Intergovernmental Oceanographic Commission

Workshop Report No. 204

Geo-marine Research along European Continental Margins

International Conference and Post-Cruise Meeting of the Training-through-Research Programme

Bremen, Germany
29 January - 1 February 2007

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Editors: G. Bohrmann
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UNESCO 2007

IOC Workshop Report No. 204
Paris, September 2007
English only

For bibliographic purposes
this document should be cited as:

Geo-marine Research along European Continental Margins. International Conference and Post-Cruise Meeting of the Training-through-Research Programme. Bremen, Germany, 29 January - 1 February 2007. IOC Workshop Report No, 204 (English). UNESCO, 2007.

(SC-2007/WS/35)

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PREFACE

"Geo-marine Research along European Continental Margins" – International Conference and a Post-cruise meeting of the "Training-through-Research" programme was held from 29 January to 1 February, 2007 at the University of Bremen (UB), Germany. It was organized by the Research Centre Ocean Margins (RCOM) in co-operation with the UNESCO Chair in Marine Geosciences at Moscow State University (MSU) and the Intergovernmental Oceanographic Commission (IOC). It was hosted by RCOM.

The "Training-through-Research" (TTR) international programme has been successfully operating since 1991 as part of the capacity development efforts of the IOC and specifically the Training, Education and Mutual Assistance (TEMA) Programme of the Organization. It has also been supported by a number of international and national programmes and projects. Among the most recent ones are: (i) project on "Geosphere-Biosphere Coupling Processes in the Ocean: the Training-through-Research approach towards Third World involvement" (TTR-*Flanders* project, 2004-2007) that has been funded by the UNESCO/Flanders Funds-in-Trust for the Support of UNESCO's Activities in the Field of Science (FUST) and (ii) European project on "Hotspot Ecosystem Research on Margins of European Seas" (HERMES, 2005-2009).

Since 1993 TTR Post-Cruise Meetings have been held regularly hosted by universities actively involved in the programme. They aim in facilitating the exchange of information between participants in the TTR cruises, summarising the collected data, and also in providing students and young scientists with opportunities to present results of their research to a broad academic audience.

This Conference/Post-Cruise Meeting was focused on the results of the TTR-15 (2005) and TTR-16 (2006) cruises. However results from other TTR cruises, as well as research findings made by other research groups relevant to the themes of the Conference were presented. Reflecting main sectors of research activities of TTR, the Conference covered the following aspects of science related to:

- Magmatic volcanism along margins;
- Tectonic processes at continental slopes;
- Geophysical studies of ocean sediments;
- Formation of methane and other gases in sediments;
- Gas hydrates, seafloor emissions and seeps;
- Mud volcanoes in the marine realm;
- Sub-seafloor fluid flow;
- Biological and microbiological habitats and ecosystems;
- Coupling of geosphere, Biosphere and Hydrosphere processes.

The Conference programme was set up by the Organizing Committees:

- Prof. Dr. Gerhard Bohrmann (RCOM) and
- Prof. Dr Michael Ivanov (MSU).

The meeting was attended by over 60 participants from the following countries: Belgium, Cote d'Ivoire, France, Germany, Italy, Morocco, Mozambique, the Netherlands, Norway, Portugal, Russia, Saudi Arabia, Turkey and UK. Attending were researchers and students with different specialities (sedimentology, geophysics, geochemistry, microbiology, biology, palaeontology, structural geology) and research interests falling in the area of the Conference theme. Half of the participants were students and PhD students. Altogether, 39 oral and poster presentations were made. The participants expressed great satisfaction with the Conference as having fully accomplished its objectives and facilitated fruitful contacts between the attendees. Special words of gratitude were addressed to Prof. Dr. Gerhard Bohrmann (RCOM) and his group for excellend organization of the meeting.

The Nomination committee was established (A. Akhmetzhanov, A. Mazzini, H. Sahling) that selected three best students' presentations. In the concluding remark a very high level of presentations by students was noted. The first prize was attributed to a very interesting and rather unique crystallographic study of gas hydrate structures made by S. Klapp (University of Bremen). The 2nd one was attributed to geochemical studies of oil seeps in the Black Sea made by D. Nadezhkin (MSU, Russia) and the 3rd one to research on microbial communities in the Gulf of Cadiz made by L. Santos (University of Aveiro, Portugal).

During the Conference discussion of plans for the future TTR research took place. On 31 January meeting of the TTR Executive Committee was organized. It considered a number of items related to the organisation of the TTR cruises, as well as publication of the TTR data.

The book of abstracts was compiled by H. Sahling (RCOM). For the present Report, it was further edited by A. Suzyumov (IOC). The abstracts are in the alphabetic order by first author. Reporting authors are marked with asterisks. Annex I contains the conference programme. The participants are listed in Annex II in the alphabetical order.

The conference was supported by the Intergovernmental Oceanographic Commission of UNESCO (through its TEMA Programme, TTR-*Flanders* and HERMES projects) and RCOM. Travel and accommodation of international participants was also supported by various national and international programmes and projects (reflected in Acknowledgements in individual abstracts).

ABSTRACTS

DEPOSITIONAL PROCESSES ON THE DISTAL RHONE NEOFAN: PRELIMINARY RESULTS OF LEG 2 OF CRUISE TTR-16

Akhmetzhanov, A.*, Wynn, R. B., Talling, P. J., Kenyon, N., Ivanov, M., Dennielou, B., UK TAPS group and TTR-16 shipboard scientific party
(*) National Oceanography Centre, Southampton, UK, Andrey.Akhmetzhanov@noc.soton.ac.uk

Our knowledge of gravity flow deposits and processes was further advanced during Leg 2 of the TTR-16 cruise, which formed part of the UK-TAPS Rhone Fan Project. The cruise focused on an area on the outer part of the Rhone Neofan (Western Mediterranean) where a 30 kHz side scan sonar image obtained during TTR-2 (Kenyon et al., 1993) showed a terminal depositional lobe with distinctive feather-edged planform geometry (Fig. 1). A single preliminary core from this area encountered ~2 m of medium to coarse sand located a few centimetres below the sea floor (Mear, 1984). This ungraded sandy interval contained mud clasts and may represent a debris flow deposit. The aim of the cruise was to (1) map the lobe, and similar features which were expected to be found in the vicinity, with high-resolution deep-towed sidescan sonar, and (2) core selected sites in order to calibrate sediment facies of fan-fringe deposits that display lobate or feather-edged planform geometry.

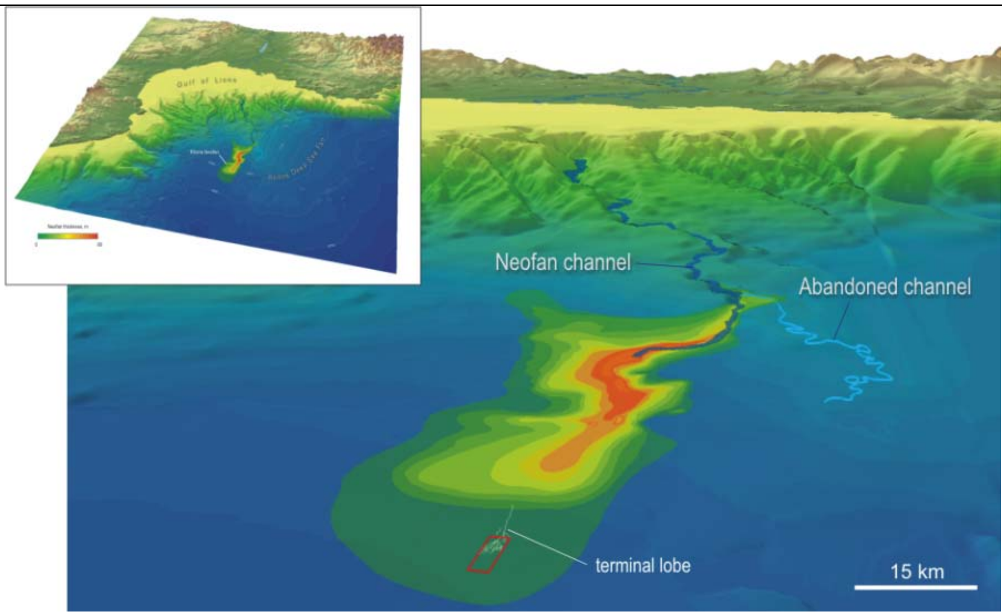

Figure 1. Location of the study area of TTR-16 (Leg 2) on the Rhone Neofan.

Preliminary results of geophysical data analysis show that the terminal depositional lobe is linked to a system of shallow distributary channels emanating from the Rhone neochannel; these channels were mapped with deep-towed 30kHz sidescan sonar system during TTR-14 (Dennielou and Droz, 2006). The lobe represents a mounded, acoustically transparent feature on the sub-bottom profiler record, and is up to 10 m thick. Unfortunately, only limited recovery of sediment gravity cores was achieved, presumably due to presence of sandy sediments.

Changes of slope gradient are of critical importance in development of this depositional system. Slopes of ≥0.2° are sufficient for gravity flows to travel for almost 40 km through the sinuous channel network. The formation of feather-edged terminal lobe facies is related to a reduction in slope gradient to 0.1°. This change causes flows to slow down and halt within a distance of about 6 km. We are now investigating further the link between terminal sandy lobes, shallow distributary channels to the south of the neochannel mouth, and a field of giant scours located southwest of the neochannel mouth (Kenyon et al, 1995; Bonnel et al., 2005).

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GULF OF CADIZ MUD VOLCANOES: ROV-READY SITES

Akhmetzhanov, A.*, Ivanov, M., Masson, D., Berndt, C., Pinheiro, L. M.
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The major objective of the EU-funded FP6 Integrated Project HERMES (Hotspot Ecosystem Research on the Margins of European Seas), coordinated by the National Oceanography Centre, Southampton is to understand how environmental variables affect the biodiversity, structure, function and dynamics of faunal communities on the continental slope.

Mud volcanoes and areas of active fluid escape at the seafloor are among the 'hotspots' to be targeted by HERMES. Improving our understanding of the processes involved in transporting organic-rich fluids from the geosphere into the biosphere is an important HERMES goal, because these fluids have a profound impact both on benthic ecosystems and the deep biosphere. Flux rates within passive margin fluid flow systems vary by several orders of magnitude from small, episodically active cold seeps to continuously active mud volcanoes.

The mud volcanoes in the Gulf of Cadiz are more active and more numerous than anywhere else on the European Atlantic margins because they are located in a compressional tectonic province.

They are found in water depths between 200 and 4000 m and show considerable variations in dimensions, morphology and composition of erupted material and fluids.

Recent survey work was undertaken during CD166 and TTR-16 cruises in 2006 on several key mud volcanoes from different waterdepths as an essential prerequisite for the HERMES ROV cruise. The surveying was done using multibeam echosounder, high resolution 3D seismic system and deep-towed high resolution sidescan sonar. The geophysical data were groundtruthed by near-bottom video and sampling with gravity corer and TV remote controlled grab. The newly acquired data show that nowadays fluid escape sites on mud volcanoes are found in much localised areas (0.8-2.5% of the total area of MV) where evidences such as authigenic carbonates, chemosynthetic communities and gas hydrates were encountered.

The detailed mapping established key differences between surveyed mud volcanoes and will result in much more efficient use of the ROV during 2007 campaign which, amongst other tasks, will characterise the impact of these differences on benthic ecosystems.

METHANE SEEP-RELATED CARBONATE PRECIPITATES FROM THE DOLGOVSKOY MOUND, SHATSKY RIDGE, NORTH-EASTERN BLACK SEA

Bahr, A.*, Pape, T., Bohrmann, G., Mazzini, A., Ivanov, M.
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Carbonates recovered from the Dolgovskoy Mound (DM, SE of the Crimean Peninsula, north-eastern Black Sea) during the TTR-15 cruise onboard R/V *Prof. Logachev* were examined using stable oxygen and carbon isotopes, X-ray diffraction and biomarker analyses. The DM is an irregular seafloor structure 800 m wide and 70 m high, which is located on the Shatsky Ridge in 2004 m water depth, and extensively covered with carbonate precipitates. Although fluid seepage has been visually observed, the lack of mudflows or mud breccia deposits suggests that the DM does not represent a mud volcano. The scope of this study is to get insight into the formation mechanisms of the carbonates at the DM, in order to understand the origin of the DM.

The carbonates exhibit a variety of different geometries ranging from planar slabs to complex constructions with a cavernous interior. They are commonly associated with thick microbial mats located mainly on the lower side but also inside the precipitates. Vertical sections show several characteristic lithological facies building up these carbonates: the slabs mainly consist of cemented hemipelagic sediments (coccolith ooze) and intercalated, up to 10 cm thick homogeneous micritic layers. In the case of more complex build-ups, the lower side and the cavities are filled with yellowish, botryoidal carbonate crusts, originally attached to microbial mats. Beside the yellowish carbonates, dark areas with organic, clay-mineral and pyrite-rich coatings are common on the lower side of the carbonates.

Mineralogical analyses showed that the only detectable carbonate phase is calcite, while aragonite and dolomite have not been found. There is a clear separation into low-magnesium calcite (LMC) on the lower side of the precipitates (very pure yellowish carbonate) and high-magnesium calcite (HMC) constituting the carbonate phase in the other parts of the carbonate structures. Additionally, coccoliths are a source for non-authigenic LMC in the coccolith ooze and to a minor degree also in the homogeneous micritic layers.

Isotopic analyses indicate that the LMC and HMC phases originated under different conditions, with relatively negative $\delta^{18}O$ values between 0.0 and -0.6 ‰ in the LMC and slightly more positive values (0.0 to +0.8 ‰ PDB) in the HMC parts. Assuming recent bottom water conditions, the formation temperatures of the HMC lies within today's bottom water range of 9°C, while the formation temperatures of the LMC carbonates were calculated to be generally elevated with values of up to 12°C (each temperature was calculated with respect to the Mg-content of the particular calcite phase). However, pore water measurements (M. Haeckel, pers. comm.) show that fluids depleted in ^{18}O are migrating upwards at the sampled site and thus affecting in particular the LMC phases on the lower side of the crust. Including these pore water values into the temperature reconstructions gives results that fall within the expected range around 9°C.

The $\delta^{13}C$ values are not affected by the LMC vs. HMC division; they are generally much depleted with values between -30 and -41‰ (PDB) which is typical for methane-seep related carbonates. This is also in line with a high abundance of biomarkers from micro-organisms performing the anaerobic oxidation of methane (AOM). A comparison with previously published data from mud volcanoes from the nearby Sorokin Trough (Mazzini et al., 2004) shows that the carbonates from the DM plot within a cluster of $\delta^{13}C$ values interpreted to be dominated by a microbial methane source, the influence of thermogenic methane seems to be less important. Compelling evidence for the presence of gas hydrates has not been found.

As a model for the formation of the carbonates at the DM site a system of self-clogging is supposed, where fluid activity fuels the AOM by a consortium of methanothrophic archaea and sulphate reducing bacteria. AOM creates environmental conditions (high alkalinity) favouring HMC-carbonate precipitation in the upper few centimetres of the sediment column, with the depth-limiting factor being the sulphate availability. With ongoing calcification the sediment gets increasingly impermeable and gas overpressure is created within the sediment. Below the cemented part of the sediment the overpressure forms large cavities, filled with fluids, microbial mats and associated LMC-carbonates. This process pushes the overlying strata upwards until calcite cementation advances so far, that the sediments could not be deformed anymore. Since the vertical fluid migration is hindered by the progressive calcite precipitation, fluids migrate preferentially horizontally, causing the lateral extension of the carbonate pavements.

Reference

Mazzini, A., M. K. Ivanov, J. Parnell, A. Stadnitskaia, B. T. Cronin, E. Poludetkina, L. Mazurenko and T. C. E. van Weering (2004). Methane-related authigenic carbonates from the Black Sea: geochemical characterisation and relation to seeping fluids, *Marine Geology*, *212*(1-4), 153-181.

PORE WATER COMPOSITION AND AUTHIGENIC CARBONATE PRECIPITATION AT THE MUD VOLCANOES FROM THE GULF OF CADIZ (PRELIMINARY RESULTS OF THE TTR-16 CRUISE)

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Nine mud volcanoes (MV) from the Gulf of Cadiz were studied for chemical composition of fluids. Samples were analyzed in order to determine main anions' and cations' content. Chlorine ions show clear anomaly at the Bonjardim and Carlos Ribeiro mud volcanoes: concentration decreases very fast with depth from 550 mM (15 cm) to 290 mM (150 cm). Also decreasing in Cl^- concentration with depth is observed at the Semenovich, Porto and Olenin mud volcanoes (Fig 1). Pore water analyses from mud breccia of the Soloviev mud volcano show significant depletion of chlorine ion at the depth of 80 cm (up to 420 mM), which could point to the gas hydrate decomposition at this interval. During TTR-16 cruise gas hydrates were recovered only from the Bonjardim mud volcano, whereas at the rest of the mentioned mud volcanoes clear indications of gas hydrates presence were observed (gas bubbling, "Roquefort" structure of mud breccia etc.). In the mud breccia recovered from the Bonboca and Shouwen mud volcanoes and sediments from Pen Duick Escarpment no chlorine anomaly was found (Fig. 1).

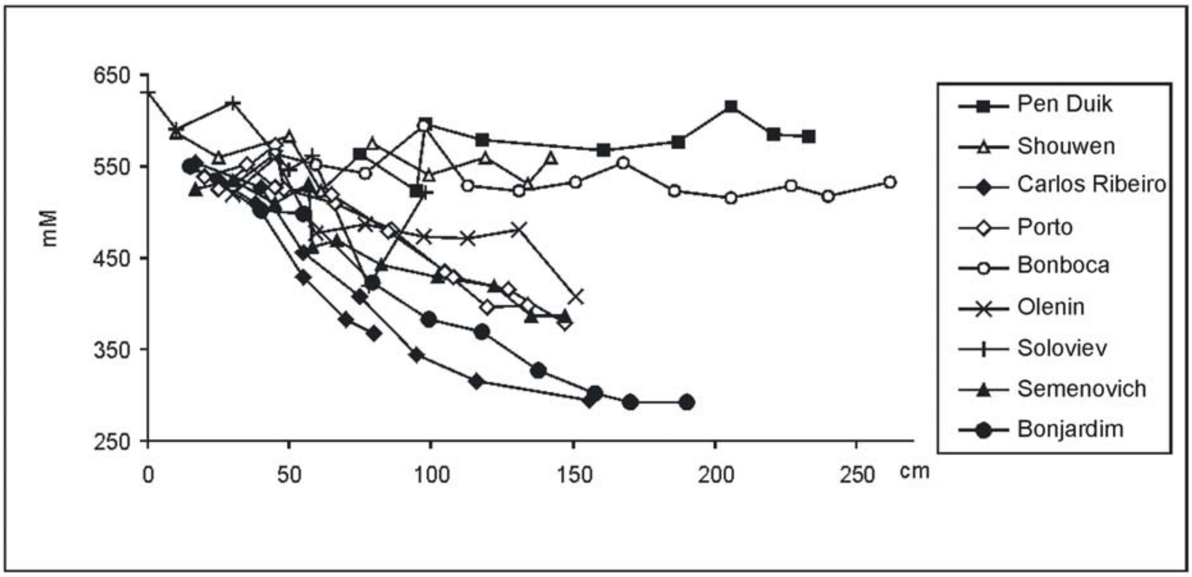

Figure 1. Cl^- ions distribution with depth in mud volcanic deposits.

Distribution of sulfate ions with the depth (up to 250 cm) demonstrate the same peculiarities: very rapid consumption of sulfate ion due to sulfate reduction at the Bonjardim, Carlos Ribeiro, Soloviev and Semenovich mud volcanoes, relatively less active SO_4^{2-} consumption at the Porto and Olenin mud volcanoes, and almost absence of sulfate reduction processes (up to depth 2.5 m) at the Bonboca, Shouwen MVs and the Pen Duick Escarpment. Alkalinity increases with depth at the Bonjardim and Olenin mud volcanoes.

Pore water analyses from mud volcanic breccia clearly indicate the most active mud volcanoes and reveals two main sources of fluid: (1) sea water (Shouwen, Bonboca, Pen Duick structures) and (2) mud volcanic signatures (Bonjardim, Carlos Ribeiro, Porto, Soloviev and Seminovich MVs). At the Olenin mud volcano pore water composition points to the mixed origin of fluids.

High microbial activity at the uppermost part of mud volcanoes and rapid decreasing with depth in concentration of Ca^{2+} and Mg^{2+} ions at the pore water profiles point to intensive authigenic carbonate precipitation. In six TTR cruises in the Gulf of Cadiz authigenic carbonate crusts, tubes and concretions were collected from 11 mud volcanoes. They are mostly consisting of aragonite, calcite and high Mg-calcite. Stable carbon isotopic composition of carbonate is depleted up to -30‰ PDB, which clearly points to its origin due to anaerobic methane oxidation (Fig. 2). $\delta^{18}O$ values vary from -3.8‰ PDB to +5.66‰ PDB what can be explained by different mineralogical composition and age of the carbonate formation.

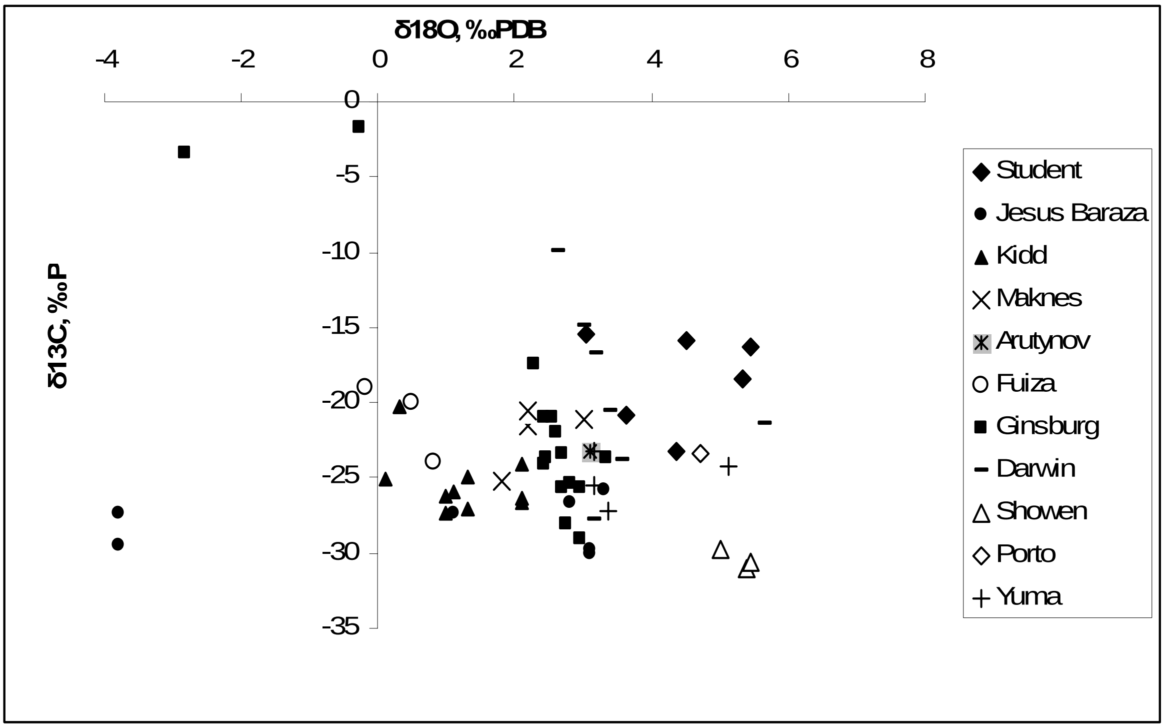

Figure 2. Stable carbon and oxygen isotopic composition of authigenic carbonates from mud volcanoes in the Gulf of Cadiz.

NEW RESULTS FROM AMSTERDAM MUD VOLCANO (ANAXIMANDER MOUNTAINS, MEDITERRANEAN SEA)

Bohrmann, G. * and M70/3 shipboard scientific party

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During cruise M70/3 (March 15 – April 25, 2006; Iraklion - Iraklion), R/V *METEOR* investigated processes of fluid seepage in the area of the Anaximander Mountains (mainly at Amsterdam Mud Volcano) south of Turkey (Fig.1). Investigations in that area before the cruise documented methane seeps at several mud volcanoes in about 2000 m water depth. Gas hydrates exist in the sediments of the mud volcanoes and there was strong evidence that at some of the structures methane escapes as free gas bubbles from the seafloor. The main objective during leg M 70/3 was to find and document the bubble release and to sample the gas and determine how much methane is escaping from the seafloor. Tools that were specially designed for the acoustic and optical detection of bubbles are presently under development at the RCOM. Using ROV QUEST, the 4000 m remotely operated vehicle of the Research Center Ocean Margins (RCOM) in Bremen, it was planned to deploy the entire suite of sampling tools at the seeps. A further goal was to quantify the amount of gas and gas hydrate in the sediments using the dynamic autoclave piston corer (DAPC). DAPC can retrieve sediment cores of up to two meter in a pressure-tight housing at in-situ pressure. Degassing of this core under controlled pressure conditions allowed quantifying the amount of gas and gas hydrate in the sediments.

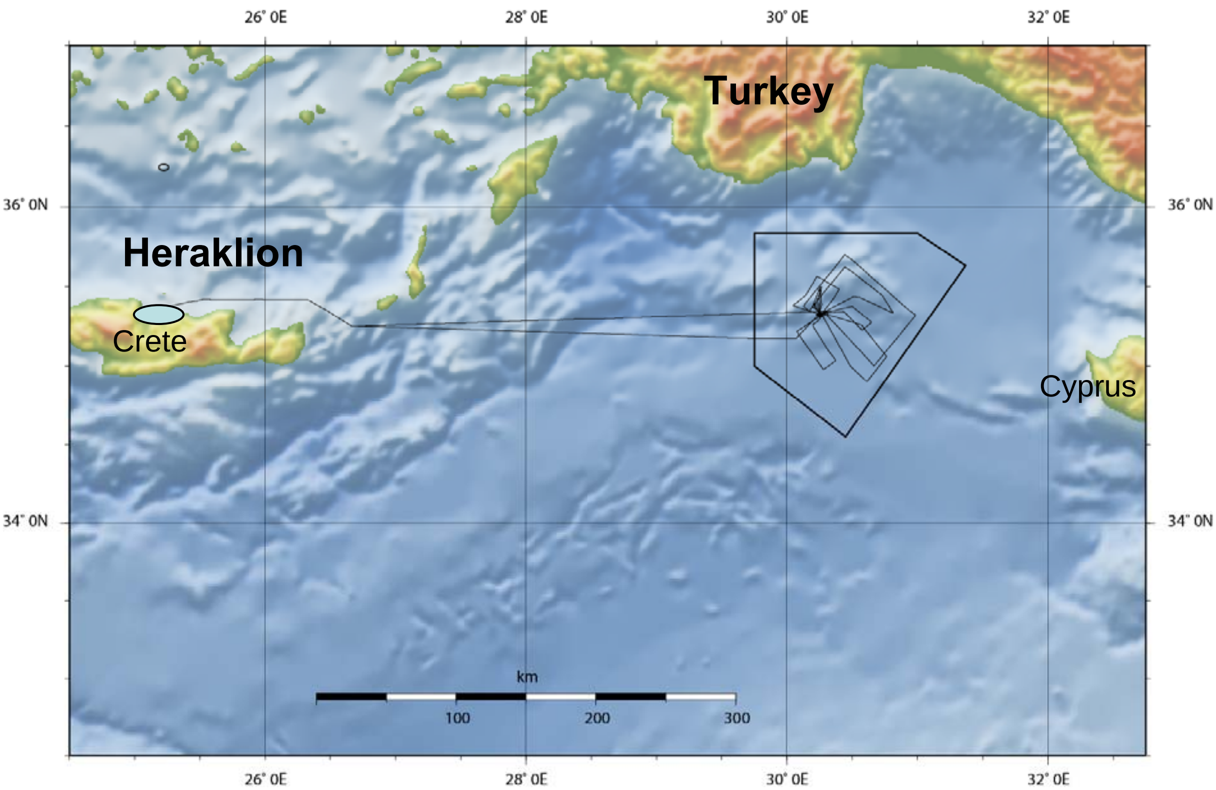

Figure 1. Track lines of R/V Meteor during cruise M70/3 (March 15 – April 25, 2006; Iraklion - Iraklion)

Our new surveys on Amsterdam Mud volcano showed much more details than earlier cruises. At the eastern wall, where our French colleagues observed in the past more massive vestimentiferan tube worms, we only found single tube worms distributed in larger areas. Within the caldera of the Amsterdam mud volcano the detailed morphology of the seafloor varies. In the area of the "ring depression" plateau-like areas often alternate with depressions showing fresh edges of sediment fractures. In the centre of the mud volcano a morphologically chaotic seafloor was found, where we recovered several gas hydrate samples by gravity coring. During the second dive we already could prove the postulated gas bubble emission at the seafloor. First of all the bubbles had been identified and localized as an acoustic anomaly in the water column, by means of the forward looking ROV-sonar. After moving the ROV to the anomaly, the ROV followed the bubbles down to the seafloor where the emission sites could be documented in detail with the new HDTV-camera. The bubbles continuously leaked out at several points from the seafloor appearing in rather different speed and leaving the seafloor. The emission locations were limited to a small area < 1 square meter and the seafloor was definitely dark coloured by hydrogen sulfide, darker than outside this area. In the gas seep we found very small worms (pogonophora), bivalves, snails and crabs.

Gas bubbles were collected in an upside-down funnel. Under the high pressure in the water depth of 2000 m and with 14°C gas bubbles turned immediately to porous gas hydrate. Thus the gas hydrate was drawn into the pressure-tight container which enabled us to sample the original gas stored in the gas hydrate and later into the sample container. This was successfully done and the gas analyses revealed that beside methane ethane occurs in small amounts. The gas hydrates sampled from sediments show a clearly increased ethane content.

On the Athina mud volcano we found large areas covered by authigenic carbonates and dense populations of vestimentiferan tube worms where revcovered which were unknown to occur in such densities in the Eastern Mediterranean up to now. Although this cruise was very short it was very successful with its 9 ROV-dives, 10 gravity cores, 2 multi-cores, 5 autoclave samples, 2 MOVE deployments and additional EM 120 and Parasound profiling.

EXPLORING MUD VOLCANOES ON THE CALABRIAN ARC, CENTRAL MEDITERRANEAN SEA

Ceramicola, S., Praeg, D.*, Unnithan, V., Wardell, N., Freiwald, A. & the OGS Explora and Meteor Scientific Parties
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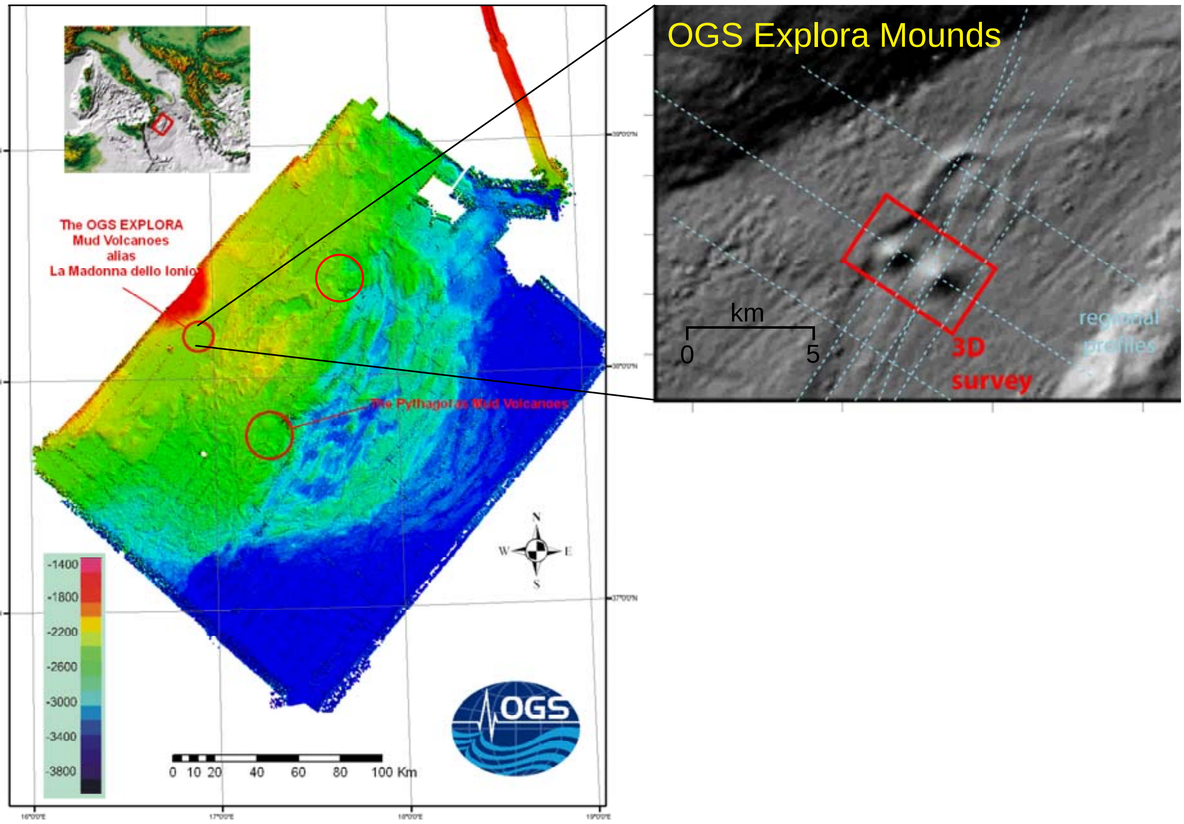
A new province of cold seep features was discovered in the Mediterranean Sea during the summer 2005 campaign of the Italian research vessel OGS Explora (Ceramicola et al. 2006). The purpose of the campaign was to investigate processes of geosphere-biosphere coupling on the Calabrian Arc, an accretionary prism thought likely to host seabed seeps by analogy with the larger Mediterranean Ridge to the east. Multibeam data (plus Chirp profiles) acquired across most of the Arc (225 x 160 km area) led to the identification of several sites of suspected mud volcanism; multichannel seismic reflection data and gravity cores were acquired from two such sites, on the inner and outer Arc. Ongoing work on these features has included seabed investigations of one mud volcano during the M70-1 campaign of the German FS Meteor in late 2006.



The mud volcanoes on the inner and outer Arc are referred to as the OGS Explora Mounds and the Pythagoras Mounds. The OGS Explora mounds lie in the Spartivento Basin, within a fault-bounded seabed depression, and include a pair of cones, each up to 200 m high and 1.5 km wide. Seismic profiles across the structure show the twin cones are flanked by Plio-Quaternary strata and appear to be rooted on the fault. The Pythagoras mounds on the outer Arc are dominated by a circular mud pie up to 250 m high and 8 km wide, the top of an inverted mud cone that extends at least 2 seconds below seabed within nappe structures. Gravity cores from both features proved grey mud breccias (diamicts containing angular sedimentary clasts to cobble size) to lie at or near seabed, suggesting recent extrusive activity. Seabed observations during the Meteor M70-1 campaign from the eastern of the two cones of the OGS Explora Mounds using the ROV Quest confirm the widespread occurrence of mud breccias, including clasts up to 0.5 m in length, as well as possible products of active fluid venting. Sediments collected during the survey are being analysed for indications of chemosynthetic communities.

Seismic acquisition across the OGS Explora Mounds included 630 line-km of data to construct a short-offset 3D-seismic volume over an area of c. 3 x 5 km across the twin cones. This volume is being analysed to understand the growth of the mud volcanoes over time and the nature of their rooting structures in relation to faults and indications of shallow gas/fluids (including possible gas hydrates). Other work in progress includes integration of the multibeam bathymetry and backscatter with previous seismic and sample data across the Arc to identify all cold seep sites (which may include brine pools and pockmarks as well as mud volcanoes). Much remains to be discovered on the Calabrian Arc about the geological drivers of seabed seepage (e.g. tectonism, sources and pathways of hydrocarbons, activity over time) and how they are coupled to seabed ecosystems.

Acknowledgements:
The HERMES project is funded within the European Community 6th Framework Programme (EC FP6 contract GOCE-CT-2005-5111234). The HYDRAMED project was funded from 2004-2006 by a Marie Curie Intra-European Fellowship held by D. Praeg within the European Community 6th Framework Programme (contract MEIF-CT-2003-501814).

Reference:

Ceramicola, S., Praeg, D. & the OGS Explora Scientific Party (2006). Mud volcanoes discovered on the Calabrian Arc : preliminary results from the HERMES-HYDRAMED IONIO 2005 campaign. CIESM Workshop Monographs, n. 29, p. 35-39.

MORPHOSTRUCTURAL STUDY OF THE "MONTAGNE DE TANGER" MUD VOLCANO FIELD (NW ALPINE RIF BELT, MOROCCO)

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In the El Fahs structural domain (NW alpine Rif belt), the Numidian outcrops that appear as isolated massifs ("Montagne de Tanger", Jbel Dhar Zhirou and Jbel Zinat) aligned according to various directions, were considered as allochtonous nappes complexes separated from their substratum (Hoyez, 1989). However, aside the Oued Lihoud succession that exhibit proximal deep sea fan facies sequence, all the other Numidian successions display deltaic facies sequences and lies conformably under a succession composed from the base to the top of the poorly sorted Tangier unit and the varicoloured clays bearing "tubotomaculum". The Tangier unit is interpreted as mud volcanic deposits on the base of its sedimentary facies and the tubotomaculum are identified as fossil corals epigenized and coated by Fe and Mn oxides (Hamoumi, 2005).

The aim of this work is to present the preliminary results of the morphostructural study conducted in NW alpine Rif belt in order to: (1) precise the geomorphological configuration of the geological structures previously interpreted as mud volcanoes by Hamoumi (2005), (2) establish the morphostructural framework for the studied area and (3) better understand the tectonic control.

The approach adopted for this study is based on two methods: the one that use landscape relief and drainage network analysis (Prud'homme, 1972) and the one developed by D. Horton (1945) that use the description and hierarchisation of the drainage network. Database from detailed digitalisation of the Western Tangier topographic maps of 1/25000 scale on the GIS environment (Map Info software 7.5) was compiled in Surfer 8.0 software in order to establish a digital model of landscape and a morphostructural map.

The 3D digital model of landscape and associated drainage network allow to identify in the "Montagne of Tanger" more mud volcanoes than previously suspected by satellite imagery (Hamoumi, 2005) and to obtain more precise information about their geomorphological characteristics. Five conical shape features of varying size and a ridge were identified. They are aligned according to a WNW- ESE direction and display geomorphological characteristics similar to those of mud volcanoes and associated ridges described in the El Araich field (Van Rensberge et al., 2005). These are:

- the El Hafyane ridge of lunar shape, reach 90 m in height and 1125 m in length;
- the Medyouna mud volcano: the largest one, it is 250 m high and 2250 m wide and exhibits concave and convex slopes and an irregular crater depression that may reach 50 m in width and 30 m in depth;
- the isolated Jbila mud volcano and the Ziaten Labranes complex of three mud volcanoes; these display a flat top and linear or convex slopes and range between 90 m and 130 m in height and 600 m and 1500 m in width.

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CARBONATE MOUNDS, COLD WATER CORALS AND SEEPAGE PROCESSES IN THE GULF OF CADIZ; MOUNDFORCE AND MICROSYSTEMS PROGRESS

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Carbonate mounds and seepage processes at the Pen Duick Escarpment (Gulf of Cadiz) are being studied as a comparative study in relation to ongoing cold water coral covered carbonate mound research in the Rockall Trough and Porcupine Seabight by the Royal Netherlands Institute for Sea Research (NIOZ) since 1998.

The mounds and mound forming processes are studied by means of seabed observations (photo and video), sampling (box and piston cores), seismic surveys, multibeam sea bed mapping, water column characterisation (CTD) and near bed hydrographic and sediment transport studies (BOBO lander).

Seismic investigations show that the mound morphology in the Gulf of Cadiz is related to the tectonic setting, favouring mud diapirism and volcanism and development of mound structures. Some of these topographic structures actively vent gases of thermogenic origin. At present the highest fluxes of thermogenic hydrocarbons are found at mud volcanoes (for instance the Al Idrisi mud volcano). Hydrocarbon fluxes on the mounds at the Pen Duick Escarpment are significantly lower. The mud volcanism is found associated with authigenic carbonate formation and, locally, cold water corals at the summit of the mud volcanoes.

A comparison of the hydrodynamic condition at the Pen Duick Escarpment to the Rockall Trough Margin and Porcupine Seabight mound areas suggests that coral growth at the Pen Duick Escarpment is most likely the result of a combination of the presence of internal waves and high current velocities, favouring enhanced particle and thus food supply to and over the mound tops. Although hydrocarbon seepage as such does not seem to play any role in coral growth it plays an important role as driving force behind mud diapirism and volcanism and thus in the formation of a topography that is favourable for coral growth.

Seabed sample and video analysis has revealed that although at present not much living corals are present, in the recent past (up to 300 years ago) cold water corals were far more abundant in the area. Further study has to reveal the cause of this change. Understanding why cold water corals appear and disappear at these carbonate mounds will increase our understanding of not only the mounds at the Pen Duick Escarpment but also of the formation of cold water coral covered carbonate mounds in general.

UPPER ORDOVICIAN COLD CARBONATE MOUNDS AND ASSOCIATED DEPOSITS OF EASTERN ANTI-ATLAS (MOROCCO): FACIES, DEPOSITIONAL MODELS AND CONTROL

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Eastern Anti-Atlas (Tafilalt and Maider) displays exceptional and unique upper Ordovician (Cardoc - Ashgill) series that are really different from the other Moroccan upper Ordovician siliciclastic successions (Hamoumi, 2001). In the Alnif area, the upper Formation of Tiouririne (Destombes et al., 1985) that overlies conformably the middle Ordovician storm dominated delta and offshore siliciclastic succession is composed of three depositional sequences. The lower one is a tide and storm dominated littoral and shelf siliciclastic sequence that includes carbonate mounds. The second one is a fan delta sequence made up of a muddy level sharply overlaid by a spectacular conglomeratic horizon where the nature of the sediment and the facies indicate reworking by gravity flow processes of the underlying carbonate formation and glacial sediment discharges. The upper one is composed of glaciomarine sediments and tide dominated delta sequence and it is overlaid by the tide and glacial dominated littoral sequence of the 2nd Bani Formation. In the eastern Tafilalt the upper Ordovician successions where the 2nd Bani formation was not identified (Destombes et al., 1985) are characterized by a low thickness and extent and a high content of carbonate and bryozoans. The biostrome of bryozoan limestones of Khabt El Hajar (Clariond, 1944) is considered as the laterally variant of the upper Formation of Tiouririne and corresponds to the oldest outcrops in this area (Destombes et al., 1985). The facies sequence suggests deposition in cold peritidal mixed siliciclastic/carbonate high energy littoral, adjacent to a carbonate platform. Evidence of glacial action is strongly suggested by the existence of fields of dessication polygons, soft sediment deformations, frost shattering, topography in ruins and glacial sediments.

The facies and the trend of these depositional sequences reflect a complex history of this part of the Moroccan North Gondwana platform under the interplay between tectonics and the upper Ordovician glaciation (Hamoumi, 1999). The eastern Anti-Atlas that corresponded to a storm and/or tides dominated epeiric silisiclastic sea with the E-W to ENE-WSW trending isopachs, during the lower and middle Ordovician being part of the whole « anti-atlas basin» recorded major paleogeographical changes during the upper Ordovician. An extensional tectonic event related to the reactivation of the pan-African fault movements according to NE-SW direction leaded to the creation of a through of the NW-SE direction between two ramp type platforms where the sedimentation developed under the control of the glaciation (change in the climate and glacial mass, sea level fluctuations and glacial discharges) and tectonic controls. The eastern Tafilalt platform developed on previously (lower and middle Ordovician) submerged areas and the Maider platforms took place on the previous siliciclastic shelf. During phases of sea level rise the water depth over the ramps allows the development of bryozoan mounds and the sedimentation in peritidal zones that were alimented by biogenic gravels and sand derived from subtidal areas and siliciclastic sediments derived from glacial discharges. Phases of sea level fall resulted in the stop of bryozoan mounds build up, their degradation by mechanical erosion and their accumulation with the sediment discharges from the Saharan ice sheet in fan delta systems in the through.

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COLD-WATER CORALS IN THE GULF OF CADIZ – SPATIAL AND TEMPORAL DISTRIBUTIONS AND THEIR FORCING FACTORS

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Cold-water corals are widespread along the European continental margin and, recently, have been also reported from the Gulf of Cadiz, where they are mainly hosted by mud volcanoes (MV). The observations of cold-water corals in this area indicate that these organisms only thrive in waters shallower than 1300 m water depth. In order to investigate the long-term development of cold-water corals in this region a grab sample from Hesperides MV and gravity cores taken from other MVs have been analysed. Radiocarbon-datings on a number of corals taken from the Hesperides MV grab revealed that four different cold-water coral species invaded the Gulf of Cadiz at different time intervals ranging from 1.000 to 48.000 yrs.

Observations of recent occurrences of cold-water corals point to a strong relation to vigorous current regimes as corals are preferable found to grow on elevated seafloor structures, where currents are enhanced, and thus, supply food to the filter feeders and simultaneously prevent them from burial with hemipelagic sediments. However, no evidence is given, whether currents are major driving mechanisms or rather belong to a complex pool of forcing conditions, primarily because very few data exist about the effect of changing current regimes on the development of cold-water coral ecosystems. Grain size analyses of three sediment cores collected in the Gulf of Cadiz (Hésperides and Faro mud volcanoes, Renard Ridge) show that coral-bearing sequences within the cores correspond to coarser grain sizes (i.e. stronger bottom currents) of the surrounding sediment, whereas coral-barren zones are associated with finer grain sizes (i.e. weaker bottom currents). Additional information provided by stable oxygen isotope data measured on the same cores, reveals that all coral-bearing sediments as well as the retrieved coral-barren sediments have been deposited under glacial or intermediate climate conditions, but not during interglacials. Taxonomic analyses display distinct temporal changes in the cold-water coral faunal assemblages (mainly composed of *Lophelia pertusa* and

Madrepora oculata), pointing at least to a link between the composition of the coral fauna and climatic changes, as e.g. *L. pertusa* appears to be more abundant during intermediate climate conditions.

Thus, for the first time it has been demonstrated that the presence or absence of cold-water corals largely depends on the local bottom current regime, whereas overall climatic changes appear to affect the species composition only.

WORM GALORE IN THE GULF OF CADIZ

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Siboglinids were formerly called Pogonophorans and included two groups of marine protostomes, frenulates and vestimentiferans. Both groups lack a functional gut as adults and rely on endosymbiotic bacteria for nutrition. Both taxa occur in reducing environments and typically are found at depths below several hundred meters.

"Many questions on the morphology, physiology embryology, ecology, systematics and geographical distribution of the Pogonophora are still far from clear or have not been touched upon, and we are far from drawing up any reasonably complete list of species. The growing scale of deep-sea exploration and the discovery of pogonophores in many different parts of the world, including the shores of Western Europe, justify the hope that many more investigators will join in research of these creatures" (A. V. Ivanov, 1963). Ivanov's hope was partially fulfilled with the discovery of deep sea communities dominated by large vestimentiferans, which came to symbolize hydrothermal vents in the Pacific, and with their discovery at cold seeps in the Gulf of Mexico and elsewhere, became the icon of communities driven by chemosynthetic primary production. On the other hand, frenulates, due to the limited number of samples and the difficulty of retrieving life specimens remain poorly studied.

Biological research on mud volcanoes in the Gulf of Cadiz started in 2000 within the TTR programme; hundreds of samples were collected and more than 500 species identified, which brought these ecosystems to the list of the "hotspots" ecosystems on the European margins. Studies of faunal assemblages have shown that chemosynthetic communities in most of the mud volcanoes are dominated by frenulate siboglinids. Molecular and morphological analysis of specimens collected from several mud volcanoes during the TTR-16 cruise showed that there are at least 8 different species of 5 different genera, from which at least two species and one genus are new to science. Preliminary observations show that *Siboglinum* is the genus with the widest geographical distribution, being present in all the studied mud volcanoes, and that Porto mud volcano has the largest diversity of frenulate siboglinids, with species from at least 4 genera. Future analysis to the microbiological communities, sediment and pore water chemistry, and current systems are fundamental to understand the biogeography of such a wide diversity of siboglinids in the Gulf of Cadiz.

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HYDROTHERMAL SALT – WHAT IS IT?

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Laboratory experiments have demonstrated that supercritical water has extremely low solubility for normal sea salts. This fact opens up the possibility for the precipitation of salt from seawater that circulates in faults and fractures close to a heat source in tectonically active basins (typically extensional pre-rifts and rift settings). Seawater attains supercritical conditions at depths exceeding 2,800 metres (corresponding to a pressure of 300 bars) and temperatures above 405°C. Salts may also precipitate by the boiling of seawater in sub-surface or submarine settings. This is demonstrated by a simple laboratory experiment. The theoretical basis for the precipitation of salts from seawater attaining supercritical condition has been examined by molecular modelling. These processes of salt precipitation constitute a new approach to the geological understanding of salt deposits, and two regions are selected to examine whether salt may have deposited under such hydrothermal conditions today: the Atlantis II Deep in the Red Sea (sub-marine setting), and Lake Asale, Dallol, Ethiopia (continental setting).

The new model can be used to understand the emplacement of deep-water salt accumulations, such as those in the abyssal Gulf of Mexico, abyssal Mediterranean, off Brazil and West Africa. Furthermore, local salt accumulation and alteration of sedimentary rocks by supercritical water at basin floors can also explain the formation of salt-cored and mud-cored piercement structures in deep-water settings.

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MINERALOGICAL INVESTIGATIONS OF GAS HYDRATES SAMPLED ALONG CONTINENTAL MARGINS

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In shallow marine sediments along continental margins, gas hydrates store significant amounts of methane and other gases, which are considered both climate relevant and an energy resource. In nature, gas hydrates occur in different structures which depend on physical and chemical parameters on the one hand and on the available gas on the other hand. Generally, methane is by far the major component in gas hydrates; the presence or absence of other gases determines the actual gas hydrate structure.

Hydrates presented here stem from four different seep areas in the Black Sea, sampled during the TTR- 15 cruise in June 2005 by gravity coring or TV grab. They contain predominantly gas hydrate structure type I; type II is present only at two locations and only as a minor constituent.

At locations featuring two structures, larger total fractions of gas hydrate were found although the amount of structure II is only a few percent; at those places were only structure type I is present the total amount is much less. The preservation of the gas hydrates might be due to the broader stability field of structure type II gas hydrate or the mixture of the two structures. Other locations on Earth like some areas in the Gulf of Mexico yield only gas hydrate structure type II; the gas hydrate fractions there are as high as at those locations in the Black Sea where the two structures are present.

The gas hydrate microstructures are supposed to be one major factor controlling the stability fields of the two different structures. Today, micropores of 200-400 nm diameter within the gas hydrates are considered a general characteristic of gas hydrates. We present first Cryo-Field-Emission-Environmental-Scanning Electron-Microscope investigations pointing to noticeable differences in the microstructure. Images of structure II hydrates reveal the absence of such micropores but instead show very dense surfaces. These surfaces are easily etched by electron beaming; also, features resembling small crystal planes are discernable.

By illuminating differences in the microstructure of gas hydrates, one factor is found which might account for different stability fields and thus help understanding the gas hydrate occurrences in the Black Sea.

METHANE-RELATED AUTHIGENIC CARBONATES OF THE PEN DUICK ESCARPMENT

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The Pen Duick escarpment forming steep southern slope of the Vernadsky Ridge in the El Araish (Gulf of Cadiz) was revisited and investigated during TTR-16 Cruise onboard the R/V *Professor Logachev*. Two profiles with MAK-1M in 100 KHz-frequency mode (MAKAT 126 и MAKAT 127) were made. Zones with high back-scattering were investigated with the TV-grab, revealing fields of cabonate crusts and coral colonies related to accumulation of carbonate slabs. Two locations were sampled with the TV controlled grab and the gravity corer, getting a lot of carbonate crusts and tubes, that showed wide variety of morphology and structure.

Carbonate crusts were divided into 6 groups according to their shape, colour and type of the material. Studying of the thin sections reveals similarity in the composition of the crusts, suggesting all of them to consist of foraminifera and molluscan fossils with some terrigenious admixture cemented by the micritic carbonate material. The differences can apear in proportions of these components. The crusts of the same type show mostly identical proportions. Crusts of the 'A', 'B'and 'E' types have the biggest amount of foraminifera, crusts of type 'E' contain high amount of shell fragments, amount of terrigenious admixture is usually less then 6 % .Crusts of the 'C' type contain less foraminifera and more terrigenious admixture, when the crusts of 'D' type consist mainly of micritic carbonate material.

The relative content of different carbonate minerals and terrigenous admixture was calculated based on the X-Ray-analysis, showing that calcite and high-Mg calcite are predominant components in most part of the samples (up to 90 %). The amount of the aragonite varies in wide interval from 0 to 55 %, dolomite admixture varies from 2 to 13 % (Fig.1).

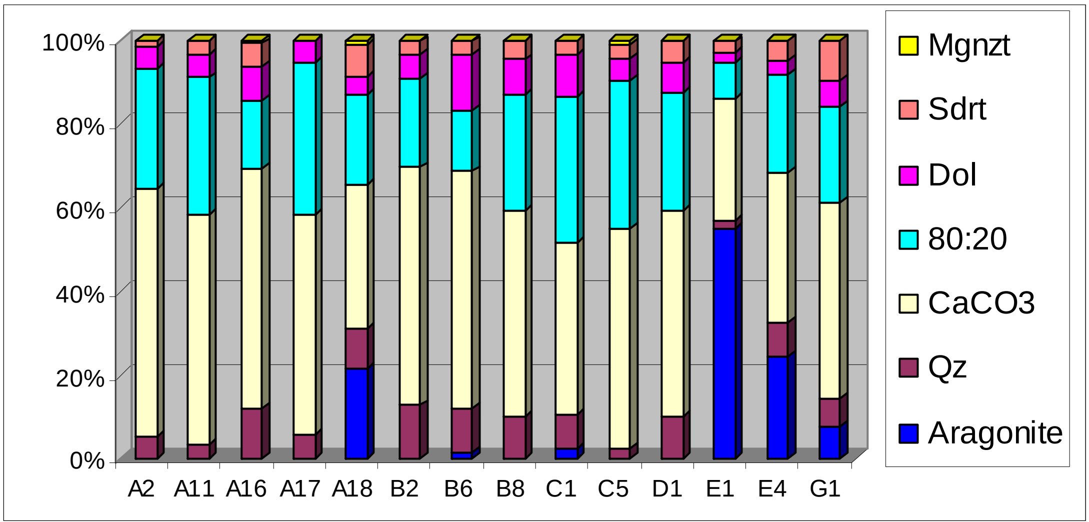

Figure 1. Relative content of carbonate minerals and quartz admixture in the authigenic carbonates of the Pen Duick escarpment.

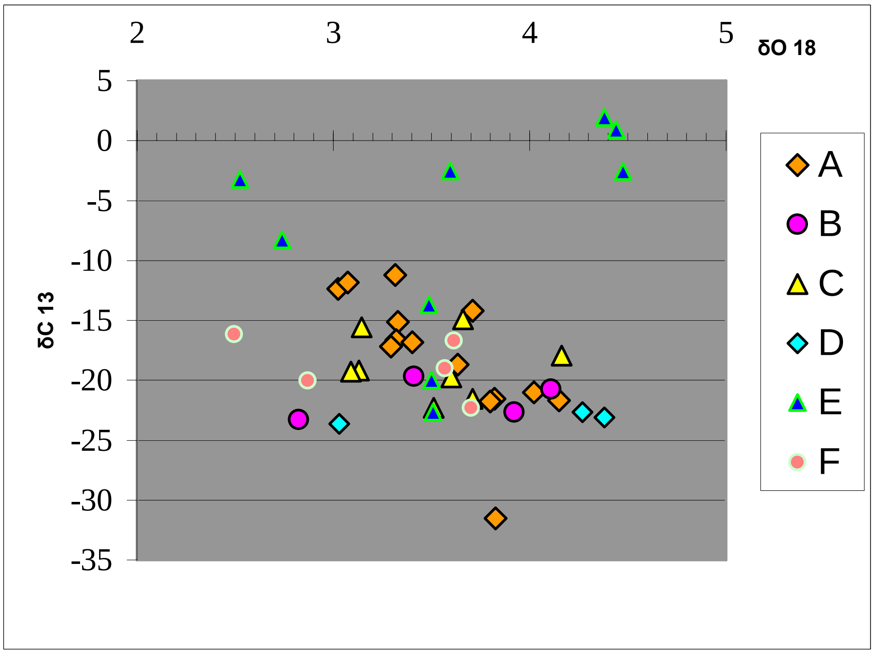

Figure 2. Isotopic composition of the carbonate crusts of the Pen Duick escarpment.

The carbon isotopic measurements of the crusts material ranged from -8 ‰ (crusts with big amount of molluscal fossils) to -31 ‰ (material filling the internal space of the tube), while most part of the samples have the $\delta^{13}C$ about 12-24 ‰ (Fig.2). The isotopic composition of the walls of the tubes, the interfilling material and the carbonate from the surrounding from different parts of the crust was compared and it has been found out that in most cases their isotopic composition is very close, meaning the same source of the carbonate for all zones of the tube.

Carbonate crusts can be characterized as beeing precipitated from the thermogenically formed gas, forming different morphologies depending on the material, that is beeing cemented, and the depth of their formation meaning the activity of the bioturbation proceses within different levels of the sediments.

FREE OIL HYDROCARBONS IN THE MAIKOPIAN CLAY FROM THE PETROLEUM MUD VOLCANO (THE TUAPSE TROUGH, BLACK SEA)

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During the last 25 years several mud volcanic areas were discovered in the Black Sea at the depth up to 2200 m. A lot of data on morphology and structures of mud volcanoes (MV) and composition of the products of their activity were collected during TTR-1, 3, 6, 11 cruises (carried out in 1991, 1993, 1996, 2001 correspondingly) in the central part of the Black Sea and the Sorokin Trough (Ivanov et al., 1996). During the TTR-15 cruise several mud volcanic fields (either discovered by the "Yuzhmorgeologia" Co. (Russia) or by petroleum companies) were investigated. The Petroleum Mound mud volcano (MV), situated in the Tuapse Trough close to the Shatsky Ridge (Eastern Black Sea) at the depth of 1980 m was investigated using seismic and acoustic systems, and sampled by the TV-grab and a gravity corer.

The Petroleum Mound mud volcano erupts with gas and water saturated mud breccia which consists of clayey matrix with rock clasts up to 5 cm, carbonate crusts and oil slik. Usually rock fragments from the Black Sea mud volcanoes are represented by claystones from the Maikopian Formation (Oligocene-Lower Miocene) (95-99%), as well as sandstones and marlstones (1-5%). In contrast to those, mud breccia clasts from the Petroleum Mound mud volcano include only two very similar types of the Maikopian claystones that are different in color.

Clasts and matrix of the Black Sea mud volcanoes were described and investigated under microscope and with the Rock-Eval pyrolysis and XRD analysis. The Rock-Eval pyrolysis is used to identify the type and maturity of organic matter and to detect petroleum potential in rocks (Espitalie et al., 1977).

Samples from mud breccia matrix demonstrate low total organic carbon (TOC) content (0.1-0.18%) and very low maturity, according to pyrolysis parameter Tmax (364-398°C) and clay minerals composition. The content of TOC in clasts varies from 0.7 to 2.37%, the amount of hydrocarbons

(S_1+S_2) is 0.54-14.7 that belongs to a source rock with a moderate and good oil/gas potential. The maximum of hydrocarbon production (Tmax) values of all studied samples are relatively low (less than 427°C) indicating that organic matter (OM) has not experienced any strong thermal maturation. According to wide range of hydrogen index (HI) values (83 to 291 mg HC/g TOC), OM of the studied samples belongs to Types II and III, which are usually related to marine phytoplankton material with admixture of terrestrial higher plants debris.

High production index PI - 0.53-0.54 ($PI = S_1/[S_1 + S_2]$) shows a very high evolution level of the organic matter which contradicts data on maturity level according to Tmax and composition of clay minerals. In this case the production index shows intensive processes of primary migration. Oil drops desorbed from kerogen to pore space and did not migrate to a trap. Evidences of oil migration were observed in thin-sections. Gas-chromatography-mass-spectrometry investigation of oil slick from the Petroleum Mound MV shows the immature Maikopian oil (Nadezhkin et al., this volume).

Origin of free oil hydrocarbons in the mud breccia clasts from the Petroleum Mound MV is still a topic for discussion. The possible explanations are: (1) immature oil can be formed from rich in organic carbon but immature kerogen of the Maikopian claystone *in situ* under specific conditions or (2) migrated from very closely situated oil field also from the Maikopian Formation.

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HOLOCENE SANDY TURBIDITY CURRENTS IN THE NORWEGIAN SEA

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The high-latitude Andøya Canyon is a strait, 40 km long and up to 1100 m deep, V-formed incision on the northern Norwegian continental slope. In order to identify the most recent canyon processes and their age gravity core samples have be acquired from various settings during Training-Trough-Research 13 including: 1) the thick right-hand levee at the canyon mouth, 2) the poorly developed levee of the Lofoten Basin Channel, the deep-sea canyon continuation, and 3) the distal Lofoten Basin Channel floor. The 480-cm-long gravity core from the canyon mouth levee comprises thin sand layers (< 2 cm thick) inferred to be turbidites interbedded with thicker hemipelagic mud intervals. Here three levels were dated and the results were: 12175 +/-90 ^{14}C years BP at 463-466 cm depth, 11562 +/-49 ^{14}C years BP at 277-280 cm depth, and 7859 +/- 42 ^{14}C years BP at 51-53 cm depth. From the above results we find that turbidity currents large enough to overspill the levee has occurred during the late glacial as well as during the early Holocene. A 40 cm long core comprising two massive sandy turbidites was recovered from the Lofoten Basin Channel levee. ^{14}C AMS dating gave: 5190 +/-45 ^{14}C years BP at 33-35 cm depth, 3645 +/-40 at 18-20 cm depth and 4550 +/-45 at 8-10 cm. Inferring that the uppermost dated level is too old due to contamination of older microfossils we find that the lower sandy turbidite was deposited in the period from 5190 – 3645 ^{14}C years BP and that the upper is younger than 3645 ^{14}C years BP. This shows that turbidity currents were routed through the channel and into the deepest part of the basin also during the late Holocene. Slightly further into the basin a 158 cm long core sample from a channel floor dominated by longitudinal erosional bedforms display about 75 cm of hemipelagic (massive) and turbiditic (laminated) mud overlying a 57 cm thick interval of sand lenses and gravel in a muddy matrix. The mud-sand-gravel facies is inferred to represent sediments deposited from and modified by turbidity currents. Alternatively, they may represent debris flow deposits. From this core three levels have been dated and the results are; 4095 +/-50 ^{14}C years BP at 151-153 cm depth, 2385 +/-35 at 50-52 cm depth and 1475 +/-40 at 23-25 cm. Thus the oldest turbidite (or debris flow) was deposited sometime during the period from 4095 – 2385 ^{14}C years BP. Afterwards, two turbidites were deposited, one in the period from 2385 – 1475 ^{14}C years BP, the uppermost is younger than 1475 ^{14}C years BP confirming the late Holocene turbidity current activity of the canyon-channel system. The Holocene turbidity currents probably originated from canyon headwall piracy of alongslope oriented ocean current transported sediments or mass wasting within the canyon.

MICROBIALLY-MEDIATED FORMATION OF METHANE-DERIVED CARBONATES FROM THE GULF OF CADIZ

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Within the framework of the INGMAR, TASYO, Moundforce and MVSEIS projects (among others) several UNESCO/IOC cruises (TTR-9, TTR-10, TTR-11, TTR-12, TTR-14, TTR-15 and TTR-16) have been carried out, during the last 7 years, with objectives that included the study of fluid escape structures and processes in the Gulf of Cadiz. These cruises allowed the recognition of methane-derived authigenic carbonates in the Gulf of Cadiz. Identification was based on geophysical and underwater video observations.

The cruises allowed the collection and the identification of different types of authigenic carbonates in the Gulf of Cadiz: (1) dolomite crusts, dolomite nodules, chimneys or filled burrows and (2) aragonitic slabs or pavements. They all correspond to the cementation of sediments through the precipitation of authigenic carbonates and the different lithological types correspond to different geochemical environments of formation. The dolomitic samples consist of microcrystalline dolomite cements with subordinate high and low magnesium calcite cementing a detrital quartz and minor feldspar, clays, bioclasts of planktonic foraminifera (globigerinoids), ostracods, and pellets. The aragonite pavements form tabular to nodular precipitates consisting mainly of aragonite and calcite cementing mud volcano mud breccias, shells and clasts from previous generations of crusts, and detrital quartz, clays and bioclasts of planktonic foraminifera. Authigenic carbonates with low $\delta^{13}C$ values indicate the oxidation of methane as the major carbon source. Authigenic pyrite with negative $\delta^{34}S$ values indicates an anoxic environment with sulphate-reducing bacterial activity promoting sulphide precipitation.

The presence of clotted microfabric in both aragonitic and dolomitic cements is indicating a microbial mediation in carbonate authigenesis, particularly in the initiation of precipitation. This interpretation is also supported by other fabrics and precipitates such as: (1) microbial filaments; (2) high Mg-calcite and dolomite crystal aggregates calcifying filaments, some of them being incorporated by dolomite and calcite crystals; (3) rods with brush-like terminations; (4) structures that resemble dumbbell-like and cauliflower morphologies; (5) aragonite batons, ball-capped batons and nanograins; and (6) microbial and mucous biofilms, draped between the aragonite fibres and needles of stromatolitic layers.

^{13}C-depleted lipid biomarkers were identified in the dolomite chimney samples. They include tail-to-tail linked acyclic isoprenoids such as PMI (2, 6, 10, 15, 19-pentamethyleicosane) and squalane (2, 6, 10, 15, 19, 23-hexamethyltetracosane). These compounds derive from archaea involved in the anaerobic oxidation of methane. The aragonite crusts showed even better preserved biomarker patterns in comparison with the dolomite chimneys. PMI ($\delta^{13}C$ = –101‰ VPDB) is accompanied by unsaturated derivatives with 1 to 3 double bonds (PMIΔ = –75‰ VPDB). Isotopically-depleted PMI represents the most widespread and persistent hydrocarbon biomarker for AOM-performing archaea. Lipid biomarkers of sulphate-reducing bacteria show $\delta^{13}C$ values ranging from –95 to –99‰ VPDB.

In conclusion, the results of the SEM observations and the biomarker analysis show that microbes were involved in the formation of the authigenic carbonates. An organogenic formation is proposed not only for dolomite but also for the other authigenic carbonates (aragonite, calcite and Mg-calcite).

Acknowledgements

The shiptime of the TTR cruises was jointly funded by the following projects: INGMAR (PLE/4/98, FCT) and Euromargins MVSEIS Project (01-LEC-EMA24F; PDCTM72003/DIV/40018); and the UNESCO/IOC Training-through-Research Programme (including through the EC-HERMES and TTR-*Flanders* Projects). This work was developed as part of the Vitor Magalhães PhD project, supported by the FCT fellowship SFRH/BD/11747/2003.

LIPID BIOMARKER COMPOSITION IN MUD BRECCIAS FROM THE CAPTAIN ARUTYUNOV AND GEMINI MUD VOLCANOES IN COMPARISON WITH SEDIMENTS FROM THE PEN DUICK ESCARPMENT. THE GULF OF CADIZ, NE ATLANTIC

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This paper shows results and preliminary interpretation of lipid biomarker study performed for mud breccia samples from two mud volcanoes (MVs), the Captain Arutyunov and Gemini and for sediments from the Pen Duick Escarpment. Samples were obtained during the two Training-through-Research (TTR) cruises in 2002 (TTR-12) and in 2006 (TTR-16). The aim of this study was to compare the main sources of organic matter from these MVs and from the Pen Duick Escarpment in order to compare lipid biomarker properties with the already existing data from MVs from the Gulf of Cadiz (Stadnitskaia, 2006) and to find out whether the Escarpment has a mud volcanic origin or not.

Mud breccia matrixes from the Captain Arutyunov and Gemini MVs showed almost identical lipid biomarker compositions (Fig. 1). The CPI values for C_{25-34} alkanes are ca. 0.6-0.7 which imply relatively high maturation of the organic matter, perhaps close to the oil window interval.

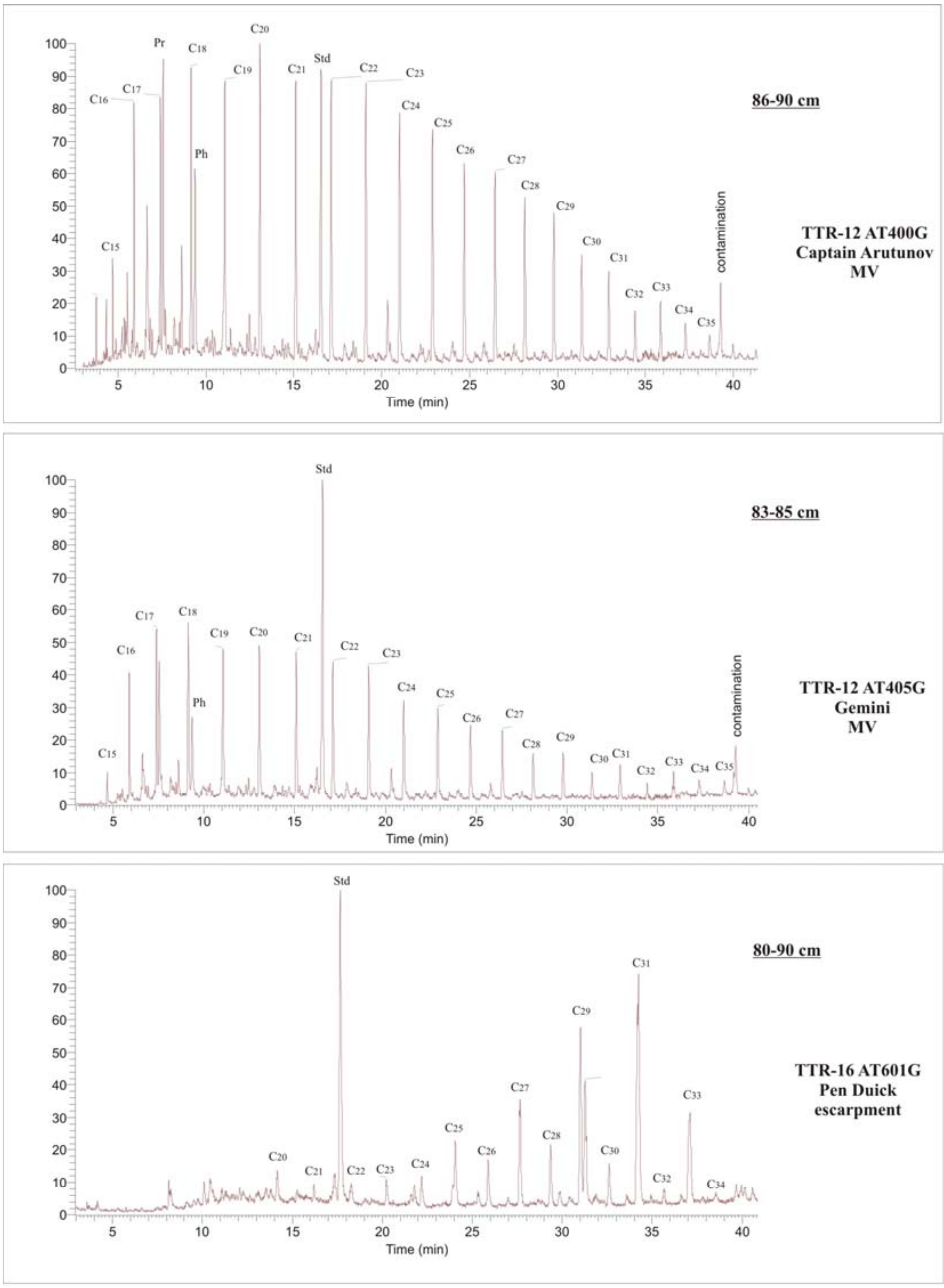

Fig.1 Distribution of *n*-alkanes using m/z 57+71 from mud breccias of the Gemini and Captain Arutunov Mvs and pelagic sediments from the Pen Duick escarpment.

distribution of *n*-alkanes indicates an admixture of petroleum-derived compounds. In contrast, sediments from Pen Duick Escarpment show the presence of noticeably different type of organic matter. The lack of marine-sourced *n*-alkanes, strong dominance of C_{27}-C_{33} *n*-alkanes and high CPI values for C_{25-34}, i.e. from 8 to10, mark immature organic matter with high input of terrestrial-sourced components.

Distribution of hopanes in the mud breccias from the Captain Arutyunov and Gemini MVs is also identical. The values of 22S/(22S+22R) ratio for the C_{31}, C_{32} and C_{33} homohopanes is close to 0.6, which indicates relatively mature characteristics of the organic matter. However, the occurrence of minor amounts of straight chain alcohols in both MVs and straight chain fatty acids found only in the Gemini MV indicates an admixture of immature organic matter. In contrast, sediments form the Pen Duick Escarpment show absence of hopanoids and the presence of even-numbered straight-chain alcohols with C14-30 as the dominant members. These also can have terrestrial sources.

Thus, lipid biomarker distributions and maturity properties from the mud breccias show similar characteristics, and the presence of petroleum-derived hydrocarbons was also noticed in both MVs. These data is consistent with the data reported by Stadnitskaia (2007). In contrast, lipid biomarker distributions in the pelagic sediments from the Pen Duick Escarpment show no deep fluid inflow within the sampling location and immature, dominantly terrestrial organic matter. Accordingly, these data suggest a non-mud volcanic origin of the Pen Duick Escarpment.

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GAS HYDRATES AND HYDROCARBON-RICH FLUID SEEPAGE IN THE VØRING-STOREGGA REGION (NORWEGIAN SEA): SAMPLING AND SEA FLOOR OBSERVATIONS

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During the Training Trough Research Cruise in 2006 (TTR-16) in the Nyegga region, Norwegian Sea, six large pockmark and mound features (CNO3, G11, Tobic Dodo, Sharic and Bobic) were explored with TV remote controlled grab and gravity corer devices with a total of 23 sampling stations. This region was initially visited during TTR-8 and TTR-10 cruises (Kenyon *et al.*, 1999; Kenyon *et al.*, 2001; Mazzini *et al.*, 2005) and, more recently, new discoveries of authigenic carbonate deposits have triggered new interest on mechanisms of seepage activity (Hovland and Svensen, 2006; Mazzini *et al.*, 2006).

TTR-16 investigations inside the pockmarks and the mounds observed up to several metres wide/high blocks of authigenic carbonates as well as laterally extensive carbonate pavements. No obvious evidence of fluid seepage was observed during the TV surveys and no living chemosynthetic bivalves were observed or sampled. Nevertheless, several observations and data support possible active fluid-seepage at these structures. Numerous pingo structures were distinguished usually associated with pogonophoras fields and whitish microbial colonies. The sediment and carbonates recovered from these sites revealed a strong smell of H_2S and microbial filaments were seen within the hemipelagic sediment associated with authigenic carbonate. These observations suggest that AOM is locally ongoing. Aragonite is the main mineral forming the authigenic carbonates. Sampling revealed that large amount of shell debris form subvertical narrow deposits in the subsurface indicating that chemosynthetic colonies were thriving along fluid pathways.

For the first time, gas hydrates were sampled from the Nyegga region, supporting the inference of several authors that hydrate is present, but which had never been verified by sampling. Gas hydrate and strong bubbling was observed in the bottom part of several shallow cores from five of the visited structures. In particular at Sharic location at ~1 m bsf the sediment was collected entirely cemented by microcrystalline hydrate also forming distinct mm thick layers.

Geochemical analyses on hydrates reveal that methane is the main component with minor amount of CO_2 and ethane, pointing out to a Structure I type hydrate. Methane carbon isotopes show strong depletion in ^{13}C suggesting a significant biogenic input. Ignition test on sediments samples containing hydrates showed that, despite the high clay content, flames were observed burning for several minutes although small amount of gas hydrates was visible with naked eyes. CT scanning of sediment samples containing gas hydrates revealed the presence of subparallel mm thick hydrate layers crossed by a network of microfractures- and pore- filling hydrates. These images confirm the presence of a significant amount of gas hydrates within the clayey sediment.

The presence of gas hydrate does not necessarily provide evidence of actual or very recent flow of free gas at the locations investigated. P-T variations of the actual hydrate stability field could trigger the release of significant amount of methane.

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ABSORPTION OF GASEOUS HYDROCARBONS TO MARINE SEDIMENTS

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For constraining reservoirs of low-molecular weight hydrocarbon (HC) gases in marine sediments, it is necessary to assess the amount of sorbed gases. Sorption of HC-gases to marine sediments is a well-known phenomenon, but has not yet been quantified and mechanistically constrained. The dynamics of gas partitioning between the four gas reservoirs, i.e., aqueous state, as solid clathrate, free gas, and bound to sediment particles by sorptive forces, and their relationship to turnover of HC-gases are not understood. Our study seeks to obtain a better understanding of the least explored gas pool, sorbed gas, and to assess its importance in biogeochemical processes.

First, we compared protocols for the extraction of sorbed HC-gases and found that a recently introduced technique (Hinrichs et al., 2006) based on leaching of the sediment in 1-N aqueous NaOH resulted in up to an order of magnitude higher yields than obtained from previously applied approaches based on treatments with boiling phosphoric acid (e.g. Whiticar & Suess, 1990; Knies et al., 2004) or autoclaving (Sugimoto et al., 2003). Our observations do not support previous interpretations of sorbed gas as mostly derived from thermogenic sources due to their ^{13}C-enrichments relative to dissolved gas (Whiticar & Suess, 1990). Instead, we suggest that previously applied protocols selected for pools of gases that were isotopically enriched relative to bulk sorbed gas. This statement is supported by observations of relatively large variations of isotopic compositions of sub-samples, released in increments from single samples of sediment or clay mineral. The origin of the sorbed gas pool appears to be closely related to that of the other gas pools and is interacting with these through a variety of processes, including biological ones.

The partitioning of methane and other HC-gases between the dissolved and sorbed pools is highly variable. In some occasions, the sorbed pool exceeds the amount of HC-gases dissolved in the pore water by several orders of magnitude. In the deep Japan Trench, sorbed methane is typically more abundant than dissolved methane. Carbon isotopic values of both pools clearly indicate microbially-derived gases ($\delta^{13}C$ = -80‰ to -70‰). The difference between δ-values of the sorbed and

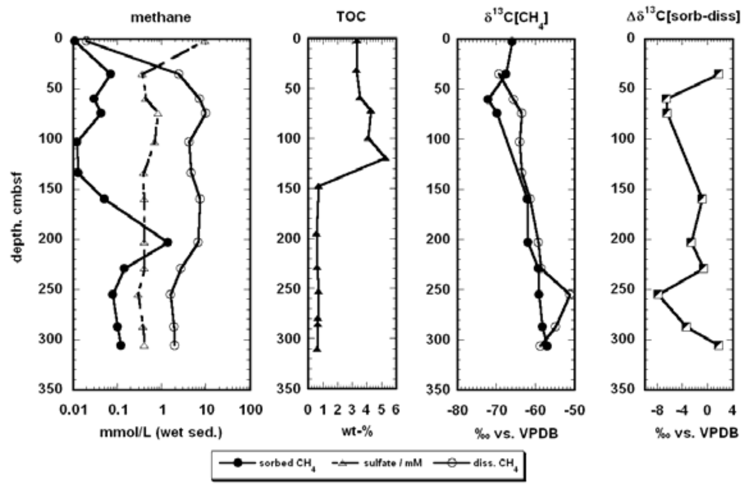

Figure 1. Depth profile of a cold seep sediment core of the Turkish Margin in the SW Black Sea (Trakya, close to Bosporus outlet, 883 mbsf, BS-340-G, TTR15).

dissolved gas phase, $\Delta\delta^{13}C$-values, range from -8 to +4‰ vs. VPDB (Fig. 1). The mechanistic causes of these differences are not yet fully understood, but the current evidence points towards strong isotopic partitioning of the gas pools by biological sources and sinks in combination with distinct kinetics of certain sorptive sites in clay minerals regarding sorption and desorption.

Likely adsorbents are layered clay minerals such as smectites. This is supported by computational geochemistry (Sposito et al., 1998), the efficiency of the extraction procedure with NaOH, which is likely to cause delamination of layered clay minerals, thus causing release of enclosed gas (cf. Hinrichs et al., 2006), and, most importantly, laboratory experiments with pure clay minerals. For example, in autoclave experiments at 200 bar, we were able to show uptake and subsequent extraction of ~ 43 mmol/kg Na-montmorillonite. These observations support a key role of layered clay mineral as sorbents for HC-gases in marine sediments.

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GEOCHEMICAL CHARACTERISTICS OF OILS FROM SEEPS IN THE EASTERN PART OF THE BLACK SEA

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Numerous oil and gas fields are well known onshore the Black Sea. Petroleum systems of the Black Sea region are in the focus of intensive research.

This work is based on the study of three areas in the Black Sea: Area I – the Ukrainean margin, the Sorokin Trough (Kazakov mud volcano); Area II – the Russian margin, the Tuapse Trough (Petroleum Mound); Area III – the Georgian margin (Colkheti Seep, Pechory and Iberia Mounds) (Fig.1). Samples of oil and mud breccia from mud volcanoes (MVs) and seeps were collected for detailed analysis in the laboratory. Bitumen was extracted from rock clasts of mud breccias. Additionally, oil from the onshore Supsa oil field (Georgia, Area III) related to the Maikopian Formation was analysed to compare the onshore Eastern Black Sea petroleum system with the offshore oils and bitumens.

Figure 1. Location map of the studied areas in the Eastern Black Sea.

Saturate and aromatic fractions of samples of oil and bitumen were studied by gas chromatography, gas chromatography-mass spectrometry (GC, GC-MS). According to the sterane distribution the organic matter from all samples belongs to a mixed type of marine and terrestrial material (Fig. 2). Each study area can be characterized by specific distribution of biomarkers (for example, distribution of tricyclic terpanes, tetracyclic terpanes and hopanes and others). Bitumens from rock clasts of the Kazakov mud volcano is immature, while samples of oil and bitumen collected from other areas are more mature based on alkanes and aromatics distribution.

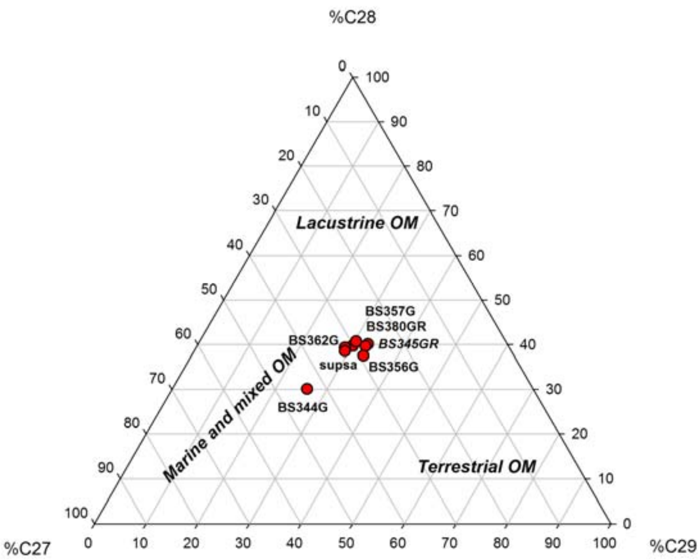

Figure 2. Distribution of αββ(S+R) (m/z 218) $C_{27\text{-}29}$ steranes (indicate initial organic matter). Sample stations:
Area II: BS344G, BS345GR, BS345GR (clasts); Area III: BS356G, BS357G, BS362G, BS380G, Supsa.

Specific distributions of tetracyclic terpanes for each area were defined. Homologues of tetracyclic terpane T24 were recorded in m/z 191. Amount of these homologous differs for Area II and Area III (Fig. 3).

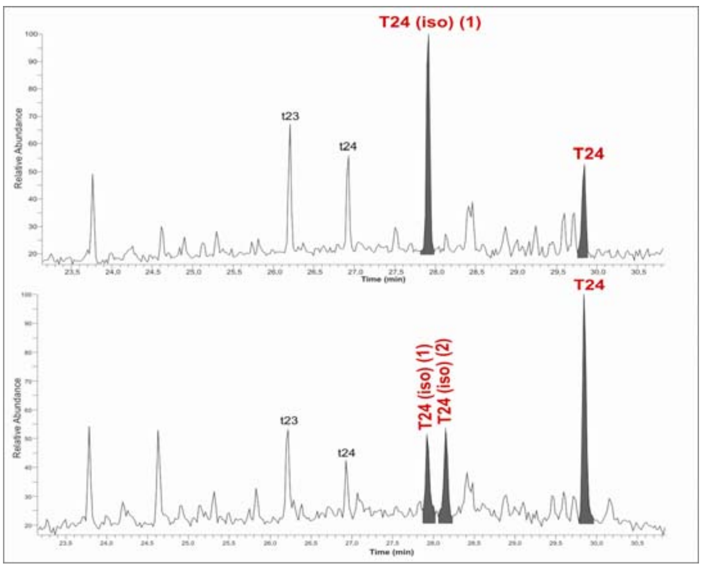

Figure 3. Distribution of tetracyclic terpane homologous (m/z 191) in samples of oil and bitumen from Area III (upper graph), and Area II (lower graph).

Similar distribution of biomarkers is recorded for oil from the Supsa oil field and for the offshore oil (Georgian margin, Area III). Distribution of biomarkers in oils and bitumens from Maikopian claystone of the Tuapse Trough are similar (Area II).

In the Black Sea region the Maikopian rocks (Upper Palaeogene-Lower Neogene) are believe to be the main source formation. Differences between biomarkers distribution for two areas (II, III) show different paleodepositional environments and biota in the Maikopian time.

HYDRO-ACOUSTICAL SURVEY OF METHANE PLUMES IN THE ANAXIMANDER MOUNTAINS, EASTERN MEDITERRANEAN SEA

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To quantify and characterize the temporal and spatial distribution of methane seeps, sonar data were collected during METEOR M70-3 survey in the area of the Anaximander Mountains, Eastern Mediterranean sea. This area is characterized by the occurrence of mud volcanoes in about 2050m water depths (Limonov et al., 1995; Woodside et al., 1998). During the survey a high-resolution mapping of seep areas was carried out by use of the PARASOUND echo-sounder (ATLAS Hydr.), operating at 18 kHz.

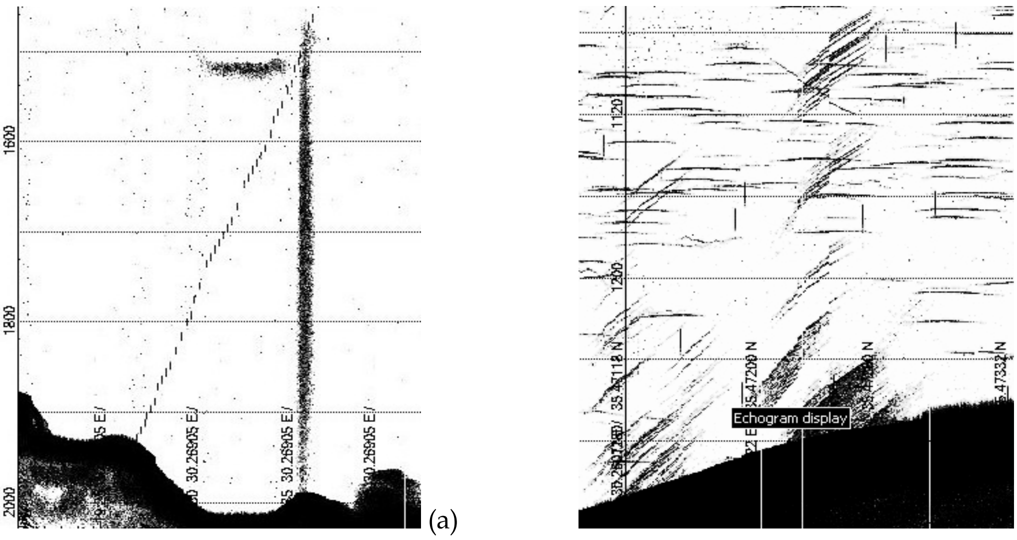
The echo-sounder profiles were registered at ship's speeds of ~8 and ~12 knots (when mapping the area), and at ~0.5 to ~1.5 knots (when surveying plume areas). At high ship speed the detection of seep flares was very difficult. The data quality was affected by extremely high noise from the ship's thrusters; which made it impossible to visualize weak scattering produced by bubbles in the water column. The combination of low ship's speed and the above mentioned echosounder settings allowed a very clear visualization of bubble plumes that were passed during the survey. This enabled getting relatively reliable information about the distribution and location of bubble plumes within the areas where there existence has not been detected before.

Direct evidence of gas bubbles in the water column is confined to the few sites at which visual observations (by the remotely operated vehicle 'Quest') have been made and also a correlation between visual observations and echosounder records demonstrates that bubble plumes can be identified acoustically. Fish also produce strong reflections in the water column.

Bubble streams in the water column were detected at all three of our study areas, Amsterdam, Athens and Thessalonica Mud Volcanoes. Bubble streams are evident as 'hyperbolic echoes' (Sauter et al., 2006) on acoustic profiler records and are being emitted from a traceable origin on the seafloor. The span and distribution of the active bubble streams were clearly identified at the seep sites. However, on the acoustic records the deep water (~2030m water depth) bubble streams displayed different signatures than the bubble streams detected in the shallower areas (~1400m water depth). An example is given in Fig 1. On the acoustic profiler records, the bubble streams from the Amsterdam MV study areas (Fig. 1a) were narrow with low backscatter amplitude, the columnar regions appeared to narrow as they rise towards the surface.

In the Athens and Thesalonika MV, the Parasound survey detected 20 sets of bubble streams rising from the crests of the main mound. In these areas the bubble streams were wide and short, with significant backscatter from individual bubbles, Fig 1 (b).

During the survey a number of interesting results from the present echo-sounder survey were obtained. On the echograms 25 distinct vent sites were registered, ranging about 20m in diameter and



(a) (b)

Figure 1. Bubble plume at 2030m water depth (a), and a stream of bubbles at 1300m water depth (b)

50 m to 600 m in height, reaching up to 900 m below the sea level. The measured volume backscattering strength of methane plumes show the highest values around the bottom and the middle of plumes, whereas the backscattering strength is relatively low at the top of plumes. The backscatter values were used for calculating the quantity of emitted gas flux in a form of methane bubbles. Also, several chunks of methane hydrate were sampled by piston coring at the area where methane plumes were observed. The recovered methane hydrate indicated existence of thick hydrate deposits in shallow sediments near the vent sites.

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BIOGEOCHEMICAL ASPECTS OF METHANE-RELATED MICROBIAL MATS AND CARBONATE PRECIPITATES FROM THE NORTHERN BLACK SEA

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Submarine gas seepages, releasing vast amounts of volatile hydrocarbons are well known from various sites of the northern Black Sea. While the majority of seeps were found on the continental shelf and slope, some emission sites were discovered even in deep-waters below 2.000 m depth. Associated to seepage sites within the permanently anoxic water column microbial mats mediating the anaerobic oxidation of methane (AOM) as well as carbonate precipitates are frequently observed. It is generally believed that AOM leads to an increase in local alkalinity, thus favouring the precipitation of carbonate.

During several research cruises in the north-western and north-eastern Black Sea we explored the distributions of seeping sites, the concentrations and compositions of the seep gases, as well as specifics of seep-associated microbial mats and carbonate precipitates. On the Ukrainian shelf west of the Crimean peninsula we focused on an area characterized by an extremely high density of active gas seeps at a water depth of about 230 m. As indicated by its $\delta^{13}C$ values of –62.4 to –68.3 ‰ the methane, which accounted for about 95 % of the gas, is of microbial origin.

By use of the research submersible 'JAGO' we investigated huge microbial structures emerging up to 4 m from the sea floor in the permanently anoxic water column. These build-ups comprised thick microbial mats which are stabilized by carbonate precipitates. Strong ^{13}C depletions of total biomass (about –72 ‰) and of carbonate carbon (about –30 ‰) indicate methane to be the dominant carbon source. As evidenced by molecular biological approaches the mats mainly consist of densely aggregated archaea (ANME-1 cluster) and sulfate-reducing bacteria (SRB: *Desulfosarcina/ Desulfococcus*-group) performing combined anaerobic oxidation of methane (AOM) and sulphate reduction (SR). However, cross sections of the mats displayed macroscopically different microbial mat types. As evidenced by a combined approach using lipid biomarker and fluorescence in situ hybridization these mat types were dominated either by ANME-1 or ANME-2 communities. It was found that lipid biomarker patterns allow for a differentiation between these ANME consortia, since substantial differences between the mat types regarding both, their composition and the compound specific carbon isotope signature occur. The transfer of an active massive AOM-performing microbial mat into a laboratory enabled us to investigate *in vitro* metabolic and biosynthetic activities.

In order to gain information on specific AOM consortia involved in the precipitation of carbonates, we analyzed distribution patterns and stable carbon isotopic compositions of lipids preserved in the carbonates stabilizing the microbial structures. For comparison a sample of surface sediment recovered from a nearby non-seep site and a carbonate precipitates dredged in an area of intense gas bubble discharge at 1555 m water depth were studied for their lipid composition. Differences of the dominant AOM-performing communities between the carbonates indicated by specific lipid patterns appear to be influenced by the respective biogeochemical settings. High proportions of ANME-2 consortia were found to be directly associated to sites of high partial pressures of methane while ANME-1 associations dominate at low-seepage areas.

During an expedition to the north-western Shatsky Ridge located east of the Crimean Peninsula we recovered carbonate precipitates from top of the Dolgovskoy Mound in a depth about 2000 m. Strong depletions in ^{13}C measured for methane (–79.8 to –80.8‰) dissolved in interstitial waters of shallow sediments and for carbonate carbon (–30 to –41‰) indicate AOM consortia being involved in the carbonate precipitation in general. However, studies on cross sections revealed that these carbonates are build up by significantly different lithological facies (see also A. Bahr et al., this publication). Lipid biomarker analyses suggest similar compositions of ANME communities being involved in carbonate precipitation of the different facies.

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METHANE-SEEP MICROBIALITES – EXAMPLES FROM THE BLACK SEA

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Methane-seeps are common along most ocean margins and are typified by their dense biological colonization. Chemotrophic microorganisms form the base of the food web at seeps, also supporting eukaryotic life at many sites. Another consequence of chemosynthesis at methane-seeps is the formation of authigenic carbonates. These carbonates, being the product of microbial activity, archive information on biogeochemical processes that led to their formation. Carbonate precipitation is induced by the anaerobic oxidation of methane by a microbial consortium of methanotrophic archaea and sulphate-reducing bacteria. Proof for an involvement of microbes in the formation of methane-seep limestones stems from carbonate fabrics, stable isotopes, and lipid biomarkers. The carbon of early diagenetic carbonate phases is predominantly derived from the oxidation of methane, which results in low $\delta^{13}C$ values. Pyrites enclosed in seep limestones generally show low $\delta^{34}S$ values and a significant variability of their isotopic composition on a small scale, both indicating bacterial sulphate reduction as the sulphide-generating process. ^{13}C-depleted lipid biomarkers characterise the microbial populations involved in the cycling of carbon at methane-seeps. Typical compounds include isoprene-based lipids from archaea, and linear and monomethyl-branched carbon skeletons assigned to sulphate-reducing bacteria, consistent with the syntrophic relationship of these microbes in the anaerobic oxidation of methane. Other microbial processes that are recorded in seep limestones include aerobic oxidation of methane, iron reduction, and sulphide oxidation.

ACOUSTIC GEOCHEMICAL EVIDENCE OF SUBSURFACE GAS OCCURRENCE OFF KOLA PENINSULA (BARENTS SEA)

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Studied area is located within the Kolska-Kaninska monocline (Southern Barents Sea) in the area perspective for oil and gas structures occurrence. During extensive 2-D and 3-D multy-channel seismic investigation three proposed places for drilling rigs have been identified. The target oil and gas bodies are located within the Permian reef trap at a depth of 1.1 to 1.2 sec.

On-site high resolution seismic profiling proves that the studied areas are characterized by extensive faults and cracks system. The main faults are represented as a tree-type structure that goes from the depth of the target oil body up to the surface. The faults' magnitudes range from 0 to 20-30 m. Within the upper part of the sediment sequence significant evidences of gas occurrence was obtained.

The main task of these investigations was to confirm the place for proposed drilling rig by means of Fe, Mn, Hg, gas and liquid Hydrocarbons water and sediment sample analysis in the near-bottom water and surface sediment samples.

The study of complex hydro-geochemical exploration was held according to the patent p-346204 "Complex geochemical way to identify anomalies of gaseous and liquid hydrocarbons, migrating from the deeper accumulations to the subsurface, as indicators of oil, gas, gas condensate bodies and natural environmental pollution'', which has been registered in the patent office in the Republic of Poland. The author is Tkachenko G.G. This method was tested on the shelves of the Baltic, Barents, Black and Azov Seas jointly with scientists of the VNIIOkeangeologia Institute (Russia). The main results of the analysis are as follows:

- pH, Hg anomalies in the sediment samples have been identified just above the reef trap. The shapes of these anomalies are in good correlation with the reef trap contour;
- liquid hydrocarbons anomaly in the bottom water is moved SW-ward from the reef trap. The character of this anomaly may prove an occurrence of oil-type hydrocarbons within the trap;
- temperature and oxygen anomaly in the water column is identified over the reef trap;
- maximums of the Hg, Fe, Mn, liquid hydrocarbons, methane and methane+ethylene sum in the sediments are controlled by the shape of the reef trap. The maximums of the anomalies are correlated with abundance of deep tree-type faults.

From the above evidences we could suggest the following:

1. Within the proposed for drilling reef traps we could expect an oil-type hydrocarbon occurrence;
2. An extensive tree-type fault systems are pathway for gas and liquids discharge;
3. Complex of the mentioned chemical and acoustic anomalies may be considered as methods of the identification of oil or gas type of the pool.

GAS HYDRATE STABILITY IN THE MEDITERRANEAN SEA OVER GLACIAL-INTERGLACIAL TIMESCALES: RESULTS FROM THE HYDRAMED PROJECT

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The potential gas hydrate system in the Mediterranean Sea is evaluated by determining the thickness and extent of the hydrate stability zone (HSZ), both at present and for conditions approximating glacial stages. The HSZ is calculated using gridded parameters for pressure (water depth) and temperature (bottom waters and geothermal gradients, the latter based on an updated compilation of c. 1200 marine sites), assuming a range of possible gas compositions and pore water salinities.

Results for the present-day show that, for pure methane in seawater (3.5% NaCl), the MHSZ is present throughout the Mediterranean Sea, at great depths (>1000 m) due to high overall bottom water temperatures, and in significant thicknesses (>200 m) only in the east due to lower geothermal gradients. Gas compositions including higher hydrocarbons increase hydrate stability, but the effects are small compared to decreases in stability due to higher pore water salinities, which render methane hydrate unstable throughout the Mediterranean Sea for salinities above 20%. Pore water salinities at DSDP/ODP sites vary from 3.5% to over 30%, so hydrates are inferred to be stable in much of the Mediterranean, but to be sensitive to locally elevated salinities.

Glacial conditions were simulated by uniformly lowering both sea level (-125 m) and bottom water temperatures, the latter assuming two possible models (-4°C and –8°C) for the last glacial maximum (LGM) in the Mediterranean. Either model shows that the MHSZ was significantly thicker (by up to 100%) and its upper limit shallower (by up to 600 m). The dramatic reduction in hydrate stability during the glacial to interglacial transition has implications for slope stability along basin margins and the functioning of cold seep systems above any hydrate reservoirs during glacial-interglacial cycles.

Comparing the results to the thickness of the Plio-Quaternary succession shows that the base of the MHSZ lies above the Messinian evaporitic succession over much of the Mediterranean (and did so at the LGM), except in a large area along the Mediterranean Ridge where the Plio-Quaternary succession is thin. In most other areas it should be possible to observe bottom simulating reflectors (BSRs) within the Plio-Quaternary succession, if gas hydrates are present. A number of areas of interest for prospective hydrate occurrence are identified (Fig.1), based on correlation of a thicker MHSZ (>100 m) with Plio-Quaternary depocentres (>1 km), basin margins where the Messinian salt seal is thin and areas of known seabed seepage. Areas of highest interest all lie in the eastern Mediterranean and include the Calabrian Arc, the subject of an OGS joint acquisition campaign in 2005 (Ceramicola et al. 2006), and the Nile Fan.

Acknowledgement:
The HYDRAMED project was funded from 2004-2006 by a Marie Curie Intra-European Fellowship held by D. Praeg within the European Community 6th Framework Programme (contract MEIF-CT-2003-501814).

MARIE CURIE **ACTIONS**

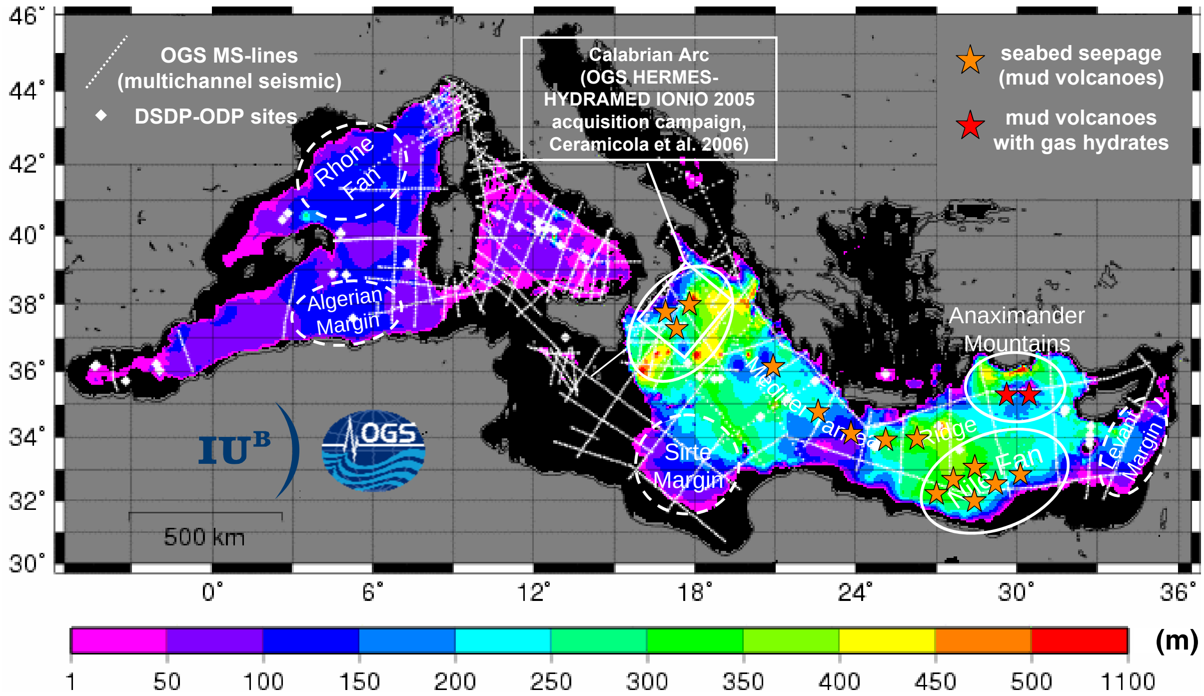

Figure 1. Hydrate stability zone for pure methane in seawater (3.5% NaCl), showing identified areas of interest for further investigations of hydrate occurrence.

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GEOCHEMICAL EVALUATION OF PORE FLUIDS OF COLD SEEPS OFFSHORE GEORGIA, EASTERN BLACK SEA

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Different cold seep sites, offshore Georgia, eastern Black Sea, containing subsurface gas hydrates, authigenic calcium carbonate, and at some locations oil, were analyzed with respect to their pore fluid geochemical and isotopic composition to unscramble the origin of the escaping gas and fluids. At all seep sites anaerobic oxidation of methane (AOM) is taking place at shallow sediment depth. Even though, the production of methane gas is obvious at all sites, there is only one site, Pechori Mound, that shows evidence for significant ascent of pore fluids from deeper sediment levels. The combination of pore fluid concentrations and isotopic ratios (i.e. $\delta^{18}O$, $\delta^{37}Cl$, $^{87}Sr/^{86}Sr$) indicate deep fluids that experienced smectite-illite transformation at temperatures >60 ˚C. Variations of Sr concentrations and isotopic composition seem to be mainly affected by the formation of authigenic carbonate precipitation in the subsurface sediments.

CHEMOSYNTHETIC-BASED COMMUNITIES IN GULF OF CADIZ: TROPHIC RELATIONSHIPS AND PROKARYOTIC ENDOSYMBIONTS

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In some environments microbial chemoautotrophic primary production can replace photosynthesis as the dominant source of energy production. The high production of organic carbon sustains high biomasses and typical macro-invertebrates that host chemosynthetic endosymbionts. Symbiotic associations with thiotrophic (sulfur-oxidizing) and methanotrophic (methane-oxidizing) bacteria occur in a wide array of animal species that live in reducing environments with high sulfide and methane concentrations. Stable isotope techniques have been an essential tool for the research on the energetic basis of chemosynthetic communities: they are used to examine trophic relationships between organisms and to establish the dependence of species on chemosynthetically produced organic material, via thiotrophy or methanotrophy.

Several chemosynthetic species have been discovered recently in the mud volcanoes from Gulf of Cadiz. These include the widespread siboglinid polychaetes of the genus *Siboglinum* and solemyid bivalves (*Acharax* sp.) but also other genus of siboglinids and lucinid (*Lucinoma* sp.), thyasirid (*Thyasira* sp.) and mytilid (*Bathymodiolus* sp.) bivalves.

Stable isotope analyses ($\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$) were carried out aiming to determine trophic relationships between some species collected during the last TTR's from several mud volcanoes. The $\delta^{13}C$ ratio suggests dual symbiosis in *Siboglinum* spp, presence of methanotrophic bacteria in *Bathymodiolus* sp and sulfur-oxidizing bacteria in *Acharax* sp., *Lucinoma* sp. and *Thyasira* sp. The values for the solemyid, lucinid and thyasirid bivalves are in line with data for other bivalves known to host thiotrophic symbionts that use CO_2 as their carbon source and do not reflect the isotopic value of the source methane. On the other hand, species such as *Bathymodiolus* sp. is expected to reflect the isotopic value of the source methane because they probably host methane-oxidizing symbionts incorporating methane carbon with little expression of isotopic fractionation.

Furthermore the molecular identification of chemosynthetic prokaryotic endosymbionts associated with *Acharax* sp. and *Lucinoma* sp. bivalves collected from Mercator mud volcano, during TTR15 was carried out using PCR-DGGE analysis of bacterial 16S rRNA genes. Bacteria were detected in the gills of both species and preliminary results suggest that these bivalves contain a diverse range of prokaryotic endosymbionts, including sulphur-oxidizing related bacteria. Further investigation will be carried out to evaluate the full diversity of endosymbiotic prokaryotes and their role in the nutrition of several bivalve species.

MICROBIAL COMMUNITIES INVOLVED IN ANAEROBIC METHANE OXIDATION IN MUD VOLCANOES FROM THE GULF OF CADIZ

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Microbial communities involved in methane anaerobic oxidation in mud volcanoes of the Gulf of Cadiz were characterized by lipid biomarker analyses by gas chromatography. Mud volcanoes sediment samples were collected during the cruise TTR-15/Leg 4 (July-August 2005) of the R/V *Professor Logachev*. In the deeper mud volcanoes, Porto and Semenovich (depth 3878 m and 3242 m), the archaeal lipids archaeol and sn-2-hydroxyarchaeol ranged from traces to 0.06 and to 0.03 µg g-dw^{-1}, respectively. The bacterial lipids i-$C_{15:0}$ and ai-$C_{15:0}$ varied between 0 and 0.03, and between 0 and 0.05 µg g-dw^{-1}, respectively. A peak of archaeal and bacterial lipids was observed between the depth of 75 and 145 cm, where the methane concentration increased from traces to 0.8 mM. At this horizon, the ratios between archaeol and sn-2-hydroxyarchaeol and between ai-$C_{15:0}$ and i-$C_{15:0}$ were respectively, 10 and 4 in the Porto MV, and 2 in the Semenovich MV. In the shallower mud volcano, Meknés (depth 705 m), the concentration of lipid biomarkers decreased with sediment depth. The archaeol and sn-2-hydroxyarchaeol ranged from traces to 0.08 and 0.04 µg g-dw^{-1}, respectively. The i-$C_{15:0}$ and ai-$C_{15:0}$ varied, respectively, between 0 and 0.02, and between 0 and 0.03 µg g-dw^{-1}. Methane (0-0.25 mM) arising from deeper layers was completed exhausted at the uppermost 20 cm layer of the sediment. The vertical correspondence between methane depletion and maxima of lipid biomarkers indicated the presence of methanotrophic communities. The relative higher amounts of archaeol compared with sn-2-hydroxyarcheol and the relative higher amounts of bacterial ai-$C_{15:0}$ compared with i-$C_{15:0}$ suggested the dominance of anaerobic methanotrophs-1 (ANME-1) communities in the three mud volcanoes investigated.

DISTRIBUTION AND ACTIVITY OF PROKARYOTE COMMUNITIES IN THE SEDIMENTS OF THE MUD VOLCANO PORTO (GULF OF CADIZ)

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Prokaryote communities from the mud volcano Porto were characterized in terms of abundance, living biomass, ectoenzymatic activities and rates of monomers incorporation. The enumeration of viruses was also attempted. Sediment samples were collected by gravity coring during the TTR-16 cruise to the Gulf of Cadiz, 2006. Total prokaryote number was determined by epifluorescence microscopy after staining with acridine orange (Hobbie, 1997) and living microbial biomass was estimated from the ATP concentrations determined by the luciferine-luciferase method (Karl, Craven, 1980). Viruses were counted under epifluorescence microscopy after staining with SYBR Gold (Fischer et al., 2005). Potential rates of ectoenzymatic activities involved in the degradation of polymeric sub-

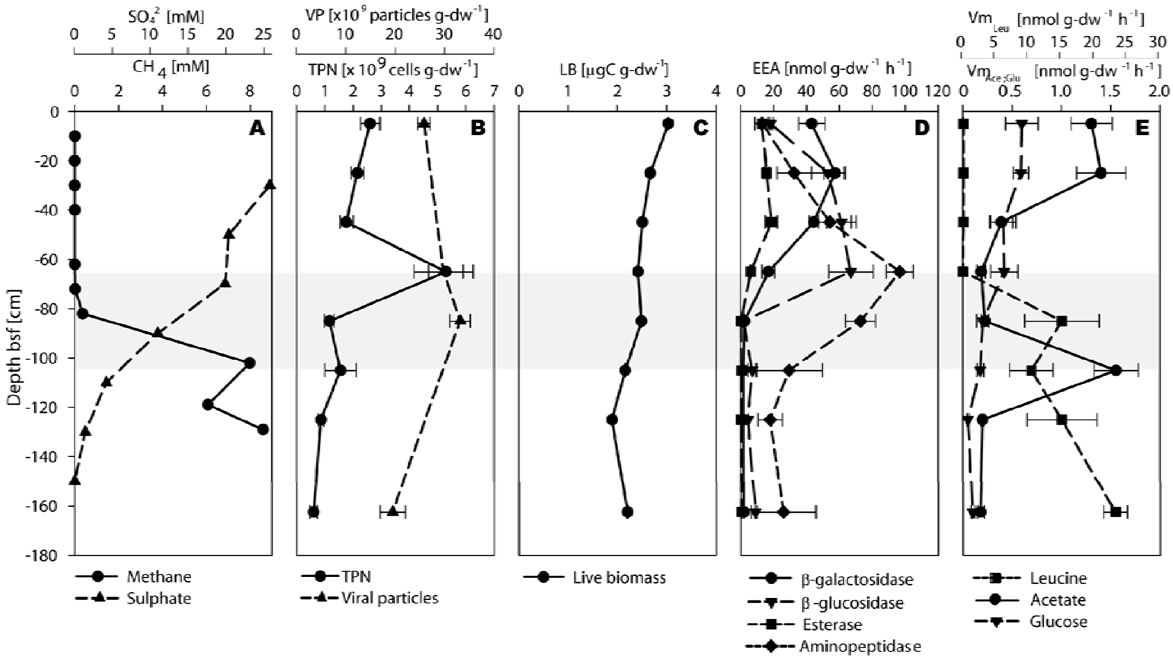

Figure 1. Vertical profiles of methane and sulphate concentrations (A), prokaryote (TPN) and viral (VP) abundances (B), live biomass (LB) concentration (C), ectoenzymatic activity (EEA) (D) and monomers incorporation (Vm) (E) in the sediments of the Porto mud volcano.

strates were analysed in sediment slurries as the maximum hydrolysis rates of model substrates (Boetius et al., 2000). The heterotrophic metabolism of glucose, leucine and acetate was described by the maximum rates of uptake of ^{14}C-labbeled substrates (Gocke, 1977). The profiles of geochemical variation showed a clear and distinct sulphate-methane transition zone (SMTZ) between the 65 and 105 cm depth (Fig.1A). At this zone, methane concentration increased from <0.01 to 7.98 mM and sulphate concentration decreased from 19.8 to 4.16 mM. Prokaryote (0.60-5.30 x 10^9 cells g-dw^{-1}) and viral (19.4-33.1 x 10^9 particles g-dw^{-1}) abundances peaked at the SMTZ and decreased just above and below of this horizon (Fig.1B). The living microbial biomass concentration ranged from 1.89 (125 cm) to 3.03 µgC g-dw^{-1} (surface), showing a slight peak at the SMZT (Fig.1C). The potential rates of β-glucosidase and aminopeptidase activities peaked at beginning of the SMTZ, varying between 1.65 and 67.0 nmol g-dw^{-1} h^{-1} and between 13.3 and 96.7 nmol g-dw^{-1} h^{-1}, respectively (Fig.1D). The highest rates of β-galactosidase activity (57.4 nmol g-dw^{-1} h^{-1}) were observed at 20 cm depth, decreasing with depth below this horizon to the minimum value (1.67 nmol g-dw^{-1} h^{-1}). The lowest rate of ectoenzymatic activity was observed for the enzyme esterase, ranging from 0.36 (125 cm depth) to 18.6 nmol g-dw^{-1} h^{-1} (45 cm depth). The rate of leucine incorporation was below <0.10 nmol g-dw^{-1} h^{-1} in the first 65 cm horizon, increasing downwards to 23.2 nmol g-dw^{-1} h^{-1} and peaking at the SMTZ (Fig.1E). Glucose was more rapidly incorporated by the surface communities (0.60 nmol g-dw^{-1} h^{-1}) and the rates decreased with depth. The profiles of acetate incorporation showed two peaks at 25 and 105 cm depth, with the maximum values observed at the deepest. The prokaryote communities of the Porto MV are influenced by the geochemical characteristics of the sediments, describing vertical profiles of distribution and activity characterized by increases at the SMTZ. The increase of abundance, β-glucosidase and aminopeptidase activity as well the rates of incorporation of leucine and acetate at this specific zone, could be relate to the presence of consortia of anaerobic methane oxidizers and SRB communities. Further studies, using *fluorescent in situ hybridization* (FISH), will be carried out in order to investigate the structure of the microbial communities and to evaluate the presence of communities involved in anaerobic methane oxidation.

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DISTRIBUTION OF INTACT POLAR LIPIDS IN THE BLACK SEA WATER COLUMN

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The restricted water circulation in the Black Sea results in a stratified water column with a distinct vertical succession of redox zones. Our study provides insight into the associated changes of microbial community structure over a water depth range of 2000 m, from the sea surface to surface sediments. Samples from the water column and surface sediment were analyzed by HPLC-ESI-MS^n for their intact polar lipid (IPL) composition. IPLs are taxonomically specific biomarkers and representative of the active members of the microbial community (Sturt et al., 2004, Biddle et al. 2006). The IPL patterns change markedly over depth, thus mirroring the community shifts coupled to the stratified water column.

The top 10-70 m (oxic zone) are dominated by lipids typically found in photosynthetic algae and cyanobacteria, i.e., in order of relative abundance: betaine lipids, phosphatidylglycerol (PG), phosphatidylcholine (PC), monoglycosyldiacylglycerol (MGDG), diglycosyldiacylglycerol (DGDG), and sulfoquinovosyldiacylglycerol (SQDG). Near the chemocline, archaeal monoglycosyl glycerol-dialkylglyceroltetraethers (monoglycosyl-GDGT), and diglycosyl glyceroldialkylglyceroltetraethers (diglycosyl-GDGT) are found. Diglycosyl-GDGT, a compound previously described for sedimentary archaea, is restricted to a small horizon between 77-115 m.

Overall, suboxic and anoxic waters are clearly dominated by bacterial lipids, even at the chemocline with maximum abundance of archaeal IPLs, they comprise more than 90% of the overall IPL composition. Among the most prominent bacterial IPLs are phosphatidylethanolamine (PE) and phosphatidylmonomethylethanolamine (PMME) with both ester and mixed ester/ether-bound alkyl chains, and PG. PE, PMME, and PG are found in members of the bacterial order ε-proteobacteria and δ-proteobacteria, e.g., sulfate reducing bacteria. These bacteria were independently identified with specific FISH probes in the respective depth horizons (Lin et al., 2006). IPL analysis adds a new layer of information to previously available molecular data (e.g., Vetriani et al., 2003). In particular, the technique provides alternative information on the relative abundance of biomass from major groups of microorganisms. Additional IPL-specific isotopic data will provide further insights into the patterns of carbon flow in water column communities in the Black Sea.

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APPLICATION OF LIPID BIOMARKERS TO DETECT SOURCES OF ORGANIC MATTER IN MUD VOLCANO DEPOSITS AND POST-ERUPTIONAL METHANOTROPHIC PROCESSES IN THE GULF OF CADIZ, NE ATLANTIC

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The Gulf of Cadiz is known as an active mud volcano (MV) and fluid venting region discovered during the Training Through Research (TTR) expeditions in 1999 (TTR-9). Here we report a study of lipid biomarkers which was for the first time performed for MV deposits collected from three MVs, the Bonjardim, Ginsburg and Jesus Baraza, from the Gulf of Cadiz.

The lipid biomarker composition revealed strong compositional resemblance as well as similar thermal maturity properties for the studied MVs. This indicates that the primary source of the erupted material for these MVs is located in similar litho-stratigraphic units. In both areas, upward migrated fluid went through the sedimentary series of the allochthonous Olistrostrome and through the Upper Cretaceous horizons.

The relatively immature characteristics of organic matter from both mud breccia rock clasts and matrix together with the more mature properties of hydrocarbon gases from the same sampling locations indicate that source strata of the primary fluid are located deeper than the source strata of the organic matter from the erupted sedimentary material.

The presence of microbial lipid biomarkers derived from archaea and sulfate reducing bacteria in the mud breccias revealed anaerobic oxidation of methane (AOM) as a dominant microbial process in these habitats. The low concentrations of AOM-related biomarkers in these MVs suggest relatively low intensities of AOM in the studied MV deposits. The distribution of biomarkers suggests an abrupt and brief cold seep activity in the past and the absence of a continuous methane influx in the studied locations.

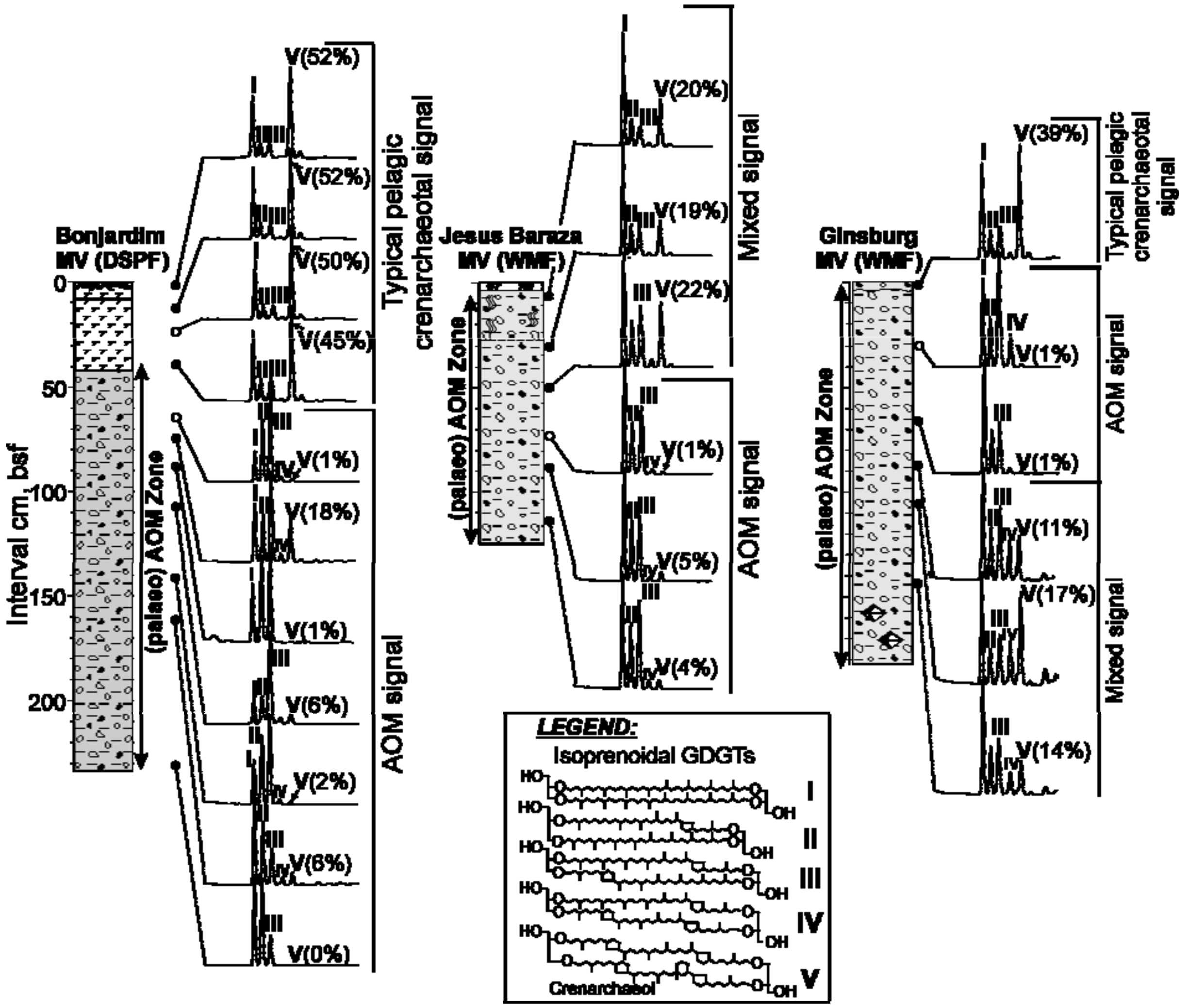

Figure 1. Base peak HPLC chromatograms of the polar fractions from mud breccia matrixes showing compositional variations among the glycerol dibiphytanyl glycerol tetraethers (GDGTs) along the sedimentary successions. Circles indicate subsampling interval. White circles specify samples, which were selected to cleave ethers in GDGTs through the HI-treatment. Roman numbers refer to structures in the legend. Percentage values in parentheses next to "V" denote the content of crenarchaeol from the total identified GDGTs.

COLD WATER CORALS AND ASSOCIATED BIOTA OF THE PEN DUICK ESCARMENT (GULF OF CADIZ)

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Statistical evaluation of the presence and distribution of cold water corals and associated biota of the Pen Duick Escarpment (Gulf of Cadiz) was carried out within the framework of the Euromargins programme Moundforce. The aim of the present study is to show the distribution of living and dead cold water corals and other biota on the Pen Duick Escarpment on the Moroccan margin of the Gulf of Cadiz. The Pen Duick Escarpment is located at about 50 km offshore the Moroccan coast. It corresponds to a fault scarp of about 4.5 km long, 100 m high (Van Rensbergen et al, 2003). Carbonate mounds characterised by the presence of cold water corals present in this area are much smaller in size (about 50 m high) and consist mainly of fine grained sediment (De Haas et al, 2006).

Eight video lines recorded by a hopper camera (stations: 1, 6, 7, 9, 11, 18, 26, 27) along transects across the Pen Duick Escarpment were recorded during cruise M2005 with R/V *Pelagia* Leg 1 in the Pen Duick Escarpment area (Fig. 1). These were subjected to a description and statistical study.

Dead and living cold water corals were determined, counted and presented as a percentage of the abundance of living and dead colonies, with an approximation of the size of these colonies, using the diameter of the trigger weight hanging, on a rope on the hopper camera, in each station. In addition the sessile and mobile megafauna were counted. Other features like biological features and sedimentary structures were noted. On the basis of these statistical analysis, several maps were constructed which present the data.

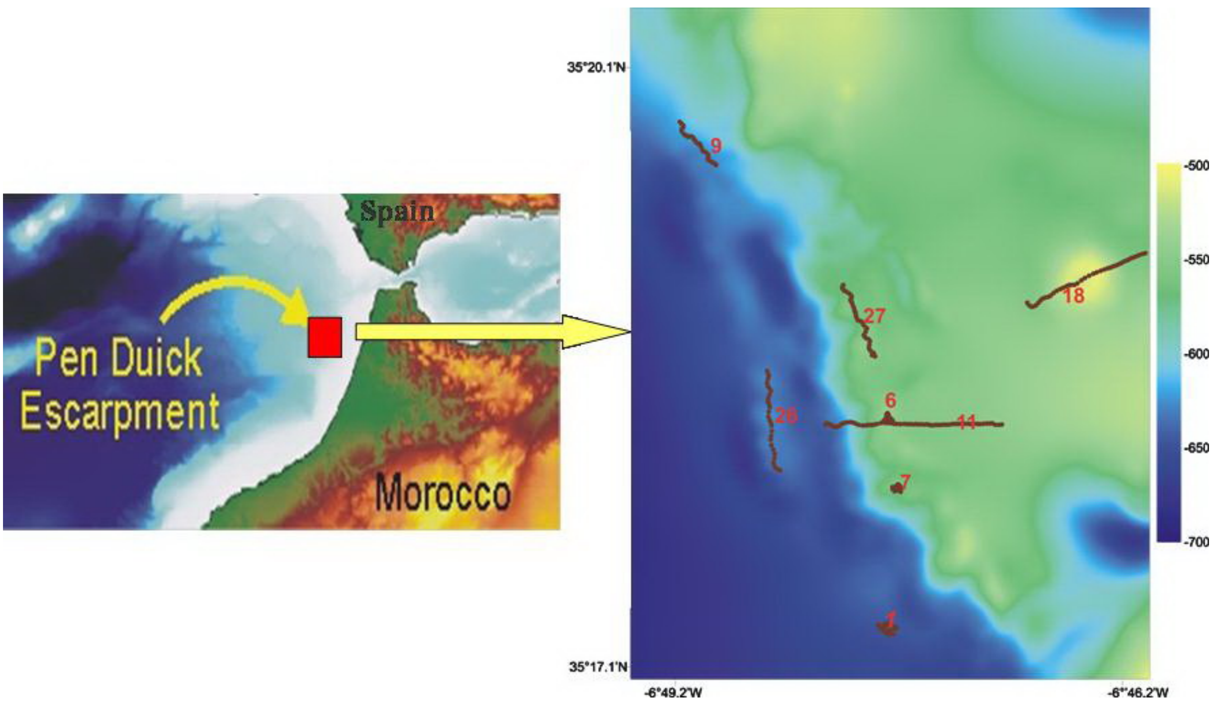

Figure 1. Study area with stations map

To the west of the Pen Duick Escarpment, showed the presence of a medium community of corals with high percentage of living ones, and the number of living corals increases with the occurrence of a hard substrate in the northern zone, which prove that most of the corals are more adapting to the hard ground, including carbonate crust.

The summits of the mounds at the eastern part of the Pen Duick Escarpment are covered by a high percentage of living corals, except for the summit of the eastern mud volcano where a high percentage of dead corals is present.

The mobile megafauna existing in the study area includes tube worms, red fish, shrimp, starfish, crab, molluscs and sea urchins.

Furthermore, some species of corals as Isidella grow in the soft sediment, which shows that the nature of the substrate influence the type species of living corals present.

However the size of the living corals in the Pen Duick Escarpment is relatively small and varies between less than 7 cm to 14 cm. Only rarely larger colonies occur, which can indicate that it is a new generation which starts to adapt to this area.

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EXTERNALLY DRIVEN EARLY CEMENTATION OF CARBONATE MOUNDS ON THE SW ROCKALL BANK

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Carbonate mound provinces form an extended belt along the continental European margin. One of the most intensively studied sites is the Rockall Bank west of Ireland, where several mound provinces occur in water depths between 550 and 1200 m. Base diameters of single mounds can be up to 2 km and elevations up to 350m above the surrounding seafloor. Thickets of living cold-water corals species Lophelia pertusa and Madrepora oculata overgrow the investigated exposed mounds and many others.

Carbonate lithification is an essential mechanism in mound evolution as they provide a stable colonization substratum for mound-building invertebrates to attach to and stabilize the steeply inclined mound flanks in this high bottom current environment.

This contribution describes on-going research into several on-mound cores from the SW Rockall Bank area. Based on absolute datings (U/Th) and stable oxygen isotope records the stratigraphic record reveals semi-continuous sedimentation for at least the last ~20.000 years. Prior to this period numerous hiatuses can be observed, indicating several erosional events. These hiatuses are represented in the sediment record by lithified and well cemented sediments, indicating they have undergone a different type of- or enhanced diagenesis in comparison to the surrounding sediments. These cemented intervals have been investigated by means of cathode luminescence, SEM, microprobe investigations and thinsection petrography. The early lithification of the carbonates can be explained by an enhanced carbonate ion transfer into the sediments. The driving mechanism is most likely a diffusion process maintained by a saturation gradient between seawater and interstitial water. Strong bottom currents enhance the carbonate ion diffusion from seawater through the surface sediments, thus maintaining a pumping mechanism.

These results clearly point towards external environmentally driven processes to control the evolution of the carbonate mounds.

A PRELIMINARY EVALUATION OF THE SEISMIC EVIDENCE FOR THE PRESENCE OF METHANE HYDRATE AND FREE GAS IN AND AROUND FLUID-ESCAPE CHIMNEYS IN THE NYEGGA REGION OF THE VØRING PLATEAU, NORWAY: RESULTS FROM TTR CRUISE 16, LEG 3

Westbrook, G. K.*, Exley, R. J., Jose, T., Minshull, T. A., Nouzé, H., Plaza, A., Schofield, N. and the scientific party of TTR Cruise 16, Leg 3.
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As part of work packages WP3 and WP4 of HERMES to study gas-fluid seeps, their anoxic environments and their biological communities, the R/V *Professor Logachev*, during Training Through Research Cruise 16 Leg 3 (8 June to 2 July, 2006), conducted two high-resolution seismic experiments employing 4-component OBS (Ocean-Bottom Seismic recorders) to investigate the 3D structure of fluid-escape chimneys beneath the actively seeping G11 and CN03 pockmarks. The chimneys in the Nyegga region of the Norwegian continental margin, may be representative of a class of feature of global importance for the escape of gas from beneath continental margins and for the provision of a habitat for the communities of chemosynthetic biota that are dependent, directly or indirectly, on the methane that flows through them. Seismic profiles were made with 13/35 mini GI gun and two 24/24 mini-GI guns, in the course of shooting into the two arrays of OBS and these were supplemented by MAK deep-tow 5 kHz profiles.

Many chimneys, such as those associated with the CN03 pockmark and Tobic (Fig.1), show pull-up of the reflectors at the margins of the chimneys. Much of this has been produced by deformation related to the formation of the chimneys, but many show a differential pull-up in which the amount of pull-up increases with depth, consistent with presence of higher velocity material in the margins of the chimney than in the surrounding strata. If this is so, the material could be hydrate or authigenic carbonate. Chimneys, such as those associated with the CN03 pockmark and Tobic, show seismic scattering and attenuation, which is characteristic of both the presence of gas and of heterogeneity that could be caused by discrete concentrations hydrate. A chimney near Tobic, however, displays a bright negative polarity reflector that pinches out away from the chimney and which may be caused by the invasion of free gas.

There are several reflectors deeper than about 250 m below the seabed that, from their high amplitude and negative polarity, appear to be gas-charged. One prominent group of these reflectors lies beneath the area of the G11 pockmark at a travel time of ~1.4 s. Where they pass beneath the slope at the edge of the Storegga slide, they are intersected by the base of the gas hydrate stability field, and lose their high amplitude where they pass through it, producing a form of BSR that is common in this region. Beneath this group of bright reflectors, other reflectors show strong attenuation and increases in inter-reflector travel times, indicating a thick zone in which free gas exists. These reflectors all lie below the

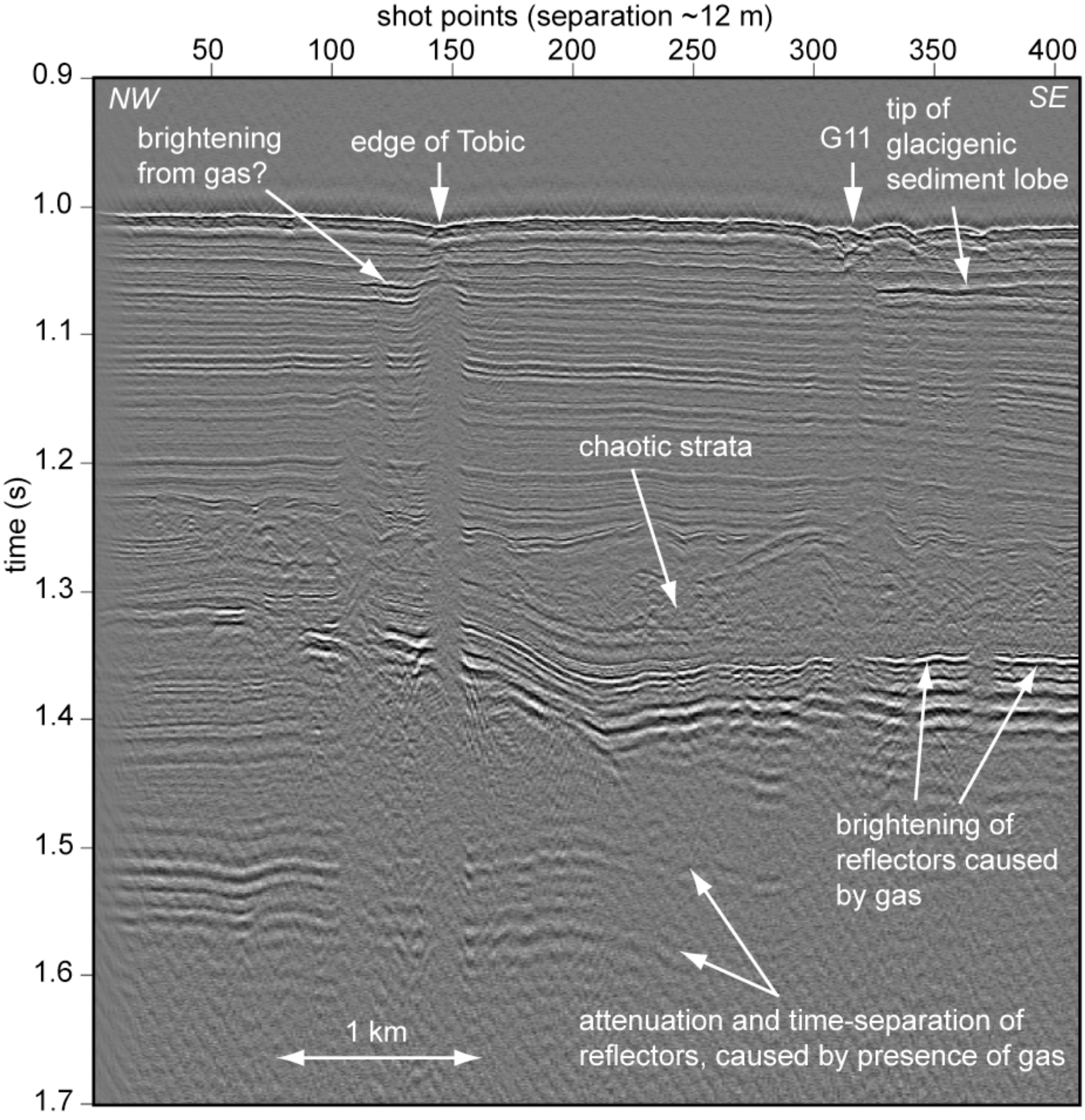

Figure 1. Part of seismic reflection section crossing pockmark G11 and the southern edge of the Tobic complex pockmark. Beneath the edge of the moat surrounding the mounded interior of the pockmark, which is out of the plane of the section, lies a chimney with a 150-m-wide reflection-free core. The strata at the edge of the chimney are bowed upward slightly. To the left of the chimney are images of two smaller chimneys that do not reach the seabed in the plane of section. The presence of free gas brightens reflectors between 1.3 and 1.4 s and causes the lowering of frequency and reduction in amplitude of reflectors beneath >1.5 s. The chimney cuts through both these groups of reflectors. In the left flank of the chimney at ~1.05 s, the local brightening and negative polarity of a reflector may be caused by shallow free gas. (The section, shot with 2 mini GI-guns of 24/24 cu. in. capacity, has a trace spacing of ~12 m and has been migrated at water velocity.)

hydrate stability field, but the indications of gas shallow depths in the chimneys are at temperature and pressure conditions that are normally within the hydrate stability field, and so some extra factor is required to prevent the gas forming hydrate, such as insufficient pore water locally to turn all the gas to hydrate, locally high salinity or a narrow plume of warm water in which the gas can migrate or be carried to the seabed.

TECTONIC AND GRAVITATIONALLY INDUCED DEFORMATION IN THE ACCRETIONARY WEDGE OF THE GULF OF CADIZ

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Interpretation of a compilation of multibeam bathymetric data acquired from several different sources, including the Cadisar, Cadisar2, TV-GIB, Delila, DelSis and GAP cruises, and of seismic reflection data acquired by the Delsis and SISMAR cruises has revealed a variety of tectonic and gravitationally induced structures in the accretionary wedge of the Gulf of Cadiz. While the western and southern, and to a lesser degree the northern, margins of the wedge display compressional structures, the eastern and central parts of the wedge exhibit evidence of extension that is, presumably, a consequence of gravitational spreading.

The structures of the western and southern boundaries of the accretionary wedge are typically outward-vergent folds and thrusts. Along the western boundary, where the top third of a 3-4 km-thick sequence of sediments is accreted, the thrusts do not cut through the uppermost 300-m-thick layer of sediment, which is gently folded. A chaotic unit, previously identified as an olistostrome of Tortonian age is a layer 200-300 m thick beneath the abyssal plain. It is thickened by folding and thrusting within the accretionary wedge, but is only part of the material that forms the wedge rather than being its principal component. Along the southern boundary the outermost structures are covered by the sediments of the Rharb submarine valley, but, further north, compressional structures are currently active. The rapid deposition of the thick valley fill, appears to have halted the southward advance of this edge of the wedge, and deformation has progressed by thickening and steepening of the slope.

Diapirs of Triassic salt have been incorporated into the southern part of the wedge. In the shallow part of the wedge, near its toe, they form homogeneous relatively competent units. Deeper and more landward their structure is more obscure, but may play a role in the gravitational spreading of the thicker more eastern parts of the wedge that is manifested as a network of large-scale tensional ‘cracks’ (faults) similar to those developed above outer part of the Mississippi fan, which is dominated by halokinesis. Gravitational spreading moves material outward in two lobes that extend westward from the upper, thicker part of the wedge.

Mud volcanoes are prevalent in the wedge and are, in part, controlled in their distribution by the shape of the top of the crystalline basement beneath the wedge. The Bonjardim mud volcano, lying about 50 km east of the toe of the wedged, has it source in the deepest part of the wedge beneath it, or possibly in the sediments underneath, and it may be part of the system that allows these sediments to dewater beneath the load of the wedge.

ANNEX I

CONFERENCE PROGRAMME

Sunday, 28 January

19:00	**Icebreaker** Geo Building (first floor) at University Bremen, Klagenfurter Strasse

Monday, 29 January: Seminar Room of the MARUM Building (Leobener Strasse)

10:00 – 10:20	**Welcome and opening remarks**
10:20 – 10:40	Mazzini, A., Ivanov, M., Svensen, H., Westbrook, G.K., Planke, S: *Gas hydrates and hydrocarbon-rich fluid seepage in the Vøring-Storegga region (Norwegian Sea): sampling and sea floor observations*
10:40 – 11:00	van der Land, C., Mienis, F., de Haas, H., de Stigter, H., van Weering, T., van Breukelen, M., Vonhof, H., Davies, G.: *Externally driven early cementation of carbonate mounds on the SW Rockall Bank*
11:00 – 11:20	Laberg, J.S., Vorren, T.O., Ivanov, M., Kenyon, N.H.: *Holocene sandy turbidity currents in the Norwegian Sea*
11:20 – 11:40	Kolganova, Y., Blinova, V., Ivanov, M.: *Methane-related authigenic carbonates of the Pen Duick Escarpment*
11:40 – 12:00	Santos, L., Almeida, A., Boetius, A., Cunha, A., Niemann, H., Magalhaes, V., Pinheiro, L.M.: *Microbial communities involved in anaerobic methane oxidation in mud volcanoes from the Gulf of Cadiz*
12:00 – 12:20	Stadnitskaia, A., Ivanov, M., Sinninghe Damsté, J.S.: *Application of lipid biomarkers to detect sources of organic matter in mud volcano deposits and post-eruptional methanotrophic processes in the Gulf of Cadiz, NE Atlantic*
12:20 – 12:40	de Haas, H., de Stigter, H., Epping, E., Kuzub, N., Mienis, F., Richter, T., Starkov, K., Tokarev, M., van der Land, C., van Weering, T., Verhagen, I.: *Carbonate mounds, cold water corals and seepage processes in the Gulf of Cadiz; Moundforce and Microsystems Progress*
12:40 – 13:00	Blinova, V., Mazurenko, L., Ivanov, M.: *Pore water composition and authigenic carbonate precipitation at the mud volcanoes from the Gulf of Cadiz (preliminary results of the TTR-16 cruise)*
13:00 – 14:00	**Lunch**
14:00 – 14:30	De Lange, G.: *Mud flow eruption frequencies and gas composition in sediments of the Eastern Mediterranean – an Overview*
14:30 – 14:50	Magalhaes, V.H., Pinheiro, L.M., Birgel, D., Peckmann, J., Niemann, H., Santos, L., Vasconcelos, C., McKenzie, J.A., Ivanov, M.: *Microbially-mediated formation of methane derived carbonates from the Gulf of Cadiz*

14:50 – 15:10	Malyk, J., Stadtnitskaia, A., Ivanov, M., van Weering, T.C.E., Sinninghe Damsté, J.S.: *Lipid biomarker composition in mud breccias from the Captain Aruntunov and Gemini mud volcanoes in comparison with sediments from the Pen Duick Escarpment*
15:10 – 15:30	Hilário, A., Johnson, S., Cunha, M.R.: *Worm galore in the Gulf of Cadiz*
15:30 – 15:50	Rodriques, C.F., Webster, G., Blinova, V., Weightman, A.J., Cunha, M.R.: *Chemosynthetic-based communities in Gulf of Cadiz: trophic relationships and prokaryotic endosymbionts*
16:00 – 16:30	**Coffee break**
16:30 – 16:50	Terhzaz, L., van Weering, T., de Haas, H., Mienis, F., Hamoumi, N.: *Cold water corals and associated biota of the Pen Duick Escarpment (Gulf of Cadiz)*
16:50 – 17:10	Westbrook, G.K., Exley, R.J., Jose, T., Minshull, T.A., Nouzé, H., Plaza, A., Schofield, N. and Scientific Party TTR Cruise 16, Leg 3: *A preliminary evaluation of the seismic evidence for the presence of methane hydrate and free gas in and around fluid-escape chimneys in the Nyegga region of the Vøring Plateau, Norway: results from TTR Cruise 16, Leg 3.*

Tuesday, 30 January: Seminar Room of the MARUM Building (Leobener Strasse)

09:00 – 09:30	Westbrook, G.K., Gutscher, M.-A.: *Tectonic and gravitationally induced deformation in the accretionary wedge of the Gulf of Cadiz*
09:30 – 09:50	Akhmetzhanov, A., Wynn, R.B., Talling, P.J., Kenyon, N., Ivanov, M., Dennielou, B.: *Depositional processes on the distal Rhone Neofan: preliminary results of Leg 2 of cruise TTR-16*
09:50 – 10:10	Ceramicola, S., Praeg, D., Unnithan, V., Wardell, N., Freiwald, A.: *Exploring Mud Volcanoes on the Calabrian Arc, central Mediterranean Sea*
10:10 – 10:40	Henriet, J.-P. *Building a GBCP Lab through TTR spirit, brick by brick: the first five years*
10:40 – 11:00	Bohrmann G. and M70/ 3 shipboard scientific party: *New results from Amsterdam mud volcano (Anaximander mountains*)
11:00 - 11:30	**Coffee break**
11:30 – 11:50	Nikolovska, A.: *Hydro-acoustical Survey of Methane Plumes in the Anaximander Mountains, Eastern Mediterranean Sea*
11:50 – 12:20	Hovland, M.: *Hydrothermal salt - what is it?*
12:20 – 12:40	Hamoumi, N.: *Upper Ordovician cold water carbonate mounds and associated deposits of eastern Anti-Atlas (Morocco): facies, depositional models and control*
12:40 – 13:00	Hebbeln, D. and Wienberg C.*:* *Cold-water corals in the Gulf of Cadiz – spatial and temporal distributions and their forcing factors*

13:00 – 14:00	**Lunch**
15:00 – 17:00	Guided tour (City Hall, Market Square and Schnoor)

Wednesday, 31 January: Seminar Room of the MARUM Building (Leobener Strasse)

09:00 – 09:30	Peckmann, J.: *Methane-seep microbialites – examples from the Black Sea*
09:30 – 09:50	Bahr, A., Pape, T., Bohrmann, G., Mazzini, A. Ivanov, M.: *Formation mechanism of methane seep-related carbonate precipitates from the Dolgovskoy Mound, Shatsky Ridge, North-Eastern Black Sea*
09:50 – 10:10	Pape T., Blumenberg M., Seifert R., Nauhaus K., Reitner J., Widdel F., Michaelis W., Bahr A., and Bohrmann G.: *Biogeochemical aspects of methane-related microbial mats and carbonate crusts from the northern Black Sea*
10:10 – 10:30	Kozlova, E., Ivanov, M., Bohrmann, G.: *Free Oil Hydrocarbons in the Maikopian Clay from the Petroleum Mud Volcano (the Tuapse Trough, the Black Sea)*
10:30 – 10:50	Wagner-Friedrichs, M.: *Seafloor seepage in the Black Sea: Mud volcanoes in the Sorokin Trough and gas seeps off Georgia*
11:00 - 11:30	**Coffee break**
11:30 – 11:50	Reitz, A., Haeckel, M, Aloisi G., Liebetrau V., Wallmann, K.: *Geochemical evaluation of pore fluids of cold seeps offshore Georgia, eastern Black Sea*
11:50 – 12:10	Nadezhkin, D.; Ablya, E., Ivanov, M.; Bohrmann, G.: *Geochemical characteristics of oils from seeps in the Eastern part of the Black Sea*
12:10 – 12:30	Schubotz, F.: *Distribution of intact polar lipids in the Black Sea water column*
12:30 – 12:50	Mohr T., Sylva S., Seewald J., Kai-Uwe Hinrichs: *Adsorption of gaseous hydrocarbons to marine sediments*
12:50 – 13:10	Klapp, S.: *Mineralogical Investigations of Gas Hydrates sampled Continental Margins*
13:10 – 14:00	**Lunch**
14:00 – 15:00	TTR Executive Committee Meeting
14:00 – 16:00	Poster Session
15:30 – 16:00	**Coffee break**
16:15 – 17:15	RCOM seminar: Neil Kenyon (Southampton Oceanography Centre): *Mobile sands at offshore wind and tidal farms*
17:15 – 17:45	**Closing Session**

Thursday, 1 February

Day trip to Bremerhaven

10:00 – 12:30	Visit to the Alfred-Wegener-Institute for Polar and Marine Sciences
14:00 – 16:00	Visit to the German Maritime Museum

ANNEX II

LIST OF PARTICIPANTS

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2	CICAR Ichthyoplankton Workshop, Mexico City, 16-27 July 1974 (UNESCO Technical Paper in Marine Sciences, No. 20).	E (out of stock) S (out of stock)
3	Report of the IOC/GFCM/ICSEM International Workshop on Marine Pollution in the Mediterranean; Monte Carlo, 9-14 September 1974.	E,F E (out of stock)
4	Report of the Workshop on the Phenomenon known as 'El Niño'; Guayaquil, Ecuador, 4-12 December 1974.	E (out of stock) S (out of stock)
5	IDOE International Workshop on Marine Geology and Geophysics of the Caribbean Region and its Resources; Kingston, Jamaica, 17-22 February 1975	E (out of stock) S
6	Report of the CCOP/SOPAC-IOC IDOE International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific; Suva, Fiji, 1-6 September 1975.	E
7	Report of the Scientific Workshop to Initiate Planning for a Co-operative Investigation in the North and Central Western Indian Ocean, organized within the IDOE under the sponsorship of IOC/FAO (IOFC)/UNESCO/ EAC; Nairobi, Kenya, 25 March-2 April 1976.	E, F,S, R
8	Joint IOC/FAO (IPFC)/UNEP International Workshop on Marine Pollution in East Asian Waters; Penang, 7-13 April 1976	E (out of stock)
9	IOC/CMG/SCOR Second International Workshop on Marine Geoscience; Mauritius 9-13 August 1976.	E, F, S, R
10	IOC/WMO Second Workshop on Marine Pollution (Petroleum) Monitoring; Monaco, 14-18 June 1976	E, F E (out of stock) R
11	Report of the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions; Port of Spain, Trinidad, 13-17 December 1976.	E, S (out of stock)
11 Suppl.	Collected contributions of invited lecturers and authors to the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions; Port of Spain, Trinidad, 13-17 December 1976	E (out of stock), S
12	Report of the IOCARIBE Interdisciplinary Workshop on Scientific Programmes in Support of Fisheries Projects; Fort-de-France, Martinique, 28 November-2 December 1977.	E, F, S
13	Report of the IOCARIBE Workshop on Environmental Geology of the Caribbean Coastal Area; Port of Spain, Trinidad, 16-18 January 1978.	E, S
14	IOC/FAO/WHO/UNEP International Workshop on Marine Pollution in the Gulf of Guinea and Adjacent Areas; Abidjan, Côte d'Ivoire, 2-9 May 1978	E, F
15	CPPS/FAO/IOC/UNEP International Workshop on Marine Pollution in the South-East Pacific; Santiago de Chile, 6-10 November 1978.	E (out of stock)
16	Workshop on the Western Pacific, Tokyo, 19-20 February 1979.	E, F, R
17	Joint IOC/WMO Workshop on Oceanographic Products and the IGOSS Data Processing and Services System (IDPSS); Moscow, 9-11 April 1979.	E
17 suppl.	Papers submitted to the Joint IOC/WMO Seminar on Oceanographic Products and the IGOSS Data Processing and Services System; Moscow, 2-6 April 1979.	E
18	IOC/UNESCO Workshop on Syllabus for Training Marine Technicians; Miami, U.S.A., 22-26 May 1978 (UNESCO reports in marine sciences, No. 4 published by the Division of Marine Sciences, UNESCO).	E (out of stock), F, S (out of tock), R
19	IOC Workshop on Marine Science Syllabus for Secondary Schools; Llantwit Major, Wales, U.K., 5-9 June 1978 (UNESCO reports in marine sciences, No. 5, published by the Division of Marine Sciences, UNESCO).	E (out of stock), S, R, Ar
20	Second CCOP-IOC Workshop on IDOE Studies of East Asia Tectonics and Resources; Bandung, Indonesia, 17-21 October 1978	E
21	Second IDOE Symposium on Turbulence in the Ocean; Liège, Belgium, 7-18 May 1979.	E, F, S, R
22	Third IOC/WMO Workshop on Marine Pollution Monitoring; New Delhi, 11-15 February 1980.	E, F, S, R
23	WESTPAC Workshop on the Marine Geology and Geophysics of the North-West Pacific; Tokyo, 27-31 March 1980.	E, R
24	WESTPAC Workshop on Coastal Transport of Pollutants; Tokyo, Japan, 27-31 March 1980.	E (out of stock)
25	Workshop on the Inter-calibration of Sampling Procedures of the IOC/ WMO UNEP Pilot Project on Monitoring Background Levels of Selected Pollutants in Open-Ocean Waters; Bermuda, 11-26 January 1980.	E (Superseded by IOC Technical Series No.22)
26	IOC Workshop on Coastal Area Management in the Caribbean Region; Mexico City, 24 September- 5 October 1979.	E, S
27	CCOP/SOPAC-IOC Second International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific; Nouméa, New Caledonia, 9-15 October 1980.	E
28	FAO/IOC Workshop on the effects of environmental variation on the survival of larval pelagic fishes. Lima, 20 April-5 May 1980.	E
29	WESTPAC Workshop on Marine Biological Methodology; Tokyo, 9-14 February 1981.	E
30	International Workshop on Marine Pollution in the South-West Atlantic; Montevideo, 10-14 November 1980.	E (out of stock) S
31	Third International Workshop on Marine Geoscience; Heidelberg, 19-24 July 1982.	E, F, S
32	UNU/IOC/UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the context of the New Ocean Regime; Paris, France, 27 September-1 October 1982.	E, F, S
32 Suppl.	Papers submitted to the UNU/IOC/ UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the Context of the New Ocean Regime; Paris, France, 27 September-1 October 1982.	E
33	Workshop on the IREP Component of the IOC Programme on Ocean Science in Relation to Living Resources (OSLR); Halifax, 26-30 September 1963.	E
34	IOC Workshop on Regional Co-operation in Marine Science in the Central Eastern Atlantic (Western Africa); Tenerife, 12-17 December 1963.	E, F, S
35	CCOP/SOPAC-IOC-UNU Workshop on Basic Geo-scientific Marine Research Required for Assessment of Minerals and Hydrocarbons in the South Pacific; Suva, Fiji, 3-7 October 1983.	E
36	IOC/FAO Workshop on the Improved Uses of Research Vessels; Lisbon, Portugal, 28 May-2 June 1984.	E
36 Suppl.	Papers submitted to the IOC/FAO Workshop on the Improved Uses of Research Vessels; Lisbon, 28 May-2 June 1984	E
37	IOC/UNESCO Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs; Colombo, 8-13 July 1985.	E
38	IOC/ROPME/UNEP Symposium on Fate and Fluxes of Oil Pollutants in the Kuwait Action Plan Region; Basrah, Iraq, 8-12 January 1984.	E
39	CCOP (SOPAC)-IOC-IFREMER-ORSTOM Workshop on the Uses of Submersibles and Remotely Operated Vehicles in the South Pacific; Suva, Fiji, 24-29 September 1985.	E
40	IOC Workshop on the Technical Aspects of Tsunami Analysis, Prediction and Communications; Sidney, B.C., Canada, 29-31 July 1985.	E
40 Suppl.	First International Tsunami Workshop on Tsunami Analysis, Prediction and Communications, Submitted Papers; Sidney, B.C., Canada, 29 July-1 August 1985.	E
41	First Workshop of Participants in the Joint FAO/IOC/WHO/IAEA/UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region (WACAF/2); Dakar, Senegal, 28 October-1 November 1985.	E
43	IOC Workshop on the Results of MEDALPEX and Future Oceanographic Programmes in the Western Mediterranean; Venice, Italy, 23-25 October 1985.	E
44	IOC-FAO Workshop on Recruitment in Tropical Coastal Demersal Communities; Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986.	E (out of stock) S
44 Suppl.	IOC-FAO Workshop on Recruitment in Tropical Coastal Demersal Communities, Submitted Papers; Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986.	E
45	IOCARIBE Workshop on Physical Oceanography and Climate; Cartagena, Colombia, 19-22 August 1986.	E
46	Reunión de Trabajo para Desarrollo del Programa "Ciencia Oceánica en Relación a los Recursos No Vivos en la Región del Atlántico Sud-occidental"; Porto Alegre, Brasil, 7-11 de abril de 1986.	S
47	IOC Symposium on Marine Science in the Western Pacific: The Indo-Pacific Convergence; Townsville, 1-6 December 1966	E
48	IOCARIBE Mini-Symposium for the Regional Development of the IOC-UN (OETB) Programme on 'Ocean Science in Relation to Non-Living Resources (OSNLR)'; Havana, Cuba, 4-7 December 1986.	E, S
49	AGU-IOC-WMO-CPPS Chapman Conference: An International Symposium on 'El Niño'; Guayaquil, Ecuador, 27-31 October 1986.	E
50	CCALR-IOC Scientific Seminar on Antarctic Ocean Variability and its Influence on Marine Living Resources, particularly Krill (organized in collaboration with SCAR and SCOR); Paris, France, 2-6 June 1987.	E
51	CCOP/SOPAC-IOC Workshop on Coastal Processes in the South Pacific Island Nations; Lae, Papua-New Guinea, 1-8 October 1987.	E
52	SCOR-IOC-UNESCO Symposium on Vertical Motion in the Equatorial Upper Ocean and its Effects upon Living Resources and the Atmosphere; Paris, France, 6-10 May 1985.	E
53	IOC Workshop on the Biological Effects of Pollutants; Oslo, 11-29 August 1986.	E
54	Workshop on Sea-Level Measurements in Hostile Conditions; Bidston, UK, 28-31 March 1988.	E
55	IBCCA Workshop on Data Sources and Compilation, Boulder, Colorado, 18-19 July 1988.	E
56	IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Cleveland, Australia, 24-30 July 1988.	E
57	IOC Workshop on International Co-operation in the Study of Red Tides and Ocean Blooms; Takamatsu, Japan, 16-17 November 1987.	E
58	International Workshop on the Technical Aspects of the Tsunami Warning System; Novosibirsk, USSR, 4-5 August 1989.	E
58 Suppl.	Second International Workshop on the Technical Aspects of Tsunami Warning Systems, Tsunami Analysis, Preparedness,	E

No.	Title	Languages
	Observation and Instrumentation. Submitted Papers; Novosibirsk, USSR, 4-5 August 1989.	
59	IOC-UNEP Regional Workshop to Review Priorities for Marine Pollution Monitoring Research, Control and Abatement in the Wider Caribbean; San José, Costa Rica, 24-30 August 1989.	E, F, S
60	IOC Workshop to Define IOCARIBE-TRODERP proposals; Caracas, Venezuela, 12-16 September 1989.	E
61	Second IOC Workshop on the Biological Effects of Pollutants; Bermuda, 10 September-2 October 1988.	E
62	Second Workshop of Participants in the Joint FAO-IOC-WHO-IAEA-UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region; Accra, Ghana, 13-17 June 1988.	E
63	IOC/WESTPAC Workshop on Co-operative Study of the Continental Shelf Circulation in the Western Pacific; Bangkok, Thailand, 31 October-3 November 1989.	E
64	Second IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Phuket, Thailand, 25-31 September 1989.	E
65	Second IOC Workshop on Sardine/Anchovy Recruitment Project (SARP) in the Southwest Atlantic; Montevideo, Uruguay, 21-23 August 1989.	E
66	IOC ad hoc Expert Consultation on Sardine/ Anchovy Recruitment Programme; La Jolla, California, U.S.A., 1989	E
67	Interdisciplinary Seminar on Research Problems in the IOCARIBE Region; Caracas, Venezuela, 28 November-1 December 1989.	E (out of stock)
68	International Workshop on Marine Acoustics; Beijing, China, 26-30 March 1990.	E
69	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Leningrad, USSR, 28-31 May 1990.	E
69 Suppl.	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Submitted Papers; Leningrad, USSR, 28-31 May 1990.	E
70	IOC-SAREC-UNEP-FAO-IAEA-WHO Workshop on Regional Aspects of Marine Pollution; Mauritius, 29 October - 9 November 1990.	E
71	IOC-FAO Workshop on the Identification of Penaeid Prawn Larvae and Postlarvae; Cleveland, Australia, 23-28 September 1990.	E
72	IOC/WESTPAC Scientific Steering Group Meeting on Co-Operative Study of the Continental Shelf Circulation in the Western Pacific; Kuala Lumpur; Malaysia, 9-11 October 1990.	E
73	Expert Consultation for the IOC Programme on Coastal Ocean Advanced Science and Technology Study; Liège, Belgium, 11-13 May 1991.	E
74	IOC-UNEP Review Meeting on Oceanographic Processes of Transport and Distribution of Pollutants in the Sea; Zagreb, Yugoslavia, 15-18 May 1989.	E
75	IOC-SCOR Workshop on Global Ocean Ecosystem Dynamics; Solomons, Maryland, U.S.A., 29 April-2 May 1991.	E
76	IOC/WESTPAC Scientific Symposium on Marine Science and Management of Marine Areas of the Western Pacific; Penang, Malaysia, 2-6 December 1991.	E
77	IOC-SAREC-KMFRI Regional Workshop on Causes and Consequences of Sea-Level Changes on the Western Indian Ocean Coasts and Islands; Mombasa, Kenya, 24-28 June 1991.	E
78	IOC-CEC-ICES-WMO-ICSU Ocean Climate Data Workshop Goddard Space Flight Center; Greenbelt, Maryland, U.S.A., 18-21 February 1992.	E
79	IOC/WESTPAC Workshop on River Inputs of Nutrients to the Marine Environment in the WESTPAC Region; Penang, Malaysia, 26-29 November 1991.	E
80	IOC-SCOR Workshop on Programme Development for Harmful Algae Blooms; Newport, U.S.A. 2-3 November 1991.	E
81	Joint IAPSO-IOC Workshop on Sea Level Measurements and Quality Control; Paris, France, 12-13 October 1992.	E
82	BORDOMER 92: International Convention on Rational Use of Coastal Zones. A Preparatory	E
83	IOC Workshop on Donor Collaboration in the Development of Marine Scientific Research Capabilities in the Western Indian Ocean Region; Brussels, Belgium, 12-13 October 1992.	E
84	Workshop on Atlantic Ocean Climate Variability; Moscow, Russian Federation, 13-17 July 1992	E
85	IOC Workshop on Coastal Oceanography in Relation to Integrated Coastal Zone Management; Kona, Hawaii, 1-5 June 1992.	E
86	International Workshop on the Black Sea; Varna, Bulgaria, 30 September – 4 October 1991	E
87	Taller de trabajo sobre efectos biológicos del fenómeno «El Niño» en ecosistemas costeros del Pacífico Sudeste; Santa Cruz, Galápagos, Ecuador, 5-14 de octubre de 1989.	S only (summary in E, F, S)
88	IOC-CEC-ICSU-ICES Regional Workshop for Member States of Eastern and Northern Europe (GODAR Project); Obninsk, Russia, 17-20 May 1993.	E
89	IOC-ICSEM Workshop on Ocean Sciences in Non-Living Resources; Perpignan, France, 15-20 October 1990.	E
90	IOC Seminar on Integrated Coastal Management; New Orleans, U.S.A., 17-18 July 1993.	E
91	Hydroblack'91 CTD Intercalibration Workshop; Woods Hole, U.S.A., 1-10 December 1991.	E
92	Réunion de travail IOCEA-OSNLR sur le Projet « Budgets sédimentaires le long de la côte occidentale d'Afrique » Abidjan, côte d'Ivoire, 26-28 juin 1991.	E
93	IOC-UNEP Workshop on Impacts of Sea-Level Rise due to Global Warming. Dhaka, Bangladesh, 16-19 November 1992.	E
94	BMTC-IOC-POLARMAR International Workshop on Training Requirements in the Field of Eutrophication in Semi-enclosed Seas and Harmful Algal Blooms, Bremerhaven, Germany, 29 September-3 October 1992.	E
95	SAREC-IOC Workshop on Donor Collaboration in the Development of Marine Scientific Research Capabilities in the Western Indian Ocean Region; Brussels, Belgium, 23-25 November 1993.	E
96	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Zanzibar, United Republic of Tanzania, 17-21 January 1994.	E
96 Suppl.	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Submitted Papers 1. Coastal Erosion; Zanzibar, United Republic of Tanzania 17-21 January 1994.	E
96 Suppl	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Submitted Papers 2. Sea Level; Zanzibar, United Republic of Tanzania 17-21 January 1994.	E
97	IOC Workshop on Small Island Oceanography in Relation to Sustainable Economic Development and Coastal Area Management of Small Island Development States; Fort-de-France, Martinique, 8-10 November, 1993.	E
98	CoMSBlack '92A Physical and Chemical Intercalibration Workshop; Erdemli, Turkey, 15-29 January 1993.	E
99	IOC-SAREC Field Study Exercise on Nutrients in Tropical Marine Waters; Mombasa, Kenya, 5-15 April 1994.	E
100	IOC-SOA-NOAA Regional Workshop for Member States of the Western Pacific - GODAR-II (Global Oceanographic Data Archeology and Rescue Project); Tianjin, China, 8-11 March 1994.	E
101	IOC Regional Science Planning Workshop on Harmful Algal Blooms; Montevideo, Uruguay, 15-17 June 1994.	E
102	First IOC Workshop on Coastal Ocean Advanced Science and Technology Study (COASTS); Liège, Belgium, 5-9 May 1994.	E
103	IOC Workshop on GIS Applications in the Coastal Zone Management of Small Island Developing States; Barbados, 20-22 April 1994.	E
104	Workshop on Integrated Coastal Management; Dartmouth, Canada, 19-20 September 1994.	E
105	BORDOMER 95: Conference on Coastal Change; Bordeaux, France, 6-10 February 1995.	E
105 Suppl.	Conference on Coastal Change: Proceedings; Bordeaux, France, 6-10 February 1995	E
106	IOC/WESTPAC Workshop on the Paleographic Map; Bali, Indonesia, 20-21 October 1994.	E
107	IOC-ICSU-NIO-NOAA Regional Workshop for Member States of the Indian Ocean - GODAR-III; Dona Paula, Goa, India, 6-9 December 1994.	E
108	UNESCO-IHP-IOC-IAEA Workshop on Sea-Level Rise and the Multidisciplinary Studies of Environmental Processes in the Caspian Sea Region; Paris, France, 9-12 May 1995.	E
108 Suppl.	UNESCO-IHP-IOC-IAEA Workshop on Sea-Level Rise and the Multidisciplinary States of Environmental Processes in the Caspian Sea Region; Submitted Papers; Paris, France, 9-12 May 1995.	E
109	First IOC-UNEP CEPPOL Symposium; San José, Costa Rica, 14-15 April 1993.	E
110	IOC-ICSU-CEC regional Workshop for Member States of the Mediterranean - GODAR-IV (Global Oceanographic Data Archeology and Rescue Project) Foundation for International Studies, University of Malta, Valletta, Malta, 25-28 April 1995.	E
111	Chapman Conference on the Circulation of the Intra-Americas Sea; La Parguera, Puerto Rico, 22-26 January 1995.	E
112	IOC-IAEA-UNEP Group of Experts on Standards and Reference Materials (GESREM) Workshop; Miami, U.S.A., 7-8 December 1993.	E
113	IOC Regional Workshop on Marine Debris and Waste Management in the Gulf of Guinea; Lagos, Nigeria, 14-16 December 1994.	E
114	International Workshop on Integrated Coastal Zone Management (ICZM) Karachi, Pakistan; 10-14 October 1994.	E
115	IOC/GLOSS-IAPSO Workshop on Sea Level Variability and Southern Ocean Dynamics; Bordeaux, France, 31 January 1995	E
116	IOC/WESTPAC International Scientific Symposium on Sustainability of Marine Environment: Review of the WESTPAC Programme, with Particular Reference to ICAM, Bali, Indonesia, 22-26 November 1994.	E
117	Joint IOC-CIDA-Sida (SAREC) Workshop on the Benefits of Improved Relationships between International Development Agencies, the IOC and other Multilateral Inter-governmental Organizations in the Delivery of Ocean, Marine Affairs and Fisheries Programmes; Sidney B.C., Canada, 26-28 September 1995.	E
118	IOC-UNEP-NOAA-Sea Grant Fourth Caribbean Marine Debris Workshop; La Romana, Santo Domingo, 21-24 August 1995.	E
119	IOC Workshop on Ocean Colour Data Requirements and Utilization; Sydney B.C., Canada, 21-22 September 1995.	E
120	International Training Workshop on Integrated Coastal Management; Tampa, Florida, U.S.A., 15-17 July 1995.	E
121	Atelier régional IOC-CERESCOR sur la gestion intégrée des zones littorales (ICAM), Conakry, Guinée, 18–22 décembre 1995	F
122	IOC-EU-BSH-NOAA-(WDC-A) International Workshop on Oceanographic Biological and Chemical Data Management, Hamburg, Germany, 20-23 May 1996	E
123	Second IOC Regional Science Planning Workshop on Harmful Algal Blooms in South America; Mar del Plata, Argentina, 30 October–1 November 1995.	E, S
124	GLOBEC-IOC-SAHFOS-MBA Workshop on the Analysis of Time Series with Particular Reference to the Continuous Plankton Recorder Survey; Plymouth, U.K.,4-7 May 1993.	E
125	Atelier sous-régional de la COI sur les ressources marines vivantes du Golfe de Guinée ; Cotonou, Bénin, 1-4 juillet 1996.	E

No.	Title	Languages
126	IOC-UNEP-PERSGA-ACOPS-IUCN Workshop on Oceanographic Input to Integrated Coastal Zone Management in the Red Sea and Gulf of Aden. Jeddah, Saudi Arabia, 8 October 1995.	E
127	IOC Regional Workshop for Member States of the Caribbean and South America GODAR-V (Global Oceanographic Data Archeology and Rescue Project); Cartagena de Indias, Colombia, 8-11 October 1996.	E
128	Atelier IOC-Banque Mondiale-Sida/SAREC-ONE sur la Gestion Intégrée des Zones Côtières ; Nosy Bé, Madagascar, 14-18 octobre 1996.	E
129	Gas and Fluids in Marine Sediments, Amsterdam, the Netherlands; 27-29 January 1997.	E
130	Atelier régional de la COI sur l'océanographie côtière et la gestion de la zone côtière ;Moroni, RFI des Comores, 16-19 décembre 1996.	E
131	GOOS Coastal Module Planning Workshop; Miami, USA, 24-28 February 1997	E
132	Third IOC-FANSA Workshop; Punta-Arenas, Chile, 28-30 July 1997	S/E
133	Joint IOC-CIESM Training Workshop on Sea-level Observations and Analysis for the Countries of the Mediterranean and Black Seas; Birkenhead, U.K., 16-27 June 1997.	E
134	IOC/WESTPAC-CCOP Workshop on Paleogeographic Mapping (Holocene Optimum); Shanghai, China, 27-29 May 1997.	E
135	Regional Workshop on Integrated Coastal Zone Management; Chabahar, Iran; February 1996.	E
136	IOC Regional Workshop for Member States of Western Africa (GODAR-VI); Accra, Ghana, 22-25 April 1997.	E
137	GOOS Planning Workshop for Living Marine Resources, Dartmouth, USA; 1-5 March 1996.	E
138	Gestión de Sistemas Oceanográficos del Pacífico Oriental; Concepción, Chile, 9-16 de abril de 1996.	S
139	Sistemas Oceanográficos del Atlántico Sudoccidental, Taller, TEMA;Furg, Rio Grande, Brasil, 3-11 de noviembre de 1997	S
140	IOC Workshop on GOOS Capacity Building for the Mediterranean Region; Valletta, Malta, 26-29 November 1997.	E
141	IOC/WESTPAC Workshop on Co-operative Study in the Gulf of Thailand: A Science Plan; Bangkok, Thailand, 25-28 February 1997.	E
142	Pelagic Biogeography ICoPB II. Proceedings of the 2nd International Conference. Final Report of SCOR/IOC Working Group 93; Noordwijkerhout, The Netherlands, 9-14 July 1995.	E
143	Geosphere-biosphere coupling: Carbonate Mud Mounds and Cold Water Reefs; Gent, Belgium, 7–11 February 1998.	E
144	IOC-SOPAC Workshop Report on Pacific Regional Global Ocean Observing Systems; Suva, Fiji, 13-17 February 1998.	E
145	IOC-Black Sea Regional Committee Workshop: 'Black Sea Fluxes' Istanbul, Turkey, 10-12 June 1997.	E
146	Taller Internacional sobre Formacíon de Capacidades para el Manejo de las Costas y los Océanos en le Gran Caribe, La Habana, – Cuba, 7–10 de Julio de 1998 / International Workshop on Management Capacity-Building for Coasts and Oceans in the Wider Caribbean, Havana, Cuba, 7–10 July 1998	S/E
147	IOC-SOA International Training Workshop on the Intregration of Marine Sciences into the Process of Integrated Coastal Management, Dalian, China, 19-24 May 1997.	E
148	IOC/WESTPAC International Scientific Symposium – Role of Ocean Sciences for Sustainable Development Okinawa, Japan, 2-7 February 1998.	E
149	Workshops on Marine Debris & Waste Management in the Gulf of Guinea, 1995-97.	E
150	First IOCARIBE-ANCA Workshop Havana, Cuba, 29 June-1 July 1998.	E
151	Taller Pluridisciplinario TEMA sobre Redes del Gran Caribe en Gestión Integrada de Áreas Costeras Cartagena de Indias, Colombia, 7-12 de septiembre de 1998.	S
152	Workshop on Data for Sustainable Integrated Coastal Management (SICOM) Maputo, Mozambique, 18-22 July 1998	E
153	IOC/WESTPAC-Sida (SAREC) Workshop on Atmospheric Inputs of Pollutants to the Marine Environment Qingdao, China, 24-26 June 1998	E
154	IOC-Sida-Flanders-SFRI Workshop on Ocean Data Management in the IOCINCWIO Region (ODINEA project) Capetown, South Africa, 30 November-11 December 1998.	E
155	Science of the Mediterranean Sea and its applications UNESCO, Paris 29-31 July 1997	E
156	IOC-LUC-KMFRI Workshop on RECOSCIX-WIO in the Year 2000 and Beyond, Mombasa, Kenya, 12-16 April 1999	E
157	'98 IOC-KMI International Workshop on Integrated Coastal Management (ICM), Seoul, Republic of Korea 16-18 April 1998	E
158	The IOCARIBE Users and the Global Ocean Observing System (GOOS) Capacity Building Workshop, San José, Costa Rica, 22-24 April 1999	E
159	Oceanic Fronts and Related Phenomena (Konstantin Fedorov Memorial Symposium) – Proceedings, Pushkin, Russian Federation, 18-22 May 1998	E
160	Under preparation	
161	Under preparation	
162	Workshop report on the Transports and Linkages of the Intra-americas Sea (IAS), Cozumel, Mexico, 1-5 November 1997	E
163	Under preparation	
164	IOC-Sida-Flanders-MCM Third Workshop on Ocean Data Management in the IOCINCWIO Region (ODINEA Project), Cape Town, South Africa, 29 November – 11 December 1999	E
165	An African Conference on Sustainable Integrated Management; Proceedings of the Workshops. An Integrated Approach, (PACSICOM), Maputo, Mozambique, 18 –25 July 1998	E, F
166	IOC-SOA International Workshop on Coastal Megacities: Challenges of Growing Urbanization of the World's Coastal Areas; Hangzhou, P.R. China, 27 –30 September 1999	E
167	IOC-Flanders First ODINAFRICA-II Planning Workshop, Dakar, Senegal, 2-4 May 2000	E
168	Geological Processes on European Continental Margins; International Conference and Eight Post-cruise Meeting of the Training-Through-Research Programme, Granada, Spain, 31 January – 3 February 2000	E
169	International Conference on the International Oceanographic Data & Information Exchange in the Western Pacific (IODE-WESTPAC) 1999, ICIWP '99, Langkawi, Malaysia, 1-4 November 1999	***under preparation***
170	IOCARIBE-GODAR-I Cartagenas, Colombia, February 2000	***under preparation***
171	Ocean Circulation Science derived from the Atlantic, Indian and Arctic Sea Level Networks, Toulouse, France, 10-11 May 1999	E
172	(*Under preparation*)	
173	The Benefits of the Implementation of the GOOS in the Mediterranean Region, Rabat, Morocco, 1-3 November 1999	E, F
174	IOC-SOPAC Regional Workshop on Coastal Global Ocean Observing System (GOOS) for the Pacific Region, Apia, Samoa, 16-17 August 2000	E
175	Geological Processes on Deep-water European Margins, Moscow-Mozhenka, 28 Jan.-2 Feb. 2001	E
176	MedGLOSS Workshop and Coordination Meeting for the Pilot Monitoring Network System of Systematic Sea Level Measurements in the Mediterranean and Black Seas, Haifa, Israel, 15-17 May 2000	E
177	*(Under preparation)*	
178	*(Under preparation)*	
179	*(Under preparation)*	
180	Abstracts of Presentations at Workshops during the 7th session of the IOC Group of Experts on the Global Sea Level Observing System (GLOSS), Honolulu, USA, 23-27 April 2001	E
181	*(Under preparation)*	
182	*(Under preparation)*	
183	Geosphere/Biosphere/Hydrosphere Coupling Process, Fluid Escape Structures and Tectonics at Continental Margins and Ocean Ridges, International Conference & Tenth Post-cruise Meeting of the Training-through-Research Programme, Aveiro, Portugal, 30 January-2 February 2002	E
184	*(Under preparation)*	
185	*(Under preparation)*	
186	*(Under preparation)*	
186	*(Under preparation)*	
187	Geological and Biological Processes at deep-sea European Margins and Oceanic Basins, Bologna, Italy, 2–6 February 2003	E
188	Proceedings of 'The Ocean Colour Data' Symposium, Brussels, Belgium, 25-27 November 2002	E
189	Workshop for the Formulation of a Draft Project on Integrated Coastal Management (ICM) in Latin America and the Caribbean (LAC), Cartagena, Colombia, 23–25 October 2003 Taller de Formulación de un Anteproyecto de Manejo Costero Integrado (MCI) en América Latina y el Caribe (ALC), Cartagena, Colombia, 23–25 de Octubre de 2003	E F ***(electronic copy only)***
190	First ODINCARSA Planning Workshop for Caribbean Islands, Christchurch, Barbados, 15–18 December 2003	E ***(electronic copy only)***
191	North Atlantic and Labrador Sea Margin Architecture and Sedimentary Processes — International Conference and Twelfth Post-cruise Meeting of the Training-through-research Programme, Copenhagen, Denmark, 29–31 January 2004	E
192	Regional Workshop on Coral Reefs Monitoring and Management in the ROPME Sea Area, Iran I.R., 14–17 December 2003	E ***(under preparation)***
193	Workshop on New Technical Developments in Sea and Land Level Observing Systems, Paris, France, 14–16 October 2003	E ***(electronic copy only)***
194	IOC/ROPME Planning Meeting for the Ocean Data and Information Network for the Central Indian Ocean Region	***(under preparation)***
195	Workshop on Indicators of Stress in the Marine Benthos, Torregrande-Oristano, Italy, 8–9 October 2004	E
196	International Coordination Meeting for the Development of a Tsunami Warning and Mitigation System for the Indian Ocean within a Global Framework, Paris, France, 3–8 March 2005	E
197	Geosphere-Biosphere Coupling Processes: The TTR Interdisciplinary Approach Towards Studies of the European and North African Margins; International Conference and Post-cruise Meeting of the Training-Through-Research Programme, Morocco, 2-5 February 2005	E
198	Second International Coordination Meeting for the Development of a Tsunami Warning and Mitigation System for the Indian Ocean, Grand Baie, Mauritius, 14–16 April 2005	E
199	International Conference for the Establishment of a Tsunami and Coastal Hazards Warning System for the Caribbean and Adjacent Regions, Mexico, 1–3 June 2005	E
200	Lagoons and Coastal Wetlands in the Global Change Context: Impacts and Management Issues — Proceedings of the International Conference, Venice, 26–28 April 2004 (*ICAM Dossier N° 3)*	E
201	Geological processes on deep-water European margins - International Conference and 15th Anniversary Post-cruise Meeting of the Training-Through-Research Programme, Moscow/Zvenigorod, Russian Federation, 29 January-4 February 2006	E
202	Proceedings of 'Ocean Biodiversity Informatics': an international conference on marine biodiversity data management Hamburg, Germany, 29 November - 1 December, 2004	E
203	IOC-Flanders Planning Workshop for the formulation of a regional Pilot Project on Integrated Coastal Area Management in Latin America, Cartagena de Indias, Colombia, 16 - 18 January 2007	*In preparation*
204	Geo-marine Research along European Continental Margins, International Conference and Post-cruise Meeting of the Training-through-research Programme, Bremen, Germany, 29 January – 1 February 2007	E