Thomas Cawthern is a PhD student in the Department of Earth Sciences at the University of New Hampshire. His current research is aimed at reconstructing the marine stratigraphy and sedimentology of the Andaman accretionary wedge. His advisor is Dr. Joel Johnson.

Introduction

In the marine environment, stable conditions for gas hydrate formation are common on many passive and active continental margins. Convergent margins, however, provide the most favorable environment for gas hydrate accumulation because of their characteristic high sedimentation rates, intense tectonic activity, which provide vertical and horizontal conduits by which gases and fluids can migrate, and overall higher average organic matter concentrations because of upwelling initiated by characteristic narrow shelves and steeper slopes[1]. Fundamental to understanding the controls on the formation and occurrence of gas hydrates in continental margin marine settings are detailed stratigraphic and geochemical studies. The purpose of this study is to characterize the host sedimentology and stratigraphic evolution of marine gas hydrate-bearing sediments from a recently collected core in the Andaman accretionary wedge. This record is dominated by largely undeformed marine pelagic sediments containing variable amounts of calcium carbonate, biosiliceous material, and volcanic ash. Within this record, gas hydrate is concentrated in volcanic ash layers. In this study I will integrate existing ocean drilling data sets from this site with new X-ray diffraction measurements and trace and rare earth element measurements to characterize the sedimentology and reconstruct the geological evolution of this active margin gas hydrate province.

Proposed Research

In 2006, a gas hydrate dedicated drilling expedition (NGHP-01), led by the National Gas Hydrate Program of India was launched in order to assess the potential reserves of gas hydrate along the Indian continental margins (Fig. 1)[2]. In this proposal, I focus solely on a ~700 meter long (~9.4 Ma) gas hydrate-bearing marine sedimentary record recovered from the Andaman accretionary wedge (NGHP-01 Site 17). Stratigraphic data for the marine sedimentary record recovered at NGHP-01 Site 17 were generated from shipboard[2] and early post-cruise investigations (Fig 2)[3,4]. My proposed research plan capitalizes on this initial research, and provides me with the unique opportunity to pursue research directions focused on the long timescale oceanographic and geologic evolution of this gas hydrate-bearing region. In this project I address three research questions:

(1) What is the timing and origin of an observed change from biosiliceous-dominated to carbonate-dominated plankton at Site 17? What is the relationship of this change to similar changes observed in the Atlantic and Pacific oceans during this time?

(2) Does an observed depositional hiatus at Site 17 represent a single, long duration event, or does it consist of numerous shorter duration periods of non-deposition?

(3) What is the origin of observed compositional variability in the ashes preserved at Site 17? Does this variability imply major changes in the Andaman-Sunda arc through time and/or volcanic inputs to the Site 17 region?

To address these research questions I will integrate existing ocean drilling data sets from Site 17 with new X-ray diffraction measurements and trace and rare earth element measurements. Pursuing these new research directions will allow me to reconstruct the ~9.4 Ma depositional history preserved at Site 17 from a geologic, oceanographic, and volcanic perspective.

Geologic and Oceanographic Setting

NGHP-01 Site 17 is located in a relatively undeformed portion of the Andaman accretionary wedge, just east of Little Andaman Island (Fig. 1). The uplifted seafloor and volcanoes in the Site 17 region formed as a result of the subduction of the India plate beneath the Sunda plate in the Sumatra-Andaman region since the Cretaceous (~130 Ma)[5]. Along the subduction zone margin, volcanic activity is currently active in the south on and near Sumatra and, to a lesser degree, in the Andaman region (Fig. 1)[6]. Volcanic activity has been present in the Sumatra region since the Cretaceous[5], whereas volcanism in the Andaman region and farther north is much younger, and began in the late Pliocene (<3.4 Ma)[7]. The proximal location of Site 17 to several volcanic centers has resulted in the preservation of numerous volcanic ashes (Fig. 2). Initial major element analysis of 4 ash layers reveal mineralogically distinct ashes at the base of the core (basalt) and felsic ashes at the top (rhyolite)[8]. Based on Hf and Nd isotopic signatures of regional volcanoes and 12 ashes from Site 17[8], I hypothesize that the downcore variability of these ashes records the evolution of a small arc segment. To better document this change and test my hypothesis I plan to determine the trace and rare earth elements for 35 discrete ash layers.

Past reconstructions of ocean circulation in the Bay of Bengal-Andaman Sea sector suggest that the expansion of Antarctic ice during late Pliocene and early Pleistocene glacials at ~3.5 Ma, 2.6-2.4 Ma, ~2.15 Ma, and 1.8-1.7 Ma[9] are believed to have led to a strengthening of the northward-flowing Circumpolar Deep Water (CPDW) and Antarctic Bottom Water (AABW), and a concomitant weakening of the North Atlantic Deep Water (NADW). Suppression of the NADW most likely resulted in a weakening of southwest monsoon-driven upwelling in the northern Indian Ocean since the mid-Pleistocene transition[10]. Changes in upwelling in pre-Pleistocene time, however, are more difficult to establish.

Shipboard smear slide and coarse fraction analyses of the sediments at Site 17 indicate that a shift in the marine planktonic organisms has occurred during the past ~9.4 Ma[2]. Specifically, biosiliceous and carbonate marine organisms dominate the lower half of the core, whereas only carbonate-bearing marine organisms dominate the upper half of the core (Fig 2). Detailed examination of this transition at Site 17 and its timing relative to other documented paleoceanographic changes in the region and in the global oceans will allow me to interpret the most likely origin for this major change in community structure. My research will investigate the timing and cause of this transformation and enable me to correlate this record in the Andaman Sea region to similar changes that have been documented in the Pacific Ocean and elsewhere around the world.

The nannofossil biostratigraphy at Site 17 reveals two distinct time intervals with different sedimentation rates separated by an apparent depositional hiatus lasting ~1.2 Ma (Fig 2)[11]. This hiatus occurs around the middle Pliocene (~3.8 Ma-2.6 Ma) and suggests that a fundament change in sedimentation rate was either produced through erosion or prolonged near-zero sediment accumulation. The seismic profile across the core location, however, documents a relatively flat-lying stratigraphy with no obvious unconformities, suggesting the missing time was produced through a major decrease in sedimentation. The distinct shift in sedimentation rate and the occurrence of a possible depositional hiatus within the sedimentary record at Site 17 has important implications concerning the depositional history at this site, and higher resolution studies across this interval will elucidate the exact nature of this zone.

Research Approaches

1. Investigating the Biogenic Silica to Carbonate Transition

I will quantitatively measure the biogenic silica (BSi) content at Site 17 in order to constrain the timing of the biogenic silica to carbonate transition. To measure BSi, I will use standard X-ray diffraction (XRD) techniques on a Siemens D 5000 X-ray Diffractometer located at the University of New Hampshire. Sample material for XRD measurements is available at a sampling frequency of 1sample/1.5m core section throughout the record from residual core sample material that is now housed at UNH.

2. Characterizing the Depositional Hiatus

The depositional hiatus in the sedimentary record at Site 17 will be further characterized through more detailed measurements of bulk mineralogy using the XRD. Bulk mineralogical XRD measurements at a sampling frequency of 1sample/1.5m core section will be measured across this transition zone in order to identify any unique changes in sediment composition that might have accompanied or been concentrated during the hiatus. These efforts will provide detailed information regarding whether or not the hiatus is a single, prolonged event, or if it represents a series of events of shorter duration.

3. Determining Ash Geochemistry

The volcanic ashes at Site 17 will be characterized with respect to trace and rare earth element abundances. Trace and rare earth elemental compositions will be measured on 35 ash samples that were recovered from Site 17 and are now at UNH. Elemental abundances will be measured at the University of New Hampshire using the Nu AttoM high resolution single collector inductively coupled plasma mass spectrometer (LA-HR-ICP-MS). Results from this effort will serve to establish the compositional changes in the ashes though time and have implications for understanding the evolution of the arc.

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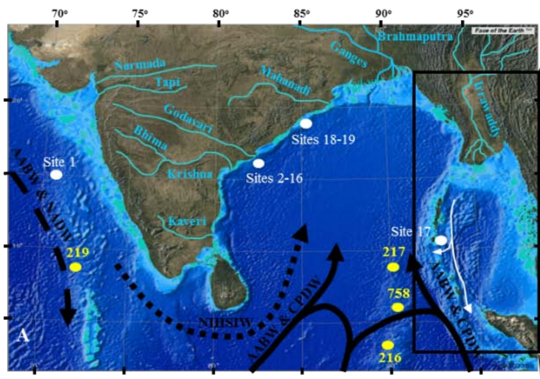
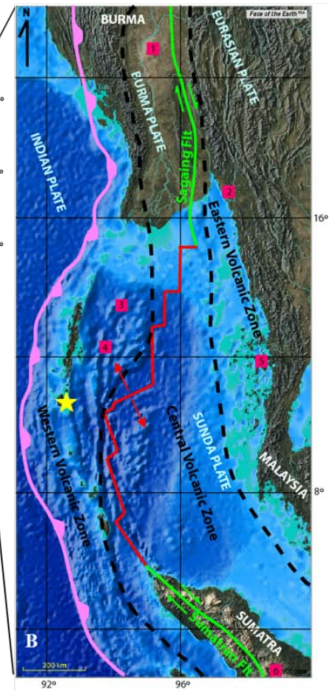


Figure 1: A) Regional map of the NE Indian Ocean region showing core locations from NGHP-01 (white dots) and IODP/ODP sites (yellow dots), the location of major rivers entering the NE Indian Ocean and Andaman Sea, and generalized ocean circulation for the NE Indian Ocean. Solid black lines are deep water masses, coarse dashed lines are intermediate waters, and fine dashed lines are shallow marine water masses. Solid white lines in the Andaman Sea show deep water circulation paths and outlets. B) Regional volcanic and tectonic map of the North Sunda subduction zone showing the location of Site 17 (yellow star), important plate boundaries (colored lines), and the location of key volcanic centers (pink boxes).



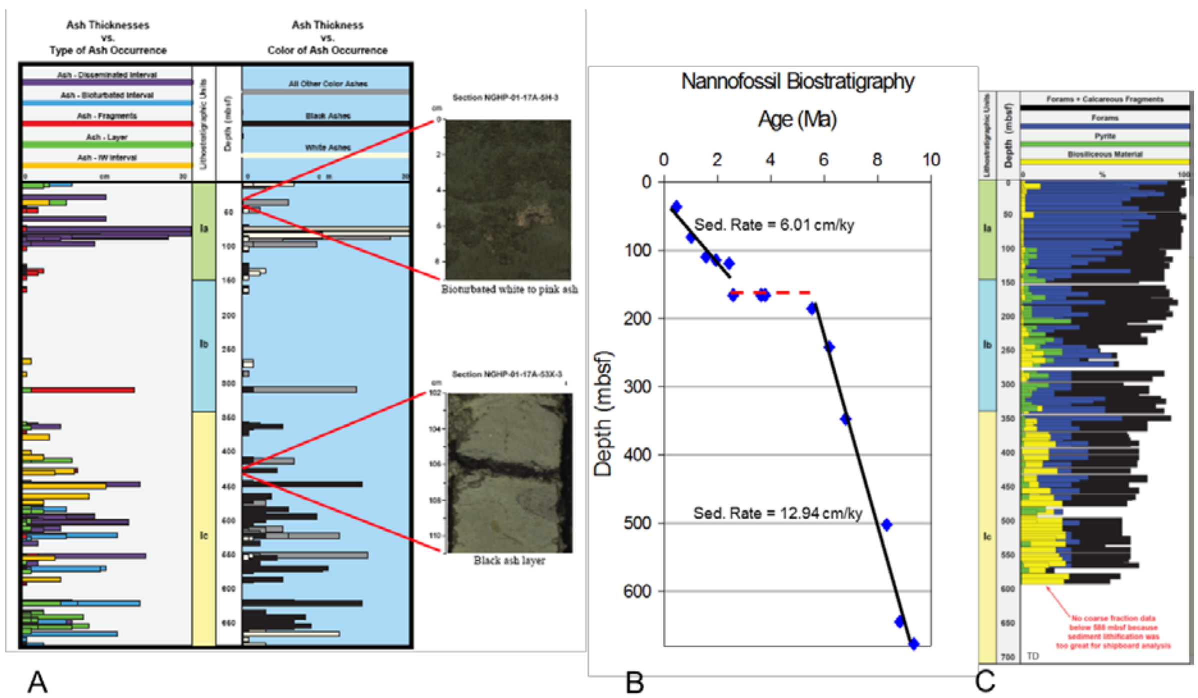


Figure 2: A) Summary of ash types, thickness, and occurrences with depth (left) and the color of ash versus depth (right) (Collett et al., 2008). Core photographs show characteristic light and dark colored volcanic ashes. These color contrasts, along with a preliminary examination of volcanic ashes at Site 17 reveal these beds are mineralogically distinct. This study will capitalize on previous research on the nannofossil biostratigraphy (B) and coarse fraction analyses (C) at Site 17.