Intergovernmental Oceanographic Commission

Workshop Report No. 183

Geosphere/Biosphere/Hydrosphere Coupling Processes, Fluid Escape Structures and Tectonics at Continental Margins and Ocean Ridges

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

Aveiro, Portugal
30 January-2 February 2002

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Editors: M. Cunha
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A. Suzyumov

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Abstract

The "Geosphere/Biosphere/Hydrosphere Coupling Processes, Fluid Escape Structures and Tectonics at Continental Margins and Ocean Ridges" - International Conference and Tenth Training Through Research (TTR) Post-Cruise Meeting, took place from 30 January to 2 February 2002 at the University of Aveiro. The meeting brought together over 60 participants involved or interested in the TTR research. 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. A total of 40 oral communications and several posters were presented during the conference, arranged in thematic sessions that reflect the main research activities of TTR, such as mud volcanism, diapirism and gas hydrates; deep-sea depositional systems and modern analogues; hydrothermalism and hydrogenous supply of elements to the sea floor; biosphere – geosphere interaction; and tectonics.

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PREFACE

The "Geosphere/Biosphere/Hydrosphere Coupling Processes, Fluid Escape Structures and Tectonics at Continental Margins and Ocean Ridges" - International Conference and tenth Training Through Research Post-Cruise Meeting, took place from 30 January to 2 February 2002 in the University of Aveiro, and was hosted by the University of Aveiro together with the Portuguese Geological and Mining Institute. This year, the scope of the meeting was extended, bringing together scientists involved in active research in cold seeps and in hydrothermal systems, to promote future collaboration within the framework of a new IOC Programme on Geosphere/ Biosphere Coupling Processes.

The meeting brought together over 60 researchers and students from 10 countries (Belgium, France, Germany, Italy, Norway, Portugal, Russia, Spain, Turkey, and the United Kingdom) with different specialities (sedimentology, geophysics, geochemistry, microbiology, biology, palaeontology, structural geology) and research interests related to the Conference theme. A total of 40 oral communications and several posters were presented during the conference, arranged in thematic sessions that reflect the main research activities of TTR:

- Mud volcanism, diapirism and gas hydrates;
- Deep-sea depositional systems and modern analogues;
- Hydrothermalism and hydrogenous supply of elements to the sea floor;
- Biosphere – geosphere interaction;
- Tectonics.

The Conference started with the official Opening Session. Prof. M.H. Nazaré, Rector of the University of Aveiro, opened the meeting by welcoming the participants. Prof. M. Ruivo addressed the participants on behalf of the Portuguese Committee for the Intergovernmental Oceanographic Commission (IOC) and Dr. A. Suzyumov conveyed a message to the participants of the meeting on behalf of Dr. P. Bernal, Assistant Director General of UNESCO and Executive Secretary of the IOC.

During the scientific sessions of the Conference the main results of the research carried out during TTR cruises in the Black and Mediterranean Seas, the Gulf of Cadiz and other areas in the North Atlantic were highlighted. All participants expressed great satisfaction with the Conference as having fully accomplished its objectives and facilitated fruitful contacts between the attendees. A group of students proposed to establish an e-mail network to promote scientific discussion and further contacts among TTR students. Prizes for the best student presentations were awarded to Susana Muinos (IGM/DGM, Portugal), Olga Kovalenko (MSU, Russia) and Rien Deschamps (Univ. Ghent, Belgium).

On the 31st January, an Open Session with the TTR Executive and Scientific Committee, convened by Prof. J.-P. Henriet, was organized to discuss with the participants the launching of the new IOC programme on Geosphere-Biosphere Coupling Processes. During the restricted meeting of the TTR Executive and Scientific Committee which was held in the same day, the plans for the future TTR research were discussed and a number of items related to the organisation of the TTR cruises, as well as publication of the TTR data were considered.

The Conference programme was set up by the Organizing Committee, namely:

- Luís Menezes Pinheiro, Universidade de Aveiro (Chairman)
- Marina Ribeiro da Cunha, Universidade de Aveiro
- José Hipólito Monteiro, Instituto Geológico e Mineiro
- Mikhail Ivanov, Moscow State University
- Fátima Abrantes, Instituto Geológico e Mineiro
- Vítor Hugo Magalhães, Instituto Geológico e Mineiro
- Dmitri Ovsyannikov, Moscow State University, Russia
- Maria Dulce Subida, Universidade de Aveiro

- Henrique Guerreiro Duarte, Universidade de Aveiro
- Inês Lima, Instituto de Ciências Biomédicas Abel Salazar.

The book of abstracts was compiled by the Organizing Committee. For the present report, it was further edited by Dr. M.R. Cunha and Dr. L.M. Pinheiro (University of Aveiro) and Dr. A.E. Suzyumov (UNESCO). The organization of this report reflects the Conference schedule. Thus the abstracts are in the order in which the presentations were given. Annex I contains the programme showing the titles and authors of presentations, along with the division into different sessions and chairpersons of the sessions. The abstracts follow the same sequence in this report and are likewise grouped thematically under the same headings as the different sessions. The participants are listed in Annex II in the alphabetical order by country.

The conference was supported by the Intergovernmental Oceanographic Commission of UNESCO, the Fundação para a Ciência e Tecnologia (Programa Operacional Ciência, Tecnologia, Inovação do Quador Comunitário de Apoio III), the University of Aveiro and the Instituto Geológico e Mineiro (INGMAR Project). The conference was also sponsored by the Town Hall (Câmara Municipal de Aveiro), the Portuguese Youth Institute (IPJ) and Montepio Geral. Valuable assistance was provided by the Portuguese Committee for IOC.

MESSAGE TO PARTICIPANTS OF THE CONFERENCE

from Patricio Bernal,
Assistant Director-General, UNESCO
Executive Secretary, Intergovernmental Oceanographic Commission

Dear Participants to the Annual TTR Conference,

It gives me great pleasure to welcome you, students and scientists of Aveiro University and those who have come to Aveiro from the many countries participating in and contributing to the IOC-sponsored Training-through-Research (TTR) programme.

Indeed during the past years, TTR has progressed a long way to an endeavour, recognized throughout the world as a successful international undertaking. In addition to the outstanding training it affords, TTR has made a considerable contribution to a number of important international research projects and even triggered some of the recent European undertakings, thus advancing, in a multi-disciplinary way, knowledge on processes in the world ocean. TTR is unique in providing training in core science at both undergraduate and post-graduate levels and involving young researchers from many countries in all steps of data collection, interpretation and dissemination of the research findings. As the result, a closely linked international community of young scientists is fostered, this in addition to well-established cooperation between high-level professional researchers from many countries. These well-trained young researchers coming from various countries appreciate and gain from the cultural variety represented in their working groups. The contribution by TTR to the development of a universal culture of peace and tolerance has been recognized by the United Nations.

The topic selected for the Conference in Aveiro is very much relevant to the IOC Ocean Science Programme as adopted by the Twenty-first Session of the Assembly (2001). The Conference will further develop an important subject of interaction between geosphere and biosphere in complex systems on the sea floor, such as cold seeps, hydrothermal vents, mud mounds, gas hydrates and active tectonic settings, by using a multi-disciplinary approach. The main purpose of this meeting is to scope the possibilities for developing a new IOC programme on Geosphere-Biosphere Coupling Processes (GBCP) under the Ocean Ecosystems and Marine Environment Protection component. The TTR programme, which has already made some progress in studying these processes, will serve as the basis for this exercise. It is worth reminding you that TTR was among the first to recognize the importance of these interactions, and that the IOC-sponsored conference under the title “Geosphere-Biosphere Coupling: Carbonate Mud Mounds and Cold Water Reefs” was organized and hosted by Ghent University (Belgium) in 1998.

It may be considered symbolic that the Conference to advance the subject, which is very new to marine researchers, takes place in Portugal, one of the oldest maritime nations. Efforts by Aveiro University in this effect and valuable support, provided to the event by the Portuguese Committee for IOC are very much appreciated.

In closing I wish to express my hearty support for the TTR programme and wish full success to your Conference.

30 January 2002

WELCOMING ADDRESS

by Mario Ruivo
Chairman, Portuguese Committee for IOC

The tenth International Conference of the IOC-sponsored TTR programme, organized and hosted by the University of Aveiro together with the Portuguese Geological and Mining Institute, represents an important step forward in the development of the Ocean Sciences Programme of the Commission. Its theme, Geosphere/Biosphere/Hydrosphere Coupling Processes, Fluid Escape Structures and Tectonics at Continental Margins and Ocean Ridges, indicates the latest development in multidisciplinary research on complex processes of matter transformation and various kinds of interactions on the world continental margins and in the deep ocean.

TTR made valuable contribution to the International Year of the Ocean 1998 by bringing together experienced scientists and students from many nations, to work together in truly interdisciplinary teams. The Portuguese Committee for IOC has assisted TTR in various ways, for example during the visit of the R/V *Professor Logachev* to the Expo Ocean'98, where TTR was presented to the visitors.

The Portuguese association with the TTR programme was initiated in 1998, with the participation of a group of researchers from the Marine Geology Department of the Geological and Mining Institute (IGM/DGM), Lisbon, to study sedimentation patterns off West Iberia. Every year since then, and thanks to the support of the Portuguese Foundation for Science and Technology (INGMAR Project of IGM/DGM and, more recently, also the CZCM Research Unit of the University of Aveiro), Portuguese scientists, young researchers and students (both graduate and post-graduate) from IGM/DGM and the University of Aveiro have participated in the TTR cruises (TTR-8, TTR-9, TTR-10, TTR-11). Students from other Portuguese Universities (University of Lisbon, University of Porto) have also been invited and joined the cruises.

The main scientific objectives of the Portuguese participation have been: (1) to study the deep-sea sedimentation and active tectonic processes off West and South Iberia; (2) to study mud volcanism, gas hydrates and the associated ecosystems in the Gulf of Cadiz; (3) to investigate the geology, magmatism, chemosynthetic communities and the occurrence of massive sulphides in the Mid Atlantic Ridge, near the Açores (Lucky Strike segment); (4) to investigate the occurrence of polymetallic crusts in the Madeira EEZ. Co-operation with scientists and students from Moscow State University (the principal organizer of the TTR cruises), as well as from many other European and American academic and research institutions, fostered by the TTR programme, has been of great value for the progress of marine sciences in Portugal.

The University of Aveiro and the Geological and Mining Institute, as well as the Organizing Committee of the Conference made an important effort to extend the scope of the meeting and bring together scientists involved in active research on cold seeps and on hydrothermal systems, to promote international collaboration within the framework of a new IOC programme on Geosphere/Biosphere Coupling Processes.

I wish you all the very best for the tenth TTR Conference, and I am confident it will be a success.

ABSTRACTS

Mud volcanism, diapirism and gas hydrates

COLD SEEPS ON THE DEEP SEA EUROPEAN MARGINS. DISCOVERIES, IDEAS, QUESTIONS

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(Abstract not provided)

COMPARATIVE CHARACTERISTICS OF THE RUSSIAN AND TURKISH NEAR SHORE AREAS IN THE EASTERN BLACK SEA

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The Russian Shelf is characterized by the effects of contemporary uplift and faulting resulting from the compressive tectonic regime building the Caucasus Mountains. The shelf is characterized as a flat and smooth surface with a gentle inclination towards the shelf break with a general inclination of 0.4°. It can be subdivided into the coastal slope (inshore part) and coastal platform. The coastal slope extends from the coastline to the 60 m depth contour, showing current ripples in a NE-SW direction. The coastal platform is situated between the 50 and 100 m contours. A very distinct shelf edge marks the transition to the Continental Slope at 100 m depth contour, and is generally marked by the deeply incised headwalls of slope canyons.

The Russian Continental Slope is characterized by a highly dissected canyon system. The Slope has concave morphological characteristics, in which the gradient becomes progressively gentler as it is traced towards the foot of the slope (slope angle decreases from 27° to less than 5°). This is the result of a cycle of erosion, which causes parallel retreat of the slope and the development of a random network of dendritic valleys. The initial part of the Slope is situated between the 100 and 120 m depth contours. The bedrock surface outcrops in this area at the 105 m contour. The slope is crossed by minor to major V-shaped canyons, becoming broad U-shaped valleys in deeper parts of the Black Sea. The canyons and ridges exhibit varying orientations of fan toe spreading. The ridge sediments consist of very soft clay, which is susceptible to creep and slumping. The canyons exhibit retrogressive erosion in their steeper V-shaped sections. The canyon floors at the top of the Slope exhibit a near-continuous veneer of slump/debris flow material, which is generally blocky in nature and contains numerous boulders.

The Russian Apron area is defined by a number of ridges and intermediate submarine valleys in an east /west alignment parallel to the coastline. The ridges, which lessen in relief to the west, are remnants of an anticlinorium and can be regarded as a continuation of the Western Caucasus structure. The Quaternary sediments, with a thickness ranging between zero and several hundred meters, superimpose the older rocks unconformably. Areas of acoustically transparent/chaotic reflectors, with acoustic blanking at depth, are noted near the Continental Slope/Apron boundary. High amplitude reflectors (possibly gas hydrates) are observed within the sub bottom near the 2000 m water depth contour. Gas migration in this area has caused localized collapse of sediment, resulting in seabed depressions, or pockmarks.

In contrast to the concave Russian Continental Slope, the Turkish Continental Slope has a convex morphology. The slope gradient becomes progressively steeper as it is traced down slope, which is the result of mass movement and/or structural control. The slope is cut by only a small number of canyons and valleys, which are generally on a smaller scale than those found on the Russian Continental Slope. The lower section of the slope comprises relict slump structures overlain by a semi-continuous surficial unit of parallel-bedded sediments. Features related to creep are observed on the side scan sonar records in this area.

Based on bathymetry, the Turkish Shelf can be divided into 3 distinct sub-areas as plateau, terraced slope and shore approach. The *plateau* overlies the Mid Black Sea Ridge, the surface of which is marked by pockmarks, circular and elongated depressions with diameters of up to 500 m and lengths of several km. The pockmarks result from gas or fluid liquefaction, and are often associated with subsidence structures and slumping of sediments towards their centres. Towards the outer margin of the plateau, the pockmarks become more elongated and tend to follow a linear trend. The orientation of these pockmarks is sub-parallel to the underlying Mid Black Sea Ridge. The *terraced slope* has a mean gradient of 0.9°. The sub bottom records display horizontal parallel bedding thickening coastwards. Anomalous strong reflectors occur at a depth of 25 m, and represent gas pockets and horizons of shallow gas. A break in the seabed topography marks the transition between the terraced slope and the shore approach. The above slope break coincides with a terrace formed during a different stage of the Yeşilırmak delta development and Pleistocene sea level changes.

EVIDENCE OF NEAR-SURFACE SEDIMENT MOBILIZATION AND METHANE VENTING IN RELATION TO HYDRATE DISSOCIATION IN SOUTHERN LAKE BAIKAL, SIBERIA

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Four seeps and mud extrusion features at the lake floor were discovered in August 1999 in the gas hydrate area in Lake Baikal’s South Basin. This paper describes these features in detail using side-scan, detailed bathymetry, measurements of near-bottom water properties, and selected seismic profiles. The interpretation of this data is integrated with data from shallow cores and with heat flow values calculated from the depth of the hydrate layer as well as obtained from *in situ* thermoprobe measurements. The seeps are found in an area of a high heat flow where the base of the gas hydrate layer is shallowing rapidly towards the vent sites from about 400 m to about 160 m below the lake floor. At the site of the seep, a vertical seismic chimney disrupts the sedimentary stratification, from the base of the hydrate layer to the lake floor. The seeps are identified as methane seeps and form mud cones or low-relief craters at the lake floor. Mud cones appear to be older than craters and have a different structural setting; mud cones occur at the crest of rollover structures in the footwall of a secondary normal fault, the craters occur at splays of the secondary fault. It is concluded that focussed destabilization of gas hydrate caused massive methane release and forced mud extrusion at the lake floor. This is the first time that methane seeps and/or mud diapirs associated to gas hydrate dissociation are observed in a sub-lacustrine setting. The finding demonstrates that gas hydrate de-stabilization can cause sediment extrusion in mud diapirs at the sediment surface.

COMPOSITION AND ORIGIN OF HYDROCARBON GASES FROM MUD VOLCANOES OF THE BLACK SEA

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Hydrocarbon gases were collected during the first leg of the TTR-11 cruise from central and eastern (Sorokin Trough) parts of the Black Sea. In total twenty cores were taken from different mud volcanic structures and six of them were investigated: BS-314G (Vassoevich mud volcano), BS-319G (Kovalevskij mud volcano), BS-320G (TREDMAR mud volcano), BS-325G (NIOZ mud volcano), BS-331G (Kazakov mud volcano) and BS-336G (Odessa mud volcano). For analyses of molecular composition and content of hydrocarbon gases from C_1 to C_5 about 150 samples were collected. Stable isotope's measurements of carbon from methane were performed for seven gas samples. About 90 samples from these cores were sub sampled for determination of total organic carbon (TOC) content and 90 – for fluorescent analyses of extractable organic matter (EOM).

The composition and distribution of C_1 to C_5 hydrocarbon gases in gas-related pelagic sediments and mud volcanic deposits have been determined for indication of a possible linkage with hydrocarbons that have migrated through zones of weakness from subsurface accumulations. Gas measurements revealed, that all studied cores are characterized by methane (C_1) predominance over other hydrocarbon gases (C_{2+}). According to the composition of the gas mixture we can divide the studied cores into three types.

The first type is represented by the core BS-325G (NIOZ mud volcano). The gas phase is characterized by high concentrations of methane. It accounts here from 20 ml/l to 160 ml/l, and its content varies from 99.0% to 99.5% of the total hydrocarbon gas. Ethane (C_2) is the main homologue, and its content in some samples exceeding 0.5%. The concentration of propane (C_3) in some cases is too low to be detected. The EOM consists of waxy compounds, and TOC content varies from 0.45% to 0.59%.

The second type of the gas phase was observed in the sediments from cores BS-314G (Vassoevich mud volcano), BS-319G (Kovalevskij mud volcano), BS-320G (TREDMAR mud volcano) and BS-336G (Odessa mud volcano). This type observes the same concentrations of methane as for the first type (up to 150 ml/l). However, C_{2+} hydrocarbon gases are represented by set of alkanes from ethane to butanes, and in some cases (BS-320G and BS-336G) occur up to pentanes. It should be noted, that unsaturated homologues, such as ethene and butene were also detected in minor concentrations. In total, the content of methane homologues does not exceed 1%.

In these cores TOC content varies from 0.32% to 2.11%, with the highest value (2.11%) belonging to sapropel layer observed in core BS-320G. EOM mainly consists of “light” organic components.

The third type was identified in the sediments of core BS-331G (Kazakov mud volcano). The content of C_{2+} hydrocarbon gases here is different from those for the previous types. It exceeds 4%, and in some samples reaches up to 6% from the total hydrocarbon gases. The molecular composition of the gas mixture includes all set of alkanes, from C_1 to C_5, including hydrocarbons with isomeric chain structure (i-C_4, and i-C_5), and unsaturated gases, such as butenes and ethene. The main homologues are ethane and propane. TOC content varies from 0.45% to 0.78%. EOM is represented by “light” bitumoid.

All studied cores show that unsaturated hydrocarbons (ethene and propene) were presented in very small amounts or were not detected. This fact attests to maturation of the gas mixture. It worth to be noted, that iso-butanes are predominant over n-butane (except the Odessa mud volcano, where n-alkanes are predominant over iso-alkanes, which could suggest dispersal migration mechanism). Absence of correlation between TOC content and hydrocarbon gas concentration and distribution also allows concluding that hydrocarbon gas is allochthonous.

In all examined cores, uppermost part of the sediments is characterized by low methane concentrations. In different cores it occurs at different intervals (from 30 cm in BS-331G, the Kazakov mud volcano, to 85 cm in BS-320G, the TREDMAR mud volcano). We can suggest, that the low methane values can be associated with the zone of anaerobic methane oxidation, mediated by consortia of methanogens (Archaea), operated in reverse and sulphate reducers.

In the cores BS-314G, BS-325G and BS-336G seep-related authigenic carbonate crusts were found. The distribution of hydrocarbon gases in these cores demonstrates absence of any regularity. For instance, in core BS-314G decrease of methane is associated with the increase of C_{2+}, whereas in cores BS-325G and BS-336G rapid increase of methane, ethane and propane is related to decrease of butanes and n-pentane.

The $\delta^{13}C$ of methane ranged from -35‰ in some locations to -64‰ in others, indicating that the methane in these gas-venting sediments is a mixture of gases with a thermogenic and a biogenic origin.

Therefore, all of the above suggests the influence of fluid inflow in all of the studied cores. It is clearly indicated by the high concentration of methane and its homologues (C_{2+}), composition of C_{2+}, predominance of saturated alkanes over unsaturated ones, predominance of iso-alkanes over n-alkanes, isotopic composition of methane, fluorescent characteristics of EOM, and absence of correlation between hydrocarbon gases and TOC content.

LIPID COMPOSITION FROM GAS-RELATED SEDIMENTS AND MUD VOLCANIC DEPOSITS OF THE SOROKIN TROUGH, NE BLACK SEA. PRELIMINARY RESULTS

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We present the preliminary results of organic geochemical investigation of three mud volcanoes sampled by coring during the first part of the 11th Training-Through-Research cruise in the Sorokin Trough (Black Sea). The composition and distribution of lipids extracted from mud breccia is used to reveal the origin of organic matter as well as its alterations under gas-charged fluids.

The extractable organic matter expelled from mud volcanoes in the Sorokin Through is of mixed origin and has a variable maturity. At all of the studied sites, C_{23} to C_{33} n-alkanes with an odd-over-even carbon number predominance occur. The abundance of C_{29}, C_{31}, C_{33} n-alkanes attests for the presence of organic matter with significant amount of terrestrial admixture (Tissot and Welte, 1984). Organic matter from the Odessa and NIOZ mud volcanoes is immature (CPI=1.7-4). In contrast, organic matter from the Kazakov mud volcano is more mature: aromatic and cyclic biomarkers (napthalene, phenanthrene, etc.) are present in high concentrations in all samples. In particular, the hopanoids which have a predominantly 17α(H), 21β(H)- configuration, demonstrate higher maturity of the organic matter. The variable degree of organic matter maturity in the mud volcanoes of the Sorokin Trough possibly indicates a variable depth of erupted sediments.

The lipid extract from mud volcanic sediments contains abundant archaeal and bacterial biomarkers. In particular, in samples from the NIOZ mud volcano, the diether archaeol (bis-O-phytanylglycerolether), as well as isoprenoidal C_{30} mid-chain and C_{25} 1,2-diOH diols are present in high amounts. These compounds are common constituent of archaeal membranes and are especially prominent in methanogenic archaea (Tornabene, 1979). In fact, the common presence of elemental sulphur in cores suggests that sulphate reduction is an important biogeochemical process in surface sediments of the mud volcanoes.

These observations are consistent with the presence of the prokaryotic consortium of microorganisms responsible for anaerobic methane oxidation at cold seeps worldwide, including mud volcanoes (Pancost et al., 2000; Boetius et al., 2000). Anaerobic methane oxidation could thus be an important biogeochemical process also in the mud volcanoic sediments of the Sorokin Trough. This hypothesis will be further investigated by determining the isotopic composition of lipid biomarkers.

PORE WATER CHEMISTRY IN GAS HYDRATE-BEARING MUD VOLCANO DEPOSITS OF THE BLACK SEA

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Pore waters from the mud volcano deposits in the Sorokin Trough and in the central part of the Black Sea were analysed for their principal element composition. Sixty samples of pore water from 11 cores were collected during the UNESCO/IOC Training through Research cruise. Samples were centrifuged, filtered and stored in plastic vials at a temperature of 4^{o}C until analysis. Pore water was analysed both on board (Alk-, sum of Ca^{2+} and Mg^{2+}, and SO_4^{2-}) and in MSU laboratory (Cl^-). The onboard measurements then were repeated in the laboratory and the concentrations of Ca^{2+} and Mg^{2+}, and SO_4^{2-} showed no significant variations between the two sets of analyses. The standard titration technique was used for all of the determinations. The obtained data were compared with the chemical composition of near-bottom and pore waters in the pelagic sediments from the deep Black Sea (Valyashko and Gurskii, 1977).

A number of anomalies were observed in concentrations of the principal elements in pore water and in their distribution along the cores.

Chloride content in most of the sampled cores is generally lower than that in the overlying sub bottom waters. It is in the range from 227meqv/l to 372 meqv/l. Sharp decreases in chloride concentrations nicely fit to gas-hydrate bearing intervals.

With some exceptions, sulphate gradually decreases downwards until 0 meqv/l. The decrease in concentrations of sulphate within the upper 2 m of sediment is characteristic of the bacterial sulphate reduction processes. The alkalinity concentrations are variable and some are not in the ranges expected for the deep Black Sea water. The highest values of Alk^- up to 60 meqv/l were observed within the Kasakov mud volcano deposits. This may be due to advected pore water input and calcium carbonate co-precipitation.

Ca^{2+} and Mg^{2+} contents in the pore waters of most of the cores are significantly lower than in the sea bottom waters. The concentrations are ranging between 0 and 33 meqv/l and 0 to 79 meqv/l for calcium and magnesium respectively. A lowering of Ca^{2+} and Mg^{2+} concentrations should result from precipitation of calcium carbonate.

The chemical characteristics of the samples suggest that the gas hydrate formation is the main agent that controls the changes in the chemical composition of pore water within the studied mud volcano deposits of the Black Sea.

<u>Reference</u>:

Valyashko, M.G., U.N. Gurskii (1977). Zakonomernosti formirovaniya himicheskogo sostava ilovyh vod Chernogo morya. Nauka, Moscow (in Russian)

SHALLOW GAS IN THE RÍAS BAJAS (NW SPAIN): FLUID ESCAPES

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The Rías Bajas of Galicia are located on the passive Atlantic margin of south-western Galicia (NW Spain). The rías physiography shows a distinctive funnel shape in plan view, with the widths and depths decreasing landward. It is generally understood that rías formed by the drowning of the lower part of a river valley. The Rías Bajas trend at nearly right angles to the region's Palaeozoic basement structure. The basement is composed of Palaeozoic metamorphic and granite rocks cut by NE-SW, NW-SE and N-S trending faults.

The water depths within the rías range from 5 m in their inner parts, up to 55 m at the outer (southwest) entrances to the sea. The general pattern of grain-size distribution at the present seafloors of the Rías consists of mixed siliciclastic and skeletal gravels in both the outer areas and edges of the Rías. The central and inner parts of the Rías are dominated by clay and silt which have up to 10% organic matter content.

Grids of shallow seismic, 3.5 kHz sub-bottom profiler, echosounder and sidescan sonar data acquired in the rías have been the subject of detailed interpretation allowing the mapping of shallow gas accumulations and gas escape features. The various gas accumulations features have been classified into five types according to their specific seismic signatures: 1. acoustic blanket, 2. acoustic curtains, 3. acoustic columns, 4. acoustic turbidity, and 5. seafloor domes. Mapping of the distribution of these features has enabled several fields to be recognized, mainly at the central and inner parts of the rías. X-ray photographs of gravity cores and vibrocores have been used as direct evidence of the presence of gassy sediments. Originally gas filled pores can be seen as white elongated spots with larger deformation at the edges of the cores.

At the same time, six types of gas escapes features have been distinguished: 1. acoustic plumes, 2. cloudy turbidity, 3. pockmarks, 4. relict collapse structures, 5. dark patches, and 6. small seafloor mounds. Mapping of areas of gas escapes shows that these are located either above the shallower gas accumulations or in the outermost zones of the gas accumulations fields. In these areas the porosity of the overlaying facies would not be enough to constitute an efficient seal, allowing the gas to be released in those different ways.

Direct gas analysis is not available at present but the limited thickness of sediments (less than 100 m) and the shallow water depth (less than 50 m) excludes a thermogenic gas origin, and the presence of gas-hydrates. The required pressures and temperatures would not be reached in the rías. Thus, bacterial degradation of organic matter in shallow sediments is considered the most likely source for the gas in the Rías Bajas. As methane is the only gas found in significant quantities in marine sediments (Floodgate and Judd, 1992), it is considered likely that the gas here is principally methane.

The spatial distribution of the gas fields and gas escapes in the Rías Bajas is interpreted as evidence of control by the sedimentary facies, the porosity/permeability and the quantity of gas within them. Preliminary data (internal report) shows authigenic gypsum and microbiological activity related to the seal facies.

Worldwide concern for the warming of the planet through the 'Greenhouse effect' has highlighted the possibility that gas venting from the sediments beneath the oceans may be making a significant, yet not very well known, contribution to the atmospheric methane and CO_2 concentrations. Quantitative data on gas flux rates from seabed seepages has been forthcoming from only a few authors (Hovland and Judd, 1988; Dimitov, 1988; Judd, 2000). Calculations in the Ría de Vigo (García-Gil et al., in press) indicate mean density of 1.7 acoustic plumes per km^2 and 1.6 pockmarks per km^2. If we make the assumption that all the gas is methane, estimations of gas flux towards the water column range from 206.25 t/yr to 5907 t/yr and from 144 t/yr to 4135 t/yr towards the atmosphere from a territory of 176.4 km^2. Calculations in the Ría de Arosa (internal report, preliminary results of PGDIT00PXI Project) indicate mean density of 10.9 acoustic plumes per km^2 and 19.5 pockmarks per km^2. Similar estimations of gas flux towards the water column range from 670 t/yr to 19188 t/yr and from 469 t/yr to 13431 t/yr towards the atmosphere from a territory of 230 km^2. The volume of removed sediment due to the pockmarks would be 421 738 856 m^3.

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APPLICATION OF TIME-FREQUENCY ANALYSIS OF SEISMIC DATA TO SHALLOW GAS STUDY

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Shallow gas accumulations in sedimentary sequence often lead to observation of well-known hydrocarbon indicators on reflection seismic records, such as bright spots, acoustic voids, etc. Distinguishing of these indicators is mainly based on the amplitude analysis of the data. However, similar amplitude anomalies can also be caused by other reasons, not related to gas. For instance, constructive and destructive interference of several waves reflected from closely bedded boundaries may lead to significant local amplitude variations which can easily be confused with common hydrocarbon indicators. Thus, interpretation of a certain amplitude anomaly as being gas-related, ideally, shall be confirmed by estimating of some other parameters of the reflected signal.

Intrinsic attenuation of acoustic energy propagating through a sediment is proved to be much more sensitive to the type of pore fluid than to lithology. Thus, a local significant increase in intrinsic attenuation, when identified, may be considered as a reliable evidence for shallow gas accumulation. Since, attenuation is frequency dependant, its variations can be evaluated by analysing changes in frequency content of the reflected signal with the time.

In this paper, a method of time-frequency analysis of reflection seismic traces is proposed for shallow gas studies. The method is based on distribution of Cohen's class (Cohen, 1989). For each single trace, a time-frequency distribution is calculated, showing variations in the frequency spectrum of the signal versus two-way travel time. Since free gas in pore space of the sediment leads to significant increase in intrinsic attenuation, and higher frequencies are attenuated much more efficiently than lower ones, a calculated time-frequency plot must demonstrate a decrease in low-frequency components directly below a gas accumulation.

The method was tested on the seismic data collected during several TTR cruises (TTR-6, 1996; TTR-10, 2000; and TTR-11, 2001) within two areas in the Black Sea (Sorokin Trough offshore Crimea and central part of the Black Sea) and an area in the Marques de Pombal Fault Zone. In all of the areas, local high amplitude seismic reflections (bright spots) were observed. Both areas within the Black Sea are known for mud volcanism and extensive fluid venting though the seafloor, so interpretation of the bright spots there as being gas-related sounds very reasonable. In opposite, gas seepage within the Marques de Pombal Fault Zone has not been reported so far.

The calculated time-frequency distributions for the bright spots in both areas of the Black Sea have demonstrated distinct abrupt decrease in high frequencies, directly below the high-amplitude events continuing downwards. This fact can be considered as an evidence for intrinsic attenuation within the strata corresponding to the local high-amplitude horizons being significantly greater than that in the surrounding sediment. This confirms the hypothesis that these bright spots are indicating shallow gas accumulations.

In opposite, the calculated time-frequency distributions for the examined high-amplitude seismic event from the Marques de Pombal Fault Zone do not show any noticeable changes in the frequency content at the corresponding two-way travel times. This suggests, that this particular amplitude anomaly is most likely to be not related to gas and shall be explained by some other reasons, such as a local lithological change or a result of constructive interference of several reflections.

Reference:

Cohen, L. (1989) Time-Frequency Distribution - A Review. *Proceedings of the IEEE*, 77 (7): 941-980.

NATURE OF ENIGMATIC STRONG REFLECTOR ON MAK-1M SUBBOTTOM PROFILER RECORDS FROM THE BLACK SEA.
GEOPHYSICAL PROCESSING AND ANALYSES OF THE SUBBOTTOM PROFILER DATA

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During the 11th Training-through-Research Cruise (2001) an area of the Sorokin Trough in the Black Sea was studied. This survey followed previous TTR investigation of the same area that was carried out in 1996.

On the MAK-1 acoustic profiler records obtained in 1996, an unusual strong reflector was observed. Generally, it has a relief which does not follow the sea floor topography and which is discordant to the layering of the overlaying sediments. This reflection has a depth of 4.5-8 m bsf, and sometimes approaches the sea floor. Below the reflector the sediments are either acoustically transparent or opaque. It was suggested that the reflection could either be caused by local accumulations of migrating gases, or could represent a top of gas-hydrate bearing sediments (Ivanov et al., 1998).

In 1996, the acoustic profiler recorded only an envelope of the real signal that made impossible further geophysical processing/analysis of these data. However, the new data of 2001 contain not only the amplitude information but also information about phase of the signal. Thus, it was possible to process and analyse this record in a similar way as it is being done with reflection seismics, in order to try and determine the nature of the interesting reflection. The processing includes the following procedures: static correction, trim static correction, amplitude corrections, and deconvolution. As a result, it was made possible to analyse average amplitude, polarity and frequency content of the target reflection.

The polarity of the strong reflection was determined to be definitely positive, being the same as that of the seafloor reflection. This excludes the hypothesis of the gas front, strongly suggesting that the reflection cannot be caused by gas.

The analyses of the frequency spectrum of the target horizon demonstrate that the spectrum of this event is noticeably depleted in low-frequency components, relatively to the seafloor reflection. Since all natural frequency-dependant factors affecting wave propagation (intrinsic attenuation, scattering) lead to more efficient dissipation of higher frequencies, the only possible explanation of this result is wave interference. Thus, the examined acoustic event appears to be not a single reflection but a result of interference of reflections from several closely bedded boundaries.

Average amplitude of the target horizon was estimated to be twice greater than that of the seafloor reflection, suggesting that the reflectivity of this boundary is also approximately twice greater than that of the water/seafloor interface. Assuming the reflectivity of the seafloor to be 0.1-0.2, with knowing the approximate velocity and density of the sea water, and using an empirical relationship between acoustic impedance and velocity in marine sediments proposed by Gardner et al. (1974), it was estimated that the layer, underlying the strong reflector shall possess the velocity of 1900 – 2670 m/sec and bulk density of 1.44 – 1.96 g/cm^3. These values could indicate either gas-hydrate bearing sediment or coarse material like sand or gravel. If one assumes that the reflector does represent the top of hydrate bearing strata, its interfering character could possibly be explained by interbedding of thin gas-hydrated layers sandwiched between layers of normal sediment. However, in general, the elucidated interfering nature of the event, indeed, makes the estimated values of velocities and densities less reliable.

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VECTOR VISUALISATION OF SEISMIC SECTIONS. AUTOMATION OF PRELIMINARY SEISMIC INTERPRETATION

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Vector visualisation of seismic profiles is based on similarity method (Baranov, 1961; Rabiner and Gould, 1975). A seismic time-section is divided into small windows of equal size. For each window, a position of the largest similarity (correlation) between neighbouring traces is calculated and replaced by a vector. As a result, a seismic line is represented as an array of vectors corresponding to the continuous reflectors. The angle of a vector represents dip of the reflector at this particular point, while its magnitude is proportional to the correlation coefficient between the adjacent traces.

Calculating of the correlation function requires multiplication of amplitude values of adjacent traces. This procedure is not linear and the spectrum of the resulted correlation function appears to be significantly broader than that of the original seismic traces, with amplifying of noise. Apparently, this may lead to misidentification of the maximum of the correlation function. To avoid this effect, a band-pass filtering of the correlation function is needed, making its spectrum approximately as narrow as that of the original traces.

The software implementation of the method allows for choosing vertical and horizontal sizes of the widow as well as the maximum angle for which the correlation between traces is calculated. This provides the required level of flexibility to keep the operation robust when processing the data of various qualities acquired in areas of various geological environments.

The method was tested on the seismic data obtained during several TTR cruises. It has been proved to be useful for automation of the process of fast preliminary seismic interpretation (e.g. on board a research vessel). In certain cases it helps to resolve questions when tracing of seismic horizons is not very clear.

The method was implemented as a part of a commercial RadExpro seismic processing software package that is being developed at the Department of Seismics and Geoacoustics, MSU.

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METHANE-INDUCED PRECIPITATION OF AUTHIGENIC CARBONATES IN MUD VOLCANO DEPOSITS OF THE BLACK SEA

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During UNESCO/IOC TTR-11 cruise a number of authigenic carbonates was collected from mud volcano deposits in three areas of the Black sea at a water depth ranging from 800 to 2100 m.

Authigenic carbonates are distributed at different levels within the sediment sequence take a form of thin crusts and irregular concretions. A diversity of bacterial colonies found to be associated with authigenic crusts collected near the water-sediments interface. Localized groups of ostracods are also associated with these crusts.

Authigenic carbonates take a form of cemented mud breccia fragments, irregular crusts and thin flatten crusts. The last, which were collected near the water/sediment interface, contain a great number of holes around 0.5 mm in diameter, which are filled with mucus-like slimy-matter of bacterial colonies. Most of living bacterial colonies are concentrated on the bottom surface of the crusts, where they form bacterial mats.

Petrography, mineralogy and chemistry of all authigenic carbonates were studied. Microscopic examinations were made with the optical microscope on 12 samples. In thin sections most of the samples show porous structure. A variety of framboidal pyrite is disseminated through the carbonates. All samples are characterized by large amounts of organic matter concentrated inside porous.

X-ray powder diffraction analysis within the limited interval of Bragg angles was carried out with aim to investigate the qualitative and quantitative mineralogical composition of carbonate phase in carbonate precipitates. Morphology of authigenic minerals was examined with a scanning electron microscope (SEM). Carbon and oxygen isotope composition of authigenic carbonates was analysed according to the standard procedure described by McCrea (1950). The results are given in per mil ($^{0}/_{00}$) deviation from PDB standard.

The carbonate part of the crusts is dominated by a variety of high-Mg calcites. Low-Mg calcite, calcite and dolomite are present in the crusts in minor amount. The assemblage of high-Mg calcite has a complex composition. The amount of $MgCO_3$ in the crystal lattice is in the range from 9 to 18 mole%. SEM observation indicates that high-Mg calcites have serrated microtexture characteristic for bacteria-mediated precipitates. The dolomite is presented in the Ca-enriched forms with the composition $(Ca_{0,58}Mg_{0,42})(CO_3)_2$.

Generally, the carbonates are characterized by negative $\delta^{13}C$ values varying from -10.5 to -44.7 $^{0}/_{00}$. This suggests that carbonate precipitates are dependent at least partially on carbon dioxide delivered from anaerobic oxidation of methane.

In addition to general ^{12}C enrichment of carbonates, an abundant of bacteria biofilm fragments, which was found in carbonates during SEM observations indicates a strong imprint of bacteria in carbonate aggregation. $\delta^{18}O$ values of carbonates ($-0.2\,^0/_{00}$ to $+1.6\,^0/_{00}$) are similar to the present Black Sea water isotopic characteristics.

The obtained data show that mineralogical assemblage of studied carbonates is dominated by high-Mg calcite with variable amount of $MgCO_3$ in crystal lattice that is typical for cold seep authigenic carbonates. Large variations of carbon isotope values in studied carbonates may reflect to different rate of methane oxidation as well as variability of bacterial communities, which are able to induce precipitation of carbonate. A diversity of bacteria in cold seeps is strongly dependant on chemical composition of fluids. We suppose that this can be reflected in isotopic characteristics of precipitated carbonates.

Both, mineralogical and isotopic data show no evidence of gas hydrate influence on the precipitation of authigenic carbonates in studied sediments.

CARBONATE CRUST STRATIGRAPHY FROM THE BLACK SEA

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Part of a recent survey of the Training through Research Programme (TTR-11) carried out investigations in the Black Sea. One of the aims was to retrieve samples from previously studied areas characterised by the presence of hydrocarbon fluid seep structures. Three main areas were explored: (1) the north-western section of the Black sea, (2) the central part of the Black sea, and (3) the Sorokin Trough. In all three study areas, three main units were recovered that characterise the pelagic depositional processes in the Black Sea: Unit 1 (thin laminations of alternating coccolithic ooze, sapropelic laminae and clayey sediment), Unit 2 (thin laminations of sapropel), and Unit 3 (laminations of terrigenous clayey material). Carbonate cemented crust samples in all three units were retrieved from the different areas. Detailed petrographic studies of the crusts within these different lithologic units of the sedimentary column allow a new classification of different types of carbonate crust.

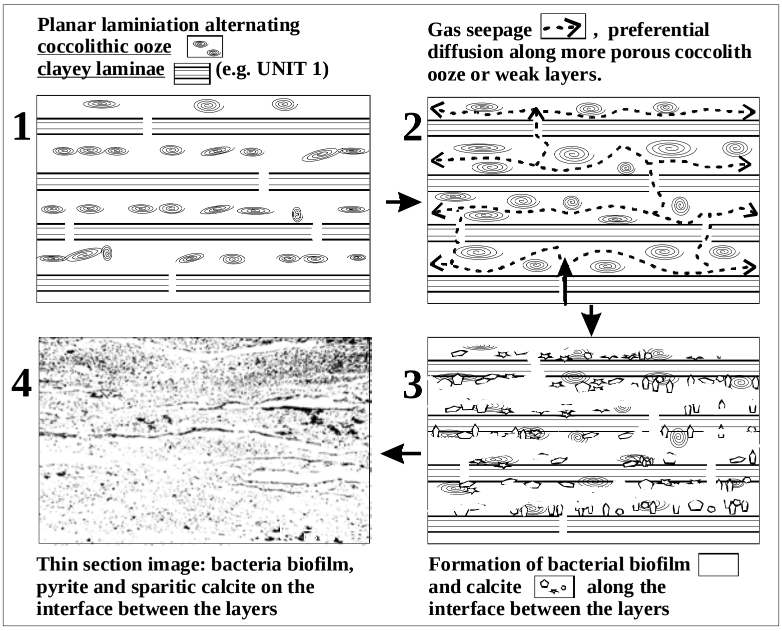

Fig. 1: Suggested model for layered crust formation

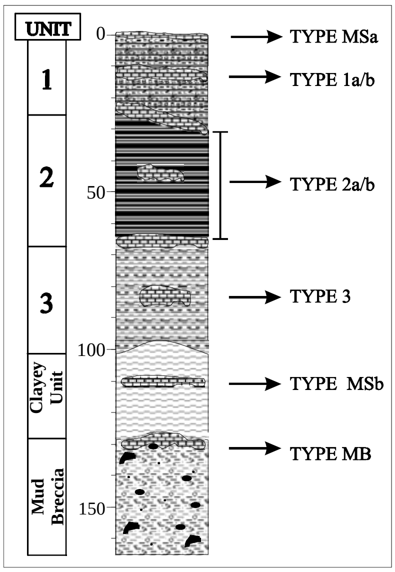

Fig. 2: Combined sequence of carbonate crusts.

Five main types of crust were recognised. These can be further subdivided into subtypes. Type 1 is composed of cemented Unit 1. Type 1 may be either porous and poorly cemented (Type 1a) or less porous and well cemented (Type 1b). Type 2 consists of thin and dark, and generally well-cemented sapropelic (Unit 2) layers. They may be either porous and poorly cemented in the central part of Unit 2 (Type 2a) or well-cemented crust from either the upper or the lower part of the unit (Type 2b). Type 3 is finely laminated, cemented Unit 3. Type MB includes poorly cemented fragments of mud breccia retrieved in Area 3. Type MS shows light-coloured and micritic slabs characterised by higher (Type MSa) and lower (Type MSb) internal porosity, found on the sea floor and in cores respectively.

Samples that show layered structures (Types 1-3) vary in lithification and porosity but they all share common characteristics. Micro- and macro-vesicles were observed on the external surfaces of the crusts and within them. In some instances vesicles crosscut the planar lamination and are interpreted as evidence of vertical seepage of gas. A thick bacterial mat was observed on the layers and coating the vesicles. Electron microscopy shows bacterial biofilm at the interfaces between sub-millimetric laminae in the crusts, frequently associated with coccolith rich layers (Type 1). Commonly, larger calcite crystals are seen surrounding pores or vesicles, where calcite crystals had more space to develop suggesting enhanced carbonate precipitation due to hydrocarbon seepage. Framboidal pyrite was pervasively distributed through the carbonate crusts, but was mainly observed at the interfaces between layers and intimately associated with the bacterial biofilm. This suggests that the pyrite might represent an early diagenetic product linked with the activity of sulphate-reducing bacteria in the anoxic sulphidic zone. Also the fact that flat fragments of gas hydrates were recovered on the interface between layers, confirms that the gas (either saturated in pore fluids or as free gas) preferentially moves horizontally between the layers. The suggested model of layered crust formation is sketched in Fig. 1.

Cemented mud breccia (Type MB) was retrieved form the Kazakov mud volcano in Area 3. This type of crust shows cement with calcite crystals larger than those observed in the other crusts. We suggest that the slabs Type MSa (retrieved after underwater video observations) could form a “buffer“ layer for the gas seepage, favouring the precipitation and growth of authigenic carbonate in the underlying mud breccia unit. The underwater TV survey performed well below the oxic/anoxic interface zone shows smoothed slabs of crust Type MS most likely moulded by the strong currents. The retrieved samples show absence of sedimentary structures, high Ca content, and have no common features with the other described cemented units. This suggests that this type of crust precipitated directly on the sea floor in anoxic conditions. A combined sequence of carbonate crusts is summarised in Fig. 2.

Oxygen δ^{18} O and carbon δ^{13} C stable isotope analyses were also performed. Type 1 crust, retrieved from Area 1, shows an isotopic signature strongly depleted in ^{13}C, as light as –46‰, whilst a single Type MS crust shows negative δ^{18} O and heavier carbon values. Area 2 comprises two stations from the Vassoevich mud volcano. Although the crusts recovered in both the cores are of different types, they all show moderately negative δ^{13} C values (typically around –20‰). The two trends seen in area 1 and 2 are both seen in Area 3. One group of sampling stations reveal δ^{13} C values around –20‰, whilst the other group shows values as light as -45‰. The first group of data suggests a bacterial oxidation of organic matter via sulphate reducers and the second indicates a bacterially mediated oxidation of methane coupled with sulphate reduction. Also, the variety of values from Area 3 can be grouped according to their geological setting. Therefore it can be generally stated that crusts retrieved from the same sampling stations, or from adjacent settings, share common isotope values regardless of type, as opposed to a pattern in which individual crust types share similar values at different localities.

CARBONATE CHIMNEYS COLLECTED IN THE GULF OF CADIZ: A PETROLOGIC AND ISOTOPIC ANALYSIS

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A number of carbonate crusts and chimneys were sampled during the TTR-11 cruise in the Gulf of Cadiz. Samples can roughly be subdivided in two main groups, namely: group I with samples having an oxidized red brownish coloured exterior and group II with samples without any sign of iron-oxidation having a pale white colour. The difference between these groups can be explained either by a difference in age between oxidized and non-oxidized samples or by the oxidation of organic material inside the carbonates.

Microscopic analysis reveals that in the carbonate matrix often quartz grains characterized by sharp edges and cracks occur. Feldspar detritals have not been detected. The maximum size of the quartz grains is 100 m. The latter features indicate a limited transport of these grains from a nearby provenance. The overall distribution of these detritals in the carbonate matrix is very irregular with regions containing many of the detritals and regions devoid of them. Possibly this relates to bioturbation. The matrix is fined crystalline (<15µm in size) with bioclasts (mainly foraminifera and thin-walled shall fragments). Calcite and dolomite crystals are detected in the thin sections, contrary to aragonite. Cracks locally occur, which are inclined (±45°) with respect to the chimney walls. In thin-section cement phases of different sizes occur in cracks and holes, but in the matrix no real indications of cements were found. These cements and calcite matrix is dark to dull cathodoluminescent, which might relate to the ferrous nature of the carbonate. However dark orange luminescent phases locally occur. Yet the quartz crystals give a blue luminescence (possibly indicating a magmatic origin). The dolomite rhombs, maximum 50µm in size, are red luminescent. However, it is not unlikely that some dolomite phases possess a dull luminescence.

AAS trace element analysis revealed high Sr concentrations (0.5 wt%) in some samples, which suggests that aragonite might be present in some samples. The Fe and Mn-concentration varies between respectively 1.1–9.7wt% and 0.5-1.5wt%. XRD proves that dolomite is more abundant than calcite. Noteworthy is that the dolomite samples are iron-rich (till 9.58 wt%), which might explain the low signal of Mg in SEM-EDX analysis.

The cement is covered with a brownish substance, rich in iron and showing graduation from a dark brown at the upper side of the sample to a rather greybrownish colour at the interior side of the sample. The stable isotopic composition of the matrices varies between -27‰ and -46‰ for carbon and from 3.90‰ to 6.30‰ for oxygen. The depleted values of carbon support oxidation of methane. The positive oxygen values are even more interesting. Since these values are not in equilibrium with seawater they either indicate the biological fractionation by bacteria or/and the involvement of hypersaline. Involvement of hydrates in the seeping of methane is less likely.

In some thin sections of chimneys framboidal phases, probably pyrite, were present which would be suggestive for sulphate reduction (SR). The presence of (SR?)-Bacteria are also supported by SEM-analysis. The matrix consists of minute cauliflower crystal aggregates. Most of the crystals display a knobbly, rounded to elliptical outline, 1-2 micron in size. A lot of flakes were noticed in the matrix, which at first glance looked to be flat, but which turned out to consist of these micron-sized crystal aggregates. Different stages of bacterial involvement, i.e. from pure biological to pure crystalline, sometimes grouped, could be distinguished. Here also semi-dumbbell-like features occur. Peculiar feature is also the presence of flat hexahedral calcite crystals that were loosely attached to the matrix.

MINERALOGY AND GEOCHEMISTRY OF CARBONATE CHIMNEYS FROM THE GULF OF CADIZ: PRELIMINARY RESULTS

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During the TTR-11 cruise (August/September 2001), the area south and southwest of the Guadalquivir Diapiric Ridge was intensely surveyed with seismics, side scan sonar (MAK), underwater TV and sampling. This area (water depth between 800 and 1200 meters) is characterized by a very strong backscatter on the available sidescan sonar images (Gardner, 2001) and a very irregular seafloor, with a large amount of dome-like features (mud diapirs and mud volcanoes) and sedimentary structures associated with the outflow of the Mediterranean water (MOW). Based on the data and samples collected during the TTR-11 cruise (TV lines and sampling), complemented with data from the ANASTASIA 2000 and 2001 cruises (Diaz-del-Rio, 2001) it seems that this area corresponds to a large field of carbonate chimneys and crusts, which appear to be responsible for the strong backscatter observed on the sidescan images.

Dredge profiles on the Iberico dome and west of this structure, on the main channel of the MOW, yielded a large amount of carbonate slabs and chimneys. These consist essentially of intrapelbiomicrite. Petrographic and XRD shows that their mineralogical composition consists mainly of dolomite, calcite, quartz, feldspar and clays. Bioclasts of plantonic foraminifera (globigerinoids), ostracods and peletts are observed. Iron and manganese oxides are present and the cement is essentially biomicrite.

In different samples from the same chimney a variation on the dolomite/calcite ratio is observed from the interior to the external part of the chimney. Values of dolomite (by chemical analysis) show a variation from 47% in the interior to 17 % in the exterior. As regards $Si0_2$ (19-16%), Al_2O_3 (4-3%) and Fe_2O_3 (5-7%), the variations observed are not significant.

METHANE-RELATED AUTHIGENIC CARBONATE FORMATION: MOLECULAR, MINERALOGICAL AND ISOTOPIC EVIDENCE. GULF OF CADIZ, NE ATLANTIC

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During TTR-10 cruise an area of active mud volcanism situated in the Gulf of Cadiz was studied. One of the newly discovered structures, the Student mud volcano was investigated using TV-controlled grab sampler. Underwater TV record shows a variety of massive crusts and irregular edifices. They vary from localised blocks to semi-continuous crust pavements up to several decimetres in thickness.

Herein we report the results of comprehensive study of two carbonate crusts and two sediment samples collected from the Student mud volcano. The main interest was directed towards evaluation of the factors responsible for carbonate precipitation controlled by hydrocarbon gas seepage in this location. In order to find out diagenetic stable fingerprints for authigenic carbonate formation, the biomarker patterns were compared with stable isotope data of organic compounds and carbonate cement, as well as with petrographical and mineralogical characteristics of these carbonates.

Authigenic carbonates (AT-239Gr-1 and AT-239Gr-2) occurred in the form of irregularly shaped crusts, which are fragments of carbonate-cemented layer. The carbonates are yellowish in colour, indicating an oxygen-rich environment. Based on molecular, petrographic and mineralogical compositions of the crusts, samples were divided into two types (referred as Type I and Type II).

The Type I carbonatesare lithified limestones consisting of conglomerate of centimetre-sized rock fragments of carbonate lithology immersed in fine cement. The carbonate contains numerous rock clasts and bivalve shells. The mineralogy of the cement is composed by high-Mg calcite with various amounts of MgCO3 in lattice (from 13 to 15 mole%), calcite and minor amount of aragonite. Aragonite forms fibrous crystals in cavities inside the shell fragments.

The Type II carbonates are limestones, showing petrographic characteristics similar to those of Type I but this carbonate is poor lithified. The cement of the carbonate is dominated by high-Mg calcite (with 15 mole%). This carbonate contains small amount of dolomite (less then 13%), which was found near the top surface of this crust. Dolomite is characterized by significant disordering of crystal lattice that is typical for gas-related precipitates. During SEM observations dolomite was observed in the form of small rhombic crystals with size up to 10µm. Framboidal pyrite is disseminated through the carbonate.

Both crusts exhibit negative carbon isotope composition, which is ranging from –15.8‰ to –18.37‰ (Type I) and from –20.78‰ to –23.25‰ (Type II). The $\delta^{18}O$ values of the carbonates vary from +3.03‰ to +5.46‰.

Biomarker study of two carbonate crusts revealed different features of their lipid composition and distribution. ^{13}C depleted archaeal lipids, [tail-to-tail linked C_{25} isoprenoid 2,6,10,15,19-pentamethylicosane (PMI), and its C_{20} counterpart 2,6,11,15-tetramethylhexadecane (crocetane)], occurred in both crusts. The carbonate crust of Type I is characterized by a high content of crocetane (up to 78% of relative abundance). In Type II its content is twice lower. Carbon isotopic compositions of crocetane are depleted in ^{13}C with values ranging from –40.4‰ to –98.7 ‰. The lightest one is characteristic for the Type I carbonate. PMI, indicative of methanogenic and anaerobic methane-oxidizing Archaea, has a stable carbon isotope composition as low as –91.2‰ for Type II and –94.3‰ for Type I. In Type I carbonate crust the low δ-value was also observed for unsaturated n-$C_{24:1}$ (-88.6‰). This compound occurs here in similar relative content as PMI, and its source is difficult to explain.

One of the distinct features of these carbonates is the occurrence of isotopically light hopanes of ββ and βα series. The $\delta^{13}C$ values vary from –40.6 ‰ to –68.3 ‰, whereas normal sedimentary lipids usually depict $\delta^{13}C$-values around -30‰. Relatively light isotopic composition of these hopanes supposed, that the carbon source used by hopane-formed biota could partially derived from migrated methane. The presence of hopanoids may be attested to aerobic methanotrophs, and suggests in certain degree aerobic oxidation of methane. In addition, significant content of straight-chain n-alkanes were observed. Enhanced abundance of odd carbon numbered n-alkanes in the C_{23}–C_{33} carbon number range may be indicative of a land plant contribution. The combined results showed that carbon released from methane oxidation was partially involved in precipitation of carbonates.

Anaerobic methane oxidation in both carbonate crusts is traced by isotopically depleted archaeal lipids (crocetane and PMI). However, isotopic data demonstrates that anaerobic methane oxidation was performed by diversity of microorganisms. Crocetane and PMI from Type I, and PMI from Type II carbonates are in the same range of isotopic values, which may indicate one principal carbon source derived from methane of the same origin. Obtained data also suggest that carbonate formation was performed not only by anaerobic, but also by aerobic methane oxidation processes, e.g. the precipitation is started under anoxic conditions and continued when environments changed towards oxyc-inreached one. This fact is confirmed by difference in isotopic composition of carbonates crusts, which accounts to 8‰. The assumption also could be supported by presence of diageneticaly formed hopanoids, which have not been found yet in obligate anaerobic microorganisms (V. Thiel et al., 2001), and may be considered as aerobic methanotrophs.

MUD VOLCANISM, CARBONATE CHIMNEYS AND GAS HYDRATE STABILITY IN THE GULF OF CADIZ: ARE SEA-FLOOR METHANE FLUXES MODULATED BY EPISODIC TECTONIC AND CLIMATE/OCEANOGRAPHIC EVENTS?

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Since 1998, four oceanographic cruises aboard R/V "*Cornide de Saavedra*" and "*Hesperides*" as part of the TASYO project, have allowed to discover a large number of deep seafloor structures related to hydrocarbon seeps throughout the Iberian Margin of the Gulf of Cadiz. A large variety of methods was used: EM12 multibeam echosound, parametric echosound (TOPAS), single (sparker) and multichannel seismic, gravimetry, magnetism, heat flow probes, BENTHOS underwater camera, dredging and coring.

In the Gulf of Cádiz, sub-circular sea-floor features may be defined as mud volcanoes, mud cones and crater-like collapse structures, as a function of their morphology, seismic expression and sedimentary nature of the gas-related deposits. Three morphological types of mud volcanoes has been identified: single circular (*Anastasya*, *Pipoca*, *Társis* and *Gades*), oval (*Faro*, *Almazán* and *Cibeles*) and multicone (*Hespérides*), all bearing mud brecia deposits with obvious indications of gas saturation: degassing structures, a strong H_2S smell and chemosynthetic fauna (such as Pogonophora tube worms). Single circular cones show gentle slopes ranging between 3-7º whereas oval and multicone has moderate slopes of 9º-12º. Four mud cones with steep flanks, up 25º, with extensive presence of pipe-like chimneys have also been discovered (*Ibérico*, *Cornide*, *Arcos* and *Coruña*). Dolomite chimneys interpreted to be cemented conduits, which results from methane-enriched fluid expulsion showing a wide variety of shapes and sizes, that point out to variability in the methane-enriched discharges.

The deep flux of methane is related to both along-slope gravity gliding and lateral tectonics of the shale/salt units of the olistostrome/accretionary complex units (Vazquez *et al*., 2001). Multifold seismic provide geometric evidence for shale/salt tectonics and related hydrocarbon seepage on the sea floor. In this way, overpressure compartments generated beneath salt/shale wedges and diapiric ridges, providing avenues for hydrocarbon fluids and fluidised sediments and fluxing upwards through contractional toe-thrust structures, has been suggested as a mechanism causing seepage on seafloor (Somoza *et al*., 2001). Otherwise, massive and episodic dissociation of gas hydrates of these over-pressured gas stored in permeable sediments caused by warming of the Mediterranean Outflow Water (MOW) might be the mechanism for the widespread and episodic shallowest gas-charged fluid venting on the sea floor and the collapse crater-like structures (Gardner *et al*., 2001).

We suggest that episodic hydrocarbon seeps are probably modulated by tectonic and climate/oceanographic factors in response to: (a) NW directed convergence between Africa and the Eurasian plates, (b) gravitational advance of salt/shale wedges, (c) increase of contourite/shelf wedge sedimentary loading and (d) destabilisation of gas-hydrate by episodic warming under the influence of the MOW undercurrent.

The TASYO project is funded by CYTMAR 98-0209. Web site of the TASYO project is located at http://tierra.rediris.es/TASYO

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DETECTING GAS HYDRATES - TOMORROW'S FUEL OR TODAY'S RISK?

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Gas hydrates are ice-like compounds that lock up vast amounts of methane gas, within the seabed, on the margins of the world's oceans and seas. This methane gas has the potential to be a clean energy source for the future. They are also assumed to play a major part in large-scale slope failures of the sea floor, which have been thought to cause devastating tsunamis in our recent past. This is due to gas hydrates only being stable under certain conditions, which can be altered by global warming or increasing industrial activities by oil companies. However, to assess the potential benefit or hazard that gas hydrates may pose a clear understanding on the extent and distribution of these hydrates are required. Therefore, as part of a European Research Programme (HYDRATECH), a specially designed laboratory apparatus (Resonant Column) is to be constructed to simulate the conditions that allow gas hydrates to be grown artificially. The resonant column will also allow experiments to be conducted to characterise the seismic signature of sediments containing gas hydrates. The results of the experiments will allow scientists to better identify and estimate the use or threat that gas hydrates may pose.

Deep-sea depositional systems and modern analogues

SOME CONTROLS ON SEDIMENTARY ARCHITECTURE ALONG THE NORTHEAST ATLANTIC CONTINENTAL MARGIN

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A fundamental change in style along the northeast Atlantic margin occurs north of Ireland and is associated with the presence of ice. Fast flowing ice streams reaching the shelf edge cut cross-shelf troughs and leave glacial fans on the slope. The fans are built of huge numbers of stacked, elongate debris flows and the Bear Island Fan is one of the worlds largest. These glacial debris flows are mainly sticky clay. Between the glacial fans, and in a few cases on the fans, there are giant submarine slides. The resultant debris flows are different in shape and composition from the glacial debris flows, being much wider and including large blocks, up to kms across in some cases. Thick turbidites deposited by the infrequent slides are found on the basin floors beyond the debris flows. From the Porcupine Seabight northwards the margin is strongly modified by along slope currents at several depths. The giant slides tend to have failed in areas of contourite sedimentation rather than in areas of ice transported sediment.

Off northeast Greenland there are no recognised glacial fans or giant slides. Instead there are extensive networks of small tributary channels, and sediment waves oriented along the contours. Because of the colder ice cap, resulting in less mobile ice than on the European margin, the northeast Greenland shelf was not crossed by ice-sheets during the last full glacial. Instead the melting and freezing of sea-ice caused dense water production and this may account for the unusual sedimentary style.

The margin from west of Ireland and south to west of the Atlas Mountains is dominated by submarine canyons. At the foot of the canyons are sandy fans and beyond are basin plains. The canyons are probably cut by turbidity currents, caused by delivery of large quantities of sediment to the shelf edge through river channels fed by meltwater and high rainfall, at times of low sea level. Most canyons are inactive except where there is transport at the present day to the shelf edge. This includes the northern Bay of Biscay and areas of narrow shelf such as off the Atlas Mountains and near Lisbon.

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GEOLOGICAL STRUCTURE AND DEVELOPMENT OF THE BRANCHING CHANNEL SYSTEM SITUATED ON WESTERN MARGIN OF IRELAND ACCORDING TO SEISMIC DATA

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This work is a continuation of investigation, which was done after 10 cruise of R/V Professor Logatchev in the year 2000. Seismic profiling in western continental margin of Ireland was carried out in 3rd leg of that cruise. 18 profiles were shot to study branching channel system, situated in this area. As a result of interpretation 4 main seismic units were identified and described.

The aim of this paper is to compare this study with the NIOZ seismic profiles, situated in the area. These profiles were acquired during the cruise of R/V Pelagia in 1999. The data were interpreted by M. Stocker (1998).

The central frequencies of the *Logatchev* and *Pelagia* seismic systems are nearly the same (about 100 Hz), which allow us to easily correlate the reflectors on different profiles.

The comparison of the NIOZ profiles from the study area and to the south and north from it showed some interesting details. The reflection pattern from the C20 reflector, defined by M. Stocker to the seabottom on the profiles, situated in study area is differs from the other parts of Rackall Trough. And this happens only in the area of investigation, while the seismic pattern to the north and to the south from it is nearly the same. But main reflectors, defined by M. Stocker can be traced in the study area, and these reflectors are connected with global changes of deep-sea water circulation in Rackall Trough (Stoker 1998). So it can be suggested that this channel system started to functioning after the C20 reflector age (early Miocene) and sedimentary processes in the study area differed from the areas without channel activity, but global changes of sedimentary processes influenced on this area too.

Also it was made a comparison of several profiles situated on the slope. It is clearly seen there that the depth of channels now is much smaller than it was in relatively modern time. It means that channel activity was much higher. Probably these palaeovalleys can explain presence of discontinuous reflectors in almost all profiles.

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SAND LOBES IN THE GULF OF CADIZ: TOWARDS BETTER UNDERSTANDING OF CLASTIC RESERVOIR HIGH-RESOLUTION ARCHITECTURE

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Several high-resolution studies, including three TTR cruises, conducted recently in the Gulf of Cadiz provided new insights on the complex sedimentary regime of the area strongly affected by the fast flowing Mediterranean Undercurrent. A major portion of the undercurrent sweeping the upper continental slope has a geostrophic behaviour and flows along contours. Another, minor, portion of the Undercurrent, being ageostrophic, descends downslope and forms several well-marked channels. Coarse sediments are funnelled into the channels and transported by the bottom current down a gentle gradient to a depth of about 1300-1400 m. This coincides with the depth range where, according to oceanographic measurements, the Undercurrent lifts off the seafloor. Below this depth bottom currents transport little or no sediment. Significant sediment accumulations, with sand in particular, are being built out to this point. Below here the increase in slope gradient is sufficient to allow initiation of gravity driven sedimentary flows. As a result, 3 depositional lobes have been formed in the area. They are remarkably similar in size and morphology to each other being about 3 km wide, up to 7 km long and few tens of meters thick and are fed by narrow sinuous channel-like features. Long range sidescan sonographs show that several sub-lobes can be identified within each of the lobes reflecting their complex structure formed by episodes of activity of different age. Gravity cores and piston cores have recovered up to 8-m of fine-medium massive sand with scattered mud clasts.

A high-resolution deep-towed sidescan sonar survey, conducted during TTR-11 allowed resolution of some details of the lobe morphology on a meter scale. There is a complex bifurcating system of multiple, narrow sinuous channels. The system reveals a gradual transition from erosional to aggradational forms which are primarily controlled by slope gradient. The channels are mainly erosional within a feeder zone developing on a steeper slope and become aggradational, with well-developed channel-levee complexes on the lobes, where the seafloor flattens. Bottom sampling confirmed that these channels are conduits through which sand is funnelled out into the basin even at the present time. The studied sand lobes have much in common with deep-sea depositional lobes described from outcrops (e.g. Tanqua Karoo, South Africa) as well as closely resembling features identified on commercial 3D seismic datasets. This allows us to consider that we are dealing with a modern, and still active, analogue for deep-sea clastic reservoirs. Resolving its architecture and facies distribution with high resolution should be useful for the modelling of the producing reservoirs.

THE MAIN ACTIVE DEPOSITIONAL PROVINCE OF THE CONTOURITE DEPOSITIONAL SYSTEMS OF THE GULF OF CADIZ: A QUATERNARY RECORD OF PALEOCEANOGRAPHIC AND TECTONIC INFLUENCES

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The Contourite Depositional System of the Gulf of Cadiz is located mainly in the middle slope of the northern margin. It is composed of several morphosedimentary provinces, but, in the central and NW sectors, depositional processes are dominant. Thus, the Faro-Albufeira contourite system represents the main active depositional province inside of a major depositional system, and it was recently studied in detail by Llave et al. (2002). A morphosedimentary and Quaternary stratigraphic analysis of the Faro-Albufeira drift system has been realized (Fig.1) by the interpretation of a broad database including: 1) bathymetric and geomorphological data; 2) high-resolution seismic data, obtained during the last 5 years.

The Faro-Albufeira contourite system is composed of 5 morphological elements which are, from the upper to the middle slope: a.- Erosional surface on the upper slope; b.- Alvarez Cabral Moat; c.- Mounded elongated and separated drift of Faro-Albufeira; d.- Sheeted drift of Faro-Albufeira and Bartolomeu Dias, and e.- Erosional features over the drift. The Faro-Albufeira contourite system is an upslope migrating deposits (separated drift), developed parallel to the margin and laterally associated with a flanking boundary channel (the Alvarez Cabral moat) that depicts the zone of Mediterranean Outflow Water (MOW) acceleration and/or focussing. The consequent erosion at the right border and deposition at the left border are produced in this sector. The basinward prolongation of the mounded drift is a dissected sheeted drift system occupying a large part of the basin floor where the MOW is more widely spread out.

Two major high-order depositional sequences have been recognised in the Quaternary sedimentary record of the contourite deposits (Fig.1), named Q-I and Q-II, composed of eight minor high-order depositional sequences (from A to H). The same trend is observed in every major and minor depositional sequence, especially in the separated drift within Q-II formed by: a) transparent units at the base; b) smooth, parallel reflectors of moderate-high amplitude units at the upper parts; C) erosive continuous surface of high amplitude on the top of reflective units. There is an important change in the overall architectural stacking of the mounded contourite deposits (Fig.1) from a more aggrading depositional sequence (Q-I) to a clear progradational body (Q-II). We suggest that Q-I & Q-II constitute high-order depositional sequences related to a 3rd-order cycle at 800 ky separated by the most prominent sea-level fall which occurred 900-920 ky ago at the Mid Pleistocene Revolution (MPR). The discontinuity has been correlated with the onset of asymmetric 4th-order sea-level cycles of 41 ky (obliquity cycles) before the MPR and the onset of the 100 ky eccentricity orbital cycles.

In more detail Q-I and Q-II can be divided into 4th-order asymmetric sequences of approximately 400 ka (Q1–Q4), 200 ka (A to H) and 100 ka. The major high-order depositional sequences (from A to H) are separated by erosive discontinuities, which are associated with sea-level falls produced by the most prominent Quaternary events.

In the middle slope, the Faro-Albufeira contourite system has a syntectonic development with diapiric intrusions and the Guadalquivir Bank uplift. This evolution affected the overall southern sheeted drift from the A to F depositional sequences, but G and H are less affected with an aggrading stacking pattern that overlaps the older depositional sequences of the Guadalquivir Bank uplift and diapiric intrusions.

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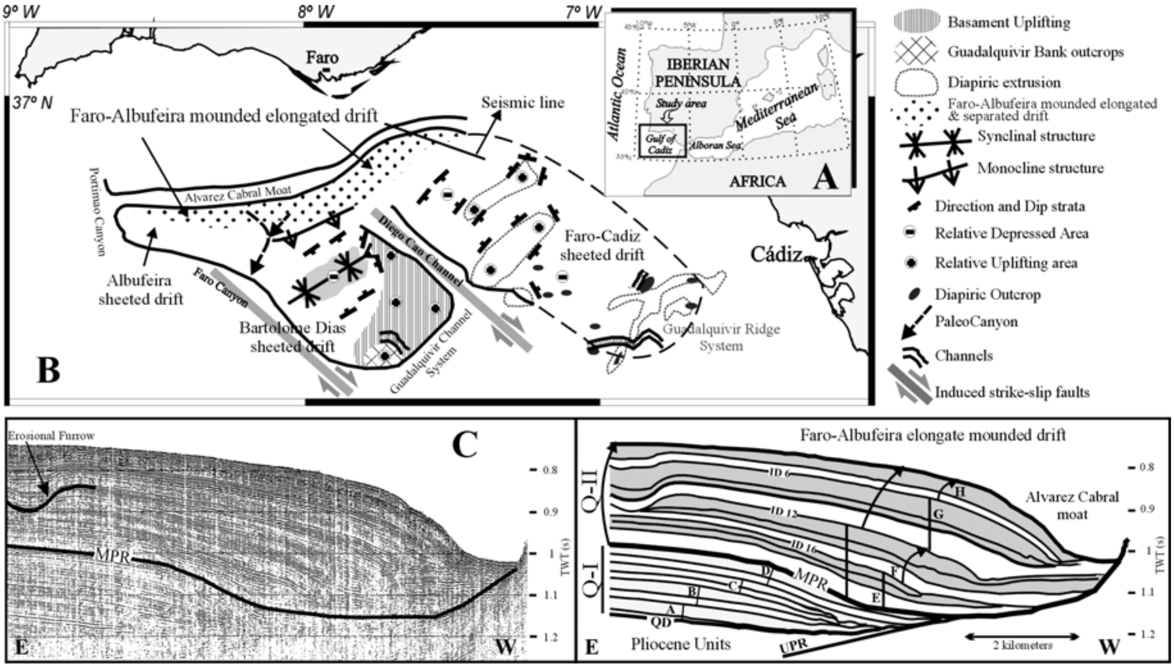

Fig. 1: A) Location of the study area.
B) Morphosedimentary sketch of the Faro-Albufeira *contourite system*.
C) Sparker seismic profile and drawing line in the Faro-Cadiz *elongate separated mounded drift*.
In grey the reflective seismic facies and in white the transparent seismic facies.

Hydrothermal and hydrogenous supply of elements to the sea floor

SERPENTINITE-HOSTED HYDROTHERMAL ACTIVITY AND METHANE PRODUCTION ON THE MID-ATLANTIC RIDGE, SOUTH OF THE AZORES

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Following up on the results of segment scale geology and plume detection studies, (German et al., 1996, Bougault et al., 1998) diving operations were conducted during the Flores cruise (1997, Mast-3 AMORES Project, European Union) to find the Rainbow field and to study various aspects of hydrothermal processes on the MAR between 36ºN and 37ºN (Fouquet et al., 1998).

Rainbow chimneys and massive sulphides are enriched in Cu, Zn, Co and Ni compared to other sites in basaltic environments. The Rainbow hydrothermal site is hosted by serpentinites, which compose the Rainbow crest. There is a sulphide stockwork in serpentinites. Basalts are restricted to a thin veneer to the E of the Rainbow site, covering the serpentinites. These consist mostly of coarse- and fine-grained, porphyritic and non-porphyritic serpentinites with well-developed mesh textures. The main components of the Rainbow serpentinites are serpentine group minerals (antigorite/lizardite + fibrous chrysotile in late fractures), magnetite (± chromite) and aragonite in late veins. Bastite phenocrysts are present in some specimens. The lack (or scarcity) of brucite suggests that most serpentinisation took place at temperatures between 350-500ºC.

The presence of a thin basaltic cover, without intervening abundant gabbros (or sheeted dykes), suggests that magmatic productivity became very low, or ceased, in this part of the ridge segment. In particular, magma chambers may be minor or absent. Thus the Rainbow hydrothermal site may result from hydrothermal circulation through peridotites/serpentinites, possibly driven, at least in part, by heat extracted directly from these rocks, not only from their cooling, but also from the exothermic serpentinisation process. These data have interesting consequences on the evolution of the oceanic crust (Barriga, 1999).

The Saldanha site (Barriga et al., 1998) is an area on the summit of a nearly 700-metre elevation, located on the southern tip of the FAMOUS segment in a second order discontinuity cutting the MAR south of the Azores. It was selected for detailed investigation through combination of new high-resolution multibeam bathymetry, sidescan sonar, dive data, and strong CH_4 hydrothermal anomalies (Bougault et al., 1998). These indicated discharge associated with serpentinisation of an ultrabasic diapir in the area. Mount Saldanha was identified as the likely candidate. During the Flores cruise, CTD / Rosette / Minirosette determinations confirmed the large production of methane associated with the site. Nephel and transmissometer anomalies, although present, are distinctly smaller than for example at Rainbow (German et al., 1996). During the Saldanha cruise a detailed diving survey of Mount Saldanha enabled discovery of a summital area of discharge of diluted, warm fluid. The venting orifices, through sedimentary ooze, are lined with hydrothermal precipitates and bacterial mats, but no protruding structures were found. The site is hosted in a melange of folded lithified sediment, relatively fresh to deeply altered basalt, variably deformed ultramafic rocks and some gabbroic rock, in large part covered by sedimentary ooze. The ensemble is interpreted as resulting from active serpentinite protrusion. Sediment clogging may explain the dominantly diffuse discharge of methane with only minor visible venting. It is considered likely that sulphide precipitation is taking place within the top of the rock pile, under a blanket of sediment.

The Saldanha cruise is part of the AMAR project (Praxis XXI/ICTE, Portugal), co-sponsored by IFREMER and benefited from investigations of the European projects MARFLUX and AMORES. The latter project included the Flores cruise.

FERROMANGANES DEPOSITS FROM THE NAMELESS SEAMOUNT. PRELIMINARY RESULTS

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During the TTR-11 cruise, samples of ferromanganese nodules and crusts were collected in the NW corner of Nameless Seamount. The samples were collected using a TV-Grab device at 1840-1855 m water depth (Fig. 1), from areas showing high crust contents on the TV-Run profiles.

Ferromanganese deposits from the Nameless Seamount consist of nodules and crusts with a variety of shapes and dimensions and some deposits have phosphatized material as substrate or nucleus. Processes of phosphatization and precipitation of manganese oxides are mutually exclusive, as they are formed in distinct conditions of Eh-pH. For this reason, the study of the sequence of layers of manganese oxides and phosphatic material is an important key for the determination of paleoclimatic and paleoceanografic changes.

The growth structure and chemistry of one manganese nodule, 3476-B.3.4 (352GR) was studied in detail. This nodule shows a zonal growth with six distinct areas (A, B, C, D, E, F). Due to its complex growth, one selected profile, from A to F, was analysed by microprobe (CAMECA CAMEBAX).

Some considerations can be made from these results:

Area A: internal core area composed of calcite, showing some heterogenities. It has 5 mm of diameter;

Area B: medium core area of dark yellow phosphatized limestone with planktonic foraminifers with content of P reaching 11%; This area has an excentric growth and varies from 0 to 1 mm thickness;

Area C: external core area of high P (10-14%) white to pale yellow phosphatized limestone. It presents some planktonic foraminifers and some interpenetrations of Fe-Mn oxides. As Area B, this area also shows an excentric growth, which varies from 0 to 1 mm thickness;

Area D: Fe-Mn oxides with dendritic columnar growth structures. Manganese varies between 16-25% while iron varies between 13-23% with a negative correlation between the two elements. Cobalt (Co) varies from 0,62-0,96%. This area is approximately 7 mm thick;

Area E: composed of Fe-Mn oxides showing laminated growth structure with alternating micro layers. Manganese varies between 18-28% and iron between 14-25%. Co varies from 0,63 to 1,42%. We can denote a correspondence between the highs of manganese and the highs of cobalt. This area is approximately 8 mm thick;

Area F: outer layer (2-3 mm) of Fe-Mn oxides with laminated growth structure. This area is not sufficiently analysed.

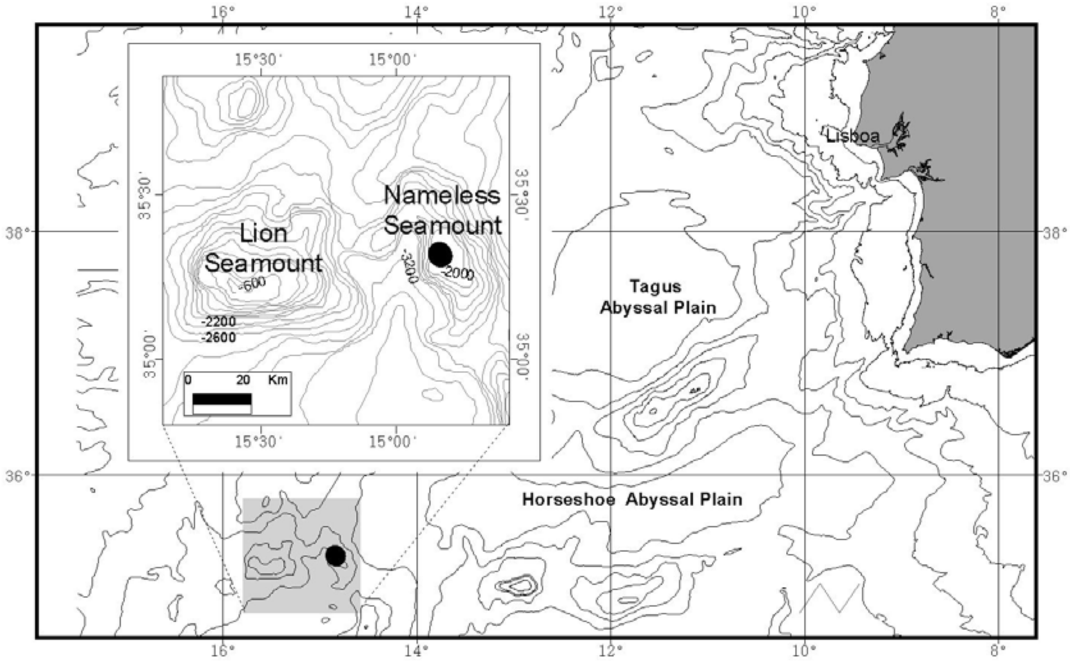

Fig. 1. Location of the sampled area

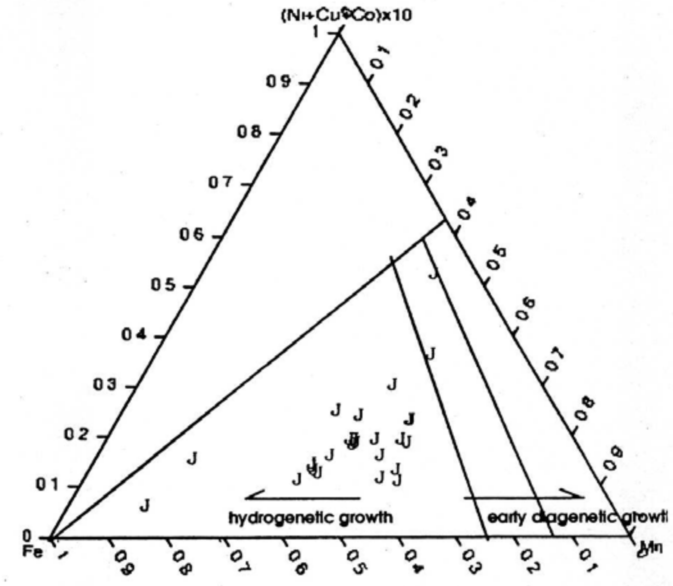

Fig.2. Projection of 3476-B.3.4 microprobe analyses in the Three-Component Diagram (adapted from Jauhari, 1987)

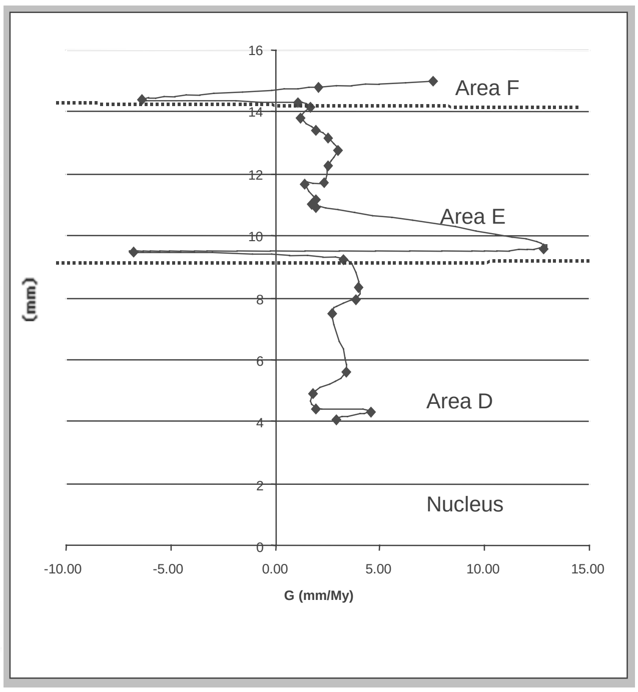

Fig. 3. Growth rates calculated from the Co profiles of sample 3476-B.3.4

The growth of the nodule is complex: it has an initial carbonate nucleus around which two layers of phosphatized material have grown. Gaspar (2001) referred that the high values of P might correspond to the presence of francolite, indicating the association of phosphorites with the ferromanganese deposits from the Lion Seamount (located at 40 nautic miles West of Nameless Seamount). The origin of ferrromanganese crusts associated with phosphorites have in common phenomena related with ocean depths, which involve the Oxygen Minimum Zone (OMZ). These layers were formed in different conditions of Eh-pH from those of the Fe-Mn oxides. While Fe-Mn oxides are formed in oxidazing conditions, the phosphatized material requires reducing conditions for their formation. Furthermore, there must have been an event with high phosphate supply in the water column before the time of crust growth. One possible explanation for the existence of those phosphatized layers is that they were formed at a different depth, within the domain of the Mediterranean Water (MW) where the content of oxygen dissolved in the water column is lower. This composite nucleus (A, B, C) was later remobilised to deeper water layers, where the Fe-Mn oxides have precipitate when deeper, colder waters, rich in oxygen were mixtured with the Mn-rich, oxygen-depleted waters due to the turbulence caused by the bathymetry (seamounts). Other possible explanation is to consider episodes of high productivity, which can explain the impregnation of crusts with apatite at some million years ago, as it was referred to in Koschinsky *et al*. (1996) for the ferromanganese deposits of the Lion Seamount.

Manganese and iron are inversely correlated, and for the three areas composed by Mn and Fe (D, E and F) the Mn/Fe ratio is close to 1, leading us to the conclusion that they are hydrogenetic, although there are two data points that show a ratio higher than 2.5 and high values of Cu, typical of early diagenetic deposits (Fig. 2). These two diagenetic events are coincident with the boundaries D/E and E/F and might reflect episodes of increased productivity and biogenic particle flux (Koschinsky et al., 1996). As it was already studied for other occurrences of ferromanganese deposits in the NE Atlantic (Koschinsky et al., 1995, 1996; Gaspar, 2001), sample 3476-B.3.4 also indicates a hydrogenetic origin, in general.

Fig. 3 shows the growth profile calculated from the Co profile of the studied sample. The empirical formula (G mm/My = 1.28/(Co(%)-0.24)) for calculating the growth rate and age of hydrogenetic crusts is based on the reverse relationship between the concentration of Co, which is considered the purest hydrogenetic element in the crusts, and the growth rate of the corresponding crusts layer (Koschinsky et al., 1995). Considering the growth profile of Fig. 3, the mean growth rate for the Area D is around 3.16 mm/My and 1.94 mm/My for Area E. Considering a mean growth rate of 1.08 mm/My for Area F the age of the crust is around 6.05 My, not considering the two diagenetic events. This dating is based on an empirical formula and must be compared with precise dating for further conclusions.

The inexistence of an old phosphatized crust generation, as it was reported for the hydrogenetic occurrences of the Pacific, leads us to the conclusion that the formation of Atlantic crusts is younger (Koschinsky *et al*., 1996).

Koschinsky *et al*. (1996) have dated one crust from the Lion Seamount (^{10}Be dating) and obtained an average growth rate of approximately 4.5 mm/My, which gives an age for initiation of crust growth of 8.5 My (for a crust with 38-mm-thick). Based on this age, two compositional peaks from the crust were also dated obtaining the ages of 6.2 and 1.6 My coinciding, respectively, with the beginning of the Messinian age and with the initiation of northern hemisphere glaciation.

The high variability in element distributions from the sample (Fig. 4) indicates that the growth history and oceanographic conditions have been variable. Due to the sample location (influenced by the connection of the Atlantic and the Mediterranean Sea), Nameless Seamount may have experienced environmental fluctuations as Koschinsky *et al*. (1996) pointed out for the Lion Seamount. Fluctuations in the intensity of the OMZ may have interrupted crust growth at certain times and the strong influence of the Mediterranean Water (MW) in this area should have influenced the composition of these crusts, which should have recorded changes in the seawater composition.

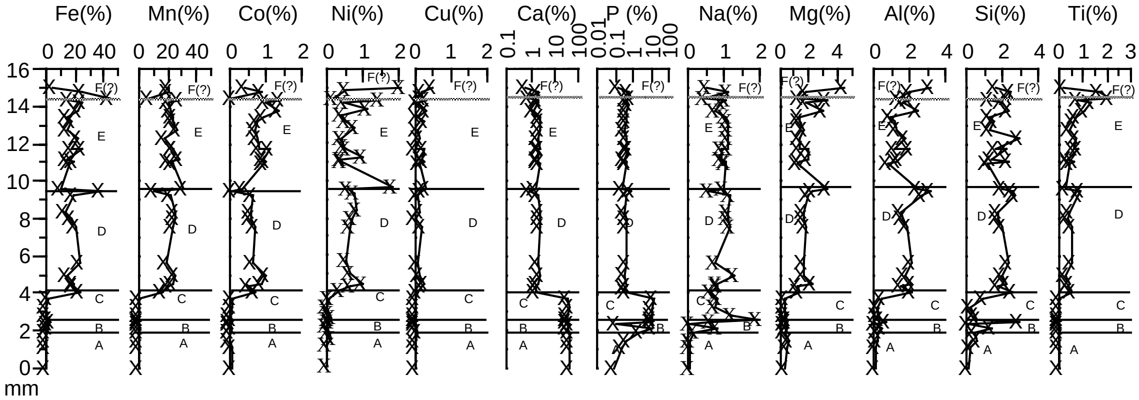

Fig. 4. Depth profile of chemical composition

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INTERNAL STRUCTURE AND DISTRIBUTION OF THE ELEMENTS IN THE FERROMANGANES CRUSTS FROM THE NAMELESS SEAMOUNT

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Ferromanganese crusts have been collected during the 3rd Leg of the TTR-11 cruise from the Nameless seamount, using the TV-controlled grab system. 8 polished samples and 11 thin sections were analysed under optical and scanning microscopes to study the internal structure of the collected crusts. Bulk chemical composition of the crusts (Fe, Mn, Co, Ni, P, V, Ti, Al, Si, Zn, Mo, Ba, Cu) was determined by microprobe analysis.

It was found that studied crusts consist of inner (phosphatized) and outer (non-phosphatized) growth generations. Sometimes the boundary between these generations marked by highly phosphatized (about 20% of P) layer. Basically, the internal structure of the crusts is represented by lamination of Mn-hydroxide and oxyhydroxide layers, which are hydrogenetical in origin. The chemical composition of the laminae and their shapes vary significantly. Besides, the sediments, which were captured during the crusts growing, affected the lamination, creating gently sloping shapes of the layers.

Under optical microscope in reflected light the layers are light grey, grey, dark grey and black in colour.

Typical shapes of the laminae of the inner part of the crusts are porous-dendritic, dendritic, dendritic-columnar. Laminae chemical bulk composition vary significantly: 0.8-21% P, 4-32% Mn, 1.5-14% Fe, 0,03-0,6% Ni, 0.07-0.4% Co, 0.02-0.15 % V, 0.08-0.4% Ti, 0.9-1.8% Al, 1.3-2.5% Si, 0.0-0.15% Zn, 0.0-0.07% Mo, 0.0-0.9% Ba, 0.0-0.16% Cu. Within the inner part the light grey layers are characterized by relatively high content of Fe, Mn, Ni, Co, Ba, Cu, V, Al and lower content of P. The grey layers show high (up to 21%) P content. Typical shapes of outer part layers (young generation) are dense, dense-columnar, dendritic-columnar. This generation are characterized by chemical bulk composition: 0.7-0.8% P, 16-18% Mn, 14-16% Fe, 0.25-0.35% Ni, 0.65-0.75% Co, 0.09-0.11% V, 0.9-1% Ti, 3.4-3.6% Al, 3.1-3.2% Si, 0.1-0.12% Zn, 0.01% Mo, 0.075% Ba, 0.06% Cu.

The different types of the structure and distribution of elements were defined basing on the microscopical investigation and microprobe analysis. Main differences in the composition of the young, non-phosphatized and the old, phosphatized generations are expressed in P, Mn, Fe contents. The bulk content of P is very high in inner, old generation. The analysis of the outer part of the crusts shows low P-content (not more than 1%). In bottom part of the crusts the average content of Mn about 16.8%, Fe 14.9%, Co 0,63 %; in upper part Mn 17.2% , Fe 16%, Co 0,81%. In light grey layers content of Mn is less and content of Fe is more than in other layers.

Summarizing, the results of chemical analyses were plotted onto triangular factor diagram. On this diagram two fields are seen, corresponding to chemical composition of the inner and outer parts of the crusts. Within the field of the inner parts of the crusts two areas are determined, relating to chemical composition of the dark and light layers. The corners of the diagram are correlated with P, Mn and Fe.

The boundaries of the laminae are sharp, the laminae themselves are well expressed, and the bulk chemical composition of the laminae differs significantly from layer to layer. This can imply an abrupt changes in palaeoenviroment during the crust formation.

PHOSPHATIC AND FERROMANGANESE CRUSTS IN THE GUADALQUIVIR BANK (GULF OF CÁDIZ, SW IBERIAN CONTINENTAL MARGIN): A "HARDGROUND" RELATED TO MEDITERRANEAN OUTFLOW VARIABILITY?

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In September 2000, the cruise Anastasya 09/2000 aboard the R/V Cornide de Saavedra was conducted in the Guadalquivir Bank area (7°40´ W and 36°30´ N) by the Spanish Oceanographic Institute and the TASYO project. Samples of crusts were dredging at 400-500 m deep along the summit of this basement high. At first, samples were considered to be genetically related to the widespread carbonate methane-related chimneys, collected only a few miles southwards, but the unusual mineralogy and textures of the crust samples suggests that they are of a different origin. These crusts have never been described before in this area, and hence there is no information of their composition, occurrence or genesis. Preliminary studies include XRD, optical microscopy, SEM/BSE and EDS analysis.

Crusts are massive to breccia-like, with mm–cm sized fragments immersed in a fine rusty-orange matrix/cement. Laminated black samples were also observed. The orange matrix is mixed with arborescent dark coloured material. XRD analysis indicates that are made of carbonates (calcite and dolomite), phosphates, goethite and phyllosilicates. Optical and electron microscopic studies reveal that massive orange crusts are composed of dolomite crystals (~15 µm) and hexagonal prisms of francolite (<5 µm). Francolite is abundant and occurs disseminated and replacing microfossil tests. Calcite occurs as coatings around detrital grains, with dolomite, phosphates and Fe-Mn oxides. Detrital grains are: phyllosilicates, feldspars, calcite and microfossils. Glauconite is also present in the massive and breccia like samples, as pellets, coatings and intergrowth with oxides and feldspars. XRD analyses of laminated black areas, up to

10 cm thick, indicate that they are made of goethite, Fe-Mn oxides and apatite. Silt sized detrital grains can be also be observed included in these layers. Characteristic platy and fibrous crystals of Mn oxides can be observed by SEM.

Fe-Mn and phosphatic crusts have been described in the Betic Cordillera by Martín Algarra and Vera, (1994) and Jiménez Millán et al., (1998). Ferromanganese microcrust have been also been described in relation to glacial/interglacial stages in Pleistocene sediments from Ampere Seamount (Kuhn et al., 1996), nevertheless, phosphatic and Fe-Mn crust have never been described in the Gulf of Cádiz. This crust can be described as a hardground over the Guadalquivir bank and related to the uplift and Tertiary evolution of this high. Important paleoceanographic information in the Western Atlantic, related to MOW evolution and low-sedimentation stages, can be obtained from these samples if a suitable time stratigraphy can be established.

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GEOCHEMICAL INVESTIGATIONS OF THE HYDROTHERMAL ACTIVITY PRODUCTS FROM THE LUCKY STRIKE ORE FIELD

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During the “Training through Research” (TTR-10) cruise in the Atlantic Ocean the investigation of the Lucky Strike area was carried out. The Lucky Strike ore field is situated in the segment of a Mid-Atlantic Ridge (MAR) rift valley MAR (36-38°N). The field is associated with a depression between three volcanic cones on an elongated volcanic plateau, located in the middle of the axial zone of the Lucky Strike segment (37°17.5'N; 32°16.7'W) (Fouquet et al., 1994). A zone of hydrothermal alterations of rocks covers the area of 0.5 km^2 and is associated with a "lava lake" in the depression between three cones. The basalts composing the volcanic cones show no or very little traces of alteration. The basalts forming volcanic cones differ strongly from the typical mid-ocean ridge basalt (MORB), that testifies for the presence of a different magma chamber (Stepanov, 2001).

The following equipment was used during the investigations: TV-grab, dredge, CTD system, and OREtech deep-towed side scan sonar. As a result, a number of samples of MARB were collected from both the ore field and adjacent areas. Tops and slopes of volcanic cones, volcanic plateau, depression, and bottom of the rift valley at a distance up to 20 km from the ore field were investigated. Beside fragments of chimneys of active and inactive black smokers, hydrothermally altered rocks were subsampled. In 2001, analysis of thin-sections from the samples of MARB and polished section samples from the sulphide formation were carried out in laboratories of Moscow State University. The result of this study was compared with the existing dataset (Cannat et al., 1999; Fouquet *et al*., 1994). This comparison and, also, interpretation of the deep-towed 30 kHz side-scan sonar line (ORAT-38) allowed to make the prospective scheme of evolution of the Lucky Strike ore field and model of hydrothermal activity.

In order to confirm our assumption about the structure and evolution of the Lucky Strike ore field, a set of the geochemical investigations were made. It includes x-ray, chemical and isotopic analyses of sulphur.

For samples of crystal aggregates of variable morphology, before isotopic study, x-ray analysis was made, in order to confirm their mineralogical composition. These samples were taken from the peripheral parts of the lava lake area (diffusion character of hydrothermal activity). As a result, the following mineral composition was identified: two samples – barite with quartz admixture, and another sample – anhydrite. This apparently suggests low-temperature formation (90-120^{0}C) of all these samples.

The sulphur isotopic composition was investigated in the samples of active and inactive chimneys and of the basement of the chimney build-ups in minerals – chalcopyrite, chalcopyrite with bornite, chalcopyrite with covelline, pyrite with bornite and covelline (AT-272). The investigation of the pure sulphur (AT-271) was carried out as well. The samples from the Lucky Strike ore field are characterized by large variation of interrelation of isotopes, from anomalous depleted –6.96‰ to relatively heavy +13.31‰. For the "pure" chalcopyrite, isotopic composition of sulphur ranges from –3.10 to –1.09‰. The covelline from the wall of an inactive chimney was found to be most enriched by heavy sulphur isotope +33.81‰. Such "bounce" may be interpreted as an indicator of the sedimentary origin of the sulphate. The natural sulphur sample is also characterized by high ratio of δ^{34}S - +11.80‰, which is close to the values, typical of the ocean water sulphate.

It worth to be noted, that zonal change in isotopic composition of sulphur in minerals from the channel to peripheral parts of the chimneys was observed. The ground mass (pyrite with bornite) of the samples from an active black smoker characterized by +2.08‰ ratio, but in chalcopyrite from an inner wall of an active channel the contribution of the depleted sulphur isotope (-3.10‰) increases. So, the zonal clast of the chalcopyrite with bornite and with covellin is characterized by "wavy" distribution of the isotopic ratio values, varying from –5.70 to –6.96 and +13.31‰. Such a depleted ratio of isotopes is testified for mantle origin of the fluid (Herzig et al., 1998).

Nowadays, there are several sources of the oreforms fluid: (1) the sulphate-ion reduced from the ocean water (seabottoms lowtemperature processes); (2) the sulphur from the basalt layer (inactive chimneys, and also outer wall of older parts of chimneys); (3) mantle (?) or magma chamber fluid.

Thus, evolution of the hydrothermal activity of the Lucky Strike ore field is directly connected with evolution of the volcanic build-up of the Lucky Strike segment. This connection can be traced from the time of the plateau formation and until the present hydrothermal activity. Consequently, large variation of sulphur isotope data is a result of existence of several fluid sources, as well as of multiple stages of sulphide formation.

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Biosphere – geosphere interaction

ANAEROBIC OXIDATION OF METHANE MEDIATED BY MICROBIAL CONSORTIA IN GASSY SEDIMENTS

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Stable isotope signatures, radiotracer and modelling techniques have established that most of the methane in marine sediments is oxidized microbially under anoxic conditions. This has been observed in the methane-sulphate transition zone of subsurface sediments as well as in surficial sediments of cold seeps, mud volcanoes and above dissociating gas hydrates. Hence, anaerobic oxidation of methane (AOM) is the major biological sink of methane in the ocean and crucial in balancing the emission of this important greenhouse gas into the atmosphere. However, details of the related biochemical mechanisms and organisms are still largely unknown. The isotopic and genetic signatures of microbial biomass in gassy sediments show that AOM is mediated by different microbial consortia, which generally include archaea and reducing-reducing bacteria growing together in symbiotic association. Among the archaea from gassy sediments, rRNA probes target specifically the ANME-2 group, belonging to the *Methanosarcinales*, and the ANME-1 group. New data show that these archaea can also occur as single cells or in clumps without a symbiotic partner and might still be capable of anaerobic oxidation of methane. The process of AOM can support significant microbial biomass, despite the very low energy yield predicted by thermodynamic models. New results on the study of AOM are presented from expeditions to the Pacific margin, Gulf of Mexico, Black Sea, Arctic Ocean.

BACTERIAL MATS AT TWO SEEP LOCATIONS, NORTH SEA

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Bacterial mats suspected to consist of the sulphur-producing filamentous bacterium *Beggiatoa* sp. has been found to occur at two locations in the Norwegian sector of the North Sea. At Tommeliten, Block 1/9, the mats occur in small circular patches of about 1 m diameter and also in larger irregular patches up to about 5 m across. Further north, at Kvitebjørn, Block 34/11, they occur in large, more-or-less continuous patches up to tens of metres wide.

At both locations, there is prolific methane seepage nearby, and at Kvitebjørn, the gas seeps through holes in the mats. In several places at Tommeliten methane bubbles rise from beneath the mats, when they are pierced by an ROV manipulator arm (ROV=remotely operated vehicle). The seafloor sediments at Tommeliten consist of sand and clay, whereas they are coarser (sand and gravel) at Kvitebjørn. Wherever mats occur, the underlying sediments are black because of sulphide formation. The sulphides indicate anoxic porewaters in the sediments immediately below the mats. Recent new results from methane seepage locations elsewhere (Boetius et al., 2000) suggest that consortia of AOM-aggregates utilize the seeping methane as a substrate, and are thought to cause conditions ideal for *Beggiatoa* mat formation (AOM=anaerobic oxidation of methane).

Furthermore, field-studies carried out at the Tommeliten methane seeps, suggests that the seeps may seal themselves after some time because of a) carbonate precipitation and b) utilization by organisms. During a visual and ROV-mounted side scan sonar survey, flat slabs of methane-derived authigenic carbonate cemented sediments previously called “bioherms” (Hovland and Thomsen, 1989) were sampled. Based on this new information, it is suggested that there may be three phases leading to the sealing and re-routing of upward directed fluid flow. These phases are manifested by:

1) Virgin seeps, where the gas comes directly from small vents in the sandy seafloor.

2) Oxidation of methane with sulphate by the AOMs, providing sulphide to bacterial mats (i.e., *Beggiatoa* sp.) where the gas accumulates in sandy sediments before occasionally venting through holes in the mats.

3) Authigenic carbonate cemented slabs where no visible gas is evident, but where sampling of carbonate nodules suggests that gas migrates up to the lower part of the slabs and seeps through small holes and is utilized in different ways, including anoxic oxidation.

These results, therefore, suggest that the formation of the bacterial mats may represent the first phase of natural sealing. The formation of the “bioherms”, which host numerous sessile and filter-feeding organisms, represents the final phase in the natural seep sealing process. In other regions of the oceans, where other gas compositions, migration rates, and sediment conditions prevail other sealing processes will occur.

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BIOMARKERS OF POSSIBLE SOURCE ROCKS FOR HYDROCARBONS IN COLD VENTS OF THE GULF OF CADIZ

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Some molecules (biomarkers) in total lipid fraction of extractable organic matter (EOM) can indicate depositional environments and degree of thermal maturity of the rocks in the sedimentary sequence. Using the biomarker parameters one can correlate oil in the reservoirs and bitumen of source rocks, and estimate the maturation of organic matter (OM).

Since 1999 we studied organic matter in the rock clasts from mud volcanic breccia in the Gulf of Cadiz. Samples from different mud volcanoes of the deep-water part of the Gulf of Cadiz were collected during the “Training through Research” TTR-9, 10 and 11 cruises. A series of rock fragments separated from matrix of the breccia were investigated by set of organic geochemical methods such as Rock-Eval pyrolysis; gas chromatography of EOM; infrared spectrometry, CuPyrolysis and elemental analysis of isolating kerogen. Age range of rock clasts was determined from Cretaceous to Pleistocene (Sadekov, 2000). Six samples were selected for gas chromatography - mass spectrometry analysis (GC-MS) according to high contents of total organic carbon (TOC) and high or excellent oil-gas potential. The dark grey claystone was dated as upper Cretaceous, the age of two dark grey limestones, grey and black claystones was determined as Miocene, crystalline limestone was dated as Pliocene. According to Rock-Eval pyrolysis all these samples have low maturity (Tmax = 418-428°C).

GC-MS analyses were performed using an HP 6890 gas chromatograph (heating program 100 to 300°C at 4°C/min followed by an isothermal period of 30 min at 300°C), coupled to a HP 5989 mass spectrometer. Compounds were identified basing on their mass spectra, GC retention times and comparison with library spectra (Philp, 1985; Waples et al., 1991).

The total ion current (TIC) chromatogram of the Cretaceous claystone is characterised by unimodal distribution of n-alkanes (from nC_{14} to nC_{27}) with the maximum at nC_{17}, high contribution of aromatic hydrocarbons, presents of steranes and hopanoids. The pristane/phytane ratio here is 1.76.

Two chromatograms of limestones from the Burdigalian-Langian stage of Miocene have the same distributions of n- and iso-alkanes (predominance of short-chain n-alkanes with maximum at nC_{17}), and presence of cycloalkanes, derivatives of naphtalene and antracene. There are differences in the amounts of steranes, hopanes, dibenzothiophene and squalane in these samples. The n-alkanes from nC_{13} to nC_{35} with the maximum at nC_{17} prevail in the TIC of the lower Serravalian claystones. Naphtalenes, fluorenes, pyrenes, as well as small amount of steranes, are also present.

The chromatogram of the bitumen of Serravallian-Tortonian claystone is characterised by n-alkane distribution ranging from nC_{11} to nC_{33} with the maximum at nC_{16}. The isoprenoids were identified from C_{16} and C_{20}. In the TIC, the dominance of derivatives of benzene and naphtalene, and triaromatic steranes were found.

The TIC of the bitumen of Pliocene crystalline limestone is characterised by diverse n-alkane distribution ranging from nC_{12} to nC_{35} with the maximum at nC_{16}, and predominance of nC_{27}, nC_{29}, nC_{31} compounds among the long-chain alkanes. The different aromatic and SNO-compounds were found.

The predominance of short-chain n-alkanes with maximum at C_{17} from almost all samples indicated a marine origin of OM with low contribution of specific lacustrine or marine algae. Only OM from Pliocene limestone has marine origin with terrigenous input. Pristane versus phytane ratios in the samples varying from 1.23 to 1.86; and distribution of C_{27}:C_{28}:C_{29} steranes also indicate marine organic matter deposited under suboxic conditions.

The maturity level of all samples can be estimated as low and very low according isomers ratios for C_{29} regular steranes, moretane/hopane, diasteranes/regular steranes and methylphenantrenes indexes (Waples et al., 1991). However polycyclic aromatic hydrocarbons (pyrene, chrysene, anthracene etc.) in the Cretaceous claystone and Pliocene limestone are obtained by the distillation of crude oil and can be an indicators of high thermal maturity hydrocarbons from the depth.

Geochemical investigations the selected samples show the good and excellent potential for hydrocarbon production of OM in the rock clasts. The OM implies a predominantly marine origin, but low maturity level. The further investigation of biomarkers in the known oil fields on the Spanish and Moroccan shelves, with comparing them in the EOM of the examined samples, can provide information about real source rocks of the deep-water part of the Gulf of Cadiz.

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DISTRIBUTION AND STABLE CARBON ISOTOPIC COMPOSITION OF BIOMARKERS IN METHANE-RELATED CARBONATE CRUSTS. SOROKIN TROUGH, NE BLACK SEA. PRELIMINARY RESULTS

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To determine the metabolic processes of specific venting-related microorganisms, the lipids and their carbon isotopic composition of seep-related carbonates collected from NIOZ and Odessa mud volcanoes (the Sorokin Trough) during the first part of TTR-11 Cruise (2001) in the Black Sea were studied. These investigations were carried out within the framework of the co-operation between NIOZ and UNESCO/MSU Centre for Marine Geology and Geophysics. The examined authigenic carbonates belong to different lithological units and exhibit various morphologies. They occurred in forms of flat thin crusts and massive slabs in association with brownish and pink microbial mats.

All studied carbonate crusts contain pentamethylicosane (PMI), several unsaturated PMI's, and a variety of glycerol dialkyl glycerol tetraethers (GDGT's) but in varying amounts. For instance, carbonate crust from the Odessa mud volcano shows predominantly unsaturated PMI, whereas carbonate crusts from the NIOZ mud volcano contain only small amounts of these compounds. The distribution of dialkyl glycerol tetraethers also varies between crusts. These archaeal biomarkers are strongly depleted in ^{13}C, which indicates, that methane is one of the main carbon sources for these organisms. However, the ^{13}C-values are highly variable which testify to the degree of methane oxidation, the isotopic heterogeneity of methane, or, perhaps, to the heterogeneity of archaeal communities, which probably use other acceptable class of substrates leading to alteration of metabolic pathways. It demonstrates significant differences between the archaeal communities in Odessa and NIOZ mud volcanoes

These observations support and expand on previous observations (Hinrichs et al., 1999; Thiel et al., 1999; Elvert et al., 1999; Pancost, et al., 2000; V. Thiel, 2001), which demonstrated that anaerobic methane oxidation is an important biogeochemical process leading to formation of authigenic carbonate crusts.

PECULIAR BENTHIC ECOSYSTEMS OF CONTINENTAL MARGINS AND RECENT DISCOVERIES: MAJOR ECOLOGICAL PATTERNS OF METHANE SEEPS AND CORAL COMMUNITIES FROM SUBMERSIBLE OBSERVATIONS

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Several benthic ecosystems occur on active and passive continental margins. Their complexity and heterogeneity are linked to the variability of energy sources and geological contexts. The environmental contexts favours either detritic based communities indirectly feed by photosynthetic production from the upper layer of the ocean, either chemosynthetis based communities related to methane seeps. The synthesis of the biological knowledge and recent submersibles programmes carried out by Ifremer (Nautile and ROV Victor) allowed to highlight some general ecological patterns and new questions.

The detritic-based ecosystems in the deep sea are usually characterized by a high biodiversity a low biomass of mainly small size species living in the superficial sediment. However, there are also luxuriant deep coral communities living on carbonate seamounts. These communities, recently observed on the northeast Atlantic and Equatorial African margins may be developed on habitats indirectly related to hydrocarbon seeps as suggested by recent observations. The chemosynthesis-based communities depend of an autochtonous and local geo-chemical energy, which through microbial mediation produces organic carbon in large quantities. This original and high organic carbon production leads to the large size of the organisms (vesicomyidae, mytilidae and pogonophoran or siboglinidae tube worms…) and the high density and biomass of the seep communities. The discovery of cold seep communities on active and passive margins has shown that the chemoautotrophy and the symbiont containing organisms are not only related to hydrothermal vents. Cold-seep ecosystems can occur under a very broad range of environmental conditions concerning geological settings and fluid flow. The overview of ecological studies allowed to evidence patterns of distribution, biodiversity, trophic behaviour and fluid dependence, which will be summarized. Most of the symbiont-containing species or assumed to contain chemosynthetic bacteria are new for science and mostly undescribed: today about 70 species are already identified but mainly at the family and genus level. The trophic behaviour of seep megafauna is an indicator of the location of methane or sulphide rich environments as their nutrition is derived from symbiotic relationships with sulphide- or methane-oxidizing bacteria. Consequently the spatial heterogeneity of the communities may be indicators of fluid escape characteristics. Seeps can occur on both convergent and passive continental margins where hydrocarbons (oil and gas) have been accumulated. The known cold seep areas are located in the Atlantic and in the Eastern and Western Pacific oceans within depths ranging between 400 and 7000 m. Recent research programs have also allowed the discovery of new sites in the Mediterranean Sea and on the Equatorial African margins. However, the geographical extent of these peculiar communities is unknown because these environments are not fully explored.

Our knowledge still lies in the understanding of numerous fundamental questions: how biological systems can adapt to extreme conditions and fragmented habitats? how the fauna responds to temporal and episodic variations of cold seeps? how the diversity, the biomass and the production of chemoautotrophic fauna are controlled by the fluid flow and the chemical composition of the fluids, how the peculiar and rich ecosystems (cold seep and deep sea coral) influence the organic carbon cycle in the deep ocean? In these habitats, both the characters and the functioning of these ecosystems are incompletely understood and we do not know how both type of detritic and chemosynthetis based ecosystems interact. There is a clear need of more field investigations. But with new technical developments both in deep sea submersible technology and physico-chemical measurements simultaneously with new assessment of spatial and temporal variability of communities and environmental conditions, our understanding will continue to grow. Next approaches need to be interdisciplinary with combined *in situ* observations, sampling and physico-chemical measurements.

COMMUNITIES, DIVERSITY AND ZONATION PATTERNS IN *LOPHELIA* MOUNDS: PREPARATION OF A PRACTICAL HANDBOOK

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A biological handbook (part II in the series: Geological and Ecological Surveying in areas of Exploitation of Natural Resources) will be developed in the framework of the Belgian Russian collaboration project ‘Joint Curriculum Development in Geo-Ecological Surveying in areas of development of Natural resources’. The purpose of this handbook is to give graduate and undergraduate students the chance to put their theoretical knowledge about ecological principles into practice and to be acquainted with the ecosystem formed by cold water corals. It will consist of three major parts: (1) a literature study describing sampling techniques and introducing results of former investigations about cold water corals, (2) a manual for the practical elaboration of several ecological exercises and (3) an interactive CD-rom.

The basis of the handbook and especially of the exercises will be video footage of cold-water corals in the Porcupine Seabight and the Rockall Trough. The *Lophelia* mounds are very diverse both in faunal and structural diversity. They form a surprising and interesting deepsea habitat and they are of course extremely beautiful. This makes them very suitable for educational purposes.

In this practical handbook the emphasis will be on three major ecological concepts: community composition, diversity and zonation patterns. Obviously, due to the use of video footage, these aspects can only be applied to the recognisable megafauna. The objective of this handbook is therefore not only to get to know the species associated with *Lophelia,* but also to explore the cold water coral system at the level of community structure. A community is an assemblage of species populations that occur together in space and time. An important characteristic of the community structure is the diversity, which has been defined as: "a parameter describing the complexity of the environment, the interspecific relations and the stability of the community." Diversity incorporates both species richness (i.e. number of species) and evenness (i.e. expression of rarity and commonness). The diversity of cold water coral systems is considered to be very high due to the presence of a stable environment and of different niches related to the three-dimensional structure of the corals: surface of living coral and dead coral, cavities in the coral skeleton made by boring organisms and the space between the coral branches. The data on changes in species composition along video-transects can be used to define different communities and to identify zonation patterns in the coral communities.

By means of examples and exercises on how to describe and characterize a community in terms of composition at different taxonomical levels, biodiversity and zonation patterns the user of the handbook will get familiar with the ecosystem of cold water corals and with the most important ecological concepts related to community research.

MACROFAUNAL COMMUNITIES ASSOCIATED TO CARBONATE CHIMNEYS FROM THE GULF OF CADIZ. PRELIMINARY RESULTS FROM VIDEO IMAGERY AND DREDGE SAMPLING OBTAINED DURING THE TTR-11 CRUISE

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During the TTR-11 Cruise, the Iberico structure and the Guadalquivir diapiric ridge were studied using video imagery and dredge sampling. These two locations, at about 800 to 1000 m depth, are characterized by the occurrence of carbonate chimneys.

At the top of the Iberico structure, the chimneys, mostly semi-buried in the sediments, were beautifully adorned with large colonies of *Callogorgia verticillata* and other gorgonia-like anthozoans. The small patches of fine sediments among fallen chimneys frequently showed abundant burrows of different types and other signs of bioturbation, while large patches of sediments with coral debris appeared to be less populated. Many specimens of sea urchins (Cidaridae) and sea stars (mainly Asterinidae) were observed throughout the record as well as different species of fish and shrimp, often observed at the borders of the cnidarian patches. Contrasting with the dense and diverse fauna at the top of the structure, the record made at the sandy slope at the flank showed a poor assemblage characterized by the presence of large unidentified worms and a few shrimps, fishes and sea stars. In the Guadalquivir diapiric ridge the topography was highly variable. Rocky areas alternated with well-sorted sediment patches among fallen chimneys. In the rocky areas, the fauna was dominated by echinoderms similar to those observed in the Iberico. However in some areas, sea urchins were seen forming clusters of up to twenty individuals. Many small sponges and decapods hiding in rock crevices were also observed. The chimneys were covered by colonies of small-sized cnidarians. A few fishes and shrimps, swimming very close to the sediment as well as crabs and their burrows were observed in the sandy patches. Except for these crab burrows, other signs of bioturbation were not evident.

The smaller epifauna retrieved from the chimneys collected at the top of the Iberico (AT-335-D), was characterized by the occurrence of brachiopod clusters (*Gryphus vitreus*) incrusting sponges, several species of small-sized bivalves and polychaetes. Many of the polychaete specimens were observed crawling out of tiny conduits of porous rocks. These were picked up by hand and later identified as *Pholoides dorsipapillatus*. The species richness and abundance of the epifauna on the chimneys collected during the second dredge operation (AT-339-D) were higher. Several species of hydrozoans (mostly Plumulariidae), small-sized anthozoans, including a few living colonies of a Madreporaria coral, many different small sponges and serpulidae polychaetes dominated the sessile assemblage. Caprellidae, frequently hanging to the hydrozoan colonies, Aoridae amphipods, Asellote isopods as well as different species of polychaetes and molluscs are some examples of the fauna retrieved from this sample. A few specimens of the pogonophoran *Siboglinum* were also found.

In the studied sites the chimneys were covered in varying degrees by rich and conspicuous epifauna contrasting with the usual deep-sea landscape. The existence of hard substrate and the three-dimensionality of the carbonated structures provide recruitment surfaces for sessile fauna as well as hiding places and refuges for many organisms. This increase in habitat heterogeneity, *per se*, favours an increase in diversity and complexity of the faunal assemblage. However, the abundance of organisms and the stability of the assemblage must also require a considerable supply of food and this aspect must be further investigated.

Striking differences among sites were evident from video imagery and from the study of the specimens retrieved from dredge samples. The geological setting and hydrodynamic conditions are likely to be structuring features of the faunal assemblages but the discovery of chemosynthetic organisms (*Siboglinum* sp.) may also point out to an active expulsion of methane-rich fluids.

ECOLOGY OF INTERESTING GEOLOGICAL FEATURES: AN INSIGHT OF NAZARÉ SUBMARINE CANYON (NE ATLANTIC)

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Until recently and regarding biology, deep-sea research focused mainly regular deep-sea areas, which apparently had high diversity but no large ecological differences besides the marked depth gradient. With the discovery of hydrothermal vents in 1976 (Lonsdale, 1977), and later cold seeps, mud volcanoes and other unusual structures, intense research programmes arose and significant literature was produced. The amount of biological information concerning the diversity of life regarding these strange environments is relatively well known nowadays. These environments are so extreme that communities tend never to reach maturity, therefore diversity is low, but as oceans do not present significant barriers to larval dispersion these communities tend to show the same patterns everywhere and the same kind of animals, as these tend to use specific resources in a very specific way.

But other structures presenting different features are also important for science showing economical and political relevance. Submarine canyons are one example of these structures, being important in the transition from coastal to oceanic waters. Large quantities of materials pass through these structures sometimes with high organic loads meaning higher food supply for the benthic populations during a small period of time. Ecological patterns in these structures sometimes resemble hydrothermal vents as abundance and dominance is high, and diversity is low, with specific species dominating the community, sometimes associated to the use of ephemeral resources such as high amounts of organic material.

Geology is closely related to the functioning of marine systems therefore it is influencing the biology of the populations inhabiting these structures. By presenting a pure ecological work undertaken in a submarine canyon in the Iberian margin we are trying to understand what kind of relevant information is lacking in order to produce better data and more solid conclusions. We try to relate ecological data (abundance patterns, number of species and community structure) to the underlying geology of this specific geological feature.

This work was undertaken in the middle and final sections of Nazaré Submarine Canyon corresponding to 3 sampling sites with depth ranging from 2894 to 4141 metres. Samples were collected with a boxcorer during a cruise of OMEX II programme.

The sampling site at 2894 m presents high abundance values, low diversity and is strongly dominated by a single species, *Cossura* sp.A. These results are probably due to its location, in an area of the submarine canyon where sedimentation is high and therefore sediments accumulate and, during a certain period of time, organic matter is sufficient to nourish abundant populations.

PLANKTONIC FORAMINIFERAL ZONATION OF A SAPROPELIC BED FROM THE LATE QUATERNARY SEDIMENTS OF THE WESTERN BALEARIC SEA

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The existence of Plio-Pleistocene organic rich layers (ORL) deposited within the Mediterranean Basin has been known for the last 50 years (Cramp and O'Sullivan, 1999). Initial studies were concentrated on ORL recovered from eastern basins where they have extensive spatial coverage. However more recent publications devoted to studies of ORL in the Western Mediterranean represent a particular interest (Emeis et al., 1991; 2000; Comas et al., 1996; Krishnamurthy *et al*, 2000; Bernasconi and Pka-Biolzi, 2000).

This work provides results of investigations of distribution of plankton foraminiferal assemblages across ORL, which was recovered within the Upper Pleistocene sediments from the Western Balearic Sea (coordinates: $37^0$15.96' and $00^0$02.99') and described during the TTR-9 cruise of RV "Professor Logachev". The ORL is located at 343 cm bsl, and is 20 cm thick. Its lower part is characterized by thin lamination. This part is interrupted by an interlayer (1 cm in thickness) of normal pelagic sediments. The upper part is represented by more massive sediments with thin burrows.

The ORL containes 1.3% of organic carbon by weight. Thus, according to the Kidd et al. (1978) classification, this is a sapropelic layer. The plankton foraminifera from the interval containing this sapropelic bed were analysed quantitatively in fraction > 150 µm.

The R-mode factor (principal component) and cluster analysis of 25 species in each of the 17 samples were used to delineate the peculiarity of theirs stratigraphical distribution. According to the cluster analyses, three assemblages were selected: tropical-subtropical, transitional and salinity-dependent. The same assemblages (in composition) have been for the first time described by Thunell (1978) for the whole Mediterranean, and this fact suggests that deposition of the ORL was not related to turbidities and slumps.

According to distribution of most informative species in assemblages the interval under investigation was subdivided into four intervals (ecozones).

Ecozone 1 (pre-sapropelic interval: 27-12 cm below the base of ORL): this interval is characterized by the dominance of transitional species (Thunell, 1978; Pujol and Vergranaud Grazzini, 1995) such as: *Gbigerina bulloides* (>20%) and *Globorotalia inflata* (15-20%). The percentage of the *G.* ex. gr. *ruber* is less than 10% but shows an upward increase, that has perfect negative correlation with a trend of *Neogloboquadrina pachyderma* and *G. qunqueloba*. Within this interval *N. pachyderma* sin has also been found.

Ecozone 2 (sapropelic thin laminated interval-12 cm below the base of ORL): the foraminiferal assemblage is characterized by relatively high values of *N.duterdrei* (8%) and related group *N. pachyderma/dutertrei* (>20%). The percentage of the *G* ex. gr. *ruber* is higher (13-20%). In the central part of the interval relatively higher percentage of *N. pachyderma* sin is recorded.

In the “interrupting” event (1 cm layer of normal pelagic sediments): the maximum of percentage *Gr. inflata* (26%) and relatively high *Globigerinoides trilobus* s.l. correspond to this interval. The percentage of *N. pachyderma* and *G.* ex. gr. *ruber* are not relevant in the event.

Ecozone 3 (sapropelic thin laminated, massive intervals and post-sapropelic: 10cm above the top of the ORL (probably re-oxidized part of ORL), normal pelagic marl, 10-15 cm thick). The microfauna is characterized by a significant percentage of *G*. ex. gr. *ruber* (20-33%) and relatively high abundance of *G. trilobus* and *G. tenellus*.

Ecozone 4 (25-35 cm above the top of ORL): the composition of the plankton microfauna is rather similar to that of the Ecozone 1, but the percentage of *N. pachyderma* is lower (< 15%).

Substitution of the transitional assemblage by tropical-subtropical, suggested that the initiation sapropelic bed accumulation related to the global climatic warming and deposition during almost all interglacial time. Beside that the interval of increasing organic carbon contend in laminated part of the ORL is correlated with high percentage of *N. dutertrei* (and *N. pachyderna/dutertrei*). The positive correlation of these species was described by many authors in the Eastern Mediterranean sapropels (Nedri et al., 1999) and was interpreted as decreasing salinity of surface water mass at that time.

The event interrupting the sapropelic deposition (after the Ecozone 2) shows perfect correlation with the percentage of *Gr. inflata* and probably can be explained (Thunell, 1978; Pujol and Vergranaud Grazzini, 1995) by increased vertical mixing within the water column during winter seasons or/and by the Atlantic inflow (Ariztegui et al., 2000).

The increasing of a percentage of *Gr. inflata* was also found in layers, which interrupts sapropels- S1 in the Eastern Mediterranean (De Rijk *et al*., 1999; Ariztegui et al, 2000). This phenomenon of abrupt interruption of sapropels is usually correlated with local cooling of the sea surface water mass (De Rijk et al., 1999), but in the present work we have not found any significant evidence of the cooling.

All presented results indicate high similarities between some characteristics of our ORL from the Western Balearic Sea and sapropels from the Eastern Mediterranean, but also show multiformity of factors influencing the initiation and accumulation of sapropels in the Mediterranean Sea.

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Tectonics

RECENT SEDIMENTATION PROCESSES AND EFFECTS IN THE BLACK SEA

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The Black Sea is a large marginal sea located within complex folded chains of the Alpine system, represented by the Balkanides-Pontides belt to the south, and by the Caucasus and Crimea Mountains to the north and northwest. The Black Sea comprises two extensional basins formed in a back-arc setting above the northward subducting Tethys Ocean, close to the southern margin of Eurasia. Observing and analysing the extensional tectonics of the Black Sea and the of the Mid-Black Sea ridge, it is possible to show that this region was affected by two main rifting phases (Middle Jurassic and the upper part of the Lower Cretaceous). During the last geodynamic process, the opening of deep Black Sea took place as a consequence of the formation of two back-arc basins behind the W and E-Pontides. Two basins coalesced late in their post-rift phases in the Pliocene, forming the present single depocentre. The mountain-building processes and their subsequent erosion around the basin have contributed to high sediment input. Seismic studies indicate a 15 km thick blanket of sediments with unusually low seismic velocities (3.0-4.5 km/s) that reach potentially back to the Early Cretaceous (130-110 Ma).

Sediment back stripping and corrections for isostatic compensation show that the Black Sea proper originated as a marginal basin in the Upper Cretaceous. The basin has been under going more-or-less continuous sedimentation and tectonic subsidence. The interval sedimentation rate varied between 0.1-0.6 m/ka for the period 5.3-0.7 Ma, but increased sharply to 1.2-1.3 m/ka starting in the Cromerian, when lacustrine megavarve deposition and episodic slumping set in. During the past 20 ka, primarily climatic changes and the impact of man have controlled the sedimentation rate. During the peak Weischel Ice age; rates were characteristically low because of the wide areal coverage of ice sheets and permafrost in a reduced drainage area. From 15 to 7 ka before present, there was a rapid increase in sedimentation rate as a result of deglaciation and massive release of detrital material. From there on to about 2 ka before present, it is averaged around 10 cm/K, only to rise again as a consequence of the activities of man, especially via deforestation and land use.

Although there is excessive supply of terrigenous sediment (exceed 100 million tones per annum) in Black Sea, pelagic sedimentation plays the major role in the deep basin. Those sediments are rich in calcite and organic carbon, the latter showing a high degree of presentation due to anoxia in waters below 100-150 m. The Black Sea is one of the richest waters having immense gas and gas hydrate accumulations. The sediments of high sedimentation rate at slope and shelf areas are the methane sources. Methane is geologically and economically important, because migration of methane in sediments may cause massive slope failures especially at the slope regions; methane seeps may indicate the deeper hydrocarbon reservoirs; and methane hydrate may be an important energy source for the future. Some marine geophysical surveys have been carried out in the Eastern Black Sea region using state-of-the-art technology to obtain sonar and high-resolution seismic data. Throughout the Turkish near shore, shallow gas has been detected on the subbottom profiler records and it continues beneath the sea floor about 25-65 m below. The presence of the shallow gas in the sediments is marked as bright and cloudy spots, sometimes pockmarks and masking of the reflectors, whereas the gas hydrate layers in the sediment strata are often represented by dark strong reflections on the sub bottom profiler records.

Like crude petroleum and natural gas, the methane that makes up of the hydrates has been formed from the remains of living things. For thousand of years, bacteria in sediments deep below the seabed have been munching their way through layers of organic-rich material, releasing methane gas as they feast. As the gas bubbles upwards, it reaches water-bearing sediments. And where methane gas and low temperatures -just a few degrees Centigrade- encourage the formation hydrate: molecules of methane trapped inside dodecahedral-shaped ice cages. Most of the world's hydrate deposits are spread over many thousands of square kilometres deep beneath the seabed. This could be the future energy source of the world after the depletion of oil and gas reserves. The Black Sea is one of the richest waters having immensive hydrate accumulations. One of the best techniques for surveying large areas of the seafloor is sonar and seismic profiling, This involves beaming pulsed sound waves into the sediments, and detecting the waves that reflect back from boundaries where the density or porosity of the rock beneath change abruptly. Layers of hydrate are easily spotted. The transition between hydrate-bearing sediments and those below them containing only gas and water causes a very strong reflection.

ACTIVE TRANSTENSIONAL DEFORMATION WITHIN THE NORTH AEGEAN TROUGH ASSOCIATED WITH THE WESTWARD EXTENSION OF THE NORTH ANATOLIAN FAULT

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The eastern Mediterranean is characterised by high rates of deformation and seismicity. The Anatolian block is being expelled westward by the collision of Arabia with Eurasia, with much of this motion accommodated by the dextral North Anatolian Fault (NAF). West of Turkey, this dextral motion gradually changes to N-S extension within central Greece and the Aegean as this block migrates towards the Hellenic trench. The NAF shows an increased extensional component within the Sea of Marmara and this continues into the North Aegean. This transtensional deformation has caused the subsidence and formation of the Gulf of Saros and North Aegean Trough (NAT) basins. In order to understand the tectonics of the NAF projection into the NAT, a geophysical survey was conducted during the TTR11 Cruise in the eastern part of the trough. Sidescan sonar and 5kHz sediment profiler data highlighted the presence of active faulting and sedimentary processes within the basin (Fig. 1).

From collected and published datasets, the SW-trending Ganos fault lies just offshore the northern Gelibolu Peninsula. SW of the peninsula, the fault appears to terminate or have significantly reduced displacement. The margins of the NAT are bounded by WSW-trending normal faults with significant vertical displacement (>500 m based on bathymetry). On these margins, the lateral component of displacement remains unknown. The fault bounding the southern basin margin does not appear to connect with the Ganos fault to the east. The axis of the Gulf of Saros basin contains two faults dipping towards the axis with minimal normal displacement (less than 50 m) and which extend a few kilometres into the North Aegean Trough.

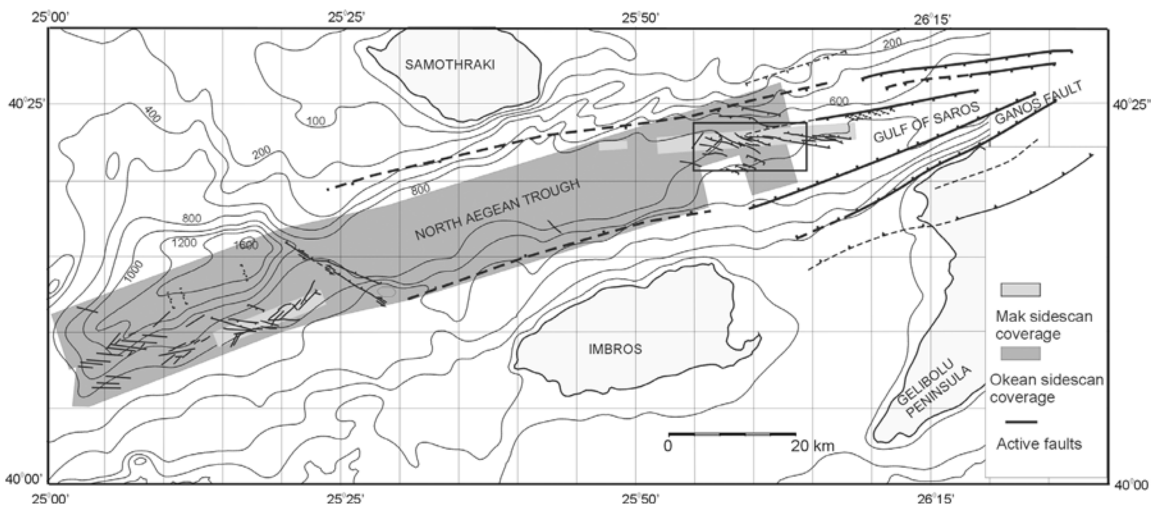

Fig. 1. Structural map of the eastern North Aegean, showing active faults interpreted from sidescan sonar and 5 kHz profile data during TTR11 and multichannel seismic in the Gulf of Saros (after Kurt et al., 2000). Box indicates Fig. 2 location.

These faults are sub-vertical in profile and coincide with en echelon NW-trending fractures in sonar images (Fig. 2), similar to fractures observed in the Sea of Marmara. We interpret these faults to have a significant lateral component. Higher frequency sidescan surveys of two areas of the basin (one in the centre of the graben mentioned above and secondly on the southern basin margin) revealed en echelon fractures compatible with WSW dextral Riedel shear (R, P, and R' shears were observed). These faults have small vertical displacements and locally lateral displacement was observed. We hypothesize that these fractures are the surface expression of through-going strike-slip faults. Evidence of lateral displacement on the southern margin of the basin suggests that this basin-bounding normal fault also has a significant lateral component. The large vertical displacement on the basin-bounding normal faults leads to steep basin margins and associated gravitational sediment transport indicated by submarine canyons, gullies and slump deposits at the base of slope.

Comparison with earthquake focal mechanisms shows evidence for both pure strike-slip and oblique (transtensional) slip within the North Aegean Trough. The faults identified in this study agree with this style of deformation with probable oblique-slip faults bounding the basin and dominantly strike-slip faults within the centre of the basin. The North Aegean Trough can be divided into several sub-basins distinguished by an intervening bathymetric high, relative lateral displacement or significantly different basin floor depths. In the study area, there is some evidence for structural control of basin position or contrasting sedimentation rates influencing the basin morphology.

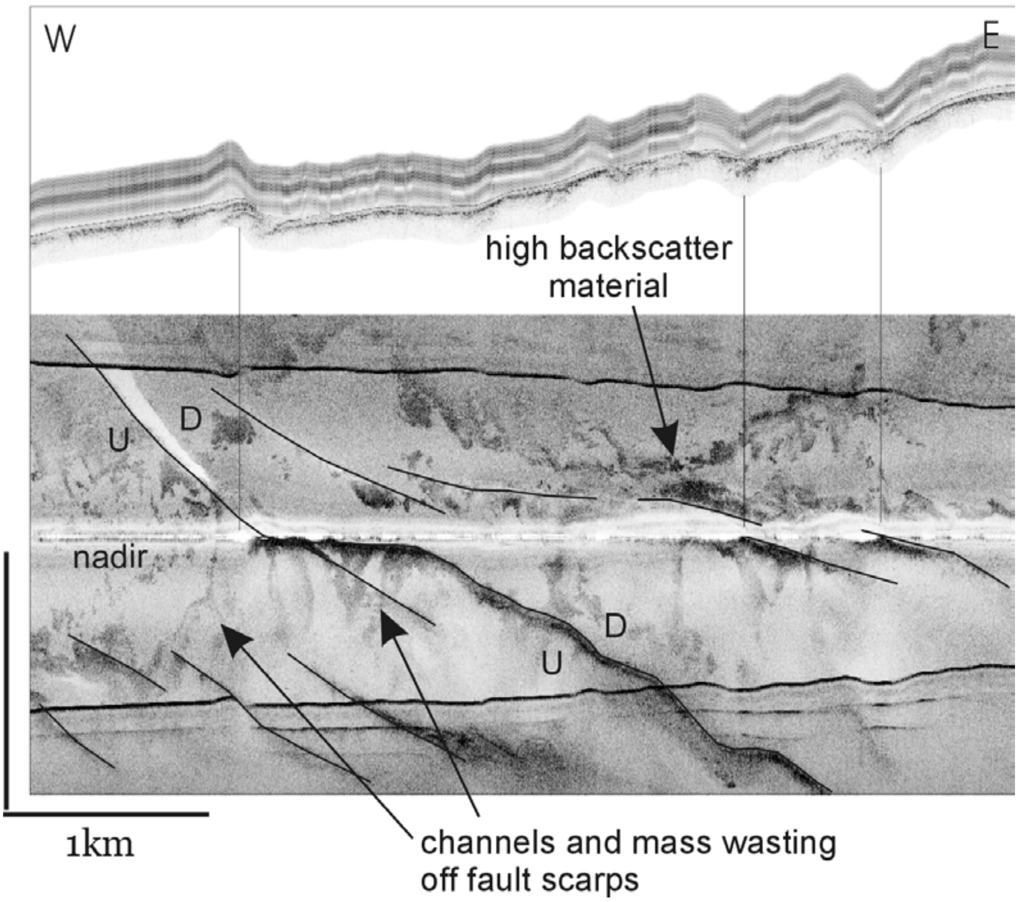

Fig. 2. Mak sidescan sonar (bottom) and 5kHz profile (top) in NE of study area showing en echelon WNW-trending fractures with small vertical displacement.

Reference:

Kurt, H., Demirbag, E., and Kuscu, I., 2000, Active submarine tectonism and formation of the Gulf of Saros, northeast Aegean Sea, inferred from multichannel seismic reflection data: Marine Geology, 165, 13-26.

NEW DEVELOPMENTS ON THE TECTONO-SEDIMENTARY INTERPRETATION OF THE MARQUÊS DO POMBAL AREA (SOUTHWEST PORTUGAL)

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The SW margin of Iberia is an area affected by catastrophic earthquakes and tsunami. The present diffuse pattern of seismicity results from a complex tectonic framework dominated by the convergence of the Eurasia and African plates (Ribeiro et al., 1996). The Lisbon event in 1755 was one of the most destructive historical events (estimated magnitude 8.5) causing over 10.000 casualties of which 2000 can be attributed exclusively to the tsunami (Baptista et al., 1998). The tectonic structure that is probably the source of this earthquake has been recently identified in a seismic profile (Zitellini et al., 1999), west of S. Vicente Cape. This structure, over 50 km in length, was later named as the Marquês de Pombal fault (Zitellini et al., 2001).

To make a complete study of the Marquês de Pombal fault the European Community funded the BIGSETS project (*Big Sources of Earthquake and Tsunami in SW Iberia*) during 1998-1999 and this area was also a target of the TTR-10 cruise. The work presented here exploits mostly the BIGSETS data set and is an example of the active research going on in this area. The main objectives were: 1) to define the structural framework; 2) to detail the interpretation of the Marquês de Pombal fault; 3) to identify and follow 4 representative seismic horizons; 4) to constrain the age of these horizons through the computation of synthetic seismograms for the boreholes available to the north of the study area; 5) to obtain structural and thickness maps for the studied sedimentary sequences; 6) to define a Tectono-Sedimentary model that can explain the interpreted structure.

The Present dominant tectonic regime west of S. Vicente cape is compressive. A few strike-slip faults were also identified despite its weak expression on the seismic lines. The inferred fault movement is compatible with the Quaternary kinematic model proposed by Srivastava et al. (1990) and Argus et al. (1989). The most active tectonic period extends from the end of the lower Cretaceous to the Tortonian. The only major structures that are recognized as active after the Tortonian are the Marquês de Pombal fault and the Pereira de Sousa fault (a N-S rift fault, located north of the MPF).

The study of seismic lines and thickness maps point to the fact that the Marquês de Pombal fault possesses two different segments, north and south, with a different tectonic activity. The northern segment acted as a normal fault from the Mesozoic rifting and was reactivated as a reverse fault at least from Neogene times until Present. The southern segment, which was not active during the Mesozoic rifting, shares the inversion tectonic kinematics of the northern segment. The orientation of both segments suggests that they may represent old Late Variscan faults reactivated first under extensional and later compressional regimes. The isopach maps also showed other extension-inversion structures and overbanking and fan deposits associated with the Cape S. Vicente canyon.

<u>References</u>:

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Baptista, M. et al. (1998) The 1755 Lisbon Tsunami: evaluation of the tsunami parameters. *Journal of Geodynamics*, 25 (2): 143-157

Srivastava et al. (1990). Motion of Iberia since the Late Jurassic: results from detailed aeronagnetic measurements in the Newfoundland Basin. *Tectonophysics,* 184: 229-260

Ribeiro, A. et al. (1996). Stress pattern in Portugal mainland and the adjacent Atlantic region, West Iberia. *Tectonics*, 15 (2): 641-659

Zitellini et al. (1999). The tectonic source of the 1755 Lisbon earthquake and tsunami. *Annali di Geofisica*, 42 (1): 49-55
Zitellini et al. (2001). Source of 1755 Lisbon Earthquake and Tsunami Investigated. *EOS,* 82 (26): 285-291

STRUCTURE, ACTIVE TECTONICS, MASS WASTING AND SEDIMENTARY / EROSION PROCESSES IN THE AREA OF THE MARQUÊS DE POMBAL – SAN VICENTE CANYON, SW PORTUGUESE MARGIN. RESULTS FROM DEEP TOWED SIDE SCAN SONAR (TOBI)

E. Gràcia[1], J. Dañobeitia[1], P. Terrinha[2], Ph. Blondel[3], C. Roque[4], **J. Gafeira**[4]
and HITS Scientific Cruise Party [a]

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[2]*Dep. de Geologia da Faculdade de Ciências da Universidade de Lisboa, Portugal;*
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Tectonically active structures prone to cause devastating earthquakes and tsunamis on the SW Portuguese Margin, such as the Lisbon, 1755 earthquake, were first depicted on Multi-Channel Seismic (MCS) profiles shot during the ARRIFANO survey (Zitellini et al., 1999). Later, these structures were surveyed in detail by means of a denser coverage of MCS profiles and high-resolution Multi-Beam bathymetry acquired by the BIGSETS project (ENV4-CT97-0547, 1998-2000) (Zitellini et al., 2001). The most important of these structures – The Marquês de Pombal fault – and adjacent area was investigated during the TTR-10 cruise (Training Through Research, UNESCO/IOC) in 17th–20th July 2000 using single channel seismic profiles, 3.5 kHz seabottom profiler, 10 kHz OKEAN long range side scan sonar, 30 kHz ORETECH deep towed side scan sonar and high resolution seabottom profiler.

The HITS (High Resolution Imaging of Tsunamigenic Structures in SW Iberia) multidisciplinary project resulted from international cooperation with the aim to evaluate the seismic activity of the "Marquês de Pombal Fault" and other active structures, in order to determine its detailed faulting geometry and associated landslide deposits, calculate recurrence intervals, and identify the possible seepage of fluids. The approach of the HITS cruise, based on a combination different survey methods and resolutions, is fundamental to allow a detailed characterization of the superficial and sub-seafloor structure of active tsunamigenic faults to assess the seismic hazard in the Southwest Iberian Margin (Gràcia et al., 2001). The San Vincent canyon was also mapped using the same instrumentation. The HITS-Leg 1 (carried out on from the 2/9 to the 24/9/2001 on board the Spanish RV Hespérides) designed to determine the geometry of active structures in the SW Iberian Margin by detailed mapping and geophysical profiling, was based on the following instrumentation: High-Resolution Sidescan Sonar TOBI (Towed Ocean Bottom Instrument) from the Southampton Oceanography Centre (UK). This is a geophysical exploration instrument operating 200-400 m above the seafloor, up to depths of 5000 m. It includes a 30 kHz sidescan sonar, a 6-7 kHz sub-bottom profiler and a 3 component magnetometer. The sonographs mosaics, 6 m de resolution and 6 km swath, allow us to identify and cartography the structures not visible with conventional acoustic methods. Simrad EM12 swath-bathymetry/acoustic backscatter and, TOPAS sub-bottom profiler and gravity data were also acquired, providing complementary information of seafloor morphology and deep structure.

The results accumulated by the mentioned campaigns and projects using MCS profiles, high resolution seismics, high-resolution bathymetry and shallow- (OKEAN) and deep-towed side-scan sonar (TOBI and ORETECH), allowed a progressive better understanding of tectonic and sedimentation processes in the study area.

It is shown that the recent mass wasting processes associated with the Marquês de Pombal structure were accommodated by two large landslides that cover an area of 20x13km. Other structures such as slump folds, and tensile fractures separating disrupted blocks are also seen in the TOBI images.

The most important Neogene through Quaternary depocentre of the area is bound by the Marquês de Pombal plateau, the Principe de Avis Mountains and the Pereira de Sousa, which is a Mesozoic rift fault that is presently undergoing uplift and from whose scarp more than 20 turbidite ridges.

The São Vicente Canyon is beautifully depicted by the MultiBeam bathymetry and TOBI images. The bottom of the canyon shows a highly reflective image, with stepped surfaces that correspond to sub-horizontal hard bed-rock strata. The canyon is almost barren of recent sediments and made up of two linear segments, with different orientations, that bear a different tectonic control.

[a] R. Bartolomé, L. Bullock, M. Farrán, M. Gómez, G. Lastras, H. Perea, M.J. Román, V. Willmott.

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Gràcia, E., J.J. Dañobeitia and HITS cruise party (2001). "High-Resolution Imaging of Tsunamigenic Structures in the SW Iberian Margin (Eurasia-Africa Convergence): Implications for Seismic Hazard Assessment". *Eos Trans AGU*, Fall meeting, S51: 610

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STRUCTURAL CONTROL OF MUD VOLCANISM IN THE GULF OF CADIZ

L.M. Pinheiro[1,2], V.H. Magalhães[1,2], M.C. Fernandez-Puga[3], L. Somoza[3], J.H. Monteiro[2], J. Gardner[4] and M Ivanov[5]

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Extensive mud volcanism and fluid escape structures related to hydrocarbon rich fluid venting are observed throughout the South Portuguese Margin and the Gulf of Cadiz. A large mud volcano field, confirmed by coring, was discovered in this area in 1999, at water depths between 700 and 3500 m. Since then it has been intensively investigated by single channel seismics, long range and deep-tow sidescan sonar, underwater TV, dredging and coring. The sediments from the mud volcanoes show obvious indications of gas-saturation: degassing structures, a strong H_2S smell, chemosynthetic fauna (such as Pogonophora tube worms) and authigenic carbonates. Gas hydrates were recovered from the top of two active mud volcanoes: Ginsburg (910 m wd) and Bonjardim (3060 m wd). The gas released from the hydrates is essentially hydrocarbonic with a high content of methane homologues, indicating its thermogenic nature and suggesting the existence of hydrocarbons and gas-rich overpressured sediments at depth, and the upward migration of these fluids and fluidised sediments along faults to the seafloor. Pore-water composition studies suggest that gas hydrates are likely to be present in other mud volcanoes in the area, as well.

Although some of the widespread shallow fluid venting on the seafloor in the northern part of the Gulf of Cadiz could be due to the destabilization of gas hydrate rich sediments, in contact with the Mediterranean Outflow, most of the mud volcanism, in particular the active mud volcanoes in deep water, appear to be tectonically controlled. On the side-scan sonar images, several mud volcanoes and fluid escape structures appear to be located along major NW-SE and NE-SW trending faults. Based on the available seismic profiles acquired during the TTR-9, TTR-10, TTR-11, together with high resolution sparker and deep multichannel seismic profiles (IAM– Iberian

Atlantic Margins Project) these faults are interpreted as corresponding to the reactivation, in a strike slip regime, often transpressional, of older structures. Some of these structures appear to have formerly behaved like normal faults.

THE GUADALQUIVIR DIAPIRIC RIDGE: DEEP TECTONICS AND RELATED GAS SEEPAGE

M.C. Fernández-Puga[1], L. Somoza[1] , L.M. Pinheiro[2], J.T. Vázquez[3], V. Díaz-del-Río[4] and M. Ivanov[5]

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Cooperation between the Spanish TASYO project during the cruises Tasyo/2000, Anastasya/99, Anastasya/00 and Anastasya/01 and the UNESCO-IOC Training Trough Research Programme during the TTR-9, TTR-10 and TTR-11 cruises have permitted to identify numerous structures related to hydrocarbon seepages in the Gulf of Cadiz, located between the African and Eurasian plates.

The interpretation of multibeam bathymetry and a large database of reflection seismic profiles show two important morphotectonics structures: the Cadiz Diapiric Ridge (CDR) and the Guadalquivir Diapiric Ridge (GDR). The CDR is a diapiric elongate structure located between 400 and 700m depth with a N-S direction. Westward of this structure GDR is situated a longitudinally shaped diapirs oriented in NE-SW direction located along the shelf and slope between 300-1100m depth. This highly deformed ridge has been mapped using industrial multifold seismic, core log, gravity cores, dredge samples and photographs obtained during the ANASTASYA 01/09 cruise. These data have shown that it is composed of early-middle Miocene blue marls (Maldonado *et al,* 1999), mud breccias and calcarenites. In fact, this diapiric structure is associated with a complex tectono-sedimentary history related to along slope gravity gliding and tectonic compression westward the fronts of the deformed wedges of the “Olistostromic allochtonous units” (Somoza et al., 1999).

According to the observed and sampled structures along the GDR, this ridge can be divided in three areas: (a) The NE area is characterized by the existence of a serie of wide single sub-circular mud volcanoes (Anastasya, Tarsis and Pipoca) surrounded by a ring shaped seafloor depression. In these mud volcanoes mud breccia was collected (ANAS00-TG5, TG6, TG7, TG8 and ANAS01-TG2); (b) a medium sector with long rounded like craters structures. There were collected calcarenites (ANAS01-DA13). These structures have an uncertain origin, and (c) SW sector, between 8ºW and 7º40´W that is characterized by a series of mud mounds boundaring the Cadiz channel named Iberico, Cornide and Hormigas. In this area it was collected abundant carbonate chimneys, slab and calcarenites (ANAS00-DA10, ANAS01-DA1, DA2, DA15). All these seabed structures suggest interpreted as result of high-pressure expulsion of methane-enriched muds along thrusting faults.

This research has been supported by the "TASYO" project *(Tecto-sedimentary transfer from shelf to Horseshoe and Seine abyssal plains in the Gulf of Cadiz*) of the Spanish-funded Marine Science and Technology programme (CYTMAR 98-0209) in the frame of the Spanish-Portuguese agreement for scientific co-operation.

<u>References</u>:

Maldonado, A., L. Somoza, L. Pallarés (1999). The Betic orogen and the Iberian-African boundary in the Gulf of Cadiz: geological evolution (Central North Atlantic). *Mar. Geol.*, 155: 9-43

Somoza, L., A. Maestro, A. Lowrie (1999). Allochtonous Blocks as Hydrocarbon Traps in the Gulf of Cadiz. *Offshore Technology Conference* OTC 10889: 571-577

ANNEX I

CONFERENCE PROGRAMME

TUESDAY, JANUARY 29
University of Aveiro, Library Building, Helene de Beauvoir Hall

18:30–21:30 Welcome and registration of participants

WEDNESDAY, JANUARY 30
University of Aveiro, Pedagogic Complex, room 23.1.5

9:00–10:00 Registration of participants

Plenary Session:

11:00 Official opening
Welcoming addresses by:
M.H. Nazaré, Rector of the University of Aveiro
M. Ruivo, Portuguese Committee for the Intergovernmental Oceanographic Commission
A.E. Suzyumov, United Nations Educational, Scientific and Cultural Organization

11:45 ***M.K. Ivanov***
THE TRAINING THROUGH RESEARCH PROGRAMME. WHY? HOW? WHAT?

12:00 ***L.M. Pinheiro****, J.H. Monteiro, M.R. Cunha*
GAS-HYDRATES AND MUD VOLCANISM IN THE GULF OF CADIZ AND THE SOUTH PORTUGUESE MARGIN. MAIN RESULTS FROM THE PORTUGUESE PARTICIPATION IN THE TTR PROGRAMME.

12:15 ***J.-P. Henriet***
GEOSPHERE/BIOSPHERE COUPLING PROCESSES

Session 1: Mud volcanism, diapirism and gas hydrates
Convenors: *Luis Menezes Pinheiro and Luis Somoza*

14:00 ***M.K. Ivanov****, N. H. Kenyon, L.M. Pinheiro and J.-P. Henriet*
COLD SEEPS ON THE DEEP SEA EUROPEAN MARGINS. DISCOVERIES, IDEAS, QUESTIONS

14:30 ***G. Çifçi****, D. Dondurur and M. Ergün*
COMPARATIVE CHARACTERISTICS OF THE RUSSIAN AND TURKISH NEAR SHORE AREAS IN THE EASTERN BLACK SEA

14:50 ***P. Van Rensbergen****, J. Poort, R. Kipfer, M. De Batist, M. Vanneste, J. Klerckx, N. Granin, O. Khlystov and P. Krinitsky*
EVIDENCE OF NEAR-SURFACE SEDIMENT MOBILIZATION AND METHANE VENTING IN RELATION TO HYDRATE DISSOCIATION IN SOUTHERN LAKE BAIKAL, SIBERIA

15:10 ***E. Poludetkina****, A. Stadnitskaia and V. Blinova*
COMPOSITION AND ORIGIN OF HYDROCARBON GASES FROM MUD VOLCANOES. CENTRAL AND EASTERN (SOROKIN TROUGH) PARTS OF THE BLACK SEA

15:30 *V. Blinova,* ***A. Stadnitskaia****, I.J.S. Sinninghe Damsté, M. Baas and T.C.E. van Weering*
LIPID COMPOSITION FROM GAS-RELATED SEDIMENTS AND MUD VOLCANIC DEPOSITS OF THE SOROKIN TROUGH, NE BLACK SEA. PRELIMINARY RESULTS

15:50 ***N. Tyrina*** *and I. Belenkaia*
PORE WATER CHEMISTRY IN GAS HYDRATE-BEARING MUD VOLCANO DEPOSITS OF THE BLACK SEA

Session 1: (continuation) Mud volcanism, diapirism and gas hydrates

Convenor: *Michael Ivanov*

16:40	***S. García-Gil*** *and F. Vilas* SHALLOW GAS IN THE RÍAS BAJAS (NW SPAIN): FLUID ESCAPES
17:00	***S.V. Agibalov*** *and A.M. Almendinguer* APPLICATION OF TIME-FREQUENCY ANALYSIS OF SEISMIC DATA TO SHALLOW GAS STUDY
17:20	***D. Modin*** NATURE OF ENIGMATIC STRONG REFLECTOR ON MAK-1M SUBBOTTOM PROFILER RECORDS FROM THE BLACK SEA. GEOPHYSICAL PROCESSING AND ANALYSES OF THE SUBBOTTOM PROFILER DATA
17:40	***S. Shkarinov*** VECTOR VISUALISATION OF SEISMIC SECTIONS. AUTOMATION OF PRELIMINARY SEISMIC INTERPRETATION

Aveiro, Town Hall

18:45 "Port of Honour" offered by the Mayor of Aveiro

THURSDAY, JANUARY 31

University of Aveiro, Pedagogic Complex, room 23.1.5

Session 2: Deep-sea depositional systems and modern analogues

Convenors: *Javier Hernandez-Molina, Neil Kenyon*

9:00	***N.H. Kenyon*** SOME CONTROLS ON SEDIMENTARY ARCHITECTURE ALONG THE NORTHEAST ATLANTIC CONTINENTAL MARGIN
9:40	***A.M. Akhmetzhanov****, N.H. Kenyon, E.L. Habgood, J. Gardner, M.K. Ivanov and P. Shashkin* SAND LOBES IN THE GULF OF CADIZ: TOWARDS BETTER UNDERSTANDING OF CLASTIC RESERVOIR HIGH-RESOLUTION ARCHITECTURE
10:00	*E. Llave,* ***F. Hernández-Molina****, L. Somoza, A. Maestro, J.T. Vázquez, V. Díaz-del-Río, D.A.V. Stow, F.J. Lobo and J.M. Alveirinho Dias* THE MAIN ACTIVE DEPOSITIONAL PROVINCE OF THE CONTOURITE DEPOSITIONAL SYSTEMS OF THE GULF OF CADIZ: A QUATERNARY RECORD OF PALEOCEANOGRAPHIC AND TECTONIC INFLUENCES

Session 1: (continuation) Mud volcanism, diapirism and gas hydrates

Convenors: Gunay Cifci and Grigoryi Akhmanov

10:50	***O. Kovalenko*** *and I. Belenkaia* METHANE-INDUCED AUTHIGENIC CARBONATES IN MUD VOLCANO DEPOSITS OF THE BLACK SEA
11:10	***A. Mazzini****, B.T. Cronin and J. Parnell* CARBONATE CRUST STRATIGRAPHY FROM THE BLACK SEA
11:30	***R. Descamps*** *and R. Swennen* CARBONATE CHIMNEYS COLLECTED IN THE GULF OF CADIZ: A PETROLOGIC AND ISOTOPIC ANALYSIS
11:50	***V.H. Magalhães****, J. Bobos, L. Gaspar, L.M. Pinheiro, J.H. Monteiro and M.K. Ivanov* MINERALOGY AND GEOCHEMISTRY OF CARBONATE CHIMNEYS FROM THE GULF OF CADIZ. PRELIMINARY RESULTS
12:10	*A. Stadnitskaia, J.S. Sinninghe Damsté, I. Belenkaia, C. Pierre and J.P. Werne* METHANE-RELATED AUTHIGENIC CARBONATE FORMATION: MOLECULAR, MINERALOGICAL AND ISOTOPIC EVIDENCE. GULF OF CADIZ, NE ATLANTIC
12:30	***L. Somoza****, V. Díaz-del-Río, J.M. Gardner, F.J. Hernández-Molina, L.M. Pinheiro, T. Medialdea, J.T. Vázquez, A. Lowrie, R. León, M.C. Fernández-Puga, A. Maestro, L.M. Fernández-Salas, E. Llave and J. Rodero*

MUD VOLCANISM, CARBONATE CHIMNEYS AND GAS HYDRATE STABILITY IN THE GULF OF CADIZ: ARE SEAFLOOR METHANE FLUXES MODULATED BY EPISODIC TECTONIC AND CLIMATE/OCEANOGRAPHIC EVENTS?

TTR-IOC Open Meeting
Convenor: Jean-Pierre Henriet

14:00	Perspectives for future research under the auspices of the TTR programme - IOC of UNESCO: Geosphere-Biosphere Coupling Processes, Ocean Ecosystems and Marine Environmental Protection. Open discussion.

Poster Session

16:00	Posters' presentantions by the authors and discussion.

Session 3: Hydrothermal and hydrogenous supply of elements to the sea floor
Convenors: José Hipólito Monteiro and Fernando Barriga

17:00	***F. Barriga*** SERPENTINITE HOSTED HYDROTHERMAL ACTIVITY AND METHANE PRODUCTION ON THE MID ATLANTIC RIDGE, SOUTH OF THE AZORES
17:40	***S. Muiños****, L. Gaspar, J.H. Monteiro, R. Salgueiro, J.F. Ramos, V.H. Magalhães and T Rodrigues* FERROMANGANESE DEPOSITS FROM THE NAMELESS SEAMOUNT. PRELIMINARY RESULTS
18:00	***V. Torlov*** INTERNAL STRUCTURE AND DISTRIBUTION OF THE ELEMENTS IN THE FERROMANGANESE CRUSTS FROM THE NAMELESS SEAMOUNT

<u>FRIDAY, FEBRUARY 1</u>
Session 4: Biosphere-geosphere interaction
Convenors: Myriam Sibuet and Antje Boetius

9:00	***A. Boetius*** ANAEROBIC OXIDATION OF METHANE MEDIATED BY MICROBIAL CONSORTIA IN GASSY SEDIMENTS
9:40	***M. Hovland*** BACTERIAL MATS AT TWO SEEP LOCATIONS, NORTH SEA
10:00	***E. Kozlova****, C. Largeau, S. Derenne and F. Baudin* BIOMARKERS OF POSSIBLE SOURCE ROCKS FOR HYDROCARBONS IN COLD VENTS OF THE GULF OF CADIZ
10:20	***A. Stadnitskaia,*** *J.P. Werne, J.S. Sinninghe Damsté, M. Baas, E. Hopmans, M.K. Ivanov and T.C.E. van Weering* DISTRIBUTION AND STABLE CARBON ISOTOPIC COMPOSITION OF BIOMARKERS IN METHANE-RELATED CARBONATE CRUSTS. SOROKIN TROUGH, NE BLACK SEA. PRELIMINARY RESULTS
11:10	***M. Sibuet*** *and K. Olu-Le Roy* PECULIAR BENTHIC ECOSYSTEMS OF CONTINENTAL MARGINS AND RECENT DISCOVERIES: MAJOR ECOLOGICAL PATTERNS OF METHANE SEEPS AND CORAL COMMUNITIES FROM SUBMERSIBLE OBSERVATIONS
11:50	***S. Vandendriessche****, A. Vanreusel and J.-P. Henriet* COMMUNITIES, DIVERSITY AND ZONATION PATTERNS IN *LOPHELIA* MOUNDS: PREPARATION OF A PRACTICAL HANDBOOK
12:10	***M.R. Cunha****, M.D. Subida, S. Vandendriessche, I. Lima, A. Ravara and the TTR-11 Scientific Party* MACROFAUNAL COMMUNITIES ASSOCIATED TO CARBONATE CHIMNEYS FROM THE GULF OF CADIZ. PRELIMINARY RESULTS FROM VIDEO IMAGERY AND DREDGE SAMPLING OBTAINED DURING TTR-11 CRUISE
12:30	***J. Cúrdia****, S. Carvalho, A. Ravara, J.D. Gage, A.M. Rodrigues and V. Quintino* ECOLOGY OF INTERESTING GEOLOGICAL FEATURES: AN INSIGHT OF NAZARÉ SUBMARINE CANYON (NE ATLANTIC)

12:50 ***A.Yu. Sadekov***
PLANKTONIC FORAMINIFERAL ZONATION OF A SAPROPELIC BED FROM THE LATE QUATERNARY SEDIMENTS OF THE WESTERN BALEARIC SEA

Conference excursion

14:00 Visit to Porto and sightseeing tour.

SATURDAY, FEBRUARY 2

Section 5: Tectonics

Convenors: Pedro Terrinha, Mustafa Ergün

9:00 ***M. Ergün***
RECENT SEDIMENTATION PROCESSES AND EFFECTS IN THE BLACK SEA

9:40 *A. Mille,* ***L.C. McNeill*** *and TTR-11 Scientific Party*
ACTIVE TRANSTENSIONAL DEFORMATION WITHIN THE NORTH AEGEAN TROUGH ASSOCIATED WITH THE WESTWARD EXTENSION OF THE NORTH ANATOLIAN FAULT

10:00 ***H. Matias****, L. Matias and P. Terrinha*
NEW DEVELOPMENTS ON THE TECTONO-SEDIMENTARY INTERPRETATION OF THE MARQUÊS DO POMBAL AREA (SOUTHWEST PORTUGAL)

10:20 *E. Gràcia, J. Dañobeitia, P. Terrinha, Ph. Blondel, C. Roque,* ***J. Gafeira*** *and HITS Scientific Cruise Party*
STRUCTURE, ACTIVE TECTONICS, MASS WASTING AND SEDIMENTARY/EROSION PROCESSES IN THE AREA OF THE MARQUÊS DE POMBAL – SAN VICENTE CANYON, SW PORTUGUESE MARGIN. RESULTS FROM DEEP TOWED SIDE SCAN SONAR (TOBI)

10:40 ***L.M. Pinheiro****, V.H. Magalhães, M.C. Fernandez-Puga, L. Somoza, J.H. Monteiro, J. Gardner and M.K. Ivanov*
STRUCTURAL CONTROL OF MUD VOLCANISM IN THE GULF OF CADIZ

11:00 ***M.C. Fernandez-Puga****, L. Somoza, L.M. Pinheiro, J.T. Vázquez, V. Díaz-del-Rio and M.K. Ivanov*
THE GUADALQUIVIR DIAPIRIC RIDGE: DEEP TECTONICS AND RELATED GAS SEEPAGE

Closing Session

11:50 Main conclusions, prizes for best students' presentations and closing of the meeting

POSTER PRESENTATIONS
(alphabetical listing by first author)

M.R. Cunha, M.D. Subida, A. Hilário and I. Teixeira
LIVING IN EXTREME ENVIRONMENTS: AN EXAMPLE FROM THE LUCKY STRIKE VENT FIELD

M.R. Cunha, M.D. Subida, S. Vanderdriessche and I. Lima
EPIFAUNA ON CARBONATE CHIMNEYS FROM THE GULF OF CADIZ

M.P. Mata, F. López-Aguayo, L. Somoza, V. Díaz del Río and J. Alveirinho Dias
PHOSPHATIC AND FERROMANGANESE CRUSTS IN THE GUADALQUIVIR BANK (GULF OF CÁDIZ, SW IBERIAN CONTINENTAL MARGIN): A "HARDGROUND" RELATED TO MEDITERRANEAN OUTFLOW VARIABILITY?

J. Priest
DETECTING GAS HYDRATES - TOMORROW'S FUEL OR TODAY'S RISK?

A. Stepanov
GEOCHEMICAL INVESTIGATIONS OF THE HYDROTHERMAL ACTIVITY PRODUCTS FROM THE LUCKY STRIKE ORE FIELD

ANNEX II

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