On-board Report for training on
BEAGLE 2003
Blue Earth Global Expedition 2003

R.V. Mirai: leg 3: Valparaiso, Chile – Santos, Brazil
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Contents:

1. Background

Whereas sediment-coring activities in Namibia are carried out mainly on the inner shelf to investigate the microbial processes taking place in the diatomaceous mud; cores taken during this cruise focused on the palaeo-oceanographic record of overlying water column processes, to fall within the objectives of the " Southern Hemisphere Hydrographic Navigation" or BEAGLE cruise. The participants in this cruise included Japanese Marine Science and Technology (JAMSTEC); Universities of Hokkaido, Nagoya and Kyushu, Japan; University of Concepcion, Chile; Marine Works Japan (MWJ); GODI as well as national institutes and universities in Argentina, Uruguay and Brazil.

We are very grateful to JAMSTEC for the opportunity to have been included in this leg of the cruise: special thanks to overall cruise-leader Prof. Masao Fukasawa and chief scientist of leg 3, Dr. Naomi Harada for making this possible.

In Namibia only two scientists, Bronwen Currie and Kathleen Peard, participate in sediment-coring activities as part of a study of biogeochemical processes in the inshore Namibian diatomaceous mud sediments (<100m water depth). These processes result in methane and hydrogen sulphide generation close to the sediment –water interface. Under certain trigger conditions (that are not fully understood), methane gas contained in gas pockets within the sediment is released into the overlying water column, carrying hydrogen sulphide to the sea surface and creating an anoxic water column environment which causes mortality of fish and crustaceans trapped by the eruption. The loss of potential fish recruits of economically important fish species such as hake *Merluccius capensis*, is of significance to the Namibian Ministry of Fisheries. Cruises take place on a 2-monthly basis over a 3 year period, in association with the BENEFIT programme, a southern African regional science fund, and Max Planck Institute for Marine Microbiology in Bremen. Due to the small size of the Namibian Fisheries research vessel multicorer only can be deployed. The sulphate reduction rates of hydrogen sulphide utilizing sulphur bacteria (such as *Thiomargarita namibiensis*, *Thioplaca* and *Beggiotoa* - the latter two also occur in sediments from the Chile coast) are measured from multicores

injected with S^{35}.Analyses of the methane concentration and pore water hydrogen sulphide and sulphate content of the sediment are carried out.

Deep cores however were recently taken off Namibia during *RV Meteor* cruises (M48/3 in 2000 and M53/2 in 2003). These could be of interest for comparative palaeo-oceanography in the two regions. During the first 4 months of 2004 the *RV Humboldt* will conduct a cruise in Namibian waters, including full sediment sampling legs.

At recent collaborative efforts between scientists of the Benguela and Humboldt regions (workshops of November 2002 and March 2003 in Namibia), the biogeochemical zones in the two upwelling regions were considered important future research foci. Both Humboldt and Northern Benguela regions collaborate on various aspects with German institutions (Max Planck Institute for Marine Microbiology, Institut fur Ostseeforschung); participation in this cruise widens our international contact.

In preparation for the Leg 3 cruise the Namibian contingent were requested to assist as required with processing of samples for the various projects, rather than to propose and run an additional project.

2. Objectives of Leg 3 (from Dr Naomi Harada – Cruise leader)

Past variation and changes in the thermohaline circulation and biogeochemical cycle recorded in marine sediment provide important information to predict the future global climatic change. Since a large part of southern hemisphere is occupied by ocean, southern ocean significantly influences theclimatic change of southern hemisphere. Sediment work on legs 3 and 6 of the BEAGLE cruise will address three themes which are important in paleooceanography:

1. deep water circulation, the southern ocean is an area of deep water formation, such as the Circumpolar Deep Water and Antarctic Bottom Water, thus playing a key role in the earth climate system. Deepwater circulation changes in the Southern Ocean will be the focus of leg 6 when several core samples are to be collected from the Kerguelen Plateau.
2. biogeochemical / carbon cycle
3. phase lag or synchronization of the sea surface environment between southern and northern hemispheres.

A hypothesis for each theme was made and survey results seek to test these hypotheses. Based on the results, it is hoped to define the past environmental change in the whole southern hemisphere since the last deglacial period, and make use of data collected to construct a paleo climate prediction model.

2.2 Carbon cycle: According to the vertical profile of pCO_2 in the Vostck ice core,PCO2 in the air during the last glacial maximum (LGM) was very low. One of the hypotheses to explain low pCO2 is that the release of CO2 from the sea surface of the southern ocean decreased because of the expansion of the sea ice area during the LGM. .We will use sediment cores at the off Chile for estimation of sea ice expansion. If the sea ice area were expanded in the southern ocean during the Lower Glacial Maximum (LGM) rather than Holocene, the polar front located at 40~50˚S in the modern south Pacific would have migrated to a more northern latitude. We will collect three piston cores between 30˚ and 60˚S and will estimate paleo sea surface temperature by $\delta^{18}O$ and alkenone methods to determine the variation of north-south migration of polar front.

Another reason for low pCO2 could be that phytoplankton were better able to fix carbon due to more efficient utilization of nutrients and / or changes in the phytoplankton assemblages at that time. The Cd/Ca ratio of planktonic foraminifera will be used as a nutrient proxy to determine variations in the nutrient cycles of the southern oceans. To understand possible changes in productivity, opal and organic carbon contents of the sediments will be analysed as well as the stable isotope ratio of carbon and nitrogen. Primary production increase in LGM could have resulted from increase in supply of e.g iron from wind borne dust, so metal isotope ratios such as Rb-Sr, Sm-Nd and Lu-Hf originated from dust will be measured.

- **2.3 Climate linkages between Northern and Southern Hemispheres**

The bipolar seesawing climate change in sub-Milankovitch to millennium time scales has been hypothesized by researchers based on climate reconstructions from both ice-sheet and deep-sea sediment records. However, there is no clear consensus on the interhemispheric climate linkage yet, but researchers argue that interhemispheric climate change was synchronous in the same time scales.

$\delta^{13}C$ and micro metals such as Mg, Cd will be analysed in multi species of planktonic foraminifers and alkenone SST within high time resolution by using sediments from the Chile region. These data provide us time-series data on ocean surface environments to resolve sub-Milankovitch to millennium scale climate changes in the Southern Hemisphere.

- **2.4 Geological and Geochemical analyses**

We are planning total 6 piston core sites and 6 multiple core sites in this cruise. Three piston cores and three multiple cores will be obtained at the off Chile in the Pacific, two piston cores and two multiple cores on the Kerguelen plateau in depth transect, and one piston core and one multiple core on the southeastern Indian Ridge in the Indian.

After the sediment coring, not only visual description, but also some physical property data, magnetic susceptibility, density, color, invisible structure will be taken by a multi sensor core logger, a colorimeter, a soft x-ray system, all equipment is on board the *RV Mirai*.

In order to achieve good and multiple paleaoceanographical resuts, the geological and geochemical analyses and number of persons in charge are planned as follows:

a) $\delta^{18}O$ and $\delta^{13}C$ of planktonic and benthic foraminifera……..3
b) Micro-metal (Cd, Mg) of planktonic and benthic foraminifera…..2
c) Planktonic foraminiferal assemblage……...2
d) Radioralia assemblage……...2
e) Diatom assemblage……2
f) Coccolith assemblage……2
g) Total carbon, organic carbon, total nitrogen content and $\delta^{13}C$ and $\delta^{15}N$ of bulk organic matter……2
h) Opal content……..2
i) Alkenone ……2
j) ^{14}C (foraminifera, bulk organic matter, specific organic compound)..2
k) Paleo-magnetic intensity……..2

l) Dust origin metal isotopic ratio (Rb-Sr, Sm-Nd, Lu-Hf)……2
m) Grading and ice rafted debris analysis ……..2
n) Others (besides a – m)……a few

3. Sampling Stations:

Station No	Date	Latitude	Longitude	Cores	Surface Water samples
1	20 10.2003	$36^0$13.33S	74^0 00.00W	Piston Gravity (x2) Multicores	50 litres 2 litres
2	21.10.2003	40^0 00.28S	74^0 25.29W	Piston Gravity Multicores	50 litres 2 litres
3	24.10.2003	52^0 51.64S	74^0 01.46W	Piston Gravity Multicores	50 litres 2 litres
4	25.10.2003	53^0 34.27S	70^0 40.45W	Piston Gravity Multicores	50 litres 2 litres

4. Samples – an overview of sample types taken by all groups during leg 3

1. Meteorological observation
2. Geological/geophysical
    a. Multi-narrow-beam observation
    b. Sea-surface gravity measurement
    c. Surface three components magnetometer
3. Sediment
    a. Visual core descriptions
    b. Colour reflectance
    c. Multi-sensor core logging
    d. Soft X-ray photographic analysis
    e. Microfossils
    f. Biochemical and geological components (include paleomagnetism, radionuclides, a suite of biochemical compounds including alkenone biomarkers of paleoclimate; and strong emphasis on isotopes)
4. Plankton (continuous underway measurement from flow through system, intake at 4m below surface)
5. Continuous underway surface (4m) sampling
    a. Salinity, temperature,
    b. DO and fluorescence
    c. Nutrients
    d. Continuous pCO_2
    e. Continuous total inorganic dissolved carbon TIC
6. Shipboard
    a. ADCP
    b. Satellite
    c. Bio-optical – radiation and primary production measurements
7. Atmospheric
    a. Aerosol
    b. Particulate carbon

Cloud and rain

5. Sample Processing

Water: 50 litres of water was collected from the continuous flow through system in the sea surface water monitoring lab, the depth of water intake being 4m below surface. This was filtered through pre-combusted filters for analysis of material collected on the filters for surface production, isotopes and degradation products. The filters were immediatlely frozen for shore based analysis by University of Concepcion.
An additional 2 litres of water were filtered at each station through 0.45µm Millipore filters for immediate microscopic inspection of the phytoplankton assemblage in the surface waters.

Sediment: Prior to commencing a station, a site survey was conducted to select the specific coring site using multi-narrow beam observation. An XBT was deployed to determine the exact water depth before deploying the first core. All coring equipment was prepared by Marine Works Japan (MWJ) and deployed by MWJ and the deck crew of *RV Mirai*.

Three types of coring devices were deployed:

1. The piston corer is 8cm inner diameter and 20m in length,
2. The gravity corer has 12cm inner diameter and is 7m long
3. The multiple corer has 8 sub-cores, and each sub-core is 8cm inner diameter and 30cm in length.

The cores were split and sectioned (1cm intervals). Sections were further processed by teams in the laboratories adjoining the main deck, working to divide the sections appropriately into samples, packaged and preserved according to the required analyses, which will be carried out at the home-laboratories. All cores were processed in the days between and following coring stations, amounting to several thousand packaged samples. This practical core-to-sample processing was completed on 31 October.

Assistance was rendered to JAMSTEC scientists in the geological laboratory during subsampling of cores, specifically :

- piston and gravity cores : 2.2cm cube samples were taken (T. Mashima) these subsamples will be used to determine the age of cores through paleomagnetic features (magnetostratigraphy). The samples will also be used to determine changes in the sea bottom environment by measurement of the amount and physical parameters of magnetic minerals.
- piston cores subsamples were taken (H. Kanke) to measure the ^{14}C age of compound specific molecules which is a very new technique in geochemistry.

In conclusion I would like to thank Captain, cruise-leader, crew, scientists and technical staff for this enriching and very enjoyable and special cruise. We plan to keep in contact regarding future collaboration. My grateful thanks for the invitation to participate in this cruise from JAMSTEC, as well as for payment of my berth fees on board *RV Mirai* and in particular to IOCCG for scholarship funds for travel costs to and from the *RV Mirai*.

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On board *RV Mirai*