and compare to Tethyan sites using the aforementioned assemblage changes and zonation schemes. Achieving a resolution of 0.5-1My is problematic in the Western Interior since important marker species for this boundary are reported at many different stratigraphic levels across the C/T boundary, possibly reflecting diachroneity of extinctions or problems with rare/poorly preserved specimens (Bralower and Bergen, 1998; Desmares et al., 2007). Published detailed biostratigraphy recording nannofossil abundances is limited to Utah, Colorado, and Kansas while analyses of material from Oklahoma, Arkansas, and Texas are mainly taxonomic discussions of useful marker species (Gartner, 1968; Bukry, 1969; Hill, 1976; and Smith, 1981). More detailed analysis of southern sites and from known sections in the central part of the seaway will improve regional paleoceanographic interpretations and correlation of the Western Interior to global records.

Materials/Methods

Material for this project will include outcrop and core samples from new sections in west Texas, reexamination of previously described localities in Colorado and Kansas, and analysis of existing data sets collected from Tethyan sites. Samples have already been collected and prepared from a complete Cenomanian through Coniacian exposure located west of Langtry, TX, at Lozier Canyon (Donovan and Staerker, 2010). This site is located along the margin of what was once a broad carbonate platform centered around the San Marcos Arch - Llano Uplift, which may have acted as a sill at times between the waters of the Western Interior and the tropical Gulf of Mexico (Slingerland et al., 1996). Analysis of nannofossil assemblages from this site would be unique in being able to provide evidence of surface water conditions at a critical separation between the two basins. Additional material will be collected from outcrops along nearby road cuts and possibly from a core collected behind the Lozier Canyon site for more detailed sampling of important stage and sequence boundaries.

The western Kansas Rebecca Bounds core from western Kansas, housed in Lawrence, KS with the Kansas Geological Survey will also be sampled and analyzed with slides already prepared from outcrop localities in Mesa Verde and Pueblo, CO. The Pueblo site is the Global Boundary Stratotype Section and Point (GSSP) for the Cenomanian-Turonian boundary.

There are many existing Tethyan datasets that will also be incorporated into this work. Several studies provide data across Europe from Germany, Poland, France, Italy, Romania, and Morocco. Scientific results from many IODP/ODP and DSDP cruises also contain calcareous nannofossil data from the C/T boundary interval (Legs 17, 26, 41, 50, 62, 80, 89, 122, 123, 198, and 207). Using these sources a transect can be made from the Indian Ocean and Western Australia to the western and central Equatorial Pacific, Equatorial Atlantic, Central Atlantic, and northeast Atlantic just southwest of the United Kingdom.

Calcareous nannofossils will be studied using a light microscope with 60x oil immersion objective lenses for a total magnification of 960x. Preparation of the collected samples will follow Bown and Young’s (1998) method for making smear slides. Point counting of these slides will provide abundance data for specific indicator species useful for the interpretation of ecological and climatic conditions. Once collected these data will be used for a quantitative analysis of nannofossil species using the paleontological data analysis program Past (Hammer and Harper, 2006). Foraminiferal, palynomorph, macrofossil, and isotopic analyses are also being performed by other researchers for the Lozier Canyon outcrop, which will improve correlations with similar data sets collected globally and in the Western Interior. Correlation of all sites to a peak in δ13C values, called The Bonarelli Event, will be especially important as it is used to define the Cenomanian-Turonian boundary (Arthur et al., 1988).

A series of quantitative statistical tests will be performed on the different data collected and assembled for this project. Counts of nannofossil species will be used for paleoecological analysis through tests such as Principle Components Analysis and Correspondence Analysis to expose possible environmental influences or gradients between single and groups of taxa (Hammer and Harper, 2006). Data limited, or converted, to presence/absence of species cannot be used for such detailed environmental interpretation. Quantitative biostratigraphic analysis, through the methods of Ranking and Scaling, Constrained Optimization or Unitary Associations, will be used to develop an order for events (e.g., first and last occurrences) and zones based on event groupings using this kind of data (Hammer and Harper, 2006). This allows for statistically significant biostratigraphic correlations which will greatly improve the current understanding of the

Cenomanian-Turonian boundary interval. Since a large composite data set will be created for this purpose it will be a perfect candidate on which to apply all three statistical methods, not only to test their validity but as a more comprehensive investigation of the usefulness of established markers.

Summary and Expected Dissertation Goals

Results from this project are expected to accomplish three goals. (1) Some of the first detailed calcareous nannofossil biostratigraphic work for the mid-Cretaceous of the southern Western Interior Seaway will be developed for the Lozier Canyon site. This is expected to be incorporated into a complete sedimentological, stratigraphic, and paleontological analysis with other geologists working in conjunction with BP. (2) Statistical analysis of the record at Lozier Canyon and detailed abundance data from Colorado and Kansas will allow for a better interpretation of surface water conditions effecting calcareous nannofossils in the Western Interior and the southern carbonate platform separating it from the Gulf of Mexico. Nannofossil preservation and abundance of oligotrophic surface water indicator species are predicted to diminish across all sites as productivity increased during OAE2, though abundance data and appearance of biostratigraphic markers in Texas sites may more closely match those of other oceanic localities because of tropical water influx from the Gulf of Mexico. (3) Lastly, a review of global Tethyan data sets comparing established marker events to those in the Western Interior will be analyzed using three different quantitative biostratigraphic methods. This will produce the most likely sequence of events, such as first/last occurrences and relative abundance shifts, and reveal whether marker species are actually diachronous in the region. It would also be ideal if new markers or events are identified to improve the resolution of regional zonations and correlation to global schemes.

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