MIDAS
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Managing impacts of deep sea resource exploitation

Spring 2014 Issue 1

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Welcome to the first newsletter of the MIDAS project. We have been underway for 6 months and have already begun to make an impact. The kick-off meeting in November 2013 was a success, not least in revealing the extent and complexity of the project and enabling partners to see clearly where their work fits into the big picture. Since then there have been a number of important internal events such as the WP3 ecotoxicology workshop in Portugal and the WP6 workshop on benthic ecosystem response to disturbance, both of which were important steps in starting practical work and are reported in this newsletter.

Marine science is dependent on research cruises to collect data, and the MIDAS community will be involved in numerous field campaigns over the next few years. The first expeditions have already been completed and you can read about some of these in this newsletter. This has enabled some of our experiments to get underway, such as the deployment of long-term moorings to measure currents and the release of tracers to provide mixing/dispersion data for physical oceanographic models. Our work on gas hydrates is also underway with a geophysics cruise to the Danube deep-sea fan to collect important data on the extent of gas hydrate deposits in that area.

I recently presented the aims of MIDAS to a meeting of OSPAR's Environmental Impacts of Human Activities Committee. They are keen to maintain close contact with MIDAS to keep up to date with progress on environmental issues related to mining. We have also established links to the European Commission's Directorate for Maritime Affairs and Fisheries and Directorate for Enterprise, both of whom have interests in deep-sea mining issues - we will develop our relationship with these groups further during the project.

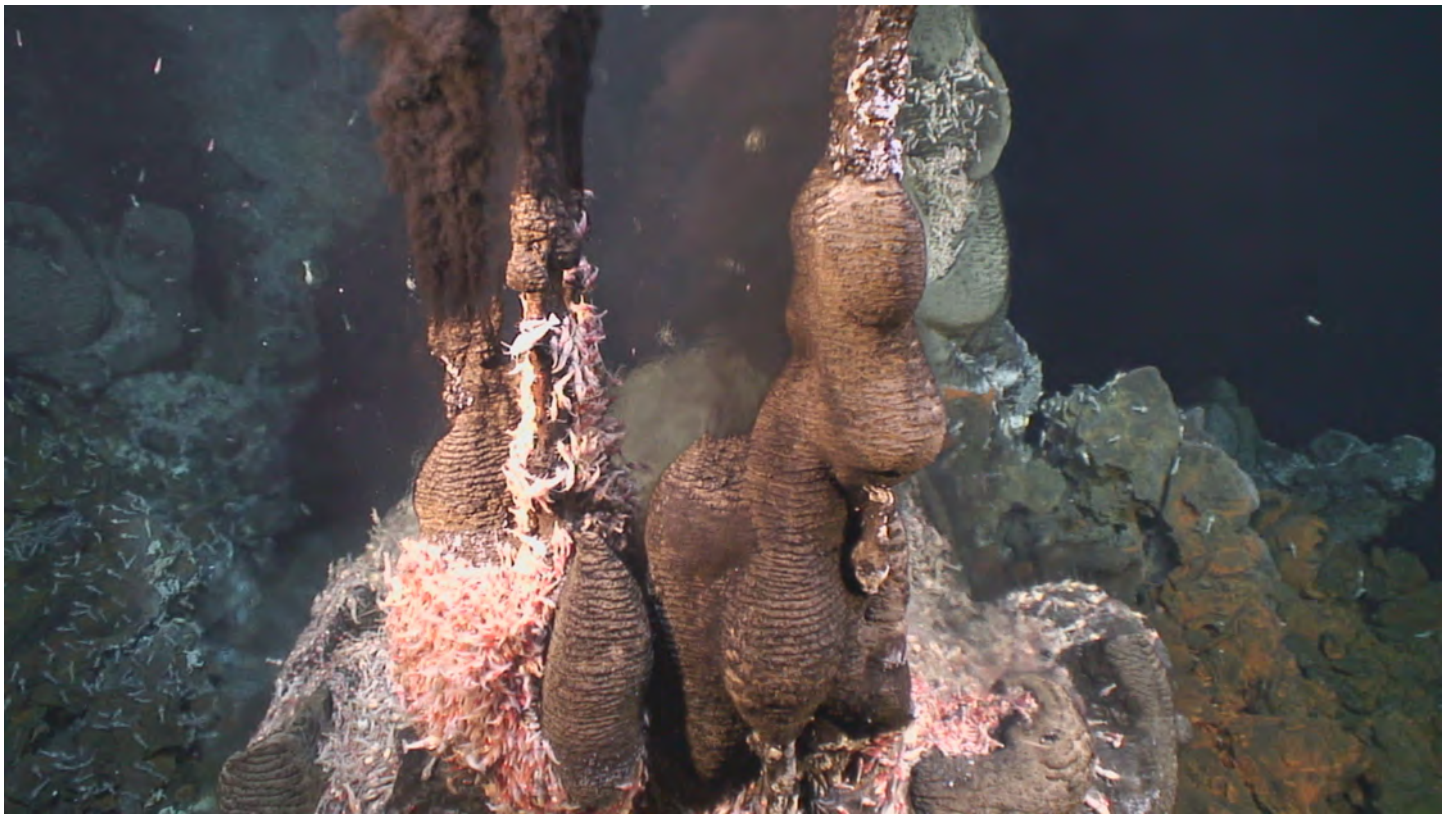
At present we are compiling a MIDAS response to the stakeholder engagement exercise initiated by the International Seabed Authority. We hope that this will create a pathway for MIDAS to contribute to the ongoing development of the regulatory framework for mineral exploitation in areas beyond national jurisdiction. This consultation is very timely for MIDAS as it will run in parallel to our research and help us to focus our efforts where they can be of most value. The Deep Ocean Stewardship Initiative (DOSI) will also be making significant contributions to this process. We have established strong links with DOSI and have also starting working with the SPC-EU Deep Sea Minerals Project (see p15).

The MIDAS website (www.eu-midas.net) has been online for some months now, and will continue to evolve over the course of the project. We hope it is both informative to the general public and useful for project partners. Please feel free to make suggestions for additions or improvements. There is considerable media interest in deep-sea mining, which will no doubt intensify now that Nautilus Minerals Inc. has agreed terms for mining sulphide deposits at the Solwara 1 site offshore Papua New Guinea. We will be watching developments there with great interest.

Prof. Phil Weaver
MIDAS Coordinator
Seascape Consultants Ltd

Bicose 2014: Exploring ridge ecosystems at TAG and Snake Pit

The Bicose expedition aboard the RV *Pourquoi pas?* set sail from Pointe à Pitre on 10 January 2014 for a 32-day investigation of the active and inactive vents at TAG and Snake Pit, two hydrothermal vent fields of the mid-Atlantic ridge. These areas are now included under the French exploration license for massive sulphide deposits granted by the International Seabed Authority.



Above: Shrimps and other chemosynthetic fauna thrive at The Beehive hydrothermal vent at the Snake Pit vent field, located at 23°N along the Mid-Atlantic Ridge. Image copyright Ifremer/Victor 6000, Bicose cruise (2014).

The two sites were specifically chosen so that the ecosystem and habitats at a young, active hydrothermal vent site (such as Snake Pit, which is thought to be less than 4,000 years old) can be compared to that found at a much more mature site such as TAG, which is estimated to be more than 40,000 years old. The aims of this multidisciplinary cruise were to characterise and decipher 1) interactions among the geological settings of the vents; 2) the geochemistry of the fluid along gradients of dilution; 3) the composition, metabolisms and activities of microbial communities; 4) the distribution and diversity of vent and non-vent assemblages; 5) the reproduction ecology, larval ecology; 6) host-symbiont relationships, and 7) physiological responses to stress of key symbiotic species such as *Rimicaris exoculta* and *Bathymodiolus puertoserpentis*.

The TAG and Snake Pit sites were both studied at nested spatial scales with the ROV *Victor*. At landscape scale, high-resolution bathymetric surveys were complemented with seafloor image mosaicking and video surveys in the periphery of active vents. At the scale of single vents, assemblages dominated by shrimps, mussels, gastropods or sea anemones were mapped and sampled and coupled with physico-chemical characterisation of the hydrothermal fluid. Substrates for colonisation were installed along gradients from active to inactive vents and autonomous pumps were deployed for 24-hour periods in order to sample larvae. Shrimps and mussels were sampled and kept under pressure no their journey from the seafloor up to the IPOCAMP and BALIST, two pressurised tanks designed for *in vivo* experiments. Under different sources of stress, the physiological response to increasing concentrations of copper was monitored in the shrimp *Rimicaris exoculata* and its bacterial symbionts.

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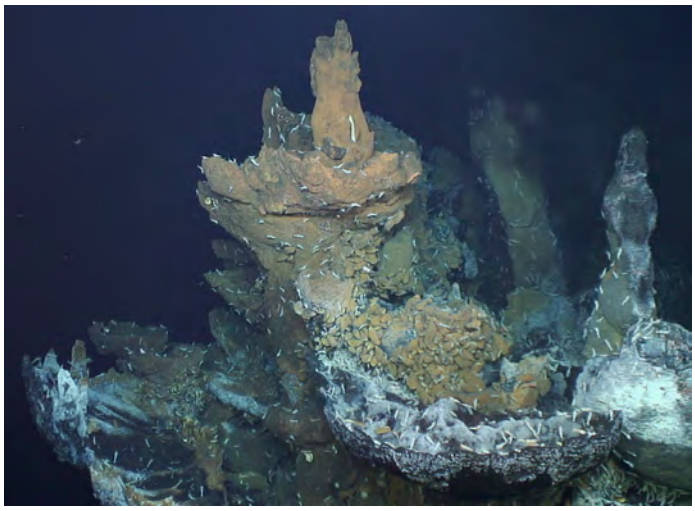
Preliminary observations show that both the epibenthic megafauna and macro-infauna are sparse at inactive vent sites. However, aside from the few occurrences of charismatic species like black corals, closer scrutiny reveals a hidden fauna such as likely new species of amphipod that lives in pairs on a stalk. The cruise also shed light on the reproduction of *Rimicaris* shrimps, with spatial segregation among males, females and juveniles. Many gravid females were observed forming swarms bathing in the warm fluid close to the vents, while isolated individuals away from the vents were mostly males. The youngest juveniles were observed aggregating near diffuse venting and seem to join the swarm later on in their development stages.

Results from the Bicose cruise will increase our understanding of the distribution and functioning of benthic communities at both active and inactive vents. Comparisons with other vent fields will provide clues on connectivity patterns along the Mid-Atlantic Ridge. These are the first steps towards a sound environmental management of mineral mining activities in the northern Atlantic.

The Bicose cruise blog can be viewed online (in French) at http://blogs.ifremer.fr/bicose/



Right, top: Black corals attached to rocky substrate on the Mid-Atlantic Ridge. Bottom: Chemosynthetic communities at The Moose, Snake Pit vent field, 23°N along the Mid-Atlantic Ridge. Images copyright Ifremer/Victor 6000, Bicose cruise (2014).

Workshop on the Spatial Environmental Management of Polymetallic Sulphide Minerals, NIWA, 2-4 April 2014

With increasing interest in polymetallic sulphide mineral resources in international waters and within the Exclusive Economic Zones (EEZs) of many nations, including Portugal, there is increasing interest in introducing regional environmental management plans for the conservation of biodiversity.

The VentBase 2014 workshop was held at National Institute for Water and Atmospheric Research (NIWA), Wellington, New Zealand, on 2-4 April 2014 to address this issue. The workshop was convened by Malcolm Clark, Ashley Rowden and Rachel Boschen of NIWA and attended by 24 participants including MIDAS partners Telmo Morato, (Instituto do Mar, Azores), Leigh Marsh (University of Southampton) and David Billett (Deep Seas Environmental Solutions Ltd).

The workshop was split into two themes. One theme compared the principles of regional spatial management for polymetallic sulphide mining by considering the existing regional spatial plan for polymetallic nodules in the Clarion Clipperton Zone (CCZ) in the equatorial eastern Pacific Ocean. The workshop assessed whether the scientific principles guiding the CCZ plan could be applied to seamount chains and mid-ocean ridges. The second theme investigated how new molecular genetic techniques might be applied to spatial planning in the oceans, and, in particular, to mid-ocean ridges, seamounts and back-arc basins, where polymetallic sulphide deposits are most likely to be found.

BGR exploration cruise into the NE Pacific: Analysis of the German manganese nodule license areas continues

A group of 9 scientists and technicians from the German Federal Institute of Geosciences and Natural Resources (BGR) recently boarded the American research vessel RV *Kilo Moana* for a 42-day expedition (15 April – 27 May 2014) to the German manganese nodule exploration license area in the Clarion-Clipperton Zone (CCZ), located between Hawaii and Mexico. This is BGR's sixth cruise into the area, licensed to Germany by the International Seabed Authority since 2006 for the exclusive rights to explore the inventory of metal-rich manganese nodules in a 75,000 km^2 area in the CCZ at a water depth of around 5,000 m over a period of 15 years.

During this research cruise, three economically interesting areas each with a size of ca. 1,500 km^2 will be analysed in detail. Exploration now focuses on those parts of the seafloor that have a favourable topography and the highest nodule abundances. At these potential mining sites, high-resolution samples of nodule-bearing seafloor sediments will be obtained using a box corer. A video sledge will be towed a few meters above the seafloor to obtain several km-long profiles of the seafloor. The combination of ground-truthing nodule abundance values and video and photographic material allows for a particularly good identification of nodule-rich zones. Nodules will be analysed geochemically for their metal and trace element contents in the home laboratories of BGR.

A further focus of the research expedition is the survey of biodiversity and faunal connectivity in the analysed areas. Five scientists from the German Centre of Marine Biodiversity Research (DZMB) of the Senckenberg Institute in Wilhelmshaven have joined the BGR exploration cruise for these purposes. During the exploration cruise last year, scientists from BGR and DZMB defined two reference areas required for the analysis of the environmental impacts of potential future mining: one prospective area in which the influence of (test) mining on the ecosystem should be investigated (known as the impact reference area), and one environmentally similar area located about 60 km to the west of the impact reference area which should remain pristine to provide the source for faunal recolonisation of impacted areas after mining (known as the preservation reference area). The benthic communities of these two areas are currently being studied morphologically and genetically from box core, multicore and epibenthic sledge samples taken in 2012, 2013 and now in 2014 to ensure the determination of potential spatial and temporal variability of species composition and to provide the basis for a future evaluation of the disturbance of the seafloor associated with possible tests of deep-sea mining equipment in the impact reference area.

Last but not least, three long-term Ocean Bottom Moorings (OBMs) equipped with 600 kHz ADCPs and 2 MHz Seaguard RCMs that were deployed in the eastern CCZ in April 2013 will be retrieved and redeployed for another year. These OBMs collect data on background mean flow current variability and tide-wave action close to the seafloor at hourly intervals throughout a time period of one year. Furthermore, a fourth mooring equipped with a longer ranging 150 kHz ADCP will also be deployed in order to obtain high resolution current data in 10 min intervals throughout the next year. These data are important for our understanding of the hydrodynamic regime of the area and are required as input for modeling studies aiming at evaluating the potential dilution and dispersion potential of the sediment plume produced by deep-sea mining nodule collectors.

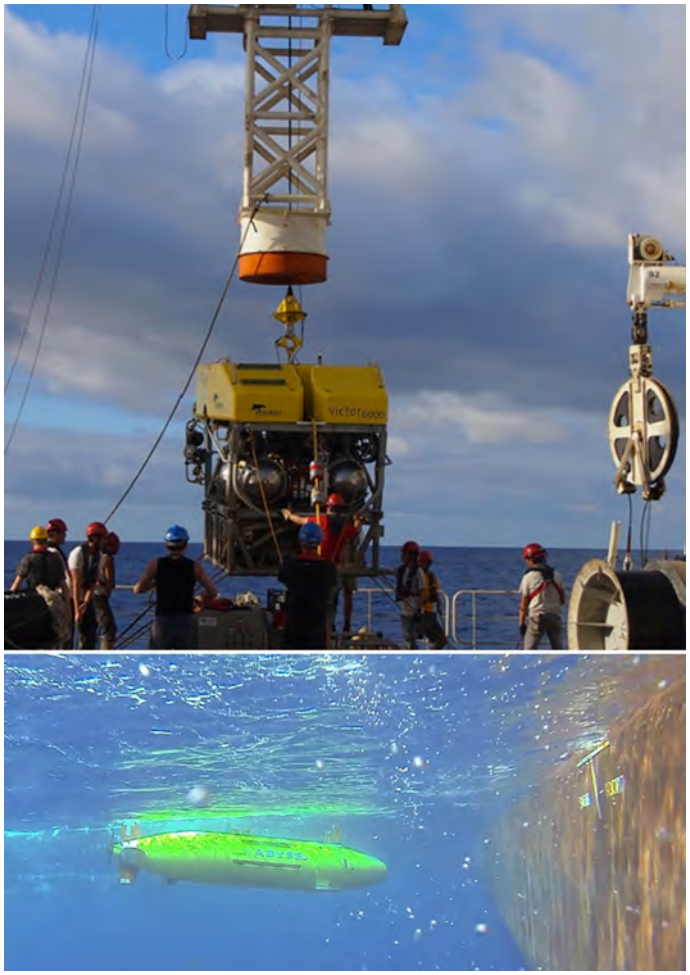
Above left: The RV Kilo Moana. Image courtesy University of Hawaii. Right: Polymetallic nodules on the seafloor in the Clarion Clipperton Zone. Image courtesy BGR.

The ODEMAR cruise: ROV & AUV investigations of oceanic detachments at the Mid-Atlantic Ridge

J. Escartín & the ODEMAR Scientific Party

Oceanic detachment faults, which may be associated with up to 50% of lithospheric accretion along slow-spreading mid-ocean ridges such as the Mid-Atlantic Ridge (MAR), expose deep-seated rocks at the seafloor and are systematically associated with hydrothermal activity. The ODEMAR cruise (Cabo Verde, 13 November to Guadaloupe, 20 December 2013) was supported mainly by CNRS/IFREMER (ship and ROV time, logistics), IPGP (logistics) and GEOMAR (logistics and AUV operations), and included scientists and engineers from 15 institutions across Europe and the USA.

During the ODEMAR cruise we deployed German AUV ABYSS and French ROV VICTOR to investigate oceanic detachments at 13°20'N and 13°30'N along the MAR (Figure 2). The 13°30'N site includes the Semenov hydrothermal fields, explored during previous Russian cruises, with 4 reported inactive fields and one active vent site. Hydrothermal deposits were also found at the 13°20'N detachments, but no exploration with deep-sea vehicles had been conducted in the area prior to the ODEMAR cruise. AUV and ROV dives were complemented with dredging, shipboard multibeam mapping, and CTD casts during downtime of the deep-sea vehicles. Owing to a medical emergency, work at the Mid-Atlantic Ridge finished 6 days earlier than planned, and we conducted a 3-day AUV and ROV survey of an active normal fault between the islands of Guadaloupe-Les Saintes and Dominica in the Antilles, which was the locus of a significant seismic event in 2004, a minor tsunami in the area, and a subsequent seismic crisis spanning several months.



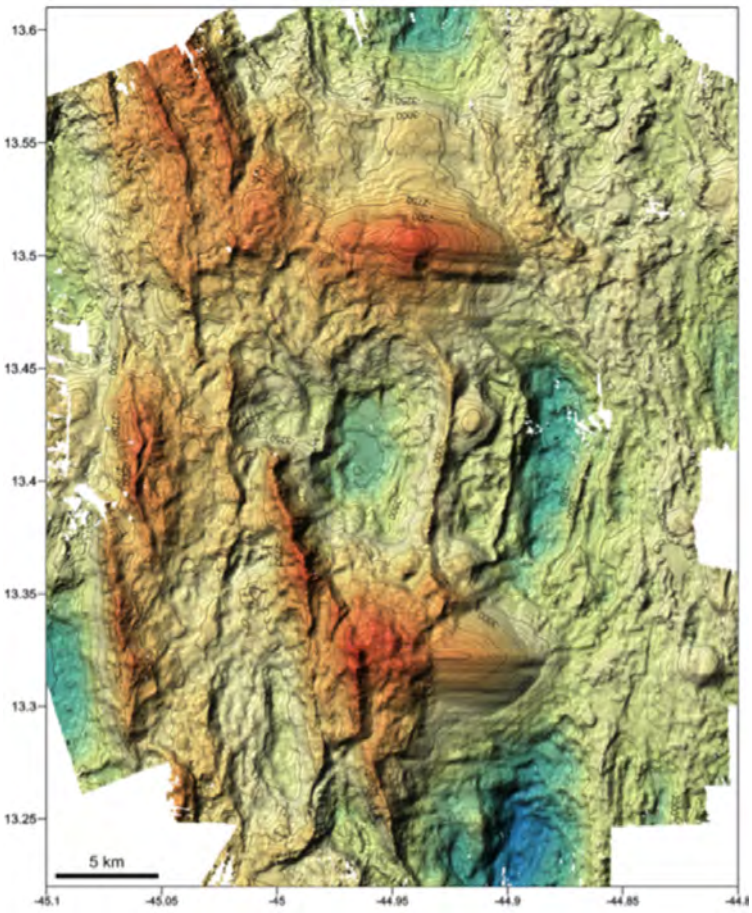


Figure 1, above left: The ROV VICTOR 6000 (top) and AUV ABYSS (bottom) used during the ODEMAR cruise aboard the French research vessel RV Pourquoi Pas? Figure 2, above right: Multibeam bathymetry map of the ODEMAR study area at the Mid Atlantic Ridge, showing the striated 13°20'N and 13°30'N detachments.

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Investigating the active oceanic detachments

A total of 9 AUV ABYSS dives were conducted to acquire microbathymetric data over the two detachments, covering a surface of ~75 km^2 at a spatial resolution of 2 m (blue areas in Figure 3). The AUV also collected magnetic data, and water column parameters (Eh, temperature, nephelometry) to investigate the seafloor magnetic structure and search for evidence of hydrothermal plumes, respectively.

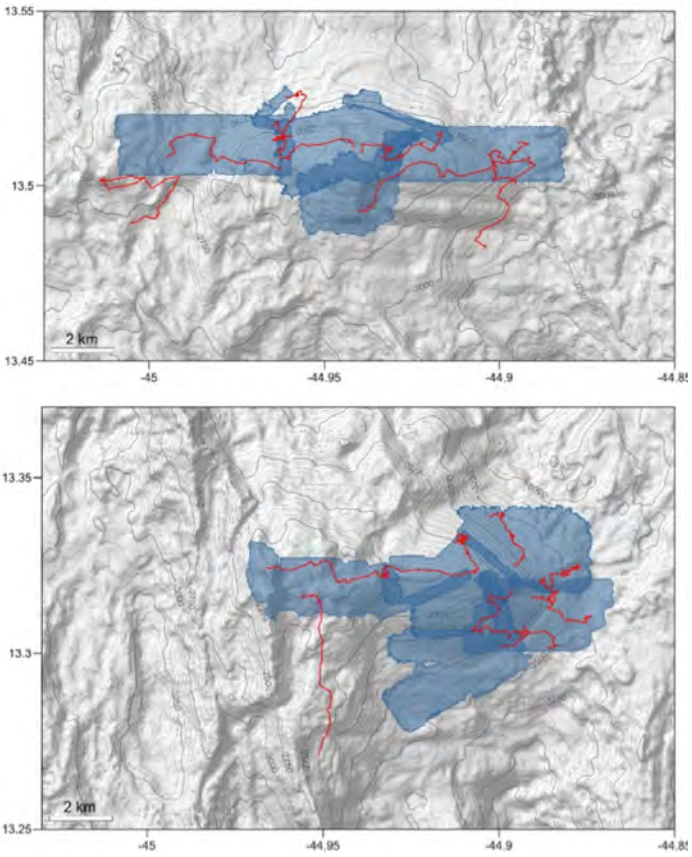

Figure 3: Shaded relief map showing the 9 AUV ABYSS microbathymetric survey areas conducted in the study zone (blue shaded areas), and the ROV VICTOR tracks (red) for geological observations and sampling.

Microbathymetry from the AUV was pre-processed on board immediately after each dive, allowing the science team to identify geological targets for ROV VICTOR dives. A total of 21 dives were conducted in the study area (red tracks in Figure 3), during which we collected a) more than 425 geological samples, with >50% in situ and oriented, b) HD video imagery of geological outcrops for videomosaicking, c) HD video captures for 3D video terrain reconstruction, d) fluid sampling at active vents (see below), and e) geomicrobiological sampling.

ROV geological investigations and sampling focused on key structural elements of the detachment, including the limit between the rift valley floor and the detachments, the termination where the detachment fault dives into the rift valley, the striated surface and the associated fault rocks, and the crust between the limit of the striations away from the axis and the breakaway, which is considered to indicate the initial fault scarp at the seafloor.

During the AUV dives we identified two areas of active hydrothermal activity. The Semenov 2 hydrothermal area at 13°30'N, located in crust between the striated surface and the breakaway (~9 km from the detachment termination), is associated with a weak Eh anomaly. Here ROV surveys identified a field with three active vents, with clear fluid outflows at up to ~310°C from anhydrite chimneys, areas of diffuse flow with mussel beds and several inactive structures. At 13°20'N the AUV water column measurements detected a clear Eh, temperature, and nephelometry signal over the northern flank of the striated detachment fault, ~6 km away from the detachment termination towards the axis. An ROV dive identified an active hydrothermal field, Irinovskoe, encompassing two active vents with sulphide chimneys actively venting black smoker fluids at temperatures of >350°C.

Mapping active normal faults in the Antilles

The work in the Antilles focused on the mapping of the Roseau Fault, on the southwestern flank of a graben that runs between the islands of Guadaloupe/Les Saintes and Dominica. In this area we conducted nested microbathymetric surveys with a dive of the AUV ABYSS (2 m resolution), and two dives of the ROV VICTOR (50 cm resolution).

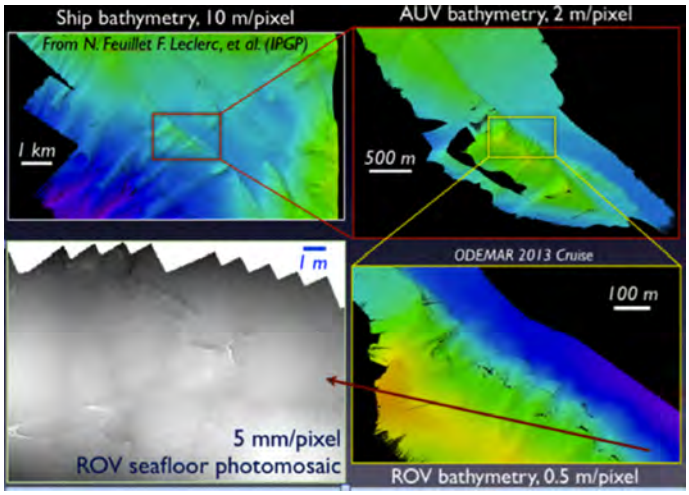

Figure 4: Nested geophysical studies of the Roseau Fault between the Les Saintes Islands (Guadaloupe) and Dominica, in the Antilles. The Roseau Fault, defining the SW edge of a graben trending NW-SE, was mapped using shipboard bathymetry (top left). The AUV ABYSS survey (top right) and the ROV VICTOR survey (bottom right) provide a detailed view of the fault scarp, its structure and geology. This is complemented by seafloor photomosaics (bottom left) obtained with a vertical camera during the ROV dives.

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The ROV dives also included extensive imaging of the seafloor using a vertical camera to generate georeferenced photogigamosaics of the seafloor (resolution of 5-10 mm); multibeam bathymetry with a nominal resolution of ~10 cm was also acquired during the optical, photomosaic surveys.

ODEMAR and MIDAS

Several of the institutions participating in the ODEMAR project (IPGP, GEOMAR, U. Girona) are also partners in MIDAS. While the ODEMAR scientific objectives differ from those of MIDAS, data acquired during the cruise can contribute towards the advancement of MIDAS. Firstly, this includes the characterisation of natural hydrothermal systems, fossil and active, in a Russian mining claim area likely to contain some of the more extensive sulphide deposits (e.g., site characterisation). Secondly, we have acquired high-resolution acoustic and optical imagery at different, nested resolutions; this dataset is well suited for development of integrated optical and acoustic data interpretation. Third, the data will be exploited for anciliary ecological studies, including automatic identification of macrofauna and other structures on video imagery and optical camera images.

The ODEMAR science team:

M. Andreani (U. Lyon, co-PI), N. Augustin (GEOMAR), A. Bezos (U. Nantes), D. Bonnemains (IPGP), M. Cannat (CNRS/IPGP), V. Chavagnac (CNRS/U. Toulouse), Y. Choi (CNRS/IPGP), R. Garcia (U. Girona), M. Godard (CNRS/U. Montpellier), C. Haaga (U. Bergen), C. Hamelin (U. Bergen), B. Ildefonse (CNRS/U. Montpellier), J. Jamieson (GEOMAR), B. John (U. Wyoming), T. Leleu (U. Toulouse), C. Macleod (U. Cardiff), M. Massot (U. Balears), C. Mével (CNRS/IPGP), E. Noumikou (U. Athens), J. A. Olive (MIT/WHOI), M. Paquet (IPGP), S. Petersen (GEOMAR), C. Rommevaux (CNRS/IPGP), M. Rothenbeck (GEOMAR), A. Steinfuhrer (GEOMAR), M. Tominaga (Michigan, St. U.), L. Triebe (GEOMAR).

Above: The ODEMAR Science Team aboard RV Pourquoi Pas?

Searching for TREASURE on the MAR with RV *Pelagia*

Researchers from NIOZ will shortly embark on a field campaign to the Mid-Atlantic Ridge that combines the research questions of two projects within a single scientific cruise. The RV *Pelagia* expedition 64PE388 (10-31 May 2014) will contribute data to both the Netherlands research council (NWO) funded TREASURE project *(Towards Responsible ExtrAction of SUbmarine Resources*) and MIDAS.

The overall goal of both projects is the development of a science-based approach and suitable tools for monitoring, predicting and mitigating the environmental impact of deep-sea mining operations. In the upcoming cruise, geological, geochemical, biological and ecological aspects will be investigated by the TREASURE team, whilst the MIDAS team will focus on physical oceanography.

RV *Pelagia* is expected leave the Azores on 10 May for a 3-week expedition to either the Lucky Strike region or the Rainbow field on the mid-Atlantic ridge (depending on permissions). The ship will be equipped with EM300 multibeam echosounder, 3.5 kHz acoustic bottom profiler, CTD/ADCP, vessel mounted ADCP, benthic landers and oceanographic moorings equipped with ADCP, currentmeters, and McLane profiler, box-, multi- and piston corer, and HD underwater video.

The MIDAS team will assess the spatial and temporal variability of oceanographic and hydrodynamic conditions relevant for plume dispersion. Special attention will be given to processes interacting with horizontal and vertical dispersion of tracers, such as the presence of highly non-linear and turbulent flows, tidal flows, mixing-driven residual flows and internal wave fields. The data collected will enable initialisation and validation of in situ data for use in numerical models with different spatial and temporal resolutions (MITgcm, FVCOM, NEMO, ROMS&WRF). This will be achieved with an intense hydrographic survey with CTD/LADCP (temperature and current velocity measurements, whole water column), in the near field and far field of the hydrothermal vent. Three oceanographic moorings will be deployed to continuously measure the current velocity field and temperature values in the water column at three different locations. These moorings will be recovered during a second cruise scheduled for autumn 2014.

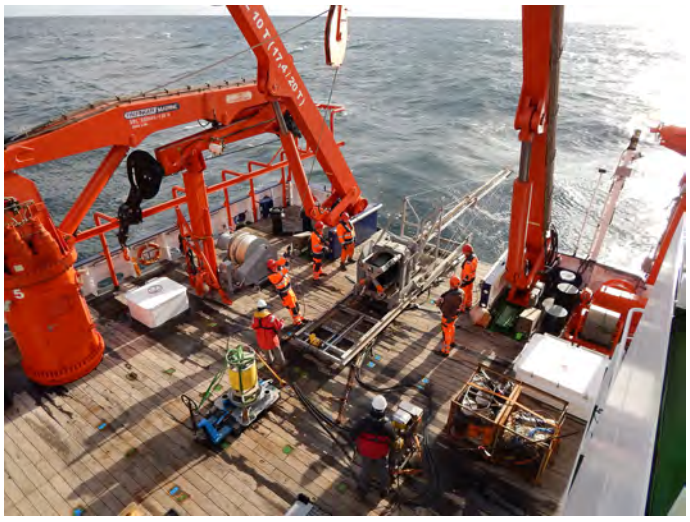
Investigating gas hydrate deposits in the Danube fan: The MSM34 "SUGAR site" cruise

Jörg Bialas, Ingo Klaucke, Matthias Haeckel and MSM34 legs 1 & 2 scientific parties

In December 2013 and January 2014 a group of scientists from Germany, France and Turkey visited the Black Sea on board RV *Maria S. Merian* (cruise MSM34) to investigate the gas hydrate accumulations in the Paleo Danube delta.

Gas hydrates have been the focus of scientific and economic interest for the past 15-20 years, mainly because the amount of carbon stored in gas hydrates is much greater than in other carbon reservoirs. Several countries including Japan, Korea and India have launched vast research programmes dedicated to the exploration for gas hydrate resources and ultimately the exploitation of the gas hydrates for methane.

The German SUGAR project, financed by the Ministry of Education and Research (BMBF) and the Ministry of Economics (BMWi), aims to develop technology for exploiting gas hydrate resources by injecting and storing CO_2 in place of methane in the hydrates. This includes development of techniques to locate and quantify hydrate reservoirs, drill into the reservoir, extract methane from the hydrates by replacing it with CO_2 and monitor the newly-formed CO_2-hydrate reservoir. Numerical modelling has shown that any exploitation of the gas hydrate can only be successful if sufficient hydrate resources are present within permeable reservoirs such as sandy or gravelly deposits. SUGAR's ultimate goal is a field test of the technology developed within the project, meaning that knowledge of a suitable test site is crucial. Within European waters only the Norwegian margin and the Danube deep-sea fan show clear geophysical evidence for large gas hydrate accumulations, but only the Danube deep-sea fan is likely to contain gas hydrates within sandy deposits.



Left: Deployment of the piezometer from the RV Maria S. Merian

Prior to cruise MSM34 only limited information about the Danube deep-sea fan was available: publications by Lericolais et al. (2009), Popescu et al. (2007), Popescu et al. (2006), a Diploma thesis by Baristeas (2006) and reports from the EU projects ASSEMBLAGE and BLASON.

The work of Baristeas (2006) was based on a selection of seismic profiles from a 3D seismic survey undertaken by TOTAL in 1994 and 2001, a dataset that was not available for the cruise MSM34. Baristeas (2006) mapped two areas of Bottom Simulating Reflector (BSR) distribution north and south of the Viteaz canyon and interpreted irregular and increased amplitudes underneath channel axes as indications for free gas. Similar patches were interpreted underneath the levees. Baristeas (2006) speculates that microbial gas migrates upwards along the coarse-grained, high permeable sediment fill of the channel axis. Vertical migration is limited or inhibited by fine-grained sediments, and formation of hydrates provides a seal as indicated by the BSR. Further distribution of gas will be guided horizontally into the at least horizontally permeable levee system. Baristeas (2006) observed patches of a double BSR in the northern area. Discussions of models for the formation of a multiple BSR were not concluded. Nevertheless in his summary Baristeas assumes that upward migration of thermogenic gas may have contributed increased amounts of higher carbon gases, which may have caused secondary BSRs due to modified stability boundaries.

Popescu et al. (2006, 2007) used data provided by the BLASON cruises undertaken by IFREMER and GeoEcoMar in 1998 and 2002. Selected datasets, provided by IFREMER, were available prior to the MSM34 cruise. Popescu et al. (2006) interpreted multiple BSRs observed at channel-levee systems of the Danube fan. They conclude that the uppermost BSR marks the current equilibrium depth of the base of the gas hydrate stability zone (BGHSZ) for gas compositions of more than 99% methane. This BSR1 has been mapped within three areas of the Danube fan. Chaotic reflection patterns underneath the BSR1 were found underneath the channel axis indicating the accumulation of free gas. The levees are partially underlain by stacks of up to four additional BSRs. Indications of free gas are provided by amplitude reversals of the reflection events where they cross the BSRs. Successive steps of climate warming are thought to be the cause of the additional BSRs. Free gas resulting from

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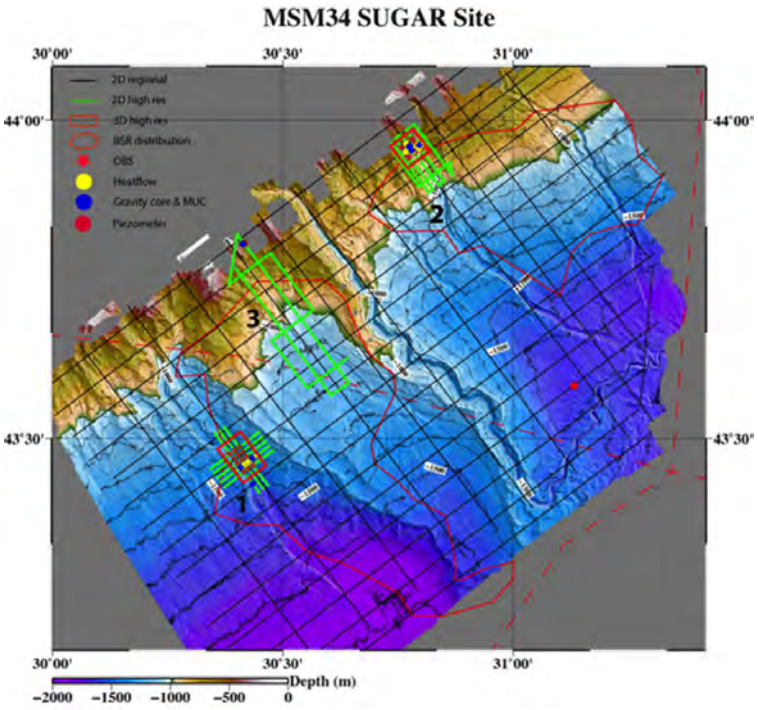
destabilisation through the climate changes is expected to migrate within the strata. Mineral reactions may have taken place locally and provide a seal for further fluid migration, which is imaged as paleo-BSR (Popescu et al., 2006).

As the available data did not provide a reasonable data coverage of the working area, cruise MSM34 consequently set out to establish the bathymetric and seismic database to prepare a selection of further high resolution seismic study areas (see map below). Leg 1 acquired the necessary grid of 2D-seismic profiles using a 1 km-long multichannel streamer operated by IMST-SeisLab and deployed two long-term piezometers operated by IFREMER. Based on this dataset, two target areas were selected for high resolution 3D-seismic imaging during Leg 2. High-resolution 2D-seismic acquisition and wide-angle observations by Ocean-Bottom Seismometers (OBS) complemented the 3D-seismic surveys. Sediment samples were taken with gravity (GC) and mini-multicorer (MC) and a violin heatflow probe (HF) was used to obtain temperature gradients in the working areas. Sample stations for GC, MC and HF at working area 2 were extended into the adjacent canyon.



Above: Map showing the working area of cruise MSM34

Working area 1 is underlain by buried channel. A BSR, increased amplitudes and inverted reflection events are interpreted as indications for gas migration and hydrate formation at shallow depth. Geochemical analyses did not show enhanced methane values in the seafloor sediments arguing for a sealed hydrate deposit. Further analyses are proposed for a third SUGAR phase in co-operation with MIDAS.

Working area 2 was chosen where an unexpectedly strong upward bending of the BSR underneath a slump site was observed. The failed part of the slope has been mapped at a water depth of 600 m to 700 m covering the 650 m water depth limit of the hydrate stability zone. Reduced heatflow values and active flares circling the hanging wall point towards changes in the slope and hydrate stability conditions.

Due to unexpectedly favourable weather, additional high-resolution 2D-seismic profiles were acquired across a buried channel system in working area 3. Indications for slump events within the channel fill were interpreted from regional 2D-seismic images and shall be investigated further.

A full overview of cruise MSM34 and its first results is available as GEOMAR report no. 15 (Bialas et al., 2014). A PDF copy is available under http://dx.doi.org/10.3289/GEOMAR_REP_NS_15_2014.

Acknowledgements

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The authors wish to express their gratitude to all the colleagues who have supported the work before, during and after the cruise. Much of the work done during the cruise was only made possible by the scientists', technicians' and the crews' experience.

Particular thanks are directed to the masters (Björn Maaß and Ralf Schmidt) and their entire crew of R/V MARIA S. MERIAN for the excellent support throughout the cruise.

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Shaken and stirred: getting a taste of mining impacts on deep-sea sediments

Felix Janssen, Thomas Soltwedel, Ingo Schewe, Marianne Jacob & Christiane Hasemann: AWI, Germany

Mining of polymetallic nodules from soft sediments in international waters may begin within the next couple of years. There is no doubt that this will remove any nodule-attached fauna from the mined area along with their substrate, which needs millions of years to return. But what about the organisms thriving in the sediments below, which even the most selective nodule collector will affect? As the open ocean floor develops at a very slow rate, nodule mining will easily disrupt a habitat that has taken thousands of years to form. Usually, the highest abundances of organisms are found in this top layer of the seabed where most food is supplied as fresh particles from the overlying waters. Particularly variable geochemical conditions in the surface sediments offer a wide range of microhabitats that host a huge variety of microorganisms and representatives of many different animal phyla.

The deep seafloor is still poorly studied and numerous questions as to the biodiversity and spatial distribution of deep-sea soft-bottom communities remain unsolved. With respect to mining impacts, questions on the organisms' potential to withstand disturbances and recolonise as well as the timescales to reform stable communities need to be considered as a prerequisite for any impact assessment and management plan. With the present rush for deep-sea mineral resources we may lose unique ecosystems that we are only beginning to understand and which potentially provide relevant services for mankind, such as carbon sequestration, recycling of nutrients and supply of genetic biodiversity for biotechnology applications.

How to assess mining impacts on sediment ecosystems

Disturbance experiments are key in assessing and predicting impacts of mining and other anthropogenic activities on deep-sea ecosystems but typically require major efforts and huge funds. The largest experiment of this kind was the DISturbance and re-COLonization experiment (DISCOL) carried out in the late 1980s in the south-eastern tropical Pacific. Though far from reaching realistic industrial scales, DISCOL involved the ploughing of an 11 km^2 area of the seabed. However, much smaller disturbances may be adequate if specific questions are posed, with the additional benefit of reduced efforts and more easily controlled experimental conditions. MIDAS partner institution Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI) in Bremerhaven, Germany developed the so-called 'Integrated Sediment Disturber' (ISD) - an autonomous instrument that is able to expose deep-sea sediments to different levels of physical perturbation to study the impact on small scale organisms and sediment functions.

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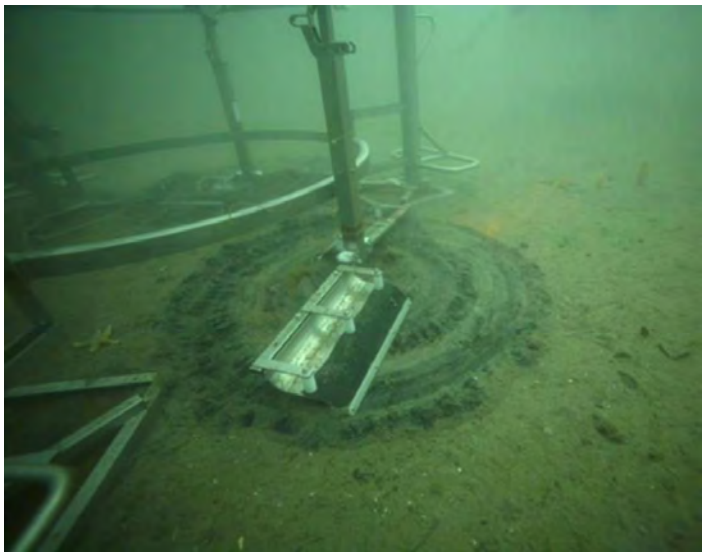

Above left: The Autonomous Sediment Disturber upon deployment at HAUSGARTEN off Svalbard. In the lower left corner push cores used for sampling by a remotely operated vehicle are visible. Image: MARUM at Bremen University and Thomas Soltwedel, AWI. Above right: The rotating plough-like unit disturbing sediments in a shallow water deployment to assess impacts on small sediment fauna and functions. Image: Thomas Soltwedel, AWI.

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Sediment disturber experiment in the Arctic

AWI will focus on an ISD deployment at HAUSGARTEN west of Svalbard, one of the very few sustained long-term deep sea ecosystem observatories. There are no plans to mine this area, yet existing long-term time series at the site facilitate impact studies as natural variations are known. During a one-year deployment, the ISD system disturbs three approx. 1 m^2 areas by means of rotating plough-like units. Sediment samples are obtained from the disturbed patches and nearby reference areas. These are used to investigate abundances and biodiversity of microorganisms and the sub-millimetre representatives of higher life (meiofauna) by means of microscopy and genetic fingerprinting techniques. Vertical oxygen profiles are obtained with microsensors in order to assess sediment oxygen demand. This serves as a parameter of the overall organic matter degradation of the sediments which represents a key function of seafloor communities. Previous short-term ISD studies in shallow waters off southern France and Scotland showed strong and complex impacts of disturbance on all investigated chemical and biological ecosystem components. Established vertical gradients (e.g., in terms of organic matter or organism abundances) were disrupted and sediment oxygen uptake bounced up due to the sudden bottom-water exposure of reduced sediments from deeper layers. In contrast to most other groups of meiofauna, nematodes seemed to resist or even profit from the disturbance, and increased in abundance. Based on these findings we expect that the small-scale deep-sea disturbance study will provide valuable information on potential mining impacts on sediment ecosystems in the deep ocean.

Further reading

Jacob et al. (2013) Biogeography of Deep-Sea Benthic Bacteria at Regional Scale (LTER HAUSGARTEN, Fram Strait, Arctic); www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0072779

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IMAR sets up atmospheric and pressurised lab experiments

The Institute of Marine Research at the Department of Oceanography and Fisheries, University of Azores has set up laboratory experiments at LabHorta, aiming simulate the deposition of particles from mining-related sediment plumes onto deep-sea benthic organisms. Physiological response studies will be performed to understand the short-term impact of sediment burial and toxicity on the hydrothermal vent mussel *Bathymodiolus azoricus* and the cold-water coral *Dentomuricea* sp..

The trials will be conducted under both atmospheric pressure and hydrostatic pressure using the IPOCAMP pressure vessel. Collaboration between IMAR/DOP-UAz and the Université Pierre et Marie Curie has enabled the adaptation of IPOCAMP for the planned trial. By bringing together UPMC's technical know-how in pressure vessel specifications and the scientific expertise of researchers at IMAR/DOP-UAz it is now possible to mimic the same aquarium sediment deposition conditions at pressurised conditions. Studies will include (i) measurements of survival and organism-level key physiological functions (e.g. respiratory metabolism); (ii) energy budgets (elemental and biochemistry); (iii) evaluation of antioxidant enzyme activity and quantification, and (iv) differential expression of immune and antioxidant genes.

Above: The laboratory setup at LabHorta, designed to investigate the short-term impacts of sediment burial on the cold-water coral Dentomuricea *sp. (top and bottom right) and the hydrothermal vent mussel* Bathymodiolus azoricus *(bottom left). Images courtesy IMAR/DoP-UAz.*

WP3 lab exposures workshop at the University of the Algarve

On 1 April 2014 partners from MIDAS WP3 (Ecotoxicology) were hosted by Dr Maria Bebianno at the University of the Algarve in Faro, Portugal. This one-day meeting was used to finalise the approach to the laboratory toxicant exposures to be conducted in the first year of the MIDAS project. The overall aim of WP3 is to establish the toxic effects on key biological species of metals and rare earth elements that might be released through deep-sea mining activities. This will be achieved in part by carrying out a series of lab experiments under high pressure, low temperature conditions that are representative of the deep-sea environment.

The meeting started with a presentation by Alistair Brown (U.Southampton) on his work towards building a database of existing metal toxicity data. This led into a useful and interesting discussion of the challenges to applying existing laboratory data and ecotox protocols to deep sea mining where, in situ, organisms will be at low temperature and high pressure. Arising from this discussion was the agreement that WP3 should concentrate on the fundamental principles underlying ecotoxicological assessment using a small number of species and metals. There was agreement that this would be a more tractable problem that could be successfully addressed, rather than trying to specifically establish toxicity limits for a vast range of metals and metal cocktails in different phases in multiple species.

After lunch, discussions continued to plan the timeline for laboratory work this year as well as the sharing of biological specimens and samples within the group. WP3 contributions to the Portman Bay experiment and the El Hierro cruises, both organised and run by the University Barcelona in 2014, as well as the mine tailings experiments aboard the RV *Gunnerus* cruises (as part of WP5) were also discussed.

Above: Participants of the WP3 Laboratory Exposures workshop (L-R): Nelia Mestre (UALG), Cátia Cardoso (UALG), Alastair Brown (USOU), Inês do Carmo Alves Martins (IMAR), Maria João Bebianno (UALG), Bruce Shillito (UPMC), Magali Zbinden (UPMC), Chris Hauton (USOU), Ann Vanreusel (UGENT), Sven Thatje (USOU).

Environmental Impact Assessment in the real world

More than 30 MIDAS scientists and external experts met at the Natural History Museum in London on 19-20 March 2014 for a workshop on environmental impact assessment (EIA) in the deep-sea mining sector, jointly convened by Dan Jones (NOC), Ian Stewart (Fugro-EMU) and Kevin Murphy (ERM). The workshop had two principal aims: 1) to introduce the concept of EIA and indicators to the MIDAS science community and improve the knowledge of scientists about industrial practice, and 2) to define a framework for determining optimal environmental indicators for environmental impact assessment of deep-sea mining.

The MIDAS scientific work packages (WP1-6) will produce a range of environmental data relevant to deep-sea mining. A key objective of this workshop was to ensure that these data feed into practical indicators of ecosystem health that can be used across the environmental impact assessment process. Ultimately, MIDAS aims to produce cost-effective real-world indicators or techniques that can be used by industry in the EIA process. This requires robust indicators and methods for measuring them that have been tested and are understood. Both the natural variation and the response of indicators to specific disturbances need to be known for useful impact assessment and monitoring. In addition, the indicators ultimately need to be measured with commercial equipment by commercial contractors over a realistic timeframe and at reasonable cost.

Valuable contributions to the workshop were made by invited external experts Cindy Van Dover (Duke University), Lisa Levin (USCD), Sandor Mulsow (International Seabed Authority) and Hannah Lily (SOPAC-DSM project).

MIDAS WP6 workshop on the response of deep-sea benthic fauna to natural and anthropogenic disturbance

The deep seafloor holds considerable amounts of mineral resources. There are, however, numerous unanswered scientific questions to resolve before these resources can be exploited. One major question relates to the nature and scale of the response of deep-sea ecosystems to mining activity.

On 11-13 March 2014, MIDAS scientists from across Europe gathered at the Senckenberg institute (DZMB) in sunny Wilhelmshaven (Germany) with three main objectives in mind. The first objective was to summarise the 'knowns' on the resilience of deep-sea benthos to impacts from test mining operations and natural analogues such as volcanic eruptions and iceberg scouring. Experimental test mining for manganese nodules in deep-sea sediments was performed in the Pacific more than two decades ago and recent results show that even this small-scale test mining caused significant disturbance to benthic communities; after more than 25 years the faunal diversity in this area has not recovered.

Unfortunately, studies of this kind have not been carried out at sites of potential massive sulphide or ferromanganese crust mining. Volcanic eruptions at hydrothermal vent sites can be used as natural analogues to study the recovery rate of communities impacted by anthropogenic disturbance. Whilst vent communities at fast-spreading mid-ocean ridges appear to recover relatively quickly, there is an urgent need to fill the gaps in our understanding of the recovery dynamics of ecosystems at slow-spreading ridges, which are of greater interest to mining industry due to their rich resources.

The second objective of the workshop was to identify the 'unknowns', such as the limited background information available on diversity, abundance, densities and dominance structure. In order to acquire an accurate insight into the impact of mining activities, baseline studies will be critical in detecting any change.

The third objective was to find ways to fill these knowledge gaps by using state-of-the-art modeling approaches, and additional sampling and experimentation strategies such as enhanced background fauna sampling and colonisation studies.

In summary, the mining targets are so diverse that a single assessment of mining activities at the deep seafloor is not feasible. Instead, current knowledge should be used to identify specific questions for each ecosystem such as recolonisation patterns at active and inactive vents in different geological settings. Modelling approaches can help in identifying species for monitoring programs as well as understanding the potential impacts of distinct disturbance effects such as removal of key species, or enhanced food supply on ecosystem function.

Below left: MIDAS scientists examine a large polymetallic nodule from the Clarion Clipperton Zone in the Pacific. Below right: Participants of the WP6 workshop in Wilhelmshaven. Images courtesy Torben Hofmann, Senckenberg Institute.

DOSI: The Deep-Ocean Stewardship Initiative

The Deep-Ocean Stewardship Initiative (DOSI) seeks to integrate science, technology, policy, law and economics to advise on ecosystem-based management of resource use in the deep ocean and strategies to maintain the integrity of deep-ocean ecosystems within and beyond national jurisdiction.

DOSI had its inception in April 2013 at an international workshop in Mexico City. DOSI is an evolving initiative and the leads are actively seeking funding in order to launch the programme proper. Significant activities are underway to address some of the crucial issues that will lead to structured stewardship of our deep oceans. To date, directed DOSI activities include briefs submitted to the Global Ocean Commission and to the Legal and Technical Commission of the International Seabed Authority on advancing environmental planning and management of deep seabed mining. DOSI goals have been communicated to a wide audience via the INDEEP office and during a variety of relevant meetings and workshops attended by DOSI members. One of the most prominent meetings in terms of media output for the initiative was the recent DOSI session at AAAS, sponsored by INDEEP, Deep-Ocean Industrialization which generated extensive press coverage. Speakers represented the fields of biology, policy, economics, industry and regulation. DOSI recently hosted the workshop "Defining "Significance" in Environmental Impact Assessment for Deep-Sea Mining" in March 2014 at Scripps Institution of Oceanography. Existing approaches to environmental impact assessment (EIA) of deep-sea mining were explored, with a focus on manganese nodules, massive sulphide deposits, cobalt crusts and phosphorite nodules or deposits. The workshop considered challenges and practical options for evaluating significant environmental impact related to deep-sea mining in light of direct, indirect, and cumulative impacts to the deep ocean. Participants represented the fields of deep-sea biology, law and policy, economics, regulation, industry and conservation, and considered both national and international jurisdictions. The workshop had financial sponsorship from INDEEP. The resulting report and publications are intended to provide guidance to the International Seabed Authority and to individual nations currently facing decisions about and enacting regulations for deep-sea mining. A full workshop report will be made available shortly on the DOSI webpage.

DOSI will continue to promote new collaborations via a number of mechanisms to generate proactive engagement in stewardship. DOSI also hopes to help coordinate various stewardship groups, fostering communication and collaboration among them. On 7 May 2014 DOSI will kick off an online interactive web series: Integrating Deep-Ocean Stewardship Activities. This will involve information sharing among deep-sea organizations and practitioners to identify mutual agendas and reduce duplication. DOSI, MIDAS, DSCC, IUCN, GOBI, SOPAC, DOOS, ISA and WOC are among the invited participants.

For further details about DOSI please see the latest newsletter and DOSI webpage: www.indeep-project.org/deep-ocean-stewardship-initiative

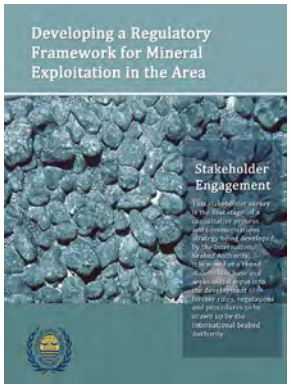
Towards a Strategic Environmental Assessment for mineral mining along the Mid-Atlantic Ridge (SEAMAR)

A Strategic Environmental Assessment and a Regional Management Plan for mineral mining along the Mid-Atlantic Ridge could consider the effects and intensity of cumulative impacts and existing activities, associated management rules and potential cumulative impacts. It could assist in the planning of future seabed mining activities in the context of past, present and future impacts of human activities including climate change.

The Deep Ocean Stewardship Initiative (DOSI) and MIDAS project wish to foster cross-jurisdictional, cross-sectorial and cross-ecosystem environmental plans to better protect the marine environment of the Mid-Atlantic Ridge. In this respect, DOSI and MIDAS are planning to hold a joint workshop in the Azores on 27-29 October 2014 to gather the main stakeholders together with scientists from different disciplines in order to identify elements for a draft Strategic Environmental Assessment and Regional Management Plan that will tackle the crucial issue of sustainability from legal, economic and ecological perspectives. More information on this workshop will be available in due course.

Stakeholder consultation exercises initated by ISA and DG MARE

The International Seabed Authority has launched a Stakeholder Survey Questionnaire aimed at soliciting relevant information for the development of a regulatory framework for the exploitation of minerals in the Area. The aim of the survey is to begin a process of stakeholder engagement and consultation following a recommendation by the ISA Council that more in-depth studies should be done on the development of an exploitation code for marine minerals in the Area, and that stakeholder engagement should be an integral part of this process.



The Stakeholder Survey is the first in a series of stakeholder engagements anticipated by the Authority to begin the development of a regulatory framework which will incorporate contemporary best practice and from which the Authority expects to benefit from the in-depth views, analysis and opinions from experts on activities in the Area. For full details of the survey please visit the ISA website www.isa.org.jm. The consultation closes on 16 May 2014.

In a separate exercise, the European Commission's Directorate for Maritime Affairs and Fisheries has also initiated a stakeholder consultation exercise on seabed mining. Posted as an online questionnaire on the Maritime Forum site (http://ec.europa.eu/dgs/maritimeaffairs_fisheries/consultations/seabed-mining), responses are welcomed from public authorities, citizens, companies and organisations concerned with seabed mining. This consultation is open until 16 June 2014.

MIDAS will submit a response to both consultation exercises on behalf of the MIDAS community, but individuals are of course free to submit a personal response if they wish.

Governance of seabed mining around Pacific Island States

The SPC-EU Pacific Deep Sea Minerals Project is helping Pacific Island countries to improve the governance and management of their deep-sea minerals resources through improved legal frameworks, increased technical capacity and effective monitoring systems.

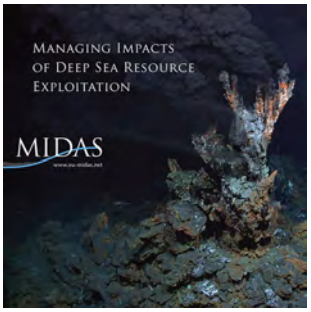
A primary objective of the project, which started in 2011, is to support informed and careful governance of any deep sea mining activities in accordance with international law, with particular attention to the protection of the marine environment and securing equitable financial arrangements for Pacific Island countries and their people. The Project is also working to encourage and support participatory decision-making in the governance and management of national deep sea minerals resources.

The Pacific Deep Sea Minerals Project is funded by the European Union and managed by SOPAC, the Applied Geoscience & Technology Division of the Secretariat of the Pacific Community, on behalf of 15 Pacific Island Countries.

A number of key documents have been published by this project, including a series of documents outlining the state of knowledge of Pacific marine minerals based on previous marine scientific studies and exploration. These documents - produced via a colalboration between SOPAC and GRID-Arendal - are available to download from the SPC-EU project website at www.sopc.org/dsm. The project has also produced a regional legislative and regulatory framework for deep sea minrweal exploration and exploitation, also available to download from the project website.

MIDAS brochure now available

The new MIDAS project brochure is now available. If you would like copies please email the MIDAS Project Manager, Dr Vikki Gunn (vikki.gunn@seascapeconsultants.co.uk). The brochure is also available to download as a PDF from the MIDAS website: www.eu-midas.net



The MIDAS newsletter is published quarterly. The deadline for articles for the summer 2014 issue is Friday 18 July 2014 - please email vikki.gunn@seascapeconsultants.co.uk