MIDAS

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MANAGING IMPACTS OF DEEP SEA RESOURCE EXPLOITATION

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Issue 6

Return to DISCOL

Megafauna distribution 26 years after simulated nodule mining

Autun Purser, Yann Marcon, Antje Boetius

Alfred Wegener Institute, Germany

Holothurian and shrimp: two mobile, non-sessile species within a DISCOL ploughmark. Initial analysis of the data, indicates it is likely that individuals of such species are as abundant within and outside of the ploughed areas, unlike the majority of sessile fauna species imaged in the region.

In 1989 the German project DISCOL (DISturbance and reCOLonisation experiment) was started in the Peru Basin, at 4150 m depth in the Southeast Pacific. During the late 1980s it seemed a possibility that the commercial interest in extracting rare metals from manganese nodule ecosystems would be sufficient for exploitation of this unusual resource to commence. The aim of the DISCOL project was to experimentally simulate such an extraction activity by ploughing surface nodules into the seafloor and creating a sediment plume throughout an area of ~6km diameter. The functioning of manganese nodule ecosystems in the 1980s, and still today, is poorly understood. The DISCOL project started with a baseline survey, prior to ploughing, using the German research vessel 'Sonne'. Immediately after experimental ploughing, and for the subsequent decade, return visits by the same vessel investigated if or how quickly components of the ecosystem such as megafauna, meiofauna infauna or ocean chemistry could revert to pre-disturbance conditions. At that time, other important ecosystem functions like microbial biodiversity or seafloor respiration rates could not be assessed in situ, and no robots were available to carry out habitat surveys.

During the summer of 2015 the new German RV *Sonne* revisited the DISCOL site, 26 years after the experimental disturbance. Two multidisciplinary and international 'JPI Oceans' cruises involving many MIDAS researchers set out to deploy variety of novel marine technologies such as a deep water ROV, AUV, crawler and landers in order to assess conditions at the site today. How marine ecosystems can be sustainably managed is still an important question, particularly if the availability of high-tech metals from land based sources is driving interest in potentially exploiting these deep-sea ecosystems. The two RV *Sonne* cruises, SO242/1 and SO242/2, along with further details on the DISCOL project, were introduced in issue 5 of the MIDAS newsletter (Summer 2015). In this current article we will comment on some of the observations made of megafauna within the DISCOL region, as imaged by the AWI-Launcher Ocean Floor Observatory System (OFOS) system, during SO242/2. This instrument was used to provide ecological context to the high resolution biogeochemical studies in different areas of the inner DISCOL experimental area (DEA), as well as outside the DEA. It complements further surveys carried out during leg SO242/1 with the AUV and other imaging platforms at different spatial scales.

MIDAS has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under Grant Agreement no. 603418. For more information about MIDAS visit the project website at www.eu-midas.net

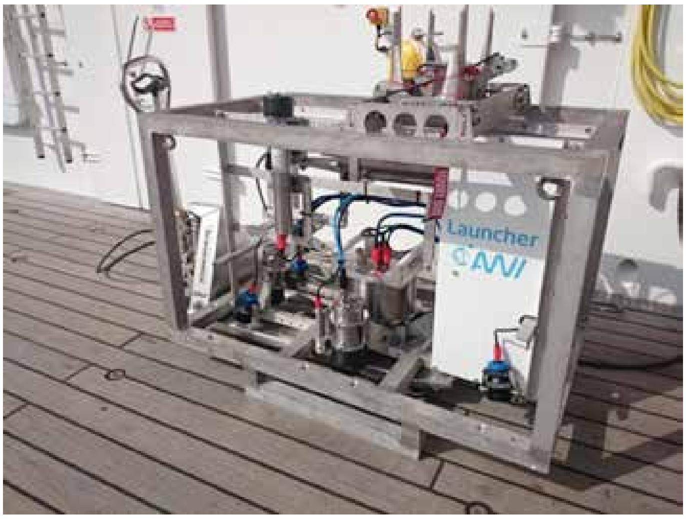


Figure 1: The OFOS system on deck

The OFOS AWI-Launcher (Figure 1) is a sophisticated camera system that can be lowered from a research vessel to take videos and still images of the seafloor from a height of ~1.5m, and automatically log position data for each image or frame of video collected. Under normal operations, the system is towed behind the research ship with video collected constantly throughout each dive, and still images collected at fixed intervals. For most of the dives carried out during SO242/2, a ship speed of 1.5 knots and a 15 second interval between camera images insured that there was no overlap in seafloor coverage by the still images, ensuring that when images were analysed, no individuals were counted twice.

SO242/1, under the leadership of Jens Greinert from GEOMAR, used an AUV and shipboard sonar systems to make backscatter maps of the DISCOL region. These maps clearly showed the experimental plough marks from 1989. Kindly, these maps were provided to us onboard SO242/2 so we could carry out targeted biogeochemical sampling embedded in camera surveys – comprising, in addition to the OFOS work, many experimental ROV dives, lander work and water column work – with good knowledge of where the experimental disturbance tracks were located.

We used the OFOS system to image areas of the seafloor which were directly ploughed in 1989, as well as areas adjacent to these plough marks, within the central ~6km region of DISCOL and further afield, in reference areas of the seafloor outside of the central ~6km area. The central area surveyed, and the seafloor categories imaged, are shown in Figure 2.

The main aim of our OFOS work was to determine whether or not different communities of megafauna were present within the various habitats imaged (within track, edges of tracks, within disturbed ~6km area but not directly ploughed, outside central DISCOL region). Such studies had been conducted with earlier OFOS systems in the months and years after the ploughed disturbance. By comparing the communities observed in these habitats today with those observed in the past, JPIO and MIDAS researchers will be able to assess the rates of recolonisation of the habitats following the removal of the nodules. As with the majority of studies published from the DISCOL area in the past, we focused on identifying megafauna to broad taxa levels, such as crustacea, holothuria etc. Identification and counting of the fauna is in the process of being carried out, using the open-source PAPARA(ZZ)I image analysis program developed by the current authors in the context of the Robotic Exploration of Extreme Environments (ROBEX) project. The application was developed for the analysis of the OFOS images and is designed to allow users to investigate and label fauna rapidly in an image data set and extract numerical information on abundances easily. The application and user manuals are available at https://papara-zz-i.github.io/

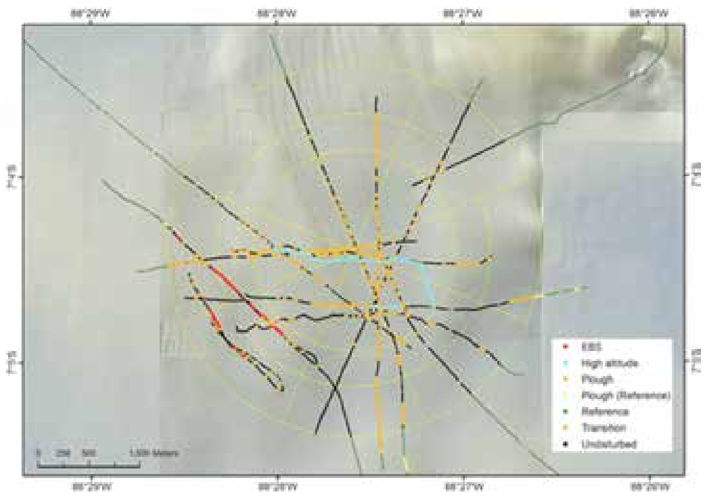


Figure 2: Map of the central DISCOL area showing the categories of seafloor imaged during the OFOS deployments

Initial observations

Given the depth and location of the DISCOL manganese nodule province, the seafloor megafauna in unploughed areas of the seafloor is rather high, with both sessile and mobile megafauna present in most ~5.5m^2 images of the seafloor. The hard substrate provided by the nodules augments the soft sediment habitat generally present in the area and provides niches for fixed sessile fauna, such as some crinoids, tunicates, some stalked and non-stalked sponge species and some polychaetes which were only observed on such nodules (Figure 3). Some mobile fauna, such as the isopods also visible in figure 3, were not in obligate

relationships with nodules or nodule fauna, but were observed to be in higher abundance in the vicinity of certain sponges or nodule substrate.

Our observations show that removal or burial of nodules by the experimental ploughing or by the plume of resuspended material settling from the water column after ploughing has resulted in a near-total loss of such sessile fauna from directly ploughed areas of the seafloor, and a reduced abundance immediately next to plough tracks. Other fauna, including hemichordates (Figure 4), ophiuroids, anenomes, crustacea, holothurians, jellyfish and many fish species appear to be as abundant within the disturbed areas as adjacent to them. In places the initial plough tracks are still rather steep features of the seafloor, and recent disturbance with an epibenthic sledge (EBS) show that anthropogenic disturbance of the seafloor will also change the local hydrodynamic conditions. In Figure 5, dead salps that have fallen from the overlying water column have become trapped within the broken structure of a recent EBS trawl, focusing a deposit of food locally on the seafloor, possibly here being utilised by a holothurian.

Ongoing work

In the next months the SONNE cruise participants and other JPIO and MIDAS members will continue to analyse and compare their results. We expect very useful information for the further development of technologies for environmental assessments (MIDAS WP10) as well as for management plans for these interesting and still poorly understood extreme environments in general.

Left, from top:
Figure 3: A sponge attached to a manganese nodule, with several isopods visible on the sponge.
Figure 4: Lophoenteropneusta hemichordate, *leaving a characteristic spiral waste trail.*
Figure 5: Two dead salps hydrodynamically trapped within an area of broken sediment left by an epibenthic sled trawl. A holothurian may be taking advantage of the additional food accumulation associated with the feature.

Recent relevant publications

Glover A, Dahlgren T, Wiklund H, Mohrbeck I & Smith CR (2016) An End-to-End DNA Taxonomy Methodology for Benthic Biodiversity Survey in the Clarion-Clipperton Zone, Central Pacific Abyss. J. Mar. Sci. Eng. 2016, 4(1), 2; doi:10.3390/jmse4010002 Supplementary video available at https://youtu.be/lo7NlFKUmYI

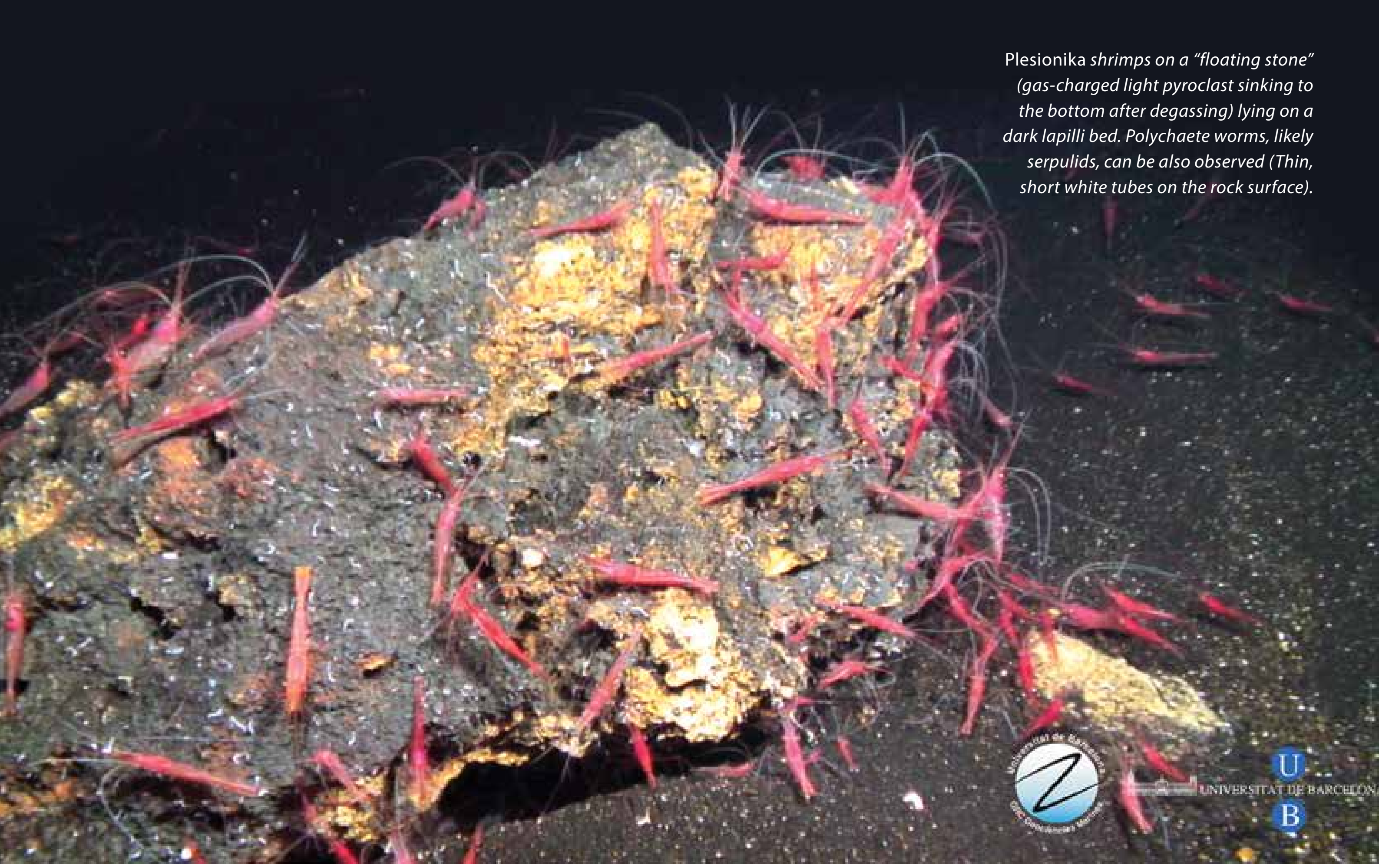
Glover A, Wiklund H, Rabone M, Amon D, Smith C, O'Hara T, Mah C, Dahlgren T (2016) Abyssal fauna of the UK-1 polymetallic nodule exploration claim, Clarion-Clipperton Zone, central Pacific Ocean: Echinodermata. Biodiversity Data Journal 4: e7251. doi: 10.3897/BDJ.4.e7251

Hernández-Ávila I, Cambon-Bonavita M-A, Pradillon F (2015) Morphology of First Zoeal Stage of Four Genera of Alvinocaridid Shrimps from Hydrothermal Vents and Cold Seeps: Implications for Ecology, Larval Biology and Phylogeny. PLoS ONE 10(12): e0144657. doi:10.1371/journal.pone.0144657

Two years on...The El Hierro volcano and surrounding area after the 2011-12 eruption

M. Canals[1], A. Aymà[1], G. Lastras[1], A.M. Calafat[1] and the MIDAS-EL HIERRO cruise shipboard party[2-4]

[1] *GRC Geociències Marines, Universitat de Barcelona, 08028 Barcelona, Spain*
[2] *Instituto Español de Oceanografía, 28002 Madrid, Spain*
[3] *Department of Marine Sciences, Polytechnic University of Marche, 60131 Ancona, Italy*
[4] *University Ghent, Marine Biology, 9000 Ghent, Belgium*



Plesionika *shrimps on a "floating stone" (gas-charged light pyroclast sinking to the bottom after degassing) lying on a dark lapilli bed. Polychaete worms, likely serpulids, can be also observed (Thin, short white tubes on the rock surface).*

A submarine volcanic eruption lasting 138 days, from 10 October 2011 to 5 March 2012, dramatically reshaped the western flank of the southern ridge of El Hierro Island in the Canary Islands. The eruption produced a new volcanic cone and deep apron where lava accumulated, and resulted in the release of volcanic ash and fluids loaded with particles, which stained the otherwise highly transparent waters of the area. The injection of fluids into the water column also led to its acidification.

The first multibeam bathymetric survey, carried out 15 days after the eruption started, revealed a ~650 m basal diameter cone topping out at 205 m water depth, masked by an eruptive plume and growing in a pre-existing valley. Prior to the eruption, the same point was located at ~363 m depth. The final cone comprised four vents along a NNW-SSE ridge, with the shallowest summit at 89 m depth, indicating the total height of the new volcanic cone as 274 m. The total accumulated volume was 329 x 106 Non-Dense Rock Equivalent m^3, of which one third formed the cone.

The MIDAS-EL HIERRO cruise took place aboard R/V *Ángeles Alvariño* from 28 October to 17 November 2014, funded by the Spanish Ministry for Economy and Competitiveness (MINECO). The main goal of the cruise was to assess the status of the benthic and pelagic populations in the area directly affected by the 2011-12 eruption via *in situ* inspection with ROV. The impacts of the eruption can be viewed as a possible analogue for deep-sea mining operations involving the injection of large quantities of particles into the ocean from a point source and the associated acidification of the water column.

The ROV used for the inspection work was the Liropus 2000 belonging to Instituto Español de Oceanografía. This is a Super-Mohawk ROV system manufactured by Sub-Atlantic, rated to 2000 m water depth. The system comprises a Tether Management System (TMS), a Launch and Recovery System (LARS), and a workshop and control premises (Fig. 1). The Liropus 2000 ROV has a wide set of cameras: a full HD colour camera (front), a low light black and white camera (front), a pal colour camera (front) and a mini camera (rear). It has two manipulators, HLK-HD45 5Func and HLK-47000 6Func, the latter with an additional mini-camera. The ROV is also equipped with a CTD SBE37Microcat, two LASER pointers 532 nm, a sampling skid, a dual frequency SONAR 325kHz and 675kHz, an altimeter and an acoustic Beacon MST 324. The TMS is equipped with an extra low light back and white camera, as well as a CTD Midas Valeport, a current meter Midas Valeport and an acoustic beacon MST 324.

Two main products of interest for MIDAS are video image and telemetry. Video was displayed on control and survey screens, and was recorded in raw format on hard drives from where it was downloaded to a hard drive backup after each dive. Telemetry combined all data coming from sensors: CTD, Motion Reference Unit, GPS, current meter and so on. For data display and record a software package named PIT (in Spanish, Telemetry Integration Program) was developed. All telemetry data was recorded in GMT served by the Network Telemetry Processor (NTP) with an error of less than 200 microseconds. Parameters recorded are: date, time GMT, ROV position (longitude and latitude), ROV's sensor depth, ROV's CTD depth, TMS's CTD depth, ROV attitude (pitch and roll), ROV altitude (acoustic altimeter), ROV heading, TMS heading, water current intensity in TMS, water current direction in TMS, water current intensity Vx in TMS, water current intensity Vy in TMS, temperature measured by ROV's CTD, salinity measured by ROV's CTD, temperature measured by TMS's CTD, and salinity measured by TMS's CTD.

Figure 1: Liropus 2000 ROV deployment using the A-frame in the stern deck of R/V Ángeles Alvariño during the MIDAS-EL HIERRO cruise. ROV is located inside the TMS (framework in the middle of the image with the yellow umbilical on top).

A total of 22 ROV dives were performed during the MIDAS-EL HIERRO cruise, of which one had to be aborted due to bad weather conditions. Figure 2 shows the location of all dives conducted. The volcanic nature of the seafloor was well depicted in the imagery, with basalts, pyroclastic blocks, pillow lavas, lapilli and ash accumulations, as well as areas of homogeneous muddy cover. Large life forms, both benthic and pelagic, in the ROV-monitored area were generally scarce or absent, with some local exceptions, such as the uppermost part of the newly formed volcano, which is well within the photic zone. The number of species looked in general rather low, although individual species showed a a large number of individuals.

In the upper part of the volcano, around 100 m depth, juveniles of a likely oyster, possibly *Neopycnodonte zibrowii*, were found in locally high concentrations, almost completely covering the newly formed basaltic rocks (Fig. 3). Scattered *Antiphataria* sp. (black corals) branches were also found close to or in the same locations than the oysters.

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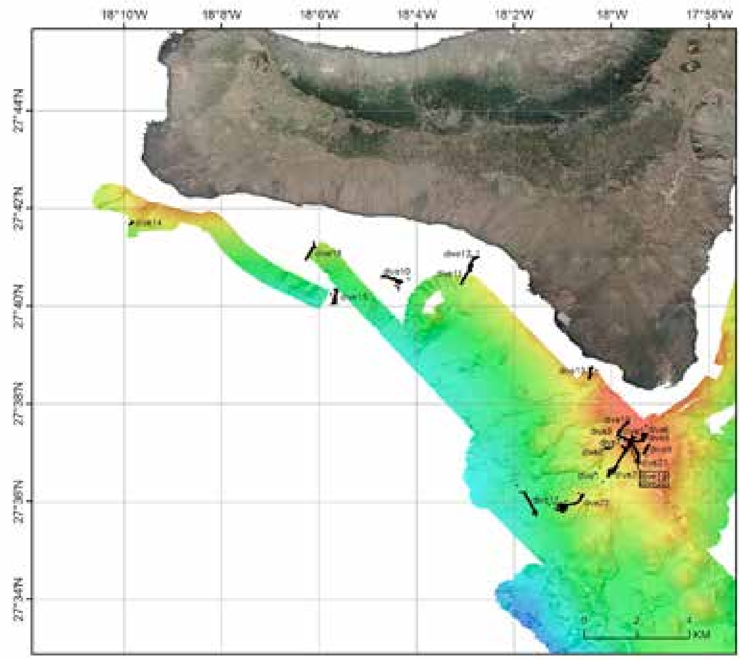


Figure 2: Map showing the ROV dives performed during the cruise.

Occasionally, cracks and isolated pyroclastic blocks in the mid and lower flanks of the volcano, down to 400m and more, were associated with large concentrations of benthopelagic *Plesionika* spp. shrimps, either *Plesionika edwardsii* or *Plesionika narval*, or both (main article image). Some of the pyroclastic blocks showed encrusting polychaete worms, likely serpulids, on their surface. Other benthic species observed in soft bottoms during ROV dives were two species of sponges (likely *Aphrocallistes beatrix* and *Regardella* sp.), the sea urchin *Cidaris cidaris*, the Cnidarian *Deltocyathus eccentricus* and some anemone and hydrozoans (Fig. 4). Decapod crustaceans are also common in some of the dives. We also found one specimen of the "leather urchin" *Phormosoma placenta*, which has not been cited before in the Canaries according to the World Register of Marine Species (WoRMS). Cold-water corals were also found in dives far from the new volcano, mostly as coral rubble although living colonies of *Lophelia pertusa* and/or *Madrepora oculata* were also found attached to old pillow lavas and rock outcrops. Some colonies of *Corallium tricolor* were identified too. Some demersal fish species were also observed, such as *Conger conger, Halosaurus ovenii, Chaunax* sp. and *Nezumia* sp., jointly with some sharks and rays.

Overall the suite of organisms observed seem to result from a combination of i) opportunistic species such as *Plesionika* shrimps and fishes, ii) early colonisers settling quickly after the submarine eruption such as the *Neopycnodonte* oysters, and iii) long-lived individuals that were able to cope with the impact of the eruption such as some sponges and corals. The

Figure 3: Neopycnodonte *sp. oysters covering newly formed basaltic rocks at about 100 m of water depth, two and a half years after the submarine eruption ended.*

high concentration of life forms in the uppermost part of the new volcano, including pelagic organisms, was noticeable.

Currently, ROV videos are being analysed in order to identify, classify and count the observed individuals to the lowest possible taxonomic level. We aim to obtain a list of the species occurring in the area and estimate their abundances a few years after the eruption. Behavioural analyses will also be conducted on the reaction of animals to ROV approach according to different levels of motility (i.e. swimming, walking or crawling). We will analyse separately fishes, which are epibenthic swimmers, and crustacean decapods, which are both swimmers and walkers with mixed epibenthic and endobenthic behaviour.

Figure 4: Old pillow lavas devoid of large benthic organisms except for a Cidaridae sea urchin. Pillow lavas were found in some of the ROV dives further away from the newly-formed submarine volcano.

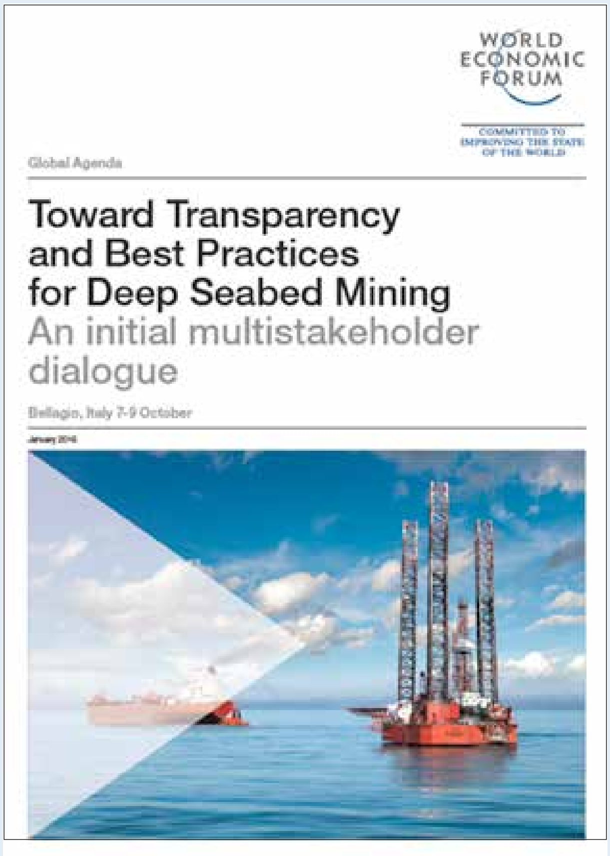
Toward transparency and best practices for deep seabed mining

By Jeff Ardron, U. Southampton / NOCS / Commonwealth Secretariat

On 7-9 Oct 2015, I attended a workshop hosted by the World Economic Forum's Global Agenda Councils (awkwardly called "GACs") on Oceans and the Future of Mining and Metals. The title explains the intent of the workshop and included people from industry, academia, environmental NGOs, national governments and international organizations. With only 23 participants in all, however, one could not say that it was fully representative, and this point was indeed made during the meeting on more than one occasion. (For example, I was the only MIDAS member there, and there was only one deep-sea scientist in attendance.) Nevertheless, its small size did allow for focussed and productive discussions.

The workshop split up into three working groups: transparency, fiscal regimes, and spatial management tools. I participated in the transparency group, which included an NGO rep, as well as two members of industry, and two members from inter-governmental organisations. Although we were all cautious and hesitant at the beginning, it ended up being an open and productive discussion, with agreement on two actions: i) to work towards a side event at the annual International Seabed Authority (ISA) July meeting, and ii) to informally discuss issues of transparency with the Legal and Technical Commission (LTC) of the ISA, so to better understand the concerns of some of its members. Regarding the side event, this possibility was later presented to the World Economic Forum, which has agreed to convene the event. Regarding the LTC, we have not yet been able to find a time to meet.

For more information, including the outcomes of the other two working groups, the workshop report is now on the DOSI site (http://dosi-project.org/wp-content/uploads/2015/08/Toward_Transparency_Best_Practices_Deep_Seabed_Mining_Bellagio_report_2016_0501.pdf).



WORLD ECONOMIC FORUM

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Global Agenda

Toward Transparency and Best Practices for Deep Seabed Mining
An initial multistakeholder dialogue

Bellagio, Italy 7-9 October

January 2016

MIDAS partners gather in Sintra for second Annual Meeting

To mark the successful completion of the second year of MIDAS, project partners congregated in Sintra, Portugal from 16-20 November 2015. During an intensive week of plenary sessions, workshops and planning meetings, some 65 presentations of data and results were made. The project has made significant progress in its second year, with more than 200 days spent at sea collecting data that will contribute to our knowledge of the potential environmental impacts of deep-sea mining.

As well as plenary sessions, participants also devoted considerable time to planning the analytical work and deliverables due for completion in the final year of the project. Considerable challenges lie ahead in bringing all the project results together to formulate clear conclusions and recommendations that will be useful for the formulation of environmental regulations for deep-sea mining.

In addition to the 70+ project scientists, members of the MIDAS Advisory Board also attended the meeting. Their role is to offer advice and guidance to the project from the perspective of stakeholders such as the International Seabed Authority, industry and the international science community. Their advice for the effective translation of MIDAS results into recommendations for the emerging deep-sea minng sector was valuable and will help guide MIDAS to a successful conclusion.

A key output of the project will be a publication of research highlights document, written in clear and accessible language, which summarises the achievements of the project and their potential application in policy development. This document is planned for release in autumn 2016, coincident with a 2-day open meeting that will showcase the results of MIDAS. Further details of this event will be announced in spring 2016.

View from the top: one of Sintra's many spectacular sights, the Moorish castle.

New project investigates sustainable harvesting of polymetallic nodules

On 1 February 2016 a new HORIZON 2020 project launched: Blue Nodules. This project addresses the challenge of establishing a viable and sustainable value chain to retrieve raw materials contained in polymetallic nodules. The project will develop and test new highly-automated and sustainable technologies for deep-sea mining with minimal environmental pressures. The technical part of the project is dedicated to subsea harvesting equipment & in-situ seafloor and sea surface processing of polymetallic nodules. The operational part is dedicated to sea operations and logistics, including compliance and development of rules & regulations and the business case. An independent, dedicated part will focus on environmental pressures and on an Environmental Impact Assessment. Blue Nodules builds on the results of the FP7 projects MIDAS and Blue Mining.

On 9-10 February the project coordinator, IHC Mining in the Netherlands, will host the Blue Nodules kick-off meeting on its premises in Kinderdijk. The project partners are excited to start the work to achieve the project objectives. Stakeholder expectations are taken into account through a stakeholder group and a critical advisory board. An independent ethics advisor will safeguard the ethics standards of the project.

Blue Nodules is a 4-year EU funded project starting in February 2016 as part of the Horizon 2020's Research and Innovation action. The project aims to develop "Breakthrough Solutions for the Sustainable Harvesting and Processing of Deep Sea Polymetallic Nodules" and is granted under the call SC5-11c-2015 "*Deep mining on continent and/or in seabed*". The consortium comprises 14 leading industry and research partners from nine European countries.

MIDAS Science-Policy Panel meeting 2015, Brussels

On 8 December 2015, the MIDAS project held its second Science-Policy Panel meeting, bringing together scientists with policymakers, NGOs and industry representatives to showcase the latest project results and facilitate open disciussion on key issues. Hosted at the Museum for Natural Sciences in Brussels (and under the gaze of some prehistoric onlookers), the meeting focused on the theme of "maximising potential for ecosystem recovery after deep-sea mining".

The event opened with a series of presentations by MIDAS researchers (Phil Weaver, Andrew Dale, Ann Vanreusel, Marina Carreiro e Silva, David Johnson and Telmo Morato) to highlight some of the scientific progress made during the second year of the project. This was followed by a lengthy question and answer session, during which a number of key topics were discussed. Participants at the meeting included representatives from the European Commission, industry groups UK Seabed Resources, MTI Holland and Global Sea Mineral Resources, the International Seabed Authority and NGOs Seas at Risk, WWF International and Greenpeace. Other interested parties such as OSPAR and IMMS also attended.

The afternoon session saw short presentations from the ISA, mining companies and NGOs followed by further round-table discussion. Key conclusions arising from the meeting included the need for scientists and industry to work more closely together, and the importance of future funding to ensure research into deep-sea mining impacts is continued beyond the lifespan of MIDAS.

A summary report of the meeting is available on the MIDAS website (www.eu-midas.net/policy-and-governance/MIDAS-SPP). The Science-Policy Panel will convene for a final time before the end of the project in autumn 2016.

Nosy neighbours: a parade of prehistoric eavesdroppers lurked outside the SPP meeting room at the Museum of Natural Sciences in Brussels.

Multi-stakeholder meeting on DSM and the role of the EU

Seas At Risk and the Deep Sea Conservation Coalition are organising a multi-stakeholder conference on deep-sea mining and the role of the European Union, to be held in Brussels on 7 April 2016. They aim to encourage an open dialogue between civil society, EU policy makers, industry and scientists which:

- Explores the need for deep-sea mining within a future circular economy, and
- Examines the role of the EU and Member States in the development of this industry and in the exploitation regulations that are being developed by the International Seabed Authority.

The MIDAS project will set the context by presenting an update on what we currently know of the potential impacts of deep-sea mining.

Participation is on an invitation-only basis. For more information please contact Ann Dom, Seas At Risk (adom@seas-at-risk.org) or Matthew Gianni, DSCC (info@savethehighseas.org)

MIDAS workshop on the colonisation of artificial substrates by deep-sea fauna, and rates and modalities of ecosystem recovery

In the framework of the MIDAS work package on ecosystem resilience and recovery (WP6), two workshops were held as a joint event: a first one on the "Colonisation of artificial substrates by deep-sea fauna" and a second one on the "Rates and modalities of ecosystem recovery". These events were held at the Faculty of Sciences of Lisbon (Portugal) on 21 - 23 November 2015, immediately following the MIDAS annual meeting. The 17 participants included both science and industry partners from 10 different institutes.

A variety of presentations were made on various aspects of colonisation experiments across different deep-sea habitats, and on the recovery potential of deep-sea ecosystems that might be subject to future mining activities. The overarching goal was to summarise current knowledge of deep-sea colonisation and recovery experiments in order to assess possible mitigation and restoration actions. From the outset of discussions, it became clear how intertwined the subjects of colonisation and recovery are. Some out-of-the-box thinking and interesting discussions led to the group identifying a wide variety of potential mitigation and restoration actions for different mining scenarios, in which technical feasibility was not considered a limitation. These included, among many others, discussions on whether the use of artificial substrates may enhance recovery processes. The existing post-disturbance studies are extremely valuable in providing insights into organism and environmental (non-) recovery and possible timescales. However, the peculiarities of the different ecosystems (hydrothermal vents, cold seeps, nodule fields, etc.) and different mining scenarios based on the resource of interest made it hard to go into generalisations.

This workshop also granted us an overview of the current limitations in our knowledge and data. Plans of possible future experiments and cruises that could help fill in some of these gaps were outlined.

Night at the Museum...MIDAS headlines at event in London

On 25 September the Natural History Museum of London (NHM) hosted the annual Science Uncovered festival as part of the European Researcher's Night initiative (www.nhm.ac.uk/visit/exhibitions/science-uncovered-2015.html). Hundreds of scientists in the NHM's galleries offered several activities including science stations, debates and behind-the-scenes tours to about 5,800 people. The MIDAS project, taking advantage of this excellent opportunity to bring science to the public, displayed a stand where we showed our preliminary results after our last cruise at the Clarion-Clipperton Zone during the JC120 cruise. Special emphasis was given to explain our results obtained so far on the molecular connectivity of marine invertebrates in the study area. The peculiar aspects of the fauna adapted to live in the abyssal plains, and the process of manganese nodule formation were also explained.

Blue Mining: Breakthrough Solutions for Mineral Extraction and Processing in Extreme Environments

Any future deep-sea mining activity requires thorough knowledge of the deep-sea ecosystem, and adaptation of the mining system and operation to control and limit the environmental impact to levels that have been agreed upon by the Authorities.

As a result, technology development, exploration and resource estimation as well as an understanding of local ecology must be developed together, beginning in the early stages of exploration where the ecological constraints balance the technological solutions and mining plan.

While we have only started to get an idea of the complexity of deep-sea ecosystems within the MIDAS project, the development of exploration and resource estimation techniques, as well as deep-sea mining technology, is well underway in the EC-funded BLUE MINING project.

Within BLUE MINING, 19 partners from 6 countries (of which a large number also participate in MIDAS) collaborate to enable cost-effective resource discovery and assessment, manage and economically evaluate these resources sustainably, and develop technologies that enable safe exploitation of these resources.

Over the last two years, BLUE MINING has made a number of advancements. Here we share a few of our achievements in improving exploration, in the tool validation used in the pre-feasibility and feasibility phase, and in development of equipment used during mining.

Important for the design of the mining operation and mitigation of technological risks is a proper assessment of the mining area. With improved 3D bathymetry, developed by NERC, the area is mapped with much more accuracy, enabling the engineers to assess risks and better design the mining operation.

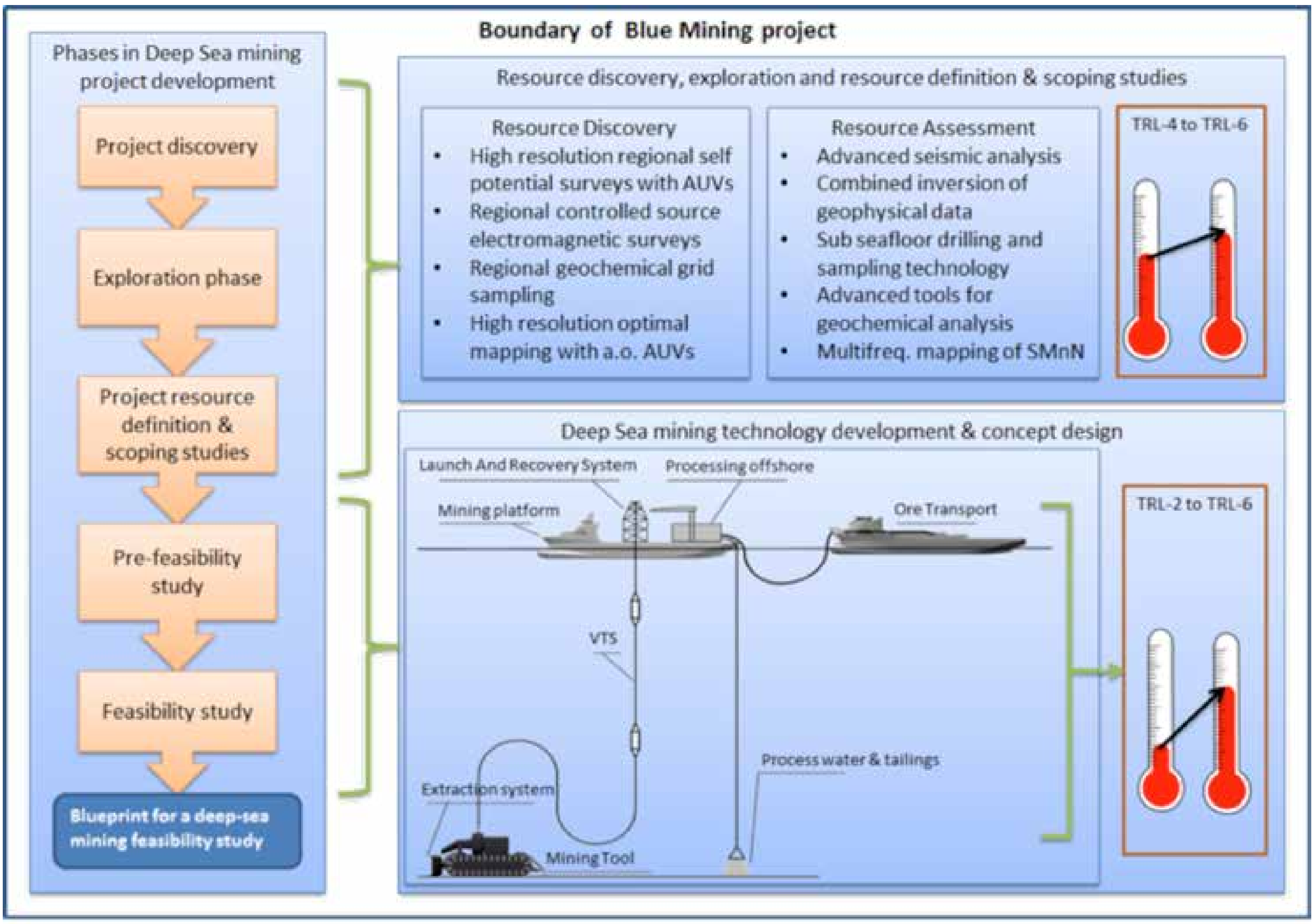

Figure 1: The objectives of the BLUE MINING project

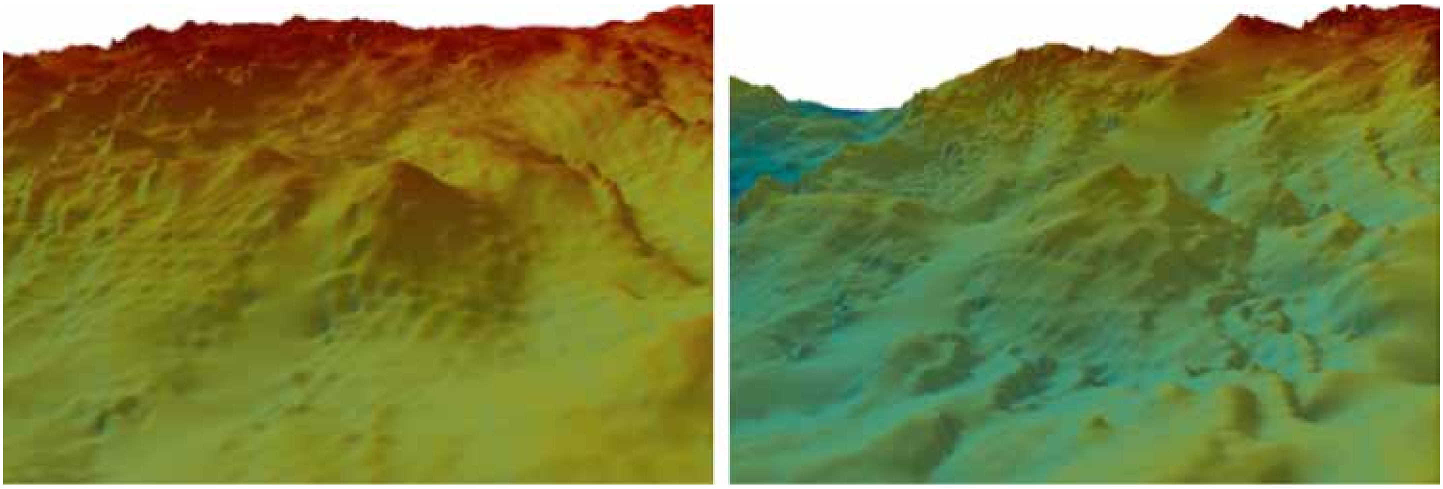

Figure 2: 3D bathymetry of Double Mound and Shinkai Mound (two of the extinct SMS deposits to be evaluated in 2016). This high resolution bathymetry, originally collected in the 1990's and made available by Susan Humphries, Woods Hole Oceanographic Institute) was reprocessed, merged with more recent bathymetric data and revisualised by Tim LeBas at NERC's National Oceanography Centre. These SMS mounds will be studied using near-bottom seismic and electromagnetic techniques, surveyed using AUV and ROV and then drilled using a seafloor drilling rig, RD2, by GEOMAR and NERC during cruises in the summer of 2016.

For seafloor massive sulphides, one of the aims is the development of techniques to aid discovery of large inactive deposits - mining them in preference to active vents would reduce the impact on chemosynthetic faunal communities. In order to develop this technology, we first have to build and validate our design tools. The first of these validation experiments has been performed at the MARIN facilities in the Netherlands. The aim of the model test was to determine hydrodynamic loads on typical riser sections and a pumping station. This was achieved by three different tests: i) tow tests to determine drag loads, ii) oscillations in still water, which is important for the estimation of factors such as the damping of vibrations, and iii) towing with oscillations to determine the excitation levels of vibrations in the risers. The resulting force coefficients will be used in computations that simulate the overall riser dynamics.

Some of the technological developments present a real win-win situation as they enhance the technical performance, decrease failure risks and decrease impacts on the ecosystem. An example is the open Permanent Magnet motor, shown below: the motor does not contain any oil, completely eliminating the risk of any oil spill. Moreover, as result of technological advancements the risk of failure is significantly reduced with respect to conventional technologies, and improved efficiency means reduced energy consumption. A final advantage is that the engine produces less noise.

Figure 3 - above left: The pumping station model (submerged yellow model) mounted on the towing carriage of MARIN's concept basin (picture by MARIN). Above right: The open PM motor (courtesy IHC Mining).

In the coming months will be very busy. Two cruises will gather a lot of data for our models, and allow testing of new equipment. In Norway, our pump drive system will be tested under real life conditions, and in Germany we will test our models describing the vertical transport of the mineral ore from the seafloor to the surface. Other important points are the wear of the riser material as result of the ore passing through it, and the safe and sustainable transfer of mined ore from the mining vessel to the transportation vessel. Furthermore we will work on the economic models required to evaluate the various mining scenarios.

In short, we're working hard on developing tools and technology required for the design of safe equipment and sustainable mining operation. On the technological side a lot more work is required, and input from ecological research is of utmost importance to establish an ecodynamic mining system design and operation that can limit impacts on the surrounding ecosystem.

We therefore have started to develop a framework that potentially can be used to reduce uncertainty in seabed mining projects through an integrated Development, Exploration, Environment Decision (DEED) framework, outlined below. The idea is to integrate environmental assessment in the process that starts with discovery of a potential project and ends with rehabilitation of the surrounding eco-systems to a level prescribed by the Authorities.

We would like to invite you to look at this framework and give us your opinion, suggestions, ideas, improvements and changes to this framework, so we can define an optimum approach.

For more information about Blue Mining, please visit www. or contact the project coordinator Robert van de Ketterij, email r.vandeketterij@mtiholland.com

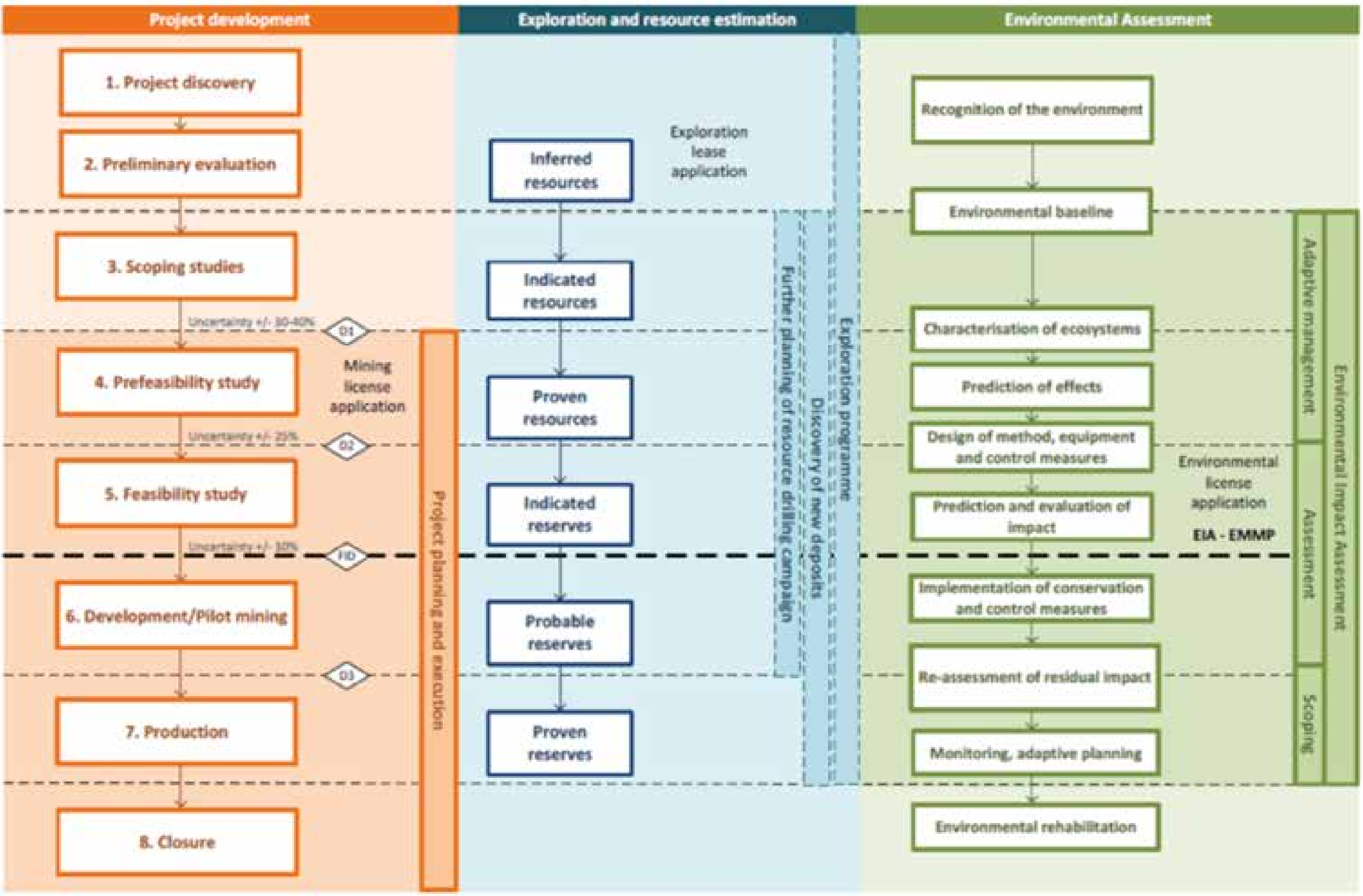

Figure 4: The DEED framework

The MIDAS newsletter is published 3-4 times per year. The deadline for articles for the Spring 2016 issue is Friday 29 April 2016 - please email vikki.gunn@seascapeconsultants.co.uk with your contributions.