Cenozoic evolution of the Indonesian Throughflow (ITF) and the origins of Indo-Pacific marine biodiversity: Mapping the biotic response to environmental change

A Marie Curie Initial Training Network

Network Training Activity 4

'Palaeoecology, geological analysis, and interpretation of past environments'

Early Stage Researcher Field Reports

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Shallow marine palaeoenvironments and the ITF

Preliminary report after the NTA-4, Java and East Kalimantan, Indonesia

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The aim of is this project is to study the evolution of shallow-water marine carbonate palaeoenvironments during the Oligocene-Miocene transition and their response to variations in the ITF.

The study area is located in East Kalimantan and Java (Indonesia).

The ITF passes today through the Makassar Strait (between the islands of Borneo and Sulawesi), allowing heat transfer between the Pacific Ocean and the Indian Ocean and thus controlling the entire oceanic circulation and the climate on a global scale.

The morphology of the Makassar Strait is fundamentally controlled by the complex tectonic history of the region, related to the convergence between the Indo-Australian and the Pacific plates; during the Oligocene-Miocene transition (about 25 Ma) the collision between the aforementioned plates determined the narrowing of the Strait and the constriction of the ITF, producing important changes on global water circulation and probably influencing global climatic systems.

At a local scale, these events should have produced changes in palaeoenvironments, affecting sedimentation patterns, organismal distributions and sea-water geochemistry, and thus influencing reef growth and carbonate production in the area.

These events are likely to be recorded in shallow-marine carbonate deposits, which are sensitive to hydrodynamic and ecological variations.

To achieve the project objectives, a second fieldwork was performed during the Network Training Activity 4 (NTA-4, 13 June–15 July 2011) in selected localities (cliffs, quarries and mines) in East Kalimantan (Indonesia).

This work included a study of the selected sections through:

- detailed recognition of sedimentary features (lithology, facies, sedimentary structures, bedding geometry, geometry of stratigraphic surfaces) and fossil assemblages;
- sampling of different facies for thin sections;

- drawing of detailed sedimentary logs;
- detailed recording of sedimentary features through high resolution photography of the outcrops.

The four week activity was divided into two main parts:

- short courses and presentations from the ESRs (13–20 June), in Bandung (Java) at the Pusat Survei Geologi, partner institution in this project.
- Fieldwork in East Kalimantan, Indonesia (21 June – 15 July).

Due to health problems I could not participate in the first week in Bandung and my return to Europe was brought forward to 7 July. In spite of the reduced length of my field season, I was able to achieve the fixed objectives, collecting a great amount of new data and samples.

The second part of the NTA-4 (fieldwork in Kalimantan) was organized by dividing the people into small groups in order to satisfy individual scientific objectives. My group consisted of Prof. Juan Carlos Braga, Vibor Novak, Anja Rösler and me, and performed fieldwork in the Mankalihat Peninsula, about 100 Km south-east of the city of TanjungRedeb (Talisayan village and surroundings) and Samarinda, according to the following timetable:

- 20-23 June: Balikpapan, organization of the fieldwork
- 24 June-3 July: Talisayan and surroundings
- 4-7 July: Samarinda and surroundings

The detailed work performed in Kalimantan included the study of 11 TF localities (TF77, 301, 302, 303, 304, 305, 306, 307, 308, 311 and Senoni) with the production of 6 detailed sedimentary logs of the carbonate bodies, for a total of about 147 m logged sedimentary succession.

The outcrop conditions in some localities did not allow detailed logging (see photos below; TF 301, 302, 305, 306, 307, 308, 309, 310); in these cases a rough log was made, differentiating the main layers and collecting samples wherever possible.

In total, 90 samples for thin sectioning were collected from the aforementioned localities, together with thousands of photographs. In each logged locality, every layer of the log is associated with detailed images.

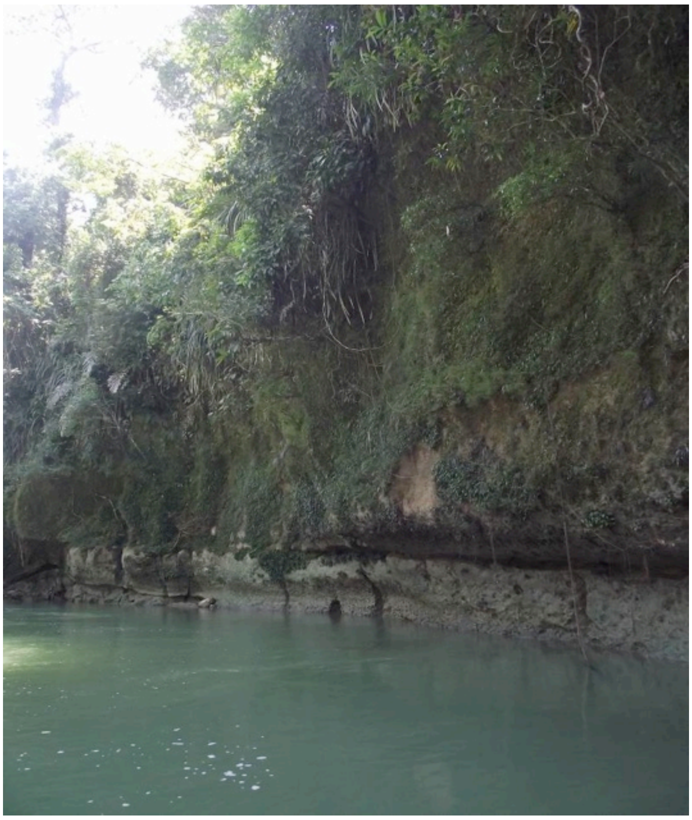

Fig. 1. Outcrop at TF305 (Taballar River).

Fig. 2. Outcrop at TF308

The subdivision of the fieldwork was as follows:

- 20 June: Arrival in Balikpapan
- 21 June: Preliminary organization of the fieldwork
- 22 June: Preliminary organization of the fieldwork
- 23 June: Travel to TanjungRedeb and Talisayan
- 24 June: Preliminary visit to TF303; study of TF301 and TF302
- 25 June: TF303
- 26 June: TF304
- 27 June: TF305
- 28 June: TF306, TF307
- 29 June: TF305
- 30 June: TF308
- 01 July: TF 304
- 02 July: Travel to TanjungRedeb; organization of the collected data, packing of the samples
- 03 July: Travel to Balikpapan/Samarinda
- 04 July: TF77
- 05 July: Senoni locality
- 06 July: TF311
- 07 July: Return to Europe

From a brief, initial analysis of the collected data, it is possible to obtain some preliminary results regarding the sedimentary features of the studied carbonate bodies:

- The studied rocks probably span the Late Oligocene–Late Miocene interval, thus extending the time interval studied in the previous Indonesian fieldwork (NTA-2), but further study is required to confirm this dating.
- The carbonate sediments represent almost the totality of the rocks cropping out in the Mangkalihat area.
- The carbonate bodies show a great thickness and lateral extent (tens of Kms) and represent sedimentation in a major carbonate platform setting; they are indicative of a very different environment than the Samarinda area where small patch reefs occur in a deltaic setting. An interesting comparison will be possible between different settings developed during the same time interval (mainly Miocene).
- Many of the outcrops do not allow detailed study due to their strong weathering in a tropical climate. The lack of active quarries accounts for an absence of recently exposed fresh rock surfaces, in contrast with the Samarinda area.

In conclusion, the NTA-4 in Indonesia was a good occasion to learn new concepts and improve some geological techniques, useful for performing fieldwork in different tropical carbonate environments, from small isolated patch reefs and carbonate banks in a deltaic setting to large carbonate platforms.

Subsequent laboratory activity (study of published literature, logs and thin sections) will lead to a more detailed interpretation of the palaeoenvironments and a comparison between different carbonate settings developed during the Miocene in the Kutei Basin and surrounding areas in response to the variations in the ITF, climate and sedimentary input.

As planned after the first travel to Indonesia (NTA-2), the extension of the studied time span to the Late Oligocene will allow a more complete and detailed interpretation of the palaeoenvironments developed during the Late Oligocene – Miocene interval.

Bryozoan taxonomy and palaeoecology in the Neogene of SE Asia: exploring the origin of high recent diversity and applying bryozoans in palaeoenvironmental analysis

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Introduction

Under the umbrella of the Throughflow Project I participated in the second fieldtrip to Indonesia from 12th June to 15th July 2011 in order to study Cenozoic bryozoans and collect samples containing these colonial animals to increase their temporal, geographical and habitat ranges from those established during last year's fieldwork. Firstly, I revisited some old localities to observe how they had changed during the past six months through human impact and the intense weathering of the rocks in this humid and rainy climate. Some of our old outcrops appeared the same, others were completely covered by the vegetation. However, new exposures had been opened through excavation for building purposes. Secondly, new localities were explored, logged and sampled. Before the fieldwork I processed some of the samples I collected last year and provisionally identified a total of 12 species not previously reported as fossils from the Indonesian archipelago. Furthermore, some taxa (*Steginoporella* sp., Calloporidae spp.) seem suitable, in terms of abundance, colony size and preservational quality, for estimating MART (mean annual range in temperature) using within-colony variance in zooid size. The main aim of this fieldwork, however, was to obtain more material in order to provide a better overview of bryozoan biodiversity.

Material and Methods

Fieldwork took place in eastern Kalimantan. The investigated sections are localized in the Samarinda area where I worked from 22nd-25th June, in the Bontang area where I worked from the 26th June - 2nd July, and the Sangatta, Bengalon and Sangkulirang areas where I worked from the 3rd - 10th July.

In the Samarinda area I revisited a total of six sections: two sections (TF52 and TF76) at Airputih, one section (TF56) at Badak, two (TF51 and TF57) in the Stadion and one at the Tridacna locality (TF79). All the outcrops are located in quarries active for building materials, except the Stadion sections, which are located in an active coal mine. In Bontang I worked on the following outcrops: TF59, TF126, TF153, TF501 and TF504. In the north (Sangatta, Bengalon and Sangkulirang) I made a reconnaissance of several different outcrops but worked mainly at localities TF511, TF518 and TF522.

During team fieldwork we standardized operating procedures, first marking the sections with their own abbreviations and GPS coordinates, then making a large-scale log and description of the sedimentary outcrops, taking photographs and collecting different types of samples where this was considered appropriate and useful to attain our different aims.

I collected a total of 52 samples (24 float samples and 28 bulk samples): 12 samples in TF76 (2 float, 8 bulk and 2 specimens samples 'in situ'), 1 bulk sample in TF79, 2 samples (1 float and 1 bulk) in TF52, 2 float samples in TF57, 1 float sample in TF51, 4 samples (1 float and 3 bulk) in TF56, 1 float sample in TF504, 4 float samples in TF153, 2 float samples in TF501, 3 samples (1 float and 2 bulk) in TF59, 10 samples (3 float and 7 bulk) in TF126, 2 samples (1 float and 1 bulk) in TF511, 5 samples (1 float and 4 bulk) in TF518, and 3 samples (1 float and 2 bulk) in TF522. Float samples consisted of platy or branching corals sometimes encrusted by bryozoan colonies clearly visible to the naked eye; in other instances the presence of bryozoans is not so obvious and it will be necessary to examine the corals more thoroughly under the microscope after cleaning in the laboratory. Bulk samples consist of muddy and silty sediments, mixed with abundant coral fragments.

Some samples were processed during the fieldtrip to check for bryozoans. Corals were washed and brushed in order to remove mud and then dried. Sediment samples were washed through two sieves (1 mm and ½ mm mesh), obtaining separate sediment fractions, dried at room temperature, and briefly observed under a stereomicroscope in order to pick out bryozoan fragments.

Work accomplished and preliminary results

Below is summarized the work accomplished and some preliminary results for bryozoans from each investigated section.

TF52 – I collected one bulk sample from the muddy carbonate level with laminated platy corals, forams and echinoids. I also collected one float sample because I was able to see encrusting bryozoans, though scarcely preserved, on coral fragments and large benthic forams in the field.

TF76 – In this section I collected eight bulk samples from "Bed 5", consisting of dark grey siltstones with a rich bioclastic content including corals, molluscs, echinoid spines and bryozoans. The material collected from "Bed 5" contains some traces of encrusting bryozoans on the bases of platy corals and also some very small fragments of erect species including Phidoloporidae (probably belonging to the genus *Reteporella*). I collected two samples from this layer comprising in situ coral specimens, one sample of corals the right way up and the other of overturned corals, to investigate differences in the epibiota related to orientation (Fig. 1).

TF79 – I did not observe any bryozoans in this section, and I collected only one bulk sample (two bags) from a layer of platy corals and silty sediment from between the corals.

TF56 – I collected from this site one float sample consisting of some fragments of branching and platy corals encrusted by bryozoans, and three bulk samples from a level of grey mud and very thin platy corals with incidentally adherent fragments of *Nellia* spp. I also collected oysters to look for bioimmurations.

TF57 – This section is located inside an active coal-mine. I collected two float samples consisting of platy corals encrusted by anascan and cribrimorph bryozoan colonies. Some of the colonies of the anascan *Steginoporella* sp. are very large and the specimens appear well preserved, suggesting that they will be useful for MART analysis (Fig.2).

TF51 – This section is located near TF57 inside the coal-mine and exposes the top of the reef. One float sample was collected, consisting of platy and branching corals encrusted by anascan and cribrimorph bryozoan colonies.

TF59 – In this section, I observed fragments of erect bryozoans scattered in the sediments between coral layers and collected one bulk sample. Other encrusting bryozoan colonies were collected by picking corals in situ or from float material.

TF126 – This section is named '3D reef' because it is possible to observe the complete development of the reef structure. It is located inside an active coal-mine. I collected seven bulk samples and some float material from two different exposures. My samples came from some layers of very thin platy corals mixed with mud. Very well preserved colonies of species of lichenoporid cyclostomes could be observed.

TF153 – In this section we found a large pile of platy corals, probably coming from the outcrop opposite, encrusted by numerous spot colonies of bryozoans. Spot colonies represent an opportunistic strategy, the colony growing until it is able to reproduce at a small size and then dying (semelparity).

TF501 – This section was interesting for the abundance of *Nellia* spp. fragments in the limestone layer on the top of the grey muddy layer with fossil seagrasses.

TF504 – In this section bryozoans were really rare. I collected only one small bag of float corals with traces of bryozoans scarcely preserved, usually represented only by the basal walls.

TF511 – This locality is a complete reef observable in three dimensions. I found encrusting bryozoans, at first sight 3 or 4 species, but mainly comprising specimens of *Steginoporella* spp., in the lower layer of platy corals. Only one bulk sample was collected from this layer because it was very hard to reach. Float material, consisting of branching corals, weathered and reddish through oxidation, contains small encrusting colonies of Calloporidae spp.

TF518 – This section is located along a river. Bulk samples for bryozoans were collected from a grey layer of platy corals. The preservational quality was not so good because the corals appear weathered and recrystallized.

TF522 – This section includes a grey-coloured lower layer with seagrass fossils where I collected bulk samples to look for the presence of *Nellia* spp. On the top is a layer of very thin platy corals abundantly encrusted by bryozoans such as Celleporidae and Lichenoporidae spp.

Fig. 1. TF 76. Encrusting bryozoans on the base of an overturned platy coral.

Figure 2. TF57. Colony of *Steginoporella* sp. on the base of a platy coral.

Skills gained

The pre-fieldwork workshop, hosted by the Pusat Survei Geologi (Geological Survey of Indonesia) in Bandung, was helpful in allowing me to gain a deeper knowledge of the regional geology, stratigraphy and palaeoecology of the fieldwork area. We were introduced to deltaic deposits and slope turbidites systems of the Kutai Basin and Mahakam Delta, including sedimentary facies and biotic associations, to mechanisms of ocean and climate variability in Southeast Asia (modern climate and oceanography of SE Asia, mechanisms and forcing of climate variability, and ocean modelling), and to palaeoenvironmental and palaeoecological analyses in carbonate and clastic facies focusing on molluscs, forams, algae and bryozoans.

During the fieldwork itself, I gained a better ability to interpret facies seen in the field and techniques for collecting bryozoans. According to a preliminary impression of the material I collected, I obtained some species not found during the 2010 field season as well as superior and additional material of species found in 2010.

Neogene circulation patterns and biogeography of foraminifera in the Indonesian Throughflow - Network Training Activity 4 Report August 2011

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Contents

1. Project Objectives

THROUGHFLOW is a European collaborative project focused upon the relationship between environmental and biotic change on coral reefs and shallow tropical marine ecosystems in the Indo-West Pacific, specifically the Indonesian Throughflow (ITF). My role within this project is to provide geochemical constraints on the magnitude and timing of environmental change in the ITF.

My current research is based upon the use of foraminifera, marine protists which build their shells from calcite, and their value in palaeoenvironmental reconstruction. Geochemical and biostratigraphic data can be gathered and analysed from foraminifera, providing archives of environmental change over glacial timescales. Samples were initially to be analysed from two sources: (i) Sediment cores retrieved from the seafloor of the Indonesian Throughflow, which are focused on the late Quaternary period, and (ii) Outcrop samples retrieved from the Kutei basin, of Oligocene-Miocene age. Samples gathered from the latter locality during NTA-2 did not meet our requirements in terms of abundance or preservation, and thus the project has now been refocused predominantly on the material gathered from sediment cores (see Chapter 3). Geochemical techniques, including stable carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotopes, magnesium/calcium (Mg/Ca) ratios, radiocarbon (C^{14}) dating and XRF core scanning (further information on these techniques is found in Chapter 3) will be employed to deliver a multi-proxy reconstruction of water mass development (and thus climatic change) in key regions of the ITF over glacial/interglacial timescales.

2. Summary of NTA-4

NTA-4 consisted of two separate parts, the first being a workshop event in Bandung, Indonesia from 12th-17th June. This event was carried out with the collaboration of the Indonesian Geological Survey (PSG), and involved a series of seminars and lectures on the use of palaeontological techniques in environmental reconstructions. The list of lectures was as follows:

(i) Clastic sedimentology: brief overview of main clastic facies found in coastal and shelf settings, as well as sedimentary structures and ichnofacies. (Irfan Cibaj, Total Indonesia)

(ii) Carbonate and clastic shallow marine facies with emphasis on larger benthic foraminifera. (Willem Renema, Naturalis, Leiden)

(iii) Microfossils and depositional environments: characterization of fluvial, coastal plain, shelf and slope/basinal facies using foraminifera and palynology, with emphasis on clastics. (Bob Morley, Palynova)

(iv) Larger foraminifera identification and field characterization of Indonesian Letter Stages using hand lens: a guide for field geologists. (Willem Renema, Naturalis, Leiden)

(v) Calcareous algae and depositional environments. (Juan Carlos Braga, Universidad de Granada, Spain)

(vi) Molluscs as indicators of depositional environments. (Jon Tood, NHM, London)

(vii) Oceanography and global climate modeling. (Mathias Prange, University of Bremen, Germany)

(viii) The use of bryozoans for reconstructing past environments. (Paul Taylor, NHM, London)

On the penultimate day of the workshop each Early Stage Researcher had the opportunity to present aspects of his or her research to project members and members of the PSG. This was a valuable chance to improve and practice presentation skills, which will become important in the attendance of conferences in the upcoming years.

The final day of the workshop was spent on a tour at Corelab in Jakarta, a petroleum service company operating in Indonesia (organised by Bob Morley). This was a valuable insight into the industrial application of our research and skills, particularly in the use of geochemistry and biostratigraphy in the petroleum industry.

After the initial workshop, there was the opportunity to spend a further period in the field, and many of the project members undertook this between the 18th June and 17th July. However, the quality of samples retrieved in the previous fieldwork (NTA-2) had not met our expectations due to the low abundance and poor preservation of foraminifera. This is likely due to high rates of weathering and dissolution of calcite in situ at the exposed outcrops, thus damaging any chance of acquiring precise geochemical information. For this reason it was not deemed to be a valuable usage of our time and resources to pursue this line of research further.

3. Progression and preliminary results

The majority of work during the past year has focused upon geochemical analysis of core MD06-3075, located in the Davao Gulf in the ITF inflow path. The core is approximately 30 m long, spanning the last 75,000 years. The goal is to quantify environmental changes over the most recent glacial/interglacial timescales, which will also provide valuable insights into the monsoon regime during periods of climatic change. For the THROUGHFLOW project, this data can provide an important analogue to changes that may have occurred during the Oligocene/Miocene.

The core has been analysed using several methods:

(i) Stable carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotopes. Carbon isotopes are related to ocean ventilation, and are thus affected strongly by changes in circulation. Oxygen isotopes are related to changes in global ice volume, temperature and salinity, so provide excellent constraints on the timing and magnitude of changes in the physical properties of the ocean water. In the upper 9 m of the core, which represents the Holocene, Termination I and end of the Last Glacial Maximum, samples have been taken at 2 cm resolution for a total of over 400 samples. Approximately 40 tests of the planktonic foraminifera *Globigerinoides ruber* (which resides in the upper 50 m of the water column, making it an ideal species for investigating changes in the surface ocean) have been picked from each sample. The tests are then crushed, split into two size fractions (the larger being used for Mg/Ca analysis – approximately 10 tests are used for stable isotope analysis), cleaned and sent for analysis. The measurement is currently in progress and the results will arrive shortly.

(ii) Magnesium/Calcium (Mg/Ca) ratios. The amount of Mg incorporated into the calcite structure of a foraminiferal test is correlated with the seawater temperature in which the test has developed. High precision Mg/Ca measurements have been carried out on this core following a rigourous cleaning routine; however, the Mg/Ca ratios in the results were unexpectedly high.

This could be a result of post-depositional processes (e.g. dissolution, infilling) acting to alter the Mg/Ca ratio. Further work will be carried out using the Scanning Electron Microscope (SEM) to determine the cause of this.

(iii) AMS dating. Samples have been dated using a ^{14}C method on the Accelerator Mass Spectrometer (AMS). This has provided a strong age model for the core, allowing accurate time constraints on the timing of climatic shifts. Several samples have been co-dated with pieces of wood from the same depth, which aims to reveal information regarding the ^{14}C reservoir age of surface waters in this area.

(iv) XRF core scanning. The elemental composition of the sediment can be determined in a non-destructive method using XRF (X-Ray Fluorescence) core scanning. Variations in element ratios (for example, the ratio of Fe/Ca) give information such as the amount of sediment from a terrigenous source, dust input, biological input, productivity and oxygenation. XRF core scanning has been completed on this core and will complement other proxies used above.

A multi-proxy approach has therefore been employed, which has enhanced and given me strong skills in a wide range of palaeo-environmental techniques, particularly in regard to laboratory skills.

Over the upcoming months, further work will be carried out on this core, with the target to produce a publication, focused upon the changes in monsoon conditions in the ITF over the past glacial cycle. Results for all the proxies described above will be completed shortly, and I shall also aim to carry out an alkenone (organic chemistry) study, which will be important in determining signals from terrigenous and marine inputs of sediment. Further work after this will involve working on the cores collected during the recent research cruise in Indonesia (see following chapter), particularly from cores taken close to the Mahakam delta, which will allow a greater overlap and collaboration with other THROUGHFLOW team members.

4. Summary of TV Sonne Cruise 217 "MAJA"

Between 25th July and 16th August, I participated in a research cruise aboard the "RV Sonne", in the Makassar Strait and Java Sea ("MAJA"), see also Appendix A. The goal of the cruise was to collect piston cores, multi cores, water samples and CTD (Conductivity, Temperature, Depth) measurements in a number of oceanographic and regional settings. The official cruise report is attached to this report (Appendix I), and describes the methods undertaken and preliminary results. In a personal sense, the cruise gave me extended training in a number of important areas, including:

(1) Coring techniques – gaining knowledge of the mechanisms of piston cores and multi cores, and how the samples are subsequently processed. This gives a clearer view of the full 'life cycle' of a sediment core from sampling to chemical analysis.

(2) CTD profiling – learning how to deploy a CTD profiler and how to interpret the results.

(3) Core description/Spectrophotometry – a large part of my duties aboard the ship involved the processing of cores after they had been retrieved. This involved undertaking core descriptions, and then performing spectrophotometry on the cores. This technique uses a machine ("Minolta"), which sends a burst of light onto the core, and measures the resulting reflection – the absorption and scattering of light depends heavily on the carbonate composition of the sediment, which is related to ocean productivity. I produced a large number of spectrophotometry plots (available in the official cruise report), many of which show clear glacial/interglacial cycles, giving a basic age control of the cores.

(4) Personal skills – Working on the ship required excellent teamwork and communication skills, in a high-pressure, time constrained environment. Developing these skills is of a great importance to future scientific work or employment. Creating a detailed plan of action and carrying it out also required strong logistical skills and the cruise has allowed me to also improve upon these.

Impact of changes in the Indonesian Throughflow on global climate evolution - a modelling approach
Network Training Activity 4 Report, 2011

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1. Brief statement of scientific questions being addressed

The overall aim of this project is to reconstruct past climate conditions and IT ("Indonesian Throughflow") characteristics in different key time periods by applying the comprehensive global climate model CCSM3 ("Community Climate System Model version 3"). Our results will be an invaluable tool for the THROUGHFLOW network to establish potential mechanisms for changes in marine biodiversity in South East Asia during the late Cenozoic. I intend to assess quantitatively the influence on the IT of some major tectonic and climatic events such as the northward drift of the Indian-Australian plate or the Middle-Miocene Antarctic glaciation. More specifically, this project is divided into three parts:

- Assessment of the impact on the IT of tectonic changes that occurred during the Oligocene/ Miocene boundary. I will perform two experiments with CCSM3 varying the local topography and bathymetry, according to these tectonic changes. Additionally, the model output from these experiments will be used to trace potential dispersal patterns of marine organisms in the Throughflow region.

- Sensitivity analysis of Oligocene climate to changes in atmospheric CO_2 concentration in the Indonesian region. Atmospheric CO_2 concentration has been proved to be an important forcing factor on climate. However, Oligocene climate is apparently rather insensitive to changes in atmospheric CO_2 content as inferred by Zachos *et al.* (1). I would like to test if my experiment confirms this apparent decoupling between CO_2 and temperature during the Oligocene and, if so, to seek an explanation.

- Simulation of the impact of Middle Miocene Antarctic glaciation on the IT region. I am currently working on this part of the project and will run two simulations with boundary conditions for the Middle Miocene that differ only in terms of sea level and continental ice-sheet volume and extent. Apart from the direct effects in the IT caused by sea-level changes, I want to test if glaciation led to a northward shift of the tropical rainbelt in the Indonesian region as proposed by Holbourn *et al.* (2).

2. Overview of methods and tools

Our main tool for the simulation of past climate conditions is CCSM3, developed at NCAR (National Center for Atmospheric Research), a global climate model that simulates the state of the entire climatic system, including atmosphere, ocean, sea-ice and land. In particular, I use the fully coupled configuration with T42 resolution for the atmosphere and the land components, which corresponds approximately to 2.8 degrees in latitude and longitude, and the so called gx1v3 resolution for the ocean and the sea-ice components. This corresponds to a longitudinal resolution of approximately one degree. The latitudinal resolution is variable, with finer resolution, approximately 0.3 degrees near the Equator.

In principle, the model is capable of simulating earth climate for any time period provided that appropriate boundary conditions (including palaeogeography, topography, ice-sheet configuration, vegetation cover, atmospheric composition, orbital parameters) are applied. The most time-consuming step in the setup of the boundary conditions is the creation of global topography/bathymetry and vegetation/continental-ice data sets for the time period of interest. These data often do not exist for deep-time periods, as in our case, and we have to compile information from different studies in order to obtain global data sets.

3. Summary of work accomplished

I installed CCSM3 and ran some test simulations at the HLRN (Norddeutscher Verbund für Hoch- und Höchstleistungsrechnen) supercomputing center (https://www.hlrn.de/home/view), using the "CCSM3.0 User's Guide" (http://www.cesm.ucar.edu/models/ccsm3.0/ccsm/doc/UsersGuide/UsersGuide.pdf) provided by NCAR. In particular, I started a simulation for the pre-industrial (i.e. around 1870 AD) climate. The results from this simulation will be used in the future as a control run, to identify the differences between the pre-industrial climate and the climate resulting from the palaeoexperiments.

I am currently working on the Middle Miocene experiment, aimed to simulate the impact of Middle Miocene glaciation on the Indonesian region. In order to generate the initial files for CCSM3 corresponding to this experiment, the setup tools package from NCAR was installed and tested on our local machines using example data. The next step will be running the setup tools using data corresponding to the Middle Miocene configuration. One of the fundamental pieces forming this set of data is a palaeobathymetry/topography map for the Middle Miocene. Nicholas Herold, a former PhD student at the University of Sydney (Australia), provided us with such a data set, based on the publication by Herold *et al.* (3). However, some modifications will need to be done to this map to ensure that it can be used as input for our specific model setup. Furthermore, two variations of this map will need to be created, one corresponding to the period before the onset of the Antarctic glaciation, with small and geographically reduced continental ice-sheets and high global sea-level, and another one corresponding to the glaciation period, with extensive continental ice-sheets and lower sea-level. Running the model with these two configurations will allow for comparison between the two simulated climates and consequently provide an estimate of the impact of glaciation on climate.

Additionally, I took the opportunity to present our network project at the 'PhD Days in Marine Sciences', a workshop organized by the University of Bremen, 13-14 April 2011, by means of a poster: 'Cenozoic evolution of the Indonesian Gateway: impact on climate and coral reefs' *(see fig. 1)*.

4. Plans for the next months

The next steps of my work include the completion of topography/bathymetry data sets for the Middle Miocene, creating a vegetation map for the same period, setting up CCSM3 with the obtained initial files, interpreting the results and writing an article on it. In addition, the comparison of the model results with data from the THROUGHFLOW network is envisaged.

5. Summary of what I learned

During the last months I learned how to use many different powerful software tools necessary to carry out this project. In addition to the modelling part, I also have to deal with data management. A very common data format for CCSM3 input/output is the so-called NetCDF format. The researcher often needs to manipulate these files. For that purpose, NCAR has created an interpreted programming language, NCL (NCAR Command Language), specifically designed for the access, analysis, and visualization of this type of data.

Also the NTAs (Network Training Activities) provided us with useful tools: during our workshop in February we learned how to classify and share our data within the Network and, even though I did not participate in the last fieldtrip in Kalimantan, I was able to attend the Bandung workshop in June, where I obtained a clear overview about which climatic information can be extracted from different fossil data. This knowledge will be useful in order to validate my model results.

Apart from the THROUGHFLOW training, I also took part in several courses organized by GLOMAR, a graduate school in Marine Sciences at the University of Bremen, in physical oceanography and use of proxy data, statistical methods for model data analysis, presentation skills and scientific writing techniques.

6. References

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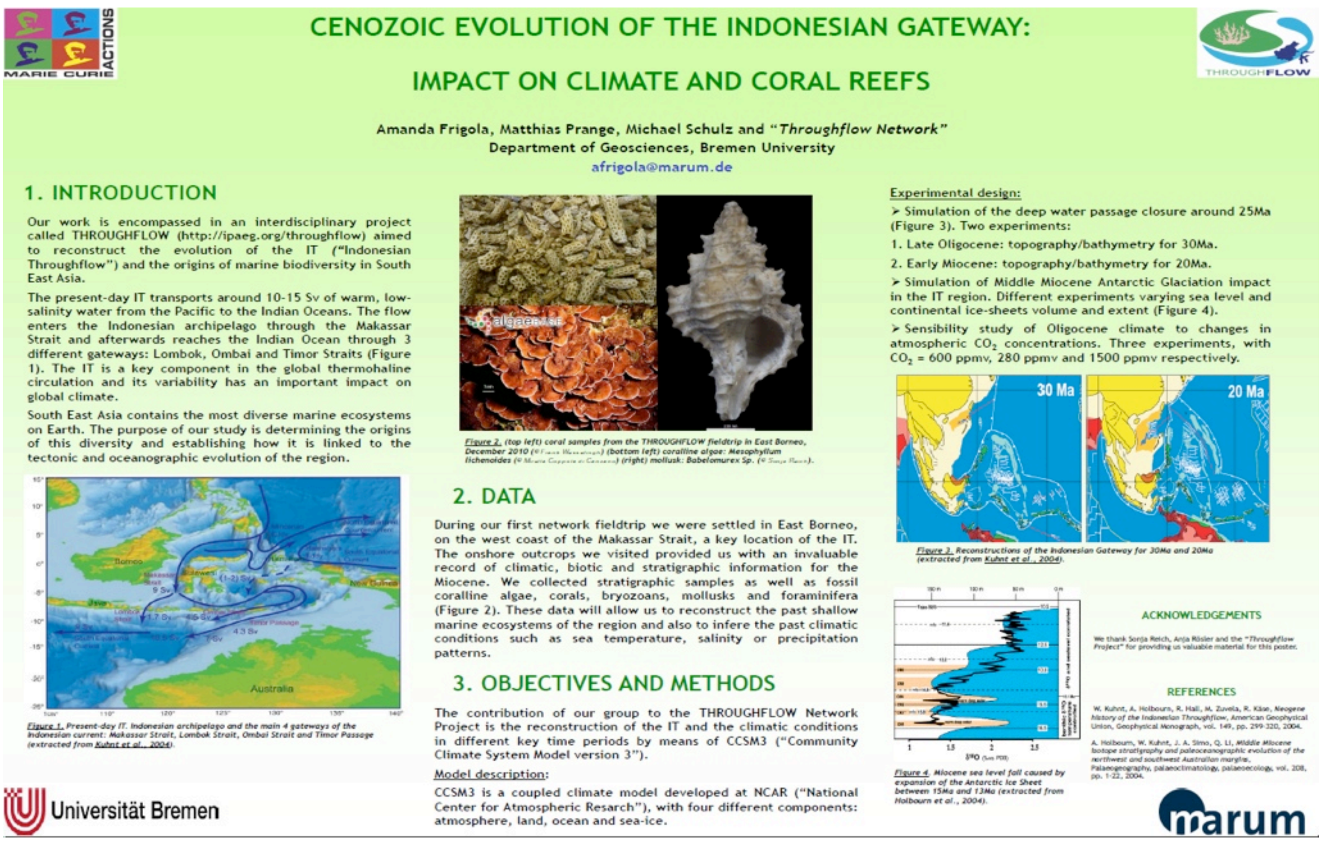

Fig. 1. Poster presented at the “PhD days in Marine Sciences”, Bremen, April 2011.

Geochemical proxy calibration along the Indonesian Throughflow (ITF) pathways

Network Training Activity 4 Report, 2011

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Contents

I. Summary of Network Training Activity 4

Network Training Activity 4: Palaeoecology, geological analysis and interpretation past environments.

The event lasted five weeks from 12th June to 17th July 2011 and was held in Bandung (Java) and in various field localities in Kalimantan. It was divided into two parts: from 12-17 June 2011 lectures and a workshop were held in Bandung in collaboration with the Indonesian Geological Survey (PSG); from 18 June–17 July 2011 the fieldwork took place in Kalimantan.

The first objective of the Network Training Activity 4 was to provide an introduction to the use of different fossils to reconstruct palaeoenvironments and, to achieve this objective, lectures were given during the first part of the NTA-4:

13th June 2011

- Clastic sedimentology: brief overview of main clastic facies found in coastal and shelf settings, as well as sedimentary structures and ichnofacies. (Irfan Cibaj, Total Indonesie)
- Carbonate and clastic shallow marine facies with emphasis on larger benthic foraminifera. (Willem Renema, Naturalis, Leiden)

14th June 2011

- Microfossils and depositional environments: characterization of fluvial, coastal plain, shelf and slope/basinal facies using foraminifera and palynology, with emphasis on clastics. (Bob Morley, Palynova)
- Larger foraminifera identification and field characterization of Indonesian Letter Stages using hand lens: a guide for field geologists. (Willem Renema, Naturalis, Leiden)

15th June 2011

- Calcareous algae and depositional environments. (Juan Carlos Braga, Universidad de Granada, Spain)
- Molluscs as indicators of depositional environments. (Jon Todd, NHM, London)

16th June 2011

- Oceanography and global climate modeling. (Mathias Prange, University of Bremen, Germany)
- The use of bryozoans for reconstructing past environments. (Paul Taylor, NHM, London)

17th June 2011

- Presentations given by the ESRs about their projects and fieldwork goals.

20th June 2011

- Visit to Corelab, a petroleum service company in Jakarta.

The second objective of the Network Training Activity 4 was training in the field, developed according to the different needs of each ERS. For this reason the group was split into several subgroups who visited different localities in Kalimantan to achieve their objectives; the base camp was established in Bontang, East Kalimantan.

I attended only the first part of NTA-4 because, unfortunately, the abundance and preservation of foraminifera in the samples we collected last year during NTA-2 were insufficient to perform geochemical analyses. Therefore, my contribution to Throughflow was focused instead on the analysis of a core from the Timor Strait and I also participated in an oceanographic cruise along the Makassar Strait during which several piston cores and multi-cores were retrieved; the second part of my project will be based on one of these cores.

II. Project Objectives

My part of the project focuses on the use of planktonic and benthic foraminifera, marine protists that build their tests from calcite or aragonite (*H. elegans*), and their use in palaeoenvironmental reconstruction. From a geochemical point of view, we used the tests of benthic foraminifera to estimate:

- Magnesium/calcium (Mg/Ca) ratios that are related to bottom water temperature (BWT) at the time of formation of the tests;
- Oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) stable isotopes that are respectively correlated with global ice volume (and therefore global temperature and salinity) and with oceanic ventilation that is strongly influenced by circulation and water masses changes.

Tests of planktonic foraminifera were used to measure radiocarbon content to date the sediments.

In addition, X-Ray Fluorescence (XRF) core scanning was used to determine terrigenous inputs and productivity.

The approach to the project consists of a multi-proxy study intended to determine changes through time in:

- Bottom water temperature (BWT)
- Salinity
- Productivity of sea surface waters
- Terrestrial flux

III. Preliminary Results and Future Work

Preliminary results

- About 4000 shells of *G. ruber*, a planktonic foraminifer, were analysed using the Accelerated Mass Spectrometry (AMS) to determine the age of the sediments.
- Mg/Ca ratios were estimated throughout the core (total length 13.5 m) with a 10 cm resolution, using the benthic foraminifera *H. elegans* and *C. wuellerstorfi.*
- Samples for $\delta^{18}O$ determination were prepared by picking *H. elegans* tests through the core at 10 cm resolution.
- XRF core scanning was performed for the upper 6 m of the core.

Future work

- Create an age model using the data provided by the AMS analysis.
- Compare the Mg/Ca ratios with the $\delta^{18}O$ curve to detect and interpret trends through time.
- Complete XRF scanning of the core and compare the trends observed with trends in other parameters.
- Pick benthic foraminifera assemblages through the core, focusing on the particular trends shown by XRF core scanning and $\delta^{18}O$ and Mg/Ca analyses in order to provide more information about environmental changes.
- Work on one of the cores retrieved during the oceanographical cruise.

IV. Progress

Even though I attended only the first part of Network Training Activity 4, I feel I improved my communication and collaboration skills and also widened my knowledge regarding how fossils can be used as proxies to reconstruct palaeoenvironments.

Communication and collaboration skills:

- Giving a presentation in Bandung to the Throughflow and PSG members was a great opportunity to practice lecturing, a crucial part of our project, and to obtain feedback about my communication skills.
- Sharing data and new knowledge with the other ERSs also enhanced my ability to communicate in a concise and scientific manner.

Palaeontology:

- Listening to the lectures given during the workshop was a very beneficial activity that allowed me to understand better the 'big picture' underlying our individual projects and to become more aware about the use of different fossils (molluscs, algae, corals, bryozoans and larger foraminifera) as palaeoenvironmental proxies and the potential collaborations between ERS.

The cruise was a unique opportunity to learn techniques for sampling piston cores, multi-cores and water, and also how to use some instruments on board, such as the magneto-susceptibility and colour reflectance instruments. Once again, teamwork was essential and communication between groups formed the basis for a successful job and an enjoyable work atmosphere. The most interesting aspects of this experience was to see what there is behind obtaining a core, from the organization of the cruise itself with a detailed plan of action, to the work on board (sampling, labelling, laboratory activities) and the preparation of samples for storage and shipment to Germany.

V. Preliminary Cruise Report

See Appendix A

Geological Evolution of the Mahakam Delta system and biodiversity in Eastern Borneo

Network Training Activity 4 Report August 2011

Nathan Marshall

Fort Hoofddijk Paleomagnetic Laboratory, Universiteit Utrecht

Project Overview

The Throughflow project concerns the Oligocene-Miocene period, which is not only the timing of the onset of high biodiversity in Indonesia but also a period of rapid climate change globally. I have focused my own research on the evolution of the Kutei Basin from its onset in the Eocene/Oligocene through the development from an offshore to deltaic system in the Miocene. My hope is to supply a sedimentological story for the basin with high resolution dating of sedimentological and biological events using magnetostratigraphy and strontium isotopes.

Workshop (June 13th-18th)

The focus of this workshop was palaeontological and how to use fossil data in the field and analytically to understand past environments and biological diversity. Experts from various European institutions gave presentations in areas of their own taxonomic expertise, which were important not only to the current project, but also provided an excellent overview of the contemporary research and applications of these taxa in the fossil record and modern. The talks lead to edifying discussion of what can be gained from the study of each taxonomic group.

In addition, a presentation by Matthias Prange, the project climate modeller, proved to be a wonderful compliment to the palaeontological information. This talk gave an important overview of climate systems in the modern and past, what parameters control climate change, and what affects climate change has on sedimentology and biology.

Fieldwork 2 (June 20th – July 16th)

The aim of this year's fieldwork was to continue sampling the stratigraphy and to collaborate closer with Throughflow, Indonesian and industry biostratigraphers. I spent the first half of my fieldwork with Wout Krijgsman, Robert Morley and Andri Perdana Putra.

This year, I started my field work in the Kuaro River inland of the city of Tanah Grogot. Here, a long succession of presumably Eocene to Oligocene overlies Cretaceous meta-basalts. While the river did not allow for timely sampling for magnetic work, samples were taken in and around a prominent foram-rich limestone, which will show if the section has a good signal, and may be useful for tectonic reconstruction. Biostratigraphical samples were taken throughout the whole sequence, which will be important in proving that this section is Eocene/Oligocene. This is important because there is no place showing this transition in the region, and it will provide information on the onset of basin filling after obduction of oceanic crust in the Cretaceous.

Fig. 1. Drilling in bedrock exposed in the Kuaro River, a section potentially contains the Eocene/ Oligocene boundary which is rarely seen in this region.

Next, we travelled to Bontang where the macropalaeontologists spent a great deal of time sampling. the thickness of the section here is relatively small, I sampled for magnetostratigraphy. A combination of biostratigraphy and regional mapping should allow the Bontang sections to be correlated with the more detailed stratigraphy obtained in the Samarinda area.

Travelling back to Samarinda, we met with Irfan Cibaj, an expert on the stratigraphy in the region, who helped us to find more locations to fill in stratigraphical gaps. We were successful in completing sampling of the stratigraphy below the important carbonate build-up sampled by the biodiversity group. I helped the biostratigraphers to collect samples through the offshore to deltaic transition in synchronicity with my own samples, which will be important when dating the section and understanding environmental changes.

I departed from the others and travelled north to Tanjungredeb to meet with Vibor Novak. In this region the Oligocene/Miocene boundary is supposed to be exposed in the Berau coal mine. Although granted only limited access to the mine, we were able to do some basic mapping of the stratigraphy and collect samples for biostratigraphy to see if the boundary does outcrop and what changes in biodiversity occur across it compared to the Samarinda/Bontang region. Insufficient time was allowed for proper sampling for palaeomagnetic study and the structure in the region might not have allowed for a complete section in any case. However, some samples were taken to test signal quality.

In my final week, I returned to Samarinda to work with Vibor on detailed carbonate stratigraphy, sampling important parts of the sections for forams. We discussed interpretations of the regional geology and stratigraphy while in the field. This is important because we are the two primary stratigraphers within the project and our research needs to be well coordinated.

The Future

Over the following months I will process my samples for magnetostratigraphy and by the spring I hope to start compiling a magnetic record in conjunction with the biostratigraphy. I will also at some point process carbonate samples for strontium to obtain a further control on age.

Inter- and intra- specific variation in large benthic foraminifera and biostratigraphy of Cenozoic of SE Asia

Vibor Novak

NCB Naturalis, Leiden, The Netherlands

1. Introduction

Network Training Activity 4 (NTA-4) organized within the Indonesian THROUGHFLOW Network Project (ITN) took place from June 10th until July 17th. During this period Early Stage Researchers (ESRs), together with their supervisors (PIs), took part in a five-day workshop *Palaeoecology and interpretation of past environments*. The workshop involved PIs and project associates giving lectures covering topics from sedimentology and palaeontology to oceanography and modelling. During the final day of the workshop ESRs presented their work progress (including results from NTA-2) and future plans (including the current fieldwork). After the workshop the group was divided according to project interests and travelled to previously planned fieldwork destinations. The fieldwork was organized to cover a wider geographical and a longer chronostratigraphical range than NTA-2: groups worked from Samarinda and Bontang to the Mankalihat peninsula, with one team heading south of Samarinda in search for new and possibly older outcrops.

As part of the carbonate team, I worked on the Mankalihat peninsula, making a reconnaisance, logging and sampling outcrops around the villages of Talisayan and Tabalar. In the second part of the fieldwork we moved further west, to the city of Tanjung Redeb, where detailed sampling inside the Berau Coal Mine took place (with their permission, driver and accompanying geologist). The final phase of fieldwork was undertaken in the area of Samarinda where we revisited and resampled some of the localities from last year (NTA-2), which was necessary to obtain a clearer picture of Kutai Basin stratigraphy. Aferwards we joined the rest of the team in Balikpapan where we exchanged data, delivered our last samples to the shipping agency, and packed for our departures to Europe.

2. Objectives

The first and main objective of the current research and its contribution to the general ITN project is to build a stratigraphical framework in collaboration with other ESRs. The biostratigraphy of larger benthic foraminifera (LBF) should provide enough information, supplemented by contributions from the ESR geochemistry group, for reconstructing palaeoenvironments, sedimentation processes and determining the chronostratigraphical age of the East Kalimantan sediments. The time span and details of the stratigraphical framework will depend on the outcrops encountered during the two planned field seasons (NTA-2 and NTA-4): it could extend maximally from Eocene to Pleistocene (~50 to 2 Ma) and minimally from Oligocene to Miocene (~35 to 5 Ma).

The second and more specific objective is to determine how environmental changes affected LBF assemblages using various analyses of foraminiferal assemblages together with algae, corals, bryozoans and molluscs. Facies analyses focuses on identifying facies types based on genera/species of LBF and their patterns of dominance in each of these facies. This should be useful for palaeoenvironmental reconstructions and the results will be correlated with those of fellow ESRs focused on facies interpretation.

The third objective is focused on the evolution of Indonesian foraminifera through time and space, trying to establish correlations with Mediterranean shallow benthic zonations. For this part of the project collaboration is essential with ESRs undertaking geochemical work, especially strontium isotope analyses.

To summarize, the main objectives regarding ITN project are:

- building a stratigraphical framework based on LBF;
- developing facies analyses model with a focus on LBF;
- determining the responses of LBF to environmental changes;
- correlating Indo-Pacific and Mediterranean shallow benthic zonations.

3. Methods

NTA-4 was a continuation of NTA-2, so the same field methods were used. These included general logging (when outcrop conditions permitted), detailed sampling of carbonate and siliciclastic rocks (hand and bulk samples), and stratigraphical correlation between different outcrops. While NTA-2 was organized and planned by Willem Renema and Kenneth Johnson, the idea for NTA-4 was to allow ESRs to plan the fieldwork, including transportation to fieldwork areas (by plane, cars and boats), accommodation arrangements, sample organization and transport to a shipping agency, and the fieldwork itself.

Fieldwork used basic methods. Before detailed work, the sections were surveyed to gather basic information for the subsequent work. Global positioning using handheld GPS devices included marking the beginning and end of the sections, obtaining GPS locations for each collected sample (GPS device error <10 m), as well as saving all the tracks for possible future work. Basic logging included measurement of bed thicknesses using measuring tape and description of the bed with a focus on lithology and determinable fossil content. Depending on sample type, ~3 kg of bulk sediment (when the sediment was loose) and ~15x15x10 cm of hand specimens from hard rock (large enough for cutting multiple thin sections) were collected.

Some outcrops were not reachable by car or foot, so the use of alternative transport was necessary. This included a boat with driver, with special techniques for entering and leaving the boat. The fieldwork also included a few jungle localities where the help of local guides was necessary for cutting through the dense vegetation and for becoming lost. In such terrains samples were collected at all possible locations where primary rocks were accessible; however, no suitable outcrops were found for making general stratigraphical logs. After completing fieldwork on specific sections, samples were examined again, properly marked and packed in plastic containers. Lists of the contents of each container were made to avoid any confusion during shipment and subsequent sorting of samples in Europe. Fieldwork finished by revisiting some of the old localities from NTA-2, together with some newly discovered outcrops in the surrounding area. Additional samples were taken to help obtain a more comprehensive stratigraphical overview.

4. Fieldwork

The fieldwork was divided into three parts, carried out in three areas: Talisayan, Tanjug Redeb and Samarinda.

4.1 Talisayan area

Talisayan is a village on the northern coast of Mankalihat peninsula. Most of the surrounding area is covered by vegetation and oil palm plantations, but outcrops on the coast and along the Tabalar river were reachable and sediments from Early to Middle Miocene were sampled.

TF300 (Palm Oil Plantation)

Sampling was carried out in the area of an oil palm plantation where outcrops are mostly covered by vegetation. Occasional primary rocks protrude along the road but section logging is impossible here. Moderately recrystallized limestones without any recognizable larger benthic foraminifera were found. Samples TF300_VN_01 to TF300_VN_09.

TF301 (Lost Hat)

This is an abandoned quarry near the road towards Tanjung Redeb. The heavily weathered outcrop contains platy corals in a white to orange clay matrix. 500 m west of the outcrop are recrystallized carbonates. Samples TF301_VN_01 to TF301_VN_04. General log by Simone Arragoni (SA).

TF302 (Menkrawit)

This outcrop shows approximately 4 m of siliciclastic sediments comprising grey to brownish silt. At the base of the section float specimens of diverse mollusc and corals occur. Samples were taken from the original bed on top and washed float sediments at the base. Sample TF302_VN_bulk and TF302_VN_float.

TF303 (Talisayan Beach)

Section starts with weathered blocks up to 5 m thick of bioclastic packstone containing molluscs and larger benthic foraminifera and continues with thick platy corals in a wackestone matrix. The overlying mudstone contains an abundance of molluscs, which also occur in the overlying siliciclastic sediment. Overlying mainly siliciclastic deposits is an approximately 3 m-thick bed of coral rubble in a packstone matrix, on top of which are marls with massive and branching corals. The section ends with a marly succession containing branching corals with bioclastic packstone above. Samples TF303_VN_01 to TF303_VN_11. General log by SA.

TF304 (Crocodile Mudtrap)

Outcrops occur along the beach west of Talisayan. Approach is possible only by boat. Interbedded massive corals in LBF wackestone matrix and weathered marls full of LBF can be found, with occasional sparse lenses containing branching corals in clay matrix. The section is capped by bioturbated marls with burrowing structures. Samples TF304_VN_01 to TF304_VN_08. General log by SA.

TF305 (Tabalar River)

A section was sampled along the banks of the Tabalar river. Along the sampled parts of the river banks are three interbedded lithotypes: (1) orange coloured wackestone to packstone full of LBF (possibly Aquitanian in age); (2) lenses of branching corals and molluss in packstone with small benthic foraminifera; and (3) brown to grey mudstone with dark grey fine sand laminae. After completing sampling of the river sections additional samples were taken on the road towards Lembake village where two lithotypes were identified: (1) recrystallized mudstone with solution voids shapes (?LBF); and (2) foraminiferal packstone with abundant LBF (probable Burdigalian in age). Samples TF305_VN_01 to TF305_VN_38. No log.

TF306 ('Jungle Forams')

A local guide took us what was supposed to be a "Skeleton Cave" with badly exposed outcrops. A first area revealed LBF washed out from underlying marls. An overgrown path through the jungle led to an approximately 20 m-high cliff of tectonized and recrystallized carbonates without any visible fossils. Samples TF306_VN_01 to TF306_VN_07. No log.

TF307 (Tabalar Bridge)

Sampling commenced near the bridge over the Tabalar River, approximately 2 km upstream from section TF305. Two main lithotypes were observed: (1) grainy foraminiferal packstone with an abundance of LBF; and (2) dolomitized carbonates with voids of probably dissolved LBF. This was also the only place where red algae were found in the Talisayan area. Samples TF307_VN_01 to TF307_VN_08. No log.

TF308 (BP Village)

Sampling began in an abandoned quarry exposing recrystallized and tectonized rocks. Continuing from Batu Putih village, a small quarry next to a construction site exposed a LBF packstone horizon.

Further west multiple outcrops along a new road construction revealed two lithotypes - white weathered marly deposits and recrystallized coral framestone - ending with weathered silts containing an abundance of molluscs (3 bulk samples were taken from different locations along the outcrop). No log. Samples TF308_VN_01 to TF308_VN_13.

TF309 (Crocodile River)

Reconnaissance of outcrops described by Leupold in the early 20th century, guide took us through the jungle towards the river but none of Arrival to the described outcrops could be located. Samples collected along the way back were mostly recrystallized carbonates, lithologicaly very similar to Tabalar River section (TF305). Samples TF309_VN_01 to TF309_VN_11. No log.

4.2 Tanjung Redeb area

The area near Tanjung Redeb was visited for detailed sampling of outcrops along the mining road inside the Berau Coal Mine. While waiting for permits, a few outcrops were sampled outside the mine area where the chronostratigraphicaly oldest sediments were found (Early Oligocene).

TF351 ('Going Carbonates')

Here an outcrop ~4 m high is composed of two main lithological types. Recrystallized wackestone occurs at the base and on top of the outcrop. Between the wackestones are grainstones of variable grain size (finer towards the top) containing LBF. Along the road towards the south is a grey recrystallized wackestone with coral fragments overlain by and grey marls. Samples TF351_VN_01 to TF351_VN_12. Log drawn by Nathan Marshall (NM).

TF352 ('Kick Out')

This outcrop has the oldest sediments found during NTA-2 and NTA-4 (Lower Oligocene). The section starts with dark grey algal rhodoliths and continues with grey wackestone containing LBF. The next lithological unit is a recrystallized wackestone with patches of dark grey foraminiferal packstone. On top of the section are alterations of grey to brown wackestone to packstone with LBF. Samples TF352_VN_13 to TF352_VN_20. Log sketch.

TF353 ('Bird Cage')

An isolated outcrop with branching corals and black coloured LBF in grey packstone to floatstone. Approximately 8.5 m high, the outcrop has alterations of grey mudstone with rare smaller LBF and wackestone to packstone with abundant elongated *Nummulites*-like foraminifera. Some parts are recrystallized and tectonized. The fossil assemblage is similar to section TF352 (only ~500 m away). Samples TF353_VN_01 to TF353_VN_11. Log sketch.

TF354 (Berau Coal)

Outcrops occur along a ~18 km-long mining road inside the Berau Coal Mine area. Starting from the end of the road are intercalations of sandstone and dark grey shales with occasional coal seams up to 10 cm thick. Magnetostratigraphical samples were taken by Nathan Marshall. Continuing towards the exit are bioclastic carbonate buildups underlain by dark grey shales. Occasional sandstone/shale intercalatIons occur with a few calcarenite beds containing abundant bioclastic material with visible gradation. Grey packstone to floatstone with algae, corals and LBF outcrops further down the road. The age of the sediments ranges from Burdigalian/Serravallian in the west to Chattian/Aquitianian in the east. Samples TF354_VN_01 to TF354_VN_50. Logs sketched by NM.

4.3 Samarinda area

Some NTA-2 localities were revisited and some new locations visited around Samarinda area in order to fill gaps in the data, and also to expand data on some of the potentially interesting newly discovered locations.

TF76 (Batu Putih 1)

Resampling of carbonate beds 2 and 3 from Batu Putih outcrops. Samples TF76_VN_20 to TF76_VN_22.

TF52 (Batu Putih 2)

Detailed sampling of carbonate bed number 1 from Batu Putih outcrops. Intercalations of platy coral and algal floatstone with LBF wackestone to packstone. Samples TF52_VN_44 to TF52_VN_55. Log drawn by NM.

TF130 ('The Rooster's Crest')

Completion of sampling started at the end of NTA-2 fieldwork. Samples were collected from both below and above those acquired last year. Grey wackestones with black pebbles and rare LBF with platy corals in gray marly wackestone. Samples TF130_VN_14 to TF130_VN_20. Log sketch by NM.

TF ('Turbiditic Forams')

Outcrop composed of sandstone and shale interbeds but with one distinct layer rich in LBF. Tf1 determined (Burdigalian). Samples TF_VN_01 to TF_VN_04.

TF101 (DPRD)

An approximately 15 m-thick succession of foralgal packstones with pure LBF limestone interbeds. Three lithological types: (1) bioturbated siltstones below the carbonate succession; (2) claystones with thin platy corals; and (3) foralgal packstones with occasional corals but mainly dominated by foraminifera. Samples TF101_VN_01 to TF101_VN_11. Log sketch by NM.

TF50 (Stadium)

Sample taken from the layer below the mollusk-rich bed. Dark grey to black, organic rich shales just above the coal layer. Sample TF50_VN_01.

5. Conclusions

NTA-4 provided the opportunity to try out a different approach to our fieldwork. This time the focus and responsibility for organizing the fieldwork according to the requirements of their research was left to the ESRs. The workshop was a nice opportunity for further expanding of our knowledge after NTA-2. The fieldwork itself was quite challenging compared to NTA-2 and included more adventurous approaches of the work, ranging from boat trips to mud traps and rivers inhabited with crocodiles, to jungle visits where we would be lost without our guides. Areas visited and outcrops sampled should provide enough information for palaeoenvironmental reconstruction and publication of some interesting results that will enlighten what happened between the Oligocene and Miocene in these areas, at least from the perspective of LBF.

I would like to use this opportunity to express my gratitude, and that of the ESRs as a whole, to our Indonesian counterparts without whom this fieldwork would have been impossible.

Molluscs from underwater meadows - On the Miocene diversification of Indo-Pacific molluscan communities associated to seagrass

Preliminary report on the THROUGHFLOW Network Training Activity 4: Palaeoecology, geological analysis, and interpretation of past environments

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1. Introduction

Network Training Activity 4 (NTA-4) took place from 13th June 2011 to 15th July 2011 in Bandung, Java and different regions of East Kalimantan, Indonesia. NTA-4 was divided into two main parts: the workshop in Bandung (13/6/2011-17/6/2011) with a visit to the laboratories of Corelab in Jakarta (20/6/2011), and fieldwork in East Kalimantan (22/6/2011-15/7/2011). This report will give an overview of my personal experiences and activities during NTA-4, stressing the work carried out for my PhD-project - 'Molluscs from underwater meadows - On the Miocene diversification of Indo-Pacific molluscan communities associated to seagrass meadows' – the scope of which has been developed during the last few months with my supervisor Frank Wesselingh. This project aims to elucidate how ancient seagrass faunas can be identified, how and when such faunas and biotopes developed, when modern type of shallow marine communities became in place, and how such ecosystems and their inhabitants reacted to regional expressions of global change. My main personal aim for this year's fieldwork was to explore fossil-bearing localities where seagrass habitats are likely to be preserved, and to collect material from these localities. This work was carried out without neglecting molluscan fossils from other community types.

2. Workshop and visit to Corelab

The workshop 'Palaeoecology, geological analysis, and interpretation of past environments' was held at the PSG (Pusat Survey Geology) in Bandung. It included lectures by the PI's of the THROUGHFLOW-project, as well as Irfan Cybai (Total Indonesie) and Bob Morley (Palynova), on different aspects of our research. The talks gave information on clastic and carbonate sedimentology, depositional systems, and microfossils with emphasis on our study area, as well as interpretation of past environments based on the study of different groups of organisms such as algae, large benthic foraminifers, molluscs and bryozoans. Furthermore, a lecture on oceanography and climate modeling was presented. The talks provided the opportunity to learn more about the different aspects of our research and to obtain a better understanding of the research interests of our colleagues.

The last day of the workshop in Bandung allowed the ESRs to present their PhD-projects and the progress they had made since NTA-3 (London, 28/2/2011-4/3/2011).

In additional to the workshop a visit was organized to PT Corelab, a petroleum service company in Jakarta. This included a guided tour through the different departments of the company (e.g. the biostratigraphy department) and the opportunity to talk to geoscientists working in a field other than research. Thus, the visit to PT Corelab gave interesting insights into job opportunities for geoscientists.

Fig. 1. A fossil *Barycypraea* in a coral-rich siltstone at TF 500

3. Fieldwork

This year's fieldwork profited from the experience gained by the participants during last year's fieldwork and from the progress the ESRs had made in their personal fields of research since then. The participants were split up into smaller groups working independently in different study areas focusing on their personal aims but also supporting each other. This division increased efficiency in data acquisition and minimized the problems which inevitably occur when dealing with large groups of people.

The following text summarizes the fieldwork that I carried out at 19 localities in different study areas. All localities are named with the initials TF (Throughflow) followed by a locality-number. The study areas are 'Bontang' (including the surroundings of the city of Bontang, Kutai Basin, East Kalimantan), 'Bengalon' (including a river section at Kampung Narut, a village close to the city of Bengalon, the mine PT Perkasa Inakakerta, and the further surroundings of Bengalon), 'Kari Orang-Sangatta' (including road-cuts within the KPC-mining area close to Kari Orang and the Sangatta dome structure south-west of Kari Orang), and 'Sangkulirang Bay' (including outcrops within the estuary Sangulirang Bay, south-west of Mangkalihat Peninsula, East-Kalimantan).

3.1 Bontang

The area of Bontang had been visited during last year's fieldwork and already provided excellent fossil material, notably molluscan faunas including seagrass-associated molluscs and also well-preserved branching corals, benthic foraminifers and bryozoans. The outcropping sediments are predominantly marine clays, silts and fine sandstones, with carbonate beds occurring to a minor extent. All localities mentioned below are of Early Tortonian (early Late Miocene) age.

3.1.1 TF 500

Locality TF 500 is situated on the opposite side of the road to TF 151 at which extensive work was carried out last year. The closeness of the two localities leads to the assumption that the same beds are exposed on both sides of the road. Although TF 500 shows less good exposure as the outcrop has been partly levelled out, the log shows the expected similarities to the succession at TF151. However, some beds could not be traced at TF 500. Float specimens and bulk sampling were collected at TF 500. Bulk samples were taken in particular from a bed of black clay containing a low abundance but well preserved fauna of molluscs (e.g. *Conus*) and the overlying bed of grey clay which contains extremely abundant fine coral sticks and mollusc shells (Fig. 1). The former presence of seagrass is unlikely at TF 500 as well as at TF 151.

3.1.2 TF 501

Locality TF 501 is a building site exposing a more than 30 m-long succession of marine sediments. The sediments consist mainly of siltstones varying in clay content, colour and fossil content, and a single limestone bed up to 5 m thick. The succession was logged and sampled at a resolution of 0.5-1 m. Collection of float specimens was carried out as well. The succession was especially interesting in the lower 11 m where alternating clay-rich dark grey layers with abundant molluscan remains (Fig. 2) and less clayey brown layers dominated by branching corals are exposed. The clay-rich dark grey layers yielded a rich and exceptionally well preserved fauna of molluscs which are highly likely to have been associated with seagrasses. Furthermore, fossil plant remains strongly resembling seagrasses were found with the mollusc fauna. The layers with seagrass and/or seagrass mollusc preservation were sampled extensively. The fossil plant remains will be presented to a palaeobotanist for further investigation. The locality also yielded fossil corals and molluscs associated with habitats others than seagrass.

3.1.3 TF 502

Fig. 2. Diverse shell remains in a dark grey siltstone at TF 501

Locality 502 is exposed along a small river. The succession consists mainly of silty clay with abundant and diverse fossil corals interbedded with three 20-50 cm thick carbonate beds. The section was logged and sampled with emphasis on the corals. Molluscs were rare and show the typical composition and preservation of coral-dominated sediments of the Bontang region, with fragments of *Tridacna*, small oysters and some trochids and turbinids.

3.1.4 TF 505 (TF 110)

Locality TF 110 is an active building site and has been sampled during last year's fieldwork (Fig. 3). The processing of the sampled material is currently in progress. The sediments of TF 110 have already yielded a rich and very well-preserved molluscan fauna, highly likely to have been associated with seagrass, and coral-associated molluscs. The revisited locality has been renamed TF 505 for the 2011 fieldwork. The outcrop had changed remarkably since last year's fieldwork: it is much larger with a longer exposed succession and a larger surrounding area cleaned of vegetation. These changes led to an improvement of the log and to the availability of more bulk samples from different beds, some of which contain likely seagrass-associated and other molluscs that were collected also in the float.

TF 508

Locality TF 508 is an excellent succession >40 m long of clastic marine sediments providing well preserved fossil material. Unfortunately my personal work at this locality was limited by a period of illness. Nevertheless, the succession has been logged and sampled for bulk and float by Willem Renema and Frank Wesselingh. Seagrass-associated micromolluscs and even plant remains assumed to be fossil seagrasses were found. The material is comparable to the fauna and flora from TF 501. Furthermore, the locality yielded fossil corals and molluscs associated with habitats other than seagrass.

Fig. 3. View from the road to locality TF 505

3.2 Bengalon

3.2.1 TF 518

Locality TF 518 is a nearly 100 m-long exposure of marine and minor freshwater sediments including silt- and sandstones as well as carbonate beds along the Sungai Kapia river at Kampung Narut (Fig. 4). Freshwater sediments could be identified by the presence of freshwater molluscs. The section was logged by Willem Renema and Frank Wesselingh. More than 50 bulk samples were taken. The resolution and sample sizes were adjusted to the fossil content of the beds without neglecting sediments lacking macrofossils. Those were sampled for lithological and micropalaeontological purposes to achieve as complete as possible picture of the sedimentology of the outcrop. The presence of seagrass-associated molluscs is unlikely in the section, although one bed of dark grey clay contains a level rich in the remains of micromolluscs at its base. The horizon has been sampled and the fauna will be investigated further.

3.2.2 TF 510-TF 511

The localities TF 510-TF 511 represent the lower and the upper parts of a large fossil reef complex located in the mining area PT Perkasa Inakakerta. Molluscs are rare, not diverse and often poorly preserved, which is why the work carried out at these localities was more general and included the identification of different coral facies associated with different zones of the reef body. The reef is of Late Miocene age, but likely older than the localities in Bontang.

Fig. 5. Large lucinids in a limestone at TF 274

3.2.3 TF 512 and TF 533

The localities TF 512 and TF 533 are small outcrops along the mining road of PT Perkasa Inakakerta within walking distance of the reef-localities TF 510 and TF 511. Especially TF 533 yielded a well-preserved fauna of reef-associated molluscs.

Fig. 4. The river section TF

3.2.4 Beach of Pantai Sekerat

Another activity carried out during the fieldwork period was a visit to the beach of Pantai Sekerat which was useful for the understanding of tropical coastal environments, such as mangroves, mudflats and nearshore sandy beaches. Typical molluscan inhabitants of mangroves (*Terebralia*, *Telescopium*) and mudflats (*Cerithium*) could be observed in their natural habitats. These species play an important role in the identification of palaeoenvironments. Additionally, taphonomic processes could be observed on numerous shells along the beach. Modern shell material was collected for comparison with the fossils from other localities.

3.3 Kari Orang -Sangatta

The study area includes several outcrops along the mining road crossing the road from Bengalon to Sangkulirang close to Kari Orang (TF 274, 275, 527, 522) and the Sangatta-dome structure south-west of Kari-Orang (TF 517, 524).

3.3.1 TF 274

Locality TF 274 is a limestone outcrop on a hill which can be accessed by a small path from the mining road. The locality is situated about 15 m above the level of the road. The exposed limestone is densely packed with different lucinid species of which one is large (Fig. 5). The palaeoenvironment remains unclear, but the possibility of the limestone being a vent or seep deposit will be investigated. Furthermore, the upper soil horizon of the outcrop contains numerous larger mollusc shells, such as

Telescopium, *Lambis* and *Arca* s.l. It was not possible to resolve whether these shells came from an assumed Pliocene marine deposit or were placed at the locality by humans who probably ate the molluscs.

3.3.2 TF275 and TF527

Dark grey silty marine clay is exposed at locality TF 275. The minimum palaeodepth of the sediment could be determined as 150 m due to the occurrence of a star-shaped, deep-water coral. The overlying sediments were identified as a slide deposit of yellowish carbonate sand with scarce molluscs. Bulk samples were taken from both beds. Marine silty clays from deeper waters are exposed at locality 527 as well. They contain molluscan remains and otoliths; bulk as well as float samples were taken.

TF522

Locality TF 522 is a 15.5 m-long section of marine siltstones varying in colour and clay content, with corals as the dominant fossil group. Molluscs are scarce, but one 50 cm-thick bed of dark grey siltstone was of special interest since it bears abundant bryozoans and plant remains assumed to be fossil seagrasses. Unfortunately, associated molluscs were rarely preserved. Nevertheless, the bed was sampled extensively, and a unique find was made of a small fossil oyster still attached to a seagrass blade (Fig. 6). This yields important information on the ecology of this oyster species which was also found at other localities with seagrasses and/or seagrass-associated molluscs.

TF534 and TF517 (Sangatta)

These localities are particularly interesting because the sediments are younger than the outcrops in Bontang but yield very similar molluscan faunas associated with different facies. This leads to the suggestion that facies changes are a more important factor accounting for differences in fossil mollusc communities within the study areas than geological time. Further research on this question will be carried out. The localities were sampled by surface and bulk collecting, and fossil plant remains assumed to be seagrasses were found.

3.4 Sangkulirang Bay

Sangkulirang Bay is an estuary south-west of the Mangkalihat Peninsula. Several historical fossil-bearing localities are located within the bay area. Coastal outcrops were explored by boat. Unfortunately, the historical localities from which seagrass-associated molluscs were described by Beets (1986) could not be relocated.

Fig. 6. Small species of *Dendrostrea* in life position attached to a seagrass blade at TF 522

TF 277

This locality is a small cliff of reddish sandstone containing fossil echinoids. It was also possible here to observe recent gastropods in their natural habitat between mangrove roots and to collect modern shell material washed onto the beach, including at least two species of the seagrass-related gastropod genus *Smaragdia*.

TF 529 and TF 530

Both localities are cliffs exposing deeper water sediments from which molluscs including a diverse scaphopod fauna were collected. Another extraordinary find was a fossil fish skull with an otolith in situ at TF 530.

4. Conclusions

The fieldwork component of NTA-4 can be regarded as very successful. Concerning my personal aims, I was able to collect fossil molluscan material highly likely to have been associated with seagrass habitats from different localities within the same timeframe (Bontang), as well as from younger sediments (Sangatta). The determination of the molluscan material as being associated with seagrasses is considerably facilitated by the remarkable occurrence of fossil seagrasses. Together with the material collected during earlier fieldwork, and that in museum collections, the size of the collections available are regarded as more than adequate for my PhD research.

The origins and evolution of the modern Indo-Pacific reef algal flora Preliminary report of the fourth Network Training Activity (NTA-4): Palaeoecology and interpretation of past environments

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Project Objectives

Within the general programme of the THROUGHFLOW project, my research project focuses on the origins and evolution of the modern Pacific reef algal flora. My aim is to document the timing and patterns of diversification of Indo-Pacific reef-building coralline algae, the second most important reef builders in the modern Indo-Pacific. This group appeared in Late Oligocene-Early Miocene times in the Indo-West Pacific area. My intention is to correlate algal origination (and extinction) events with variations in reef fossil assemblages and regional/global palaeoenvironmental changes. At the same time I will apply molecular phylogenetic analyses and chronology to living coralline algae from modern Indo-Pacific coral reefs, in order to constrain evolutionary patterns, combining the information provided by both extant and fossil reef floras. First of all I will concentrate on Mastophoroideae and Lithophylloideae, which are the most important subfamilies in reef building. It is very interesting, with the help of the fossils from Indonesia, to see clues on the influence of representatives of this group on the onset of coral reef formation, one of the key ecosystems for the high biodiversity in the region.

During the NTA-2 fieldwork (November-December 2010) my main target was to find and collect coralline algae from Miocene and Oligocene rocks in Kalimantan. Initial age analyses of the sampled sites showed that Oligocene carbonates were missing and the Miocene was not broadly covered. The fieldwork during NTA-4 was intended to infill gaps in this information.

Training

We spent the first week of NTA-4, as in NTA-2, in our Partner Institution, the Pusat Survei Geologi (Central Geological Survey), following a short theoretical course.

The first lecturer was Irfan Cibaj, from the oil company Total. Paleoecology and interpretation of past environments was his first lecture. We learned about sandstone sedimentary facies, deltaic cycles, and general deltaic sedimentology with many different examples. His second talk was about ichnofossils and ichnofabrics and their palaeonvironmental meaning.

Willem Renema from Naturalis (Leiden) was the second lecturer: he taught us about mixed carbonate-siliciclastic shallow marine facies with a focus on the effects of seasonality on foraminifera illustrated by various examples in Indonesia. In a second talk he introduced us to the "letter biochronostratigraphic scale" based on larger benthic foraminifera and how to apply it in the field. This scale has been traditionally applied to age models for Tertiary deposits in the Indo-West Pacific area.

Robert Morley, who moderated the whole workshop, gave a lecture entitled "Microfossils and depositional environments". He showed the influence of the Indonesian Throughflow on the foraminifera fauna, talked about sea level change and hyperpycnal transport. He also showed the usefulness of palynology for palaeoenvironmental interpretations, with examples in the Mahakam Delta.

The next topic was molluscs, with a talk prepared by Frank Wesselingh from Naturalis, who was not able to attend the workshop due to health problems. Jon Todd from the Natural History Museum (London) kindly introduced us to this phylum of animals and their characteristics as palaeoenvironmental indicators. Later he lectured about the Panama Paleontology Project as an example of another multidisciplinary project, showing us the methodology employed, interesting results and errors to avoid.

On the third day Juan Carlos Braga from the University of Granada gave an introduction to all the groups of calcareous algae, their meaning and appearance in the fossil record and in recent environments, with an overview of their taxonomy. He also made a diversion into calcifying cyanobacteria and sulphate-reducing bacteria and their remains in the fossil record as microbialites.

We received the next lesson, "Mechanisms of ocean and climate variability in South East Asia", from Matthias Prange from MARUM, University Bremen. This could be understood as a central topic of our project and it was very interesting to learn about the main processes in climate and how mathematical models work.

Paul Taylor from the Natural History Museum (London) gave us an introduction to bryozoans which for many of us were quite unknown. He talked about their taxonomy, evolution, ecology and methods that are helpful in the interpretation of their palaeoenvironments.

During the last day of the workshop in Bandung the ESRs presented their new results, work progress and future plans. Subsequently a new ESR representative was elected and the board meeting was held, where mainly plans for the next months and next year were discussed.

Subsequently the fieldwork started, the group being split into four smaller subgroups that travelled to different regions in Kalimantan.

Fieldwork

The first trip took me in a group with Juan Carlos Braga, Simone Arragoni, Vibor Novak and Dedy Kurniadi to the Mankalihat Peninsula. Here we were supposed to find several Oligocene outcrops, following the findings and descriptions of W. Leupold in the 1920s and the publication of M. Wilson in 1999. Within the peninsula we visited a cliff near Talisajan (TF 303 and304), a river section which was supposed to expose rocks of many different ages (TF305), outcrops of the marly Menkrawit Formation and outcrops in a palm plantation and along roads.

Some difficulties were experienced due to the lack of long sections: the very local and small outcrops were hard to correlate. At the cliff section strong weathering turned out to be an additional problem.

Although I found some fossil coralline algae in one bed, they are probably not well enough preserved to reveal taxonomic information. In general the limestones of the Miocene/Oligocene in the Mankalihat Peninsula were mainly mudstones (or foraminifer packstones) which indicate an environment probably too muddy for coralline algae.

After exploring the area around Talisajan, D. Kurniadi, JC. Braga, S. Arragoni and I returned to Samarinda to extend our investigation of the Batu Putih formation (TF 77 and 311) and complete sampling of supposedly Burdigalian outcrops. We also visited, logged and sampled a site near Senoni (TF 310), which should be the oldest limestone of this region according to Wilson (2005). This site and the Batu Putih formation show a very good conservation of fossil coralline algae. My two colleagues from Granada returned to Spain, while D. Kurniadi and I went to Bontang to revisit outcrops (TF 502, 504 and 508) discovered by colleagues of the Throughflow team one week before, to check them for coralline algae. There I found also mudstones containing branching corals, molluscs and a few benthic foraminifera, between beds with clay matrix. As in many other sites visited near Bontang during the last fieldtrip, in these types of facies, which are not part of reef constructions, almost no coralline algae are to be found.

We progressed further north to Bengalon to meet up with the rest of the group who had come back from Sangkulirang. There I visited a limestone section along a river (TF 518) with many different facies within a small thickness. In this section coralline algae were scattered, most of them encrusting corals and some with a branching morphology. On the following day the entire Throughflow group visited a huge paleo-reef (TF 510 + 511) with various bioclastic facies, many foraminifera and diverse coral morphologies. No corallines were found, probably due to the strong weathering of this outcrop resulting in a fairly “sugary” lithology. In the same area we continued to search for more limestone outcrops and went to a quarry (TF 534) where a blue limestone with corals of all shapes could be found. Also many molluscs, especially oysters, were present in the bioclastic portion. Stratigraphically beneath this layer occur facies similar to those in Bontang with branching corals and many molluscs but no algae were found. Later we went to another quarry (TF 516) with a very similar facies, also apparently without coralline algae, described as a micritic floatstone with molluscs and corals. On the last fieldwork day we went back to TF502 where I found one algal nodule.

In summary, we visited many more different formations of various ages but the yield of well-preserved fossil corallines was quite low. Nevertheless this NTA-4 was a successful event because of the huge amount of other fossil organisms found by our colleagues and also because I succeeded in enlarging the timeframe of sampled fossil corallines.

The information about the samples taken from specific localities can be found in the attached samplesheet. Their precise age will be known after other colleagues have determined their samples. Nevertheless there is some preliminary age information available as follows. The largest number and best-preserved fossil coralline algae were from Burdigalian (Early Miocene) reefs in the Samarinda and Bontang area; Langhian and Serravallian (Middle Miocene) corallines were also quite well abundant. Probable Aquitanian (Early Miocene) and Chattian (Late Oligocene) samples from Senoni and Mankalihat Peninsula contain coralline algae, although these ages need further confirmation from colleagues working on the foraminifera. The sampled interval (Late Oligocene-Middle Miocene) should include the expected time of appearance of many coralline taxa common in present-day Indo-

Pacific reefs. The study of samples after preparation will show to what extent they include a good representation of such taxa, to add information to the database on occurrences and stratigraphical ranges.

Between and after NTA-4 I mainly worked on the genetic part of my research, which included another fieldtrip for collecting Recent material from the Great Barrier Reef in Australia and laboratory work in the Genetics Department at Granada University. Sequences of different genetic markers were already obtained and many more will be added. I also took part in the 10th international Symposium on Fossil Algae and presented the project and my work (Fig. 1).

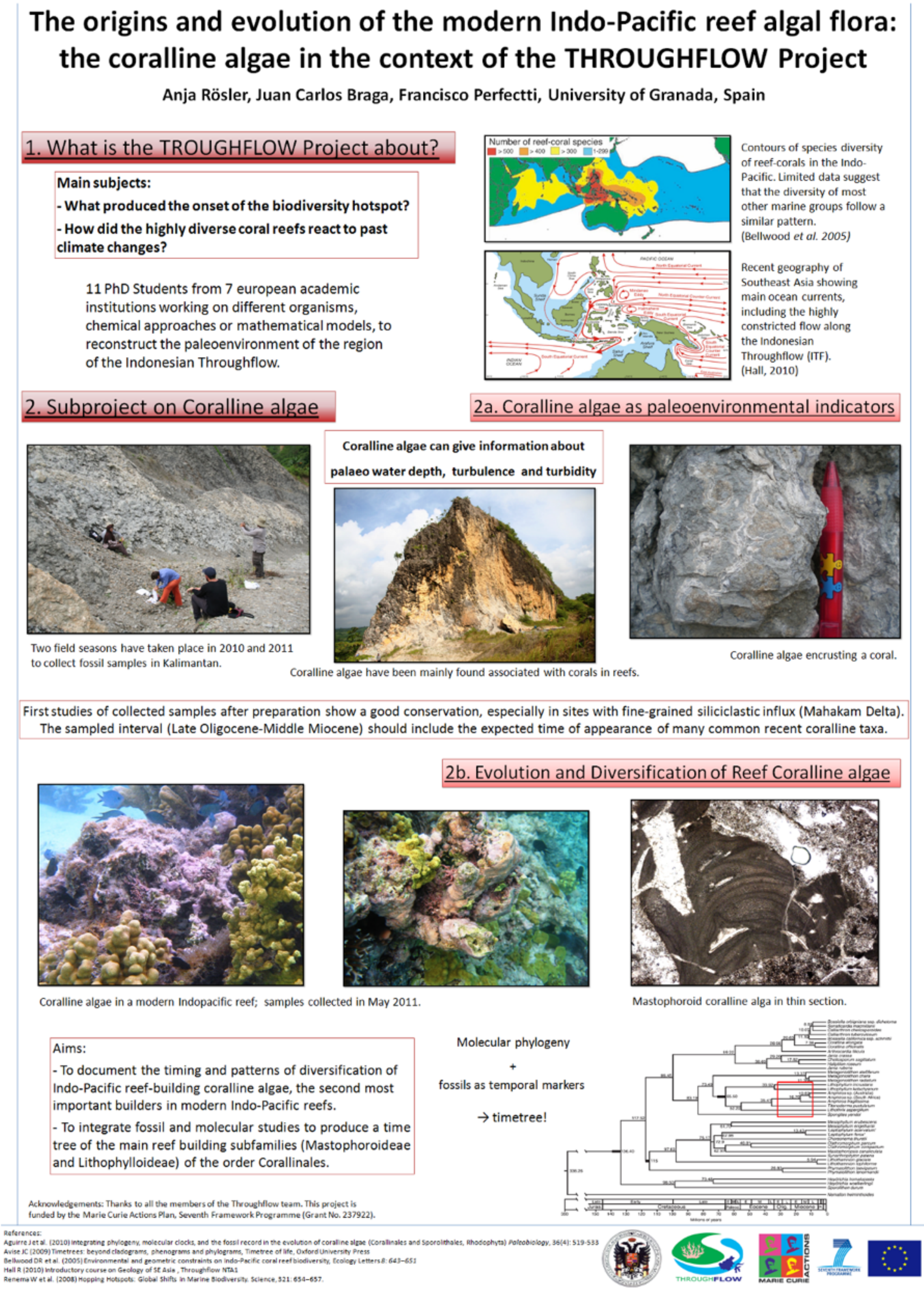

Fig. 1. Poster presented on the 10th international Symposium on fossil algae in September 2011 in Cluj-Napoca, Rumania.

Miocene coral reef ecosystems in Southeast Asia

Preliminary report of the fourth Network Training Activity (NTA-4): Palaeoecology and interpretation of past environments

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Introduction

The maximum centre of marine biodiversity (MCMB) today is located in South East Asia. Corals play an important role in the concentration of this extraordinary diversity, not only due to their diversity within this region (>500 species), but also because they are the main constructors of the carbonate framework where diversification processes of many other species have taken place. By studying fossil corals, this research aims to answer when high biodiversity originated here on a geological timescale, and which environmental factors may have been involved. Some palaeontological and molecular evidence suggest that the formation of the ancestral centre of diversity could be related to the constriction of the Indonesian Throughflow current (ITF) during the Cenozoic, resulting in increased speciation and/or immigration during the Miocene.

This project is focused on extensive collections of fossil coral specimens that can be used as direct evidence of the processes that occurred during the Miocene in the MCMB. Throughout the first expedition (NTA-2), we studied fossil coral communities associated with deltaic facies of the Mahakan River in the Kutai Basin around Samarinda and Bontang areas. The topography of the region is characterized by thrust-top anticlines parallel to the coast, on which platy corals assemblages are mainly exposed. These platy coral communities are of Burdigalian to Serravallian age. Around Bontang, younger communities were observed (Tortonian age) and they were characterized mainly by branching forms. Whether these different coral settings can be interpreted as the result of a gradient of the river influence in time and space (siliciclastic input, turbidity, light levels, among others) is a question to be addressed through further analysis.

This report aims to summarize the results obtained during the second expedition (NTA-4, 11 June to 15 July 2011) for the coral component of the TF project. The survey was focused on both completion of the collection for assessing coral diversity of selected outcrops in Samarinda and Bontang, and exploring new outcrops towards the northeastern part of the Kutai Basin near the villages of Sangatta, Bengalon, Kali Orang and Sangkulirang Bay.

Ongoing interpretation of the palaeoecological aspects of Miocene reefs in East Kalimantan is taking into account the results produced by Throughflow researchers working on molluscs, forams, bryozoans and algae, as well as data from sedimentology, stratigraphy and high-resolution proxies.

Research Questions

The umbrella questions addressed in this study are:

1. Which coral species were present during the Miocene in the SE Asia?

2.Is the high diversity of the coral triangle the result of low extinction rates or high origination rates (or both) since the Early Miocene?

3.Which environmental factors controlled the presence and distribution of coral species in SE Asia during the Miocene?

Field Methods and preliminary results

In order to cover a large geographical area and timescale in NTA-4, the TF group was divided into four teams (4-6 researchers each). The first team went to the south of Kalimantan to explore outcrops of Eocene-Oligocene age, following Verbeek's original geological map (1875). The second team went to Tanahgrogot (south of the Mahakan Delta) to perform magnetostratigraphy sampling. The third team remained around Samarinda and Bontang, and afterwards went north to the area of Sangkulirang Bay, sampling for corals, bryozoans, molluscs, larger benthic forams and stratigraphy. Finally, the fourth team went to the northernmost part of the Mankalihat Peninsula, around Tanjung Redeb and Talisayan, to survey the carbonates and larger benthic forams in outcrops of Oligocene to Pliocene age.

This report focuses on the results achieved for the coral component as part of the third team (Samarinda to Sangkulirang Bay areas). Some selected outcrops studied during NTA-2 were revisited in order to complete coral diversity inventories (Table 1) and collect further bryozoan specimens. In Samarinda most outcrops remained without major changes and were not covered by vegetation. However, in Bontang active urban development favoured greater exposure of previous outcrops (TF110, re-named TF505), and resulted in the opening of new interesting outcrops (TF 500-502, 504, 505, and 508). Willem Renema (WR), Frank Wesselingh (FW), and Sonja Reich (SR) logged the new outcrops, and coral samples were systematically collected based on their stratigraphical logs. High construction activity in Bontang city was evident, and some construction plots (TF501, electric power plant) changed drastically from one day to another. Taking advantage of this situation, extensive collection of bulk samples was performed (WR and FW samples), and an integrated analysis of their sedimentology, biostratigraphy, molluscs and corals will be achieved in collaboration with the other ESRs.

Biodiversity collections

Extensive sampling was carried out in eight revisited and 21 new outcrops, yielding a total of 138 samples (243 bags), comprising both individual specimens and bulk material (Table 1). Each sample was labelled with the stratigraphical unit/bed from which it was collected, and the respective coordinates of the section (see Appendix C). A total of 3517 scaled pictures and video files were obtained during the expedition; these images are being sorted by section and theme, such as taxonomic groups, landscapes, photoquadrats, etc. In some cases photo images will be used to reconstruct larger, broken coral colonies (Fig. 1), useful for palaeoenvironmental interpretation.

Fig. 1. (A) broken colony of *Stylophora* sp. from TF56, Badak, scale bar= 2 cm; (B-C) Coral head of *Favia* sp. from TF529, Sangkulirang Bay, scale bar=5 cm (B), showing excellent preservation of skeleton (C) likely to be used in palaeoclimate reconstruction

Sample bags were packed into fourteen crates and shipped to the NCB Naturalis (Leiden). Subsequent processing in the laboratory will include sorting, sieving (of bulk samples), cleaning, and identification to the highest taxonomic level, according to preservational state. As established in the previous report, priority was given to the sampling of TF126 (3-D reef), TF51-TF57 (Top reef Stadion), and selected localities in the Bontang area (TF102-TF154). About 75% of these samples are already washed and sieved, and now in the process of identification.

Table 1. Summary of work accomplished for the Coral Biodiversity component during NTA-4, and total number of samples collected in both expeditions (NTA-2 and NTA-4). *Revisited outcrop. Coral colony forms, *pl* (platy), *br* (branching), *ms* (massive), and *so* (solitary). Sampling type was either stratigraphical (St) when a log was available, or float for outcrops with only an estimated age.

Outcrop name	Latitude	Longitude	Code	No. samples	No. bags	Photo-transect	Colony forms	Sampling type
Top reef Stadion I	-0.58573	117.119	TF51*	9	21	Yes	pl>br	St
Top reef Stadion II	-0.58467	117.11983	TF57*	13	24	Yes	pl>br	St
Batu Putih 1	-0.46626	117.12183	TF76*	2	8	No	pl>br	St
Batu Cermen	-0.43234	117.13783	TF79*	1	1	NTA-2	pl>ms>br	St
Badak	-0.32203	117.2975	TF56*	19	23	NTA-2	pl>ms>br	St
Southern Hemisphere	-0.01819	117.35292	TF59*	5	10	NTA-2	pl>ms>br	St
Rainy Section	0.09644	117.38037	TF153*	10	10	NTA-2	pl>br	St
3D-Reef	0.1513	117.30438	TF126*	8	10	NTA-2	pl>so	St
Coalindo hauling road 4	0.87491	117.82652	TF275	4	5	no	pl>so	Float
Opposite 151	0.16741	117.43747	TF500	1	2	no	br>ms	St
Powerplant	0.16150	117.43448	TF501	5	7	no	br>ms	St
Washing ditch	0.14134	117.43147	TF502	1	1	partially	br>ms	St
Quarry	0.17218	117.43771	TF504	5	8	No	br>ms>pl	St
Sea grass	0.14062	117.42655	TF505	4	5	partially	br	St
TF 508	0.14892	117.42819	TF508	5	7	partially	br>ms	St

Sekarat 3D-reef	0.77084	117.73556	TF510	3	10	No	ms	Float
Sekarat Topreef	0.77179	117.73561	TF511	20	29	No	ms>br>pl	St
PIK-hauling road 1	0.77322	117.73156	TF512	1	2	No	br>ms	Float
Batu Putih - Sangatta	0.56565	117.63255	TF516	1	10	No	br-ms	St
Batu Putih - Sangatta	0.56778	117.63424	TF517	1	1	No	br-ms	Float
Kampung Narut	0.83528	117.72351	TF518	2	3	Yes	br>ms>pl	St
Coalindo hauling road 1	0.91167	117.77387	TF522	1	21	No	pl-ms>br	St
Coalindo hauling road 5	0.87154	117.82628	TF526	1	1	No	so	St
Coalindo hauling road 6	0.84131	117.86769	TF527	1	1	No	so	St
Tanjung Manis	0.91553	118.05256	TF529	2	2	No	so>msa	Float
Tanjung Perak	0.90411	118.06346	TF530	3	4	No	so	Float
Kg Godan	1.00638	117.99311	TF531	1	2	No	so	Float
PIK-hauling road 3	0.77374	117.73029	TF533	1	3	No	br>ms	Float
Batu Putih	0.54877	117.61980	TF534	2	6	No	br>ms	Float
Other float samples			Various	6	6			
Subtotal NTA-4	**21 outcrops**			**138**	**243**			
Subtotal NTA-2	**20 outcrops**			**127**	**221**			
TOTAL	**42 outcrops**			**265**	**464**			

Transects and photo-quadrats

The same methodology of photo-quadrats performed during NTA-2 was applied at some outcrops, in order to compare coral community structure among the different coral assemblages. Since the strike/dip varied among the outcrops, coral colonies were visible in section while others exhibited their corallite-covered surfaces. This factor limits direct comparisons, but some general characteristics will be analyzed from the pictures: colony form (branching, platy, massive, etc.), size of colonies (ratio length: width: thickness, area), density of corals in the sediment matrix, and when possible, taxonomic identification.

Preliminary results and collaborative work

At most sections collaborative studies between the ESRs and supervisors was undertaken. Since all collections employed the same stratigraphical labelling, it will be possible to integrate the results with those of other ESRs, including large benthic forams (Vibor Novak), coralline algae (Anja Rösler), molluscs (Sonja Reich) and bryozoans (Emanuela Di Martino). In addition to the on-going collaboration on the papers about the 3-D reef (TF126), Top reef Stadion (TF51-TF57), and Bontang (TF102, TF151, TF154), the newly studied outcrops provide data for interesting studies in the middle-term.

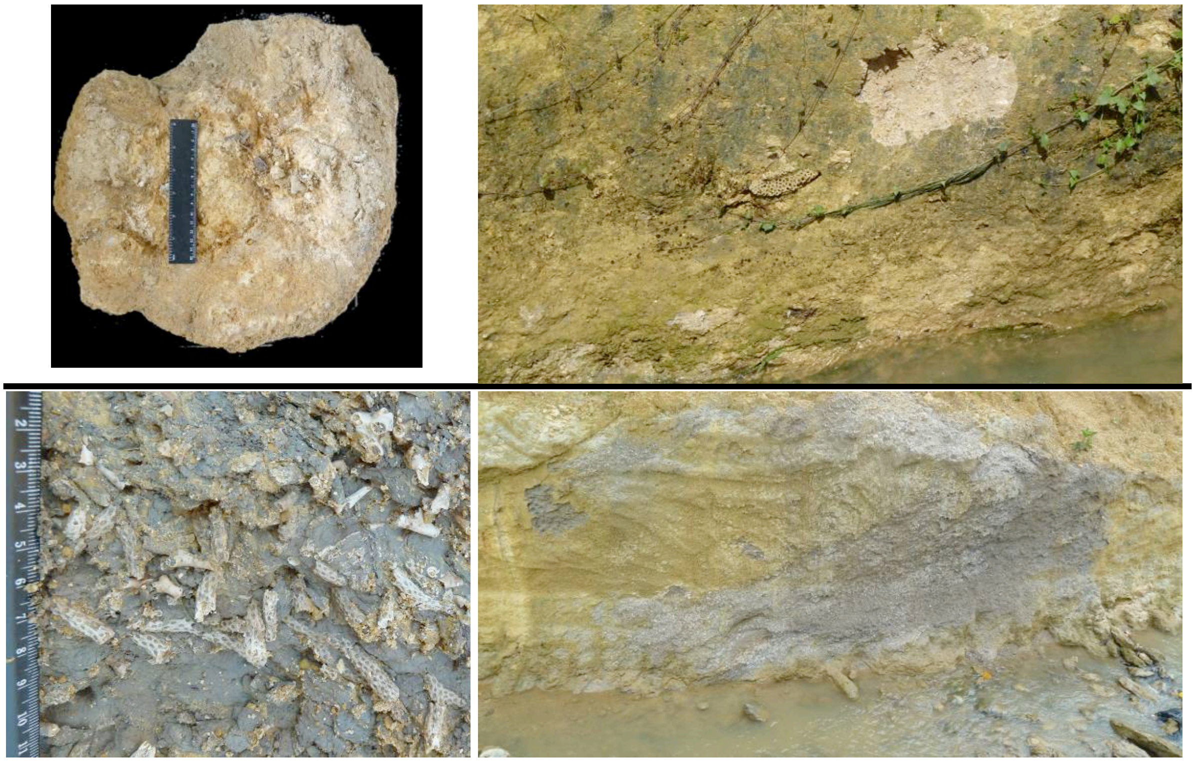

Fig. 2. Coral assemblages at TF502. (A-B) Top of the section, where massive coral heads are more common (A, *Favia* sp., scale bar=15 cm). (C-D) Base of the section, with dominance of branching corals (C, *Dictyaraea* sp.).

Bontang Area: Coral assemblages in this area encompass most of the variation that has been observed so far for the Miocene corals from East Kalimantan as a whole. On the outcrops located on the westward ridges (TF59, TF126, TF153), coral assemblages are of Middle Miocene age (Langhian to Serravallian), and are dominated by platy corals. Towards the coast, in the lowlands, coral communities are of Late Miocene age (Early Tortonian), and are dominatly branching coral species embedded in a silty-clay matrix, that gives way to communities dominated by phacelloid corals (*Caulastrea* sp.) and massive heads (mainly *Favia* and *Favites*). One of the best examples of this succession was observed at locality TF502 (Fig. 2A-D). Additionally, seagrass communities with characteristic branching coral species, containing a rich very well-preserved mollusc fauna, were also observed in this area (TF501, TF505).

Sangatta Area: These outcrops are of Late Tortonian age (TF516, TF517, TF534). Similar to Bontang, these localities are rich in branching corals, giving way to communities with more massive corals, suggesting a change in the environment from more turbid waters (probably with high resuspension of sediments and wave energy) to a less turbid, quieter waters that favoured growth of massive coral colonies. Large well-preserved coral heads were collected with a high potential for geochemistry analyses. Another notable feature was the abundance of *Acropora* spp.

Fig. 3. Branch of *Acropora* sp. in the Sangatta area (TF516)

Bengalon Area: The most important outcrops here were TF510-TF511 (Late Tortonian age). On a road-cut inside the KPC mine, these exposures are the only representatives of 'true' coral framework built by massive corals. TF510 is characterized by successive coral build-ups. More detailed information and systematic sampling was performed in the quarry located on the top part, TF511 (Fig. 4)

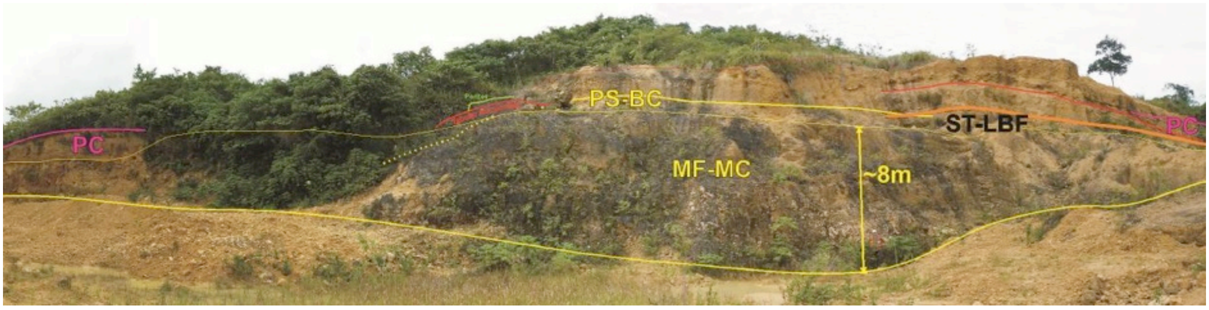

Fig. 4. Tortonian 3-D reef (TF511). Main framework (MF) of coral build-up exposed is about 8m high, dominated by massive corals (MC) mostly exhibiting poor preservation. On top is a layer of packstone containing branching corals (PS-BC). On the flanks, sandstones with abundant larger benthic forams (ST-LBF), and on top, platy corals (PC).

Kari-Orang and Sangkulirang Bay: Along the haulage road of the PIK coal mine, the base of some outcrops (TF524-TF526) was composed of deep-water sediments (silty clay with few fossils, mainly azooxanthellate corals, pteropods, scaphopods), while towards the top, shallow-water sediments were exposed (rich in reef corals, LBF, etc). The most plausible explanation for succession of shallow over deep sediments is that a major geological event during the middle Miocene resulted in massive landslides from the shallower zones onto the deeper slopes, so that complete reefal bodies with organisms in life-position were deposited on top of deep-water sediments (Ken Johnson, pers. comm.).

On the other hand, TF522 is the northernmost outcrop with platy corals (Serravallian age), and therefore, it is a good locality for comparison of the platy-coral assemblages under the gradient of influence of the Mahakan Delta. Outcrops located on the coast of Sangkulirang Bay and islands, provisionally dated as Pliocene, were explored during a one-day boat trip. These localities are characterized by uplifted deep-sea mudstones containing scaphopods, bivalves and some azooxanthellate corals. Few specimens of caryophylliids and flabelliids were recognized.

Towards a synthesis

The outcrops found and sampled during NTA-2 and NTA-4 expedition allow the study of Miocene coral assemblages of East Kalimantan in space and time. The presence of the progradational Mahakan Delta since the Early Miocene has created a gradient of siliciclastic input, controlling other environmental parameters important for the development of corals (turbidity, light, salinity, etc). Variations in the position of the delta, cycles, changes of sea-level, and active plate tectonics through time might also be considered to have an influence on coral composition. These elements will be taken into account in our integrated analysis with the other geological components of the TF project.

Although preliminary, the following general patterns can be noted:

- Platy coral assemblages are common during the Early-Middle Miocene (up to Serravallian age), especially in the vicinity of the Mahakan Delta where they seem to dominate the coral settings. Comparisons among the platy coral assemblages, from south to north (TF76-TF52, TF51-TF57, TF59, TF153, TF126), and the northernmost locality of Serravallian age (TF522), will allow assessment of the degree of influence of the Mahakan Delta on the coral communities (species composition, structure) along the spatial gradient during the Middle Miocene.
- Branching coral assemblages followed by massive corals do not occur near the Mahakan Delta, but they seem to be more frequent towards the north, far from the current delta influence. Whether the observed species turnover is due to a major change in the environmental conditions in the area after the Middle Miocene, or is explained merely by the Mahakan Delta gradient (or represents a combination of both), will be an important question for the integrated analysis.
- Azooxanthellate corals have not been considered previously but the finding of some specimens during NTA-4 opens the possibility to begin exploring the different patterns in time and space that reef corals show in comparison with deep-water corals.

Species diversity is high in both platy and branching coral assemblages, and is comparable to modern coral settings living under similar environmental conditions. A total of 51 morphospecies (36 genera) have been identified so far, from which only three genera are considered extinct: *Dictyaraea*, *Anisocoenia*, and *Fungophyllia*. Among the most abundant genera provisionally identified are *Porites*, *Cyphastrea*, *Echinopora*, *Echinophyllia*, *Leptoseris*, *Stylophora*, *Seriatopora*, *Dictyaraea*, *Goniopora*, *Cycloseris*, *Favia* and *Favites*. A complete inventory of species will be possible after examination of this material.

New skills

Based on the experience gained during NTA-2, I was better able to plan this second expedition. Priority was given to filling gaps in information or questions posed from NTA-2.

Permits were not an issue this time as all the legal procedures had been solved during NTA-2. Since the group was split, budget management and logistic arrangements were also part of my responsibilities.

This time it was also possible to interact with different Indonesian colleagues, such as Pak Untung and Pak Aseb, who kindly collaborated in the collection of corals during the field trip. The language barrier was lessened by quick learning/teaching of “survival phrases” in both English and Bahasa, and doses of humour. The multicultural ingredient was enhanced by attending an Indonesian wedding, thanks to the invitation of Dr.= Fauzie Hasibuan (leader counterpart of Pusat Survei Geologi).

Appendix

Links to data sets and other documents resulting from NTA-4.

1. List of outcrops studied during NTA-2 and NTA-4

2. List of samples collected during NTA-2 and NTA-4

3. Stratigraphic logs of studied section available on request.

4. Cruise Report Cruise report of Sonne 217 MAJA - Variability of the Indonesian Throughflow within the Makassar-Java Passage. Part 1, and Part 2.