

Intergovernmental Oceanographic Commission

Workshop Report No. 187



Geological and biological processes at deep-sea European margins and oceanic basins

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

Bologna, Italy
2 – 6 February 2003

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Editors: M. Marani
G. Akhmanov
A. Suzyumov

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Abstract

The "Geological and biological processes at deep-sea European margins and oceanic basins" - International Conference and 11th Training-through-Research (TTR) Post-Cruise Meeting took place from 2 to 6 February, 2003 at Istituto di Geologia Marina (ISMAR), Area della Ricerca del Consiglio Nazionale delle Ricerche (CNR), Bologna, Italy. The primary focus of the meeting was to discuss the results of the TTR-12 cruise (2002). It brought together participants from eight countries: Belgium, France, Italy, Morocco, Portugal, Russia, Spain and the United Kingdom. Attending were researchers and students with different specialities (sedimentology, geophysics, geochemistry, microbiology, biology, palaeontology, structural geology) and research interests falling in the areas of the conference themes. In total 25 oral presentations and seven poster presentations were made during the meeting that reflect the main research directions of the TTR programme, such as mud volcanism, fluid venting and related processes, geosphere-biosphere interactions, tectonics and sedimentation on continental margins and in deep-sea basins.

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PREFACE

"Geological and biological processes at deep-sea European margins and oceanic basins" - International Conference and 11th Training-through-Research Post-Cruise Meeting was held from 2 to 6 February, 2003 at Istituto di Geologia Marina (ISMAR), Area della Ricerca del Consiglio Nazionale delle Ricerche (CNR), Bologna, Italy.

The Training-through-Research (TTR) Programme (in operation since 1991), sponsored by the Intergovernmental Oceanographic Commission (IOC of UNESCO), has been successfully operated at seas around Europe, as well as along the northern coast of African and in the central part of the Atlantic Ocean, making sophisticated multidisciplinary research combined with advanced on-the-job training for students and young scientists in the field of marine science. These 12-year activities led to numerous exciting discoveries, and also built a new multicultural community of young geomarine scientists with high expertise and broad seagoing experience.

The TTR Post-Cruise Meetings have been held regularly since 1993, being hosted by universities and research institutions actively involved in the programme. They aim to facilitate exchange of information between participants in the TTR expeditions, to summarise the collected data, and also to provide students and young scientists with opportunities to present the results of their research to a broad academic audience. And, of course, it is always a way to meet old friends and to make the new ones.

This Conference/Post-Cruise Meeting was focussed on all aspects of marine geosciences that were addresses during the 12th marine expedition in the summer of 2002 and some previous TTR cruises. The intent was to obtain an overview of what has been done and also to outline directions for the future research activities.

The meeting brought together participants from eight countries (Belgium, France, Italy, Morocco, Portugal, Russia, Spain, and the United Kingdom). 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 themes.

In total 25 oral and seven poster presentations were made. All the participants expressed great satisfaction with the Conference as having fully accomplished its objectives and facilitated fruitful contacts between the attendees.

A guest lecture was delivered by Dr. Jean Mascle (Laboratoire de géodynamique sous marine, Villefranche-sur-mer, France) on the recent highly successful research undertaken in the SE Mediterranean Sea.

During the Conference discussion of plans for the future TTR research took place and, on 2 February, meeting of the TTR Executive and Scientific Committees was organised, which considered a number of items related to the organisation of the TTR cruises, as well as publication of the TTR data.

The Conference programme was set up by the Organising Committees:

- Michael Marani (ISMAR-CNR)
- Fabiano Gamberi (ISMAR-CNR)
- Angela Borsi (ISMAR-CNR)
- Stefano Carluccio (ISMAR-CNR)
- Mikhail Ivanov (Moscow State University)

The book of abstracts was compiled by the Organising Committee. For the present Report, it was further edited by Dr. G.G. Akhmanov (Moscow State University) and Dr. A.E. Suzyumov (UNESCO). The organisation 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 oral presentations, along with the division into different 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, Area della Ricerca del Consiglio Nazionale delle Ricerche and its Istituto di Geologia Marina, Bologna (Italy), as well as universities of Aveiro (Portugal), Ghent (Belgium), Granada (Spain), Moscow (Russia) and Southampton Oceanography Centre (UK).

ABSTRACTS

Introduction

REVIEW OF THE PRINCIPAL RESULTS OF THE TTR-12 CRUISE

M. Ivanov¹, N. Kenyon², T. Neilson³, L. Pinheiro⁴, M. Comas⁵, M. Marani⁶, J. Monteiro⁴,
P. Van Rensbergen⁷, T. Furey⁸, J.-P. Henriët⁷, and Shipboard Scientific Party

¹ UNESCO-MSU Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevy Gory, Moscow 119899, Russia, fu@geol.msu.ru

² Southampton Oceanography Centre, Empress Dock, Southampton, SO14 3ZH, United Kingdom, n.kenyon@soc.soton.ac.uk

³ Geological Survey of Denmark and Greenland, Thoravej 8, DK2400, Copenhagen NV, Denmark, tni@geus.da

⁴ Departamento de Geologia Marinha, Instituto Geologico e Mineiro, Estrada da Portela – Zambujal, Apartado 7586, 2720 Alfragide, Portugal, luis.pinheiro@igm.pt, hipolito.monteiro@igm.pt

⁵ Instituto Andaluz de Ciencias de la Tierra, C.S.I.C. and University of Granada, Campus Fuentenueva, 18002 Granada, Spain, mcomas@goliat.ugr.es

⁶ Istituto di Geologia Marina, via Gobetti 101, 40129 Bologna, Italia, michael@igm.bo.cnr.it

⁷ Renard Center of Marine Geology, Ghent University, Krijgslaan 281, S8, B-9000 Ghent, Belgium, jeanpierre.henriet@rug.ac.be

⁸ Geological Survey of Ireland, Haddington Road, Dublin 4, Ireland, thomasfurey@eircom.net

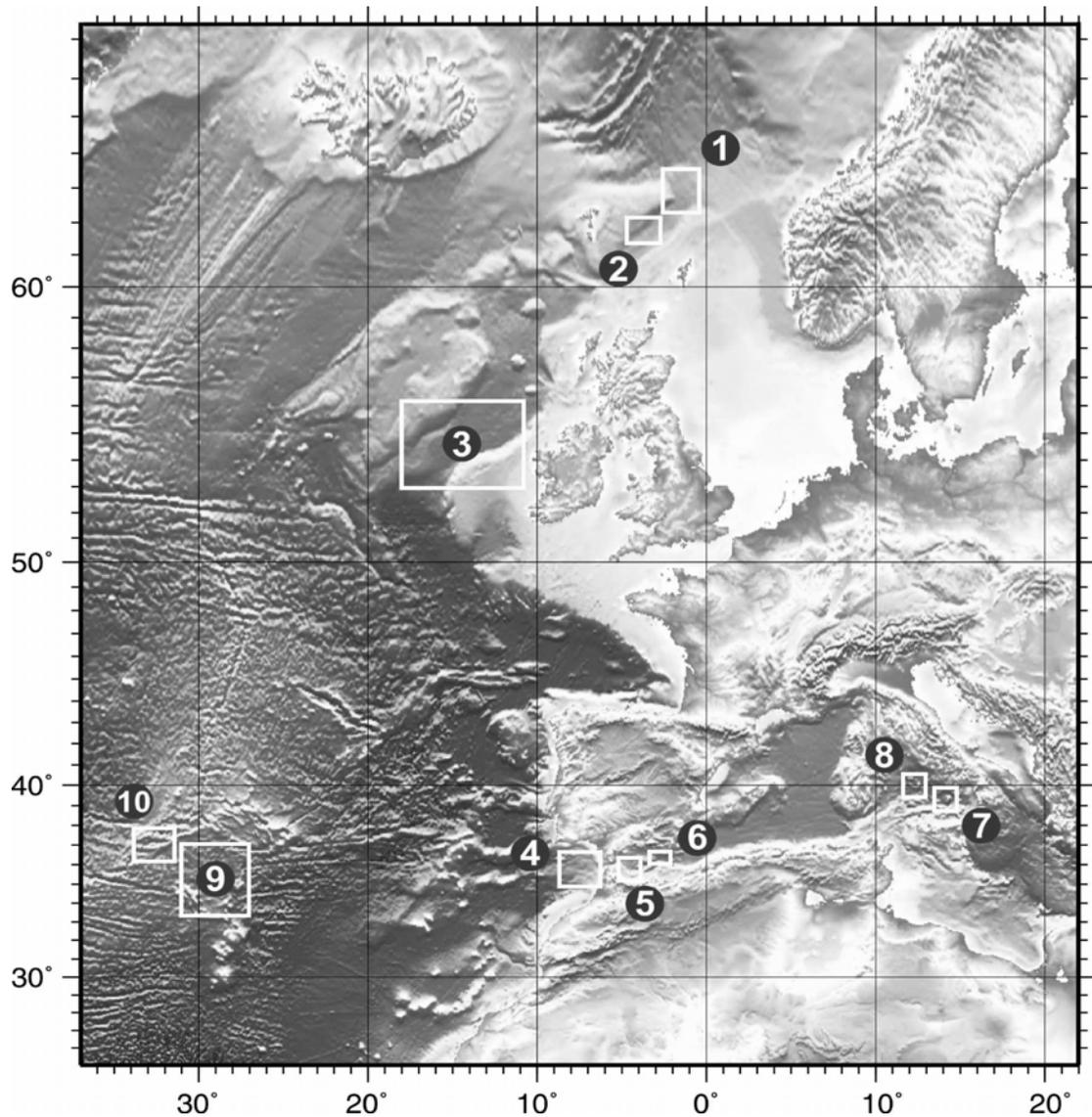
The TTR-12 cruise (2002) was focused on study of geological processes such as fluid venting, sedimentation, slope stability, volcanism, etc. on deep continental margins and oceanic basins (Fig.1). A large set of instruments, including single channel seismic, long-range and deep-towed side scan sonars, acoustic profilers, digital underwater TV and different types of bottom samplers were applied for these investigations.

Seamounts of unknown origin on a basinward continuation of the Fugloy Ridge (to the east of the Faeroes Islands) were mapped with seismic, two types of side-scan sonars, and sampled. Geophysical records indicate the presence of at least two separated groups of diapirs piercing and, as an underwater TV demonstrated, outcropping on the sea-floor. Bottom sampling data suggest that diapirs mainly consist of the Miocene semi-lithified diatom ooze with some admixture of glauconite and foraminifera. No any evidence of coral settlements or recent fluid venting has been documented. Some recent slope processes to the south-west of this area were studied as well.

An intensive bottom sampling programme was performed in the Rockall Trough area. It was mainly devoted to environmental studies of the area, but also was to calibrate acoustic facies for interpretation of a multibeam reflectivity data. Excellent collection of undisturbed sediments from different parts of the trough was obtained and subsampled for chemical, biological and physical properties investigations. However it was understood that the penetration of a box corer is not always enough for the calibration of acoustic signals with the frequency of about 10 kHz.

The main results of surveying in the Gulf of Cadiz can be summarized as following:

- finding of a new field of carbonate chimneys in the northern part of the Gulf of Cadiz, complementary to those discovered by the *Anastasia*-2000 and TTR-11 (2001) cruises;
- detailed study of a new active mud volcano in the central part of the Gulf, sampling of heavy hydrocarbon gases and gas hydrates from this structure;
- detailed study and sampling of a new mud volcanic field on the Moroccan margin, disclosed and mapped with seismic and multibeam by the Ghent University group during the *Belgica*-2002 cruise;
- mapping and sampling of deep-water coral settlements in different locations;



TTR-12 cruise map

- discovery of exotic blocks of sandstones, igneous and metamorphic rocks on tops of some shallow water mud volcanoes;
- complete mapping of the Jil Janesh deep-water sandy system with a 100 kHz side scan sonar and 5.5 kHz profiler.

Four new mud volcanoes and large fields of pockmarks were found in the Western Alboran Sea. Two of them, Kalinin and Perejill, are located in the Spanish part of the basin. Both structures are covered with relatively thick hemipelagic sediments and they look non-active in the present time. However samples of hydrocarbon gases and clasts of ancient rocks in the mud volcanic breccia gave us a good chance to define the source formation.

Investigations in the Eastern Alboran basin concentrated mostly on studying a basinward continuation of the Almeria turbidite system, which upper part was mapped with the MAK-1M deep-towed side scan sonar ten years ago, during the TTR-2 cruise. Mapping of the distal part of this system was carried out with the same instrument to show a very complex structure represented by overlapping channels and sedimentary lobes.

In the Tyrrhenian Sea the investigations focused on studies of the morphology and volcano-tectonic processes related to three biggest submarine volcanos: the Marsili, the Palinuro, and the Vavilov. Mapping of the northern side of the Marsili with a deep-towed side scan sonar has sufficiently increased our knowledge about morphology and recent activity of this volcano. Many of small-scale features corresponding to recent activities of the volcano have been found on acoustic records. Several areas of current low temperature hydrothermal activities have been observed on the top of the Marsili and the Palinuro volcanoes with an underwater TV system.

A long seismic line with two 3-litre airguns was performed across a young sedimentary basin to the south of the Azores plateau. Seismic records have demonstrated a surprisingly thick sedimentary cover - more than 1 km in thickness.

TV observations and sampling of different types of igneous rocks in the Lucky Strike segment were also carried out.

The TTR-12 cruise was the longest until present and one of the most successful cruises in the history of the TTR programme.

Fluid escape and related processes

GEOCHEMICAL CHARACTERISTICS OF HYDROCARBON GASES AND ORGANIC MATTER FROM MUD VOLCANIC DEPOSITS OF THE ALBORAN SEA

E. Poludetkina, E. Kozlova

UNESCO-MSU Research and Training Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevy Gory, Moscow 119899 Russia, fu@geol.msu.ru

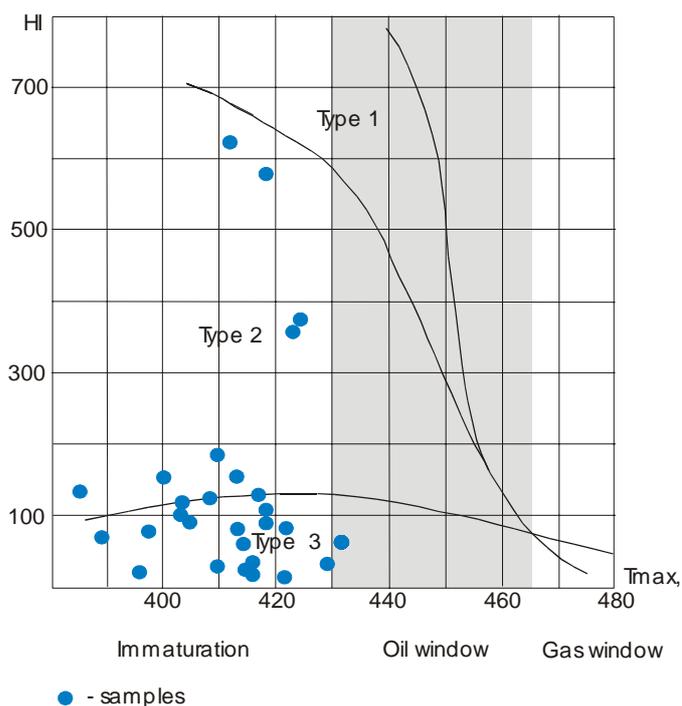
The Neogene basin of the Alboran Sea corresponds to the westernmost Mediterranean extensional basin. The basin is located within Miocene arc-shaped thrust belt formed by the Betic and Maghrebian Cordilleras (Multidisciplinary study of Geological processes on the NE Atlantic and Western Mediterranean margins, UNESCO 2000). It has been the site of a vigorous programme of oil and gas exploration since 1970`s and attracts nowadays attention as a potential oil and gas generating basin.

The materials to this research work are obtained during TTR-9 (1999) and TTR-12 (2002) cruises. During these cruises several mud volcanic structures were discovered and investigated and four of them (Kalinin and Perejil on the Spanish margin, Dhaka and Granada on the Moroccan margin) were sampled.

Methodics of our geochemical investigations included subsampling of the gas phase, matrix and clasts from mud breccia deposits. Hydrocarbon gas then was studied on gas chromatograph. Sediments and clasts were analyzed by flourescent-bituminological method; total organic carbon (TOC) content was determined. The rock clasts were studied in thin sections. Rock-eval analysis was done for 40 samples of clasts for determination of generation potential and maturity level of organic matter (OM); for 2 samples bitumen chromatography was done. Determination of age of the samples was fulfilled by A. Sautkin.

Geochemical investigations started with determination of background concentrations of hydrocarbons. In pelagic environment, the TTR12-290G core, represented by marl, mediate content of methane is up to 0.01 ml/l. Homologues are represented by a set of alkanes from ethane to propilene with predominance of alkenes under n-alkanes, that attests to biogenic origin of the gas phase.

The cores from mud volcanic structures are characterized by abnormally high concentrations of hydrocarbon gases - concentration of methane reaches up to 0.15 ml/l. Homologues are represented by the set of alkanes from ethane to butanes, including alkenes and



Van-Krevelen diagram (HI - Tmax) showing types of kerogen and maturity level (materials of E. Kozlova, TTR-9)

TTR9-258G, TTR9-259G, TTR12-288 GR). TOC content in most of the clasts does not exceed 0.3%, but there are unique clasts rich in OM (TOC=0.68-7.37%). These clasts refer to N₁², Pg₂², Pg₁² and K₂ age. Most organic rich clasts are N₂² rocks (7.37%) and K₂ siltstones (2.94%).

The Van-Krevelen diagram shows that most of the samples contain III (hymic) type of OM, that can generate hydrocarbon gas. Several samples (mostly of K₂ age) contain II (mixed) type of OM.

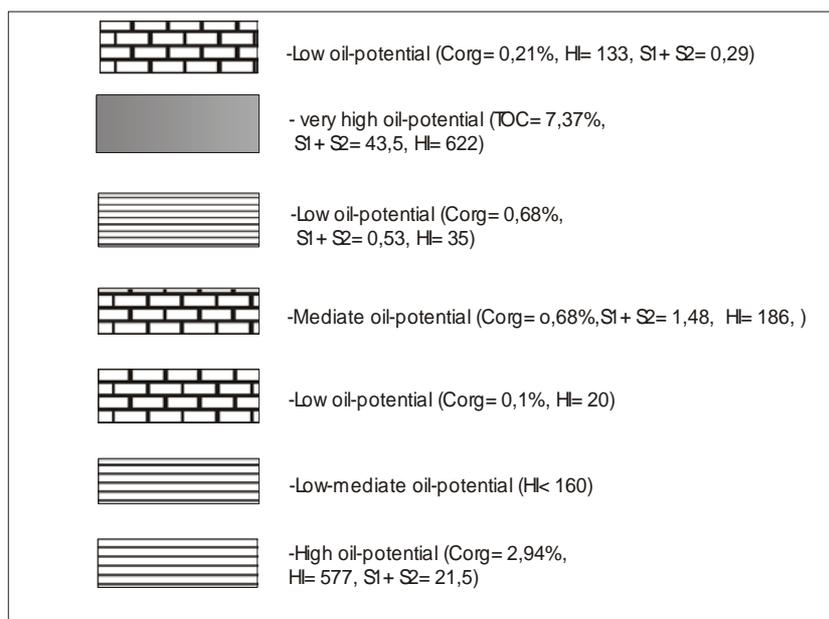
Two samples are close to the zone of the oil window - Upper Cretaceous clay and Middle Eocene clay. In common it can be seen that samples of one age have absolutely different level of maturity.

Geochemical analyses showed that the sediments of the Alboran Sea include middle and high oil-potential strata, that generate or can generate hydrocarbons. These are: N₁² sediments (TOC=7.37%; S₂=43.5 hydrocarbons, mg/rock, g - factual rock potential; HI=622 hydrocarbons, mg/TOC,

iso-alkanes - such heavy homologues are not characteristic for biogenic gas. Alkanes prevail under alkenes, distribution of TOC content is not correlating with the distribution of hydrocarbons. All these facts imply an input of thermogenic gas. Comparing gas concentrations with concentrations of hydrocarbons from the other regions of mud volcanism activity (the Black Sea, the Gulf of Cadiz), we find out that the Alboran basin is a relatively inactive region with a small input of hydrocarbon gases from the inner parts of the sedimentary sequence.

On the basis of geochemical analyses we can assume what the strata can generate hydrocarbons and thus can be considered as "potential oil- and gas-generating sediments".

The geochemical investigations of rock clasts were carried out on samples from mud volcanic deposits of the Granada mud volcano (sites



Geochemical characteristics of sedimentary units (K₂-N) (materials of E. Kozlova, TTR-9)

g - very high oil potential); Pg₁² carbonates (TOC=0.68%; S₂=1,27 hydrocarbons, mg/rock, g; HI=186 hydrocarbons, mg/TOC, g - mediate oil potential); K₂ siltstones (TOC=2.94%; S₂=17 hydrocarbons, mg/rock, g; HI=577 hydrocarbons, mg/TOC, g - high oil potential).

Thus among the studied sediments we can divide middle- and high oil-potential strata that can generate hydrocarbons nowadays or in the future. So, the Alboran Sea can be considered as a potential oil-bearing basin.

NATURE AND ORIGIN OF MUD VOLCANO SEDIMENTS OF THE GULF OF CADIZ (TTR-12 CRUISE)

M. Rachidi¹, N. Hamoumi¹, M. Labraimi¹, M. Ivanov², J.-P. Henri³, E. M. Lotfi⁴, M. Benbouida¹

¹Laboratory of Sedimentology and Marine Geology, Mohammed V- Agdal University, Rabat, Morocco

²Faculty of Geology, Moscow State University, Russia

³RCMG, Ghent University, Belgium

⁴High School of Technical Teaching (ENSET), Rabat, Morocco

Sediments sampled by dredging, TV Grab and gravity core from mud volcanoes: Idrissi (TTR12-AT411G, TTR12-AT412D), TTR (TTR12-AT414G), Jesus Baraza (TTR12-AT391Gr), Capitan Arutjunov, (TTR12-AT397G, TTR12-AT398G, TTR12-AT399Gr, TTR12-AT400G), Fuiza, (TTR12-AT403G), Gemini (TTR12-AT404G, TTR12-AT405G), Renard ridge (TTR12-AT406Gr, TTR12-AT407Gr) and Mercator (TTR12-AT408G, TTR12-AT409D, TTR12-AT410D), during the TTR-12 cruise (July 2002) in the Gulf of Cadiz were the subject of a sedimentological study in order to specify their mineralogical composition and to reconstitute their parent rocks.

These sediments consist of mud breccia composed of dominated poorly sorted matrix and sparse clasts of various sizes (mm to dm) and shapes (rounded to angular).

Petrological study under polarising microscope of the clasts allowed to recognize 10 main groups such as:

PF1 : porphyritic basalt composed of pyroxene and plagioclase phenocrysts within glassy groundmass that may exhibit alteration in chlorite, calcite, hematite and pyrite;

PF2 : finely porphyritic basalt composed of concentrically zoned amygdalae that are often filled of calcite and quartz, sericitised laths of plagioclases within glassy groundmass sometimes altered in chlorite, pyrite and hematite;

PF3 : calcareous sandstones composed of poorly sorted quartz of various shapes (rounded to angular), tourmaline, glauconite and bioclasts within a cement of microsparite;

PF4: silty biomicrite composed of lamina of micritic matrix with bioclasts and stromatolithe filaments and sparse detrital minerals: angular quartz, heavy minerals (tourmaline, zircon), micas (biotite, chlorite, muscovite);

PF5: sandy biomicrite composed of micritic or microsparitic cement, bioclasts (Echinoderm, and Foraminifera), quartz, rocks fragments (volcanic, metamorphic) and altered micas;

PF6: sandy allochemic limestone exhibiting bioclasts (Foraminifera, Echinoderm, Gastropod, algae) and detrital minerals: quartz, mica, chlorite, biotite, muscovite), heavy minerals (zircon, tourmaline) and pyrite within a cement of sparite and microsparite;

PF7: sparitic limestones;

PF8: biosparite exhibiting Echinoderm and Gastropod within microsparitic cement;

PF9: polymictic clast composed of rock fragments (carbonate, siltstone, mudstones) and carbonate crystals coated by marl and clay;

PF10: polimictic clast: clay aggregates and soft pebbles coated by mixtures of marls and clays often affected by soft sediment features.

The clasts corresponding to groups (PF1 to PF8) are realised from the disintegration of old deposit known on onshore geological formations. The volcanic rocks (PF1, PF2) are related to Triassic basalt, the mixed siliciclastic/carbonate group PF3 is originated from Oligo - Miocene

deposits, the other mixed siliciclastic/carbonate sediments (PF4 to PF6) and the calcareous groups (PF7, PF8) are related to Cretaceous deposit.

The polymictic clasts are realised during mud volcano activity, PF9 is made by early lithification during hydrate precipitation and PF10 is formed while the re-sedimentation of liquefied sediment.

The sediments of the matrix consist of gravelly sand, marls and clay. The gravelly sand are composed of: quartz, feldspar, calcite, micas, glauconite, framboidal pyrite, authigenic and detrital zircon, rock fragments (siltstones, marlstones, limestones, volcanic rocks), polymictic clasts, relict bioclasts and well preserved planktonic and benthic foraminifera, coccoliths and corals. The detrital components of the matrix are also inherited from older geological formations of Cretaceous to Oligo - Miocene age.

GAS-RELATED ACOUSTIC ANOMALIES IN THE UPPER PART OF SEDIMENTARY SEQUENCE IN THE CENTRAL PART OF THE BLACK SEA

S. Agibalov¹, V. Spiess², S. Krastel²

¹ UNESCO-MSU Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevy Gory, Moscow, 119899, Russia, agibalov@atrus.ru

² Department of Geosciences, University of Bremen, P. O. Box 330440, 28334, Bremen, Germany

The mud volcanic areas in the Black Sea were investigated during TTR-1, TTR-3, TTR-6 and TTR-11 cruises within the UNESCO "Training-through-Research" programme in 1991, 1993, 1996 and 2001. On the base of these surveys, the interdisciplinary investigations were carried out in the Black Sea within M52/1 cruise on board R/V *Meteor* Leg 1, project MARGASCH, January, 2002. This survey was devoted to study mud volcanoes, gas-hydrates, their occurrence and distribution. The investigations were concentrated in the Sorokin Trough and Central part of the Black Sea and included multichannel seismic survey, parasound, hydrosweep, side-scan sonar survey, bottom sampling and CTD. This job was based on seismic data from the M52/1 cruise with comparison of TTR-1 data (Ivanov et al., 1992; Bohrmann and Schenck, 2002). It was done in the framework of co-operation between the Bremen University, Germany and the UNESCO/MSU Centre for Marine Geoscience, Russia.

The multichannel seismic system of the Bremen University was used to collect seismic data. The streamer was 600-hundred meters long, offset length was 90 meters. It consisted of 96 channels. Two types of sources were used: GI gun (generator-injector gun, 2x1.7 l) and Water Gun (0.16 l). For data processing the following flowchart was used: data input, bandpass filtering, true amplitude recovery, static correction, deconvolution, velocity analysis, stacking and migration. These data were compared with the single channel seismic data collected during the TTR-1 cruise. For collecting data during the TTR-1 cruise the single channel seismic streamer was used. Offset length was 96 meters. The type of source was sparker.

During Meteor cruise 11 profiles were shot in the Central part of the Black Sea. Seismic lines were passing the well-known mud volcanoes (MSU, Kornev, Vassoevich and others) in submeridional direction. Mud volcanoes occur in the Central part of the Black Sea in great variety of sizes - up to 2.5 km in diameter, and may rise more than 120 m above seafloor.

Average penetration of the seismic signal was about 1.2 s (M52-1 cruise, 2002). In comparison with GI gun data (Meteor cruise) the TTR-1 seismic data had smaller penetration of the seismic signal (0.9 s). Besides, GI gun data from the Meteor cruise had higher vertical resolution - 7 m (15 m for TTR data). Water gun data theoretically had vertical resolution 3 m. But Water gun produces a mixed phase wavelet. Precursor precedes the main pulses by about 20 ms. It is possible to mute precursor above sea bottom reflection, but many of the primary reflections within the sedimentary sequence are inferred by precursor. And real vertical resolution was about 5 m.

Such acoustic anomalies as bright spots are well distinguished within the sedimentary sequence. Interpretation of a certain amplitude anomaly as being gas-related shall be confirmed by estimating of some parameters of the reflected signal.

Intrinsic attenuation of acoustic energy propagating through the sediments is proved to be much more sensitive to the type of pore fluid than to lithology. Thus, a significant increase in intrinsic attenuation, when identified, may be considered as a reliable evidence for shallow gas accumulation. On several bright spots attenuation was calculated. To obtain a value of intrinsic attenuation within the sedimentary sequence an attenuation was calculated in the area free of bright spots.

Different frequency spectrum of the seismic data collected, using Water gun source and GI gun source, allowed us to calculate attenuation more precisely and in a wide frequency range. For calculating the absorption we used the method of time-frequency analysis (Agibalov and Almendinguer, 2002).

Comparison of these values demonstrated significant increase in intrinsic attenuation from bright spots. This result allowed us to conclude that these anomalies are gas-related.

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THE AL ARAICHE DIAPIRIC FIELD AND ITS "EXOTIC" MUD VOLCANIC DEPOSITS RECOVERED DURING THE TTR-12 CRUISE IN THE GULF OF CADIZ

G.G. Akhmanov¹, M.K. Ivanov¹, J-P. Henriët², E.S. Sarantzev¹

¹ UNESCO-MSU Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevi Gory, Moscow 119899 Russia, fu@geol.msu.ru

² Renard Center of Marine Geology, Ghent University, Krijgslaan 281, S8, B-9000 Ghent, Belgium, jeanpierre.henriet@rug.ac.be

Since 1999 the UNESCO/IOC "Floating University" carries out a scientific exploration in the Gulf of Cadiz, following a broad mapping of the area with SeaMap long-range side-scan sonar performed by USA Naval Research Laboratory and concentrating mainly on detailed studies of fluid-venting related structures. During four research cruises about 20 mud volcanoes were discovered in the deep Gulf of Cadiz, most of them were sampled, and mud volcanic breccia were recovered. By 2002 a large database on composition of mud volcanic deposits of the region has been compiled and studied.

Mud volcanic deposits of the Gulf of Cadiz consist of very poorly sorted matrix-supported mixture of lithified and semi-lithified rock clasts in sandy-silty clay. The clasts are represented by large variety of siliclastic and clayey rocks and abundant micritic and detrital limestones. The rock clasts are believed to be samples of different series of olistostrome complex emplaced in the Gulf of Cadiz during Miocene, which at the present day are brought to the surface through mud volcanic conduits. The rock age ranges mainly from Upper Cretaceous to Miocene. Apart from small differences in mud breccia composition, which allowed tentative subdivision into three main mud volcanic zones of the Gulf of Cadiz (Portuguese, Spanish and Moroccan), the deep-sea mud volcanic deposits show much similarity.

The Al Araiche diapiric field discovered by Belgian scientists on shallow Moroccan margin of the Gulf of Cadiz was investigated during TTR-12 Cruise with deep-towed side scan sonar, 5 kHz profiler, and underwater TV. For the first time, comprehensive bottom sampling with large gravity core, dredge and TV-controlled grab was carried out on most prominent structures of the field and mud volcanic breccia was recovered.

Study of mud breccia composition led to intriguing results. It showed that only minor mud breccia clasts are represented by rocks well-known from deep-sea mud volcanic deposits whereas fragments of siliclastic, mostly subarkose and subquartzose series prevail among and compose up to 90% of all mud breccia clasts recovered in the area. These series are represented by coarse- to fine-grained sandstones and siltstones with some foraminifera and biotritus, mainly cemented by sparry, often poikilitic calcite. The rocks are often characterized by distinct cross-, ripple- convolute-lamination and grading. These fragments were recovered from all mud volcanoes sampled within the Al Araiche mud diapiric field and have never been described before for any mud volcano of the deep Gulf of Cadiz. They appear “exotic” for the Gulf of Cadiz. However, analogues of studied siliclastic rocks were found onshore, representing Upper Miocene – Pliocene unit of Rharb basin located on the edge and to the south of Rif belt of Morocco. The basin is known as an area of major post-Miocene subsidence and its Pliocene deposits overlie on mid-Tortonian olistostrome complex.

Result of study of mud volcanic deposits of the Al Araiche field might suggest that the Neogene complexes of Rharb basin extend offshore as far as Moroccan shelf break. Essential prevalence of “exotic” sandstones and siltstones among mud breccia clasts and exceptionally large size of their fragments can be an evidence of near-surface structural position of Upper Miocene – Pliocene siliclastic unit. Presence of limestones, claystones and sandstones, which are typical for mud volcanic deposits from the deep part of the Gulf of Cadiz, among the “exotic” mud breccia allows to assume that the Al Araiche mud volcanoes are rooted into Miocene olistostromes of the Gulf of Cadiz or underneath, in a similar way with deeper mud volcanoes. On the contrary, an extension of Pliocene sediments of Rharb basin into the deep-sea area of the Gulf of Cadiz can be ruled out as none from studied deep-water mud volcanoes extrudes “exotic” sandstones.

METHANE RELATED AUTHIGENIC CARBONATES, CHIMNEYS AND CRUSTS FROM THE GULF OF CADIZ

V.H. Magalhães^{1,3}, C. Vasconcelos², L. Gaspar¹, L. Pinheiro³, M. Ivanov⁴,
V. Díaz-del-Río⁵, L. Somoza⁶

¹ Departamento de Geologia Marinha, Instituto Geológico e Mineiro, 2721-866 Alfragide, Portugal;

² ETH-Zentrum, Geologisches Institut, CH-8092 Zürich, Switzerland;

³ Departamento de Geociências, Universidade de Aveiro, 3810-193 Aveiro, Portugal;

⁴ UNESCO Center for Marine Geosciences, Faculty of Geology, Moscow State University, Moscow, Russia;

⁵ Instituto Espanhol de Oceanografia, Spain;

⁶ IGME-Madrid, Spain.

During the TTR-11 (Leg 3) and TTR-12 (Leg 2) cruises (2001 and 2002 respectively), 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 is characterized by a very strong backscatter on the available side scan sonar images and a very irregular seafloor, with morphological and sedimentological features evidencing fluid escape structures (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 and TTR-12 cruises, complemented with data from the *Anastasia* 2000 and 2001 cruises, it seems that this area corresponds to a large field of carbonate chimneys and crusts. Dredge profiles on the Iberico dome and west of this structure, on the main channel of the MOW, yielded a large amount of carbonate crusts and chimneys. These consist essentially of intrapelbiomicrite whose petrographic and XRD

study shows that their mineralogical composition consists mainly of dolomite, high magnesium calcite, quartz, feldspar and clays. Bioclasts of planktonic foraminifera (globigerinoids), ostracods and pellets 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 show a variation from the interior to the exterior. Stable isotopic analysis of Carbon shown low $\delta^{13}\text{C}$ values (down to -46.88‰ vs. PDB) and $\delta^{18}\text{O}$ up to $+4.90\text{‰}$ vs. PDB, typical values of methane as a major carbon source for the carbonate. SEM observations reveal microbes like structures which indicate that microbial activity has played an important role on the carbonates minerals production.

MINERALOGY AND GEOCHEMISTRY OF METHANE-RELATED AUTHIGENIC CARBONATES FROM THE GULF OF CADIZ, NE ATLANTIC

V. Blinova

UNESCO-MSU Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevi Gory, Moscow 119899 Russia, fu@geol.msu.ru

A number of carbonate crusts and chimneys were sampled during the TTR-12 cruise in the Gulf of Cadiz. Three main areas were studied: (1) Formosa Diapiric Ridge; (2) Jesus Baraza mud volcano; (3) fault zone near the Pen Duick escarpment. Sampled stations were chosen basing on the TV survey and acoustic data. All collected carbonates have different structure, mineralogical and chemical composition.

Underwater TV survey, acoustic and sampling data collected during the TTR-11 and TTR-12 cruises suggest that there are extensive fields of carbonate crusts and chimneys on Formosa Diapiric Ridge. Collected carbonate chimneys and slabs are brownish in color and well cemented. The carbonate cement is represented by dolomite. Microscopic analysis reveals a lot of quartz grains, quartzite and glauconite in the carbonate matrix. XRD analysis shows that their mineralogical composition mainly consists of dolomite and quartz (80%) with some admixture of calcite, magnesium calcite and clay minerals. Plankton foraminifera and some iron and manganese oxides were also observed. Individual chimney does not show big variation on petrology from the interior to the external part. Carbon isotopic composition varies from -24.5‰ to -39.6‰ PDB while oxygen isotopes are in range from -0.1‰ to $+3\text{‰}$ SNOW.

Authigenic carbonates retrieved from the Jesus Baraza mud volcano (AT390G), occurred in the form of irregularly shaped crusts. They are yellowish grey in color, porous and poorly cemented. The samples mostly consist of the aragonite (70%) with some admixture of calcite and magnesium calcite. Based on the description of thin sections and location of the crusts in the sediment sequence, samples were divided into two types. The first type consists of carbonates obtained from the surface of the mud volcano. They are more yellowish in color, which indicates oxygen rich environment. Carbonate crusts from the second type are located deeper in sediments at the depth of approximately 20 cm. They are grey in color, less porous and better cemented. $\delta^{13}\text{C}$ for both types is approximately -28‰ PDB and $\delta^{18}\text{O}$ is about $+2\text{‰}$ SNOW.

TV grab sample which was taken from the fault zone contained a lot of carbonate slabs. The carbonate slabs are represented by cemented biogermes, mostly consist of plankton foraminifera, shell debris, corals and pellets. XRD analysis shows that slabs consist of aragonite (18%), calcite (15%) and magnesium calcite (18%) with some admixture of quartz and clay minerals. Also two main types of crusts were recognized. One type is represented by grey well-cemented carbonates and the other is more yellowish but also very well cemented. The variations observed in mineralogical composition of these types are not significant. Carbon isotope composition is heavier than in previous station (from -9‰ to -15‰ PDB).

GEOCHEMICAL CHARACTERISTICS OF HYDROCARBON GASES FROM MUD VOLCANOES OF THE GULF OF CADIZ

E. Bileva, V. Blinova

UNESCO-MSU Center for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevy Gory, Moscow, Russia, fu@geol.msu.ru

The Gulf of Cadiz is an area, characterized by extensive mud volcanism and gas venting processes. The main geochemical objectives of Leg 2 TTR-12 cruise were subsampling of mud volcanic structures and active fluid vents and study of their present activity.

Samples of pelagic sediments, mud volcanic breccia and hydrocarbon gases were collected for geochemical analyses during Leg 2. In general 14 cores were taken and 9 mud volcanoes were studied.

The main objective of this work was geochemical characterization of hydrocarbon gases and mud breccia from 15 mud volcanoes from the Gulf of Cadiz, using the data of TTR-12 cruise and the previous data, obtained in this area during TTR-10 and TTR-11 cruises (V. Blinova, A. Stadnitskaya, 2001).

Concentration and composition of hydrocarbon gas were measured using gas chromatography. Components from methane to pentane, including saturated and unsaturated ones and their isomers were determined.

Using these measurements we can conditionally divide these mud volcanoes into 2 types according to concentration of methane (in general) and its homologues: relatively passive at present days volcanoes and active volcanoes.

The first type is represented by 7 mud volcanoes: Aveiro, Jesus Baraza, Mercator, Tanger, Rabat, TTR and Tasyo. These mud volcanoes are characterized by low concentrations of hydrocarbon gases, which values don't exceed 1 ml/l. Moreover, cores from all of these mud volcanoes consist of pelagic sediments of significant thickness in addition to mud breccia. So due to these facts we can suggest that there were no eruptions from these mud volcanoes for some period.

Gas, sampled from mud breccia from these cores shows the predominance of saturated hydrocarbons over unsaturated ones, while gas samples from pelagic sediments show, that unsaturated hydrocarbons are predominant. These facts imply a presence of active oxidation processes in pelagic sediments and in the upper part of mud breccia.

It is very difficult to indicate the origin (thermogenic or biogenic) of hydrocarbon gases from the cores from mud volcanoes of the first type. However, the ratio of methane to the sum of its homologues for these cores in general does not exceed 100 that imply the thermogenic origin of the gas phase. But because of very low concentrations of hydrocarbons, these measurements are on limit of resolution of this method and we cannot completely trust these values.

Such active volcanoes as Bonjardim, Olenin, Carlos Ribeiro, Ginsburg, Captain Arutyunov, Gemini, Al Idrissi and Fuiza represent the second type of mud volcanoes of the Gulf of Cadiz. All the cores from these mud volcanoes consist mostly of mud breccia, and these cores are characterized by high concentrations of methane, which are measured in $n \cdot 10$ ml/l or higher. Homologues of methane from these cores are also characterized by extremely high concentrations. However the ratio of methane to the sum of its homologues in the area of relatively high concentrations of hydrocarbons for all of these mud volcanoes is different in different cores. According to this fact we can divide structures of this type into two groups:

- with low concentrations of methane homologues, which indicate the predominance of biogenic part of gas. Mud volcanoes Olenin, Al Idrissi, Captain Arutyunov and the bigger crater of Gemini are characterized by such values.

- with high concentrations of methane homologues, that implies the predominance of gas of thermogenic origin. Bonjardim, Carlos Ribeiro, Ginsburg, Fuiza and the smaller crater of

Gemini mud volcano represent this group. Cores from these mud volcanoes consist only of mud breccia and very rarely the presence of insignificant amount of pelagic sediments was observed.

It is very surprising, that two craters of Gemini mud volcano are related to different groups. Most likely, they have the same source of gas, but eruptions through the bigger crater probably took place earlier than through the smaller crater, that can be indicated by the presence of significant part of biogenic gases in gas mixture and the presence of pelagic sediments in the upper part of the core from the bigger crater. Gas from the smaller crater of Gemini mud volcano has not been significantly mixed with biogenic gas from surrounding sediments and its core consists only of mud breccia. Besides we have difference in carbon isotopic measurements of $\delta^{13}\text{C}$ of methane. For the bigger crater these values are lower (about -43‰), than for the smaller crater (about -37.5‰). So we can suggest, that the smaller crater is younger.

Using the same facts, as for the two craters of Gemini mud volcano, we can tell, that the first group is represented by less active mud volcanoes, than the second one.

Gas samples from all of the mud volcanoes of the second type show the predominance of saturated hydrocarbons over unsaturated ones, implying the presence of thermogenic composition part in all of gas mixtures.

All the cores studied in this work show that iso-butanenes are predominant over n-butanenes, determining the presence of focused gas flow through the sediment.

The values of total organic carbon (TOC) content in all samples are relatively low, varying from 0.22 % up to 0.54 %. It should be noted, that there is no clear correlation between distribution of hydrocarbon gases and TOC content along the cores, which indicates migratory nature of hydrocarbon gases. In all of the examined cores, the uppermost part of the sediments is characterized by low methane concentrations and the rise of methane concentrations is associated with the rise of concentrations of its homologues.

Therefore:

The influence of focused fluid inflow is present in all of the studied cores from 15 mud volcanoes.

According to the concentration of methane all mud volcanoes can be divided into two types: relatively passive at present days and active. Among active mud volcanoes two groups were allocated:

- with significant content of gases with biogenic origin;
- with the predominance of thermogenic hydrocarbons (the most active mud volcanoes).

The hydrocarbon gas from gas-venting sediments in most cases is a mixture of gases with thermogenic and biogenic origin.

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DISCOVERING ACTIVE MUD VOLCANOES IN THE ALBORAN SEA (WESTERN MEDITERRANEAN)

M.C. Comas, J.I. Soto, A.R. Talukder and TTR-12 Leg 3 (Marsibal-1) Scientific Party

Instituto Andaluz de Ciencias de la Tierra (C.S.I.C.-Universidad de Granada), Campus Fuentenueva s/n, 18002 – Granada, Spain, mcomas@ugr.es

The high-resolution survey carried out by TTR-12 Leg 3 (MARSIBAL-1 cruise; R/V *Prof. Logachev*, 2002) in the Alboran Sea has revealed the existence of recent active mud volcanism in both, the Spanish and Moroccan margins of the West Alboran Basin (WAB) (Fig. 1). The occurrence of mud volcanoes in the West Mediterranean (southern WAB) was first documented

by TTR-9 (1999). TTR-12 Leg 3 was planned to complete the study of the southern WAB volcano field and to explore on mud volcano existence in the northern WAB. The Leg successfully accomplished to discover a volcano field in the Spanish margin and two new volcanoes in the Moroccan margin.

Studies from the southern WAB volcanoes in the Moroccan margin have established ages and lithology in the volcano material (mud breccias), and argument the morphology, structure, and evolution of these volcanoes (Comas et al., 2000; Sautkin et al., in press; Talukder et al., in press).

TTR-12 Leg 3 survey in the WAB acquired high-resolution seismic profiles and concurrent OKEAN sidescan sonar images (9 kHz) to investigate on possible new volcano incidence. High-resolution sidescan sonar (MAK-1; 30kHz) and concurrent 5 kHz bottom profiles were deployed on specific mud volcanoes to better depict the volcano edifices. The extruded material was also

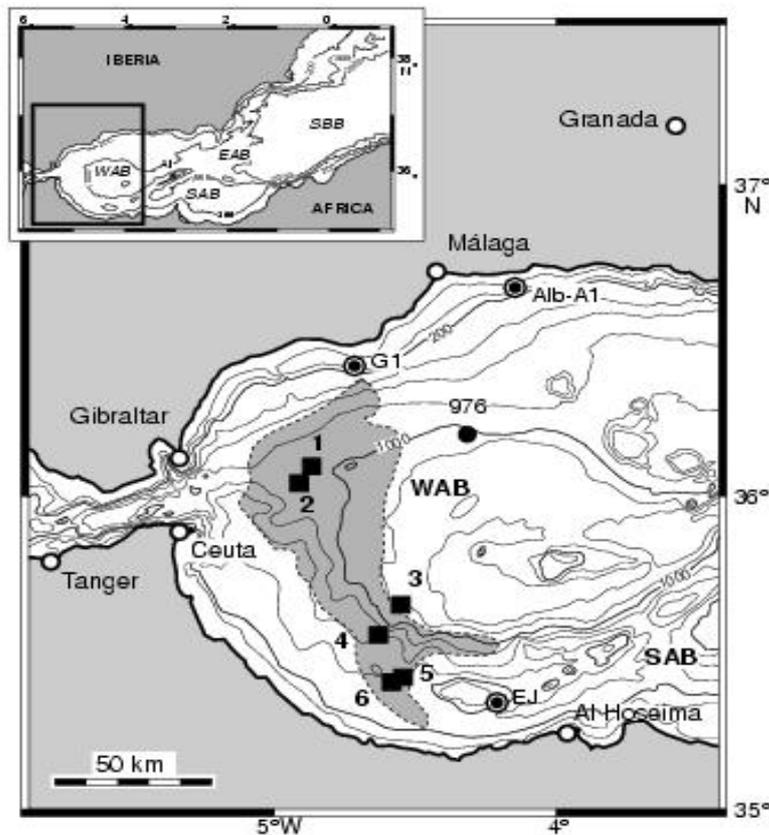


Fig. 1. Location map of the mud volcanoes in the West Alboran Basin (WAB) evidenced by TTR-9 and TTR-12 cruises. Mud volcanoes (black squares): 1= Perejil; 2= Kalinin; 3= Marrakech; 4= Granada; 5= Dhaka; 6= Mulhacen. The mud diapir province in the WAB is also shown in shading. Bathymetry contour interval is 200 m. Inset map shows the location of the surveyed area in the westernmost Mediterranean. AI: Alboran Island; EAB: East Alboran Basin; SAB: South Alboran Basin; SBB: South Balearic Basin. Commercial and scientific wells: Alb-A1= Alboran A1; G1= Andalusia G1; EJ= El-Jebha; 976= ODP Leg 161 Site 976.

sampled in and around volcano craters by gravity coring, grabbing, and dredging.

Mud volcanoes build on from the mud diapir province of the WAB and are connected to the deep diapiric structures founded in the major sedimentary depocenter of the basin (up to 7 km

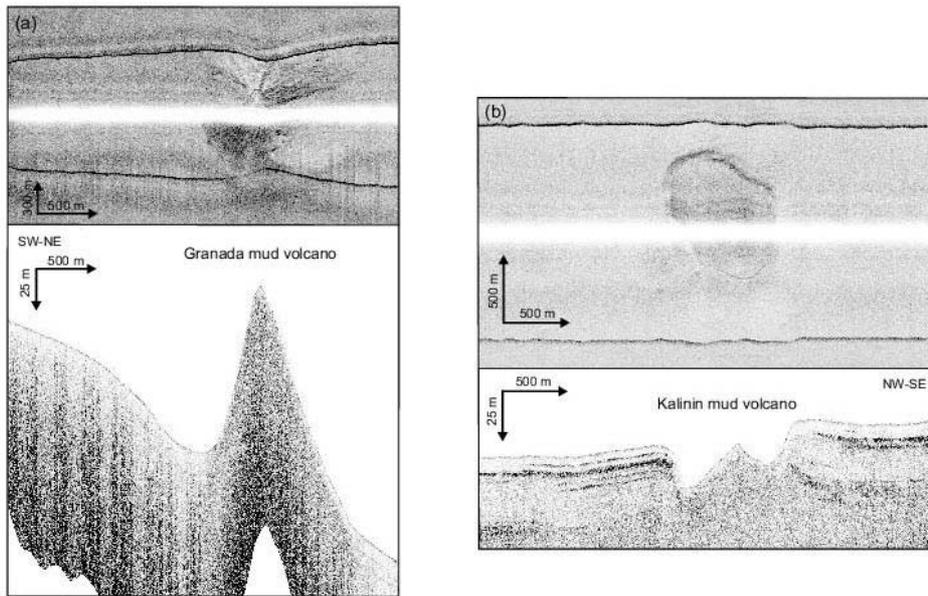


Fig. 2. MAK-1 sidescan image (30 kHz) and corresponding sea-bottom profile (5 kHz) of the (a) Granada (Profile MAK-66ms) and (b) Kalinin (Profile MAK-64ms) mud volcanoes in the WAB. For location of these mud volcanoes see Fig. 1.

in sediment thickness) (Fig. 1). The mud diapir province is formed of under compacted shale and olistostromes from the lowermost marine sedimentary sequences, early to middle Miocene in age, which overlie the metamorphic basement of the WAB. During basin extension (16 to 9 Ma) normal faulting triggered the mud diapirism, and later on, it evolved in a tectonic setting in which the basin undergone sub-meridian contraction and roughly E-W transtension (9 Ma to Holocene) (Comas et al., 1999). Regional seismic- profile correlation indicates that mud volcanism started mainly from the late Miocene, and was well developed during the Pliocene and Quaternary until Present.

The four new TTR-12 discovered mud volcanoes, are named Kalinin and Perejil, and Mulhacen and Dhaka, and are located in the northern and southern WAB, respectively (Fig.1). The high-resolution MAK-1 images and sampling from these four mud volcanoes, and the re-sampling in the Granada volcano provide an impressive amount of new information about the mud volcanism in the WAB.

The Alboran mud volcanoes are conical edifices with occasional caldera collapse structures, showing multiple erosive features in the slopes from running of extensive mud fluxes (Fig. 2a). Volcano relief elevations are from 25 m to 150 m high. Mud volcano perimeters vary from elliptical (e. g. Kalinin) to roughly circular (e. g. Perejil and Granada) shapes. The volcanic cones, with gentle lateral slopes ($\approx 2.6^\circ$), have dimensions between 1.2 km (e.g. Kalinin) and 1.6 km (e.g. Perejil and Dhaka) in diameter. Volcano craters and calderas are between 350 m (Perejil) to about 1600 m (Dhaka) in diameter. Feeder channels are cylindrical to cone-shaped showing transparent to chaotic seismic facies in the high-resolution profiles. Caldera structures show recent conical vents inside, revealing multiple events of extrusion and degasification through the feeder channel (Fig. 2b) in recent times. High-resolution seismic profiles indicate that distinct episodes of volcano collapse also occurred from the Pliocene.

Gravity cores in the craters of Perejil, Granada, and Dhaka, sampled mud breccias on the top of the volcanoes, and high gas content was revealed by a typical smell in some cores. Nevertheless, cores from Kalinin show pelagic drapes up to 1.5 m thick overlaying the mud breccias. Chemosynthetic communities of Pogonophora were found in Kalinin, beneath few cm of

pelagic drape. Few Hydrozoa and coral branches were also encountered in the Granada mud volcano. Grab and dredge sampling in Granada mud volcano evidence that the extruded material contains blocks (up to 45 cm) and clasts, boulders-to-pebble sized, from different sedimentary rocks. The extruded blocks and clasts belongs to rock-units, of very different ages, involved in the olistostromes encountered in the basal early Miocene sedimentary unit of the Alboran Basin (Comas et al., 1999). In consequence, TTR-12 Leg 3 proves that the Alboran mud volcanoes brought up material from the older and deeper sediments in the basin from more than 5 km depth, in addition to drive out mud-breccias, fluids, and gas. Multi-channel seismic reflection data across the Dhaka mud volcano show that its feeder channel reaches down to 4 s (t.w.t.), supporting that volcanic material came from very deep levels in the basin.

The absence of a pelagic drape on the top of some volcano craters together with the occurrence of Pogonophora, suggest that mud volcanoes were recently active or are still active at present.

Available data indicate that mud volcanoes developed as a consequence of fluidized sediments (fluid and gas) migration and rise through faults and fractures connected with the top of deeper mud diapirs (e.g. Kalinin, Perejil), or build on the flank of some diapir highs (e.g. Marrakesh).

Mud volcanic processes confirm the postulated gas-prone character of the Alboran Basin. Gas-rich layers inside sediments around the volcano craters (Fig. 2b) and the widespread occurrence of pock-marks in the seafloor is also indicative of the high gas content and the hydrocarbon potential of the West Alboran Basin.

Mud-volcano features in the Alboran Sea are comparable to those shown in the Gulf of Cadiz and in the Mediterranean Ridge, but illustrate occurrence and evolution in a different tectonic setting. Mud volcanism in the western Mediterranean Sea represents a case of active sediment-and-fluid flows in a back-arc basin instead of in active accretionary prism domains.

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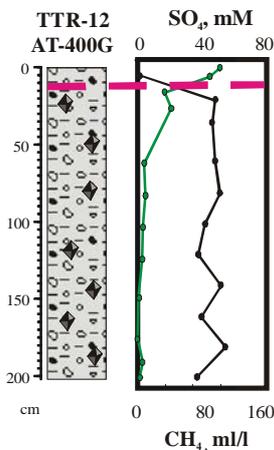
SOME GEOCHEMICAL CHARACTERISTICS OF RELATIVELY ACTIVE AND PASSIVE MUD VOLCANOES (GULF OF CADIZ AND ALBORAN SEA)

V. Blinova, E. Bileva

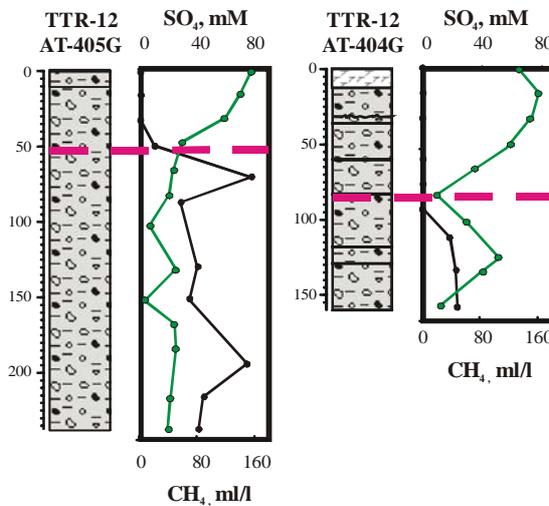
UNESCO-MSU Center for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevy Gory, Moscow 119899, Russia, fu@geol.msu.ru

During the TTR-12 cruise on board R/V *Professor Logachev* several gravity cores were taken from different mud volcanoes in the Gulf of Cadiz and the Alboran Sea. Pore water from the

CAPTAIN ARUTYUNOV MUD VOLCANO



GEMINI MUD VOLCANO



KALININ MUD VOLCANO

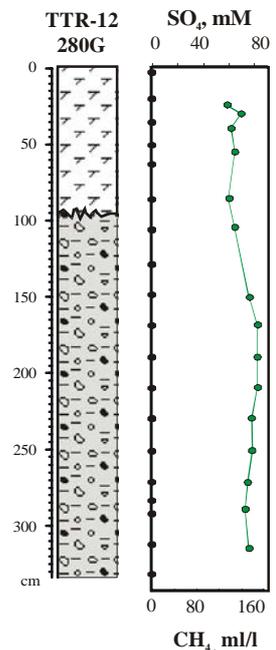


Fig 1. Position of SRZ in mud volcanoes with different intensity of fluid flow

mud volcano deposits were analysed for its principal element composition. Hydrocarbon gases were collected from the same intervals as pore water and analysed for molecular and isotopic composition. A number of anomalies in concentrations and distribution of the hydrocarbons and principal elements of pore water samples were observed.

Three types of mud volcanoes were recognized basing on their activity at present:

- (1) the Captain Arutyunov mud volcano is one of the most active among the known mud volcanoes in the Gulf of Cadiz. Sediments recovered from this mud volcano are represented by mousse-like breccia with small crystals of gas hydrates along the core. Methane concentration is extremely high (up to 126 ml/l) and $\delta^{13}\text{C}$ of methane varies from -48 to -49.2% PDB along the core and reaches -56.9% PDB in the uppermost part;
- (2) the Kalinin mud volcano is an example of a relatively passive volcano. It is covered by hemipelagic sediments and concentration of hydrocarbons is very low (CH_4 is about 0.01 ml/l);
- (3) the Gemini mud volcano has a very complex structure. It has one feeder channel and two craters of different generations. The crater of the first generation is covered by hemipelagic sediments and several layers of mud breccia are observed under the sediments cover. Hydrocarbons ($\text{C}_1 - \text{C}_5$) slowly increase with depth and methane concentrations reach 50 ml/l.

The second crater is younger and more active. Mud breccia comes to the sea bottom and methane concentration reaches 87.5 ml/l. Concentration of the higher hydrocarbons is extremely high (C_1/C_{2+} ratio is about 15). Moreover, carbon isotopic composition varies from -41.1 to -37.2% PDB for methane in the younger crater whereas in the older one it is more depleted (from -44.4 to 42.2% PDB).

Pore water analysis shows the same difference. Chloride content is in the range from 564 to 376 meqv/l in active mud volcanoes and from 554 to 612 meqv/l in passive ones.

Sulphate content gradually decreases with the depth from 80 to almost 0 meqv/l. But this decreasing in concentrations is different from one mud volcano to another. It means that sulphate reduction zone (SRZ) migrates due to differences in the fluid flow. In the Captain Arutyunov mud volcano SO_4^{2-} decreases very fast along the first 10 – 30 cm. At the same time on the Kalinin mud volcano SRZ was not observed along 3 m depth, which has been penetrated by gravity corer. In the Gemini mud volcano SRZ locates upper in relatively active crater than in inactive one. SRZ in the active crater situated approximately at the depth of 50 cm and in the inactive one – at about 80 cm or deeper (fig 1). The chemical characteristics of the samples suggest that SRZ migrates due to intensity of the fluid flow i.e. activity of a mud volcano.

MUD VOLCANOES, CORALS AND CARBONATE CRUSTS OF THE AL ARAICHE MUD VOLCANO FIELD, GULF OF CADIZ. RESULTS FROM THE BELGICA CADIPOR AND LOGACHEV TTR-12 CRUISES.

P. Van Rensbergen¹, J.-P. Henriët¹, D. Depreiter¹, N. Hamoumi², M. Ivanov³, M. Rachidi²

¹ Renard Centre of Marine Geology, Ghent University, Gent, Belgium

² University of Rabat, Rabat, Morocco

³ UNESCO Centre for Marine Geosciences, Faculty of Geology, University of Moscow, Moscow, Russia

The Al Araiche mud volcano field is situated on the Atlantic Moroccan margin. About 8 small to giant mud volcanoes are clustered around two sub-parallel thrust ridges, the Vernadsky and Renard ridges, the latter with steep fault escarpments. The ridges rise up in water depths of about 700 m and stretch to the shelf edge. Most mud volcanoes occur on top of the Renard ridge (Lazarillo de Tormes mv, Gemini mv, Don Quichote mv and Fiúza mv). The Kidd mud volcano is situated on top of the Vernadsky Ridge. Isolated mud volcanoes occur between the ridges (Adamastor mv, Mercator mv), or at their junction (Al Idrissi mv). The largest mud volcano, Al Idrissi, is situated at the shelf edge and is almost 250 m high, 5.3 km wide at the base and 1.4 km at the top. The smallest mud volcano (Lazarillo de Tormes) is 500 m wide and 25 m high. This area in the Gulf of Cadiz is especially interesting since it is a geologically dynamic region with variable oceanographic conditions, and characterized by a rich fauna.

The upslope mud volcano cluster was discovered during a R/V *Belgica* cruise in May 2002 and further surveyed during a R/V *Logachev* follow-up cruise in July 2002. The surveys yielded detailed swath bathymetry over the entire area, dense grids of high-resolution seismic data, a few very high-resolution deep-tow sub bottom profiles, side scan sonar mosaics over the major structures, selected TV-lines, TV-grabs, dredge samples and gravity cores. Integration of data sets allows to reconstruct the structure of active mud volcanoes in detail, and moreover, it allows to zoom at selected places from the regional structures gradually down to microscopic scale.

The mud volcanoes are all, regardless of their size, well developed conical hills with a crater and crater rim at the top. The structure of the mud volcanoes consist of a feeder pipe flanked with stacked outflow lenses. The mud volcanoes are flanked by erosional moats that are regularly filled in by extrusive mud flows and sediment from slope instabilities. At present the outflow events of different mud volcanoes are being correlated in a mud flow stratigraphy to analyse the mud volcano activity in the area.

In the study area small coral banks and carbonate crusts were found at the Pen Duick escarpment at the southern flank of the Renard Ridge. The Pen Duick escarpment is a fault scarp about 4.5 km long, 100 m high, and the water depth at the top is 525 m. The eastern part of the platform is characterized by a hummocky topography, to the west the pattern changes to parallel elongated ridges. On basis of the TV lines, TV guided grab samples were taken from dead coral banks and from a fault zone with carbonate slabs. The coral bank consisted of a dead coral framework with terrigenous mud matrix and few living corals at the top. It is indicative of a more favourable coral habitat in the past, probably related to strong currents in this area. The carbonate slabs consist of carbonate cement with shells, corals and debris.

MULTIDISCIPLINARY STUDY ON SEEPAGE FEATURES FROM THE BLACK SEA

A. Mazzini¹, J. Parnell¹, B.T. Cronin¹, M.K. Ivanov²

¹Department of Geology and Petroleum Geology, University of Aberdeen, Meston Building, King's College, Aberdeen AB24 3UE, Scotland, UK, a.mazzini@abdn.ac.uk;

²UNESCO-MSU Center for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevy Gory, Moscow 119899 Russia, fu@geol.msu.ru

During a recent marine survey (TTR-11 Cruise, 2001) in the Black Sea, three main areas of active fluid venting were explored and differing types of authigenic carbonate rocks were discovered. Using acoustic and sampling techniques, hydrocarbon fluid seep-structures (including eight mud volcanoes) were localised and sampled below the oxic zone.

A multidisciplinary study including petrographic and geochemical analyses was conducted on the large variety of carbonate deposits recovered from the sea floor and the shallow subsurface. Structural and petrographic observations allowed the distinction of five different types of authigenic carbonate; three of these (Type U1, U2, U3) comprise cemented hemipelagic sedimentary units (Unit 1, Unit 2, Unit 3) that broadly characterise the Black Sea; while the last two consist of cemented mud breccia sediment (Type MB) and authigenic micrite slabs (Type MS). Mineralogically, the carbonate cements consist of micrite, Mg calcite and, in one case, dolomite.

Carbon ($\delta^{13}\text{C}$) stable isotope analyses performed on all the carbonate cements, show a defined signature for each sampling location and a common ^{13}C depletion value, indicating the contribution of light carbon from methane seepage. All the samples analysed can be divided into two main clusters. The first group includes the samples from Area 1, from NIOZ and Odessa mud volcanoes (Area 3), that reveal high depletion in ^{13}C , on average higher than -40% . The second group comprises samples from Area 2 (Vassoevich, Kovalevsky mud volcanoes) and from Kazakov mud volcano (Area 3) that show higher carbon values rarely lower than -23% . A similar trend is observed for gas (methane) carbon isotopic analyses. Isotopic results, and the observed thick microbial mats, confirm that authigenic carbonates originate from the microbially mediated oxidation of methane (archaea) coupled with the sulphate reduction (sulphate reducing bacteria), and from oxidation of organic matter or methane mixed with sea water derived carbon.

A proposed formation model for the layered authigenic carbonates (Type U1-U3) suggests that the cement precipitates after methane oxidation that is concentrated preferentially on the interface between the more impermeable clayey layers. Non-layered types presumably form directly on the seafloor (Type MS) or can be buffered by overlaying slabs or sedimentary units (Type MB). The sediment gas saturation in several volcanic structures is confirmed by the presence of clathrates. Sedimentary structures often control the distribution and the shape of the gas hydrates. Their spatial association with authigenic carbonates, as well as the structural similarities (tabular and leaf-shaped in layered hemipelagic sedimentary units, and irregular shapes and pore filling in the mud breccia sediment) suggest an intimate connection between the two. X-ray diffraction on the carbonate cements indicates the predominance of high magnesium calcite and shows that crusts of the same type, regardless of different sampling location, usually

have a similar composition. Geochemical analyses on gas extracted from sediments associated with authigenic carbonates reveal that methane is the main gas component. Compositional gas signature indicates that each structure has differently rooted gas. Methane carbon isotopes helped to distinguish between the thermogenic and biogenic gases. Comparison between methane and authigenic carbonate carbon isotopes shows that they follow a similar ^{13}C depletion trend for each studied feature. The distinct signature shared by gas and authigenic carbonates further indicates that they are intimately related. Similarly, pore water compositional analyses provided relevant information about the mud volcanoes' activity and their fluid compositions.

LITHOLOGY AND ORGANIC MATTER IN ROCK FRAGMENTS FROM MUD BRECCIA OF CAPTAIN ARUTYUNOV MUD VOLCANO

O. Barvalina

UNESCO-MSU Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevy Gory, Moscow, 119899, Russia, fu@geol.msu.ru

The Captain Arutyunov mud volcano is located in the central part of the Gulf of Cadiz at $35^{\circ}39.5' \text{N} - 7^{\circ}20.0' \text{W}$. It has a conic form of about 80 m high with a base of 3 km in diameter. This mud volcano was recently active and is characterized by gas venting and presence of gas hydrates. Using a TV-controlled grab a large sample of mud volcanic deposits was collected (TTR-12-AT393GR). The main aim of this investigation was to study lithology of rock clasts from mud volcanic deposits and to determine the content and composition of organic matter in these clasts.

Rock fragments were studied in thin sections under polarizing microscope. Lithological characteristics such as color, structure and composition were defined. Dating of some rocks was based on studying calcareous nannofossil assemblages (performed by A. Sautkin). The age of the others was determined by comparing them with rocks from other mud volcanoes of the Gulf of Cadiz (Ovsyannikov, 2000). Then geochemical investigations were carried out using fluorescent-bituminological analysis (to characterize extractable organic matter (EOM)), determination of total organic carbon (TOC) content and Rock-Eval pyrolysis.

On the base of lithological investigations and micropaleontological studying all clasts, separated from mud breccia from Captain Arutyunov mud volcano, were subdivided into 15 groups. They are mainly represented by limestones, claystones and sandstones. The age of rocks varies from Upper Cretaceous to Pliocene. The Upper Cretaceous rocks are represented by claystones and limestones. Most limestones are of the Miocene-Pliocene. The sandstones were formed during Eocene and Miocene. The values of TOC content in the majority of rocks are relatively low - 0.2 % in average, but several samples are characterized by TOC > 0.5 %.

In the claystones the values of TOC content vary from 0.18 % to 1.69 %, EOM content - from 0.01 % to 0.31%.

The limestones are characterized by TOC = 0.26 - 0.54 %, EOM = 0.005 % - 0.01%.

The sandstones are poor in organic matter: TOC = 0.05 - 0.07 %, EOM - 0.01%.

According to the results of pyrolysis of several samples, the organic matter belongs to kerogen of types II and III (humic/sapropel mixed and humic matter (Tissot, Welte, 1984)). The maturity of these rocks is corresponded to the beginning of oil window ($T_{\text{max}} = 430 - 436^{\circ}\text{C}$).

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Geosphere-biosphere interactions

OBSERVATIONS ON THE DISTRIBUTION OF MEGAFUNA FROM MUD VOLCANOES LOCATED ALONG A DEPTH GRADIENT. PRELIMINARY RESULTS OF TTR-12 CRUISE IN THE AREA OF THE GULF OF CADIZ (LEG2)

M.R. Cunha¹, C. Moura¹, H. Gheerardun², V. Blinova³

¹ *Departamento de Biologia, Universidade de Aveiro, 3810-193 Aveiro, Portugal. mcunha@bio.ua.pt;*

² *Ghent University, Marine Biology Section, Belgium*

³ *UNESCO-MSU Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevi Gory, Moscow 119899, Russia, fu@geol.msu.ru*

The Gulf of Cadiz has been intensively studied since the first discovery of a mud volcano in 1999. Mud volcanism and structures related to hydrocarbon-rich fluid escape are widespread throughout the southern Iberian and northern Moroccan margins. The existence of hydrocarbon seeps enables the proliferation of chemosynthesis-based communities that depend on autochthonous geochemical energy and microbial mediated production of organic matter. The spatial patterns of fluid escape influences the distribution patterns of the fauna and the spatial heterogeneity of the assemblages that may be used as indicators of the location and characteristics of hydrocarbon-rich environments. The focus of attention has been primarily on symbiont-containing species, but these sites include a variety of taxonomic groups and feeding types of invertebrates and fish whose habitat requirements, interspecific relations and trophic interactions remain almost unknown.

Previous studies confirmed the wide distribution of Pogonophoran worms (mainly *Siboglinum*) that are especially abundant in the most active areas of the Gulf of Cadiz. However, the information on other species remains incipient. The aim of the biological programme during TTR-12 was to gather more information on the Gulf of Cadiz assemblages by using a diversified sampling gear. The TTR-12 programme included the survey of 12 different structures in the Gulf of Cadiz that were sampled by coring, dredging and grabbing. The amount of biological material collected was vast and it is still being processed. The results presented herein concern only the observations on the distributions of the megafauna and biogenic traces of infaunal organisms obtained from deep-towed TV surveys of six mud volcanoes (depths between 1300 and 200 m).

The mud volcanoes surveyed, Captain Arutyunov (the deepest), Aveiro, Gemini, Mercator, Al Idrisi (the shallowest) and TTR, showed a large faunistic heterogeneity. Each one had a peculiar characteristic. For example, Captain Arutyunov was typified by the abundance of solitary Pandalidae decapods swimming near the floor, the basis of the Aveiro volcano was populated by large siliceous sponges, while the Mercator showed a population of tubicolous polychaetes and the TTR was characterized by the abundance of stalked sponges.

Suspension-feeding organisms like sponges and branched cnidarians dominated the landscape in most mud volcanoes except for Captain Arutyunov where the latter were not represented. Biogenic traces were also frequent and consisted on a variety of feeding, resting and crawling traces, different sized burrows isolated or in clusters of up to 20 elements, small mounds and other dwellings. In some volcanoes (e.g. Aveiro, Mercator) there was a clear distribution pattern of the burrows that formed dense aggregations of large clusters at the basis of the cone, decreasing their abundance towards the top where they were often absent. This pattern may be related with the degree of physical disturbance of the sediments in different areas of the volcanic cones.

Increasing richness of the assemblages appeared to be mainly a depth-related pattern. The abundance and number of species, especially crustaceans and fishes, increased noticeably from the deeper (Captain Arutyunov, Aveiro) to the shallower mud volcanoes (Mercator, Al Idrisi). Fish

fauna of the Al Idrisi was particularly exuberant and there were many signs of fishing activity lying on the sea floor. Due to the proximity of the euphotic zone and the availability of a greater variety of food sources, the assemblage includes many species that are not typically associated with hydrocarbon-rich environments.

Habitat heterogeneity also contributed to species enrichment. The presence of hard substrates such as rock outcrops, carbonate crusts or dead coral reefs provides recruitment surface for the settlement of a variety of sessile organisms. Cracks, cavities and the space among coral branches are used by many small organisms to build dwellings or as hiding places to escape predation. This heterogeneity favouring the diversity and complexity of the assemblage was particularly evident in the TTR mud volcano where large rock blocks were covered by a variety of sessile organisms and deep-water corals hosted abundant epifauna and different species of mobile animals.

The identification of the macrofaunal species collected by the different sampling devices will allow a more complete description of the assemblages that will be further discussed in relation to the characteristics of the different fluid escape structures.

BIOLOGICAL SURVEYS OF THE LUCKY STRIKE SEGMENT (MAR) AND THE ATLANTIS SEAMOUNT. PRELIMINARY RESULTS OF TTR-12 CRUISE IN THE AZORES AREA (LEG 5)

M.R. Cunha¹, N. Peralta¹, M.J. Amaral¹, V. Blinova², A. Ravara¹

¹ *Departamento de Biologia, Universidade de Aveiro, 3810-193 Aveiro, Portugal, mcunha@bio.ua.pt;*

² *UNESCO-MSU Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevi Gory, Moscow 119899, Russia, fu@geol.msu.ru*

The Lucky Strike segment of the slow-spreading Mid-Atlantic Ridge is characterised by an unusually large central volcanic complex centred at 37°17.5'N, 32°16.5'W and composed by three cones around a central lava lake. Hydrothermal vents are distributed around this lake at approximately 1,700 m depths. During the TTR-10 cruise (August 2000) a geological and biological survey of Lucky Strike was carried out, but most samples were collected inside the vent field covering the area between the lake and the base of the volcanic cones. During the TTR-12 (August 2002) sampling effort was directed towards a broader understanding of the system by collecting samples at different depths along the segment and at some distance of the rift.

The biology and ecology of Lucky Strike have been intensively studied since the first discovery of this hydrothermal vent field in 1993. Despite the abundant information on Lucky Strike fauna, one of the best known in the MAR, the TTR-10 survey provided a new insight on the spatial distribution of the assemblages because, unlike most biological surveys, it did not concentrate sampling close to the most active sites. The fauna collected during the TTR-10 yielded not only the most typical vent organisms but also a variety of vagrant or background organisms.

Over 90% of the species collected from vent fields are considered endemic but endemism is difficult to prove due to the general lack of information on non-vent, deep-sea hard substrates. It is well known that the probability of penetration by non-vent bathyal species increases with the decreasing depth of the vent fields and the main goal of the biological survey during TTR-12 was to obtain data on the faunal assemblages outside the vent field, towards a better understanding of the relations between the vent ecosystem and the deep-sea surroundings.

The sampling included a survey of the segment with locations north of the vent field (two TV-grab samples), inside the vent field (three TV-grab samples) and south of the vent field (two dredge hauls and one TV-grab sample) and a survey of the off-axis area east of Lucky Strike (two dredge hauls and one TV-grab sample). The Atlantis seamount, located at some distance northeast of the Lucky Strike (34°06'N, 30°12'W), was also surveyed (one dredge haul and one grab sample)

and provided another example of bathyal hard substrate for further faunistic comparisons. Deep towed TV was used to obtain video footages of the top of the Atlantis seamount and of the off-axis summit east of Lucky Strike and provided information on the megafauna distribution.

The grab and dredge samples yielded over 1,000 specimens that were picked from the surface of the sediments and rocks, recovered from rock washings and sorted from sieved sediments. The specimens were ascribed to about 150 different taxa but many organisms are not yet fully identified to species due to the large number of groups that need taxonomic expertise.

A preliminary overview of the data allows the following remarks:

1) From the 50 species collected inside the vent, none occurred at the off-axis area or at Atlantis, seven were found at other locations on the segment (mainly in the north) and at least six other species are known from non-vent bathyal areas. These non-endemic species are mainly polychaetes and small crustaceans (isopods and amphipods).

2) The off-axis summit east of Lucky Strike shows more similarity to the Atlantis seamount (at least six species in common) than to the segment locations. This similarity is also evident from the video footages that show, in both locations, a megafaunal assemblage dominated by large suspension feeders like sponges, corals, gorgonians and anemones.

3) The species richness of the samples collected inside the vent field and at the Atlantis seamount was comparable but the vent assemblage was dominated by small sized detritus-feeders (mainly crustaceans) and showed paucity in large suspension-feeders. Small crustaceans, like tanaids, isopods, amphipods and cumaceans accounted for 75% of the species richness and 70% of the abundance of the vent samples, while sponges and cnidarians accounted for 40% of the species and 60% of the abundance of the seamount samples.

These are preliminary remarks on the samples collected and cannot be generalised without further investigations.

Tectonics, volcanism and sedimentation in the Atlantic Ocean and deep Mediterranean Sea

THE ALMERIA CHANNEL AND SURROUNDING AREAS FROM MAK-1 IMAGES AND 5 KHZ SEISMIC PROFILES: RECENT SEDIMENTARY EVOLUTION

F. Estrada¹, B. Alonso¹, G. Ercilla¹, M.J. Jurado²,

¹ CSIC, Instituto de Ciencias del Mar de Barcelona, Spain

² CSIC, Instituto de Ciencias de la Tierra de Barcelona-“Jaume Almera”, Spain

Introduction

The Almeria Channel is one of the most important architectural elements of the Almeria Turbidite System (ATS) developed on the Almeria margin and the Alboran Trough (Eastern Alboran Basin) (Fig. 1). This sedimentary system is Late Pliocene-Quaternary in age (Alonso and Maldonado, 1992) and it shifted progressively eastwards and retrograded till the present-day position (Estrada et al., 1997). It is fed by the Andarax River, a relatively long submarine canyon (55 km) and several gullies that erode the slope deposits. The ATS is surrounded by several morphologic highs and affected by two main fault systems (NE-SW and NW-SE). In fact, the Almeria Canyon appears faulted and a rejuvenation of its profile and related canyon-wall slumps occur (Estrada, 1994). During the TTR-12 cruise (Leg 3) on board of R/V *Professor Logachev* seven MAK-1 sonar lines (30 kHz) and 5 kHz seismic profiles were obtained in the distal reaches of the Almeria Channel and surrounding areas (Fig. 1). The studied area extends from base of slope to the Alboran Trough (1,400 to 1,900 m water depth).

Results and discussions

The MAK-1 mosaic shows a generalised medium backscatter locally affected by features of high and low backscatter. The most significant backscatter contrasts comprise the following morpho-sedimentary features: channel-like features with sinuous and meandriform paths, erosive features (spoon-shaped scours and rectilinear lineations), scarps and irregular reflective patches.

The sub-surficial sedimentary record (50 m thick) indicates a succession of five seismic units (s.u. 1 to 5, from older to younger) characterised by the following seismic facies (Fig. 2): s.u. 1, stratified divergent related with the development of levees; s.u. 2, opaque and semi-stratified both of high reflectivity which form lens-shaped bodies; s.u. 3, transparent to semitransparent which appear forming an extensive sheet-drape; s.u. 4, stratified divergent related with the development of levees, parallel stratified, semitransparent and opaque forming lens-shaped bodies; and s.u. 5, transparent, which appears forming an extensive sheet-drape and chaotic forming irregular bodies of debris-flow deposits.

The succession of these five s.u. reflects the recentmost sedimentary evolution of the Almeria Channel and surrounding areas. High-energy processes (turbidity currents, debris flows, etc.) alternate and/or coexist with phases of channel inactivity in which slow deposition from low-density currents or hemipelagic suspension prevailed. We interpret five evolutive phases (1st to 5th) corresponding to each s.u. (1 to 5) (Fig. 2). The first phase would be related with the activity of an older branch of the Almeria Channel, westward located from the present day channel and whose smoothed topography is still observed as meandriform loops in the MAK-1 mosaic. The second phase develops a succession of at least three channelized lobes. Their vertical stacking indicates an eastward shifting of the sedimentary bodies and points out an eastward migration of the Almeria Channel probably related with avulsion processes. The third phase is characterized by an extensive layer formed by semitransparent to transparent facies with an homogeneous thickness that suggests a generalized decrease in the channel sedimentary activity. During the fourth phase the sedimentary activity increases moderately as it is suggested by: the development of several small lens-shaped bodies of high reflectivity; the succession of high to low amplitude

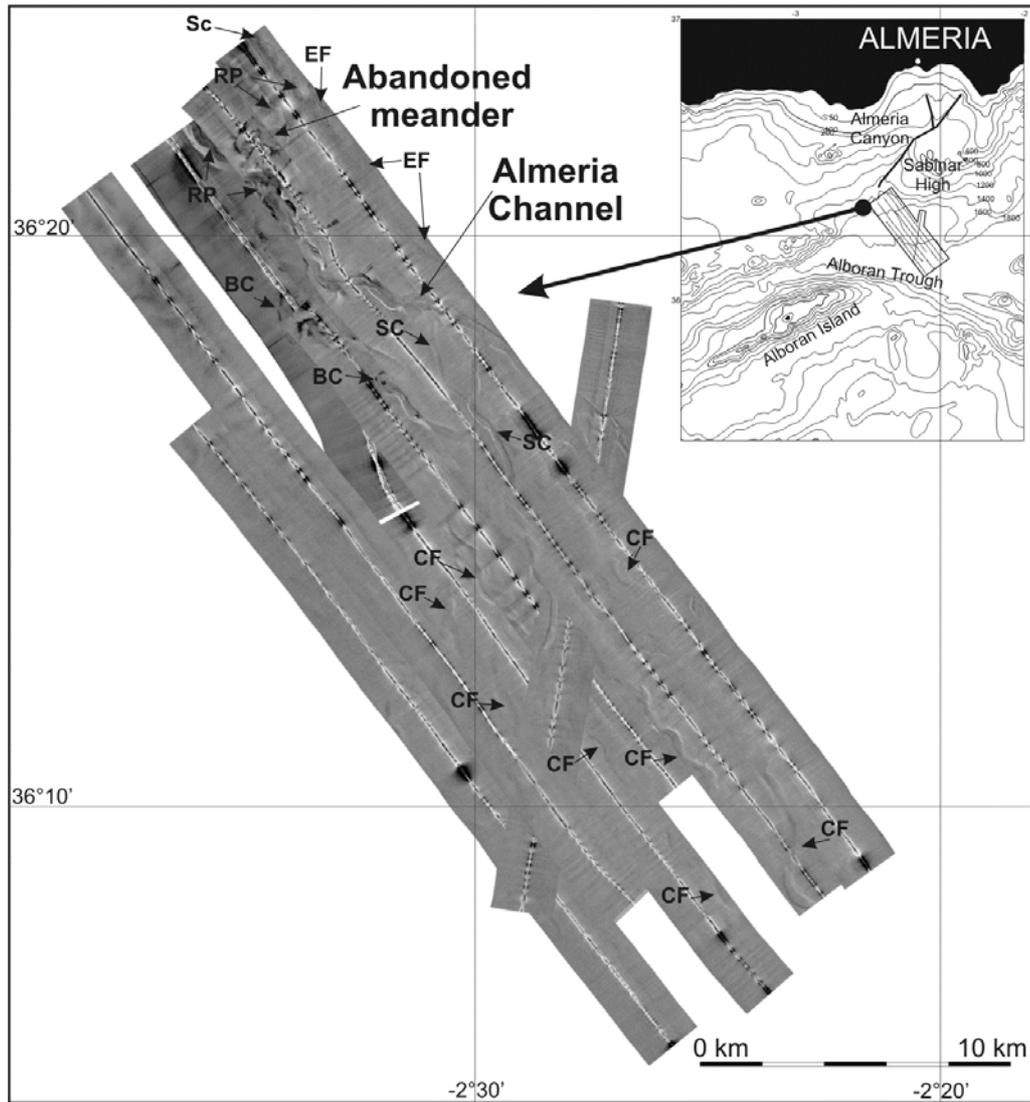


Fig. 1. MAK-1 mosaic and location of the study area. Legend: BC, buried channel; EF, erosive feature; CF, channel-like feature; RP, irregular reflective patches; SC, splay channel; Sc, scarp

reflectors on the channel-levee sediments; and the formation of splay channels (Cronin et al., 1995). The initiation of this channel reactivation is characterized by extensive discontinuous reflectors of high amplitude that in some places can form lens-shaped bodies. This could indicate instability events coming from the continental slope, probably triggered by earthquakes related with active faults. Similar high amplitude reflectors are also observed in the overlying sediments of the s.u. 4 suggesting a recurrent process. Towards the end of this phase a meander cut-off occurs in the uppermost reach of the Almeria Channel (1,525 m water depth) (Figs. 1 and 2). During the fifth phase the area is draped by a thin transparent layer (4 m average) attributed to an hemipelagic sedimentation, except in some places of the upper reaches of the Almeria Channel suggesting local erosive activity inside the channel. Coevally, debris-flows also occur in the upper reaches of the channel, closer to the Sabinar High. Its deposition results in the partial burying of the Almeria Channel.

The present-day sea-floor features observed in the MAK-1 mosaic results of the stacking of the above mentioned sedimentary processes. The generalised medium backscatter reflects the hemipelagic drape that covers the whole area during the fifth phase (Fig. 1). Most of the sinuous

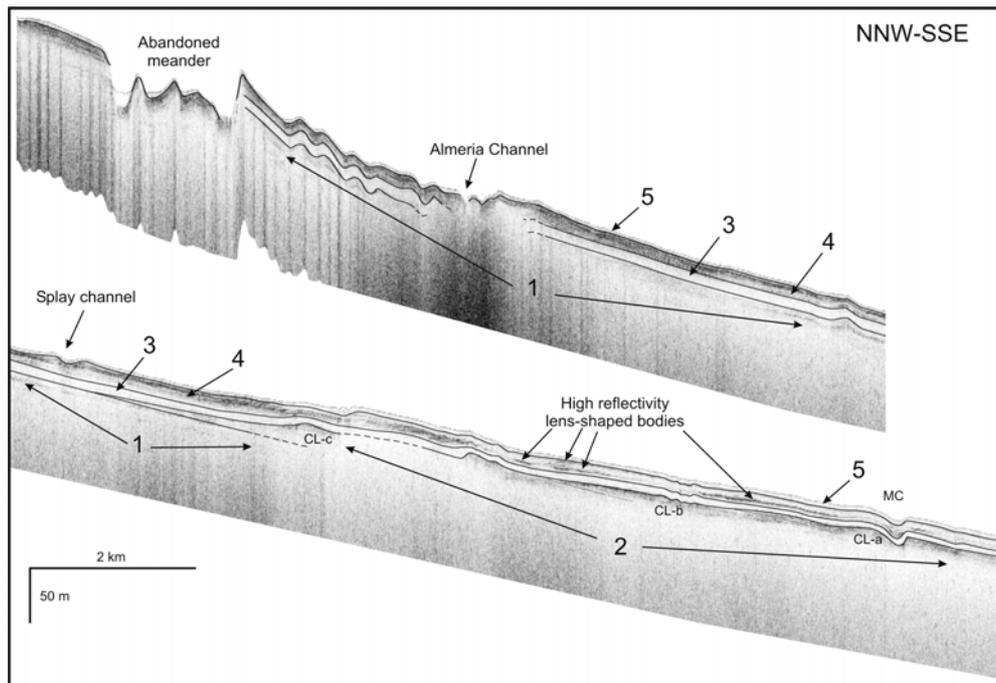


Fig. 2. Seismic profile (5 kHz) showing the main seismic units: 1, 2, 3, 4 and 5. Legend: CL, channelized lobes (a, b and c, from younger to older) and MC, mimetized channel

channel-like features correspond to those formed during second phase with more than 20 m of sedimentary cover that mimics the former channel topography (Figs. 1 and 2). On the other hand, some irregular patches and braided path features (Cronin, 1995) on the Almeria Channel floor suggest recent sedimentary activity probably related with the rejuvenation of the Almeria Canyon profile during the fourth phase. Reflective patches, scarps, erosive rectilinear lineations and spoon-shaped scours are identified at the base of the Sabinar High affecting the upper reaches of the Almeria Channel (1,600 m water depth). They correspond to those gravitative processes occurred during the fifth phase. The orientation of these erosive features coincides with that of the recent splay channels, which depict an orthogonal angle respect to the Almeria Channel. These facts suggest that splay channels are more related with sediments coming from the Sabinar High than from the Almeria Channel.

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LITHOLOGY OF RECENT HEMIPELAGIC SEDIMENTS AND QUATERNARY DEPOSITIONAL ENVIRONMENT OF THE ALBORAN SEA

A.M. Samoilov, A.Yu. Sadekov

UNESCO-MSU Research and Training Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevy Gory, Moscow 119899 Russia, fu@geol.msu.ru

During the Leg 4 of TTR-12 Cruise peculiarities of recent hemipelagic sedimentation in the Alboran Sea were investigated. Four cores were collected along a bottom sampling profile from western to eastern part of the basin. Between them two cores mostly consisted of marly sediments were chosen for investigation in laboratories of the Moscow State University: TTR12-290G from Western Alboran Basin and TTR12-293G from Eastern Alboran Basin.

The aim of the work was to study composition, grain size and planktonic foraminiferal assemblages of Quaternary hemipelagic sediments of the Alboran Sea and to discuss on recent depositional environment and climatic fluctuation in the region. The methods applied were detailed description of the cores, thin section analysis, X-ray mineralogical study, measurement of magnetic susceptibility, grain size analysis, study of planktonic foraminiferal assemblages.

During studies a presence of rock fragments in some intervals thickness - up to 0.5 cm of core TTR12-290G was determined. That fact implies a significant terrigenous input into the Western Alboran Basin and suggests that redeposition plays an essential role in sedimentation there.

Granulometric analysis along the core TTR12-293G allowed to distinguish four intervals with different grains size composition. Intervals of predominant clay-grade sediments (I and III intervals) alternate with ones (II and IV intervals), where silt-grade sediments prevail. These variations are also reflected in magnetic susceptibility curve. The intervals of mostly clay-grade sediments are characterized by high content of ferromagnetic minerals whereas others show low susceptibility.

XRD study of clay-grade of the sediments showed no variation in its composition along the core. It is mainly represented by kaolinite (~32%), illite (35%), calcite (20%), chlorite (10%) and quartz (3%).

Two main types of planktonic foraminiferal assemblages can be distinguished according results of study of distribution of species in the core: Atlantic type (presented by dominant species *Globorotalia inflata* and *Globigerina bulloides*) and Mediterranean. Mediterranean assemblages can be subdivided into two variations: cold water masses assemblages (presented by dominant specie *Neogloboquadrina pachyderma* and subdominant species *Globigerina bulloides* and *Globigerinoides ruber*) and warm water masses assemblages (presented by dominant species - *Globigerinoides ruber* and subdominant species - *Globigerina bulloides* and *Neogloboquadrina pachyderma*). Micro-paleontological data allowed to interpret intervals with different grain size composition in terms of paleoclimate. I and III intervals are characterized by warm water masses foraminiferal assemblages and increasing of value of terrigenous material transported. II and IV intervals characterized by cold water masses foraminiferal assemblages and decreasing of amount of terrigenous material.

We believe that intervals II and IV have been deposited during the period of high humidity increasing amount of terrigenous material in the sediments. On the contrary, intervals I and III have been deposited during period of high aridity reducing amount of material supplied from continent.

VOLCANIC ROCKS FROM THE LUCKY STRIKE CENTRAL VOLCANO, AZORES, MID-ATLANTIC RIDGE - SOME CHEMICAL FEATURES

P. Ferreira¹, B.J. Murton², V.S. Kamenetsky³, C. Inverno¹

¹ Instituto Geológico e Mineiro, Lisbon, Portugal

² Southampton Oceanography Centre, Southampton, UK

³ School of Earth Sciences and CODES SRC, University of Tasmania, Tasmania, Australia

Introduction

Mid-ocean ridge basalts (MORBs) are produced by decompression melting of the upper mantle and, therefore are clues to the composition of the mantle, the processes of mantle melting and the migration of melt from the mantle to the crust.

Major and trace element analysis as well as glass and mineralogical chemistry from the Lucky Strike central segment MORBs, allow us to deciphering some of the above information for this region of the Mid-Atlantic Ridge.

The rock samples analysed in our study were collected (by dredge and TV-assisted grab devices) during two cruises, TTR-10/Leg 2 and TTR-12/Leg 5, inside the Training-Through-Research Programme. The former was mainly designed to study the summit basin of the central volcano (a semi-circular area surrounded by three volcanic cones), where the Lucky Strike hydrothermal field is located, and the latter complemented the sampling of TTR-10, with collection of volcanic rocks from the central topographic high, which is made up of a composite volcano that is 13 km long, 7 km wide and 430 m high.

TTR-10 sample results

Analytical data (whole rock composition) determined in fresh basalts show typical major element MORBs composition and implies relatively primitive MORB varieties with low TiO₂

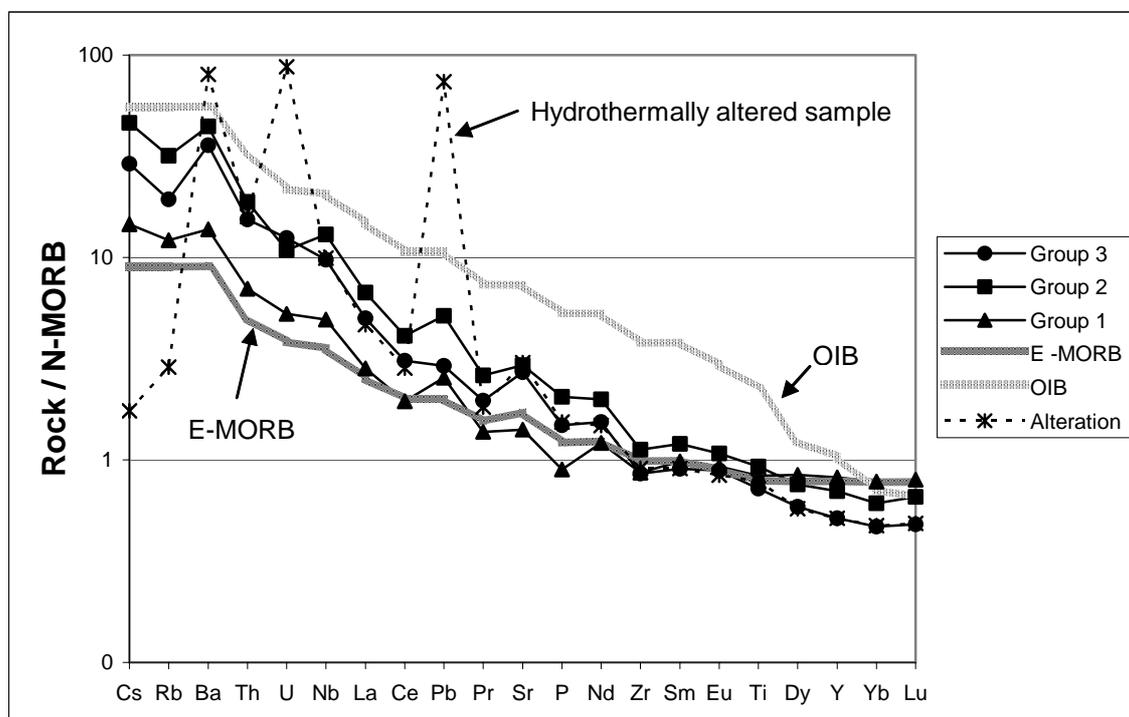


Fig. 1. N-MORB normalized compositions of representative fresh Lucky Strike basalts collected during TTR-10 cruise. Normalising values are from Sun & McDonough (1989)

contents (0.80-1.30%) and high Mg (63-74), Al₂O₃ (15-22%), CaO (12-15.50%) and Al₂O₃/TiO₂ (12.5-24). Not so typical are the high CaO/Al₂O₃ ratios (up to 0.85). With respect to the trace elements, all the Lucky Strike basalts have strong enrichment, relative to N-MORB, in the more incompatible elements (LILE). Based on the analytical data obtained, three groups of basalts, having distinct geochemical signatures, are identified (Ferreira et al., 2002). Basalts collected outside the hydrothermal field represent group 1; basalts sampled within the area surrounded by the three volcanic cones constitute the other two groups 2 and 3 (Fig. 1).

TTR-12 sample results

The sample sites were chosen based on the interpretation of the TOBI high-resolution deep-towed sidescan sonar images, dependent on the data collected during the Heat cruise in 1994 (German et al., 1996; Parson et al., 2000). Complemented with bathymetric data information, we selected sampling targets covering the different identified acoustic textures of the Lucky Strike segment. A total of 13 sampling stations were performed.

Fresh natural basaltic glasses, olivines, pyroxenes and spinels trapped in olivines were analysed in the University of Tasmania using a Cameca SX50 electron microprobe instrument.

The collected samples are very heterogeneous in texture and mineralogy, came from different volcanic flow morphologies and seem to have variable ages; the chemical composition variability is limited and, for example, MgO contents form an interval limited by 7.34% and 8.51% (corresponding to Mg 57 and 65.5, respectively). The basalts range from aphyric to porphyritic with plagioclase being the dominant phenocryst phase. Olivine phenocrysts occur only in some samples and, in these cases, are always less than 5% in modal composition. Olivine compositions range from Fo87 to Fo91, have high Ca content, and sometimes include Cr-spinel inclusions which are poor in Ti and Al (Cr/Cr+Al= 0.43-0.55) concentrations. Clinopyroxene is present in some samples as phenocrysts and/or microphenocrysts and corresponds to low-Al Cr-diopside variety.

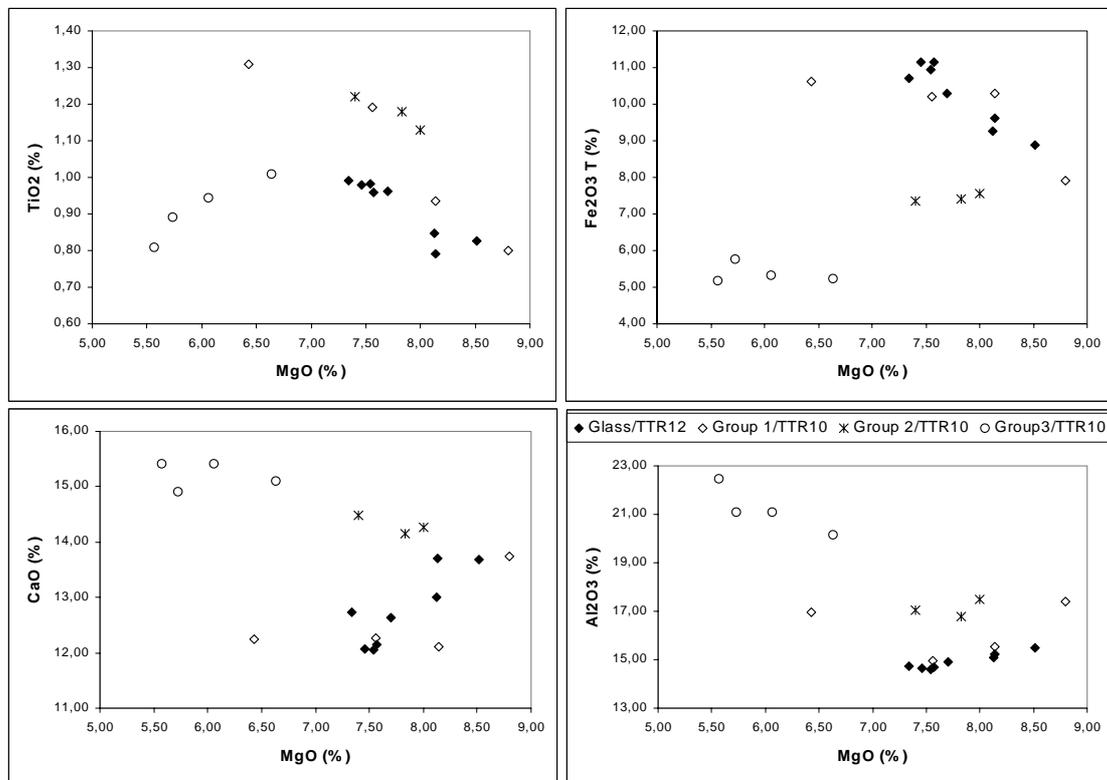


Fig. 2. Selected major element composition of representative fresh basalts (open symbols) and glasses collected during TTR-10 and TTR-12, respectively

Discussion

The new analytical data obtained for the basaltic glasses clearly show a chemical similarity to the composition of group 1 basalts, previously defined for the samples collected during TTR-10 (Fig.2). Major element variation range, previously defined, does not increase when including the samples collected along the segment, leading to the consideration of a major chemical variability in a few square km area, centred on the Lucky Strike Hydrothermal Field.

The range in MgO and in some compatible trace elements (Co, Ni, Cr) concentrations, the variation in Mg, the presence of plagioclase and olivine phenocrysts and the rare earth element (REE) patterns show that the crystal fractionation was involved in the magmatic differentiation processes for each group. However, they do not account for the entire chemical variability among the three Lucky Strike basalt groups.

The Azores mantle plume justifies the general enrichment in incompatible elements of the Lucky Strike segment basalts; however, to understand the reported small scale chemical variations it is necessary to invoke alternative processes such as: melting a small scale heterogeneous mantle or variations in the proportions of melt extracted from different depths in the melt zone (variable mantle temperature and accompanying pressure). The unusual high CaO/Al₂O₃ ratios for the glasses, which are supported by the high Ca content in olivine and with the crystallization of clinopyroxene (low-Al, Cr-diopside) could be explained by a reaction between the melts and a clinopyroxene-rich lithology (wehrlite or clinopyroxenite), or of mixing between melt fractions derived separately from distinct lithologies, including these both types and peridotite (Kamenetsky et al., 1998).

The identification of an evolution trend in the collected hydrothermal slabs, in terms of texture and mineralogy (increasing in the silicification degree, hardness and sulphide content) is matched by a clear chemical variation, leading to the formation of rocks most entirely made up of SiO₂ (65%) and Al₂O₃ (19%), with total absence of MgO, CaO, MnO and P₂O₅, and with Cu content higher than 6,000 ppm. This variation might reflect different degrees of cation exchange between the hydrothermal fluids and the existent basaltic basement. The same chemical effect is visible on the grained structured volcanoclastic / hyaloclastic material characterised by a significant increase in SiO₂, Na₂O, Ba (>3,000 ppm), Cu and Zn contents, and a progressive decrease in MgO, TiO₂, Al₂O₃ and CaO.

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Kamenetsky V.S. et al., *Earth Planet. Sci. Lett.* 160, 115-132 (1998).
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STRUCTURE AND PHYSICAL PROPERTIES OF THE SEDIMENTARY SEQUENCE IN THE SOROKIN TROUGH (NE BLACK SEA)

A. Volkonskaya¹, J. Bialas², A. Broser³

¹ UNESCO-MSU Research and Training Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevy Gory, Moscow 119899 Russia, fu@geol.msu.ru

² GEOMAR Forschungszentrum fuer Marine Geowissenschaften, Germany, jbialas@geomar.de, abroser@geomar.de

New results from refraction and reflection seismic studies in the Sorokin Trough (NE Black Sea) which were carried out during the M52/1 MARGASCH cruise of R/V *Meteor* are presented to discuss the deep structure and velocity distribution within the sedimentary sequence.

Profiles 01 and 02 are crossing profiles and located over Kazakov and Odessa mud volcano. The profiles were shot using two 32 l Bolt airguns every 60 s. OBH 12-15 are located on

profile 01 and OBS 01-10 and OBH 11 on profile 02. OBS 08 is located on top of Kazakov mud volcano and the intersection point of the two profiles. Profile 01 is located within the topographical smooth area of the Sorokin Trough and therefore should provide background information about the regional sediments and upper crust. Profile 02 crosses the 200 m high Kazakov mud volcano and continues to the NW across the SE-NW trending chain of mud volcanoes. All 15 instruments were deployed with variable spacing from 1 nm up to 2 nm. The total length of profile 01 is 35 km and of profile 02 is about 60 km. All OBS and OBH data were processed using standard processing on board. With forward modelling a two-dimensional velocity depth distribution was developed independently for both lines. These results were based on both the wide-angle observations and near vertical events.

The SW – NE trending profile 01 was used as background information. The main attention was paid to the interpretation of the NW - SE trending profile 02. Nine seismo-geological units from Quaternary to Low Cretaceous were described within the model. The velocity characteristics of these units were compared with those which were previously suggested in this region using the MCS data.

Along this profile velocities from 1.5 to 2 km/s were interpreted down to about 1 km below seafloor. Although the refraction horizons were modelled parallel to the seafloor a distinct separation between northern and southern part of the section could be developed in terms of slightly increasing velocities to the south. These observations continue within the deeper layers which were formed by velocities from 2.4 km/s to 4.3 km/s covering the depth range from 2.2 km to 8 km depth. Further down the velocity distribution is homogeneous throughout the profile. Values increase from 4.1 km/s at 6.5 km depth to 5.8 km/s at 13 km depth. These deeper horizons show a slight uplift in the southern part of the profile correspondent to the Tetyaev rise. Local uplifts of the reflection horizons were observed under the mud volcanoes as well.

EVIDENCE OF STRUCTURAL CONTROL ON THE MUD VOLCANISM IN THE GULF OF CADIZ. RECENT RESULTS FROM THE TTR-12 CRUISE

L.M. Pinheiro^{1,2}, V. Magalhães^{1,2}, P. Van Rensbergen³, C. Roque², R. León-Buendia⁴, S. Bouriak², J. Gardner⁵, M. Ivanov⁶

¹ *Dep. Geociências, Universidade de Aveiro, 3800-193, Aveiro, Portugal*

² *Dep. de Geologia Marinha, Instituto Geológico e Mineiro, Alfragide, Portugal*

³ *Renard Centre for Marine Geology, Univ. Ghent, Belgium*

⁴ *Div. Geologia Marina, Instituto Geológico y Minero, Madrid, España*

⁵ *Naval Research Laboratory, Washington DC, USA*

⁶ *UNESCO Center for Marine Geolog, Moscow State University, Geology Faculty, Russia*

The Gulf of Cadiz is situated in a tectonically very active region, in a complex setting near a major plate boundary characterized by a combination of important strike-slip movement (along the Azores-Gibraltar fracture zone) and compressional tectonics related to the Africa-Eurasia NW-directed convergence. This area is characterized by extensive mud volcanism, pockmarks, mud diapirism and carbonate chimneys related to hydrocarbon rich fluid venting. A large mud volcano field, first interpreted on side-scan sonar imaging and later confirmed by coring, was discovered in this area in 1999, during the TTR-9 cruise. Since then, this area has been intensively investigated by single channel seismics, long range and deep-tow sidescan sonar, underwater TV, multibeam bathymetry, dredging and coring. The mud volcanoes are located at water depths between 700 and 3,500 m, with a diameter that can reach more than 4 km and whose height can reach a few hundreds of meters. Gas hydrates have already been recovered from 3 mud volcanoes.

During the TTR-12 cruise, several single channel seismic lines were collected in this area, complementing an already fairly extensive database of seismic lines, both single channel and multichannel. These lines have been preliminary processed on board and later re-processed onshore to enhance the deeper structure.

A combined interpretation of the available side-scan sonar imaging and seismic lines (both single channel and multichannel) shows clear evidence of the structural control of the mud volcanism in the study area, indicating that some of the mud volcanoes appear to be located at the intersection between NW-SE strike-slip faults and thrusts of variable orientation, reflecting the curvature of the Gibraltar Arc.

ANNEX I

CONFERENCE PROGRAMME

SUNDAY, FEBRUARY 2

- 11:00 Registration of participants
18:30 Executive Committee meeting

MONDAY, FEBRUARY 3

- 09:30 Registration of participants
10:30 Opening
Welcoming address by A.E. Suzyumov (UNESCO)

Plenary Session:

- 11:30 *M. Ivanov , N. Kenyon , T. Neilson , L. Pinheiro , M. Comas , M. Marani , J. Monteiro ,
P. Van Rensbergen , T. Furey , J.-P. Henriet , and Shipboard Scientific Party*
REVIEW OF THE PRINCIPAL RESULTS OF THE TTR-12 CRUISE

Section 1: Fluid escape and related processes:

- 12:30 *E. Poludetkina, E. Kozlova*
GEOCHEMICAL CHARACTERISTICS OF HYDROCARBON GASES AND
ORGANIC MATTER FROM MUD VOLCANIC DEPOSITS OF THE ALBORAN
SEA
- 12:50 *M. Rachidi , N. Hamoumi, M. Labraimi, M. Ivanov, J. P. Henriet, E. M. Lotfi,
M. Benbouida*
NATURE AND ORIGIN OF MUD VOLCANO SEDIMENTS
OF THE GULF OF CADIZ (TTR-12 CRUISE)
- 13:10 *S. Agibalov, V. Spiess, S. Krastel*
GAS-RELATED ACOUSTIC ANOMALIES IN THE UPPER PART OF
SEDIMENTARY SEQUENCE IN THE CENTRAL PART OF THE BLACK SEA
- 15:00 *G.G. Akhmanov, M.K. Ivanov, J.P. Henriet, E.S. Sarantzev*
THE AL ARAICHE DIAPYRIC FIELD AND ITS "EXOTIC" MUD VOLCANIC
DEPOSITS RECOVERED DURING THE TTR-12 CRUISE IN THE GULF OF
CADIZ
- 15:30 *V.H. Magalhães , C. Vasconcelos , L. Gaspar , L. Pinheiro , M. Ivanov V. Díaz-Del-Río ,
L. Somoza*
METHANE RELATED AUTHIGENIC CARBONATES, CHIMNEYS AND
CRUSTS FROM THE GULF OF CADIZ
- 16:00 *V. Blinova*
MINERALOGY AND GEOCHEMISTRY OF METHANE-RELATED
AUTHIGENIC CARBONATES FROM THE GULF OF CADIZ, NE ATLANTIC

TUESDAY, FEBRUARY 4

Section 1: Fluid escape and related processes:

- 09:30 *M. Taviani*
TERTIARY TO RECENT DEEP-SEA COLD VENTING AND ITS PRODUCTS IN
THE MEDITERRANEAN BASIN: AN OVERVIEW
- 10:30 *E. Bileva, V. Blinova*
GEOCHEMICAL CHARACTERISTICS OF HYDROCARBON GASES FROM
MUD VOLCANOES OF THE GULF OF CADIZ
- 11:30 *M.C. Comas, J.I. Soto, A.R. Talukder and TTR-12 Leg 3 (MARSIBAL-1) Scientific Party*
DISCOVERING ACTIVE MUD VOLCANOES IN THE ALBORAN SEA
(WESTERN MEDITERRANEAN)
- 12:00 *V. Blinova, E. Bileva*
SOME GEOCHEMICAL CHARACTERISTICS OF RELATIVELY ACTIVE AND
PASSIVE MUD VOLCANOES (GULF OF CADIZ AND ALBORAN SEA)
- 12:30 *P. Van Rensbergen, J.P. Henriet, D. Depreiter, N. Hamoumi, M. Ivanov, M. Rachidi*
MUD VOLCANOES, CORALS AND CARBONATE CRUSTS OF THE EL
ARAICHE MUD VOLCANO FIELD, GULF OF CADIZ. RESULTS FROM THE
BELGICA CADIPOR AND LOGACHEV TTR CRUISES
- 13:00 *A. Mazzini, J. Parnell, B.T. Cronin, M.K. Ivanov*
MULTIDISCIPLINARY STUDY ON SEEPAGE FEATURES FROM THE BLACK
SEA
- 13:30 *O. Barvalina*
LITHOLOGY AND ORGANIC MATTER IN ROCK FRAGMENTS FROM MUD
BRECCIA OF CAPTAIN ARUTYUNOV MUD VOLCANO

Section 2: Geosphere-biosphere interactions:

- 15:00 *M.R. Cunha, C. Moura, H. Gheerardun, V. Blinova*
OBSERVATIONS ON THE DISTRIBUTION OF MEGAFUNA FROM MUD
VOLCANOES LOCATED ALONG A DEPTH GRADIENT. PRELIMINARY
RESULTS OF TTR-12 CRUISE IN THE AREA OF THE GULF OF CADIZ (LEG 2)
- 16:00 *M.R. Cunha, N. Peralta, M.J. Amaral, V. Blinova, A. Ravara*
BIOLOGICAL SURVEYS OF THE LUCKY STRIKE SEGMENT (MAR) AND THE
ATLANTIS SEAMOUNT. PRELIMINARY RESULTS OF TTR-12 CRUISE IN THE
AZORES AREA (LEG 5)

WEDNESDAY, FEBRUARY 5

Section 3: Tectonics, volcanism and sedimentation in the Atlantic ocean and deep Mediterranean:

- 09:30 *J. Mascle*
THE NILE CONTINENTAL MARGIN

- 10:30 *F. Estrada, B. Alonso, G. Ercilla, M. J. Jurado*
THE ALMERIA CHANNEL AND SURROUNDING AREAS FROM MAK-
IMAGES AND 5 KHZ SEISMIC PROFILES: RECENT SEDIMENTARY
EVOLUTION
- 11:30 *M. P. Marani, F. Gamberi, and Leg 4 Scientific Party*
VOLCANO-TECTONICS OF MARSILI SEAMOUNT
- 12:00 *A. M. Samoilov, A. Y. Sadekov*
LITHOLOGY OF RECENT HEMIPELAGIC SEDIMENTS AND QUATERNARY
DEPOSITIONAL ENVIRONMENT OF THE ALBORAN SEA
- 12:20 *P. Ferreira, B.J. Murton, V.S. Kamenetsky and C. Inverno*
VOLCANIC ROCKS FROM THE LUCKY STRIKE CENTRAL VOLCANO,
AZORES, MID-ATLANTIC RIDGE – SOME CHEMICAL FEATURES
- 12:50 *A. Volkonskaya, J.Bialas, A. Broser*
STRUCTURE AND PHYSICAL PROPERTIES OF THE SEDIMENTARY
SEQUENCE IN THE SOROKIN TROUGH (NE BLACK SEA)
- 13:10 *M. P. Marani, F. Gamberi, and Leg 4 Scientific Party*
EVENTS RELATED TO THE ON-GOING ERUPTION OF STROMBOLI
VOLCANO (AEOLIAN ISLANDS)
- 15:00 *M. P. Marani*
INTRODUCTION TO THE FIELD TRIP
- 16:30 General discussion
- 17:00 Closure of the meeting, prizes for best student presentation

THURSDAY, FEBRUARY 6

FIELD EXCURSION TO THE “SALSE DI NIRANO”

ANNEX II

LIST OF PARTICIPANTS

Belgium

Henriet, Jean-Pierre
Renard Centre of Marine Geology,
Ghent University,
Krijgslaan 281, S8,
B-9000 Ghent, Belgium
jeanpierre.henriet@rug.ac.be

Van Rensbergen Pieter
Renard Centre of Marine Geology (RCMG),
Department of Geology and Soil Science,
Ghent University, Krijgslaan 281 s8,
B-9000 Ghent, Belgium
Pieter_VanRensbergen@yahoo.com

France

Masclé, Jean
UMR Geosciences Azur
Laboratoire de Géodynamique Sous-Marine,
Observatoire Océanologique
B.P. 48
06230 Villefranche-sur-mer, France
masclé@obs-vlfr.fr

Italy

Consolaro, Chiara
Universita de Padova
chiaraconsolaro@hotmail.com

Marani, Michael
Istituto di Geologia Marina,
Via Gobetti 101,
40129 Bologna, Italy
marani@igm.bo.cnr.it

Taviani, Marco
Istituto di Geologia Marina,
Via Gobetti 101,
40129 Bologna, Italy

Morocco

Rachidi, Merouane
Laboratory of Sedimentology and Marine
Geology, Mohammed V- Agdal University,
Rabat, Morocco

Portugal

Cunha, Marina
Centro das Zonas Costeiras e do Mar,
Departamento de Biologia,
Universidade de Aveiro,
3810-193 Aveiro, Portugal.
mcunha@bio.ua.pt

Ferreira, Pedro
Instituto Geologico e Mineiro,
Est. da Portela - Zambujal,
Apartado 7586,
2720 Alfragide, Lisboa
Portugal

Magalhaes, Vitor Hugo
Departamento de Geologia Marinha,
Instituto Geológico e Mineiro,
Estrada da Portela - Zambujal,
Apartado 7586,
2720 Alfragide, Portugal
vitor.magalnaes@igm.pt

Russia

Agibalov, Sergey
UNESCO-MSU Centre for Marine Geology,
Faculty of Geology,
Moscow State University,
Vorobjevy Gory, Moscow, 119899, Russia
fu@geol.msu.ru

Akhmanov, Grigorii
UNESCO-MSU Centre for Marine Geology,
Faculty of Geology,
Moscow State University,
Vorobjevy Gory, Moscow, 119899, Russia
akhmanov@geol.msu.ru

Barvalina, Olga
UNESCO-MSU Centre for Marine Geology,
Faculty of Geology,
Moscow State University,
Vorobjevy Gory, Moscow, 119899, Russia
fu@geol.msu.ru

Bileva, Evgenia
UNESCO-MSU Centre for Marine Geology,
Faculty of Geology,
Moscow State University,
Vorobjevy Gory, Moscow, 119899, Russia
fu@geol.msu.ru

Blinova, Valentina
UNESCO-MSU Centre for Marine Geology,
Faculty of Geology,
Moscow State University,
Vorobjevy Gory, Moscow, 119899, Russia
fu@geol.msu.ru

Ivanov, Mikhail
UNESCO-MSU Centre for Marine Geology,
Faculty of Geology,
Moscow State University,
Vorobjevy Gory, Moscow,
119899, Russia
fu@geol.msu.ru

Poludetkina, Elena
UNESCO-MSU Centre for Marine Geology,
Faculty of Geology,
Moscow State University,
Vorobjevy Gory, Moscow,
119899, Russia
fu@geol.msu.ru

Samoilov, Aleksander
UNESCO-MSU Centre for Marine Geology,
Faculty of Geology,
Moscow State University,
Vorobjevy Gory, Moscow,
119899, Russia
fu@geol.msu.ru

Volkonskaya, Anna
UNESCO-MSU Centre for Marine Geology,
Faculty of Geology,
Moscow State University,
Vorobjevy Gory, Moscow, 119899, Russia
fu@geol.msu.ru

Spain

Alonso, Belen
CSIC, Instituto de Ciencias
del Mar de Barcelona,
Spain
belen@cucafera.icm.csic.es

Comas, Menchu
Instituto Andaluz de Ciencias de la Tierra,
C.S.I.C. and University of Granada,
Campus Funtenueva,
18002 Granada, Spain
mcomas@goliat.ugr.es

Estrada, Ferran
CSIC, Instituto de Ciencias
del Mar de Barcelona,
Spain

United Kingdom

Kenyon, Niel
Sedimentary Processes and
Hazards on Continental Margins,
Southampton Oceanography Centre,
Empress Dock, Southampton
SO14 3ZH, U.K.
n.kenyon@soc.soton.ac.uk

Mazzini, Adriano
Department of Geology and Petroleum
Geology, University of Aberdeen,
Meston Building, King's College,
Aberdeen AB24 3UE,
Scotland, UK.
a.mazzini@abdn.ac.uk

UNESCO

Suzyumov, Alexei
Environment and Development
in Coastal Regions
and in Small Islands (SC/CSI)
UNESCO, 1, rue Miollis, 75732 Paris
Cedex 15, France
a.suzyumov@unesco.org

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

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

| No. | Title | Languages | No. | Title | Languages |
|-----|---|-----------|-----|--|--------------------------|
| 125 | Plymouth, U.K., 4-7 May 1993. Atelier sous-régional de la COI sur les ressources marines vivantes du Golfe de Guinée ; Cotonou, Bénin, 1-4 juillet 1996. | E | 154 | IOC-Sida-Flanders-SFRI Workshop on Ocean Data Management in the IOCINCWIO Region (ODINEA project) Capetown, South Africa, 30 November-11 December 1998. | E |
| 126 | IOC-UNEP-PERSGA-ACOPS-IUCN Workshop on Oceanographic Input to Integrated Coastal Zone Management in the Red Sea and Gulf of Aden. Jeddah, Saudi Arabia, 8 October 1995. | E | 155 | Science of the Mediterranean Sea and its applications UNESCO, Paris 29-31 July 1997 | E |
| 127 | IOC Regional Workshop for Member States of the Caribbean and South America GODAR-V (Global Oceanographic Data Archeology and Rescue Project); Cartagena de Indias, Colombia, 8-11 October 1996. | E | 156 | IOC-LUC-KMFRI Workshop on RECOSCIX-WIO in the Year 2000 and Beyond, Mombasa, Kenya, 12-16 April 1999 | E |
| 128 | Atelier IOC-Banque Mondiale-Sida/SAREC-ONE sur la Gestion Intégrée des Zones Côtières ; Nosy Bé, Madagascar, 14-18 octobre 1996. | E | 157 | '98 IOC-KMI International Workshop on Integrated Coastal Management (ICM), Seoul, Republic of Korea 16-18 April 1998 | E |
| 129 | Gas and Fluids in Marine Sediments, Amsterdam, the Netherlands; 27-29 January 1997. | E | 158 | The IOCARIBE Users and the Global Ocean Observing System (GOOS) Capacity Building Workshop, San José, Costa Rica, 22-24 April 1999 | E |
| 130 | Atelier régional de la COI sur l'océanographie côtière et la gestion de la zone côtière ; Moroni, RFI des Comores, 16-19 décembre 1996. | E | 159 | Oceanic Fronts and Related Phenomena (Konstantin Federov Memorial Symposium) – Proceedings, Pushkin, Russian Federation, 18-22 May 1998 | E |
| 131 | GOOS Coastal Module Planning Workshop; Miami, USA, 24-28 February 1997 | E | 160 | Under preparation | |
| 132 | Third IOC-FANSA Workshop; Punta-Arenas, Chile, 28-30 July 1997 | S/E | 161 | Under preparation | |
| 133 | Joint IOC-CIESM Training Workshop on Sea-level Observations and Analysis for the Countries of the Mediterranean and Black Seas; Birkenhead, U.K., 16-27 June 1997. | E | 162 | Workshop report on the Transports and Linkages of the Intra-americas Sea (IAS); Cozumel, Mexico, 1-5 November 1997 | E |
| 134 | IOC/WESTPAC-CCOP Workshop on Paleogeographic Mapping (Holocene Optimum); Shanghai, China, 27-29 May 1997 | E | 163 | Under preparation | |
| 135 | Regional Workshop on Integrated Coastal Zone Management; Chabahar, Iran; February 1996. | E | 164 | IOC-Sida-Flanders-MCM Third Workshop on Ocean Data Management in the IOCINCWIO Region (ODINEA Project), Cape Town, South Africa, 29 November – 11 December 1999 | E |
| 136 | IOC Regional Workshop for Member States of Western Africa (GODAR-VI); Accra, Ghana, 22-25 April 1997. | E | 165 | An African Conference on Sustainable Integrated Management; Proceedings of the Workshops, An Integrated Approach, (PACSIKOM), Maputo, Mozambique, 18 –25 July 1998 | E, F |
| 137 | GOOS Planning Workshop for Living Marine Resources, Dartmouth, USA; 1-5 March 1996. | E | 166 | IOC-SOA International Workshop on Coastal Megacities: Challenges of Growing Urbanization of the World's Coastal Areas; Hangzhou, P.R. China, 27 –30 September 1999 | E |
| 138 | Gestión de Sistemas Oceanográficos del Pacífico Oriental; Concepción, Chile, 9-16 de abril de 1996. | S | 167 | IOC-Flanders First ODINAFRICA-II Planning Workshop, Dakar, Senegal, 2-4 May 2000 | E |
| 139 | Sistemas Oceanográficos del Atlántico Sudoccidental, Taller, TEMA; Furg, Rio Grande, Brasil, 3-11 de noviembre de 1997 | S | 168 | Geological Processes on European Continental Margins; International Conference and Eight Post-cruise Meeting of the Training-Through-Research Programme, Granada, Spain, 31 January – 3 February 2000 | E |
| 140 | IOC Workshop on GOOS Capacity Building for the Mediterranean Region; Valletta, Malta, 26-29 November 1997. | E | 169 | International Conference on the International Oceanographic Data & Information Exchange in the Western Pacific (IODE-WESTPAC) 1999, ICIVP '99 Langkawi, Malaysia, 1-4 November 1999 | under preparation |
| 141 | IOC/WESTPAC Workshop on Co-operative Study in the Gulf of Thailand: A Science Plan; Bangkok, Thailand, 25-28 February 1997. | E | 170 | IOCARIBE-GODAR-I Cartagena, Colombia, February 2000 | under preparation |
| 142 | Pelagic Biogeography ICoPB II. Proceedings of the 2nd International Conference. Final Report of SCOR/IOC Working Group 93; Noordwijkerhout, The Netherlands, 9-14 July 1995. | E | 171 | Ocean Circulation Science derived from the Atlantic, Indian and Arctic Sea Level Networks, Toulouse, France, 10-11 May 1999 | E |
| 143 | Geosphere-biosphere coupling: Carbonate Mud Mounds and Cold Water Reefs; Gent, Belgium, 7-11 February 1998. | E | 172 | (Under preparation) | |
| 144 | IOC-SOPAC Workshop Report on Pacific Regional Global Ocean Observing Systems; Suva, Fiji, 13-17 February 1998. | E | 173 | The Benefits of the Implementation of the GOOS in the Mediterranean Region, Rabat, Morocco, 1-3 November 1999 | E, F |
| 145 | IOC-Black Sea Regional Committee Workshop: 'Black Sea Fluxes' Istanbul, Turkey, 10-12 June 1997. | E | 174 | IOC-SOPAC Regional Workshop on Coastal Global Ocean Observing System (GOOS) for the Pacific Region, Apia, Samoa, 16-17 August 2000 | E |
| 146 | Living Marine Resources Panel Meeting, Paris, France, 23-25 March 1998. | E | 175 | Geological Processes on Deep-water European Margins, Moscow-Mozhenka, 28 Jan.-2 Feb. 2001 | E |
| 147 | IOC-SOA International Training Workshop on the Integration of Marine Sciences into the Process of Integrated Coastal Management, Dalian, China, 19-24 May 1997. | E | 176 | MedGLOSS Workshop and Coordination Meeting for the Pilot Monitoring Network System of Systematic Sea Level Measurements in the Mediterranean and Black Seas, Haifa, Israel, 15-17 May 2000 | E |
| 148 | IOC/WESTPAC International Scientific Symposium – Role of Ocean Sciences for Sustainable Development Okinawa, Japan, 2-7 February 1998. | E | 177 | (Under preparation) | |
| 149 | Workshops on Marine Debris & Waste Management in the Gulf of Guinea, 1995-97. | E | 178 | (Under preparation) | |
| 150 | First IOCARIBE-ANCA Workshop Havana, Cuba, 29 June-1 July 1998. | E | 179 | (Under preparation) | |
| 151 | Taller Pluridisciplinario TEMA sobre Redes del Gran Caribe en Gestión Integrada de Areas Costeras Cartagena de Indias, Colombia, 7-12 de septiembre de 1998. | S | 180 | Abstracts of Presentations at Workshops during the 7 th session of the IOC Group of Experts on the Global Sea Level Observing System (GLOSS), Honolulu, USA, 23-27 April 2001 | E |
| 152 | Workshop on Data for Sustainable Integrated Coastal Management (SICOM) Maputo, Mozambique, 18-22 July 1998 | E | 181 | (Under preparation) | |
| 153 | IOC/WESTPAC-Sida (SAREC) Workshop on Atmospheric Inputs of Pollutants to the Marine | E | 182 | (Under preparation) | |
| | | | 183 | Geosphere/Biosphere/Hydrosphere Coupling Process, Fluid Escape Structures and Tectonics at Continental Margins and Ocean Ridges, International Conference & Tenth Post-cruise Meeting of the Training-through-Research Programme, Aveiro, Portugal, 30 January-2 February 2002 | E |
| | | | 184 | (Under preparation) | |
| | | | 185 | (Under preparation) | |
| | | | 186 | (Under preparation) | |
| | | | 187 | Geological and Biological Processes at deep-sea European Margins and Oceanic Basins, Bologna, Italy, 2-6 February 2003 | E |