METEOR Cruise 77/1

Talcahuano (Chile) – Callao (Peru)

Weekly Report No. 1: 22. 10. -26. 10. 08

FS METEOR

Due to a delay in the ship yard inspections the M77-1 scientific party which arrived on the 20-10-08 could board METEOR only after a stay in a hotel on the morning of the 22-10-08. Until 15:00h we loaded our equipment from five containers on the pier with the help of a land crew. Four Containers were taken onboard and were unloaded by the scientists. It was also planned to refuel the ship on the same day and to leave the port lately the next morning but due to the weather situation the bunker vessel from Valparaiso was rescheduled for the afternoon of the 23-10-08. We left the shipyard in the morning of the 23-10-08 at 08.12h and anchored in the Bay of Talcahuano to await the bunker vessel which arrived at 16:00h. After refuelling followed by custom and immigration clearance we finally left Talcahuano roadstead at 23:30h with a delay of two days. Since then we are steaming north along the Chilenian coast to our first area of investigation at 18°N in Peruvian waters (Fig. 1). Our progress is supported by tailwinds and currents and we expect to arrive around mid night on Monday 27-10-08. So far we did not receive the working permission from Peru.

On behalf of the science party and ***Meteor*** crew, our very best regards.

Olaf Pfannkuche

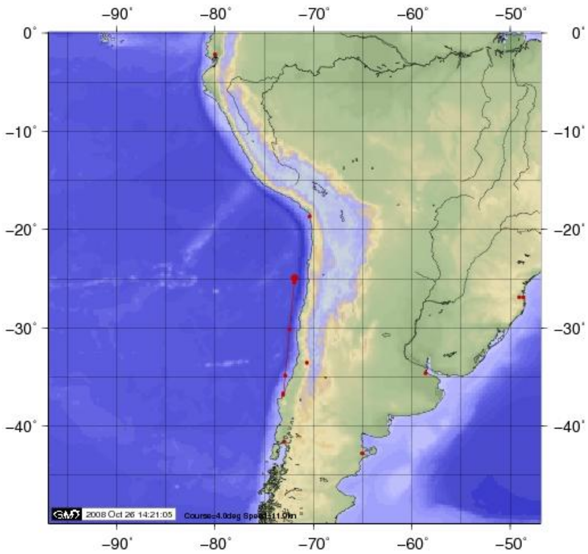


Fig. 1: Cruise track towards the 18°N station (last position noon 26-10-08).

METEOR Cruise 77/1

Talcahuano (Chile) – Callao (Peru)

Weekly Report No. 2: 27. 10. -02. 11. 08

FS METEOR

Olaf Pfannkuche

We continued our passage to the first working area until Monday evening (27-10-08) when we reached our first station in 17°50´S/072°05´W at 21:30h in the Peruvian EEZ. We started station work with a CTD/RO cast by 2000m depth commencing from here an upslope transect with multi-beam EM120/EM710 and Parasound to about 130m depth. We performed CTD/RO casts on the transect line near the 1000m, 800m, 500m, 300m and 200m depth contour. After producing a bathymetric map based on the multi-beam survey and with a more detailed knowledge of the spatial extend of the OMZ (see below) we surveyed the 18°S-transect until Thursday (30-10-08). We took benthic samples with the TV multi-corer and gravity corer by 1000m, 800m, 500m, 300m, and 200m, depth, drove three OFOS transects on the upper slope, continued our CTD/RO survey and deployed the first BIGO-Lander. With the successful retrieval of the BIGO Lander we left the 18°S-transect in northern direction heading to 11°S. It was originally planned to investigate a transect in the vicinity of 12°S but since the course of a 5 miles coastal zone which limits our research area expands too far out, due to some islands, we could not investigate water depths beyond 150m. Therefore we shifted our area of investigation to 11°S where we could sample to a depth of 80m.

We shortly interrupted our approach to 11°S at 15°S where we took a series of samples by 500m depth with gravity corer, multi-corer and CTD/RO.

We reached our first station at 11°S on Saturday evening (01-11-08) at 21:00h and started station work with a CTD/RO cast by 1000m depth followed by an upslope transect with multi-beam EM120/EM710 and Parasound to about 85m water depth on the shelf and with CTD/RO casts near the 700m, 800m, 500m, 300m, 200m, 150m and 80m depth contour. The transect extends across 40 nautical miles. The multi-beam/ Parasound tracks were continued until Sunday afternoon to produce a bathymetric map of the area which will lay the foundation of our benthic work for the next week.

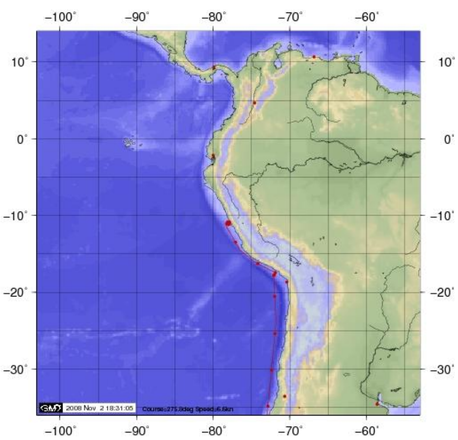


Fig. 1: Cruise track towards the 11°S-transect (last position afternoon, 02-11-08).

During the 1st week of M77-1 we completed a short survey using a CTD/Rosette water sampler (a device which measures temperature, salinity and pressure and especially for this cruise includes oxygen sensors and takes water samples) across the southern part of the Peruvian continental shelf at 18°S. We encountered the following spatial extend of the low oxygen zone (Fig. 2) in the water column across the shelf and into the open ocean. We found that dissolved oxygen was rapidly depleted from the surface waters so that by 80m depth there was less than 0.1% saturation (the percentage of the amount of oxygen that would be present if the water was at the surface and in equilibrium with the atmosphere). The OMZ continued to approximately 400 m depth after which oxygen increased again in the water due to supply via mixing with oxygen containing deep waters.

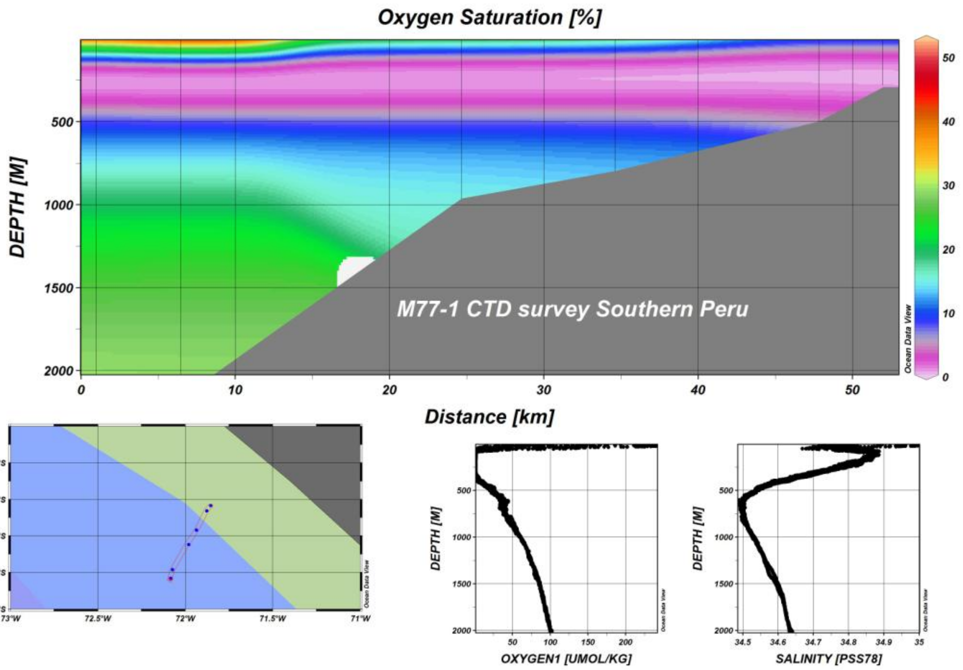


Fig. 2: The present structure of the OMZ at 18°S

On behalf of the science party and ***Meteor*** crew, our very best regards.

Olaf Pfannkuche

METEOR Cruise 77/1

Talcahuano (Chile) – Callao (Peru)

Weekly Report No. 3: 03. - 09. 11. 08

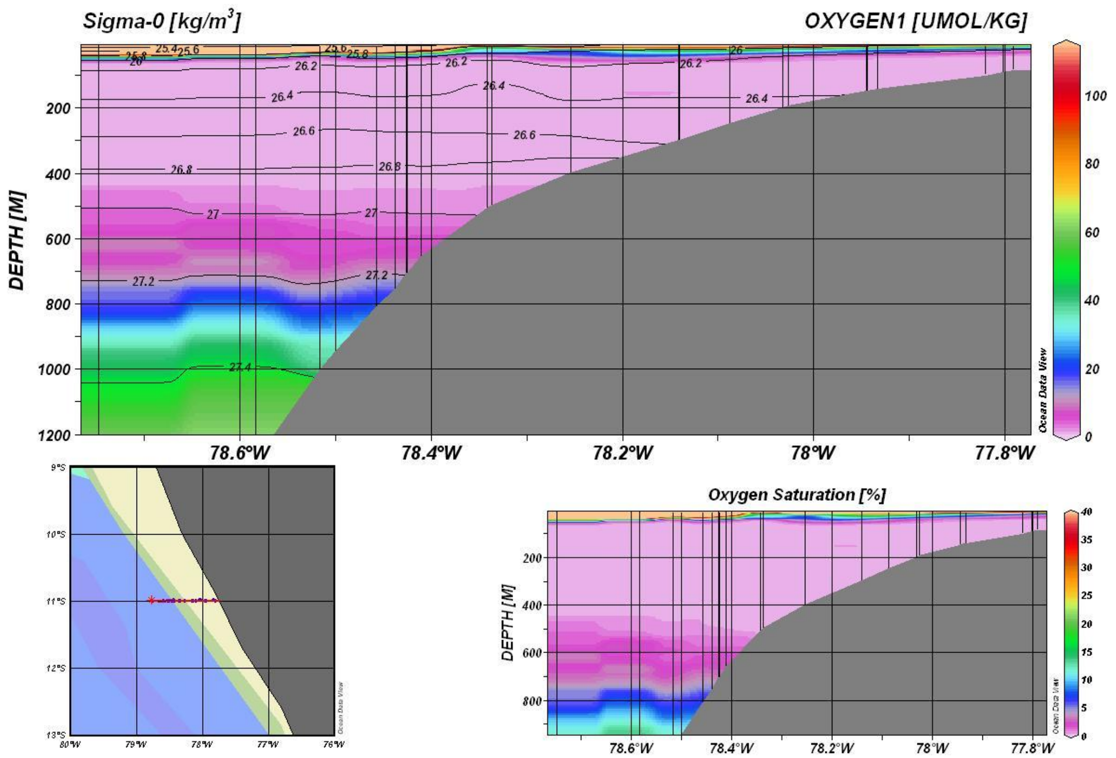
FS METEOR

Olaf Pfannkuche

The last week was dedicated to station work at the 11°S-transect which is located in the area of the strongest upwelling intensity. We mapped a transect line with the multi-beam from 80m depth on the shelf to 2000m on the continental slope stretching as far as 56nm. Our station work comprised of CTD/RO casts, OFOS-transects, multi- corer and gravity corer sampling as well as lander deployments across the full depth range of the transect.

Our CTD-survey at the 11˚S-transect line encountered a well developed low oxygen zone (Fig. 1) in the water column across the shelf and into the open ocean. We found that dissolved oxygen was rapidly depleted from the surface waters so that by 80 m depth there was less than 0.1% saturation. The OMZ continued to approximately 400 m depth after which oxygen gradually increased again in the water due to supply via mixing with oxygen containing deep waters.

Fig. 1: Oxygen concentrations across the Peruvian shelf at 11˚S derived from CTD measurements obtained during M77-1.



The low oxygen waters below the surface have strong affects on some chemical cycles. This is most important for redox reactions in which an element can be altered from one oxidation state to another such as in the case of iron where Fe(III) is present when oxygen concentrations are high. This is a highly insoluble form in water and is responsible for the formation of iron oxides. In the absence of oxygen iron can be transformed into Fe(II) which forms green coloured solutions and is highly soluble in water. Another element is iodine normally present in seawater as iodate (IO_3^-) when oxygen is present. In the absence of oxygen it is chemically reduced to iodide (I^-). Presently however we know very little about how this change occurs and what organisms may be responsible. Using water samples obtained from the CTD/rosette we are currently measuring onboard the concentrations of iodide/iodate and Fe(II) to examine the influence of the OMZ on the cycling of iodine, iron and other redox sensitive elements. Our initial results indicate that in the OMZ iodine is only present as iodide and that in the low oxygen waters near the sediments there are high concentrations of iron present as Fe(II) which have been released from the sediments.

Ocean floor observation and imaging was performed along the 11° S-transect to identify benthic habitats which can be related to different biogeochemical provinces across the continental margin. So far we did eight surveys with the OFOS (Ocean Floor Observation System) covering about 10nm of the sea floor. OFOS carries a video camera, a digital camera which triggers automatically one picture every minute and a storage CTD with oxygen optodes. So far we made about 1000 high definition photos of the seafloor. In the shallower parts underlying the OMZ large aggregations of bacterial mats occur with variable coverage (Fig. 2). At 200m depth the seafloor is nearly completely covered with bacterial mats whereas by 400m only singular patches of bacterial mats are visible. The part of the transect which is outside the core of the OMZ (between 450 and 750 meters water depth) was already completely mapped. The pictures show a great diversity of megafauna (Fig. 4). We observed distinct zones of echinoderm occurrence such as a sea and a brittle star belt. The population of the brittle stars is extraordinary high (Fig. 3). Beyond 1000 meters the number of megafauna organisms clearly decreases.

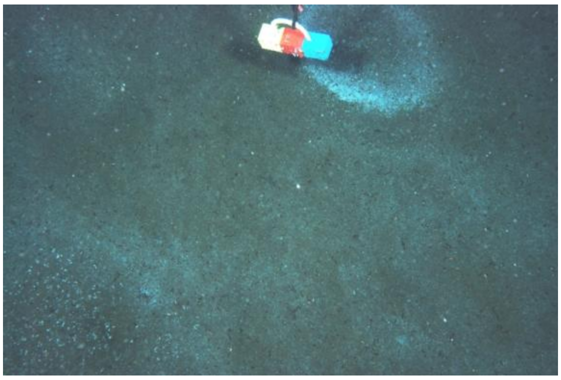
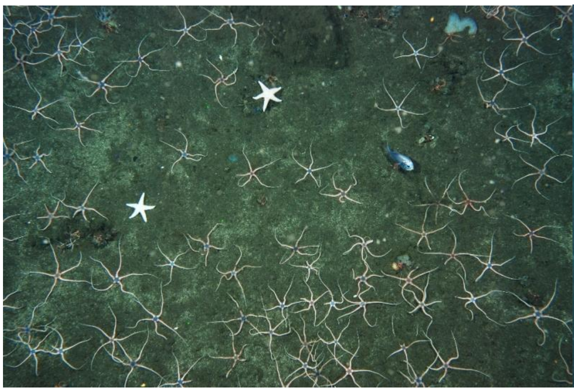


Fig 2-4: Bacterial mats (left above); brittle star belt at 650m (left below); Antozoa at 750m (right below).



We carried out a series of in situ flux measurements in the benthic boundary layer along the 11°S-transect to resolve the effect of changing oxygen conditions on the speciation and flux of nitrogen compounds across the sediment water interface. For our survey we employed the biogeochemical lander observatories BIGO and BIGO-T. Furthermore, extended measurements of N_2, Ar and other gases were conducted in the benthic boundary layer using a CTD/rosette which was equipped with the in situ membrane inlet mass spectrometer "TETHYS" (Fig. 5). These measurements are taken in cooperation with R. Camilli (Woodshole Oceanographic Institution).

TETHYS was deployed successfully during several CTD/RO casts. In a combined approach the TETHYS in situ measurements are cross-calibrated with ex situ measurements of water samples retrieved by the rosette sampler using a ship board laboratory membrane inlet mass spectrometer, MIMS, which is calibrated for di-nitrogen and oxygen. Our measurements identified distinct regions at the continental margin where the bottom water shows higher N_2/Ar ratios compared to the N_2/Ar ratio at saturation for the respective temperature and salinity. These measurements point towards benthic denitrification and/or anammox releasing N_2 into the bottom water.

Fig. 5: CTD/rosette instrumented with the in situ mass-spec. THETYS.

Strong N_2 release started at a water depth of 600 to 700 m where oxygen bottom water concentration declined below about 8% saturation. At this depth range distinct macro-benthic communities such as ophiuroids were observed to occur at extremely high densities (see above). N_2 release continued until a water depth of 200m is reached. Beyond 200m depth no indications for N_2 release were found except at the shallowest station at about 80m. This depth range is characterized by the occurrence of dense microbial mats. The 80m station might be highly dynamic with regard to benthic nitrogen turnover, periodic oxygen intrusion into greater depths might occur periodically which could trigger benthic nitrogen turnover. At depths greater than 700m no indications for nitrogen release were detected.

In the following week we will continue with lander measurements to confirm the observations we made in the bottom water and to resolve the strength of the N_2-release. First lander measurements indicate higher N_2 release at 300 m water depth compared to a site at 700 m which was just below the zone where we detected high N_2/Ar ratios in the bottom water.

On behalf of the science party and Meteor crew, our very best regards.

Olaf Pfannkuche

METEOR Cruise 77/1

Talcahuano (Chile) – Callao (Peru)

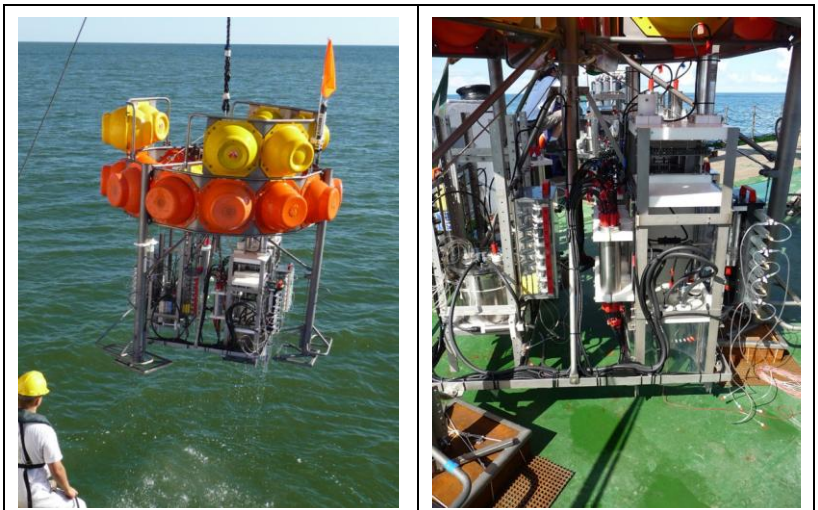
Weekly Report No. 4: 10. - 16. 11. 08

FS METEOR

Olaf Pfannkuche

Our activities during the last week were again partly dedicated to station work at the 11°S-transect. We also expanded our radius to two smaller transects 40nm north and 20nm south of the 11°-S transect. Both transect lines were mapped with the multi-beam. They extend about 25 miles each and cover a depth gradient of 200m to 1000m. Station work at the new transects was restricted to CTD/RO casts, OFOS-surveys and multi- corer sampling at key depths within and out site the core of the OMZ, whereas at the 11°-transect we concentrated to lander deployments and filled in some gaps of benthic sampling and CTD/Ro casts. By repeated CTD/RO surveys at the 300m-Station we could demonstrate the occurrence of temporal oxygen intrusion into the OMZ. In total we deployed 14 landers along the 11°S-transect line covering a depth range of 85m-1000m. The majority of landers deployed were of the BIGO-type (Biogeochemical Laboratory). The BIGO contains two benthic mesocosms to measure sediment water interface fluxes of oxidants, N-compounds and nutrients (Fig. 1). A modified version the BIGO-T (BIGO+THETYS) was deployed with one mesocosm unit replaced by the THETYS in situ mass spectrometer.

Fig. 1: Left - retrieval of BIGO after a successful deployment; **right** - a cylindrical benthic mesocosm with syringe water samplers. The mesocosm is connected to an oxistat which regulates the oxygen regime in the mesocosm (ca. 5µM accuracy) via the black hoses.

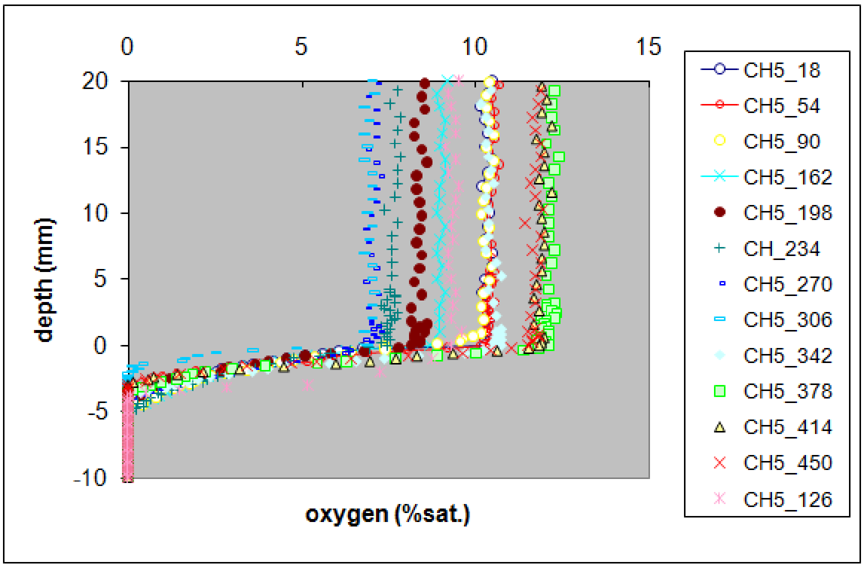


A new micro-electrode sediment profiler which was developed at IFM-GEOMAR in cooperation with Unisense (Arhus,DK) was successfully deployed down to 1000m integrated into a GEOMAR Modular Lander (Fig. 2). The profiler module can also be placed with a ROV on the sea floor. The new profiler has unlike its predecessors the capability to measure in three dimensions (x/y/z). The profiler unit carries four micro-electrodes which can measure oxygen, H_2S and pH.

Fig. 2: Left - deployment of a GEOMAR Modular Lander carrying the micro-electrode profiler module; **right -** the profiler is programmed for deployment.

A new concept of integrating a miniaturized amplifier, which hitherto was housed in a large pressure vessel, directly onto the micro-sensors allows to operate the sensors in three dimensions. Figure 3 shows a series of oxygen micro-profiles along the x axis (430mm) at 1000m water depth outside the OMZ. The maximum oxygen penetration depth was approximately 3-4 mm. The profiles were taken during a time interval of about 14 hours, the changing bottom water oxygen concentrations indicate internal periodicity (e.g. tides).

Fig. 3: Oxygen micro-profiles measured along the 430mm wide x-axis. The sediment surface (at 0mm) is indicated by a strong drop of the oxygen concentration in the bottom water close to the sediment surface.



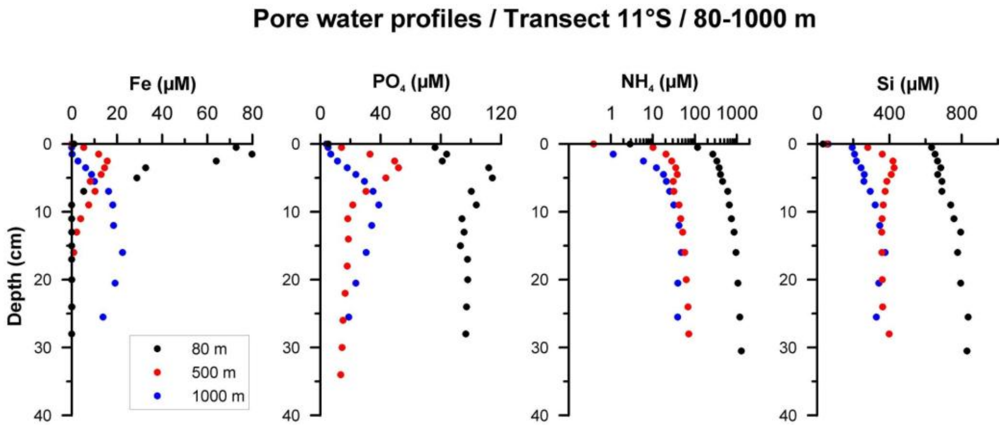
One aim of this cruise is to contribute to our understanding of the benthic-pelagic coupling in the ocean by examining key geochemical species, whose chemical behaviour and distribution are altered via changes in redox potential. It is well known that essential nutrients like phosphate and iron are preferentially released from sediments under anoxic conditions. However, the magnitude of this recycling flux, the relative importance of key control parameters, and the coupling to carbon and sulphur cycles are largely unconstrained. In order to overcome this lack of knowledge we performed geochemical analyses of pore water from surface sediments that were retrieved by multi-corer and by the benthic mesocosms of the BIGO Lander.

Based on CTD/RO casts the exact location of the oxygen minimum zone had already been characterized in detail along the 11°S-transect, so that sediment sampling could be directed to positions with varying degrees of bottom water oxygenation. In general, the sediments are rich in organic material and contain high amounts of biogenic opal (diatom ooze) and carbonate. At a number of locations diagenetic crusts and phosphorites (Fig. 4) could be observed.

Fig. 4: Large phosphorite concretions sampled with the gravity corer.

Selected pore water profiles from 3 stations at 80m, 500m and 1000m water depth (Fig. 5) illustrate differences in mineralization intensity and related benthic fluxes. Phosphate and ammonia are released into pore water by organic matter breakdown, whereas the sub-seafloor increase of silicon indicates the dissolution of diatom tests. The profiles reflect the decrease of organic matter input with increasing water depth. High subsurface peaks of dissolved iron at 500m and particularly at 80m depth further indicate the lack of oxygen and the instantaneous use of metal oxides for organic matter mineralization right below the sediment-water interface. The zone of Fe-release is shifted further downward as soon as oxygen becomes available at greater water depths (1000 m). A detailed examination of the data will help us to quantify diagenetic turnover in the sediments and hence, the quantification of benthic exchange fluxes. At present a second transect is sampled and a third one is planned for the upcoming days in order to extend the available data base and record spatial variability.

Fig. 5: Selected pore water profiles of iron, phosphate, ammonia and silicon at 11°S.



On behalf of the science party and Meteor crew, our very best regards.

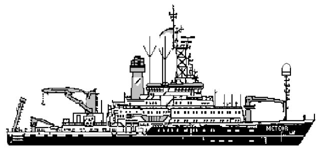
Olaf Pfannkuche

METEOR Cruise 77/1

Talcahuano (Chile) – Callao (Peru)

Weekly Report No. 5: 17. - 21. 11. 08

Last Report



FS METEOR

Olaf Pfannkuche

We worked at the 11°S-transect and its southern addition at 11°20´S until Monday evening (17-11-08). During the night we steamed South to establish another shelf - slope transect line at 12°30´S. This new transect covered a depth gradient from 160m to 1100m extending as far as 25 miles. The area was mapped with multi-beam and Parasound. Station work at the new transect was restricted to CTD/RO casts, OFOS-surveys and multi- corer sampling at key depths within and out site the core of the OMZ. Station work ended on Thursday afternoon (20-11-08) at 16:20h. We arrived at Callao harbour on Friday (21-11-08) at 07:15h. With the disembarkation of 17 scientists in the afternoon leg M77-1 ended. 9 scientists will continue their investigation during M77-2.

Cruise M77-1 was highly successful. We gained a multitude if interesting results some of which promise to be outstanding. However, most of the groups attending leg 1 will continue in leg 2 enlarging the data basis. Although shorter in time than planned, we more than fulfilled our planned sampling programme. All gear operations went smoothly facilitated by the calm weather conditions. The ship´s systems functioned well and in consequence we did not lose any station time by malfunctions. We covered 3860nm and worked with varying intensity at six locations between 18°S to 11°S (Fig. 1). Our main emphasis was clearly on the 11°N-transect. In total we drove 246 Stations with 55 CTD/Rosette casts, 16 lander deployments, 87 TV-multiple casts, 23 gravity corer casts, 34 OFOS surveys and 21 multi-beam/Parasound surveys.

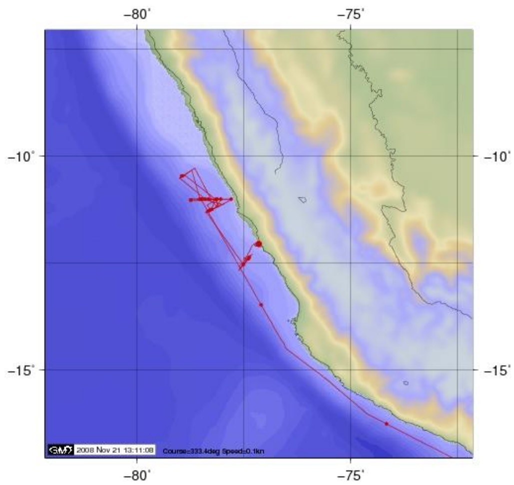


Fig. 1: Track plot Cruise METEOR 77-1.

On Saturday evening (22-11.08) a reception on board METEOR will be given to Peruvian officials from the government, IMARPE, the university and harbour authorities in cooperation with the German Embassy which will be attended by R. Schneider (chief scientist Leg 2) and me.

The success of this expedition was not possible without the dedicated and professional performance of captain Baschek and his crew which is acknowledged gratefully by us.

On behalf of the science party and Meteor crew, our very best regards.

Olaf Pfannkuche