



No. 28, March 1999

THE 9TH DEEP-SEA BIOLOGY SYMPOSIUM - GALWAY, IRELAND
25-30th June 2000
Second Announcement

As many of you already know, the next international Deep-Sea Symposium will be held in the National University of Ireland, Galway. 2000 seems to be developing into a year of "special" meetings but I hope that you will give priority to coming to Galway to make the symposium the "extra-special" meeting it usually is. The conference will make use of the lecture facilities of the University, which are fully equipped for those who wish to use videos, Powerpoint, etc. as part of their presentations. The campus is in easy walking distance of both the town and Corrib Village which houses students during term time. It will be possible for all delegates to stay there, thus facilitating after-hours discussions, etc. The cost of rooms (including breakfast) will be roughly 30 euro per person/per night (single and double rooms are available).

The proposed theme for the symposium is "The Deep Ocean Biosphere – Change and Sustainability". As with previous symposia, however, papers and posters on any aspect of deep-sea organisms (from macro to micro) and ecosystems will be welcome. Please remember that "deep sea" is not only the abyssal benthos but also deep waters and the deep sub-seafloor biosphere. Interdisciplinary papers are particularly encouraged.

Sessions which have been suggested so far include:

Biodiversity - an indicator and a resource.

Long and short term change - natural or not?

Responses of the deep ocean biosphere to natural and anthropogenic stimuli:

A) Physical

B) Chemical

Benthic flux studies

Several of you have asked for a "crystal ball" session on deep-sea biology in the next millennium, and since the symposium falls on the 50th anniversary of the great Galathea expedition (The Danish Deep-Sea Expedition Round



The Martin Ryan Institute of Marine Science.

Housed in a dedicated building erected in 1992 of some 2,800 sq m, the MRI occupies a prime site on the main UCG Campus.

the World 1950-52) I am happy to invite one of the original participants to tell us all about it (including – maybe – where he first learnt the haaka!!).

I am happy to receive suggestions from you on further topics and on anything else concerning the symposium. I am sure that those of you who have attended previous symposia will agree with me that some of the most interesting ideas have arisen outside the formal sessions. It is my intention to allow time for this, even if it proves necessary to limit the number of oral presentations. There will, of course be an excursion, and a banquet with plenty of local food and drink.

A conference web page has been set up and will be upgraded as further information on the symposium becomes available. Its address is: <http://marinemicro.ucg.ie/deepsea.html>

In order to help with planning, please either fill in the following form and post it to me, or Email me with the same information. The web and Email have greatly simplified the exchange of information concerning meetings and also allow for considerable savings on postage, etc. If I have your Email address you will be informed of all major developments and upgrades of the symposium web site. I will NOT post you hard copies of future announcements unless you specifically request so, or have no Email address. There will, of course, be further details of the symposium in future editions of the Deep-Sea Newsletter.

I hope you can make it to Galway.

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Brachiopods please!

Research on brachiopod molecular systematics and phylogeny is currently very active.

but

progress is limited by sample availability, especially from the shelf, shelf-slope and deeper North and South Atlantic.

In addition to deepwater brachiopod collections, specimens of *Argyrotheca* and of thecideidines from scuba-depth submarine caves are sought.

Specimens must be preserved in ethanol soon after collection. Some expenses can be refunded.

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See: Cohen *et al.*, 1998 a, b. Proc. Roy. Soc. B. 265: 475-482
and Phil. Trans. Roy. Soc. B. 353: 2039-2061

IUGG/IAPSO SYMPOSIUM P16

Recent Improvements to Deep-Sea Research through use of Submersibles, Remotely Operated Vehicles (ROV and AUV), Acoustic Tomography and In-situ Long Term Observations

18-30 July 1999 – University of Birmingham, Birmingham, UK

For further information and questions, please contact:

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Details are also given on the InterRidge website at:

<http://www.lgs.jussieu.fr/~intridge/bcast.htm>

The 9th Deep-Sea Biology Symposium - Galway, Ireland. 25-30th June 2000
Expression of Interest

Name:

Address:

Email:

Please keep me informed of future developments

If you need to be kept informed by post (rather than Email) please tick here ()

I hope to attend with _____ others.

I would like to make a presentation (yes _____) (no _____)

Title (or subject) if decided:

Format: Oral/Poster/ other (please state)/undecided.

Please post this to:

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Requests for receipt of D-SN should be directed to the correspondents. Contributions on new discoveries and other matters of interest to the deep-sea community may be sent through your correspondent or directly to me, whose gratitude will in both cases be unlimited.

Editor



AN ATLANTIC DATA BASE FOR EXCHANGE PROCESSES AT THE DEEP-SEA FLOOR (ADEPD)

At first it may seem that the above acronym was created to drive at our occasional incorrect usage of Latin words. Be assured that the project title was never meant to be a pun. So, what actually is ADEPD, and where does it go?

The global cycling of carbon and associated elements through the world's oceanic systems is one cornerstone of the understanding of the linkage between climate and oceanic processes addressed by the international Joint Global Ocean Flux Studies (JGOFS). In order to achieve a comprehensive view of oceanic biogeochemical cycles, the role of the long-term reservoirs of the deep waters and in particular the bottom sediments must be assessed. It is one of the major goals within the JGOFS program to reconcile rates of surface water production and rates of vertical export with data on benthic turnover to arrive at a full description of transport, burial and turnover of matter within ocean basins. Furthermore, the deep-sea ocean fluxes, albeit much smaller than those in surface waters, can be measured directly at a physical boundary and are less subjected to annual variability or short term variation. Therefore, they represent average flux rates and mirror, with some aberrations, average surface water productivity. Although the different national JGOFS programs did not specifically include benthic projects, there are a number of national and international European projects investigating benthic processes which are to some degree collaborating with JGOFS. Therefore, it would represent a substantial advantage to make the deep-sea biogeochemical data from various projects available for comparison with JGOFS data from the upper water column. This program has now been funded by the European Community since January 1998.

The first step was taken when twenty scientists from ten research facilities of six countries (one of them from outside the European Community) came together for 3 days in January 1998 at the Baltic Research Institute in Warnemünde. On the agenda of this first workshop were discussions about the variables and the regions to be covered by the project. Another principal topic was how to archive and maintain the data. It was decided early on that emphasis will be placed on the North Atlantic, since this area is covered by the most comprehensive data sets, in particular from British, French, German and American projects. Furthermore, the North Atlantic is considered to be one of the key areas for seasonal export of organic matter from surface waters and has been one of the regional study areas of JGOFS. The South Atlantic will be included to arrive at a complete description of the whole Atlantic Ocean. Each participant provided information about sources of potentially accessible data from various mostly national projects, some of them little known to the international scientific community. Variables and their preferable units to be included in the data base were determined. They comprise biological variables (abundance and biomass of different size and trophic groups, enzyme activities, DNA, adenylates, phospholipids, plant pigments, etc.), benthic flux measurements (oxygen, nitrate, silicate, inorganic carbon, etc.) and sediment particle composition (organic carbon, carbonate, opal, etc.). A list of these variables, units and their data bank IDs was compiled and distributed. One day was devoted to the introduction of the data bank to be used. Hannes Grobe and Michael Diepenbroek from the Alfred-Wegener-Institute in Bremerhaven gave an introduction to PANGAEA, a network for geological and environmental data. Besides general aspects, numerous details of practical relevance were addressed, such as data security and availability. In my opinion the most noteworthy advantage of PANGAEA is easy accessibility via the World Wide Web combined with the possibility to download data interactively. And it works, too. It may be mentioned in this context that PANGAEA comes with a couple of programs (written by Rainer Sieger, Bremen) which help to visualize the data. This software (PanPlot and PanMap) is quite ingenious in many respects and apparently heavily used by those who happen to know about it.

The second phase of ADEPD commenced right after the first workshop. Data had to be located (in some cases even typed in), re-expressed in the desired units and brought into the format required by PANGAEA. Carolin Petry did a thorough job as a data curator until she received a call to a more urgent task in November and I took over her mandate. Until the end of the year, the main bulk of the data was provided by the project members. We anticipate that the goal of the second project phase will be accomplished by March. To this day, analytical data of approximately 1070 sample sites have been archived in PANGAEA. Fig. 1 illustrates the distribution of sample sites provided by project members. Metadata as given in this example are open to the general public and can be retrieved from www.pangaea.de. Take the opportunity and browse through the various projects to learn who else is taking advantage of this neat facility. Analytical data are available only when published, otherwise you will be asked for a password. Access to analytical data provided by ADEPD members is available also via PANGAEA's

direct download interface from www.io-warnemuende.de/public/bio/adepd/adepd.html. Again, a password is needed for unpublished data.



Fig. 1. Map showing the sample sites for which project members provided benthos data.

Currently we are looking forward to our second workshop scheduled for 15-20 March 1999 in Warnemünde. The progress of data collection, problems and gaps in data coverage will be reviewed and discussed in the initial phase. It is planned that biogeochemists and biologists will analyze their data at first separately in two "subject meetings". One goal is to identify possible biogeochemical provinces in the deep Atlantic, analogous to the concept of upper ocean biogeochemical provinces (Longhurst 1995). Since many biogeochemical key variables describing standing stocks and rates of turnover in the deep ocean can for practical reasons only be obtained at a few selected stations, the extrapolation of such data from individual sites to a larger spatial scale is difficult. Our approach will be to establish empirical correlations of processes which link these limited data to "master" variables for which a large data base is already available. Rick Jahnke (1996) assessed the global ocean flux of particulate organic carbon from benthic data and demonstrated that this is feasible and that a general regional classification of the sea floor in terms of biogeochemical characteristics is possible. However, shortcomings became evident due to the rather limited amount of data available. We do hope that, by means of the data provided by the ADEPD group, Rick's very commendable work can be further substantiated and refined. Further topics on our agenda are how to 1) analyze the data in the remaining project time, 2) make the results available to a wider user group, particularly within the JGOFS community, and to authorities involved in decisions about utilization of deep-sea resources and deep-sea protection, and 3) set up our home page plus data retrieval.

If anybody is interested in our doings, feel free to drop some lines to us at: adepd@io-warnemuende.de

Literature

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LONG-TERM CHANGE IN ABYSSAL COMMUNITIES

A dramatic shift has occurred in the dominant benthic invertebrate megafauna at a depth of 4850 m in the Northeast Atlantic over a period of 10 years. We term this change the “*Amperima* event”, after the apparent bloom, in particular, of the holothurian *Amperima rosea* (Fig. 1). Significant changes in the abundance of other taxa are also apparent.

This is one of the major results from the European (MAST III) sponsored project BENGAL (see Deep-Sea Newsletter 25, p. 9). BENGAL stands for “High resolution temporal and spatial study of the BENThic biology and

Geochemistry of a north-eastern Atlantic abyssal Locality”. BENGAL was a 3-year project with 17 partners from across Europe and came to an end on 31 January 1999. A specific locality on the Porcupine Abyssal Plain was sampled between September 1996 and October 1998 on at least 6 separate occasions, using a wide variety of equipment including landers, CTDs, sediment trap arrays, time-lapse cameras, survey cameras, trawls, sledges, multiple corers, box corers, sediment profilers, and colonisation modules. The benthic community at the same locality had also been sampled on previous occasions in 1989, 1991 and 1994 (pre-BENGAL samples).

The abundance of invertebrate megafauna in the pre-BENGAL samples was about 80 individuals per hectare. In September 1996 the total abundance increased to about 150 individuals per hectare, and throughout 1997 and 1998 has varied between 200 and 350 individuals per hectare. The increase in abundance is highly significant, even though there is no significant difference in the wet weight biomass of megafauna over a similar period. A significant increase in abundance is apparent in the actinarians, annelids, tunicates and holothurians. The holothurians dominate all the samples (c. 90% by biomass), but the dominant species have changed. From a community that was dominated by *Oneirophanta mutabilis*, *Psychropotes longicauda* (Fig. 2) and *Pseudostichopus villosus*, we now have a community dominated consistently by *Amperima rosea* and, to a lesser extent,

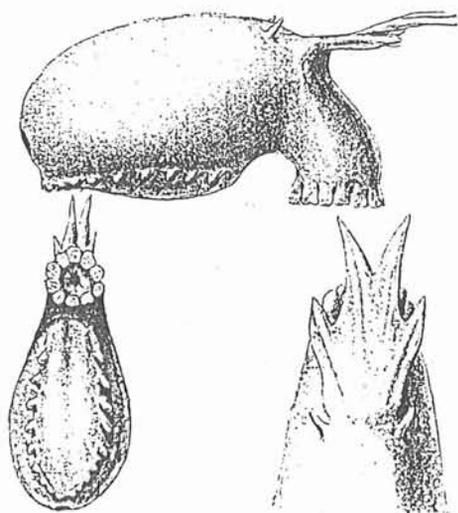


Fig. 1. *Amperima rosea*. (R. Perrier 1902: Travailleur/ Talisman Expedition).

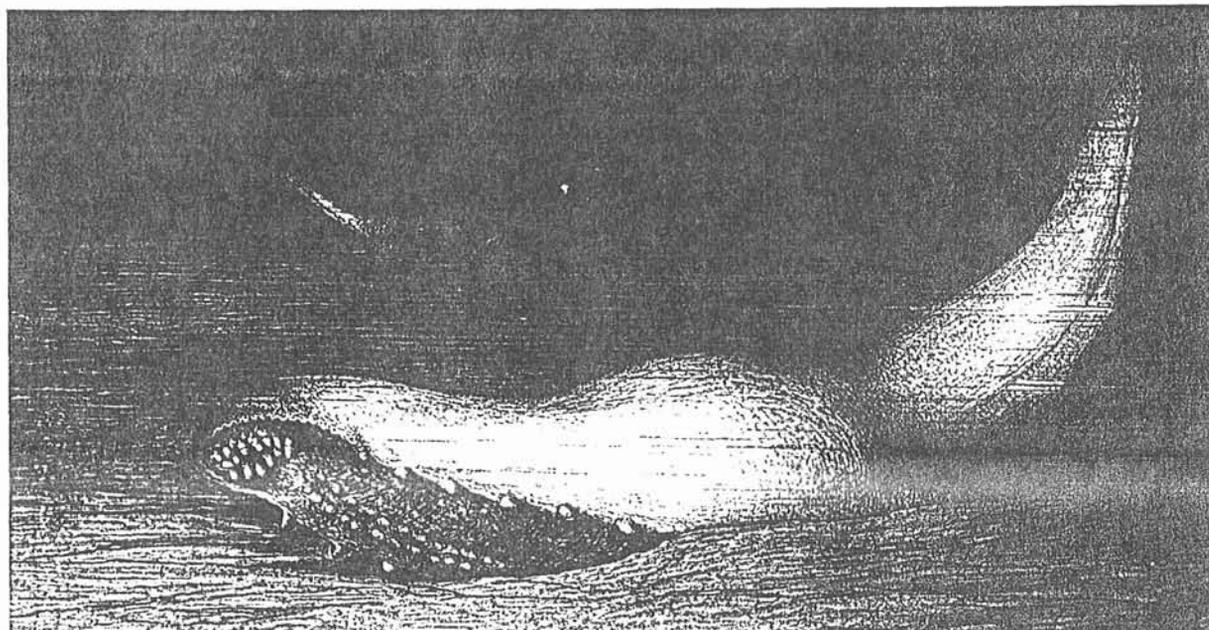


Fig. 2. *Psychropotes longicauda*. (A. Bruun 1956: Galathea Expedition).

by a species of *Ellipinion*, probably *Ellipinion papillosum* or *Ellipinion molle*. The abundance of most holothurian species has remained constant, including *O. mutabilis* and *P. villosus*, but numbers of *P. longicauda* have increased significantly and there has been a shift in the population size distribution to smaller individuals.

The causes of the transformation are unknown. The change may be stochastic, but this would seem unlikely as a number of different taxa have increased in abundance. Richard Lampitt has found considerable inter-annual variability in the supply of particulate material to the seafloor at the BENGAL site. If the two observations on long-term variability are linked, it is possible that the timing, quantity and quality of organic matter reaching the seafloor has a significant effect on the dominant organisms. If so, it presents a way in which deep-sea benthic communities might be affected by decadal-scale changes in surface waters. The BENGAL site will be sampled again on an SOC-sponsored cruise in April/May 1999.

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LEMICHE'S LOPHENTEROPNEUST WIDELY KNOWN BUT STILL AN ENIGMA

It always arouses a nice feeling when colleagues bother to react to one's writings. I have received several comments to the letter "What became of Lemche's Lophenteropneust?" (D-SN 27:21-24).

It is a disappointment that nobody claims to have found the animal or points to possible whereabouts of samples. In fact, most commentators seem to be of the opinion that Lemche's combination of a creative mind and artistic inclination may in this case have carried him too far in the interpretation of the original photographs from the SW Pacific trenches. On the other hand, several phylogeneticists have emphasized the importance of the animal if it really does exist.

A particularly elaborate answer came from Dennis Gordon (National Institute of Water & Atmospheric Research, Wellington, New Zealand). He mentions an inquiry on the presence of lophenteropneusts in the NZ collections, and some discussion on bottom photographs from the NZ region showing the characteristic trails and, in one case, an animal which possibly is an enteropneust, but without tentacles. Dennis (d.gordon@niwa.cri.nz) offers a copy to anyone who is interested. He also points out an interesting paleontological paper by Culler (1967) on possible enteropneust faecal casts in New Zealand tertiary deposits.

I should like to call attention to a fine survey of the biology of enteropneusts, from the paleontologist's point of view, in the book on animal traces by Bromley (1996).

During my yearly stay as visiting investigator at the Darling Marine Center, Maine, I came, in their library, across a large number of bottom photographs from deep bottoms in the South Pacific near Antarctica. They are published in two "Eltanin" reports (Jacobs *et al.* 1969, 1970). Many of these photographs, from between 2500 m and 4000 m, show fecal spirals or meanders, and in some cases enteropneust-like animals with a more or less pronounced collar.

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Jacobs, S. S., P. M. Bruchhausen, F. L. Rossdal, A. L. Goder, A. F. Awas & M. Belliard. 1970. Hydrographic stations, bottom photographs, current measurements, and nephelometer profiles. – Eltanin Reports, Cruises 37-39, 1969 and 42-46, 1970. Lamont-Doherty Geological Observatory, Columbia University, Palisades, N. Y.



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THE XENOPHYOPHORE *SYRINGAMMINA FRAGILISSIMA* BRADY, 1883: REDISCOVERED ON THE UK CONTINENTAL MARGIN

On the 28th of August 1882 the steamship *Triton* trawled two specimens of a very fragile agglutinated organism, the larger of which was almost 4 cm in diameter, from 1016 m water depth in the 'Faroe Channel' (NB - not the Faeroe-Shetland Channel), NW of Scotland. The specimens were described by Brady (1883) as *Syringammina fragilissima*, a new genus and species of agglutinated foraminifera. A third specimen was caught in 1910, also in the 'Faroe Channel', 850 m, during the *Goldseeker* expedition. *Syringammina* continued to be regarded as an unusual agglutinated foraminifer until Tendal (1972) transferred it to the Xenophyophorea. It is, in fact, one of the more foraminiferan-like of the xenophyophores, having a test composed of anastomosing tubes which contain the protoplasm and stercomata (waste pellet) masses. In most xenophyophores, the interior of the test also contains foreign particles (xenophyae), forming a more-or-less solid rather than tubular structure. In addition to *S. fragilissima*, the genus contains three other species: *S. minuta* Percy, 1914, *S. tasmanensis* Lewis, 1966 and *S. reticulata* Gooday, 1996.

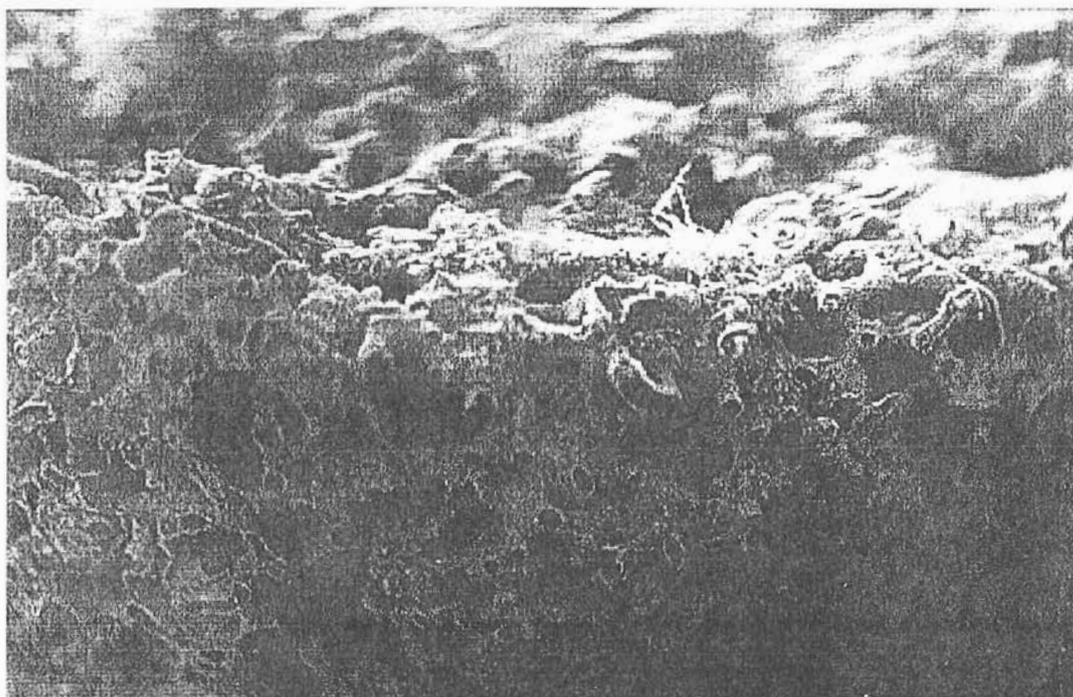


Fig. 1. *Syringammina fragilissima* Brady, 1883, from W of Rockall bank (57°26'N, 015°41'W, ca. 1100 m). Close-up showing details of largest specimen, which more than filled the 10 cm megacore. Not to scale.

A few specimens of *Syringammina fragilissima* turned up during the 1960s and 70s on the Chatham Rise off New Zealand, 740-1373 m (Tendal, 1972, 1981), and Saidova (1975) mentions a Pacific occurrence. However, there were no further records from UK waters. It appeared to be a rare, albeit widely distributed species. This impression has been dramatically revised by samples and photographs taken during a series of recent cruises on the UK continental margin. Instead of only six collected specimens, we now have another 14, collected from megacore and boxcore samples. The recovered specimens measure between 1.5 and at least 10 cm in diameter. The largest specimen (Fig. 1), from west of the Rockall Bank, more than filled the diameter of a 10 cm megacore tube. At more than 400 cc test volume, this must be one of the largest xenophyophores yet captured.

Many of our new records are from close to the type locality in the northeast corner of the Rockall Trough (Fig. 2). Although the site is referred to as the 'Faroe Channel' in the original report, the position given is within

the Rockall Trough. This can be further supported by the fact that the recorded bottom-water temperature was 7.5 C rather than near or sub-zero as might have been expected if the site was in the Faeroe-Bank or Faeroe-Shetland

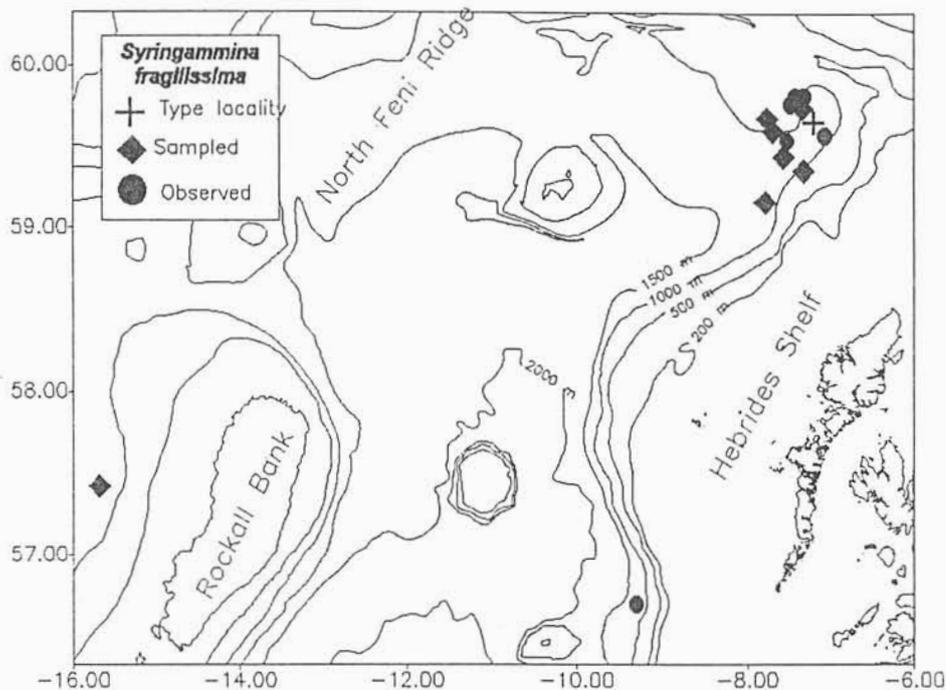


Fig. 2. Chart showing the type locality of *Syringammina fragilissima* and the locations where this species has recently been rediscovered.

Channels. Extensive seabed sampling and photography of the eastern flank of the Faeroe-Shetland Channel recently carried out by SOC did not record *Syringammina* or any other large xenophyophore.

The frequent capture of *Syringammina fragilissima* during recent cruises to the Rockall Trough suggests that it is an abundant organism. Photographic studies in the vicinity of the type locality have covered a seafloor area of approximately 25 hectares, overall *S. fragilissima* occurs at a density of one individual per 10 square metres of seafloor. The xenophyophore has a very patchy distribution and at spot locations may reach densities of almost 10 per square metre! It appears that this once 'rare' species is probably abundant and common on the UK continental margin at depths between 800 and 1300 m. A similar xenophyophore has also been photographed on the Goban Spur (49°38'N, 13°12'W, 1750 m) where it occurs at densities of up to 4 per square metre (Bett, *pers. obs.*). Further south, what may be the same species has been photographed on the continental slope off NW Africa (29°06'N, 12°27'W, 1065-1090 m; Gooday & Tendal, 1981). Members of the genus *Syringammina* appear to be equally abundant and widely distributed in the NW Atlantic (Tendal, 1988, Levin & Gooday, 1992).

The new observations have added considerably to our knowledge of the ecology of this giant protozoan. Specimens photographed on the seafloor near the type locality were particularly abundant in the vicinity of recently discovered carbonate mounds. It is possible that they are responding to a locally increased availability of food immediately downstream of these mounds (cf. the seamount observations of Levin & Thomas, 1988). During the study of these mounds (June 1988) there were considerable quantities of phytodetritus on the seabed; in some cases, photographic observations suggested that the seabed in the immediate vicinity of xenophyophores had been cleared of deposited phytodetritus, possibly indicating their feeding actions. In the same area, small white gastropods were frequently observed on top of xenophyophores - could these be predators? One of the larger *Syringammina fragilissima* specimens recovered had three circular depressions in the test surface - could these be the results of predation / grazing?

Although now known for almost 120 years, *Syringammina fragilissima* and other xenophyophores, remain enigmatic and thought-provoking organisms. These recent discoveries of abundant populations in the Rockall Trough suggest that further direct investigations of the group are both possible and profitable.

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RISKER REPORT PUBLISHED BY THE EU

Several years ago, the European Union published a call for proposals asking for “the assessment of any possible risk likely to affect the marine environment in association with research, monitoring and surveying in marine sciences and technology”. RISKER’s overall objective was to identify the types and scales of research that would be needed to predict the impacts of various deep-sea activities and to assess the likely environmental impacts, and therefore acceptability, of the environmental research itself. Future scales of environmental research will range from conventional sampling to the experimental creation of large-scale impacts for risk evaluation of commercial uses of the deep sea. The large-scale experimental approach for risk assessment has been the main focus of this study. Waste disposal into the deep sea (radioactive wastes, munition, large structures, sewage sludge, dredge spoil, carbon dioxide) and resource extraction from the deep sea (polymetallic nodules and crusts, massive sulphides, metalliferous muds, phosphorites) are considered under the aspects of waste / resource characteristics, disposal / mining techniques, environmental effects, and research required to evaluate these effects. The RISKER study concludes that traditional-scale research and large-scale scientific experiments meet the environmental acceptability criteria listed in the report. Because of their limited extent in space and time, it is believed that commercial pilot mining operations (PMOs) and pilot disposal operations (PDOs) would also be acceptable. However, careful consideration of any further development will be essential before decisions are made to proceed with these final precommercial disposal / mining activities.

The report “Environmental risks from large-scale ecological research in the deep sea: a desk study”, prepared by Hjalmar Thiel, Martin V. Angel, Eric J. Foell, Anthony L. Rice and Gerd Schriever (1998, 210 pp.; ISBN 92-828-3517-0) under contract No. MAS2-CT94-0086 may be obtained from the OFFICE OF OFFICIAL PUBLICATION OF THE EUROPEAN COMMUNITIES, L-2985 Luxembourg for 8 ECU (excluding VAT).

A summary of RISKER is published by Hjalmar Thiel and Tony (Anthony L.) Rice (1998): How do we evaluate environmental consequences of large-scale activities in the deep ocean. *Ocean Challenge* 8 (2): 51-56. This is the journal of the Challenger Society for Marine Science in Britain.

Hjalmar Thiel, Hamburg

THE FIRST RECORD OF A TESTATE AMOEBIA (ORDER FILOSEA, GENUS *GROMIA*) FROM THE DEEP SEA

It is now widely recognised that the deep-sea benthos contains some of the world's largest protists. Various groups are represented, including astrorhizacean, allogromiid and komokiacean foraminifera (Tendal & Hessler, 1977; Tendal, 1981; Gooday et al., 1994) and xenophyophores, giant rhizopods which occupy a distinct higher taxon (Tendal, 1972, 1996). Our new observations demonstrate, for the first time, that testate amoebae can also occur in the deep sea.

During RRS *Discovery* Cruise 211 to the Arabian Sea led by John Gage (see Deep-Sea Newsletter No. 23, 1995), some curious spherical organisms, 5-34 mm in diameter, were discovered in epibenthic sledge and box core samples taken between about 1200 m and 1650 m depth in the lower part of the oxygen minimum zone ($O_2 \sim 0.47$ ml per litre; Levin et al. in press) off the coast of Oman. At first sight, they appeared gelatinous and were christened 'jellyballs' by cruise participants. Subsequent examination revealed an organic wall punctuated by numerous small (20-60 μ m diameter) apertures and enclosing a mass of dark stercomata (waste pellets). Some of the apertures gave rise to filamentous structures which penetrated the sediment, possibly serving to anchor the test to the seafloor. We thought that the jellyballs must be protists, but were unable to decide whether they were very large allogromiid foraminifera or something even more exciting.

The answer was provided by cutting thick sections of the test wall (a tremendous time-saving measure when studying such huge protists; see Bowser et al., 1995) and examining these sections with the high voltage electron microscope at the New York State Health Department's Wadsworth Center in Albany. This powerful instrument revealed that the wall contained a highly structured layer, identical to the honeycomb layer found in the marine testate rhizopod *Gromia oviformis* (Hedley & Wakefield, 1969). This species, which grows up to about 5 mm in length, is widely distributed in intertidal and sublittoral settings down to a maximum reported depth of 270 m (Arnold, 1972; Bowser et al., 1996). Based on its pseudopodial morphology (Bovee, 1985), *G. oviformis* is generally regarded as a testate amoeba (order Filosea). Molecular evidence suggests that its phylogenetic position

within the radiation of eukaryotes is distinct and rather distant from that of foraminifera (Pawlowski et al., 1994). We will describe the jellyballs as a new species of *Gromia* in a forthcoming paper (Gooday, Bett, Bowser, Smith, Deep-Sea Research II). Most testate amoebae occupy terrestrial or shallow aqueous (usually freshwater) habitats. We believe this to be the first report of a truly deep-sea testate amoeba, albeit a highly unusual one.

The gromiids are clearly visible in bottom photographs, occurring in densities of 17.3 individuals per m^2 (1624 m) and 76.5 individuals per m^2 (1633 m) (Fig. 1). Specimens lay half-buried in the sediment and were often surrounded by an apron of lighter-coloured sediment, possibly representing material collected by the pseudopodia. This observation, and the presence of masses of stercomata within the test, suggests that the gromiids may play a role in the degradation of organic matter near the sediment-water interface. Their distribution on the seafloor was clearly non-random with some individuals being grouped in pairs and triplets, possibly reproductive associations.

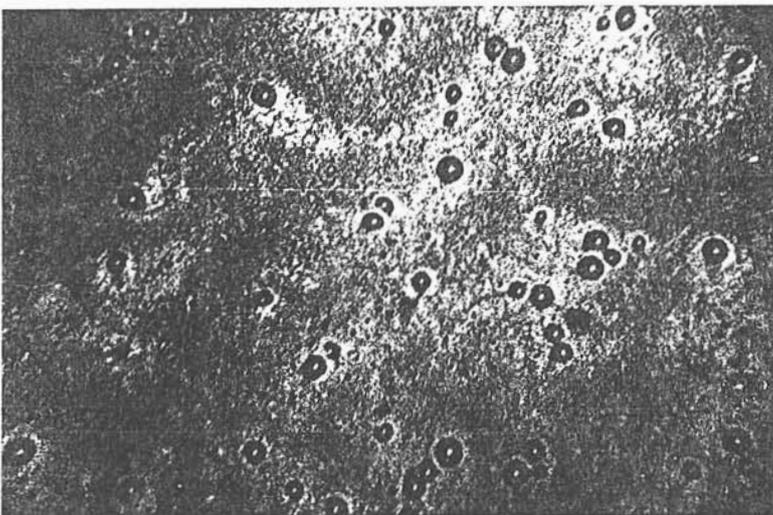


Fig. 1. Seafloor photograph showing numerous specimens of the new *Gromia* species in their life positions; *Discovery* Station 12728#2 (19°13.38'N, 58°32.87'E, 1633 m). The photograph was obtained using a single-shot Preussag model FBK 135 M 35 mm still camera mounted on the frame of an USNEL box corer. The view is approximately vertical, the longest side about 103 cm long and the largest specimens approach 4 cm in diameter.

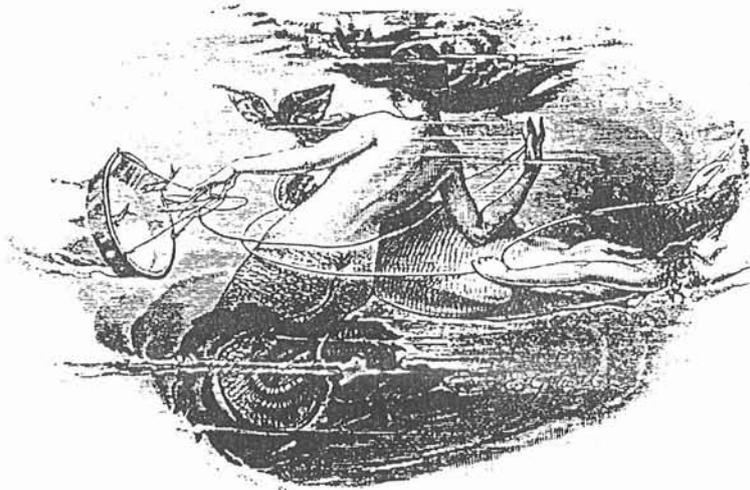
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ATIE (ATACAMA TRENCH INTERNATIONAL EXPEDITION): EVIDENCE FOR EXTREMELY RICH AND ACTIVE BENTHIC COMMUNITIES

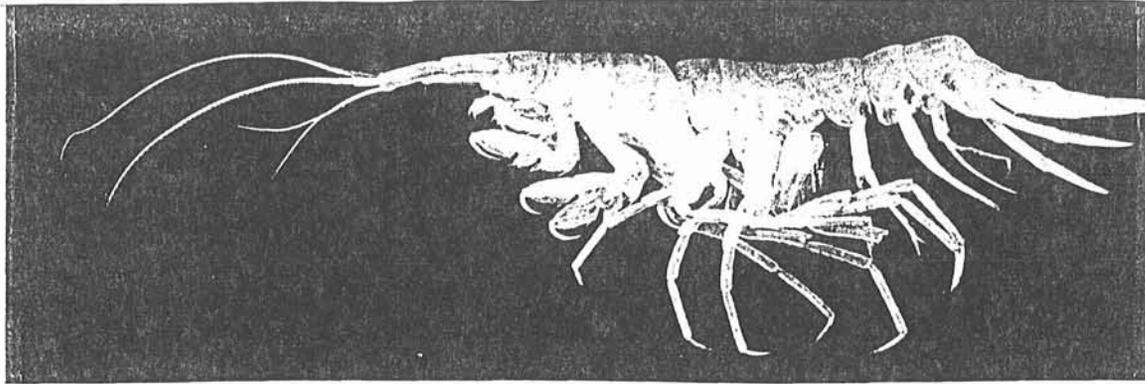


Fig. 1. *Princaxelia* sp. Length including antennae 6 cm. Atacama Trench International Expedition. Color in life pale yellow.

Although it has been recently recognized that deep-sea areas might be characterised by benthic “hot-spots”, research on trenches has so far recognized the oligotrophy of these environments both in terms of available food sources and density of benthic organisms. In September 1997, an international expedition promoted by the Istituto di Scienze Ambientali Marine of the University of Genova, involving European and Chilean institutions and with the cooperation of the “Servicio Hydrográfico y Oceanográfico de la Armada de Chile”, was carried out on board the vessel “Vidal Gormaz” to study the benthic ecology of the Atacama Trench which, due to the extremely high productivity of the area, could present special characteristics.

In an attempt to clarify the characteristics and structure of the benthic food web, chemical and microbiological analyses of sediments collected from the trench and other deep stations have been carried out. Despite the generally low benthic bacterial density, bacterial secondary production and enzymatic activities were comparable to those reported for the most productive systems of the world. The results are consistent with the large accumulation of phytopigments and other biochemical indicators of organic matter availability to consumers. Such

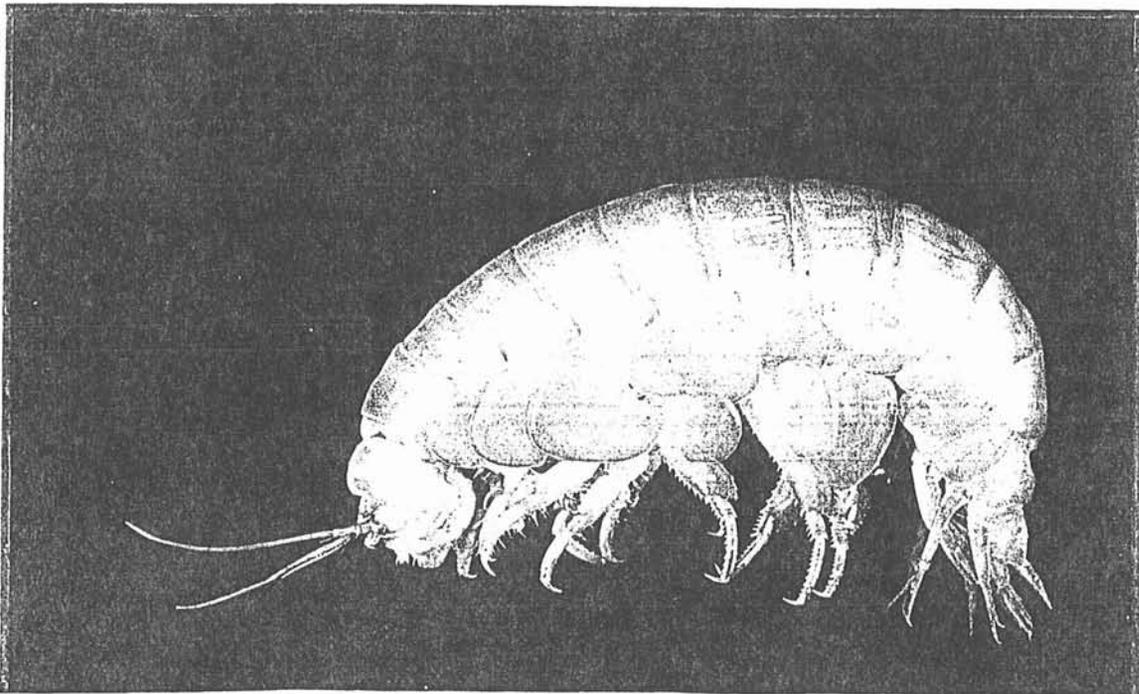


Fig. 2. *Eurythenes* sp. Length without antennae 5 cm. Atacama Trench International Expedition. Color in life deep orange yellow.

an extremely rich microbial loop is able to sustain large higher trophic level biomass and these observations are consistent with the hadal fauna found in the traps anchored over the bottom at a depth of 7800 m at 23°15'S, 71°21'W for 39 hours. It is worth noting that in four traps on the bottom no less than 910 amphipods were collected.

Thanks to the collaboration of the following specialists of different institutions, the study of the collected material is in progress:

Dr. T. Antezana	University of Concepcion	Euphausiacea
Dr. D.S.M. Billett	Southampton Oceanography Centre	Echinodermata
Dr. G. Boxshall	The Natural History Museum	Copepoda
Dr. P. Clark	The Natural History Museum	Crustacean larvae
Dr. P. Curzi	University of Bologna	Chemistry of sediments
Dr. E. Ghirardelli	University of Trieste	Chaetognatha
Dr. R. Huys	The Natural History Museum	Harpacticoida
Dr. J.B. Kirkegaard	Zoological Museum, University of Copenhagen	Annelida
Dr. J. Knudsen	Zoological Museum, University of Copenhagen	Mollusca
Dr. M.E. Petersen	Zoological Museum, University of Copenhagen	Annelida
Dr. J.C. Sorbe	Laboratoire d'Océanographie Biologique CNRS	Mysidacea
Dr. M. Thurston	Southampton Oceanography Centre	Amphipoda
Dr. Prof. W. Waegele	Ruhr-University of Bochum	Isopoda

We take this occasion to inform readers that contact with specialists on Nematoda and Micropaleontology would be greatly appreciated. Information will be provided to scientists interested in future research on trenches.

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INTERNATIONAL WORKSHOP ON "EXTREME MARINE ENVIRONMENTS"

An international Workshop on "Extreme marine Environments" was held at GEOMAR-Research Centre for Marine Geoscience, Kiel 19-22 November 1998. Over a hundred scientists from Europe and Japan participated in the meeting. The meeting was sponsored by the Directorate General XII of the EU and the Federal German Ministry of Education and Research. Members of the steering committee were:

E. Suess (D)
O. Pfannkuche (D)

J. Parkes (GB)
A. Camerlenghi (I)

T. van Weering (NL)
E. Lipiatou (Dir. XII, EU)

Workshop rationale

Modern marine science provides an increasingly important contribution to global environmental research and to the evaluation of anthropogenic and natural changes. Humanity, in reforming the surface of the Earth to meet its ever increasing needs, interferes with the variability of natural processes and creates new sometimes extreme environmental conditions to which life either adapts or vanishes.

Extreme temperatures, high pressures, and limited nutrient supply define the limits for life on Earth and have resulted in diverse survival strategies. Such extreme conditions are found today in many marine settings which can be used for model studies. In the Earth's past there is evidence that environmental conditions very different from those of today have prevailed or, as is becoming increasingly apparent, have occurred as abrupt changes.

On the basis of a detailed understanding of the processes which operate today in selected extreme environmental settings can predictions be made of how human activity superimposed on natural variability may change the global environment.

Workshop goal

Current results will be examined on the following topics and sessions with invited and contributed presentations provide the structure of the workshop:

- Fluid-matrix-biota interaction at cold seeps and hydrothermal vents
- Colonization patterns of vent ecosystems
- Ecology of extreme environments
- Variability of pelagic-benthic coupling
- Mega-eruptions at spreading ridges
- Mud diapirism and deep brine lakes
- Gas hydrates
- Deep sub-sea floor biosphere

Open questions and research strategies should be addressed by separate working groups with the following goals in mind:

- Identify major interacting parameters in complex geo- and biotopes
- Assess frequencies and magnitudes of extreme events
- Model the re-equilibration of environments after perturbation
- Predict the potential dangers of extreme events and effects caused by extreme environments on society
- Evaluate anthropogenic effects on natural variability
- Recognize feed-back mechanisms and new reaction pathways
- Develop new deep-sea technologies
- Implement a European network to coordinate and carry out joint research projects.

Societal implications

Extreme environments provide the opportunity to directly observe rates and discover new reaction pathways and feedback mechanisms affecting global change. Extreme environments may harbor exotic, often economically important minerals, solutes and organics. Micro-organisms are adapted to function in exotic settings; e.g., gas hydrate deposits, oil and gas reservoirs, sites of waste storage and dumping; they are extremophiles and will have biotechnological applications. The technology required to carry out such investigations in the marine environment has only recently been developed and become available. New, standardized, and observatory-like deep-sea technologies need to be identified.

Five oral and poster sessions were held on the following subjects:

- Material fluxes from vents-mud volcanoes-gas hydrates
- Deep biosphere-mud volcanoes-gas hydrates
- Abyssal habitat
- Hydrothermalism-revisited
- Technology: Development and challenges.

Working groups were established according to the above topics to outline future fields of research. Working group recommendations were:

1. THE ABYSSAL ECOSYSTEM

Introduction

The abyssal ecosystem is the largest habitat on earth connected by global deep ocean current systems. The exploration of the deep sea is the last great challenge on our planet and it is important because:

- the deep ocean is an integral part of the global climatic system being the biggest, long term buffer for greenhouse gases;
- the deep-sea floor is the final repository for anthropogenic wastes which reach this remote region via river discharges, air currents and rain;
- the abyss is an ecosystem of high biodiversity containing the most unknown organisms.

At present human exploitation of the deep-sea resources is minimal, but for instance hydrocarbon prospection is steadily progressing from the outer shelves down the slopes. The susceptibility of this ecosystem to disturbances has to be known before any intentional alterations are allowed to occur.

High pressure and low temperature prevail throughout this realm and may reduce the speed of life, but most organisms living in the abyss are well adapted to these environmental conditions. The most severe restriction for life in the deep sea is lack of adequate nutrition. The food supply for deep-sea organisms derives from phytoplankton primary production in the surface waters above and sinks episodically to the sea floor. Only a small fraction of ca. 1% of the surface water productivity reaches the abyssal sea floor. Therefore, the abyssal habitat is sparsely populated, albeit with a highly diverse community, and organisms are superbly adapted to survive under very low nutrient supply punctuated by short pulses of sedimentation of organic material.

Although the rate of biogeochemical transformation of materials is generally slow in the abyss, due to its vast area covering ca. 60% of the earth's surface the total turnover is very large and determines the chemistry of the deep ocean. Anthropogenic impacts have so far been relatively small. Either diffuse inputs through the atmosphere (e.g., deposition of lead from fuels, increased CO₂ in deep waters) or localized disturbances (e.g., ship accidents, dumping, mining) have affected the deep sea. Their impact on the abyssal ecosystem is extremely difficult to assess.

The deep sea is generally considered a very uniform and stable environment populated by organisms which are not capable to cope with significant variations in their surroundings. However, natural disturbances can be found in the deep sea ranging from short term, seasonal pulses of food supply to major disruptions caused by turbidities, volcanic eruptions or destabilization of gas hydrates. The latter catastrophic events happen frequently, but unpredictably, and can affect very large areas of the deep-sea floor indeed. These events may help to understand the capability of the abyssal ecosystem to survive and react to large scale disturbances. Their study may give insights how fragile or resilient the abyssal ecosystem is.

Research in the deep sea under the key actions "Global change, climate and biodiversity" and "Sustainable marine ecosystems" directly addresses the objectives of these key actions. It is an important element to foster better understanding of this extreme environment in order to:

- assess deep-sea biodiversity;
- assess the impact of global change processes on biodiversity and biogeochemical cycles,
- assess the impact of natural extreme events,
- provide the scientific basis for the development of management strategies,
- develop the instrumentation for observation systems for crucial deep-sea areas and processes.

Three main areas of research were identified and are described below as topics highly relevant for future European deep-sea research.

Biodiversity in the deep sea as an indicator of environmental change

Rationale

The view that deep-sea communities are constant in their species composition over long (decadal) periods of time is being challenged by recent European research indicating that communities can change significantly over a number of years. There is a need to understand the causes of change in deep-sea communities with time and to determine which processes contribute to the maintenance of high species diversity in the deep sea.

There is evidence that decadal-scale changes in deep-sea benthic communities may be related to inter-annual variability in the supply of organic matter and so to surface water productivity and global change. That global change may occur at abyssal depths is of great significance because it demonstrates that even remote environments like the deep sea may be affected by global forcing. Research projects are needed that 1) measure changes in community structure with time, 2) relate the changes to environmental variables, 3) assess biological interactions, such as the creation of microhabitats by large key species, and 4) set the results in the context of spatial variability.

Inter-annual variability in food supply is a form of "disturbance" of the seafloor that could be important in generating high species diversity in the deep sea. A number of intermittent processes, such as benthic storms and localised bioturbation, have been proposed in "Intermediate Disturbance Hypotheses" to account for deep-sea biodiversity, but as yet variability in food supply has not been suggested. Understanding changes in species dominance and composition with time, therefore, would aid the research proposed under the EMaPS European science plan on marine biodiversity, and the international programme for biodiversity science, DIVERSITAS, to manage the sustainable use of the marine environment. The results can be used to interpret past environmental/diversity changes in the palaeoceanographic record.

This research is important in the European context for the following reasons:

- For sustainable, integrated ecosystem management of European seas, natural temporal variability in faunal communities must be understood. For instance, anthropogenic environmental impact, such as from deep-water oil and gas exploration and production, is often measured against a baseline survey. The baseline is assumed to remain constant, at least over the timescale that any installation is in production. However, it is now apparent that baselines can move. European, deep-

water environmental monitoring/management strategies need to be amended. New research is required on the importance of natural environmental change to guide European environmental policies.

- Biodiversity in European deep waters does not appear to be immune from global change. Abyssal depths, where animals are dependent on food derived only from surface water productivity, offer a simple environment, free from large physical perturbations, in which to measure the response of biodiversity to environmental change. Studying changes in deep-sea biodiversity will be useful in evaluating apparent climate change in other environments that are subject to significant non-climate related perturbations. Changes/loss of species in the deep sea could lead to significant changes in biogeochemical cycles.

- Knowledge on biodiversity is a prerequisite to start the exploitation of marine resources such as enzymes and other potentially biotechnologically utilizable compounds. Many of the systems adapted to low temperature and high pressure developed in nature's own laboratory may present opportunities for commercial exploitation.

Approach

European time-series reference stations should be established at sites where data are already available for longer periods of time, such as in the NE Atlantic or in the eastern Mediterranean. In order to study changes in biodiversity in time and space, more than one deep-sea location is needed preferably representative for key areas. Clustering of projects working on time series at the same site would aid logistics and reduce costs.

Biodiversity needs to be assessed in terms of species morphology, genetics, functional groups and habitat types. Wide ranges of fauna, including microbes, protozoan and metazoan meiofauna, macrofauna, megafauna, benthopelagic fauna (including fish), and their interactions, need to be assessed concurrently. Data on organic input from long-term moorings, and inorganic/organic chemistry in particulate material and within the seabed will be required, in particular productivity and/or disturbance indicators. In addition to descriptive approaches, new experimental techniques should be used to assess the effects of organic enrichment and variability in food supply on benthic community structure (see below), and the effects of bioturbation (mound formation, tracks, burrows) of large key species on the micro-distribution, biodiversity and tolerance of smaller species. Additional studies on the way in which communities change with space, on a variety of scales from a few metres to ocean basin should be considered, including experiments and observations on recolonisation, recruitment, reproductive and feeding strategies.

Response of deep-sea ecosystems to food deposition: experimental approaches

Rationale

Data of moored sediment traps and fluorometers have revealed that primary production is an episodic process resulting in pulsed deposition of algal material, phytodetritus, to the sediment. Time-lapse photography of the deep-sea floor has provided clear evidence of the irregular, pulsed arrival of organic matter. The response of the benthic communities to these pulses has been investigated through a very limited number of high quality time-series observations. These studies and a modelling study indicate that short-term fluctuations in carbon deposition result in smoothed, attenuated, and somewhat delayed responses of biogeochemical processes. There are also some indications that different component groups of the benthos may react in a different way and at different time scale to deposition events. Direct field observations of the response of the benthic community to pulsed inputs is very difficult. Not only is the response rapid (i.e., within days), but it may also be rather brief (days) and the exact timing of the deposition events may vary over several weeks from year to year. Consequently, field observation programmes with a resolution of less than a week, prolonged over several weeks would be needed to observe this phenomenon. This is normally not possible for oceanographic expeditions, because of logistic and financial constraints.

With the aid of in situ experiments e.g., in benthic chambers, small scale disturbances (e.g., input of phytodetritus, input of waste, etc.) can be simulated. The response of the biogeochemical processes and the benthic community structure to these experimental manipulations can be determined. This approach enables us to

- understand the magnitude and timing of benthic response,
- provide better constraints on biogeochemical models,
- understand the community response: identify the group of reactive organisms, determine changes in physiology and the community structure.
- improve the interpretation of the paleorecord based on benthic organisms (e.g., foraminifers).
- understand the resilience of the benthic system to anthropogenic impact (e.g., dumping).

Approach

An experimental approach is proposed in which material is added in situ to benthic chambers. Investigators can control the magnitude and quality of the deposition pulse. For instance, it is possible to determine the differential response to phytodetritus, pre-treated sewage or other potentially dumped waste material. Moreover, the observation time-scale can be optimised for the

process or organism involved. The response of biogeochemical processes as well as that of bacteria, protozoa, meiofauna and macrofauna can be determined using a variety of techniques, including chemical, isotopic, molecular biological and enzymatic approaches.

This approach is complementary to previous executed and ongoing research based on detailed time-series analyses, has a high costs/benefit ratio, and is highly feasible with existing technology. Such studies are preferably executed in a well-studied area with relatively easy access. Moreover, it should ideally be linked to ongoing monitoring studies.

Large-scale natural and anthropogenic disturbances to the deep sea: Impact, response and adaptation

Rationale

Large-scale disturbances of the deep-sea floor offer the possibility to quantify and predict the response and adaptation of deep-sea communities and the geochemical environment to sudden disequilibria generated by natural events as well as by anthropogenic hazards. Natural disturbances are turbidity currents, slumps or volcanic ash deposits. Anthropogenic disturbances may be caused by accidental or intentional dumping of low toxic waste, high volumes of organic-enriched material (e.g., sewage sludge, dredge spoils) or inadvertently generated slope instabilities.

The rationale for this research is based on the assumption that these events are models for the susceptibility or resilience of the deep-sea ecosystem to large-scale impact. Biodiversity and biogeochemical cycles are drastically affected by these large perturbations which may lead to the extinction of benthic species. Recolonization and establishment of a new balance give important insights into the development and functioning of deep-sea biodiversity. Large-scale disturbances can also be used to develop and assess a suite of response scenarios and strategies for dealing with anthropogenic impacts. Predictive modelling should be developed on this basis.

Approach

In order to understand and assess the effects of large scale disturbances we need to

- investigate the destruction of benthic communities and the recolonization of destroyed habitats,
- determine the reaction of the geochemical system to burial by turbidites, to a dramatic increase of organic matter or hazardous substances,
- assess abyssal transport pathways

For the study of large scale natural disturbances a recent turbidite such as the Iceland turbidity current of 1996 should be studied. For the study of anthropogenic disturbances canyons of the European continental slope can be investigated, which serve as existing discharge conduits for high volume, low toxic sewage sludge and fly ashes.

Technological development of observation systems and experimental systems

The major problem of deep-sea research is the inaccessibility of the objects of research and the difficulty to measure pressure- (or temperature-) sensitive processes. Many of the present-day data are based on potentially erroneous shipboard measurements and, thus methods for in situ measurements or experimentation are urgently needed. Significant scientific advances in this field are only possible with the adequate technological development.

In recent years major advances in deep-sea technology have been achieved. This mainly concerns:

- benthic landers with sensors and experimental chambers (e.g., ALIPOR project),
- camera monitoring of deep-sea sites,
- recoverable units (e.g., GEOSTAR project),
- remotely operated vehicles (ROV),
- autonomous underwater vehicles (AUV),
- manned submersibles.

However, large deficits still exist for:

- energy supply for long term observations,
- long-term stable sensing systems,
- data transmission from deep-sea observation systems to the surface,
- large-scale observation of the sea floor (e.g., by autonomous vehicles),
- event-modulated measuring and sampling systems,
- improved experimental systems.

Long-term observation systems are the most cost effective means to monitor changes in the abyssal habitat in key deep-sea areas (areas particularly sensitive to climatic changes, areas affected by anthropogenic impacts). In addition to in situ

observation systems, improved experimental systems for simulated deep-sea conditions are required for biotechnological research.

The scale of resources, technologies and the breadth of expertise needed to accomplish this deep-sea research can only be achieved on a European scale.

Seafloor management: Evaluation of the anthropogenic impact on marine ecosystems

The deep oceans are the sites of catastrophic events unparalleled on land. Major submarine landslides, with associated debris flows and turbidity currents, repeatedly devastate areas of the deep ocean floor many hundred kilometres across. Volcanic eruptions can carpet the ocean floor in toxic ash. Natural petroleum seeps are common and copious. Yet the deep-ocean ecosystem, often considered as frail, is adapted to surviving these hazards. The existence of such large-scale disturbances of the deep-sea floor allows us to quantify and predict the response and adaptation of deep-sea biological communities and their associated geochemical systems to sudden and devastating events. This is critical for understanding the long-term impact on the deep oceans of anthropogenic hazards such as dumping of waste or contamination with long-lived toxins. Already we have emplaced onto the deep-ocean floor, accidentally or intentionally, millions of tonnes of shipping, all types of cargoes inside the ships, munitions, radioactive waste, sewage sludge and much more, and the pressures for further intentional disposal on the ocean floor will grow as problems of disposal on land increase.

With rapidly increasing exploration of the deeper parts of the continental margin, the need for long-term, detailed and high resolution monitoring research of environmental conditions in the deep sea increases drastically. For example, in the sediments of the Vøring Plateau at 1500 m water depth of the Norwegian Sea, approximately 80 million m³ oil and 500 million m³ gas have recently been located and exploited. Large Tension Leg Drilling platforms connected to underwater platforms at the sea floor drill for this oil and gas or separate water from oil. Such production systems on the sea floor are now looked upon as being a profitable way of implementing developments in deep water. Exploitation has started in high energetic continental margins environments (Færoe-Shetland Channel) with bottom currents exceeding 1 m/s, thus increasing the risk of equipment failure and leakage

Objectives

We need to build up a network of marine science and industry partners to prevent deleterious impacts on the resources of European deep waters. We urgently need to understand fully the dynamics of benthic ecosystems in order to assess the effects of large-scale anthropogenic impacts on natural systems. This will ensure that we develop and assess a suite of response scenarios and strategies for dealing with anthropogenic impacts which are suited to the special nature of oceanic benthic ecosystems.

Rationale

Within the 5th framework program these studies offer the possibility to evaluate the anthropogenic impact on marine ecosystems, to develop new technologies to monitor these impacts and to operational forecast for offshore activities.

As first steps along this path, we recommend two approaches:

- For the study of anthropogenic disturbances we suggest investigating the submarine canyons that border the European coasts. Many of these serve as discharge conduits for high-volume, low-toxic sewage sludge and fly ash from land. Material of this kind is regularly dumped from Spanish and Greek coastal zones into canyons of the Bay of Biscay and the Mediterranean.
- Further on, we suggest a study of shipwrecks. Between 1973 and 1995, 29.3 million tonnes of shipping, on average 1.3 million tonnes per year, were lost at sea, a significant fraction of it in the deep ocean. So far only few studies have been made on shipwrecks in the deep sea and those which have been conducted did not consider the impact of the wrecks on the local environment. An estimated 250,000 tonnes of hydrocarbons are leaked into the ocean through natural seeps each year. The study of large methane seeps provides information on the likely effects of hydrocarbon leakage from offshore structures. The same holds true for the emerging fluid of hydrothermal vents. However, it must be taken into consideration that the deep-sea communities occupying it are adapted to these natural conditions, so newly formed leaks should be studied. Large offshore platforms with small satellite fields linked by subsea collectors and pipelines should be monitored and the benthic community structure studied. Although oil companies have already carried out short-term monitoring of the environment, long-term monitoring instruments, (both mobile and stationary) should be developed and installed to observe both the sediments and the bottom boundary layer. Currently existing in situ methods, laboratory simulation and numerical modelling can be used to develop and assess the environmental impact of these events, and to devise a suite of response scenarios and strategies for dealing with these and other anthropogenic environmental impacts.

2. DEEP BIOSPHERE - GEOSPHERE COUPLING

Scientific Rational

- **A range of extreme environments has recently been discovered where there are Biosphere-Geosphere interactions of unique significance.**

These include deep marine sediments and gas hydrates, cold-fluid seeps, deep-water carbonate mounds, mud volcanoes and deep brine lakes. Such environments had been considered too extreme for life but initial evidence suggests that due to geosphere fluxes, bacterial processes continue and may even be elevated (e.g., gas-hydrate zones) in such environments. These findings have potentially profound implications for global biogeochemical cycles and the depth, magnitude and diversity of the biosphere on Earth. Therefore :

- **We need to quantify the extent, diversity, variability and geological forcing of these environments.**

Estimates of the bacterial biomass in deep marine sediments (to the global average depth of 500 m) indicates an amount equivalent to about 10% of the total surface biosphere is present in this newly discovered habitat. Investigation of other environments is essential in order to assess the true magnitude of this deep biosphere. Although information about the types of bacteria in these environments is extremely limited, initial results indicate that they are well adapted to prevailing conditions and that there is considerable biodiversity and probably some unique organisms present. Isolation of bacteria from these environments will be technically challenging, but this together with modern molecular genetic and ecological approaches is essential if we are to begin to understand how these communities exploit, respond to and modify their "geosphere" resources within the sedimentary basin. In addition, there should be considerable biotechnological application for deep-biosphere microorganisms.

- **Geosphere-Biosphere interactions are reflected through surface environments which provide "windows on the deep biosphere".**

When deep fluids and gases vent near the sediment surface they provide an additional energy source which is efficiently exploited, producing large bacterial populations, which often support diverse biological communities of grazers, filter feeders and symbiotic organisms. Such communities provide a unique "window" on the deep biosphere and an important indicator of factors controlling and modifying deep geosphere fluxes (e.g., subduction, earthquakes and other tectonic processes). They may even be biomarkers for past or present hydrocarbon seeps.

- **Global Impact**

Geosphere reservoirs contain the largest global stores of elements (e.g., carbon, nitrogen, sulphur, phosphorus, iron) and despite their slow turnover they have a major effect on global cycles. The deep biosphere represents a short circuit to these reservoirs (similar to our exploitation of deep fossil fuels) with potential, but yet to be quantified, global significance.

- **Susceptibility to Anthropogenic and Climate Changes**

We do not know how the deep biosphere would respond to these changes, but there is potential for both negative and positive feedback. For example, it has been suggested that degassing of gas hydrate deposits as a response to global warming would result in significant release of methane and hence further enhance warming; however, if temperature changes were gradual, sediment bacteria could oxidise most of the methane released. Conversely, small temperature increases might increase the total amount of bacterial methane production.

Objectives

To understand and quantify:

- The biomass, diversity, variability and eco-physiology of the deep biosphere.
- The genesis and dynamics of fluid venting, mud volcanism and deep brines.
- The genesis and dynamics of gas hydrates and associated ecosystems (shallow and deep).
- The impact of gas hydrates dissociation on margin stability.
- The genesis and dynamics of carbonate mounds and cold water coral communities.

Strategies

- **Unique multi-disciplinary approach**

Bringing together new scientific groupings of biologists, microbiologists, geochemists, geologists and geophysicists.

- **Research focused on targeted areas and key European environments**

Deep sediments and brines, fluid venting, gas hydrates, carbonate mounds and mud volcanoes.

- **Integrated in situ field measurements and experiments, and laboratory simulation experiments**

The availability of submersibles, ROV's, Long-Term Deep-Sea Laboratories and borehole seals provide the opportunity not only for detailed sampling but also for in situ experiments, such as bacterial isolation and activity measurements, determining the flux and characteristics of deep sourced bacteria, quantifying the modification of geosphere fluxes by microorganisms and the controls on this process. Related experiments can be conducted in the laboratory, such as, the impact of warming during burial on bacterial populations and biogenic:thermogenic interactions.

- **Exploit active and fossil terrestrial analogues**

Spectacular active analogues are available within Europe, such as the mud volcanoes in Italy and Greece, these will provide the opportunity for more detailed sampling and an assessment, over longer time intervals, of the variability in the microbial community and geosphere fluxes. The fossil analogues of mud volcanoes, mud diapirs, carbonate mounds, etc. and their associated biological communities will provide important information on the long term impact of the deep biosphere on geological deposits and the life history and longevity of such habitats.

- **Interactive Modelling**

Will be used to synthesise results obtained, assess the controls and impacts of the deep biosphere and to assist in the formulation of hypotheses and models to guide further research.

- **Development of innovative technology for in situ sampling, experimentation and observation**

Although submersibles and ROV's will be of great assistance in this project there will still be a requirement to develop novel sampling, observational and experimental tools to create our own windows on the deep biosphere. This would include efficient samplers for venting fluid and bacteria, sediment probes which would enable colonization by deep sourced bacteria and which on recovery would allow experimentation without depressurisation, deep fluid flow to be chemically characterised and monitored before and after flowing through a near surface biological community, measurement and sampling fluid and gas flow through a gas hydrate deposit.

3. HYDROTHERMAL SYSTEMS

Introduction

Hydrothermal vents are the most extreme marine environment known on Earth to date. They are sites where very hot water is emerging from the sea floor, and occur at all water depths from the very deep ocean to shallow coastal areas. In the deep oceans, the water emerging may be at temperatures of up to 400°C, pH as low as 2, and may contain high concentrations of dissolved toxic materials such as hydrogen sulphide and metals such as copper, cadmium, mercury. They are associated with deposits of sulphides that not only contain the toxic materials already listed, but also may be very radioactive from uranium concentrated from ocean water. In shallow seas, the water emerges boiling, and carries substantial concentrations of hydrogen sulphide, arsenic, cadmium and mercury. The deposits around these vents contain a range of toxic materials including mercury and arsenic.

Paradoxically, hydrothermal vents are associated with abundant life. The chemical energy that arises from the reactions of the sulphide, methane and hydrogen in the vent fluids with oxygen in sea water fuels biological communities based on chemosynthetic microbes, including a wide range of more or less exotic species. Images of the giant tube worms around hydrothermal vents are familiar, but there are many other types of organisms involved as well. The attraction of the source of energy are such that organisms have become adapted to living in these hostile surroundings, and in doing so, show characteristics shared by few other organisms on the planet.

The importance of hydrothermal vents in the European context arises for the following reasons:

- Hydrothermal vents are remarkable analogues for anthropogenic pollution, and yet are a natural part of the environment, with little net impact.
- Vent organisms survive in these toxic conditions, and could hold the key to bioremediation of anthropogenic wastes.
- The organisms living at vents are hosts to a wide range of potentially valuable biomolecules arising from the toxicity of the environment, and can be exploited.
- Hydrothermal vents hold the key to the origin and evolution of life, and to the understanding of evolution.
- Vents may be involved in climate change, may be sources of geothermal energy, and may be related to natural hazards.
- European waters host an extraordinary variety of vents, from the deep-water vents of the Atlantic to the shallow-water vents of the Mediterranean.

Vents as analogues for anthropogenic pollution and sources of bioremediation

There are several aspects of hydrothermal vents that closely parallel anthropogenic pollution, and each of them, though hostile at close range, is dealt with comfortably by the natural environment. There is clear potential for research that will illuminate human discharges and their impact on the environment.

The fluids that emerge from the deep-ocean vents are extraordinarily toxic to life, resembling the most toxic sewage discharges, or discharges from metal smelting. The large mounds of iron, copper and zinc sulphide that accumulate around deep-sea vent systems resemble toxic industrial waste dumps. As the fluids rise into the ocean, fine particles of black sulphide form a column of smoke above the vent, rising a few hundred metres into the water, which oxidises to iron and manganese oxide particles, and these in turn concentrate other toxic metals from seawater before sinking to form a halo of sediment around the vents. Much of this sediment is highly radioactive from adsorbed uranium. Around vents in shallow water the fluids are apparently less toxic, but the sites of venting are enriched in a wide range of toxic materials. The shallow-water vents in the coastal zone near Milos in the Aegean are associated, for example, with constantly renewed deposits of arsenic oxide.

Interaction between vents and their surroundings is mediated by the complex biological communities that surround them, providing a natural example of bioremediation in progress. And this bioremediation copes well with many of the materials that are so difficult to dispose of on land. This is especially important in the context of pressures on both land and sea waste disposal. Life forms range from extreme thermophiles to Arctic species tolerant of high sulphide and metal concentrations and include unusual mussels which live in association with both sulphide- and methane-oxidising bacteria. Many of the organisms accumulate metals in high concentrations. The biota at vents are known to have a major effect on the geochemistry of the lower temperature fluids, removing, for example, sulphides, metals and methane.

Vents can thus be used as a natural pollution laboratory in which the ways in which organisms adapt to "toxic" conditions can be studied and strategies of bioremediation for polluted marine environments developed. A promising area is the understanding of symbiotic associations between animals, especially mussels, and bacteria with the aim of understanding the controls of the symbiotic association and the possibility of adapting these associations for removing pollutants, e.g., sulphides, phosphates, ammonia and metals, from industrial effluents. Previous studies have demonstrated the feasibility of growing free-living vent bacteria which will provide laboratory cultures for studying how they live and allow the development of bioremediation systems.

We need to know: (a) what are the fluxes of toxic materials in both deep-and shallow-water vents; (b) how do the biological communities cope with their toxic environment; (c) what pathways are followed by the toxins from the vent to an eventual resting place; (d) what are the possibilities of using some of the organisms in these communities for bioremediation; (e) what impact does the knowledge of vents have on problems of waste disposal.

New molecules from the vent environment

As well as the potential of the organisms around vents for bioremediation, there are other pathways that lead to biotechnological innovation. Many of the sites have already produced organisms of actual biotechnological value or potential, although only a small part of the biodiversity present has been sampled. Important are the organisms capable of tolerating the high temperatures of the vent environment, the hyperthermophiles, which include microbes that thrive at over 110°C. The enzymes that allow organisms to tolerate such high temperatures are potentially valuable in a wide range of biotechnological applications.

Many of the substances in vent effluents have well documented mutagenic or carcinogenic properties. Vent fauna must therefore have developed efficient repair mechanisms to survive the consequent damage to their DNA.

We need to explore the biotechnological potential of vent organisms, and develop new applications from these extremophiles.

Vent biodiversity

Most European landscapes have been heavily modified, resulting in a loss of species and genetic information, although some pristine environments still exist, including most hydrothermal vent sites. These sites are, however, likely to be increasingly exploited for energy and mineral extraction, as well as tourism. Uncontrolled exploitation will destroy the richness of biodiversity of this environment, which has economic value in biotechnology (e.g., high temperature enzymes in food processing) and bioremediation. Hydrothermal areas are ideal study sites to investigate factors affecting biodiversity including evolution of species, genetic variability, adaptations to extreme and dynamic conditions, and even the origin of life. The radiation and mutagens present at such sites may even accelerate the rate of evolution in the endemic species. Vents are also good testing grounds for ecological hypothesis developed at other ecosystems, e.g., the impact of disturbances (biotic and abiotic) on biodiversity, since they are largely removed from anthropogenic perturbations.

We need to know much more about the biodiversity and the factors controlling it at hydrothermal sites. Although there is a general view that macrofaunal biodiversity (in terms of species numbers) decreases at hydrothermal vent sites, little is known

about the microbial communities and microbiological processes which are the basis for the functioning of the whole ecosystem. We expect that many endemic species with unique genetic information remain to be discovered.

Vents and climate change

Climatic change over the coming decades is predicted to lead to rising water temperatures which will alter the present ecosystem. One way in which we may forecast these changes is by studying the faunal biodiversity in the vicinity of shallow-water vents, where exotic species from southern localities are often first encountered. Rising sea level is predicted to lead to increased volcanicity and seismicity, both of which can have catastrophic consequences for coastal regions of Europe within the volcanic zones. A little recognised additional hazard is from megaplumes, which are bodies of warm water, tens of cubic kilometres in volume, produced at unknown intervals from deep-water vents. Especially in Arctic waters these have the potential to reach the surface and have impacts on the local oceanographic circulation and the climate as well as the ecosystem. Longer term monitoring of hydrothermal systems is needed to predict these events and understand their consequences.

We need to install monitoring networks to observe deep-sea vents for periodicities in their behaviour and the relationship of this to other geological phenomena such as earthquakes and eruptions.

Vents in the coastal zone

Vents inject into the sea many dissolved metals including arsenic and mercury and radionuclides. The distribution and fate of these metals has not been studied in the vent systems in shallow waters in the Mediterranean and the Açores, where they are closely involved with human activity. Are these metals readily precipitated and buried or do they find their way into the food chain and become a health hazard to consumers of seafood?

We need to know what are the natural fluxes from such systems and how may they be altered by changes in coastal zone management, and what is the exposure of humans using the coastal zone to these toxic materials.

Hydrothermal vents in European waters

European waters contain a wide diversity of sites of hydrothermal venting. Within 200 miles of the Açores are five hydrothermal sites at different water depths from 20 to 3000 m. The Juan de Castro, Saldanha, Menez Gwen, Lucky Strike and Rainbow sites each has distinctive geological, geochemical and ecological characteristics. In Icelandic waters active venting is known from many coastal locations, from a depth of 200 m south of Iceland and a depth of 100 m to the north. In the Mediterranean there is a wide diversity of sites off Italy, Greece and Turkey, in depths from the intertidal to more than 500 m.

We need to explore these sites further to extract all possible information and resources from them, and need also to make on-shore observations of vent biota under controlled conditions.

Technological developments

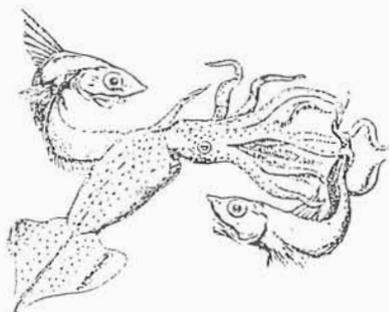
There are three types of technology needed for understanding and exploitation of vents.

First, there are exploration technologies to find new vents. There are a number of European instruments that are well suited to this, including the UK BRIDGET deep-towed plume-follower, OFOS and SCAMPI German and French photo sledges, the German Hydro-Bottom Station, and unmanned (French VICTOR) and manned (French NAUTILE) submersibles.

Second, there are long-term observation technologies equipped with sensor and sampling capabilities (including the German VESP system, the UK Medusa system, the European GEOSTAR system, and a variety of bottom landers).

Third, there is onshore laboratory capability for studying discoveries from vents. All of these basic capabilities are well in hand in Europe, thanks to national programmes and also to the MAST programme.

Three areas need attention: (a) integration of landers and other long-term observation technologies into complex observatories, with the capability of communication of results to land, (b) development of the means to deploy such complex observatories, to connect all of the subsystems on the ocean floor, and to maintain real time communication, power supplies and servicing of modules, and (c) establishment of an onshore laboratory close to the deep ocean vents on the Mid-Atlantic Ridge, which we recommend should be installed at Horta in the Açores.



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MUSICAL CHAIRS AT THE SOUTHAMPTON OCEANOGRAPHY CENTRE (SOC)

With the retirement of both Tony Rice and Mike Thurston, the DEEPSEAS Benthic Biology Group at SOC has undergone some radical changes in the last 2 years. It is not easy to replace knowledge of deep-sea ecosystems and experience of operating in this remote environment when two people of the caliber of Tony and Mike retire in quick succession. But change we have, and there are now a number of new researchers studying for PhDs, and we hope they will pick up the skills that Tony and Mike developed. The original acronym, DEEPSEAS, stood for deep-sea seasonality, but it has now been adopted to cover all our activities.

SOC is a cooperative venture between the University of Southampton and the Natural Environment Research Council (NERC). NERC used to fund the old Institute of Oceanographic Sciences (IOS). The DEEPSEAS group involves staff members from the University's School of Ocean and Earth Science (SOES) and staff still funded by the NERC as part of a SOC group known as the George Deacon Division for Ocean Processes (GDD). Some of you may remember that at the time the DEEPSEAS group moved from IOS to SOC, we became part of the Challenger Division, a multi-disciplinary group of geologists, chemists and biologists. While useful work was generated across disciplines, geological processes occurring over tens of thousands of years dominated the Challenger Division research agenda. We decided, therefore, to re-join the other deep-sea (pelagic) biologists in the George Deacon Division.

David Billett found the lure of studying sea cucumbers once more too hard to resist, and is now heading the DEEPSEAS group, having spent some 7 years in administration. The other GDD members of the group are Andy Gooday (foraminifera, meiofauna, giant protozoans) and Brian Bett (megafauna, macrofauna, metazoan meiofauna, imaging of the seafloor). SOES members are Paul Tyler (reproduction, recruitment and life history strategies), Alex Rogers (molecular biology, population genetics, deep-water coral), and a number of other academic staff on a part-time basis. Together we supervise a number of post-graduate students and we are striving to increase the number of post-doctorate appointments.

Post-graduate students include Alan Hughes (foraminifera assemblages in three contrasting environments), Ben Wigham (the biology of the holothurian *Amperima rosea*), Eva Ramirez-Llodra (fecundity of deep-sea megafauna), and Magnus Axelsson (deep-sea biology and geology from photographs and sidescan sonar).

Mike Thurston works at SOC most days and is busy with various taxonomic studies on amphipods. We see rather less of Tony, who is now much busier than ever before, publishing books (at least 3 in the pipeline) doing consultancy work, and re-landscaping his garden. Both of them send their regards to their deep-sea friends. Who said retirement was a relaxing time?

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