THROUGHFLOW ITN Midterm Research Report

December 2011

Introduction

The shallow tropical marine ecosystems of SE Asia are the most diverse in world and has been for at least the past 25 million years (Renema et al. 2008, McMonagle et al 2011). Since the time of Wallace in the nineteenth century, biologists have been working to understand the origins and maintenance of this biodiversity maximum by studying the distribution and evolutionary history of extant taxa. But fossils can provide direct evidence of past diversity and for tropical marine ecosystems, a significant portion of the biota is preserved in the fossil record. To date this valuable resource remains underexploited. In this project we examine the Miocene history preserved in the sediments of East Kalimantan to understand how these megadiverse ecosystems responded to past intervals of global and regional environmental change. The Miocene represents an ideal test case as it includes the warmest interval since the Eocene, the middle Miocene Climatic Optimum (MCO) at around 15 Ma (Zachos et al 2008). Is this interval an analog for future conditions resulting from accelerating anthropogenic climate change? When combined with increasing knowledge of other warm intervals in each of the three Cenozoic coral-reef provinces (Johnson et al. 2008), new data from the SE Asian biodiversity maximum will allow a better understanding of the potential modes of change on extant coral reefs. Analysis of these long-term data from multiple regions with differing biotic and environmental histories are required to predict the "new normal" for modern tropical shallow marine ecosystems.

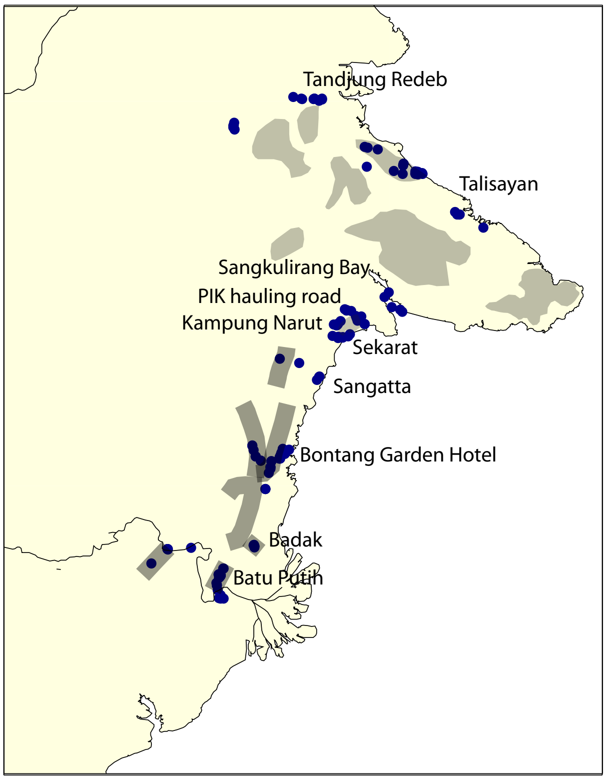

Figure 1. Map of THROUGHFLOW sampling localities showing areas mentioned in the text. Shaded regions are extensive karstic exposures or limestone ridges.

Regional geology, stratigraphy, and palaeoenvironments

Borneo formed the eastern margin of Sundaland, the stable cratonic margin of Southeast Asia, throughout much of the Cenozoic (Hall, 1998). Widespread basinal development occurred around the margins of Sundaland during the early Paleogene, and basins along the southeastern margin rapidly became marine. The Kutei basin was initiated in the Middle Eocene in conjunction with rifting and likely sea floor spreading in the Makassar Straits (Wilson and Moss, 1998; Moss and Chambers 1999). A near complete Cenozoic sedimentary record from Eocene to Recent is present within the Kutai Basin; much of it is exposed at the surface as a result of Miocene and younger tectonic processes (Moss and Chambers 1999). The Kutei basin is bounded to the North by WNW-ESE trending faults from the Mangkalihat high. Here also a near complete record from the Middle Eocene to recent is present, but, contrary to the Kutei basin, these are, in a large part, deposited away from terrestrial influence, partly as a series of large carbonate platforms.

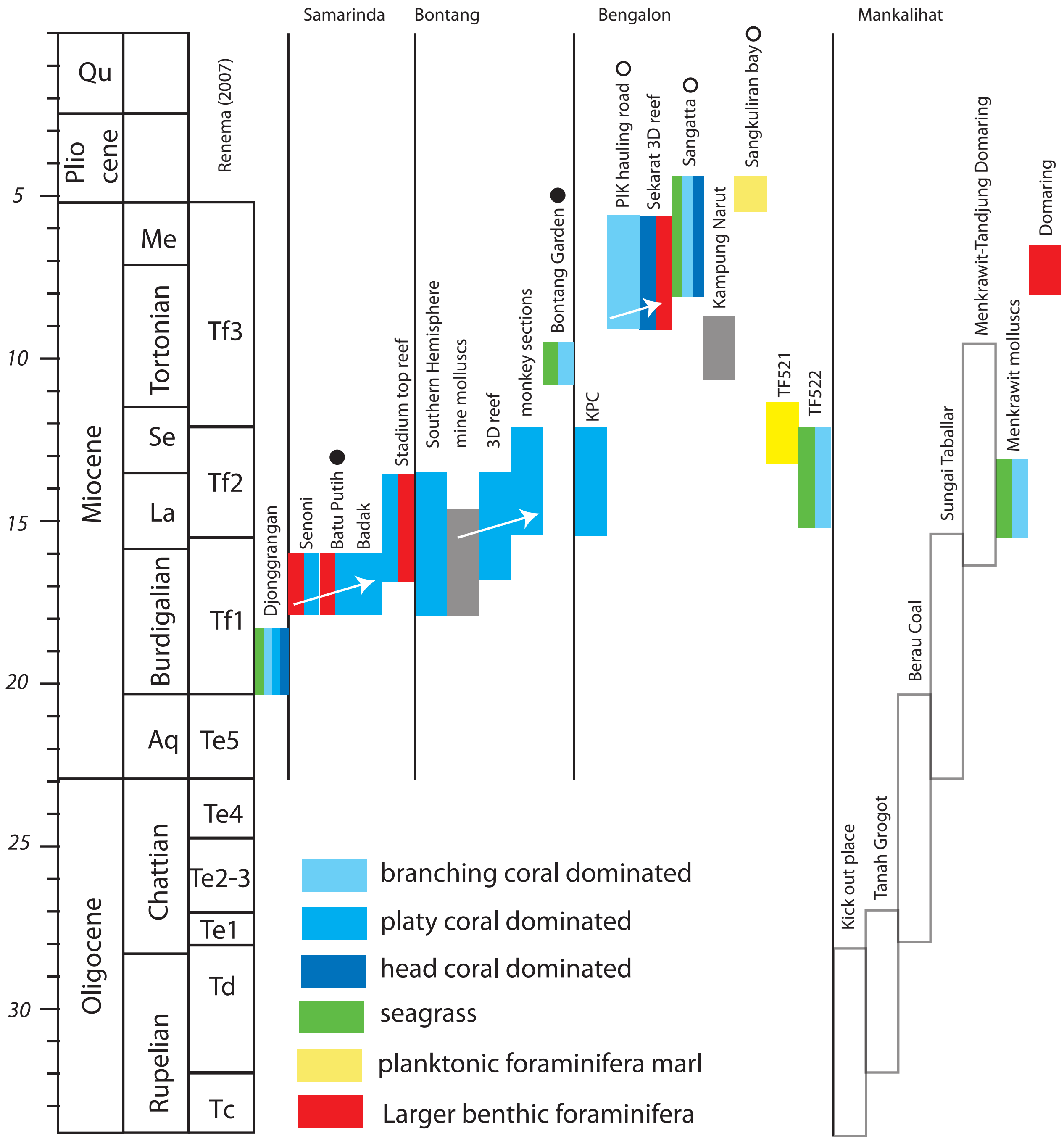

Figure 2. Stratigraphic distribution of habitat types in the marine macro-fossil bear units sampled during field training events. Age interpretations are preliminary and based on field identification oflarge benthic forams.

The THROUGHFLOW project focused on fossil-bearing units in the the Kutei basin and Mangkalihat peninsula. In the Kutei basin all of these units coincided or are associated with periods of carbonate formation, whereas macro fossils were associated with the more marly intervals in Mangkalihat. We use extensive carbonate sections on Mangkalihat, as well as long well-exposed sections in the Samarinda area to produce a stratigraphical framework for the Kutei outcrops.

The northern margin of the Kutei basin from Balikpapan to Sangkulirang consists of shelf and upper shelf slope clays over which the paleo-Mahakam delta progrades. Extensive (5-10 km long) patch reefs of the Batu Putih in Samarinda are formed in the prodeltaic environment. In most sections these develop in two or three reefal sequences separated by clays or larger benthic foraminifera (*Nephrolepidina)* packstones. The coral facies is dominated by platy corals (*Pachyseris*, *Echinopora*). Locally (TF76) very shallow reef flat type environments (including large *Tridacna*) are present. These carbonates are of late Burdigalian age.

The Batu Putih is overlain by marine shales and sands, and deltaic sediments characterized by the first occurrence of coals in an estuarine environment, followed by deltaic and fluvial / coastal plain deposits with abundant coals. A second carbonate layer is locally developed to the south of Samarinda on top of these deltaic sands. These beds develop on top of an organic carbonate rich clay layer. The carbonate is dominated by platy coral facies type as well.

Towards the north, similar facies types of similar age form ridges standing out in the landscape. These can be traced north towards Sangatta, and the limestones are of very comparable facies-types compared to the Batu Putih. How these reefs correlate, for example as a single barrier reef complex or multiple patch formed at slightly different times is still under investigation. Most outcrops are thinner than those around Batu Putih, but show different phases of carbonate development. In Badak, and possibly in the Southern Hemisphere as well, indications paleosol formation have been found within the carbonate section indicating substantial variations in sea-level during the formation of these beds.

On top of the late Early-early Middle Miocene carbonates the units with most significant coals developed and formed thick coal seams in approximately 400-800m of sediment. During the deposition of these deposits, locally conditions were suitable for the development of lacustrine to even reef environments, often with excellent fossil preservations. One of the most notable and oldest (middle Tortonian) is the Bontang Garden Hotel area. Rapid development and many building activities resulted in ~5 sections along an about 10 km transect along strike, including the entire development of this patch. Multiple levels of marine intervals, sometimes inter-fingering with coal beds of up to 1m thick, were found. Notable is the occurrence of typical sea-grass-associated mollusk faunas, as well as more reefal deposits with well preserved (and large) *Tridacna*.

To the north of Sangatta, several more of these type of patches were found, including a ~100m-long river section near Kampung Narut, which includes a transition from freshwater to reef environments, topped by a head-coral-dominated limestone. This section is likely to be of similar age as the Bontang Garden Hotel deposits. Closer to the shore in the same area a sticky coral facies was found in an about 5 m thick bed, overlain by a barren sand/siltstone and a coal. Coral and *Tridacna* preservation looks potentially sufficient for scleroclimatological analysis. On top of this a large reef formed an about 40m thick bioherm with very modern looking facies types, including framestones and foraminiferal (*Operculina*) packstones. Even further north (PIK hauling road) a different facies type occurs with abundant bedded shales with locally abundant fossil rich beds. To the east, these grade into a foraminfera rich marl. These beds are late Middle Miocene in age, but in the Sangkuliran bay extend into the youngest Late Miocene.

Sekarat, Kampung Narut, and PIK hauling road formed around a 100s meters high karstic topographic feature. Access to this karstic area was difficult, but all samples we have collected from the limestones forming this feature are of late Early-Middle Miocene age. This is further corroborated by debris of these ages found in Late Miocene marls along the hauling road.

In the Tandjung Redeb-Talisayan area (Mankalihat) we measured sections in Oligocene-Pliocene deposits. The oldest sections were found near the Berau Coal mine in limestones yielding abundant reticulate *Nummulites*, without *Eulepidina* indicating earliest Oligocene age. Around Tandjung Redeb these are overlain by limestones with *Eulepidina and Spiroclypeus* of early Early Miocene age. Most of the younger part of the section is developed here as a bedded marl. Several of the beds yield abundant larger foraminifera, probably reaching into early Middle Miocene age. We found one bed with corals and other macrofossils.

Around Talisayan during the same time interval, carbonate sedimentation was more or less continuous, even though some levels of clayey marls are present. Especially during the late Early Miocene massive carbonates were deposited. This is overlain by a marly interval with an alternation of multiple facies, including the sticky coral facies, grey silty sandstones, and platy and head coral limestones. This unit is known as the Menkrawit layers in the old Dutch literature, and constitutes a marly interval overlain by the Domaring limestones. These are deposited in slightly NE dipping beds and exposed as sea cliffs. The lowest part is early Late Miocene in age. There is continuous exposure, but the youngest deposits in this area are coralpackstones en larger benthic foraminifera (*Operculina*) packstones. Massive micritic limestone beds contain *Cycloclypeus* and *Nephrolepidina* and are of latest Miocene age.

In conclusion we have located numerous macro fossil bearing deposits from a range of environments from within the time interval of interest. We collected over six tons of samples which are now being processed. Initial results are given in the ESR-reports.

References

Hall, R. 1998. The plate tectonics of Cenozoic SE Asia and the distribution of land and sea. Pp. 99-131. In R. Hall, and J. D. Holloway, eds. Tectonic evolution of Southeast Asia. Backhuys Publishers, Leiden.

Johnson, K. G., J. B. C. Jackson, and A. F. Budd. 2008. Caribbean reef development was independent of coral diversity over 28 million years. Science 319:1521-1522.

McMonagle, L. B., P. Lunt, Wilson, Moyra E.J. , K. G. Johnson, C. Manning, and J. Young. 2011. A re-assessment of age dating of fossiliferous limestones in eastern Sabah, Borneo: implications for understanding the origins of the Indo-Pacific marine biodiversity hotspot. Palaeogeography, Palaeoclimatology, Palaeoecology 305:28-42.

Moss, S. J. and J. L. C. Chambers. 1999. Tertiary facies architecture in the Kutai Basin , Kalimantan , Indonesia. Journal of Asian Earth Sciences 17: 157-181.

Renema, W., D. R. Bellwood, J. C. Braga, K. Bromfield, R. Hall, K. G. Johnson, P. Lunt, C. P. Meyer, L. B. McMonagle, R. J. Morley, A. O'dea, J. A. Todd, F. P. Wesselingh, M. E. J. Wilson, and J. M. Pandolfi. 2008. Hopping Hotspots: global shifts in marine biodiversity. Science 321:654-657.

Wilson, M. E. J. and S. J. Moss. 1999. Cenozoic palaeogeographic evolution of Sulawesi and Borneo. Palaeogeography, Palaeoclimatology, Palaeoecology 145: 303-337.

Zachos, J. C, G. R. Dickens, and R. E. Zeebe. 2008. An early Cenozoic perspective on greenhouse warming and carbon-cycle dynamics. Nature 451: 279-83.

ESR Research Project Reports

Biodiversity Work Package

Origins of the Southeast Asian reef-coral diversity

Nadiezhda Santodomingo, Natural History Museum, London, UK

Research Questions: Evidence from palaeontological and molecular studies suggests that the Miocene was an important period for diversification in the SE Asian centre of maximum marine biodiversity. As part of the Throughflow ITN, this research addresses two main questions: 1. How diverse were corals during the Miocene, and 2. Which environmental factors controlled their diversification on both, temporal and spatial scales.

Methods: I will study stratigraphy-based collections from 42 outcrops of delta-front patch reefs of Miocene age (Burdigalian to Messinian, 20-5 Ma) located in East Kalimantan (Indonesia). Coral specimens will be identified to genera and species level (if possible), through examination of type material and reference collections (Natural History Museum, Naturalis Museum, among others).

Preliminary and anticipated results: Preliminary results suggest that species diversity can be comparable to modern coral settings living under similar environmental conditions for distinct platy and branching coral assemblages. A total of 66 morphospecies (39 genera) have been identified so far, from which only four genera are now extinct, *Dictyaraea*, *Anisocoenia*, *Cyathoseris*, and *Fungophyllia*. Descriptions and illustrations of taxa are being compiled into a database. Regarding the palaeocology, coral morphologies seem to respond to the gradient of siliciclastic sediments and nutrients input created by the progradation of the Mahakam Delta since the Early Miocene. This large river plays an important role in structuring regional ecosystems. Platy-coral assemblages were common in the vicinity of the delta, characterized by a higher turbid-water regime, and mainly from the Early to Middle Miocene. On the other hand, communities of branching corals mixed with scattered massive corals were more frequent during the Late Miocene in northern settings characterized by less deltaic influence. The results of the coral component will be part of an integrated analysis, including other taxa (bryozoans, coralline algae, molluscs and larger benthic foraminifera), as well as sedimentological and geochemical analysis, in order to produce a comprehensive model for the observed species turnover under global and regional environmental changes.

Figure 1. Platy corals *Pachyseris* sp. at the Rainy Section (TF153), Serravallian age.

Figure 2. Branching corals *Seriatopora* spp., in Bontang (TF 500), Tortonian age.

Bryozoa taxonomy and palaeoecology in the Neogene of SE Asia: exploring the origin of high Recent diversity and applying bryozoans in palaeoenvironmental analysis.

Emanuela Di Martino, Natural History Museum, London UK

Research Questions: As part of the Throughflow Project this research aims to answer the following questions: (1) How diverse were bryozoans in the Cenozoic of East Kalimantan? (2) Is Cenozoic bryozoan diversity comparable with that at the present day? and (3) how good are bryozoans as palaeoenvironmental indicators (e.g. palaeotemperature, palaeodepth)?

Methods: Seventy-four bulk and float samples have been collected from 14 different outcrops during two field seasons in east Kalimantan. The samples were washed, sieved and air dried in the laboratory. Coral specimens and sediment fractions larger than 500 μm were analyzed under a stereomicroscope to search for the presence of bryozoans. A Scanning Electron Microscope has been used to help in the identification of species and also to produce images.

Preliminary and Anticipated Results: Preliminary results show that Miocene Indonesian bryozoans are typically closely associated with corals. Bryozoan colonies are commonly found encrusting the bases of platy corals. Anascan and cribrimorph cheilostomes are the most abundant groups present. Fragments of erect branching species, such as Nellia spp., Margaretta spp. and some Phidoloporidae, are present within the sediments or adhering incidentally to the coral surfaces. Biodiversity is considerably higher than appears from the published literature. Previous publications on Cenozoic bryozoans from the entire Indonesian Archipelago have reported a total of only 21 genera. Preliminary observations already allow an increase in the recorded diversity from 21 to 32 genera. On the other hand biodiversity in the Miocene may be lower than the diversity of reef-associated bryozoans living in the same area at the present day. This may reflect the loss of bryozoan taxa with aragonitic skeletons. During the coming year the full biodiversity of the fossil bryozoans will be established, comparisons will be made with modern samples to ascertain the likely influence of loss of aragonitic taxa on bryozoan diversity, and the use of bryozoans as a proxy for temperature seasonality will be explored (MART analysis).

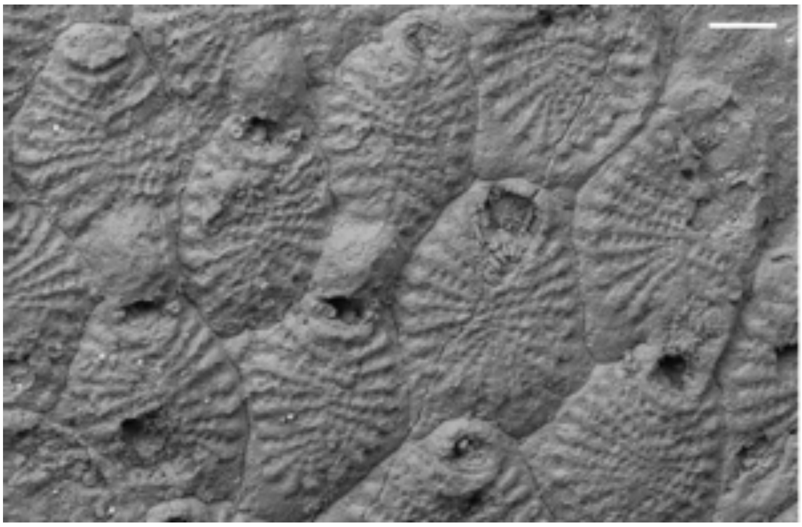

Figure 1. *Puellina* sp., group of autozooids including three ovicells. Scale bar = 100 μm

Molluscs from underwater meadows: on the Neogene diversification of Indo-Pacific molluscan communities associated to seagrass habitats

Sonja Reich, NCB Naturalis, Leiden, The Netherlands

Research Questions: In this PhD project I aim to study successive Neogene molluscan faunas associated with seagrass meadows from Indonesia. The research in this project aims to elucidate how ancient seagrass fauna can be identified, how and when such faunas developed, and when modern type of shallow marine communities became in place. Furthermore, how such ecosystems and their inhabitants reacted to regional expression of global change such as the Mid Miocene climate optimum, the Early Quaternary cooling, but also the tectonic shaping of the regional paleogeography and oceanographic conditions.

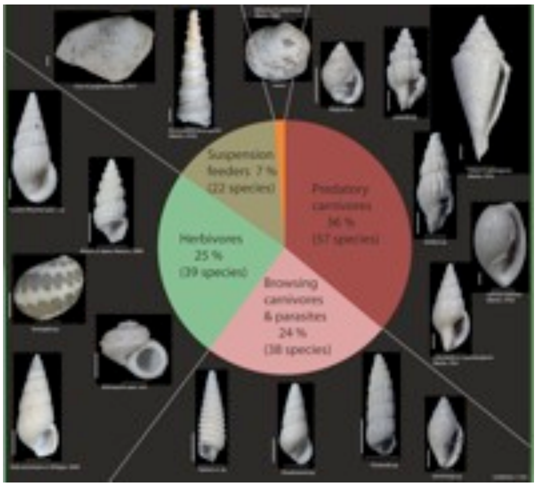

Figure 1: Species diversity per feeding guild of a diverse seagrass associated mollusc community from the Early Miocene of Banjung Ante, Java, Indonesia.

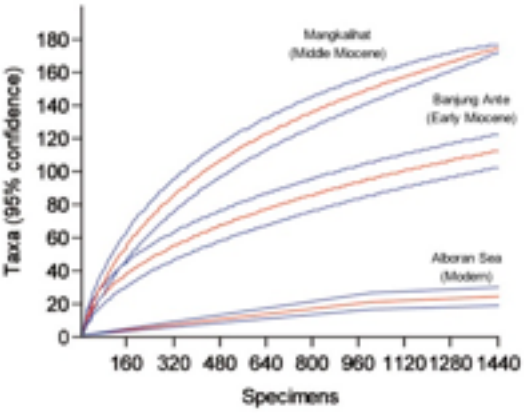

Figure 2: Rarefaction curves for two Miocene seagrass communities from Indonesia and one modern assemblage from Spain showing distinctive higher species numbers in the Miocene communities.

Methods: The first steps in the research are the taxonomical, ecological, sedimentological and taphonomical characterization of sea grass mollusc faunas. The combined data should help to differentiate those faunas from associations to those from other shallow water habitats such as reef associated communities. Furthermore, the composition and diversity in stratigraphic successive sea grass habitats will be assessed. The studied material corresponds tomuseum collections and newly collected fossil molluscs from East Kalimantan and Java (Indonesia) covering the Early Miocene to the present. The available material comprises an Early Miocene fauna from Yogjakarta (south-central Java), Middle Miocene faunas from the Mangkalihat Peninsula (East-Kalimantan), and Late Miocene faunas from the Bontang and Sangkulirang areas (East-Kalimantan). In addition, samples from modern sea grass habitats in the Spermonde region (Sulawesi) and the Berau region (East-Kalimantan) are available.

Preliminary and Anticipated Results: Extensive taxonomic work and counting of specimens have been carried out. Preliminary results reveal the possibility for the characterization of seagrass associated mollusc communities by the abundance and diversity of gastropod feeding guilds (Fig. 1). Furthermore, initial findings of this study suggest an increase of species diversity in seagrass associated mollusc communities through the Miocene in Indonesia, and a distinctive higher diversity in the Miocene of Indonesia than in modern communities from temperate regions (Fig. 2).

The origins and evolution of the modern Indo-Pacific reef algal flora

Anja Roesler, Universidad de Granada, Spain

Research Questions: I am trying to answer two research questions. One is the evolutionary history of the reef coralline algae, giving a temporal dimension to their molecular phylogenies. The second question, shared with other participants in the project, is to reconstruct the Miocene palaeoenvironments of East Kalimantan. Fossil coralline algae can give information on palaeo turbidity and turbulence of depositional settings such as reefs and associated facies.

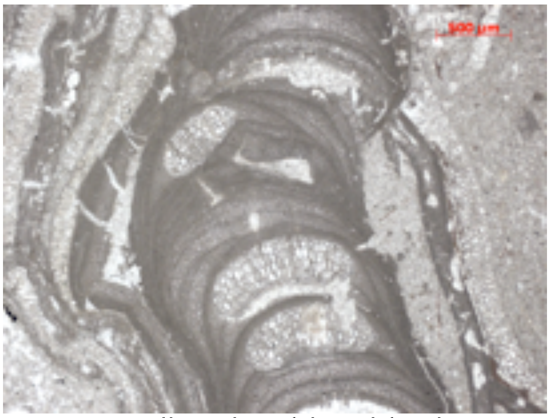

Figure 1. Coralline alga of the subfamily Melobesoideae from a Middle Miocene reef (TF126).

Figure 2. Living coralline algae I sampled in One Tree Island, Great Barrier Reef

Methods: After collecting samples in the field, identification of fossil coralline red algae sampled in the studied sections in East Kalimantan requires preparation of ultra thin sections (see Figure 1) and later examination by means of optical and scanning-electron microscopy. I have sampled living coralline species from modern Pacific reefs to study their DNA for improving the existing molecular phylogeny of reef corallines. DNA has to be extracted in the lab, certain genetic markers have to be amplified, sequenced, aligned and processed with the aid of computer programs to produce a tree. Afterwards, it is possible to calibrate the phylogenetic tree with fossil time markers and construct a time tree.

Preliminary and Anticipated Results: Until now about 600 fossil and 150 recent samples were collected in Indonesia and Australia (see Figure 2), respectively. I have examined and identified the fossil coralline algae in about 60 ultra thin slides from the first field season. About 100 sequences of four different genetic markers of 34 different samples have been obtained in the molecular analysis of living corallines. In the next year the first results regarding palaeoenvironmental interpretation will be published and the first models of molecular phylogeny will be produced.

STRATIGRAPHY WORK PACKAGE

Foraminifera assemblages of Oligo-Miocene of East Kalimantan – biostratigraphic and paleoenvironmental overview

Vibor Novak, NCB Naturalis, Leiden, The Netherlands

Research Questions: The main objective of this project is building a stratigraphic framework based on biostratigraphy of larger benthic foraminifera (LBF) which should result in chronostratigraphic information for sediments of East Kalimantan. The second and more specific objective is to determine how environmental change affected LBF assemblages. The third objective is focused on the evolution of Indo-Pacific LBF through time trying to establish a correlation with widely used Mediterranean shallow benthic zonation (SBZ) for the Oligo-Miocene.

Methods: Thin sections and isolated specimens of foraminifers are analyzed and recognized to species level (where possible) allowing age determinations of sampled sediments., Reconstruction of changes that occurred in reef ecology during the Oligocene and Miocene will be made using microfacies analyses and additional criteria, e.g. macro fossils, facies, depositional fabrics and textures, with focus on LBF assemblages. Significant number of collected samples contain macro fossils which will, in collaboration with the Biodiversity group, provide valuable additional information for paleoenvironmental reconstructions. Absolute dating and correlation with SBZ will require collaboration with the Geochemistry group of the Throughflow Project, with main focus on strontium isotope analyses.

Preliminary and Anticipated Results: Based on samples processed so far, Early to Middle Miocene intervals were determined for localities visited during NTA-2 fieldwork. Microfacies analyses reveal several facies zones dominated by different fossil assemblages (LBF, corals, algae). Future work will include processing of newly collected samples (NTA-4) which should provide broader age ranges (Early Oligocene to Late Miocene, based on field observations). Samples collected during NTA-4 should also give insight to different geological settings compared to those observed during NTA-2.

Figure 1. Reconstruction of the reef morphology based on different lithological units observed during field logging. Section TF126, 3D-Reef, Bontang.

Geological Evolution of the Mahakam Delta System

Nathan Marshall, Utrecht University, The Netherlands

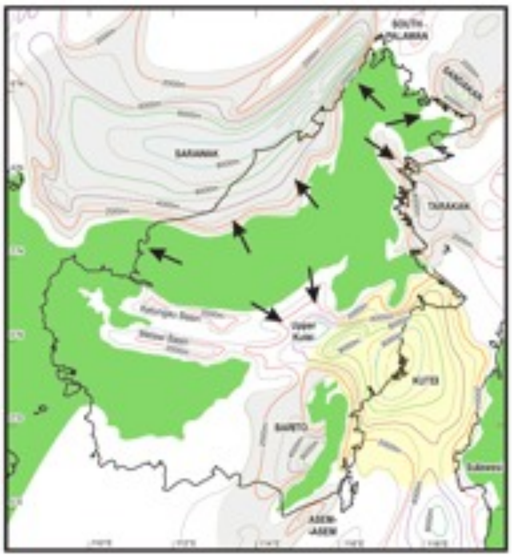

Figure 1. Position of the Kutei Basin in East Kalimantan.

Research Questions: The opening of the Kutai Basin (Fig. 1)and the development of the Mahakam River system took place during the Miocene biodiversity boom which requires more precise dating. Specific questions to be answered by this research include: What is the age of different reef buildups in the Miocene compared to their relative biodiversity? What is the periodicity of the cyclically bedded progradation pulses in the succession? What is the overall sedimentation rate? Can geographically different carbonate buildups be correlated or put in chronological order?

Methods: To answer the time-related questions above, magnetostratigraphy and Sr dating will be the tools used in conjunction with the biostratigraphy done by other groups in the Throughflow Project. Sr dates will provide pin-point dates on the fossils themselves, while biostratigraphy and magnetostratigraphy will provide a wider range of dating for the whole stratigraphy.

Preliminary and Anticipated Results: Thus far, the stratigraphic context has been recorded from the two field trips and preliminary biostratigraphy and Sr dates have put the main section of study within the middle Miocene. Reversals have been found in the magnetostratigraphic record (see Figure 2), and further work will be done this winter to refine these reversals into a more precise date based on the other techniques. By summer 2012, Sr dating and a magnetostratigraphic record will be completed.

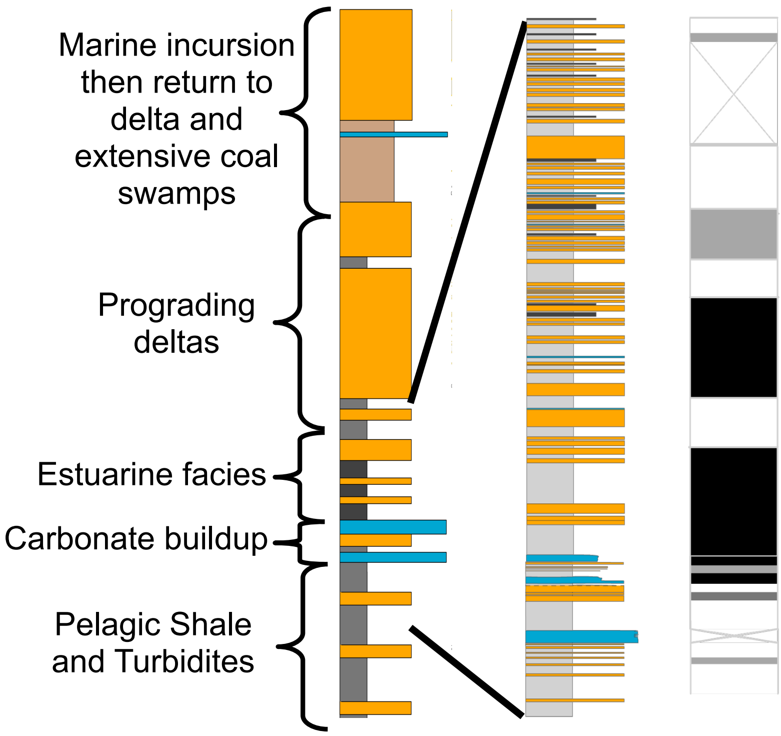

Figure 2. Schematic section of the 3km-thick deposits of Early to Mid-Miocene fluvial-deltaic to open marine sediments exposed near Samarinda.

GEOCHEMISTRY WORK PACKAGE

Well-preserved Miocene corals and molluscs from SE-Kalimantan (Indonesia) – Archives for "deep time" palaeoenvironmental reconstructions

Viola Warter, Royal Holloway University of London, Egham, United Kingdom

Research Questions: Overall aim of this project is to extract reliable palaeoclimatic/ palaeoceanographic proxy data from Miocene corals and molluscs from East Kalimantan using (isotope) geochemical techniques. Pleistocene and younger fossils are traditionally used in palaeoenvironmental reconstructions, and the question arises whether it is possible to obtain reliable palaeoclimatic information in older samples (~20 Ma). The first step is therefore to assess the degree of diagenetic overprinting of the aragonitic fossils and to evaluate their fidelity as palaeoclimatic archives. The second step of the research will focus on the interpretation of the obtained temperature- and seasonality information. Key questions are: Which proxy is the most suitable for extracting seasonality signals?; Can we link $\delta^{18}O$ and element/Ca ratios?; Which resolution is possible (annually, monthly, weekly)? The results obtained in step 1 and 2 will help resolving the bigger question of the project: Are secular changes of palaeoenvironmental parameters during the Miocene resolvable? Samples from locations of special interest for the project will be selected for the analysis.

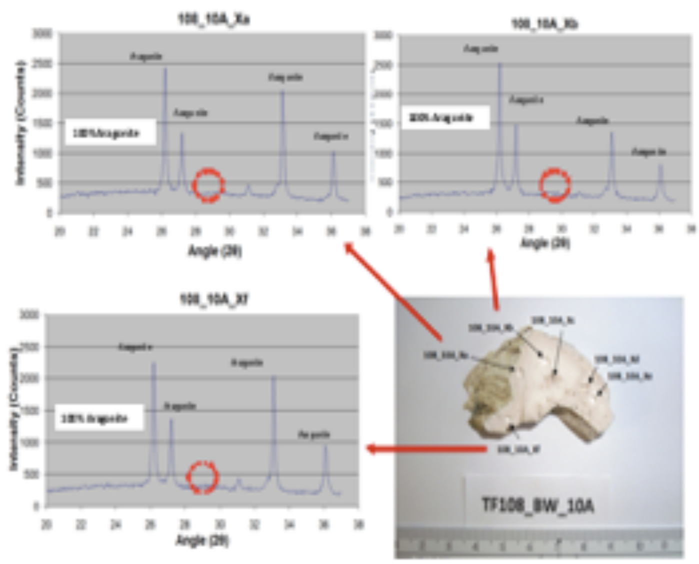

Fig.1: XRD analysis from 3 different parts Tridacnidae shell (Bontang). Results show that the shell consists to 100% of aragonite. Red circles mark the position were a peak would appear, if calcite was present.

Methods: Combined XRD, SEM and light microscopy and supplementary trace element geochemistry (LA-ICPMS) is applied for a detailed assessment of the preservation state of each sample. Furthermore, the susceptibility of the different proxies (e.g. trace elements, stable oxygen or strontium isotopic composition) to diagenetic processes is evaluated. Stable oxygen isotope and trace element/Ca ratios are used to obtain temperature/seasonality information. $^{87}Sr/^{86}Sr$ analysis via TIMS to obtain numerical ages supplementary to relative ages obtained from LBF (V. Novak, University Leiden) and magnetostratigraphy (N. Marshall, University Utrecht).

Preliminary and Anticipated Results: Initial XRD results (Fig.1) reveal that many of the samples from Bontang collected during NTA 2 are very well preserved (still 90-100% aragonitic mineralogy) – These fossils are promising palaeoclimatic archives. Preliminary age results obtained from various corals and molluscs (Bontang and Samarinda, NTA 2) by Sr-isotope chemostratigraphy (SIS) are reasonable. Even samples which contain a large amount of calcite show promising ages and match very well with relative ages obtained from LBF (V. Novak) and magnetostratigraphy (N. Marshall). Strontium isotope ratios might be less sensitive to diagenetic overprinting than other proxy data (e.g $\delta^{18}O$, trace element/Ca ratio). First trace element/ Ca ratio profiles obtained from Tridacnidae shells from Bontang show variability – possibly even seasonality. The use of trace element concentration as alteration proxies seems to be promising. Future analytical work will include samples from Sangatta and Sangkuliran Bay collected at NTA 4. After selection of best preserved samples, proxy data analysis will be performed and temperature/ seasonality interpretations conducted. Collaboration with V. Novak and N. Marshall for Sr-isotope analysis and S. Reich for stable isotope analysis is planned.

OCEANOGRAPHY AND CLIMATE WORK PACKAGE

Impact of changes in the IT ("Indonesian Throughflow") on global climate evolution – a modeling approach.

Amanda Frigola, University of Bremen, Germany

Research Questions: Which were the climatic effects of Middle-Miocene Antarctic glaciation in the Indonesian region? Did growth of ice-sheets in Antarctica lead to a northward shift of the ITCZ ("Intertropical Convergence Zone")? How were ocean currents and hydrography in the Indonesian Seas affected?

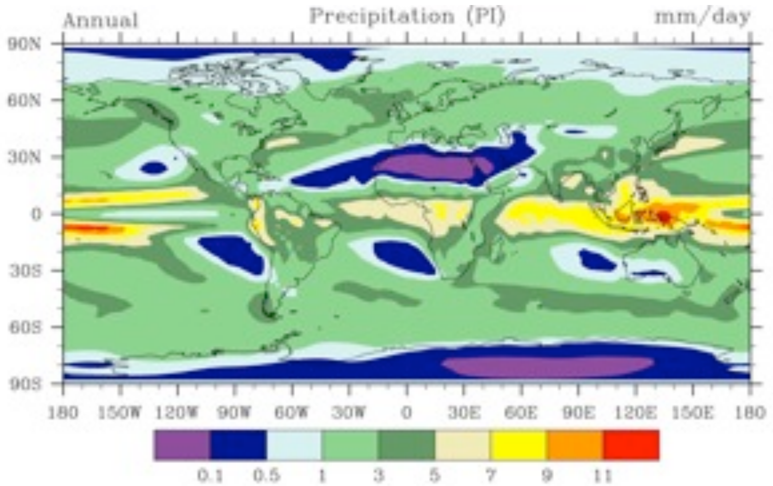

Figure 1: Mean annual precipitation (mm/day) for the pre-industrial control simulation (100-year climatological mean).

Methods: To study the questions above I use the Community Climate System Model CCSM3, a state-of-the-art global earth system model that includes comprehensive components for ocean and atmosphere. I perform two experiments with two different states of the Antarctic ice-sheet, representing the periods before and after the onset of the Middle-Miocene glaciation in Antarctica around 14 million years ago. The model input for these experiments requires Middle-Miocene boundary conditions, including paleo-topography, paleo-bathymetry, paleo-vegetation and atmospheric GHG ("greenhouse gases") concentrations.

Preliminary and expected results: So far I performed a control run with CCSM3 using modern (i.e. pre-industrial) boundary conditions. To illustrate which data can be obtained, Figure 1 shows the simulated mean annual precipitation, while Figure 2 displays mean sea level pressure for the DJF (December-February) and JJA (June-August) seasons. In the next months I will obtain the results from the two Middle-Miocene experiments. This will provide a quantitative approximation of climate changes in the Indonesian region caused by the glaciation and can be used by the other ESR ("Early Stage Researcher")'s to determine reasons for changes in paleo-biota.

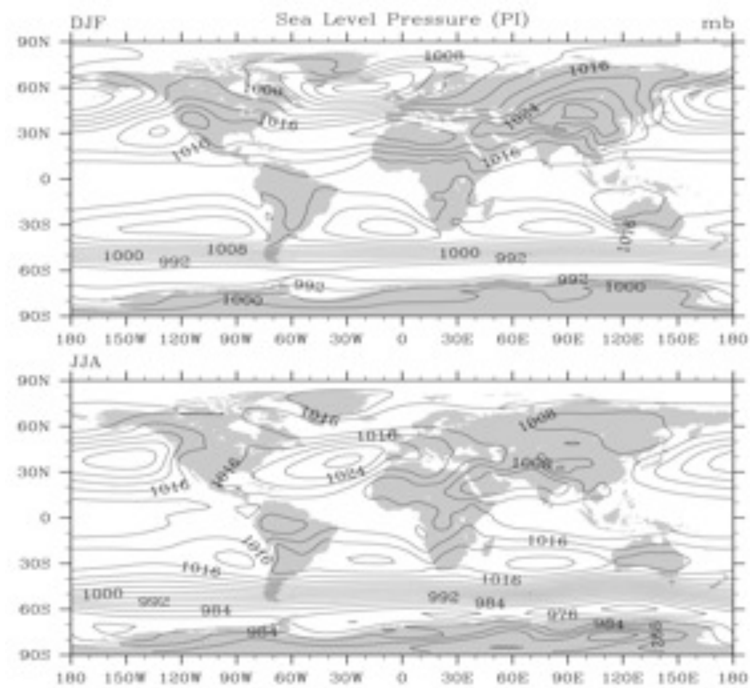

Figure 2: Mean DJF and JJA sea level pressure (mb) for the pre-industrial control simulation (100-year climatological means). Contour interval is 4mb.

Geochemical proxy calibration along the Indonesian Throughflow (ITF) pathways

Elena Lo Giudice Cappelli, Christian-Albrechts-University, Kiel, Germany

Research Questions: How did the ITF thermocline flow evolve over time? How did ITF thermocline water mass properties (temperature, salinity, water mass ventilation, oxygenation and productivity) change over time? What role did the sedimentological dynamics play in the ITF area?

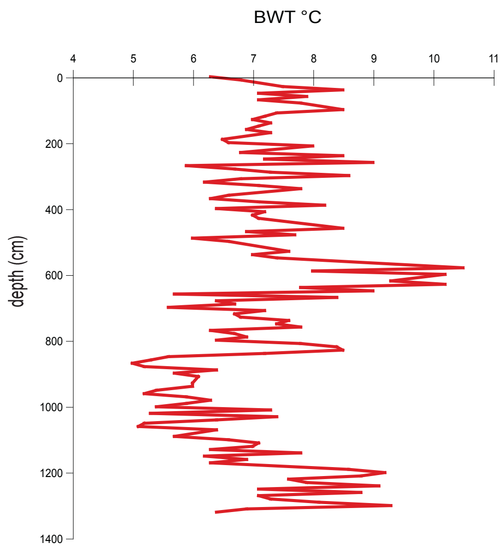

Figure 1. Bottom water temperature (BWT) trend in the Timor Strait estimated from Mg/Ca ratios in benthic foraminifera.

Methods: Benthic foraminifers Mg/Ca ratios are used to estimate bottom water temperatures (BWT; Fig. 1), and Oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) stable isotopes (Fig. 2) to infer about salinity and water mass ventilation. X-Ray Fluorescence (XRF) core scanning is used to evaluate terrigenous inputs, oxygenation and productivity. Accelerated Mass Spectrometry ^{14}C provides dates to build age models, and assemblages of benthic foraminiferans used to reconstruct environmental changes in the ITF thermocline flow.

Preliminary and Anticipated Results: BWT variability, terrigenous inputs, oxygenation and productivity were determined along the core. In the next months, stable isotopes curves will be provided and compared with the other proxy, together with benthic foraminifers assemblages to reconstruct environmental changes. A robust age model will be built based on ^{14}C data to constrain over time all the information available. Finally, all this material will be used to write a paper about the evolution of the ITF thermocline flow with a special focus on the Timor Strait, where the core was retrieved. Then, I will start working on a new core retrieved during the last cruise “MAJA” on board of the R/V Sonne.

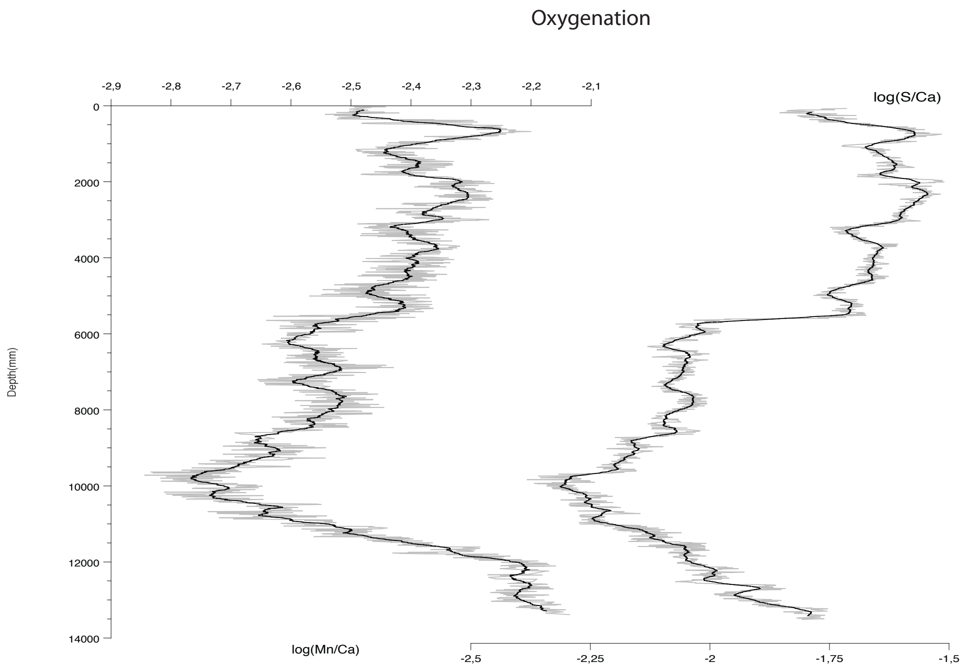

Figure 2. XRF core scanning: water mass oxygenation.

Neogene and Quaternary circulation patterns and biogeography of foraminifera in the Indonesian Throughflow

Nicholas Fraser, Christian-Albrechts-University, Kiel, Germany

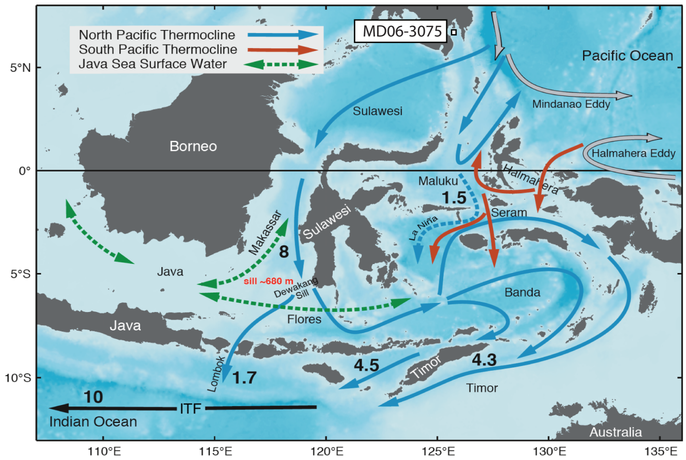

Figure 1. Modified figure of Gordon (2005), showing location of core MD06-3075 in the Davao gulf, part of the ITF inflow path. Arrows denote paths of major circulation currents, with estimates of flow volume in Sverdrups (1 Sv = 10^6 m^3/s)

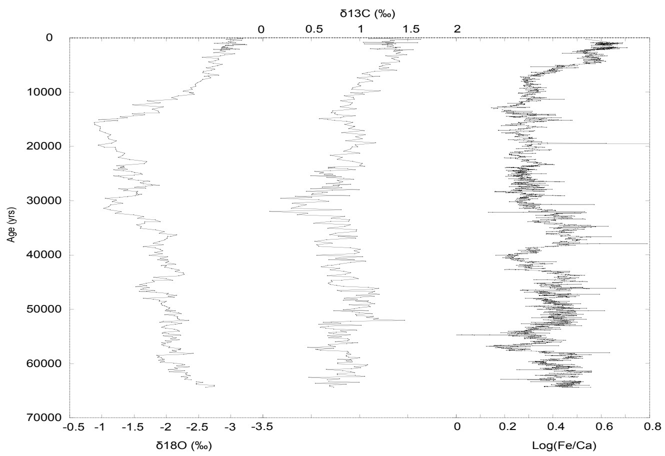

Figure 2. G.Ruber $\delta^{18}O$ (left), $\delta^{13}C$ (centre) and Log(Fe/Ca) plots for core MD06-3075. The age model is derived from AMS ^{14}C dates in the upper part of the core, and tie points with the GISP2 $\delta^{18}O$ curve in the lower part of the core.

Research questions: (1) How have local water masses in the Indonesian Throughflow (ITF) developed over orbital timescales, in terms of salinity, temperature, and chemical properties? (2)What is the response of the ITF and East Asian Monsoon (EAM) to global climate changes, specifically glacial and interglacial cyclicity?

Methods: Our methods focus mainly on the application of geochemical proxies to foraminifera, marine protists which build their shells from calcite, including: (1) Stable Oxygen isotopes ($\delta^{18}O$) - a proxy for global ice volume, water temperature and salinity, (2) Carbon isotopes ($\delta^{13}C$) as a proxy for ocean ventilation and circulation, (3) Magnesium-calcium ratios (Mg/Ca) as palaeotemperature records, and (4) AMS ^{14}C dating to produce reliable age models. Other geochemical proxies are undertaken on bulk sediments, including (1) XRF core scanning for multiple proxies, including terrigenous runoff, productivity and oxygenation conditions, and (2) organic geochemistry, e.g. $U^{k'}_{37}$ alkenone analysis for palaeotemperatures.

Preliminary and Anticipated Results: The focus of the project thus far has been on the core MD06-3075, located in the Davao Gulf, in the ITF inflow path (Figure 1). The proxies documented above have been used to create surface isotope, temperature and XRF curves (Figure 2) for this region and provide insights into climatic variation over the past 70ka. Understanding the mechanics of recent ITF variability is important to use as an analogue to changes over longer timescales. Within the next year it is anticipated that these results will be used in the production of a paper. Further work will be carried out on cores collected on the recent Sonne Cruise, which are located in the Makassar Strait and Java Sea.