Intergovernmental Oceanographic Commission

Workshop Report No. 175

Geological processes on deep-water European margins

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

Devoted to the TTR 10th Anniversary

Moscow-Mozhenka, Russia
28 January–2 February 2001

Editors: G. Akhmanov
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Abstract

"Geological Processes on Deep-Water European Margins" - International Conference and the Training-Through-Research (TTR) Post-Cruise Meeting was held from 28 January to 2 February 2001. It was devoted to the 10th Anniversary of the programme. The intent was to obtain an overview of what has been done during the last ten years and also to outline directions for future activities. The meeting brought together over 70 participants from 13 countries. Reflecting main research activities of TTR, the Conference was divided into seven scientific sections: (1) Deep-sea depositional systems and modern analogues of hydrocarbon reservoirs; (2) Geomorphology and neo-tectonics; (3) Diapirism, mud volcanism, and hydrocarbon potential of deep sedimentary basins; (4) Shallow gas, cold seeps and gas hydrates; (5) Biosphere - geosphere interaction; (6) Pelagic and hemipelagic sedimentation; (7) Special session: Volcanism and hydrothermal venting of the Mid-Atlantic Ridge. In total, 52 oral presentations and 8 poster presentations were made. Geological processes in areas of the Black and Mediterranean Seas and North Atlantic studied by TTR (but also by other programmes) were highlighted. The conference was supported by the Intergovernmental Oceanographic Commission of UNESCO, the Russian Foundation of Fundamental Research, the Ministry of Natural Resources and the Ministry of Industry, Science and Technology of the Russian Federation, and the Flemish Government, Belgium.

(SC-2001/WS/32)

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PREFACE

"Geological Processes on Deep-Water European Margins" - International Conference and 10th Anniversary of the Training Through Research Post-Cruise Meeting was held from 28 January to 2 February, 2001 at the Faculty of Geology, Moscow State University (MSU) and in Mozhenka (ca. 50 km from Moscow) at Zvenigorodskiy Resort Hotel (belonging to the Academy of Science of Russia), being hosted by Moscow State University jointly with the Academy of Science, Ministry of Natural Resources and Ministry of Industry, Science and Technology of the Russian Federation.

The Training Through Research (TTR) Programme, designed in 1990 by an international group of scientists under the auspices of UNESCO, has been executed in co-operation with the European Science Foundation (between 1992-1995) and UNESCO's Intergovernmental Oceanographic Commission (as of 1996). It has been successfully operating at seas around Europe, as well as along North African and Middle-East coasts, making sophisticated multidisciplinary research together with advanced on-the-job training for students and young scientists in the field of marine science. The 10-year activities have led to numerous exciting discoveries, and also have built a new multicultural community of young scientists, with high expertise and broad seagoing experiences.

TTR Post-Cruise Meetings have been held annually, being hosted by universities actively involved in the programme, since 1993. They aim in facilitating the exchange of information between the participants of the TTR expeditions, summarising the collected data, and also providing 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, to make new ones and to make joint planning for the future activities.

The Conference/Post-Cruise Meeting, being devoted to the 10th Anniversary of TTR, was focussed on all aspects of marine geosciences that have been studied by the TTR cruises for the last ten years. The intent was to obtain an overview of what has been done and also to outline directions for future activities.

The meeting brought together over 70 participants from 13 countries (Belgium, Brazil, Bulgaria, Georgia, Greece, France, Italy, the Netherlands, Portugal, Russia, Spain, Turkey, 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 theme.

Reflecting main research activities of TTR, the Conference was divided into seven scientific sections:

- Deep-sea depositional systems and modern analogues of hydrocarbon reservoirs;
- Geomorphology and neo-tectonics;
- Diapirism, mud volcanism, and hydrocarbon potential of deep sedimentary basins;
- Shallow gas, cold seeps and gas hydrates;
- Biosphere - geosphere interaction;
- Pelagic and hemipelagic sedimentation;
- Special session: Volcanism and hydrothermal venting of the Mid-Atlantic Ridge.

In total, 52 oral presentations and 8 poster presentations were made. Geological processes in areas of the Black and Mediterranean Seas and North Atlantic studied by TTR (but also by other programmes) were highlighted.

The Conference started with the Inaugural Session. Prof. V.T. Trofimov, MSU Vice-Rector, opened the meeting by welcoming the participants on behalf of the Moscow State University, and

Prof. B.A. Sokolov, Dean of Faculty of Geology, welcomed the participants on behalf of the Faculty. Prof. I.F. Glumov, Deputy Minister, and Dr. R.R. Murzin, Head of the Marine Department, welcomed on behalf of the Ministry of Natural Resources and Dr. V. Zhivago and Dr. Yu. Mikhailitchenko welcomed on behalf of the Ministry of Industry, Science and Technology. Dr. A.E. Suzyumov addressed the meeting on behalf of Dr. P. Bernal, UNESCO Assistant Director General for IOC.

The participants expressed great satisfaction with the Conference as having fully accomplished its objectives and facilitated fruitful contacts between the attendees.

During the Conference discussion of plans for the future TTR research took place and, on 1 February, meeting of the TTR Executive and Scientific Committees was held, 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 Organizing Committees:

INTERNATIONAL ORGANIZING COMMITTEE

- P. Bernal (UNESCO/IOC)
- J.-P. Henriet (University of Gent, Belgium)
- M. Ivanov (Moscow State University, Russia)
- N. Kenyon (Southampton Oceanography Centre, UK)
- A. Suzyumov (UNESCO Science Sector)
- J. Woodside (Free University of Amsterdam, The Netherlands)

LOCAL ORGANIZING COMMITTEE

- President: V.T. Trofimov, Moscow State University
- Vice-Presidents: I.F. Glumov, Ministry of Natural Resources
- N.A. Bogdanov, Russian Academy of Science
- B.A. Sokolov, Moscow State University
- Executive Secretary: M.K. Ivanov, Moscow State University
- Members: V.N. Zhivago, Ministry of Industry, Science and Technology
- A.F. Limonov, Moscow State University
- O.V. Krylov, Moscow State University
- S.V. Bouriak, Moscow State University
- G.G. Akhmanov, Moscow State University
- E.V. Kozlova, Moscow State University

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

The conference was supported by the Intergovernmental Oceanographic Commission (IOC) of UNESCO, the Russian Foundation of Fundamental Research, the Ministry of Natural Resources and the Ministry of Industry, Science and Technology of the Russian Federation, and the Flemish Government, Belgium.

MESSAGE TO PARTICIPANTS OF THE CONFERENCE

from Patricio Bernal, Assistant Director General of UNESCO
for the Intergovermental Oceanographic Commission
Paris, France

Dear Participants to the Annual TTR Conference,

It gives me great pleasure to welcome you, students and scientists of Moscow State University and those who have come to Moscow from the many countries participating in and contributing to the IOC-sponsored Training-through-Research programme. As you know, we are celebrating now the 10th TTR Anniversary.

Indeed during the past 10 years, TTR has progressed a long way from being an East-West co-operation activity to an endeavour, recognized throughout the world as a successful international undertaking. The contribution by this programme to the development of a universal culture of peace and tolerance has been recognized by the United Nations.

TTR is the only marine-related programme that we know of which is based on student training combined with advanced research; a combination that yields excellent scientific results as shown by the series of published scientific contributions originated by the programme. In addition to the outstanding training it affords, TTR has made a considerable contribution to a number of important international research projects, such as the Ocean Drilling Programme and various European projects, thus advancing knowledge on processes in the world ocean.

Though the previously mentioned TTR philosophy and basic principles, a closely linked international community of young scientists is fostered. These well-trained young scientists coming from various countries appreciate and gain from the cultural variety represented in their working groups. Time and again, they demonstrate admirable capability in handling advanced equipment, manage high-quality scientific data and involve themselves in writing joint scientific papers for publication.

As the result of the TTR's success, IOC has received a number of requests to launch similar projects in Africa, Latin America and other regions. It is my belief that TTR has now reached a level of maturity, which enables it to be held up as a model for similar initiatives.

On this occasion, it is with great pleasure that I present IOC Certificates of Appreciation to several colleagues, namely Dr. Neil Kenyon, Dr. John Woodside, Prof. Ivan Glumov, Prof. Mikhail Ivanov and Prof. Victor Trofimov, in recognition for their outstanding contributions to IOC of UNESCO through TTR.

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

29 January 2001

ABSTRACTS

Introduction

TRAINING-THROUGH-RESEARCH: TEN YEARS OF INTERNATIONAL CO-OPERATION

A. Suzyumov

Science Sector, UNESCO, Paris, France

In the year 2000, the Training-through-Research (TTR) programme marked its 10th Anniversary. An initiative of Moscow State University, it grown up into a truly international undertaking from discussions at a UNESCO workshop on 'Year 2000 Challenges for Marine Science Training and Education World-wide' (Paris, 1988) and from the recommendations of the UNESCO workshop on 'University Field Courses in Marine Sciences' (Moscow and Poyakonda, 1989). The launching workshop (Bologna, 1990) endorsed a proposal to organize, in 1991, the first 'Floating University' international geological-geophysical cruise in the Mediterranean and Black Seas, with both training and research aims. The Bologna workshop had a historical significance for the TTR programme as it succeeded in combining the two seemingly uncompromising needs for education and research, and formulated the concept that is reflected now in the programme title, 'Training-through-Research'.

Between 1992-1994, the critical launching period, TTR under the coordination of Dr. John Woodside (Free University of Amsterdam) was co-sponsored by the European Science Foundation. During this initial period, very important support was also provided by the Netherlands Marine Research Foundation. In 1993, the Floating University facility was officially included in the UNESCO programme, and the UNESCO-MSU Centre was established.

TTR is managed by the Executive Committee (Coordinator Dr. Neil Kenyon, Southampton Oceanography Centre, UK). In the period 1991-2000, ten annual TTR cruises were conducted in the Mediterranean and Black Seas and in the northern Atlantic on board the two sister-ships, *Gelendzhik* and *Professor Logachev*. Over 500 scientists and students hailed from 27 countries have taken part in the cruises. Eight post-cruise conferences were held. A number of other field exercises, group and individual training activities, and presentation and publication of the research results were carried out. The TTR results have been reported in many peer-reviewed and other publications. All together, well over 100 institutions have taken part in all forms of the TTR co-operation.

The basis of the TTR success is the combined advantages of the formal training of students and young scientists with the experiences gained in advanced research in marine geosciences. It provides shipboard training but is not limited to the latter, which makes it different from traditional on-the-job training programmes. TTR provides added value to European programmes and indeed has helped to trigger some of the latest European undertakings.

In recognition of its achievements and in particular its contribution to building international peace and tolerance - fundamental objectives of the United Nations - the programme was included, in 1995, in the List of Events for the celebration of the UN's 50th Anniversary. In the same year, a hitherto unknown positive relief feature was discovered in the Mediterranean Sea by the TTR-5 cruise and was given the name 'the United Nations Rise'.

Last but not least is that after ten years of operations, the TTR programme may report that it has reached its primary objective: many young, well-trained specialists continue successfully working in the marine geoscience field- in universities, research institutions, geophysical companies and oil industries. Some of those students, who first attended one of the TTR cruises years ago, have returned as experienced teachers and supervisors of students' projects and as co-chief scientist.

PRINCIPAL SCIENTIFIC RESULTS OF THE TTR. FIRST DECADE

M.K. Ivanov[1], J.M. Woodside[2], N.H. Kenyon[3] and TTR Scientific Party

[1] *UNESCO-MSU Centre for Marine Geosciences, Geological Faculty, Moscow State University, Moscow, Russia*
[2] *Faculty of Earth Sciences, Free University, Amsterdam, The Netherlands*
[3] *Southampton Oceanography Centre, Southampton, United Kingdom*

The main objective of the TTR investigations during the first decade was geological processes on deep-sea European margins. The long list of the TTR scientific items includes traditional (which have been the focus of many expeditions) and some innovative ones:

- Geological structure and neotectonics;
- Pelagic/hemipelagic sedimentation and climate variations;
- Deep-sea depositional systems;
- Cold seeps and related processes;
- Carbonate mud mounds;
- Seabed processes related to the strong bottom currents;
- and some others.

The TTR made a remarkable contribution to the study of extremely complex collision zones and active tectonics in the Tyrrhenian and Alboran Seas. Geophysical surveying of the Eratosphenes Seamount during TTR-3 (1993) has led to new interpretation of its structure that have been accepted as the basic model by ODP for the Leg 160 drilling programme. Successful coring programme during TTR-6/ANAXIPROBE cruise (1996) has established a direct correlation between the geological formations of the Anaximander Mountains and different structural zones of Southern Turkey.

Many new data on deep-sea fans, different kind of canyon systems, deposits and bedforms related to strong bottom currents were published after the TTR cruises or recently accepted for publication in international journals or special publications.

The multidisciplinary study of carbonate mud mounds in the Porcupine Seabight, Rockall Trough and Faeroe margin in co-operation with CORSAIRES and ENAM-2 programmes has not indicated their relationship with supposed hydrocarbon vents. Asymmetric distribution of the living corals across the mounds documented on underwater TV records for the first time during TTR-7 (1997) suggests that bottom currents possibly control their growth and position. However similar type of up-builds have been found recently during the TTR-9 (1999) and TTR-10 (2000) cruise on tops of some mud volcanoes in the Gulf of Cadiz, where the presence of hydrocarbon seeps are beyond any doubt.

The most significant scientific results of the TTR belong to the study of mud volcanism. The TTR indeed keeps a leading position in research of deep-water mud volcanoes and accompanying phenomenon. First of all a big number of mud volcanoes has been discovered by TTR in co-operation with other projects in the Black Sea, Mediterranean and Atlantic Ocean. Most of these structures were studied by a large variaty of methods. The reconstruction of sedimentary succession based on study of the lithology and age of clasts from mud breccia belongs to the pioneering research. The study of composition and maturity of organic matter from mud volcanic deposits has provided a unique data for estimation of hydrocarbon potential of deep-sea sedimentary basins.

During the TTR investigations new data on mineralogical composition of diagenic crusts, fluid chemistry, and isotopy of particular elements were obtained. Chemosyntetic biocommunities accompanying active vents were discribed. The TTR was lucky in discovering shallow gas hydrate accumulations in different locations, and sometimes in areas, where their existence seems to be very problematic according to thermodynamic conditions.

Deep-sea depositional systems and modern analogues of hydrocarbon reservoirs

CHANNELISED DEEP SEA DEPOSITIONAL SYSTEMS IN THE MEDITERRANEAN: THE VALUE OF SONAR BACKSCATTER MAPPING

N.H. Kenyon

Southampton Oceanography Centre, Southampton, United Kingdom

Both long range GLORIA and OKEAN sidescan sonars, long range swath bathymetry and its accompanying backscatter information, and higher resolution deep towed sidescan sonars have been used to map deep sea "turbidite systems" in the Mediterranean over the past 30 years. A major gap in knowledge is detailed information on the distribution of the sands in the systems. This is because of the difficulties of obtaining good cores through sands and because of the lack of high resolution, deep towed seismic data. The main gap in the coverage is along the margins of North Africa, with the exception of the Nile Cone which is now relatively well known (e.g. Bellaiche et al., 1999).

GLORIA and other data from along about 30,000 miles of low latitude (i.e. non glacial) continental margin, worldwide, provide sufficient data for a new classification of deep sea "turbidite systems" (Fig.1). The scheme is based on slopes with a fall of 3000 m or more and does not hold for shelf edge deltas. The plan view emphasis is a valuable complement to sequence stratigraphic schemes that are derived mainly from a study of seismic profiles and rock outcrops. The simplest classification is into a spectrum of types (Fig.1), distinguished by their channel and lobe characteristics, in which the main control is the long-term average rate of sediment input. Long-term rate of input will be affected by drainage basin size and gradient, and by climate, to a greater extent than by sea level. The model is tested for the Mediterranean using both published information, and unpublished data from west of Corsica and Sardinia and from the Tyrrhenian and Alboran Seas.

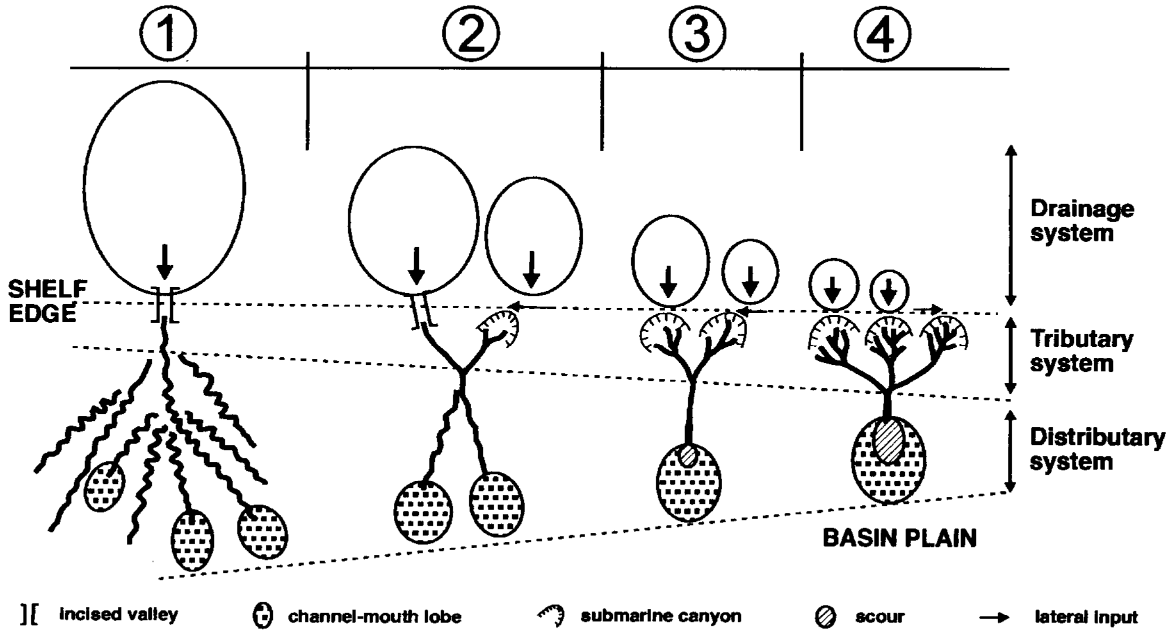

Fig. 1. Simplified classification of channelised depositional systems on low latitude margins

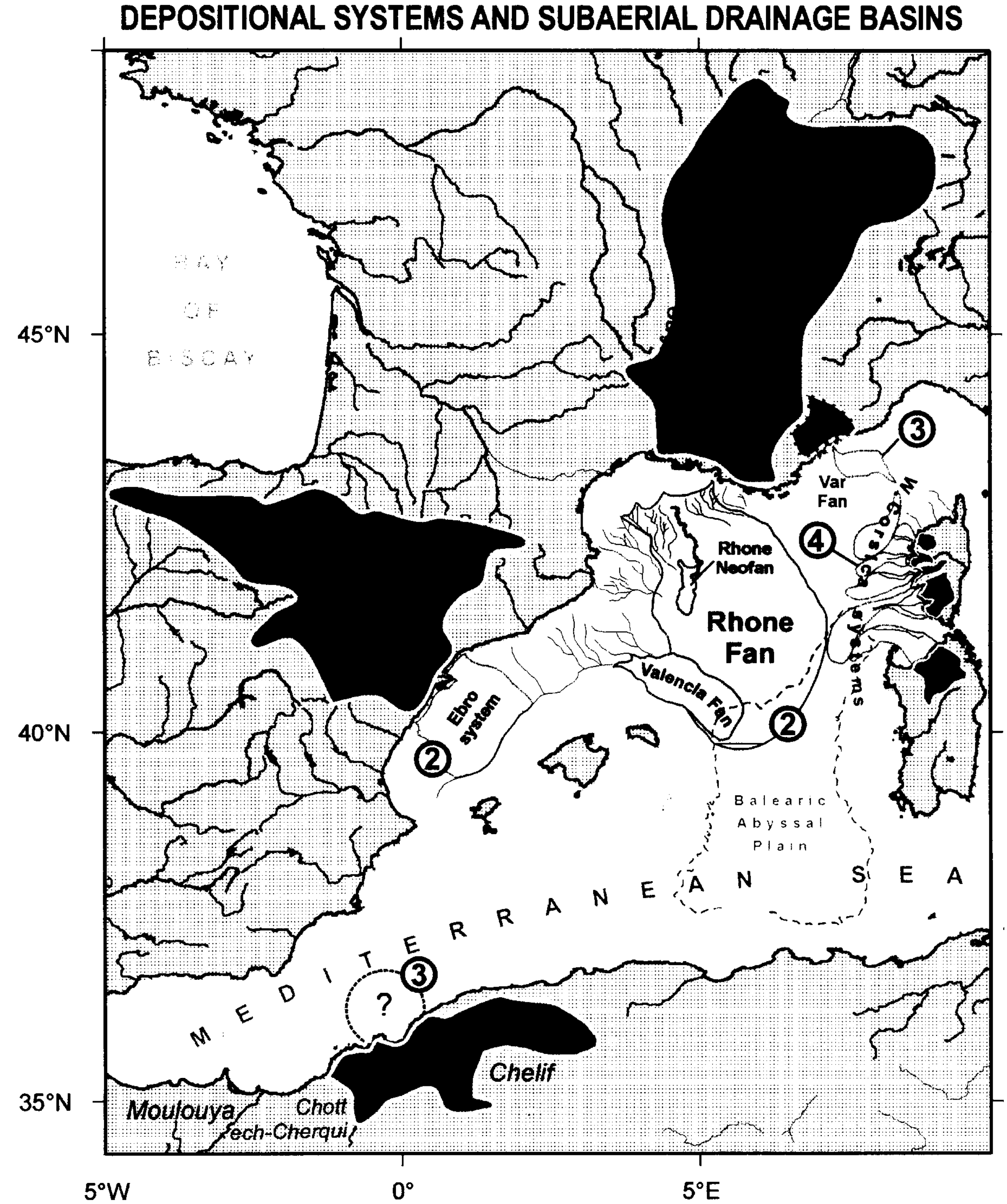

Fig. 2. Some subaerial drainage basins and their submarine depositional systems in the Western Mediterranean. The numbers refer to the types in Fig.1

TYPE 1. The model requires the mature, highest input types to have a point source, a large radial distributary channel system with sinuous channels and low fan gradients. Sinuosity should be greater than about 1.6 in the middle reaches of channels and maximum channel gradients should be less than about 1 in 100. Width to depth ratios of channels are usually less than 50. Sandy lobes are expected to be attached to the ends of channels, i.e. without extensive erosion upstream of the sand sheets. Flows are frequent, probably in excess of one per year at times of low sea level. The Nile Cone is the only system of this type in the Mediterranean, having a drainage

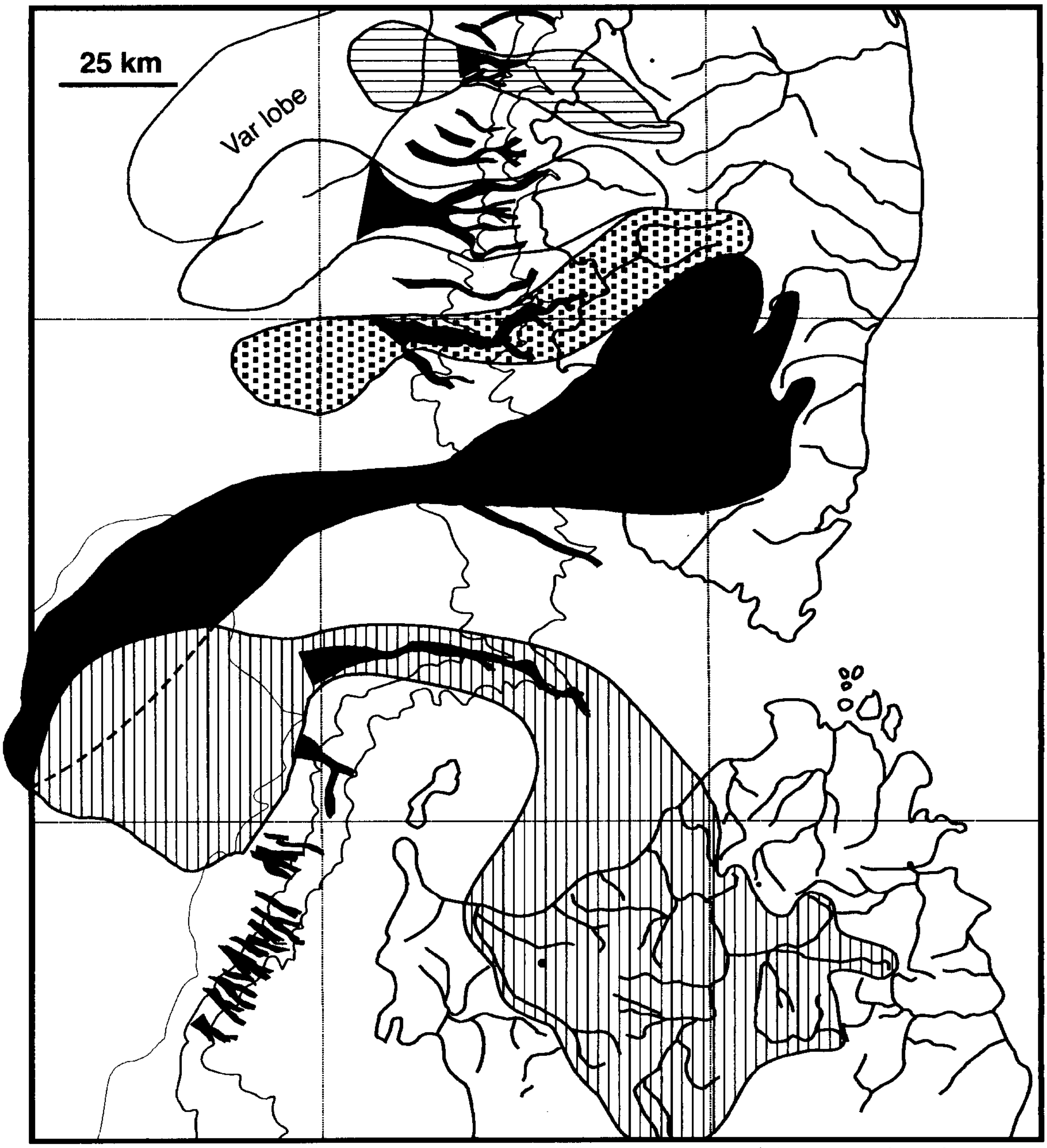

Fig. 3. Subaerial drainage basins and depositional systems west of Corsica and Sardinia (Kenyon et al., 2000)

basin of over 2 million km². It differs from the perceived ideal for a high input fan (e.g. the Indus or Amazon fans), in having slightly higher overall gradients. However the channels can be highly sinuous, up to 2 or more (Bellaiche et al., 1999). Tectonics affects the fan surface and may be the cause of the higher gradients.

TYPE 2. The Rhone Fan is close to the norm for a medium to high input type. The drainage basin is about 100,000 km² (Fig. 2) and it has a distributary pattern of channels with at least one avulsion (e.g. Torres et al., 1997). Maximum sinuosity is greater than 2 for the abandoned channel but is only about 1.4 for the newly avulsed and entrenched channel. With further growth in the new fan lobe, the sinuosity should increase.

TYPE 3. The Var and the Ebro funs are considered to fall within the medium to low input type. There is a drainage basin in North Africa (the Chelif, Fig. 2) that should be large enough to produce a type 3 system, but little is known of the submarine margin in this area. The Var

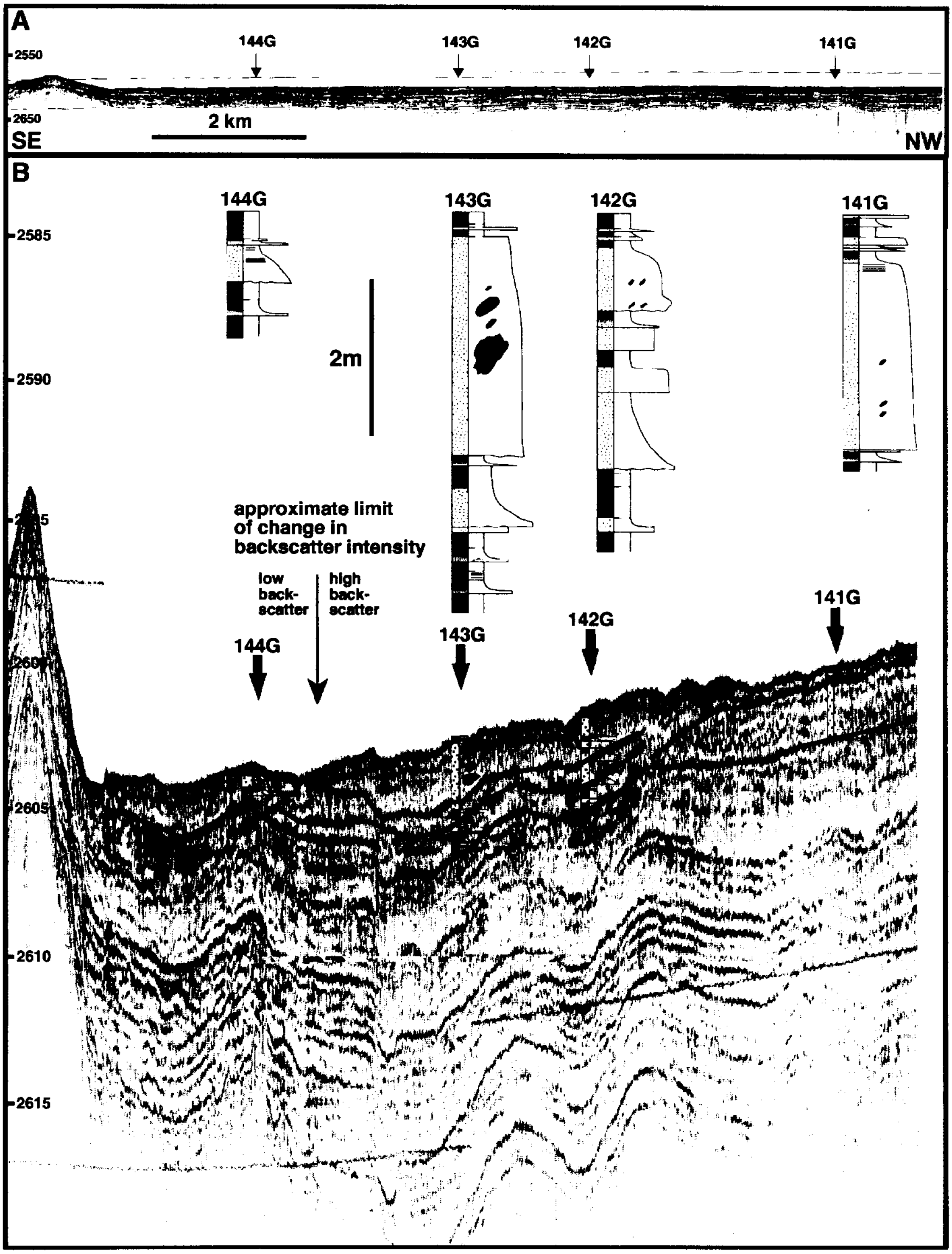

Fig. 4. 3.5 kHz deep towed profile from a lobe west of Corsica. By increasing the vertical exaggeration extensive lenses can be identified. Cores of up to 3 m of fining upward coarse sand are correlated with the lenses. TTR-4 cruise (Limonov et al., 1995)

drainage basin has an area of about 4,000 km². It is fed by very steep tributary canyons with a maximum gradient of about 1 in 5. The channel is relatively straight and wide (up to 7 km) and it has a well-developed levee along its right bank. Downslope from the leveed section of the system the channel continues with a distributary pattern developing where it becomes very shallow (about 2 m deep). A lobe can be identified from the backscatter pattern (Fig. 3). The lobe at the mouth of Ebro system has well developed scours and also constructional, probably sandy, bedforms (e.g. Morris et al., 1998).

TYPE 4. Mature lowest input types have tributary "canyon like" feeder systems and a lesser development of, or no, channel-levee systems. Channels are relatively straight, maximum channel gradients are generally over 1 in 70 and width to depth ratios are over 150 near the ends of channels. Channel-mouth sand lobes are common and extensive and usually detached from their channel by a zone of erosion. Flows are less frequent even at times of lower sea level, possibly fewer than 1 per 1000 years. There are many such systems in the Mediterranean, typified by the tributary canyon systems west of Corsica and northern Sardinia (Kenyon et al., in press). These have subaerial drainage basins of less than 1,000 km^2 and straight, wide canyons. Short leveed channels, with a width to depth ratio of greater than 100, terminate at or just beyond the base of the steep slope. Maximum channel gradients are greater than 1 in 10. The floors of these canyons are acoustically rough, as first observed for similar canyon systems off Algeria in the first recorded sidescan sonar work in the deep Mediterranean Sea (Belderson et al., 1970). The passage of fast moving turbidity currents leave scour holes and mobile gravel deposits in the western Corsican canyon axes. The rough canyon floors off Algeria were also attributed to the passage of turbidity currents such as that caused by the Orleansville earthquake, where speeds of up to 80 km per hour are reported (Heezen and Ewing, 1955). Beyond canyon mouths there are lobe shaped areas (Fig. 3) where braid like strong backscattering patterns are found together with weak backscattering patterns. These backscattering patterns correspond to sand sheets that have been cored in places and found to be up to 3 m thick (Kenyon et al., in press) (Fig. 4).

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DEEP-SEA BOTTOM CURRENT DEPOSITIONAL SYSTEMS WITH ACTIVE SAND TRANSPORT ON THE NORTH-EASTERN ATLANTIC MARGIN

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[2] *Geological Survey of Denmark and Greenland, Copenhagen, Denmark*
[3] *UNESCO-MSU Centre for Marine Geosciences, Geology Faculty, Moscow State University, Moscow, Russia*
[4] *Renard Centre of Marine Geology, Dept. of Geology & Soil Science, Ghent University, Ghent, Belgium*

Advances in underwater technology within the last decade revealed the importance of strong bottom current systems in deep-sea. Understanding of sedimentary processes taking place in such systems is particularly important for continental margins which nowadays are being actively explored by mankind.

A number of locations investigated by TTR with a comprehensive set of geophysical and geological tools in 1997-2000 on the northeastern Atlantic margin revealed evidences of strong bottom currents operating in the depth range from 500 to 1500 m. The obtained data show different depositional environments controlled to various extend by tidal currents, oceanic boundary currents and internal tides. Systems with active sand transport located on the Faeroe margin, in the Eastern Porcupine and in Gulf of Cadiz were of particular interest for the presented paper (Fig. 1).

The cold Norwegian Sea overflow water flows with considerable speed through the Faeroe Bank Channel, which is the deepest passageway for bottom water out of the Norwegian Sea into the North Atlantic. 12 kHz OKEAN and 30 kHz OREtech sidescan sonar data, together with seismic profiles and cores, were obtained on TTR-7 cruise from the RV *Professor Logachev* in order to study hitherto unknown pathways of Norwegian Sea overflow water west of the Faeroe Bank Channel. West of the mouth of the Faeroe Bank Channel there is a basement high that is flat topped and stands about 200 m above the surrounding seafloor. To the east of the high there are two shallow channels and another runs around the southern and western side of the high. Two parallel channels run along the north side of the high. All of these channels have backscattering characteristics indicative of coarse sediments, and this is confirmed by cores. The high resolution profile on the single deep towed line that was obtained indicates a thickness of sand of up to 7 m. Active bedforms such as sand ribbons and trains of sinuous crested sand waves are found associated with the channels. There is a well preserved sediment drift to the west of the basement high and its flanking channel. This drift is ornamented with mud waves with a wavelength of 1.5 km. This drift has prograded towards the east and at the same time the channel floor has shifted eastwards. The seismic character beneath the channel is indicative of a possible coarse aggradational contourite channel deposit.

High-resolution seabed mapping in the Eastern Porcupine Seabight started in 1997 during TTR-7 cruise has showed a current swept seabed in the depth range between 500 and 1000 m. The bedforms observed on the sonographs indicate that the pick current can reach a considerable speed up to 100 cm/sec or even more and is northerly directed. Analysis of bedform assemblages allowed mapping zones with different current speed within the main current pathway. On the underwater video records numerous stone pavements and fields of ripples of different morphology on the sandy and gravely seafloor confirmed side-scan sonar observations. The geometry of sand deposits was resolved on the basis of deep-towed 3.5 kHz subbottom profiler records showing a continuous sheet-like body up to 5 m thick composed by numerous amalgamated lenses probably representing individual cut-and-fill events. On the OKEAN long-range side-scan sonar seabed image a sand field with an area more than 60 km^2 was mapped. Additional information on the sand bodies morphology was obtained during deep-towed camera survey performed in 1999 by SOC researchers in the area characterised by the presence of the well-marked seabed lineation on the 30 kHz sidescan sonar records. An elongate sand ridges up to 1 m high with crests parallel to the current flow direction represent-ing previously unknown type of

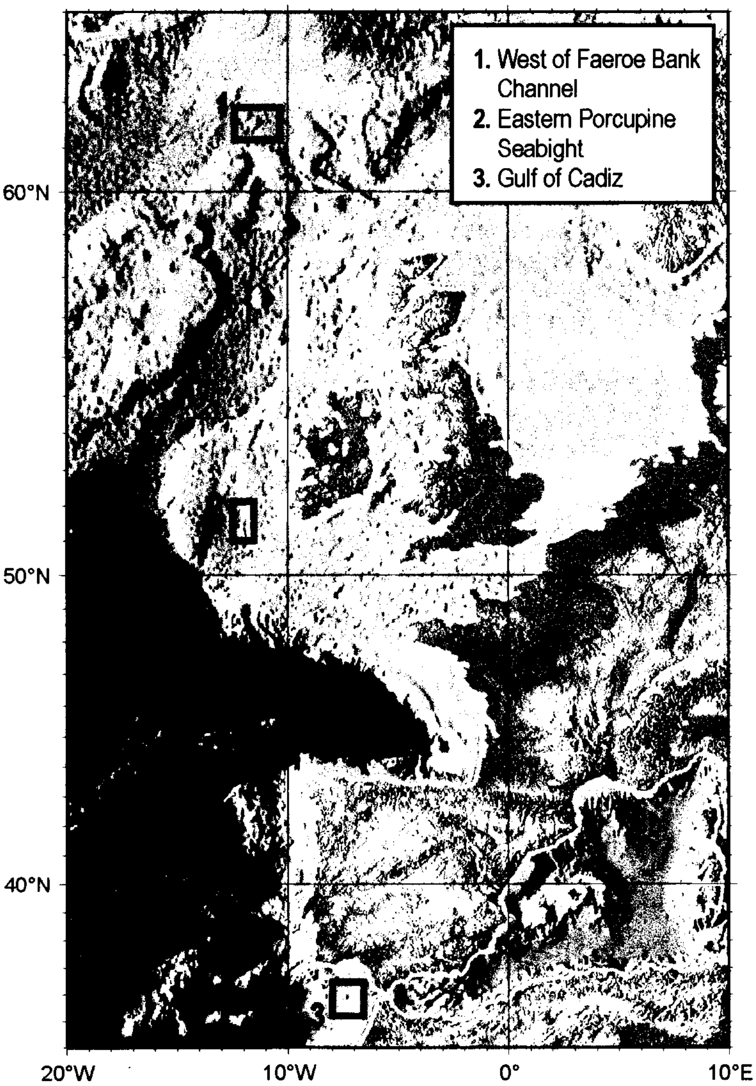

Fig. 1. Areas discussed in the text

bedforms were observed on the video records. According to side-scan sonar data they can be up to 2 km long.

One of the largest known expanses of sand laid down in the deep sea by a contour current is in the Gulf of Cadiz, where the Mediterranean Undercurrent decreases in speed as it comes out of the Strait of Gibraltar. The bedform distribution and the geometry of the sandy deposits are best known in their proximal setting (Heezen and Johnson, 1969; Kenyon and Belderson, 1973; Nelson et al., 1993) where there is a sequence of bedform zones of gravel and sand spread across a terrace in the continental slope at depths between about 700 and 900 m. Several filaments of the Undercurrent plunge down slope along channels. Sidescan sonar coverage has been obtained over the three most proximal channels with a 12 kHz SEAMAP system and with the deep towed, 32 kHz TOBI system. The widest of the channels (Channel 2 of Kenyon and Belderson, 1973) is steered by NE-SW trending diapiric ridges but the two most proximal (Channel 1 of Kenyon and Belderson and a newly discovered channel) are not controlled by underlying topography, at least at the present time. A continuous photographic traverse shows eroded walls and a floor covered in active sand waves. The two most proximal channels are flanked on both sides by large silt/mud waves. The waves are steeper sided and coarser grained nearest to the channel and in these respects they resemble turbidity current channels down which 'flow stripping' is occurring. Two of the contourite channels have gradients of about 1 in 70 and terminate at depths of about 1000 m where the current presumably lifts off the seafloor. It appears that the sand, hitherto transported by a traction current process, accumulates at the end of the channels. At the front of this depocentre a portion of the sand accumulation fails and flows down slope by a gravity driven process through much smaller, slightly sinuous channels, spreading out at the base of slope as sand lobes (Habgood et al., 2000).

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PASSAGE OF DEBRIS FLOWS AND TURBIDITY CURRENTS THROUGH A TOPOGRAPHIC CONSTRICTION: SEAFLOOR EROSION AND DEFLECTION OF FLOW PATHWAYS

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Previous studies have shown that some of the largest and most efficient submarine debris flows are to be found on the NW African margin. This margin has complex topography and is subject to continuing volcanic activity which has produced the Saharan Seamounts and the Cape Verde, Canary and Madeiran Islands. The Saharan Seamounts and Canary Islands form a ~1000 km long volcanic ridge on the margin which form an effective barrier to sediments passing down the continental slope. The region directly SW of El Hierro Island is critical as it contains the only gap in this volcanic ridge for sediments to flow through. Recently, we obtained the first deep-towed sonar images, showing sedimentary processes operating within this topographic 'gap' or 'constriction'. These images show evidence for the passage of the Saharan debris flow and highly erosive turbidity currents, including the largest comet marks reported from the deep ocean. The Saharan debris flow appears to have been deflected by a low (~20 m) topographic ridge, while turbidity currents predating the debris flow appears to have overtopped the ridge. We suggest that as turbidity currents passed into the topographic constriction they experienced flow acceleration and as a result, became highly erosive. West of 19° the Saharan debris flow has a basal volcaniclastic sheared layer, although the recent sonar data do not suggest this layer was mobilised directly SW of El Hierro. A seismic reflection profile obtained 70 km to the east, upslope of the topographic constriction indicates that up to 30 m of the seafloor sediments have been eroded by the Saharan debris flow to form a basal volcaniclastic layer.

GEOLOGICAL STRUCTURE AND MAIN STAGES OF SEDIMENTARY STRATA FORMATION ON WESTERN CONTINENTAL MARGIN OF IRELAND ACCORDING TO SEISMIC DATA

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The branching channel system located on continental slope west of the Rockall plateau were studied during the 10th cruise of R/V *Professor Logathev* within the framework of the TTR programme in 2000. A total of 18 profiles were recorded from 13th to the 15th of August 2000 totaling 430 km of seismic data. Twelve profiles were acquired in a NW-SE (strike) direction, the rest were shot in a NE-SW (dip) direction comprising one continuos line in downslope direction. The equipment consisted of 3.5 liter seismic air-gun, single channel seismic streamer. The processing included following procedures: data editing, amplitude correction for spherical divergence, and frequency filtering.

The study area can be divided into two main parts: continental slope and continental rise. During the interpretation of the acquired seismic lines a total of four different sequences or seismic units were identified on a basis of their seismic pattern, amplitudes and reflector terminations.

As a result of the interpretation, 3 maps showing the bases of the seismic units were plotted and described.

The base of the Unit 1 is traced only in profiles, which located on the continental slope. Four channels are found on this surface. Thickness of Unit 1 varies from 200 to 500 ms. The base of Unit 2 is traced almost on the all profiles. Three channels are found there. Thickness of Unit 2 layer varies from 200 to 600 ms. Very interesting structure is clearly seen on the on the northern part of the three deepest profiles. It is a lens-like sedimentary body referred to Unit 1a up to 100 ms thick. It is probably filled with deep sea fan deposits. The base of Unit 3 is traced only on the continental rise. This surface has a very contrast relief. Three channels are found there. Thickness of Unit 3 layer is up to 70 ms.

The following model can be suggested to describe the main processes, which took place in the region. The earliest period of sedimentation that we can observe started on the surface, which is represented nowadays as an acoustic basement (base of the Unit 1). Some channels are found there, which can be connected with turbidity current activity. It is an impossible to estimate the amount of sediments deposited since this layer was partly eroded later.

Then, probably, sea level decreased subsequently and character of sedimentation was changed. And a new system of turbidite channels was formed which can be observed on the map of the base of Unit 2. It causes an erosion of the sediments above the acoustic basement. This conclusion was made on a basis of the reflector's character at the boundary between Units 1 and 2. Their amplitudes and rough shape suggests their erosional nature. Probably this erosion was accompanied with sedimentation of deep sea fan deposits (Unit 1a).

After that, sedimentation continued, probably due to increasing of the sea level. As a result of it, the thickest layer in this cross-section (Unit 2) was deposited. In the continental rise area some blurred boundaries are displayed in this layer, which are likely to be associated with short gaps in sedimentation. However, in general way they follow the topography of the bottom of this Unit.

Contrast relief of the base of Unit 3 can be connected with decreasing of the sea level, what caused developing of highly active turbidite channel system, which slighly eroded the lower layer (Unit 2). The sediments, which were deposited in that time, now are presented as acoustically transparent lens-like bodies (Unit 3).

Now these channels are filled with sediments and modern seabottom is much gentler than the relief of the base of Unit 3. However, turbidity activity is not stopped now, but it is much weaker than in the time when Unit 3 was deposited.

DEVELOPMENT OF A SEDIMENT DRIFT: FENI DRIFT, NORTHEAST ATLANTIC MARGIN

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Feni Drift is the largest sediment drift in the NE Atlantic Ocean. It is an elongated and mounded contourite deposit located along the western margin of the Rockall Trough in the northeastern Atlantic Ocean. Feni Drift is formed under the influence of southward flowing deep bottom water currents (Norwegian Sea Deep Water, NSDW), which overflows the Wyville Thomson Ridge in the northern Rockall Trough. The maximum width of Feni Drift is in the order of 125 km and the maximum thickness is more than 900 m. The maximum crest height is about 2100 m below the sea surface.

The Rockall Trough is an important transport path in the global thermo-haline circulation. Variations in discharge on glacial/interglacial and stadial/interstadial time scales of NSDW through the Faeroe-Shetland Channel and overflow over the Wyville-Thomson Ridge into the Rockall Through influence sedimentary processes on Feni Drift. Thus the study of variations in sedimentary processes on Feni Drift in time and space gives important information for the reconstruction of the paleoceanography of the NE Atlantic Ocean.

In seismic sections across Feni Drift three major seismic horizons can be recognised. These reflectors result from changes in the style of sedimentation in the Rockall Trough and are related to the onset and subsequent changes of bottom-current activity resulting from regional subsidence which started in the late Eocene. The three main reflectors are the late Eocene C30 (Stoker et al., in press) reflector which is a deep water unconformity resulting from bottom-current erosion; the C20 reflector, a reflective zone formed by diagenesis in lower Miocene strata; and reflector C10 which is an early Pliocene angular unconformity.

Internally the drift is mainly built up of (semi-) parallel reflectors. Small truncations resulting from slumping (Svaerdborg. 1998), local channel formation and infill, and local temporary erosion can be found throughout the drift. On large parts of the drift sediment waves are present on top of the drift as well as in the subsurface.

North of about 56°N Feni Drift is eroded and covered with a veneer of pelagic sediment. The crest of Feni Drift shows a clear change in morphology from north to south. Around 56°N Feni Drift is plastered against the W Rockall Trough slope and a crest starts to develop. Further to the south the crest becomes detached from the western Rockall Trough margin, and changes from asymmetrical to a more symmetrical relief and finally merges into the regional sediment wave field (Kidd and Hill, 1986). Clear changes in position and the shape of the crest have occurred since the early Pliocene (See also de Haas et al., submitted).

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HIGH RESOLUTION MARINE GEOPHYSICAL DATA AS PROXIES FOR PREDICTION OF RESERVOIR QUALITY AND GEOMETRY IN DEEP-WATER SETTINGS: ANALOGUE DATA FROM MODERN, HIGH AND LOW N:G SETTINGS AND THEIR APPLICATION TO THE SUB-SURFACE

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Exploration and production from deep-water sandstone reservoirs globally has shown that traditional geological models are inadequate for predicting reservoir facies and quality. This is particularly true for West Africa and offshore Brazil, where application of geological information has not always led to successful prediction of reservoir facies distribution. An understanding of sedimentary processes occurring within individual turbidity currents (e.g. Kneller & McCaffrey, 1999), and their deposits as seen in the rock record (e.g. Mutti, 1992; Cronin and Kidd, 1998; Cronin et al., 2000), is a critical part of understanding issues of reservoir quality such as connectivity, facies heterogeneity, and distribution. However this geological visualization, based on combinations of fluid dynamic theory and rock outcrop analogy, are rarely of direct use in reservoir facies prediction on an exploration scale. This is particularly true when the limited number of geometric bodies (or architectural elements), such as channels, amalgamated sheets or lobes, in regular use for classification of external sand body geometry in deep-water settings occasionally fail to match predicted reservoir behavior, or volumes of predicted reservoir prone facies.

THE SOUTHEAST GREENLAND MARGIN: LATE QUATERNARY SEDIMENTARY PROCESSES AND OCEAN CIRCULATION CHANGES

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During the 1997 cruise of R/V *Professor Logachev* investigations were made of the southeast Greenland shelf, slope and adjacent Irminger Basin plain, using airgun seismics and sub-bottom profiler as well as deep-tow side scan sonar. For sediment sampling, a piston corer, a box corer, and a giant video-grab were deployed. In addition, multi-channel sleevegun seismic data were concurrently collected by R/V *Dana*.

The sonographs from the outer shelf reveal large, current parallel, iceberg plow marks down to a water depth of about 700 m. At greater water depth (900 - 1500 m) current-induced longitudinal bedforms indicate the occurrence of extremely strong bottom currents with a maximum speed of up to at least $1 m.s^{-1}$. This is at the depth stratum where southflowing Labrador Sea Water is found. Both at the shelf edge and on the lower slope and rise the seafloor morphology is indicative of mass flow deposition. Current-induced bedforms cutting off mass flow structures may illustrate that the main mass flow events occurred prior to the initiation of the (present) current regime. Also the seismic data demonstrate the widespread presence of mass flow deposits.

Frequent sediment waves observed along the lower slope (>1500 m depth) and rise suggest that also here relatively strong (maximum speed <1m.s^{-1}), southerly, bottom currents may occur. Individual turbidite channels can be traced as incised valleys extending in southeasterly direction on the adjacent basin plain. Associated channel levees are asymmetric, with deposition prevailing mainly on the southern channel bank. From the above acoustic and seismic information we conclude that throughout the Quaternary and latest Tertiary both contourite and mass flow deposition have been the main sedimentary processes on this margin.

The sedimentary records both from the shelf (Core DS97-4P, 620 m) and rise (Core DS97-7P, 1843 m) clearly illustrate the ocean circulation changes associated with the last deglaciation. Stable isotope and foraminiferal fauna data from Core DS97-7P demonstrate that during the Last Glacial Maximum bottom water circulation was only sluggish. These conditions with low-oxygen bottom waters and a sea ice cover during most of the year prevailed until around 13.300 14C yrs BP, when an intensifying Irminger Current advected warmer Atlantic water masses into the area. At the same time bottom water current activity increased, reflecting enhanced deep water formation and stronger Denmark Strait overflow. Turbidity flow processes at the site of Core DS97-7P were active in a period at the end of the Younger Dryas. An estimate of postglacial sea surface temperatures indicates maximum values for the period of the Holocene Climatic Optimum.

The shelf core record of Core DS97-4P reveals that after the ice margin had withdrawn from that site, conditions of (semi)-permanent sea ice cover prevailed until near 12.500 14C yrs BP. It is evident that the altered hydrographic regime with open water conditions was favourable for iceberg drift and associated melting processes, which may be reflected in a changed element (K) composition of the sediments from that time span. No evidence was found for a return to conditions of semi-permanent sea ice during the Younger Dryas. The grain size distribution of Core DS97-4P suggests a gradual, but steady increase of the East Greenland Current since the beginning of the Younger Dryas. Increasing current activity on the shelf and upper slope may have resulted in significant reworking of (fine-grained) glacial sediments, ultimately leading to conditions favourable for triggering turbidity flows. Support for an early developing East Greenland Current is also provided by provenance studies of coarse IRD. Dropstones in the form of pebbles and coarser material sampled by video-grab (DS97-18, 1256 m) from subseabed strata have a common area of provenance mainly confined to the northern (68° - 73°N) part of East Greenland. High organic carbon contents found in late Holocene sediments are in support of increased primary productivity as also indicated by foraminiferal fauna changes found in the late Holocene section of Core DS97-7P. This may be attributed to a westward shift of the Polar Front Zone after mid Holocene times, or also to increased vertical mixing associated with generally enhanced atmospheric circulation.

GRAIN SIZE COMPOSITION OF THE BEAR ISLAND AREA DEPOSITS AS AN INDICATOR OF THEIR GENESIS

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The work is based on the study of samples of bottom sediments collected during two expeditions of RV *Professor Logachev* - an international expedition in 1996 and the TTR-8 Cruise in 1988 - to the area located in the middle of the Bear Island Trough Fan at the conjunction of the Barents and Norwegian Seas. The study area is known for widely distributed slide bodies. At the same time, the Haakon Mosby mud volcano is located within the area and the results of the TTR-8 cruise suggest some indications of clay diapirism there. According to seismic and sidescan sonar data, several types of seafloor features were identified within the area. These are the mud volcano with several morphological zones and burried mud flows, inferred clay diapirs, and high-backscattering patches/zones possibly corresponding to flows of unconsolidated material.

The samples were collected from all types of the above structures with a wide-diameter gravity corer. The set of lythological methods applied included detailed visual descriptions made on board the ship during the coring operations, and the grain-size analysis upon 13 sandy-silty and clay fractions, performed at VNIIOkeangeologia research institute. The ratio of sand/silt/clay was examined in detail, as well as the vertical distribution of these fractions along the cores and spatial distribution within the study area. Grain-size histograms, empirical and cumulative curves were thoroughly analysed. The study was aimed to correlate the peculiarities of the grain-size with the genesis of the sediment and the degree of its alteration.

The lithological study of the samples allowed of distinguishing several types of deposits of different genesis, each with a typical set of characteristic lythological parameters: hemipellagic sediment, several facies of mud volcanic deposits of the Haakon Mosby mud volcano, diapiric material, and so-called "slope deposits", formed either from the mud volcanic/diapiric material or from the hemipellagic sediments. Different types of deposits were recovered from different geological structures within the area, although often they laminated each other within the same cores.

THE OUTCOME OF COLLABORATION BETWEEN TTR AND THE INDUSTRY-BASED FAROESE GEM NETWORK

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In 1996 a group of oil companies decided to form the Faroese GEM Network. The purpose of the network was to make preparations for the first Faroese hydrocarbon licensing round by providing shallow geological, environmental and meteorological/oceanographic information on a regional scale of the area east and south of the Faroe Islands.

Following initial seismic mapping and geohazard studies, which gave a preliminary outline of the seabed and shallow subbottom conditions, a collaboration between the Faroes GEM Network (GEM), the Geological Survey of Denmark and Greenland (GEUS) and the Training Through Research (TTR) project was initiated in 1998. The overall purpose was to gather new and detailed information on specific topics that could possibly represent hazards in connection with future hydrocarbon operations in Faroese waters.

The first phase of the collaboration was carried out in summer 1998 as part of the TTR-8 cruise, leg 2, with R/V *Prof. Logachev* in the North Atlantic. The main objective was to collect new data in an area of the central Faroese sector of the Faroe-Shetland Channel to investigate a possible buried slump deposit that was recognised in the initial geohazard studies. During the two days of surveying dedicated to this work, more than 400 km multichannel seismic data in 9 lines was collected using a airgun system, simultaneously with an OKEAN side scan sonar and a hull-mounted 6 kHz subbottom profiler. The seismic data confirmed the presence of a major buried slump complex that could be related to hitherto unknown (?Plio-Pleistocene) instability of the eastern Faroese slope. Moreover, the OKEAN and subbottom profiler data yielded evidence of additional surficial mass movements. To investigate this further one deep-towed side scan sonar profile and three gravity cores were collected. These data proved that repeated mass-movements had occurred in Late Quaternary times. Since slope-instability is one of the major concerns of the oil companies operating in deep waters, these new discoveries were of great importance for the Faroese GEM Network.

As a result of the 1998 success, a further collaboration with GEM took place in summer 1999, when five days of the TTR-9 cruise with R/V *Prof. Logachev* were allocated to studies in the

Faroe-Shetland Channel. The main objective of this investigation was to elucidate further the mass-flow deposits and their origin, and in particular to date the latest slope-instability event. Another objective was to study current-induced bedforms in general, and more specifically, those at the southern outlet of the Faroe-Shetland Channel. A programme was set up using single-channel seismic airgun, hull-mounted subbottom profiler, OREtech deep-towed side scan sonar, and a 6-m long gravity corer. In addition, a Preussag TV-controlled grab was used for seabed inspection and sediment sampling.

The new data acquired in the mass-flow area, now known as the Sandoy Fan Area, yield evidence of more than one phase of slope instability of Plio-Pleistocene age. The data also show that the surficial mass-movements can be traced as far up-slope as 400-m water depth. Later investigations of the cores show that the latest, large-scale mass-flow event occurred around the time of the last glacial maximum, but that minor mass-flow activity has occurred in early Holocene times. Generally, the investigation proved that slope-instability of the Faroese side of the Faroe-Shetland Channel is more widespread than previously thought.

A wide range of current-induced bedforms was observed, indicating generally stronger bottom currents towards the southern outlet of the Faroe-Shetland Channel. There are some 100-200 m high, very steep escarpments cut into the seabed in this area. The TV-inspection and grab samples provided evidence that these escarpments and a lag deposit found on the surrounding seabed are caused by the strong bottom current. As this area is of high interest for potential oil exploration, this information is very important to the Faroese GEM Network.

The outcome of the collaboration has, however, not only been of benefit for the industry operation in the Faroese deep-water areas. Also the scientific community has gained important new information that now form part of several ongoing research projects like the EU-supported STRATAGEM project and the Danish LINK project

3D GEOMETRY OF SEDIMENTARY STRUCTURES IN THE ROCKALL TROUGH AREA

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This work forms part of the NIOZ (Netherlands Institute for Sea Research) contribution to the EU-supported research projects STRATAGEM (STRATigraphical development of the Glaciated European Margin). The purpose of this project is to contribute to the understanding of continental margin development in glaciated sectors of the European North Atlantic Margin, to assess sedimentary systems and to develop a unified seismic stratigraphy for the NW European Margin. This includes quantification, definition and modeling of large-scale sedimentary processes and mass fluxes of sediments during glacial and interglacial periods, in relation to the oceanographic conditions affecting margin build-up.

In 1998 and 1999, several high-resolution seismic lines were collected by NIOZ in The Rockall Trough area during the ENAM II (Eastern North Atlantic Margin) project. The seismic lines used in this study were acquired in this area. The multi-channel seismic lines ENAM98-41 to 98-50 and ENAM99-16 to 99-32 were recorded across the Rockall Trough Margins. Lines ENAM98-41 to 98-50 and lines ENAM99-16 to 99-32 are located at the southeastern Rockall Trough Margin, in the area between 53°20' to 55°N and 11°00' to 15°50'W. The study area is a few hundreds km^2 and profiles are located approximately with 5-10 km intervals.

Processing of these seismic lines was carried out at Moscow State University by a standardized processing flow, based on preliminary tests of different processing parameters. Since this does not ensure optimal processing for each single seismic line, extra processing parameters were added, when needed.

After interpretation of the seismic units, their distribution was mapped. Mapping of the seismic units contributes to the understanding of the sedimentation pattern and gives an overview of the 3D geometry of the sedimentary structures. Due to the uniform and monotone basinward dip of all reflectors in the Rockall Trough area, depth maps were considered to be redundant, with all essential information demonstrated by the profiles. The spacing and locations of the seismic profiles are however, not optimal for this purpose. Surfaces of the units are faulted by small-scale faults; however, the throw is so small that they are not accounted for in maps. All maps are worked out in UTM projections, with depth and thickness given in two-way time (TWT).

GRAIN SIZE AND CARBONATE ANALYSIS OF TWO GRAVITY CORES FROM THE WESTERN FAEROE MARGIN

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Presented are the result of the grain size and carbonate content analysis of two gravity cores taken from SW-slope of the Iceland-Faeroe Ridge (IFR) during the second leg of the seventh Training Through Research (TTR) cruise in July - August 1997. This study was carried out at the Free University of Amsterdam as part of the sedimentary geology graduate curriculum.

A total of 53 (10 cc) samples were taken from the cores, at 10 cm intervals. All of these were subjected to grain size analyses using a Fritsch Analysette A22 laser particle sizer. Furthermore, the carbonate content was measured of every second sample. The gravity cores provide a sediment record of the ocean water circulation pattern of the Northern Atlantic Ocean from the Upper Pleistocene to recent times.

The location of the studied cores is excellent for monitoring changes in the circulation pattern of the Northern Atlantic Ocean as the overflow of Norwegian Sea Deep Water into the Northern Atlantic leads to the flow of a vigourous contour current along the southern flank of the Iceland-Faeroe Ridge, at depths below 600 meters. Therefore, any changes in the intensity of this contour-current, which might occur as a result of fluctuations in the global conveyor-belt circulation, will be reflected in the grain-size distribution of the sediment.

The presented grain-size records contain evidence of such fluctuations, with a general coarsening-upward trend as important prove of the steadily accelerating flow velocity of the contour-current in the Holocene, indicating increased deep water circulation.

Geomorphology and neo-tectonics

THE ANAXIMANDER MOUNTAINS REVISITED

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The Anaximander Mountains, comprising three main structural components (Anaximander in the west, Anaximenes in the south, and Anaxigoras in the east), were investigated during TTR-1 as one of the priority targets set up for the TTR programme at the first planning meeting. A grid of sparker seismic lines was made over the mountains along with OKEAN side scan sonar images, gravity and magnetic measurements, and sampling by wide diameter gravity corer. Initial results were sufficiently interesting that further investigations followed. The whole area was mapped by Simrad EM12D multibeam in 1995 as part of the ANAXIPROBE project, with extensive sampling and MAK deep tow sidescan and subbottom profiling during TTR-6 the following year. During TTR-7b in 1997, sampling and mapping continued. Observations and precision sampling were made from the submersible Nautile in 1998 (MEDINAUT project) and further deep tow video and ORE Tech data were obtained with more samples in 1999. Meanwhile, the neighbouring areas (Rhodes Basin to the west and the Florence Rise to the southeast) were investigated during the 1998 PRISMED II expedition. It is now becoming clearer that the Anaximander Mountains were probably formed by southeastward rifting from Turkey in post-Miocene, possibly late Pliocene to Recent time, and are now being deformed by relatively gentle northeastward compression. Gravity data from TTR-1 had already shown that the eastern part of the Anaximander Mountains are different (by about -150 mGal) from the western part; and the later multibeam data seem to confirm that the eastern Anaximander Mountains have affinity with the Florence Rise structure. The development of the Anaximander Mountains and the Rhodes Basin are probably contemporaneous, perhaps linked to the enigmatic Isparta Angle in Turkey, and related both to extension in the Aegean Sea and the increasing difference in tectonic activity between the Hellenic and Cyprus Arcs.

CONJUNCTURAL POSITION OF THE ANAXIMANDER MOUNTAINS WITHIN THE EASTERN MEDITERRANEAN TECTONICS

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The eastern Mediterranean region is a part of the African-Eurasian convergence zone and the present-day tectonic framework of the eastern Mediterranean is controlled by the last phase of collision between the two plates. The boundary between the African and Anatolian plates is delineated by the Hellenic arc and Pliny-Strabo trench in the west and the Cyprus arc and a diffuse fault systems probably associated with the Amanos fault in the east. The two arcs are near perpendicular to the relative motion of the African and Anatolian plates, delineating the subduction zones, whereas the Pliny-Strabo trench, Antalya and East Anatolian fault zones are sub-parallel to the slip vector, with predominantly transform motion.

It is generally agreed that most of the eastern Mediterranean Sea is relict of the Mesozoic Tethys and its history was, therefore, closely related to the alpine orogen. On the other hand, this basin has remained outside the realm of orogenic deformation and has preserved its passive margins and its structural continuity with the bordering lands of the Levant and northern Africa. The bottom topography of the eastern Mediterranean has been the subject of studies by a number of expeditions because of growing interest in the problems of active tectonics and sedimentation. Of particular interest was underwater morphology of the Cyprian arc, the largest tectonic positive feature in the region, and of the prominent Eratosthenes Seamount. Knowledge of morphostructure of the Cyprian arc is essential to understand the tectonic nature of the ophiolite assemblage in the Troodos Massif of Cyprus, and connection between this assemblage and other ophiolite bodies in the surrounding areas. The Anaximander Mountains lie at the junction between the Hellenic arc and the Cyprus arc where the Mediterranean ridge meets with Florence rise. The complex geomorphology of the Mediterranean ridge and Florence rise around the mountains makes it difficult to distinguish true neotectonic deformation resulting from the regional plate interactions from local effects, which may be caused, by karst, mud diapirism, or halokinesis. Although complex, the current tectonics of the whole region cannot be understood without understanding of the nature of the Anaximander Mountains.

Active consumption of newly subducted African lithosphere occurs only at the outermost trenches. Thus, in the west Hellenic arc, the entire Ionian trench may be active but, in the central and eastern segments of the Hellenic arc, only those portions of the Ptolemy and Pliny trenches which face the open Mediterranean sea are active. The relative motion is almost parallel to the Hellenic arc in the east of Crete. This has led several investigators to suggest that this zone serve, in fact, as inclined transform. However, the great depth of earthquakes associated with this inclined seismic zone in which dipslip motion was dominant. Therefore subduction in this region originated under normal circumstances. Only during the later period, the collision of a large oceanic plateau caused the division into a two-arc system, as well as the changes in sense of relative motion along the shifted segments of these.

The Anaximander Mountains lie at the junction between the Hellenic arc and the Cyprus arc where the Mediterranean ridge meets the Florence rise. The boundary between the African and Eurasian plate is delineated by the Hellenic arc and Pliny-Strabo trench in the west and the Cyprus arc in the east. There is a considerable scientific interest in the Anaximander Mountains region whether they are foundered part of Turkey, a northward collided of the African litospheric plate, or an upthrust block of neo-Tethyan seafloor. In this connection, several marine geological/ geophysical expeditions have been carried out in the region within the framework UNESCO/ TREDMAR (TTR) programme and ANAXIPROBE projects during 1991, 1995, 1996, 1997 and 1998. The excessive data of marine gravity, magnetics, high resolution seismic (25 Kjoules and as well as 200 cubic-inch sleeve gun with 500 m streamer). The seismo-acoustic surveys with the wide angle side-scan-sonar system, multi-beam swath mapping with the SIMRAD EM-12 system and the deep tow combined system of side-scan-sonar and subbotom profiler were collected during these marine expeditions. SIMRAD EM-12D is a low frequency (13 kHz) multibeam echosounder to make both high resolution bathymetric and reflectivity maps of the seafloor. It has full area coverage with a swath width up to 8 times of water depth.

The three principal mountains in the complex rise from depths 2000 to 2500 m to peaks at about 700 m (the southern mountain), 900 m (the eastern mountain), and 1200 m (the western mountain); but surrounding depths can reach more than 4000 m to the west (Rhodes basin) and 3000 m to the north (Finike basin). Each mountain in the group has a different from the others: the southern mountains is curved ridge of steeply dipping (about 25°) sedimentary strata, the western mountain is a north tilted (at about 40°) tabular block, and the eastern mountain comprises a broken NW-SE ridge on a broader plateau of rough relief. Seismic data do not indicate the apparent absence a typical M-reflector (representing either the top of the Messinian evaporates of its correlative erosional unconformity) implies that the basin formed since the Miocene.

Differential vertical movements are thought to be responsible both the elevation of the Anaximander Mountains and for the subsidence of the Finike and Antalya basins the north and northeast of the Anaximander Mountains respectively effects which seem to be connected with the development of the Hellenic arc in the case of Finike basin and with the development of the Cyprus arc in the case of the Antalya basin. Multibeam bathymetric data indicated five different geological provinces in the Anaximander Mountains area as: (i) the steep margin of southern Turkey with canyons, slums, and cross-slope faulting; (ii) the consistent Western mountain with a relative flat but northward dipping northern slope and steep southern escarpment, (iii) the relatively flat areas of the Finike basin and the region between the western and southern mountains; (iv) the rough and irregular eastern mountain; and (v) the irregular low relief of the region southwest of the mountains. A large tongue of sediment seems to extend over the basin from between the western and southern mountains. Gravity results indicate that there is a major crustal discontinuity running directly through the middle of the mountains and that the western peaks are under compensated crustal loads.

Seismic reflection data have demonstrated that the characteristic M-reflector at the top of the Messinian evaporites is absent on the mountains, although it appears around them, notably in the Antalya Basin, where it stops abruptly at the faulted eastern margin of the mountains. Instead of the evaporates, there is inferred to be an erosional surface truncating the layers of pre-Messinian rocks. This implies that the mountains already existed as positive relief by Messinian time. The western Anaximander Mountain is considered to have tilted north northwestward in post-Miocene time, with the Finike Basin forming in the subsiding northern trough between it and the Turkish margin. This mountain peak can, in fact, be treated as a rifted part of the onshore Mesozoic carbonate Bey Daglar? platform. The same thing could be said about the southern Anaximander Mountain peak, however it underwent a further rifting, and tilting associated with its neotectonic phase has proceeded much further than the western one.

The eastern Anaximander Mountain lies on the continuation of the Florence Rise from the southeast; but it is on the expected southward geological continuation of the Antalya Nappes complex to the north. There is three morphological subdivision of this mountain from the northwest to the southeast, each apparently separated by northeast-southwest-trending faults along which there are bathymetric changes. The northern part has the greatest relief and is dominated by a plateau region in the middle. Both the middle and northern sections share a linear northwest-southeast oriented faulted northeastern boundary. The southeastern section merges in the south with the Florence Rise, which joins it, a slight angle from the southeast

The MAK-1 deep-tow system was designed by the Yuzmorgeologiya Co. (the Russian Federation) to obtain acoustic images of both the seafloor surface (side scan sonar) and subbottom sediments (subbottom profiler). This system makes it possible to obtain acoustic images of seafloor surface with the side scan sonar system for a swath of up to 500 m per side in long range (LR) mode (30 kHz) and up to 200 m per side in high resolution (HR) mode (100 kHz). The subbottom profiler works at 5.5 kHz frequency.

The Amsterdam mud volcano is a large mud volcano, with the average diameter of about 6 km, as seen from the EM-12D reflectivity chart. MAK line was crossed at the northwest side of tis mud volcano. The surface of the mud volcano is a series of concentric ridges with a relief of the order of 10 m. This is shown well on the side scan sonar image which has a wide range of backscatter: high backscatter in general, probably as a result of the mud breccia erupted from the mud volcano, with shadow zones of low to no backscatter outlining the ridges. The profile shows no penetration, only many small strong diffractors near the seafloor, which is common for most active mud volcanoes because of the acoustic scattering caused by the mud breccia.

From the coring results, the mud volcanoes of San Remo, Kula, St. Ouen l'Aumone, Tuzlukus, Kazan, Amsterdam were discovered for the first time in the eastern Mediternean. The clasts from mud breccias provide important information about the composition of the deep-seated deposits and origin of the Anaximander Mountains. High gas saturation of the breccia, the presence of a large amount of shell fragments (remains of specific benthic communities in gas vent areas), and a live specimen indicate active venting through the deposits. Rock fragments that observed in mud breccia from these mud volcanoes were rather similar. Mainly limestones, sandstones, siltstones, claystones represented them, siliceous rock fragments, fragments of ancient mud breccia flows, and described as volcanic rocks. Undoubtedly, one of the most significant discoveries of this cruise consisted of a mud breccia core of the Kula mud volcano. Different sandstones, several types of cherts, limestones, clays and mudstones, represented sedimentary rock fragments obtained from the mud breccia. Besides, volcanic rock fragments, fragments of serpentine, and serpentinized peridotite were observed among the mud breccia clast implying that the Antalya Complex, or material derived from it, extend to the south from Turkey into the northeastern part of the Anaximander Mountains.

GEOLOGICAL STRUCTURE OF THE UPPER SEDIMENTS IN THE EASTERN PART OF THE MEDITERRANEAN RIDGE

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The Eastern Domain of the Mediterranean Ridge between Crete and the Libyan margin was studied during number of expeditions including TTR-3, TTR-5, and PRISMED-II cruises. PRISMED-II was designed to investigate major sedimentary and tectonic processes that compete to imprint and shape the seafloor of the Eastern Mediterranean. The survey was conducted aboard R/V *L'Atalante*, an 'Institut Francais de la Recherche pour l'Exploitation de la Mer' (IFREMER) ship. The wide area of the Mediterranean Ridge (250 km long and 200 km wide), located south of Crete island, was studied in detail using 6 channel seismic profiling and multibeam echosounder survey. The echosounder, beside the precise seafloor topography, also provided the information on the seafloor backscatering.

The Mediterranean Ridge is a relatively young accretionary complex that originated due to the convergent movements of the African lithosphere below the Eurasian one. The accretionary complex is very young and came into existence in the Late Miocene, slightly before the "Messinian salinity crisis" (Ivanov et al., 1996; Chaumillon et al., 1996). Its structure is characterised by complex relief and presence of numerous tectonic deformations.

Several morphostructural domains characterising the seafloor and subbottom of the Mediterranean Ridge were mapped and studied in detail: (1) African continental margin (Herodot Through); (2) strongly disturbed southern part of the ridge, forming outer deformation front; (3) the axial domain, with gentle seafloor surface and only small and subdued features; (4) northern part of the ridge, forming so-called backstop area; and (5) Cretan continental margin. Alterations in the deformation character as well as structures of the transitional zones between these domains and distribution of the Messinian evaporates within the sedimentary sequence were studied and described.

Mud volcanism is a widespread phenomenon on the accretionary prisms (Cita et al., 1989). Two mud volcano fields are known within the study area: Olimpi field and United Nation Rise. The seafloor bathymetry and backscatter pattern show that both these fields coincide to one and the same prolonged zone - the axial domain of the ridge. All mud volcanoes in this area could be divided into two main groups by their inner structures. The first one coincides with normal and reversed faults, whereas the second one - with strike-slip deformations.

South of Olimpi field there another belt was discovered, featuring a number of round-shape structures with high backscatter. These structures could also be connected with mud diapirism and mud volcanism.

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A PARADOX OF THE IONIAN SEA (CENTRAL MEDITERRANEAN): THE LATE MIOCENE-PLIOCENE SHALLOW-WATER BASIN UNDERLAIN BY MESOZOIC OCEANIC CRUST?

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The Ionian Sea in the central Mediterranean basin is considered to be a relic of the Mesozoic Tethys Ocean. Geophysical data testify to the oceanic nature of earth's crust underlying this basin. This is evidenced from vide-angle seismic experiments (De Voogd et al., 1992; Makris et al., 1995; Nicholich et al., 1995, and others). Bouguer gravity values are over +200 mG everywhere in the deep Ionian Basin (IBCM-G, 1989), and heat flow is low (averaging 40 mW/m^2), which is typical of oceanic basins with Mesozoic crust (Verzhbitskii, 1996). At the same time, some geological and shallow seismic data (DSDP and ODP drilling; Limonov et al., 1992; Hirschleber et al., 1994; Hieke et al., 1998, and others) show that the sea was not morphologically deep during the late Miocene - early Pliocene. Normally, in deep-water Mediterranean basins, thicknesses of Messinian and Plio - Quaternary deposits roughly correspond to the recent waterdepths of them. Concerning the Messinian evaporites, this fact is exlained by that these basins have been already deep before the evaporitic sedimentation (Ryan, 1976, 1978; Cita et al., 2000). The widely-adopted model of the Messinian evaporites formation (Hsu et al., 1978) impies that the thickest evaporites accumulated in the deepest basins. In relation to the Plio - Quaternary sediments, the correlation between their thickness and waterdepth is conditioned by relatively narrowness of sedimentary basins, in which sediments are capable of reaching their central deepest parts. However, in the deep Ionian Sea the corresponding deposits are 3-5 times thiner than in the deep-water basins of the Western and Eastern Mediterranean. This fact is in a strong contradiction with the presence of old oceanic crust below the Ionian Sea.

The contradiction can be eliminated taking into consideration the evolution of the central Mediterranean in the Middle Miocene - Quaternary. The subduction of the Ionian oceanic crust beneath the European one in the Calabrian subduction zone started at the end of the Middle Miocene (Finetti and Del Ben, 1986). This event was precoursed by very strong lateral compression in the whole central Mediterranean (Lentini et al., 1994) due to closure of the previously existed subduction zone in the area of Sicily and the recent Tyrrhenian Sea, where mountain thrust belts originated. This lateral compression could cause the shallowing of the Ionian Sea because of arching of its seafloor. The arching was accompanied by faulting and basic volcanism (Finetti, 1982). The subsequent subsidence of the basin floor to the recent depth occured during the second half of the Pliocene to Quaternary owing to lithosphere cooling and its accomodation to subduction mode.

GEOLOGICAL STRUCTURE OF THE PORTUGUESE MARGIN NEAR THE MARQUES DE POMBAL FAULT, ACCORDING TO SEISMIC DATA

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The geological structure of the Portuguese margin was studied during the first leg of the 10th cruise of R/V *Professor Logachev* within the framework of the TTR programme in 2000. The study area is located at the western Iberian margin between Setubal and St.Vicente canyons. The main objectives of the work were to investigate the Marques de Pombal Fault (MPF) and its possible prolongation to the north, as well as to study the deformation within the active fault zone and asociated sediment slumping. 470 km (10 lines) of single channel seismic profiles were collected in the area during the TTR-10 cruise. The maximum penetration of the seismic record obtained was approximately 1500 ms TWT. The basic processing graph consisted of spherical divergence corrections, band pass filtering and predictive deconvolution.

The seismic profiles, collected in this region allow to investigate upper part of the sedimentary sequence and slope instability process, associated with active tectonics in this area in more details.

As a result of the interpretation, three well imaged seismic units and acoustic basement were identified and described. The lowermost Unit 3, overlaying the acoustic basement, is a sequence that can be identified on the lines that locate on the southern part of the study area, its thickness varies from 350 ms to 750 ms here. This unit is also well imaged on NE part of the studied area on the slope that comes over in Estevao Gomes basin. In the NE its thickness varies from 200 ms to 600 ms TWT. Unit 3 is characterised by medium- to low-amplitude reflections. Most of the faults cutting Unit 3 are vertical and in most cases associate with local uplifts of the acoustic basement. Others are associated with deformation under compression.

The boundary between Units 3 and 2 is a low amplitude reflector. The thickness of Unit 2 varies from 300 ms to 900 ms, through the studied area. The unit can be well traced on all lines and is characterised by low-amplitude reflections. All faults that can be identified within this unit have vertical dipping. They are associated with recent uplifts of the acoustic basement and recent tectonic movements.

Unit 1 is characterised as rather thick sequence (max. 600 ms TWT), which is traced along all profiles and distinguished by its own acoustic features and dislocation. It is a sequence of strong high-amplitude reflectors that disappears in the places of high topography and becomes thicker in canyons. Only four faults disturb this sequence within the study area. Two of them associate with local uplifts of the acoustic basement which break trough all sedimentary sequence and expose on the seafloor. Other two faults are vertical and associated with recent tectonic movements. They also cut all identified sequences. Most probably this unit was deposited by turbidity currents.

There are two types of faults within the study area, different by their formation mechanism. The faults of the first type were formed due to the uplifts of the acoustic basement. Others were formed due to the tectonic deformation under compression. Also faults can be subdivided into two groups according the time of their formation. The faults of first group cut all sequences and are appeared to be very young. All of these faults are almost vertical. The faults of second group cut only Unit 3. Thus, the faults associated with tectonic deformation under compression in the area were formed either immediately after the lowermost unit had been deposited, or in the recent time, after the deposition of all of the units. This suggests that there were no large tectonic movements during the deposition period of the Unit 2. Therefore, the tectonic activity in the area, as reflected on the observed fault patterns, can be divided into two stages. The first stage terminated before the formation of Unit 2, while the second stage is supposed to be relatively recent, beginning after the deposition of all of the units. There are no evidences of a thrust faults plane dipping to the east. Most of the faults are interpreted as vertical movements, indicating reactivation under compression, associated with local uplifts of the acoustic basement. According to these results, the observed faults cannot be considered as a northward continuation of the Marques de Pombal fault on the studied area.

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TECTONIC CONTROLS ON THE DEPOSITIONAL AND EROSIONAL PROCESSES OFF WESTERN IBERIA

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Bathymetric, 9kHz long range OKEAN sidescan sonar, seismic reflection and 3.5 kHz profiler data are used to characterise the Cenozoic depositional processes in the Porto, Lisbon and Alentejo margins, offshore Portugal. Ten seismic units have been interpreted in the Alentejo margin whereas three seismic packages have been recognised in the Lisbon and Porto margins. They were dated using well, dredge and DSDP/ODP data. Seven types of acoustic echoes have been recognised on the 3.5 kHz profiler data obtained off Porto and Lisbon. The location of the studied regions in relation to the focuses of compression that affected Iberia in the late Cenozoic was a major controlling factor on their structural and depositional histories. Accommodation space and sediment pathways varied in relation to distinct uplift and subsidence pulses that occurred at different times, in different segments of the margin.

The relative proximity of the Alentejo margin to the Azores-Gibraltar Fault Zone resulted in folding and exposure during the middle Oligocene. Extensional collapse is recorded on the margin after the uppermost Oligocene. Paleogene subaerial exposure is absent in the Porto margin with compression in the Lisbon margin being overprinted by Neogene subsidence. In comparison with the Porto and Lisbon margins, relatively limited subsidence in Alentejo after the Tortonian produced a gentle westerly-tilting margin. In contrast, the Porto and Lisbon margins record important subsidence since then with gravitational processes dictating deposition on the continental slope and rise. Seamounts, halokinetic structures and fault-bounded sub-basins controlled the sediment distribution on the Porto margin.

Incision of the present submarine canyons can be dated as post early Pliocene, but evidence of early-Neogene channel incision in the Alentejo margin can be taken from the seismic data. This may be related with the proximity of the margin to the late Paleogene and Betic compressional fronts since the Setubal and Sao Vicente submarine canyons are coincident with highly deformed regions. The submarine canyons had an important control on the margin's depositional processes after the Paleogene, transporting sediment derived from the shelf and major onshore drainage catchments directly into the abyssal domains off Iberia. Gravitational events (mass-wasting, slides and turbidity-flows) and erosional processes (e.g. slope erosion, gullies) are presently predominant over the Porto and Lisbon continental slopes as revealed on the OKEAN and 3.5 kHz-profiler mosaics.

THE THERMAL REGIME OF THE CRUST OF THE BLACK SEA

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Investigations of the heat regime of the crust for the water area of the Black Sea attract the interest of scientists. The reason is that the description and interpretation of inhomogeneity of heat fields, characteristic of the different tectonic structures and transition zones from the slope to sea basins, may potentially bring the clue to a number of geological problems. Among these problems are the mechanism of origin of the Black Sea depression, verification of location of tectonic faults and fractures, prediction of submarine occurrences of oil and gas, etc. The geothermal field affects significantly the distribution of gas hydrates in the sedimentary cover. Thus, reconstruction of the regional and local geothermal field and their analysis can be used for prediction of potential gas hydrate accumulations.

In this paper the results of calculations of the deep temperature in the crust of the Black Sea are given. In consequence, the temperature distribution has been determined for sedimentary basement, surfaces of Conrad and Moho, for the stationary heat model of the crust.

The crust of the Black Sea has an intermediate structure between the oceanic and the continental crust models. The heat flow is distributed unevenly in the area of the sea and varies in rather broad range of 8.4-100 mW/m^2. The large heat flow variations can be explained by contrast effect of the heat conductivity on the rather close distances. The corrected values of heat flows have been used for calculation of temperature. Correction for the central part of the Black Sea caused by effect of sedimentation is estimated at 50%, and for peripheral parts at 15%.

The obtained results are given as maps of the temperature distribution for the sedimentary basement, surfaces of Conrad and Moho. Temperature calculations have been done for the points where the data of heat flow are known. The temperature varies irregularly on all the three surfaces. This can be explained by variation of heat flow and thickness of layers. Some relationships are observed on the background of these variations of the temperature field. Several temperature zones are distinguished on each border - 10 zones on the sedimentary cover, 14 zones on surfaces of Conrad and Moho.

The range of temperature variation on the sedimentary basement is of 100-250°C.There are two local zones in the central part of area where temperature attains 450°C and 600°C. Existence of such high temperature in sedimentary cover can be explained by big thickness of layer and high heat flow in these places.

The Conrad surface temperature lies in a broad interval of 100-750°C. The general temperature background is 100-200°C there. There are increased temperature zones in the Southern and the Northern parts of central area. The hot local zone (450-750°C) is in the south-east, which borders the Ajarian coast.

Temperature background is 250-350°C on Moho surface in the Western and the Eastern parts of area. The local zone of very high temperature (1800-2000°C) is observed in the south-eastern part, which borders the Ajarian coast. This zone is characterised by high and maximum heat flow (76-100) mw/m^2.

There are several hot local zones in the central part of area as well. In one of them temperature attains the values of 1600-1750°C.

As a result as the analysis of crustal thermal field of the area of the Black Sea, in the south-eastern and central parts of area the existence of the large thermal elastic stress on the basement of the crust due to the high horizontal temperature gradients is expected. This must be taken into consideration while estimating the seismology of this region.

Diapirism, mud volcanism, and hydrocarbon potential of deep sedimentary basins

LITHOLOGY OF DEEP-SEA MUD VOLCANIC DEPOSITS: GENERAL ASSESSMENT OF CURRENT KNOWLEDGE AND FUTURE RESEARCH NEEDS

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For the last 10 years the phenomenon of deep-sea mud volcanism has been a focus of research by the UNESCO "Training through Research" (TTR) programme. A number of mud volcanoes have been studied in detail within previously known mud volcanic fields, and numerous new mud volcanic structures have been discovered around deep-sea European margins during very successful TTR cruises in 1991, 1993, 1994, 1995, 1996, 1997, 1998, 1999, and 2000 (Geological.., 1992; Ivanov et al., 1996; Kenyon et al., 1999; Limonov et al., 1994; Limonov et al., 1995; Multidisciplinary.., 2000; Woodside et al., 1997). An extensive data base has been built up of marine mud volcanic deposits and large amount of analytical work has been done on their lithology during the past decade. At this point we believe it is useful to analyze what we have learned, to determine what we have missed, and to define what needs to be done in the future.

Among the numerous questions related to the geological phenomenon of deep-sea mud volcanic processes, many can be answered by studying the lithology of mud volcanic deposits. At least three main aspects of this study are: (1) mud volcanism and sedimentation; (2) mechanisms of mud volcanic processes; (3) mud volcanic deposits as an opportunity to investigate deeply buried strata. Although each aspect requires a different approach, they are all interrelated.

Mud volcanism and sedimentation

The role of mud volcanism in the framework of global sedimentation and its forms in terms of depositional processes probably started being discussed from the first geological discovery of deep-sea mud volcanoes. Several interlinked tasks are important:

(a) Recent mud volcanic deposits have to be described in detail and their lithological types classified according to their main compositional, textural, structural, and fabric peculiarities.

(b) Each lithological type of mud volcanic deposit has to be clearly explained in terms of depositional processes and inferred environments.

(c) Post-sedimentary processes in mud volcanic deposits have to be studied and their sequence and effects have to be determined.

(d) Then, we have to use the results to recognize ancient analogues of mud volcanic deposits and their extent and volume have to be estimated.

Several important attempts have been made at tasks (a) and (b) to identify lithological types of mud volcanic deposits. Staffini and colleagues made macroscopic descriptions of six typical examples of the Eastern Mediterranean mud breccia (Staffini et al., 1993), following Cita et al. (1980) and Camerlenghi et al. (1992), who proposed to use "mud breccia" as a descriptive term for the facies of abundant, pluricentimetric, subrounded to angular clasts embedded in dark grey silty clayey matrix. Six lithological types of mud breccia, three massive and structureless and three displaying various structures, were characterized in detail and are still in use by sedimentologists. Unfortunately only a very general interpretation of differences in lithology was made in terms of mud breccia origin. Staffini et al. (1993) concluded that massive texture types are indicative of successive undisturbed deposits of mud breccia and organized types are probably suggestive of reworking processes (debris flows or turbiditic events) following the extrusion of material from mud volcanoes.

The study of the material collected during the ODP cruise to the Olimpi mud volcanic area in the Eastern Mediterranean (Emeis et al., 1996) led to the appearance of several identification schemes of mud volcanic deposits by lithological types in various publications. Based on the primary observations on cores, mud breccia types were determined onboard as pebbly muds, polymictic gravels, or matrix-supported mud debris flow deposits (Emeis et al., 1996), and peculiarities of their lithology were described. A general fining-upward trend in mud breccia was noted, suggesting an energetic initial intense eruption and moderate, episodic activity thereafter, but only very general explanation of differences in lithology was made in terms of depositional processes.

Akhmanov and Woodside (1998) performed microscopic investigation of ODP mud breccia samples in thin sections. On the base of microstructural and microtextural characteristics of mud breccia, three main types were recognized and interpretation of peculiarities of genesis of each type were made. Poorly sorted, massive, matrix supported "ordinary" mud breccia was ascribed to the inner parts of mud flows; well-sorted, massive "organized" mud breccia, to upper and lower parts of mud flows; and graded, clast-supported "redeposited" mud breccia, to local gravity flows from crater or upper slope of mud volcanic edifices. In this classification each lithological type of mud volcanic deposit was attributed to different depositional processes. However the classification itself can not be considered as detailed enough.

Very detailed grain-size analyses carried out by V. Kroupskaia et al. (2001) allowed to distinguish several facies of mud volcanic deposits of the Haakon Mosby mud volcano in the Barents Sea. Different granulometric parameters were explained by differences in genesis and emplacement of the deposits. Unfortunately in this scheme, apart from grain size characteristics, much less attention is paid to structures of the deposits, which can be important for better understanding of depositional processes.

None of the classification schemes proposed for mud volcanic deposits and discussed above is universal, but all of them have rational and reasonable arguments. *Elaboration of a universal lithological and genetic classification of recent mud volcanic deposits might be an interesting research target related to further scientific needs. Furthermore, such classification can be taken as a basis for compiling a worldwide database of mud volcanic deposits.*

Regarding task (c), post-sedimentary processes in mud volcanic deposits are still little studied. Only early diagenetic processes have been discussed in some papers (Ridd, 1970; Neurauter and Roberts, 1994; Belenkaia, 1997; Aloisi et al., 2000), where all diagenetic processes were considered in relationship to intensive gas seepage and subbottom fluid migration. Only a few words about common post sedimentary processes in mud breccia can be found in the works of Roberstson and Kopf (1998) and Akhmanov and Woodside (1998) who published results of studies of ODP samples, reporting mainly scant evidences of burial diagenesis in mud volcanic deposits. *However these publications have shown the interest of scientists in the problem, and we hope that this research will be continued in the future.*

Considering task (d), mud volcanoes supply a large amount of sedimentary material to the Earth surface and probably play a significant role in global sedimentation. In papers where recent mud volcanism is discussed, we can find rough estimations of the volume of material erupted by individual mud volcanoes or by entire mud volcanic fields (Yakubov et al., 1971; Shnukov et al., 1986; Langseth et al., 1988; Prior et al., 1989; Guliev, 1992; Akhmanov and Limonov, 1999; Graue, 2000). The estimates vary from 0.5 to 11.5 km^3 for a single mud volcano and from 40 to 250 km^3 for a mud volcanic region, implying a considerable contribution of mud volcanic material among recently formed deposits. That also implies that we can expect large scale representation of mud volcanic deposits in the geological record. However, up until now, only rare and mainly presumptive mention of ancient mud volcanism and the evidence for it in the geological record has been made in literature. Ancient analogues of the Black Sea mud volcanic deposits were inferred within sedimentary series from the Middle Proterozoic by Slack et al., (1998). Lovell (1974) reported finding of mud volcanic deposits within the Silurian rocks. A Cambro-Ordovician mud volcano has been mentioned in a paper by Zimmermann and Amstutz (1972). Cretaceous mud volcanic deposits are known in Azerbaijan (Yakubov et al., 1971), and buried mud breccia has been studied in the Kerch peninsula in eastern Crimea. Moreover, some authors believe that some melanges in ancient accretionary complexes have been formed by mud volcano activities (Barber et al., 1986; Barber and Brown, 1988). Relatively recently benthic foraminifera characteristic of gas seeps and cold vents on marine mud volcanoes have been identified, indicating a potential way of identifying mud volcanoes in the geological record. These benthic foraminifera (Sen Gupta et al., 1994; 1997; Rathburn et al., 2000; Panieri et al., 2000) build carbonate tests, which will be depleted in carbon-13 relative to carbon-12 when the mud volcanoes are driven by biogenic methane. Other methods of recognizing and studying cold seeps in the geological record are now being developed (Cavagna et al., 2000; Barbieri et al., 2000).

In general, mud volcanic deposits are still considered exotic by a majority of geologists. This prejudice, and the absence of clear and unambiguous criteria to help in recognizing mud volcanic deposits within ancient sequences, may cause important information to be overlooked during geological mapping and researches. In this regard, the most important lithological peculiarities and morphological characteristics of geological bodies formed by mud volcanic deposits have been discussed in the paper of Akhmanov and Limonov (1999), who have made an attempt to work out a key for recognition of mud volcanism in the geological record. However, *further systematisation of current knowledge is needed in order to learn how to recognize ancient analogues of mud volcanic deposits. Then their extent and volume can be estimated.*

Mechanisms of mud volcanic processes

Several particular topics for lithological investigation of mud volcanic deposits were raised recently. They are extremely important for picturing different processes related to mud volcanism. Among them are the following:

(a) Processes of formation of matrix of mud volcanic deposits have to be described;

(b) Differences (or similarities) in the lithology of mud volcanic deposits within the same mud volcanic edifice have to be explained.

Processes of formation of matrix of mud volcanic deposits (a) have been discussed in several papers. Most of the papers provide the results of lithological, petrological, and geochemical investigation of mud breccia from well-studied areas of the Eastern Mediterranean, discussed in the context of regional geology, and they are mainly focussed on the very important question of sources for the matrix. M.B. Cita and colleagues suggested that the matrix material was derived from very deep overpressured shales within the sedimentary succession, and proposed to estimate the age of these shales according to the oldest fossils found in the matrix (Cita et al., 1980). Studying the organic material in the mud breccia, Shultz et al. (1997) indicated that several sources were required to form the mud breccia matrix, suggesting Messinian strata as the major one. De Lange and Brumsack (1998) favoured the matrix formation model of remobilisation of compacted mud, exploiting water from gas hydrate decomposition. In the model of Akhmanov and Woodside (1998), mud breccia matrix formation is believed to begin at the depth of the source formation. A plastic, mostly clayey, sedimentary series is forced up to the seafloor under excess pressure. During its upward migration through overlying deposits, it mechanically assimilates fragments of rocks that surround the conduit to the seafloor. These fragments can be disintegrated, at least partially, and become incorporated in the matrix. Composition of the mud breccia matrix is changed in time by assimilation of material from the clasts. Mud breccia development continues after deposition on the seafloor where chemical alteration causes further disaggregation of clasts. According to their behavior in the matrix, mud breccia clasts were classified within a series from the least to the most stable (Akhmanov and Woodside, 1998).

All these four main hypotheses were recently discussed and criticized in the paper of Kopf and colleagues (Kopf et al., 2000), where they also provided their own model mainly based on the geochemical study of organic matter from mud volcanic deposits collected in 1995 during ODP Leg160. Unfortunately, their model has also left *the question of matrix formation of mud volcanic deposits still open for the Eastern Mediterranean as well as for other areas of active mud volcanism. Further* *precise lithological investigation of the mud volcanic material may shed some light on this problem and help significantly in our understanding of mechanism of mud volcanism entirely.*

Under (b), the evolution of a particular mud volcanic structure or even an entire area can say a lot about mechanisms of mud volcanism as well. This evolution can be deduced by studying and explaining differences in lithology of mud volcanic deposits deposited in different periods within the same mud volcanic edifice. Such research has been carried out for several onshore mud volcanoes and has produced interesting results. An opportunity to investigate deep-sea mud volcanoes in this way was obtained only once when the Olimpi mud volcanic area of the Eastern Mediterranean was drilled during the ODP Leg 160. Studying samples of mud volcanic deposits from different intervals down ODP bore holes of up to 200 m depth, Akhmanov and Woodside (1998) concluded that the lack of significant differences in the composition of mud breccia from different stratigraphic intervals since at least late Pliocene suggests that source series for mud breccia have not changed for 1.5 million years (Akhmanov and Woodside, 1998). Is it a typical or an exceptional situation? That is still an open question. Thus, *the presence or absence of differences in mud volcanic material erupted within the same edifice at different times can become an interesting topic for further lithological investigation.*

Mud volcanic deposits as an opportunity to investigate deeply buried strata

One of the most intriguing peculiarities in lithological investigation of deep-sea mud volcanic deposits is that the mud breccia erupted on the surface provides very important information on the composition of the deeply buried sedimentary succession through which the mud volcano erupted. Thus, mud volcanoes act as free drilling sites, providing an opportunity for direct geological observation and the study of samples of rocks situated at depths of several kilometres. Such a lithological investigation was performed on the mud breccia samples from the three most studied mud volcanic areas of the Mediterranean Ridge, following a special scheme of lithogenetic study, which was carefully worked out step by step during the investigation. This mud breccia study led to the reconstruction of sedimentary sequences assumed to have been broken up by mud volcano eruptions in these areas (Akhmanov, 1996; Akhmanov, 1999; Akhmanov et al, submitted). Similar researches on deposits of recently discovered mud volcanoes in the Western Mediterranean and in the Gulf of Cadiz are in progress now and their first results are presented elsewhere in this volume.

The lithological studies of mud volcanic deposits described here were relatively successful in reconstructing the sedimentary succession of the eastern Mediterranean above the source formations of the mud volcanoes. However, the methodology used in these studies can not be applied to regions with little contrast between sedimentary successions (e.g. the Black Sea, Norwegian margin). In these areas the variety of lithologies among mud breccia clasts is significantly less, and thus reconstruction can not be detailed enough. *Elaboration of a universal methodology for the lithogenetic study of mud volcanic deposits with the aim of reconstruction of deeply buried strata also requires further research.*

Concluding the discussion on subjects for further lithological research in the field of mud volcanism investigations, it is important to emphasize that *many aspects in the lithological study of mud volcanic deposits have been completed already, and that we have built up an impressive data set together with a number of new research questions.*

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GEOCHEMICAL CHARACTERISTICS OF ORGANIC MATTER IN ROCK CLASTS FROM MUD VOLCANO BRECCIA (THE GULF OF CADIZ)

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The Gulf of Cadiz is large area of mud volcanic activity. During the 9 and 10 "Training-Through-Research" expedition, several mud volcanoes were discovered in the Portuguese, Spanish and Moroccian margins of the Gulf of Cadiz. The main objective of this geochemical investigation is to study the quality, quantity and maturity of organic matter in the rock clasts, separated from the mud breccia matrix. Samples used for investigations were collected from the different mud volcano: Bonjardim, Rabat, Ginsburg, Yuma and other.

First of all rock fragments from the mud breccia were collected, washed and described. Rock-Eval pyrolysis was used for the definition of the type and maturity of organic matter from the collection of more than 100 samples. The organic-richest samples, showinghigh hydrogen index values, were selected for detailed geochemical investigation, including (1) gas-chromatography analysis of the extractable organic matter (GC), (2) gas-chromatography - mass-spectrometry (GC-MS), (3) Al_2O_3 column chromatography, (4) Rock-Eval pyrolysis for the kerogen, (5) infrared spectrometry (FTIR), (6) Curie point pyrolysis-gas chromatography-mass spectrometry (CuPy-GC-MS) and (7) elemental analysis (Durand, 1980).

According to the pyrolysis data most of the samples are characterised by low and very low organic carbon content. Total organic carbon content is up to 0.33 %. In the HI-Tmax diagram all plots are in the area largely below the Tmax threshold of 435°C assigning an immature stage or the beginning of the oil window. The origin of organic matter is mainly of type II according to relatively high HI values, few samples are very closed to type III and type I organic matter's areas. Several samples have relatively high total organic carbon content from 1 to 7 %. All those samples belong to immature stage of type II of organic matter area.

The richest in organic carbon content samples show the good and excellent potential to produce gas and oil. The n-alkanes distribution indicates a predominantly marine origin for the organic matter with low terrigenous input (Philp, 1985). The dominance of even numbered alkanes argues for an anoxic environment. The pristane/phytane ratio is more than 1 also indicates oxygen-deficient condition, peak of norpristane is showing relatively low maturation of organic matter. There are phenols, benzenes and naphtalenes, which indicate microalgae input.

The richest in organic carbon content samples may characterize oil/gas source rocks in this area. Most of the samples, which were found in the mud breccia, belong to immature stage and have poor potential. They can indicate sedimentary sequence below an oil/gas reservoir.

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LITHOLOGY OF ROCK CLASTS FROM MUD BRECCIA OF THE BONJARDIM MUD VOLCANO (GULF OF CADIZ, NE ATLANTIC)

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In June-July 1999, during the TTR-9 cruise of R/V *Professor Logachev*, new mud volcanoes were discovered in the Gulf of Cadiz (NE Atlantic). Six new mud volcanoes were discovered and investigated during TTR-10 cruise, 2000.

One of discovered mud volcanoes was named Bonjardim. Three cores were taken from this structure and contain mud volcanic deposits (mud breccia).

Mud breccia provides an important information about the composition and genesis of deep-seated strata. It consist of matrix and clasts of deeply buried rocks extruded the sea bottom surface during mud volcanic activity. It was determined, that mud breccia clasts are the most informative for investigation (Akhmanov and Woodside, 1998).

The material was studied according to the method of study of rock clasts from mud breccia, which were elaborated in UNESCO - MSU Centre for marine geology and geophysics. This method was successfully used by G.G. Akhmanov (2000) for the Mediterranean Ridge mud volcanoes, basing on the material collected in several TTR cruises.

Based on the macroscopic and lithological description with binocular rock clasts were subdivided into groups. The most important lithological peculiarities during description are following: composition, colour, structure and texture. Study in thin sections under polarising microscope allowed the definition of 12 main groups. The genetic indicators of studied rocks suggest deep-sea environment during their accumulation. Rocks of similar lithology and deposited in the same environment were grouped in sedimentary units. On the base of lithological investigation and micropaleontological study the reconstruction of the sedimentary succession broken up by Bonjardim mud volcano was made.

The rock clasts are mainly represented by limestone (29%), claystone (29%), mudstone (23%), sandstone (10%), marlstone (6%) and siltstone (3%). These rocks vary in age from the Upper Cretaceous (Santonian) - Pliocene.

The Upper Cretaceous rocks are presented by bitumen claystone. Fragments of interbedding of claystone with crystalline limestone and laminated claystone of possibly turbiditic genesis, which could be deposited at the continental slope, were formed during Upper Cretaceous. Sandstone of deep-sea fan were formed in the Gulf of Cadiz also during Upper Cretaceous.

The lack of clasts, which can be date as Paleocene and Oligocene can be explained in the following way: either this deposits were disintegrated in matrix or the regression and tectonic rising were predominant in this area during that time.

The Eocene rocks are represented by hemipelagic micrite and micrite with reworked foraminiferae. Eocene deposits of turbiditic genesis are presented by claystone and polymictic sandstone with carbonate cement.

The oligomictic sandstone of deltaic genesis and marlstone, which was formed in open warm shallow basin, were deposits during the Early Miocene.

Deposits, which age was defined as Middle Miocene, are represented by polymictic sandstone with carbonate cement, which genesis was interpreted as fan deposits, pelagic claystone with admixture of pyrite and hemipelagic foraminiferal limestone.

The Upper Miocene is only represented by marlstone. The position in the sequences and the genesis of some slumped units is disputable. The data introduced above complement some additional light on the history of the Gulf of Cadiz.

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METHODOLOGY CONCERNING THE GEOCHEMICAL STUDY OF MUD VOLCANOES: FROM THE ONSHORE TO THE DEEP-WATER MARGINS

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Mud volcanoes in deep offshore act as prospecting indices in the exploration of oil and gas deposits. But the occurrence of mud volcanoes is not directly linked with the occurrence of a good petroleum system. A methology and an analytical protocol have been developped in order to evaluate the potential of the petroleum system beneath.

The methology concerning the geochemical sampling and analysis of the mud volcanoes located onshore has been applied in different areas such as Trinidad, Sicily, Kerch peninsula and Azerbaidjan.

Each kind of constituents can bring information: gas, mud, boulders.

Technics of sampling have been modified after the first analyses. In the mouth of the gryphons the influence of the density and the importance of the evaporation - and or dilution by the rain depending of the climatic area - can affect the representativity of the mud samples. Specific tools have been built. They allow us to take samples of mud up to 20 metres deep.

Onshore each sample picked up by the the geologists is chosen due to its quality; there is no random sampling ; where and how to take them is the most important question.

On the contrary in deep oceanic basins the random sampling is up to now the rule when people take core material. The poor quality of such material for geochemical studies is obvious. Methodology of sampling has a direct influence on the results and consequently on the interpretation of the data.

To recognize first, and to reach afterwards, the mouth of the gryphons under 2000 metres of water or more is the challenge that we must view for the future exploration of mud volcanoes in the deep oceanic basins. They will require specific maritime means, only available in the scope of multi-partnership collaboration.

SCALE ESTIMATION OF MUD VOLCANO DISCHARGE USING MEASURED TEMPERATURE DATA

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Gas hydrate accumulations associated with submarine mud volcanoes are known in many areas of the Ocean. The gas hydrate accumulation in the submarine mud volcano Haakon Mosby is the most extensively studied, including geothermal measurements. This accumulation has an axial-symmetric structure and is controlled by shape and size of the mud volcano. The formation of the accumulation is conditioned by ascending fluid flow that is the main source of hydrate-forming gas and water (Ginsburg et al., 1999). The measurements by geothermal probe suggest that geothermal gradients in the immediate subbottom sediments decrease with increasing distance from the mud volcano. In the central part of the mud volcano, the gradients were too high to be measured in-situ, but the onboard core temperature data suggest the extension of this relationship up to the centre. As it is inferred from core measurements, this gradient near the seafloor at the volcano centre may reach 30°C/m. The revealed temperature distribution can be explained by a model of steady-state filtration of mud fluids. Seismic records and chemical data of pore water from ODP Site 986 suggest that the source of the mud and fluid may be about 3 km depth (Hjelstuen et al., 1999). The temperature on this depth reach up to 90°C and the heat flow in the centre of mud volcano near the sea-floor accounts for $3*104 mW/m^2$. In this case the rate of fluid rise can accounts for 2.5 m/year. Based on this assumption the steady-state model of the temperature field and gas hydrate stability zone was calculated.

In addition we propose a non steady-state discharge of warm mud that spread over the seafloor and eventually flowing down-slope from the mud volcano centre. This is evidenced from temperature relationship on depth, observed in the cores from the central part of the mud volcano. Similar sheet-flows of mud and temperature features of sediments have been observed in the Gulf of Mexico (MacDonald et al., 2000). Our investigation has shown that the time of cooling of warm mud layer with thickness of 4 m can reach 30 days for an assumed temperature of 20°C of the warm mud. In this case, the vertical extend of the influence of this transient heat pulse on the underlying sequence can be close to 10 m. It means that the boundary of gas hydrate stability zone will be changed. Our results suggest that time-dependence of mud discharge should be considered when geothermal modelling of mud volcanoes is used.

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NUMERICAL MODELING OF MUD VOLCANOES AND THEIR FLOWS USING CONSTRAINTS FROM THE GULF OF CADIZ

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Mud volcanoes, ranging in size between 50 cm and 800 m high, are found both on land and in submarine environments. Their variation in height and shape reflects the driving forces building the volcanoes and the physical properties of their materials. The driving force behind the construction of mud volcanoes is overpressure of fluidised mud reservoirs at depth. Although some component of overpressure may derive from volatile generation in the reservoir, a major parameter is the thickness of the sediment pile. The maximum height attained by mud volcanoes is, therefore, mainly a function of the density contrast between the fluidised mud and the lithostatic pressure provided by the sedimentary overburden. Using a model of isostatic compensation between the mud 'lava' and the sediment pile, we are able to predict the depth of fluidised mud reservoirs beneath mud volcanoes. This model also predicts that the shape of mud volcanoes progress from cones or domes to flat-topped structures as they approach and pass their maximum heights of construction. We further predict that the eruption of fluidised mud from a reservoir at depth should lead to a subsidence basin surrounding a mud volcano. However, we often find the volume of these basins is greater than the volcano indicating volatile loss, from the fluidised mud during eruption, in the form of water or gas.

Using a viscous-gravity current model to describe the eruption of mud flows, we demonstrate that mud volcanoes are most probably composed of multiple, discrete flows. Our model predicts that the lowermost oldest flows are have the greatest radius and the flows in the centre are the youngest. These predictions are supported by observations of submarine mud volcanoes that show concentric ring structures with progressive obscurity of rings from the centre towards the margin of each volcano. The inner rings are sharply defined while the outer rings appear smoothed and partially buried by pelagic sediment. This model is in contrast to more traditional models of strataform volcano construction where younger flows progressively bury older ones and travel the furthest.

Using data for mud volcanoes obtained from the Gulf of Cadiz and the Moroccan Margin (J. Gardner, pers. comm.), our models gives quantitative estimates of flow rates, exit velocities, eruption durations, heights and conduit radii. Assuming the concentric, circular structures observed on side-scan sonar images represent separate flows, individual flow heights are found to be between 1.3 m and 1.6 m. Using a viscous-gravity current model, eruption rates are calculated to be between 10 and 20 m^3s^{-1} requiring between 5 and 12 hrs to reach a radii of ~500 m from the central conduit. For a flow rate of 10 m^3s^{-1}, the volcano conduit radius is 1.4 m, giving an exit velocity for the fluidised mud of 1.6 ms^{-1}.

NAUTILE OBSERVATIONS OF EASTERN MEDITERRANEAN MUD VOLCANOES AND GAS SEEPS - RESULTS FROM THE MEDINAUT AND MEDINETH PROJECTS

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Intense venting of methane occurs not only at Mediterranean mud volcanoes but also at seeps along related fault systems according to the first submersible observations of these phenomena in a Mediterranean setting. Carbonate pavements up to several tens of centimeters thick and a varied benthic fauna with symbiotic bacteria are associated with the fluid emissions.

Continuing deformation by mud from below creates a landscape with large crevasses and graben structures several meters wide in mud flows forming the summit of the mud volcanoes. From the submersible, the summit of the Napoli mud volcano appears to form a vast salt marsh where brines, emitted by numerous small vents, have accumulated in shallow depressions on the seafloor. Brine accumulations were also discovered outside of the volcanoes, in the Nadir Brine Lakes, where hypersaline fluids have migrated to the seafloor along deep faults. These brines are also rich in methane (133 ml/l in Nadir Brine Lake) and are thus an important carrier of dissolved gas to the seafloor.

THE BITUMINOUS CHARACTERISTIC OF MZ - KZ SEDIMENTS FROM TAMAN PENINSULA

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The Taman peninsula is located in the south - east part of Russia and it is bounded by the Azov sea on the north, by the Kerch Strait on the south and west, and by the Caucasin belts on the east. The Taman peninsula corresponds to the Azov - Taman oil and gas basin.

The first investigations in this basin were made in the middle of the XIX Century. This basin is tectonically placed in the south - east part of the Indolo-Cuban Trough, which has been formed by active subsidense from the Oligocene - Miocene till now. This tectonic elements is characterized by flexuring, in some place trough by mud volcanoes and diapiric folds. The basin is filled with the Mesozoic and Cenozoic deposits. The sediments are represented by sandstones, limestones, siltstones, marlstones and claystones. The total thickness is approximately 5 km.

The main purpose of the present work is an investigation of the bituminous characteristic of Mesozoic and Cenozoic rocks. For this investigation the samples were taken by onshore exploration drilling sites. The bituminous characteristics were studied using luminescent analysis. The bitumen can be divided into for groups - asphaltenes (solid hydrocarbons), petroleum bitumen (liquid hydrocarbons), and gas hydrocarbons (heavy hydrocarbons). The liquid and heavy hydrocarbons can migrate into overlying horizons. The Cretaceous sediments are represented by marlstones, siltstones, limestones and sandstones. The bitumen is represented by heavy hydrocarbons. The Paleocene and Eocene deposits consist of claystones, siltstones and sandstones. These rocks are also characterized by higher values of hydrocarbons, which are represented by heavy and liquid hydrocarbons. The samples of Oligocene - early Miocene are represented by claystones. The bituminous part consists of solid hydrocarbons, liquid hydrocarbons and heavy hydrocarbons. These rocks characterized by higher values of liquid and heavy hydrocarbons. The Neogene deposits are composed mainly of marlstones and sandstones. These rocks are also characterized by higher values of liquid hydrocarbons.

The results of the Mz - Kz sediments study suggest that all structure sections saturated by hydrocarbons and hydrocarbon generation are present till now. The formation of the pools takes place in overlying horizons of the structure section. Therefore, hydrocarbon pools associated with reservoirs, which are placed in the diapiric folds, and border parts of this structure can be considered as potential traps for hydrocarbons. The oil and gas contents can be associated with Miocene-Pliocene rocks.

STRUCTURAL AND TECTONIC CONTROL OF FLUID SEEPS AND MUD VOLCANOES IN THE GULF OF CADIZ.

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The Betic-Rifian is the westernmost tectonic belt of the Alpine-Mediterranean compression zone, in which south to north thrusting has over-ridden attenuated and thinned passive margins of Morocco and Iberian. In the Gulf of Cadiz, the front of the Betic-Rifian is constituted by several tecto-sedimentary complexes composed by a chaotic mixture of Triassic, Cretaceous, Paleogene and Neogene sedimentary units, overlying a Palaeozoic basement, and characterised by a giant mass movement traditionally named as "Olistostrome" involving a huge volume of shale and salt diapiris m (Maldonado et al., 1999). They extended from the shelf of the Spanish and Moroccan margins towards the Horseshoe and Seine abyssal plains, west of the Gibraltar Arc, with thickness exceeding 4 km. Alongslope, gravity spreading and sliding of these mobile shales and salt stocks along the Gulf of Cadiz, provide avenues to fluid expulsion including brines, oil, gases and fine sediment to the continental slope surface. These fluid venting structures have been investigated during the TTR-9 and TTR-10 cruises of the UNESCO-IOC TTR programme and during the Tasyo-2000 and Anastasya-2000 cruises of the TASYO project.

The cruise TTR-9 (1999) aboard R/V *Professor Logachev*, using OKEAN high-range and ORETECH high-resolution side-scan sonars, discovered and sampled two fields of gas-related venting with mud volcanoes in the Moroccan margin (named as Yuma, Ginsburg, Kidd, Adamastor) and Spanish-Portuguese area (named as San Petesburgh). Gas-hydrate samples and carbonate crusts were also collected (Ivanov et al., 2000). In May 2000, the Tasyo-2000 cruise aboard of the R/V *Hesperides* results in the discovery of a new area, the TASYO Field, of extensive deep fluid flux through the sea floor on the slope of the Gulf of Cadiz. The area surveyed with Simrad EM-12S multibeam echosound and ultra high-resolution seismic (TOPAS parametric echosound) resulted in three unexpected results: the probable presence of a number of mud volcanoes, the presence of numerous large pockmark craters, and of the remarkable features resembling scars of a large sediment slide migrating towards the Horseshoe abyssal plain. During the TTR-10, 2000 July, aboard R/V *Professor Logachev* were surveyed several mounds structures which allow to discovery some mud volcanoes in the lower slope of the Portuguese margin (Bonjardim and Ribeiro mud volcanoes). In the Moroccan margin, close to previously surveyed TTR-9 and Tasyo-2000 cruises, were collected mud breccia and carbonate slabs from new structures named as Rabat, Olenin, Baraza and Tasyo mud volcanoes. In September 2000, during the Anastasya-2000 cruise aboard R/V *Cornide de Saavedra* were surveyed several mound structures in the Spanish-Portuguese margins, collecting from gravity cores and dredges, samples of mud breccia, carbonate crusts and dolomite chimneys from several mud volcanoes in the TASYO field (named as Hesperides, Faro, Cibeles, Almazan) and close to the Guadalquivir Bank (named as Cornide, Iberico, Gades, Anastasya, Tarsis and Pipoca), ranging from 1200 m to 500 m deep.

Deformations structures observed on migrated multifold and medium to high-resolution seismic lines (Air-gun, Sparker, Geopulse and 3.5 kHz) that run along the shelf and slopes of the Gulf of Cadiz provide geometric evidence for shale/salt tectonics and related seepages on the sea floor. On the shelf, extensional faults are formed by basinward traslation the salt/shale and its overburden with associated subsidence of minibasins, and consist dominantly of listric growth faults that dip basinward and sole out into a salt weld. Basinward traslation of the shelf sequence is balanced by salt/shale extrusion and families of contractional faults on the upper slope, mainly basinward-vergent thrusts that ramp from a salt decollement. Salt bodies along toe-thrusts closed to (primary and/or secondary) welds that surface in the sea floor and supplied salt wedges: arcuate lobes of salt advancing basinward. Overpressure compartments generated beneath salt wedges provide avenues to that hydrocarbon gases fluids (brine waters) and fluidised sediments flux upwards through contractional toe-thrust structures to seepages on the sea floor (mud volcanoes, salt/shale sheets) (Lowrie et al., 1999).

The suite of mud volcanoes discovered during the mentioned cruises might be arranged into four main fields regarding its tecto-sedimentary location: A) The Moroccan-Spanish-field including the identified Rabat, Yuma, Ginsburg, Kidd, Adamastor, Olenin, Baraza, Tasyo and San Petesburgh mud volcanoes which displays an aligmnent close to the arcuate Gibraltar Arc. Fluid venting seems to be related to compression of the Gibraltar Arc. B) The Portuguese-Spanish field includes the Cornide, Iberico, Gades, Tarsis, Pipoca and Anastasya mud volcanoes. These venting structures are elongated in NE-SW direction, located in the boundary between Triassic salt and the Early Miocene marly deposits, in the front of the accretionary wedge emplaced during the Late Tortonian. Tectonical reactivation by the NW-SE African-Eurasia convergence could be a mechanism for triggering mechanism for fluid venting and diapir expulsion. C) The Tasyo Field located at the boundary between the MOW (Mediterranean Outflow Water) and the Atlantic waters, is characterized by large pock-marks craters, slumps scars with associated mud volcanoes. This field includes the Hesperides complex, Cibeles, Almazan and Faro mud volcanoes. D) The Portuguese field includes the Bonjardim and Ribeiro mud volcanoes. They both are located in the lower slope at the toe the so-called «Cadiz salt Nappe», a giant gravitational salt/shale nappe. Fluid venting is associated with contractional structures at the toe of this gravitational nappe.

All these findings had important implications regarding the likely presence of gas in sediments, of overpressured formations and of fluid circulation through the sediments and the sea floor. This deep fluid flux is related both to alongslope gravitational sliding and to tectonic compression of the "Olistostrome" forced by the African-Eurasian convergence.

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Shallow gas, cold seeps and gas hydrates

SEABED MORPHOLOGY AND GAS VENTING IN THE GULF OF CADIZ MUD VOLCANO AREA: IMAGERY OF MULTIBEAM DATA AND ULTRA-HIGH RESOLUTION SEISMIC DATA

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Co-operation between the UNESCO-IOC TTR programme (TTR-9 and TTR-10 cruises) and the Spanish marine science TASYO project (Tasyo-2000 and Anastasya-2000 cruises) have permitted to identify a large number of structures related to hydrocarbon rich fluid venting in the Gulf of Cadiz.

In 1999, during the TTR-9 cruise aboard R/V *Professor Logachev*, were identified the Yuma, Ginsburg, Kidd and Adamastory mud volcanoes and the St. Petesburg mud volcanoe along the border of the Spanish-Moroccan margins (Ivanov et al., 2000). According to the results of gas measurements, this area is characterized by relatively high gas content (up to 292 ml/l) in comparison with other areas of extensive mud volcanism as the Eastern Mediterranean and the Black Sea (Stadniskaia et al., 2000). On this basis, in May 2000, one of the main objectives of the Tasyo-2000 cruise aboard R/V *Hesperides* was to survey the Spanish-Portuguese continental margin in order to identify mud volcanism, gas-hydrates evidences from geophysical data and other gas-related sea-floor features along the slopes of the Gulf of Cadiz.

New data of more than 1200 km have been obtained during the Tasyo-2000 cruise. The Simrad EM12S-120 system, a multibeam echo sounder system, was used for mapping the sea-floor. It operates at a main frequency of 13 kHz, with 81 beams, which allow a maximum coverage angle of 120° (about three times the depth). This system triggering with a range of pulse length of 2-10 ms, reaching a resolution of 0.6 m. A preliminary processing of data has been made aboard with the Neptune software. The swath mapping provided bathymetric map contoured at an interval of 10 m also a subsidiary map showing the strength of the sea-floor backscattering of the sonar signal. The upper sediment column and sea floor were studied with high resolution methods. A Parasound echosounder TOPAS (Topographic Parametric Sound), which is a sub-bottom profiler, was used. It works with CHIRP wavelet, operating at two simultaneous primary frequencies of 15 kHz and 18 kHz. A penetration of up to 100 m has been obtained with a resolution of 1-0.5 m. A fishing-type echosound Simrad EK500 operating at a frequency 38 kHz (Splitbeam) was also used for observed in the water column targets (plumes) related to active gas venting.

The swath mapping survey of the Gulf of Cadiz resulted in three unexpected results: the probable presence of a number of mud volcanoes, the presence of numerous large pockmark craters, and of the remarkable features resembling scars of a large sediment slide migrating towards the Horseshoe abyssal plain. The main area of pockmarks craters and mud volcanoes were identified as the "Tasyo field". The Tasyo field extends within 36°15'N-7° W and 35° 45'N-7° 30'W, characterized by an irregular sea floor formed by the presence of numerous crater-like pockmarks and dome features. Depths range from 750 to 1050 m. Deeper zones correspond to large crater pockmarks whereas shallower ones are the top of dome structures. The Tasyo field is surrounded to the north by a main channel of the Mediterranean undecurrent (Mediterranean Outflow Water, MOW) and is cut by distributary channels flowing downslope.

In July 2000, during the TTR-10 cruise aboard R/V *Professor Logachev*, the Tasyo field was firstly surveyed with multifold seismic, and later, several gravity cores were collected. There were identified several large mud volcanoes (Rabat, Olenin, Baraza and Tasyo mud volcanoes), that linkage the Morrocan and Spanish margins. In September 2000, during the Anastasya-2000 cruise aboard the R/V *Cornide de Saavedra*, gravity cores and dredge samples collected from dome structures of the Tasyo field, observed on the swath mapping, revealed at least four new gas venting structures within the Tasyo field: the Hesperides mud volcanoe complex and the Faro, Cibeles and Almazan single mud volcanoes. In all of them, mud breccia, carbonate slabs and dolomite chimneys were collected. The Hesperides mud volcanoe complex, with a seabed diameter of more than 5 km building over a plateau that reaches a height of 80 m, has a complex top with a conical structure and relatively steep slopes with a relief of 15 m over the plateau. The plateau is surrounded by steep slope depressions that are clearly reflected on the multibeam mosaic. These depressions are interpreted as formed by gas venting and brines seepages (brine pools?). Presently, these depressions are cutting and filled with sandy contourites from overflowing channels of the main MOW channel. The thickness of this type of mud volcanoe evidenced by transparent acoustic facies range from 15 m on the border to 45 m on the axis. Basis on the swath mapping, at least five single cones can be identified. Dredges collected from these cones revealed large amounts of dolomite slabs (ankerite) and some samples of chimneys and matrix breccia. Pogonophora sp. and pyrite were also collected, all characteristics of chemosyntectic communities. The Faro, Cibeles and Almazan mud volcanoes with smaller dimensions, have single cones with a diameter of about 1800 m. The axis of this type of mud volcanoe show a conical transparent facies deforming the underlying sediments. They are arranged along a slide scar well observed on the swath mapping. Dredge samples collected on these structures show the same characteristics than the Hesperides mud volcanoe: dolomite crusts with sulfide matrix breccias.

Observations on the very high-resolution seismic of the mud volcanoes seems to support a pattern of episodic venting. The main mechanism to explain the observed widespread and episodic venting gas on the sea-floor subsurface, of overpressured formations and of fluid circulation through the sediments and the sea floor are:

Contractional faults regulated by salt/shale adjustment. (Somoza et al., 1999). Therefore, on the upper slope contractional faults provide avenues of vertical transport for overpressured compartments which provide the driving force for fluid and gas expulsion (Lowrie et al., 1999).

Destabilization of gas hydrates by warming of the Mediterranean Outflow water (MOW) and/or by mega-slides detached on gas-hydrate stability zone (GHZ). According to depth-temperature distribution of the sea water masses in this area and with geothermal gradients of 2.89 °C per 100 m, the GHZ begins at 680 m on the Atlantic water mass and at 850 m when MOW is present. Thus, the influence of MOW reduces drastically the existence of the gas hydrates. Both mechanism are probably modulated by sea-level changes in response to lowstand sedimentary loading and changes in current strength and patterns of the Mediterranean outflow water.

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COMPOSITION AND ORIGIN OF THE HYDROCARBON GASES FROM THE GULF OF CADIZ MUD VOLCANIC AREA

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During the 1st and 2nd Legs of the 10th "Training-Through-Research" international cruise of R/V *Professor Logachev* hydrocarbon gas samples were collected from the cores from the Gulf of Cadiz mud volcanic area. In general 7 mud volcanoes were studied and more than 20 cores were taken from this area. About 150 samples from 11 cores were analysed to determine content and composition of gas and organic matter. Gas concentrations and total organic carbon (TOC) content from sediments were measured in the Moscow State University laboratories. Fluorescent analysis, extraction and chromatography of bitumen from matrix of mud volcanic deposits were performed. The results of investigation were interpreted and discussed together with the previous data from this area obtained during TTR-9 cruise (Stadnitskaia et al., 2000; Kozlova et al., 2000).

One of the main targets of the work was to determine differences in the origin of gas in background hemipelagic sediments and from active vents. The intensity of the gas fluxes and ways of their migration from deep sources were discussed.

Concentration and composition of hydrocarbon gas were measured using gas chromatograph. The components from C_1 to C_5 including saturated and unsaturated ones and their isomers were determined. The gas measurements revealed that all sediments were characterised by predominance of methane over its homologous.

Background gas concentration, according to previous measurement (Stadnitskaia et al., 2000), was up to $4.5*10^{-2}$ ml/l for methane and about $5\text{-}10*10^{-4}$ ml/l for its homologous. In most cases, hydrocarbon concentration in sediments from the mud volcanoes was higher than background values and it increased downward alone the cores. For example, gas concentration in the cores, taken from the Ginsburg mud volcano reached to 80 ml/l. However, in the cores TTR10-AT235G (the Rabat mud volcano) and TTR10-AT241G (the Tasyo mud volcano) the concentration of hydrocarbons were defined as close to background ones ($6*10^{-2}$ml/l and $7*10^{-3}$ml/l respectively).

In the cores from the Ginsburg and Bonjardim mud volcanoes the gas hydrates were observed. Chromatography analysis, showing high methane concentration and predomination n-butane over i-butane, accorded with reported presence of hydrates. Homologous of methane from these cores were also characterised by extremely high concentrations (for instance, in the core TTR10-AT236G the sum of C_{2+} was 2.6 ml/l, and in the core TTR10-AT226G - up to 3.4 ml/l). Gas sampled from sediments showed predominance of saturated hydrocarbons over unsaturated and ratio of methane to the sum of C_{2+} was from the first unit to 150 (mostly not exceeding 100), implying a thermogenic origin (Tissot et al., 1984). In the samples from the Carlos Ribeiro and Jesus Baraza mud volcanoes CH_4/C_{2+} reached 300, suggesting that thermogenic gas was mixed with significant portion of shallow biogenic gases.

Matrix of mud breccia is barren of organic matter. 143 samples from 8 cores were studied. TOC content ranged from 0.3 to 0.6% up to 1.2%. However clear correlation between distribution of hydrocarbon gases and TOC content along the cores was not observed, which also might be indicative for mostly thermogenic origin of hydrocarbon gases.

Fluorescent analysis was performed on sediments from the intervals, where TOC and gas composition were determined. Extractable organic matter (EOM) reached 0.08% in the mud volcanic breccia where as hemipelagic sediments were characterized by less than 0.0003% of EOM. Extraction and chromatography of bitumen were made for samples enriched in organic matter. The results of chromatography of EOM were indicative for mainly suboxic conditions in mud volcanic deposits (Pr/Ph > 1) with exception for mud breccia from the Jesus Baraza mud volcano (Pr/Ph=0.88). The n-alkane distribution indicated that organic matter is mostly of marine origin with some admixture of terrestrial consistuents. Organic matter is immature, Ki ranged from 0.74 to 1.68 (Tissot et al., 1984). Signs of microbiological processes were noted in the uppermost part of the sedimentary sequence. This is confirmed by presence of unsaturated homologues (ethylene, propylene).

Results of geochemical study of the cores taken from the mud volcanoes of the Gulf of Cadiz allow to conclude:

1. The Gulf of Cadiz is an area where active mud volcanic processes take place recently.
2. Among mud volcanoes studied there are most active in present days and relatively dormant. All of them are characterised by fluid inflow from deep sources, which is clearly indicated by the composition of hydrocarbon gases in the sediments, type and origin of OM, absence of correlation between hydrocarbon gases and TOC contents, predomination of saturated homologues over unsaturated ones.
3. The Ginsburg and Bonjardim mud volcanoes are very active now. Their deposits are characterised by extremely high concentrations of hydrocarbon gases and presence of gas hydrates.
4. The Rabat, Jesus Baraza, Tasyo and Carlos Ribeiro mud volcanoes were found to be less active, with deposits showing relatively low concentration of hydrocarbon gases, but higher than reference gas concentration.
5. Whole studied area is likely to be determined as an area of active escape of deeply sources fluids through sea floor, where even hemipelagic sediments are characterised by enhanced concentration of hydrocarbon gases.

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MOLECULAR AND ISOTOPIC CHARACTERIZATION OF HYDROCARBON GAS AND ORGANIC MATTER FROM MUD VOLCANOES OF THE GULF OF CADIZ, NE ATLANTIC

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A region of active mud volcanism and gas venting was recently discovered in the Gulf of Cadiz on the Spanish and Moroccan margin. The presence of number of mud volcanoes previously assumed to be present was confirmed by bottom sampling during TTR-9 (1999) and TTR-10 (2000) cruises of the R/V *Professor Logachev*. In addition, previously unknown mud volcanoes were identified, indicating that mud volcanism is a widespread phenomenon in the Gulf of Cadiz characterized by zonal patterns of mud breccia flows of different lithology.

Herein we report the preliminary results of a geochemical study of samples from the Gulf of Cadiz mud volcanoes representing a collaborative effort between Moscow State University and the Netherlands Institute for Sea Research (NIOZ). Pelagic sediments, mud volcanic breccia and hydrocarbon gas samples were collected for analysis of the molecular composition, concentrations, and carbon-isotopic compositions of the hydrocarbon gas and the sedimentary organic matter. There are two primary objectives of this study. The first objective is to determine whether the hydrocarbon gas is derived from the organic matter in the mud breccia deposits or from some other, currently unidentified source. The second objective of this study is to investigate microbial processes related to the presence of hydrocarbon gas, primarily methane, in mud volcano sediments.

In comparison with previously studied areas in the Eastern Mediterranean Sea, Black Sea and Norwegian Sea, gas measurements revealed a relatively high background concentrations of hydrocarbon gases. The carbon isotopic measurements of C_2 - C_5 hydrocarbon gas ranged from -19.2‰ to -29‰, characteristic of thermogenically formed gas. The $\delta^{13}C$ of methane ranged from -32‰ in some regions to -63‰ in others, indicating that the methane in these mud volcano sediments is a mixture of gases with a thermogenic and a biogenic origin. Therefore, the data suggest that in the samples with co-genetic methane and C_2-C_5 hydrocarbons, the methane represents 93-95% of the total hydrocarbon gas, whereas in samples with an additional biogenic methane contribution, the methane represents > 99% of the total hydrocarbon gases. In addition, in almost all investigated cores the methane concentration shows rapid increase between ~40-60 cm below sea floor, suggesting that methane was consumed under anaerobic conditions by methane oxidizing micro-organisms.

Molecular and isotopic studies of extractable organic matter indicate that these mud volcano sediments are dominated by terrestrial hydrocarbons and fatty acids, however, isotopically depleted biomarkers related to anaerobic methane-oxidizing archaea and sulfate reducing bacteria were identified in trace amounts in mid-depth samples in several cores. These intervals are well correlated with the decrease in methane concentration. Archaeal and bacterial derived compounds identified include hydroxyarchaeol and the C_{25} isoprenoid pentamethylicosane (PMI) as well as various hopanoids. The varying distribution of these archaeal and bacterial biomarkers suggests that there is significant special variability in the microbial community in the mud volcanoes in the Gulf of Cadiz.

DEEP SEA POCKMARK ENVIRONMENTS IN THE EASTERN MEDITERRANEAN

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A great number of circular to isometric depressions have been observed on the deep water seafloor in the Eastern Mediterranean by MAK1 and ORETech deep tow side-scan sonar during several TTR cruises of the UNESCO Floating University Program, starting from 1993 and also by visual observation made during the late 1998 French-Dutch MEDINAUT expedition. They extend from the Cobblestone mud volcano area to west, passing all along the Mediterranean Ridge through the Olimpi and United Nation Rise mud volcano provinces to the Anaximander Mountains and Eratosthenes Seamount to east. These pockmark-like features vary in size running from few meters up to 250 m across with depths of less than one to more than ten meters below the sea floor. Some appear to be draped with sediment, making them smoother and shallower, others are V - shaped with sharp rims and are deeper, and the larger ones have flat floors and are like truncated cones. There are pockmarks filled with brines which contain the highest quantities of methane found anywhere in the eastern Mediterranean so far (up to 133 ml/l) and seem to be dynamic features, others are associated with gas seepage and the rest show no current activity. They are more frequent around mud volcanoes and near some of the faults but occur also in small groups or alone and, although apparently irregularly scattered, it is obvious from the analysis, that their distribution follows some distinct trends.

Several environments in which deep water pockmarks preferably occur in the Eastern Mediterranean can be distinguished as follows: (i) pockmarks confined to active mud volcanoes which resemble salses and griphones on terrestrial mud volcanoes are discussed with examples from several mud volcanoes in the Olimpi mud field and the Anaximander mountains; (ii) pockmarks associated with remnant mud volcanoes and corresponding fault systems, like pockmarks on the flanks of buried volcanoes in the Cobblestone and United Nation Rise areas; (iii) the most abundant group of active fault-related pockmarks and those on the Eratosthenes Seamount, Anaximander mountains and some other in the Mediterranean Ridge are cited; and (iv) pockmarks associated with submarine slump processes are verified. Some separate brine filled pockmarks, not mentioned in the above groups, are briefly discussed also.

Although diverse in morphology and geological environments in which they occur all pockmarks are very similar with the most likely origin related to processes of fluid or gas escape through the sediments.

GAS-SATURATED SEDIMENTS AND THEIR EFFECTS ON THE SOUTHERN SIDE OF THE EASTERN BLACK SEA

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The Black Sea is a large marginal sea located within complex folded chains of the Alpine system, represented by the Balkanides-Pontides belt to the south, and by the Caucasus and Crimea Mountains to the north and northwest. Two basins coalesced late in their post-rift phases in the Pliocene, forming the present single depocentre. The mountain-building processes and their subsequent erosion around the basin have contributed to high sediment input. A prominent regional ridge of NW-SE trend (Mid-Black Sea ridge) made up of two positive features named Andrussov separates W-Black Sea and E-Black Sea basins and Arkhangelsky ridges. This structure is very important for the understanding of the Black Sea opening because it preserves the old rift-tectonics produced when the sea was produced. The extensive deformation is here almost completely non-contaminated by successive compressive movements. The southeastern part of Mid-Black Sea ridge (Arkhangelsky) locally shows a moderate compressive deformation connected with the orogenic movements of the Pontides. This features forms a secondary basin (known as the Sinop basin) not allowing the sediment outflow from the Turkish mainland directly off to the deep abyssal plain.

The Black Sea has all the morphological features characteristics to normal deep-water basins, i.e. shelf, continental slope, continental rise (foot or apron) and abyssal plain. The shelf area of the Turkish side of the eastern Black Sea is affected by a bump of river fans. This small ridge is able to cause the accumulation of the thick soft sustain sediment. This kind sediment accumulation has not been determined near other river fans on the shelf in Black Sea, because these sediments could have drifted into the Black Sea abyssal plain. Huge quantities of plant debris and organic material from the rivers cause the biochemical gas generation. This ridge stops the sediment transportation from the end of shelf area to the continental slope and can create the hydrodynamic shade into the continental slope direction.

Pockmarks, elongated in a direction of about 1.5-2 km length and 280 m width mark the mound. Strong reflections were determined beneath the seafloor in about depths of 15-45 m. These strong reflection pockets can be interpreted as gas-hydrate layers, which are normally formed under low temperature and high-pressure conditions. Some faults or disturbances were identified with small offsets from place to place, in the area as elongated strips of the accelerating depth gradient. The presence of the rock masses in the basement of the shelf sinking part and intensive sediment input from the onshore (including plant organic matter) have created very specific conditions in which the biochemical gas generation occurring (mainly the methane) is very active.

Partially methane has got into the gas-hydrates. Structures, which contain gas hydrates, are present on the profile records as strong acoustic reflections. Those formations promote the stabilisation of the fan in its shelf part. Another great part of the gas remains in the free or soluble form in the pore water. The free gas concentrates, by the process of natural lateral migration along the inclining stratum. In this area, the sediments contain a certain concentration of gas, which can seep to the seabed surface and generate pockmarks. These seabed features can have either a circular or elongated shape. The pockmarks have a length of about 2-3 km and a width of 200-300 m in some places. It is obvious, that such structures are formed either in tectonically relaxed zones, or in linear zones of the more porositive sediments. The changing facies zones have been marked, even on the surface by the sonar data. The direction of these linear zones conforms to the beach that is natural from the viewpoint of the changing of facies.

Part of the sediments from where the gas vents out laterally, can condense and settle. This process can form small faults; this is often shown on the profile records. Diffusion and filtration of the free gas leads to the distortion of the natural sediment bedding. As a result the sediment becomes more diluted and mobile. The continental slope deepens from 600 to 1800-2000 m water depths and comprises of rectilinear gullies and V-like channels which can be identified clearly on the sonar mosaics, bathymetric charts and sub-bottom profiler records, the channels are the best visible on the cross-lines of sub-bottom profiles. Gas diffusion is marked in place to place when some parts of well-bedded layers are not observed in the sub-bottom profiles. Then they are characterised by dark spots with irregular forms on sonar data, which are most common features in the slope foot.

The seafloor of the abyssal plain is horizontally flat having fairly constant water depths of about 2150 and 2230 m. The observed sequence is formed of rather continuous well-bedded reflectors that are interrupted in places by the piercing of gas and associated disturbances in the sedimentary sequence, the horizontal movement of the sediment is rare. There are two most distinctive (prominent) types of bottom surface on the seafloor basin. The first type is the smooth horizontal seafloor. The second type is an insignificant hilly surface area. The seabed shows some irregularities due to presence of distributed spaced hillocks starting with a diameter about 5 m and a height about 2 m.

GEOCHEMICAL FEATURES OF GAS HYDRATE-FORMING FLUIDS OF THE GULF OF CADIZ

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During the TTR-9 and TTR-10 cruises onboard R/V *Professor Logachev* new mud volcanoes were discovered in the Gulf of Cadiz (NE Atlantic). For the first time, from two mud volcanoes in this region gas hydrates were sampled using a gravity corer (stations AT206G, AT208G, AT238G, 907-910 m water depth, Ginsburg mud volcano; AT246G, 3060 m water depth, Bonjardin mud volcano).

Chemical and isotopic analyses have been carried out on about 170 samples of dissimilar water in this region. Samples of sea bottom water, pore water, mud volcano fluid water, gas hydrate water and theirs mixtures have been studied. The results of these analyses testify to the presence of considerable variations in chlorinity, the Mg/Cl ratio and the isotopic composition of oxygen and hydrogen in water. The intervals of gas hydrate-bearing sediments recovered from Ginsburg and Bonjardin mud volcanoes are characterized by low chlorinity (450 mM and 415 mM, respectively). Based on the low (relative to ocean water) chlorinity of the pore water, we assume that gas hydrates also occur in sediments from Yuma (980 m water depth), Olenin (2604 m) and Carlos Ribeiro (2200 m) mud volcanoes. Our data suggest that the chemical composition (chlorinity, Mg/Cl ratio, etc.) of the mud volcano fluid and pore water from pelagic sediments are similar. Based on the chlorinity anomalies, we estimated for the sediments of different mud volcanoes in this area a gas hydrate content of about 5-30% by pore space. The gas hydrate-forming fluids of different mud volcanoes are variable in isotopic composition of water and distinct in isotopic composition from the sea water. As a rule, these fluids are characterized by significantly high values of $\delta^{18}O$ and low values of δD in comparison with normal pore and sea water. The relations revealed between $\delta^{18}O$, δD and Cl are not in agreement with results of isotopic fractionation during gas hydrate formation. They are explained mainly by differences between isotopic composition of mud volcano fluid and sea water.

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EVIDENCE FOR MODERN AND ANCIENT FLUID FLOW IN THE SEAFLOOR CRUSTS: IMPLICATIONS FOR UNDERSTANDING THE PLUMBING OF SUBMARINE SEDIMENTS

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Preliminary results of comparative studies of palaeo (Bath Area, Barbados) and recent (Voring Plateau, Norway) carbonate crusts from gas seepage areas in different settings have been obtained. Detailed studies of the samples were undertaken using standard petrographic and scanning electronic microscopy (SEM), cathodoluminescence (CL) and fluid inclusion micro-thermometry. The origin of distinctive cements, the timing of cementation, and the importance of fractures and permeability and porosity associated with these carbonate crusts have been analysed and enabled diagenetic histories to be elucidated. Comparison of modern and ancient geological processes associated with carbonate crust formation has showed their similarity.

Bath Area, Barbados: The crestal zone of the accretionary prism of the Lesser Antilles forearc is well exposed on the Barbados is. In particular, Tertiary rocks are well exposed in the Bath area, where bitumen closely related to "diagenetic carbonate" (Torrini et al., 1985, Speed, 1990, Parnell et al., 1994) appears in the fault zones. It appears that fault zones and diapirs were the preferential pathways for fluid advection. The association of limestones with molluscan fossils and fossil tube forms (Speed, 1990) suggests the existence of fluid escape vents. This is further evidenced by the light composition ($\delta^{13}C$ from -15 to -55 ‰ relative PDB) of the carbon isotopes in the area (Torrini et al., 1990) that indicates a contribution of carbon from hydrocarbon gases, presumably methane. Samples of diagenetic carbonate and bitumen were collected from the Bath Fault Zone. Petrographic analyses reveal the presence of euhedral crystals of calcite and solidified bitumen, the latter is characterised by devolatilization vesicles and conchoidal fractures. The fractures within the bitumen are interpreted as the result of bitumen contraction when exposed to seawater coupled with the effect of biodegradation and de-asphalting (Connan, 1984). The fractures were then filled with a later calcite phase, which precipitated in association with continuing methane seepage, presumably sourced from the diapirs. This calcite phase occludes porosity within the rock. This is even more evident when observing under cathodoluminescence, which mostly shows a very high luminescence. The majority of the calcite crystals show well-defined growth zones, indicating different stages of crystallisation, which were possibly related to the activity and the composition of the seep fluids. Calcite fluid inclusion measurements reveal that there are three distinct primary fluid inclusion populations. The first population consists of monophase aqueous inclusions with a probable trapping temperature of less than 50°C. The second population consists of bi-phase methane-bearing aqueous inclusions with homogenisation into the liquid phase between 121.7°C and 136.8°C (average T_h of 128.8°C), which represents the minimum trapping temperature for the diagenetic fluid. The third population consists of two-phase methane-bearing aqueous inclusions that homogenise to the gaseous phase between 149.8°C and 163.9°C (average T_h of 158.4°C). The presence of these three distinct co-existing primary fluid inclusion populations indicates that there was probable heterogeneous entrapment of water and methane.

Voring Plateau, Norway: A recent survey undertaken during the TTR-10 programme on the Voring Plateau, western Norway, targeted and located modern gas seepage areas utilising acoustic techniques (Kenyon et al., 2001). The TV survey along the active fluid escape structure, discovered in 1998 during TTR-8 cruise (Kenyon et al., 1999), showed relatively flat seafloor morphology characterised by a laterally extensive carbonate crust. Slabs are occasionally interrupted in small zones showing edifices elevated from the seafloor, where soft hemipelagic sediments are filling the depressions. Fluids are occasionally observed coming through the sediments. Associated macrofaunal taxa including shrimps, sea-spiders, ahermatypic corals, gastropodes and clams are present. For the first time a large sample (station TTR10-AT323Gr) of carbonate crust was collected from this structure. The sample, very porous with a strong smell of H_2S, consisted of precipitated carbonate minerals, skeletal bivalve remains, siliciclastic sediment and small clasts of varying lithology (possibly ice rafted sediment or transported from the upper slope from a mud volcano). The dominant chemosynthetic species lithified with the carbonate crust are large bivalves belonging to the families Vesicomyidae and Mytilidae. Other symbiont-containing species include Pogonophora worms and Cladorhizidae sponges. Petrographic analyses indicate that mainly high Mg-calcite and acicular, botryoidal, aragonite cement the crust together. Geopetal infillings occur with clay (mainly peloids) within bivalve cavities. Carbonate cements show dull cathodoluminescence, though some zoning representing different growth phases is distinguished. The terrigenous admixture (detrital sediment) and the peloids both display similar bright luminescence, suggesting a similar origin for them. SEM shows that the broadly distributed acicular aragonite is nucleated mainly on the shells or on the carbonate crystals present in the terrigenous admixture, and that it has gradually infilled the porosity of the rock. Preliminary results of microthermometry on bi-phase fluid inclusions in calcite shows homogenisation to liquid at around 65-75°C. Freezing behaviour suggests the presence of methane, and the possibility that the cements contain carbonate produced by oxidation of methane. This can be confirmed also by the extremely negative carbon isotope values (-51 ‰ relative PDB) of the authigenic carbonate.

The data obtained shows the relationships between seepages and mineral precipitation in modern environments as well as in geological past. It was found also to be possible to obtain fluid inclusion data from seafloor deposits, which might provide direct information about the fluid responsible for diagenesis in this environment.

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CARBONATE CHIMNEYS IN THE GULF OF CADIZ: INITIAL REPORT ON THEIR PETROGRAPHY AND GEOCHEMISTRY

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Dolomite chimneys associated with hydrocarbon-rich fluid venting was discovered September 2000, as part of the TASYO project (Marine and Science Technology Spanish Programme) in the Gulf of Cadiz. The unexpected discovery occurred during the cruise Anastasya/2000 aboard of research vessel *Cornide de Saavedra* dredging a 870 m-deep and 120 m-tall carbonate mound called as the "Iberico". A suite of more than 60 individual structures of chimneys were collected, which displays distinct pipe-like morphologies that varies from 1 to 0.40 m long. Fragments of chimneys from the Hesperides mud volcanoe within the Tasyo field and along the Morrocan margin were also sampled. At same time, in all of these sites, strongly sulfide mud breccia and dolomite slabs have also been collected.

Targets were previously detected in May 2000 by carrying out a detailed mapping and ultra high resolution seismic, with an extent new data of more than 1200 km obtained during the cruise TASYO/2000 aboard of research vessel *Hesperides.* The Simrad EM12S-120 system, a multibeam echo sounder system, was used for mapping sea-floor. The swath mapping provided bathymetric map contoured at an interval of 1 m also a subsidiary map showing the strength of the sea-floor backscattering of the sonar signal. A Parasound echosounder TOPAS (Topographic Parametric Sound), which is a sub-bottom profiles was also used.

The chimneys are dominated by Fe-riched dolomite (ankerite) forming aggregates with minor amounts of pyrite, iron oxide, Ta-enriched rutile, zircon and quartz. Abundant, well preserved remains of foraminifera (globigerinoids and milioids) composed of Mg-calcite are present within the matrix. Dolomite aggregrates are remarkably depleted in ^{13}C (-35 to -56 PDB) and are therefore interpreted being the result of methane oxidation by sulphate-reducing bacteria. This microbial activity is shown by abundance spheroids to euhedral pentagonal monocryst composed by up to 60 cells of sulphate-reducing bacteria. Aggregates of single bacteria of about 1 µm diameter produces rounded to pentagonal shaped framboids up to 60 µm characteristics of pyrite. Presently, mostly these bacterial-origin framboids are replaced by haematite. At same time, some of framboids have been found in the interior of the foraminifer chambers, which could suggest some symbiotic association between foraminifer and chemosyntectic bacteria.

Dolomite chimneys are interpreted as cemented conduits formed as result of methane-enriched fluid expulsion through a submarine mound, probably formed as a mud volcanoe. The abundant pseudo-pyrite framboids are related with the zone of shallow microbial sulphate reduction, a process fundamental to the nourishment of the chemosynthetic cold seep communities. In the last years, it has been considered the importance of carbonate cementation related with methane fluxes, both on submarine modern environments and on rocks of the fossil record. This carbonate cementation, in forms of chimneys, slabs, and crusts has been reported in several tectonic settings such as the Gulf of Mexico, Oregon margin, Otago slope, Monterey basin and Kattegat (e.g. Jorgensen, 1992; Orpin 1997; Stakes et al., 1999). Large fluxes of methane seem responsible for dolomite cementation, instead high-Mg calcite and aragonite when fluxes are lower. Recently, its has been hypothesis that extensive anerobial microbial communities exist in sedimentary layers below high-temperatures vent fields. Chemosyntetic bacteria are the primary producer of hydrothermal producers that are fuelled by geothermal energy. The sum of the syntrophy co-operation between methane-oxidisers (archaeobacterias domain) and sulphate-reducers micro-organism produces carbonates and sulphides at the sulphate-methane interface, which depth below sea floor is dependent on the methane flux rate (DeLong 2000)

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ACOUSTIC CHARACTERISTICS OF THE BSR AND ADJACENT ENHANCED REFLECTIONS AT THE SOUTHERN EDGE OF THE VØRING PLATEAU AND NORTH-EASTERN PART OF THE STOREGGA SLIDE AREA

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During TTR-10 expedition (R/V *Professor Logachev*) to the southern Voring Plateau and north-eastern part of the Storegga Slide, a set of seismic lines was shot. This survey was a continuation of the TTR-8 investigation of the area and was mainly focussed on the bottom simulating reflection (BSR) and adjacent enhanced reflections, possibly related to presence of free gas in the pore space of the sediment. The BSR and enhanced reflections have been previously reported in the area and discussed (Bugge et al., 1988; Mienert et al., 1998; Bouriak et al., 2000), however, no detailed analysis of acoustic characteristics of these anomalous seismic events was performed.

This work is aimed to analyse the acoustic character of the anomalous reflections observed, in order to clarify their nature. It is known that BSR is normally associated with the base of the hydrate stability field, controlled mainly by PT-conditions. Since the gas hydrate in the pore space of the sediment reduces its permeability, free gas is often believed to be trapped and accumulate below the hydrate-bearing layer. The acoustic impedance decreases at the interface between high-velocity partially hydrate-saturated sediments above and low-velocity gas-charged sediments below cause negative polarity of the seismic reflection, when it corresponds to the bottom of gas-hydrated sediments. Presence of free gas in the pore space itself affects principal dynamic characteristics of the corresponding reflections, i.e. their amplitude, phase, and frequency. Gas-containing layers often show up as reflections of enhanced amplitude and reversed polarity (bright spots). Due to enlarged attenuation of acoustic energy in gas-containing sediments, the underlying reflections sometime demonstrate decreased amplitudes (so-called amplitude shadow) and lowered frequencies (frequency shadow), relative to the same seismic events from the areas where they are not overlaid by gasified strata. All these characteristics are indicative for gas-containing layers, and their presence is considered as a strong evidence for gas hydrate and free gas occurrence.

The polarity, amplitude, and frequency band of the anomalous seismic events and underlying reflections observed both at TTR-10 and TTR-8 data were analysed. The calculated amplitude envelope (reflectivity strength) clearly demonstrates enhanced amplitudes of the target horizons, accompanied by amplitude shadow at the underlying reflections. Deconvolution of the seismic records, having improved the wavelet, allowed of identification of the reversed polarity of the observed BSR and enhanced reflections, relative to the seafloor reflection. For analysing the frequencies of the reflections, the time sections were transformed into the frequency field by counting the number of sign reversals of the signal along a trace within a sliding window. Then, a value counted for each position of the window and divided by twice the window length assumed the units of frequency. This method, though being less common than the instant frequency transformation, being applied to a trace apparently provides a generalised characteristic of the frequency band of the signal vs. depth and is known to be more robust than the latter. It was identified that the layers underlying the enhanced reflections and the BSR are characterised by distinct frequency shadows. The dominating frequency values there do not exceed 50-70 Hz, while the same reflections aside the overlying anomalies feature frequencies of about 100 Hz and higher. Such a clear frequency shadow caused by overlying enhanced reflections is a strong evidence of increased attenuation, most likely caused by free gas.

Therefore, the analysis of main dynamic characteristics of the seismic records suggests that the enhanced reflections are most likely to be related to free gas present in pore space of the sediments, while the BSR crosscutting these reflections in all likelihood corresponds to the bottom of hydrate-containing sediments, trapping free gas below.

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'SPLIT' BSR AT THE VØRING PLATEAU AND BELOW THE STOREGGA SLIDE DEPOSITS - NEW DATA OF THE TTR-10 CRUISE, AUGUST 2000

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Following the investigations of the TTR-8 (1998) the area on the conjunction of the Voring Plateau and Storegga slide was revisited during the TTR-10 expedition of R/V *Professor Logachev* with the single-channel seismic system and OKEAN long-range side-scan sonar. The main aim of the survey was to continue mapping of the spatial distribution of the BSR observed on the seismic records there, and in particular southeasterly (below the slide) and northwesterly (within the undisturbed sediments of the plateau) of the area covered by the previous TTR seismic survey.

For each of the lines where supposed BSR was observed, the theoretical bottom of the local gas hydrate stability field (GHSF) were calculated, basing on the local seafloor topography and the PT-conditions calculated by Bouriak et al. (2000) from the depth of a single BSR-location within the area. The temperature gradient of 0.055°C/m used in this calculation was also supported by direct measurements (Vogt et al., 1999). For all of the lines, the resulting calculated depths of the theoretical GHSF fit nicely to those of the BSR that were really observed, which confirm the gas-hydrate nature of the reflection.

The obtained data allowed to trace the BSR distribution below the deposits of the slide until it terminates some 15 km southeasterly of the slide scarp. To the north-west, the reflection was followed up to 64°30'N and it seems to continue farther to the north.

The BSR is expressed on the seismic records in the area either as a strong reflection of negative polarity, often crosscutting the stratigraphic layers, or as a sort of facies change between high-amplitude (enhanced) reflections below and normal amplitude reflections above it, that is quite typical BSR expression on medium to high resolution single channel seismic data (Vanneste et al., 2000). The remarkable feature of the BSR appearance within the area is that at most of the lines it is 'split' into several isolated zones. More particularly, the reflection shows up only at several apparently stratigraphic layers, sandwiched between the strata where the BSR is not observed. There are at least 4 'BSR-demostrating' layers, continuing upslope (below the GHZF) as enhanced reflections, which were correlated between the lines and mapped. Apparently, these layers need to posses some physical or pethrographical property that makes them most favorable for gas hydrate formation or/and accumulation of free gas. This could be increased, relative to host sediments, permeability due to coarser grain-size or/and change in mineralogical composition, or/and increased water content. Being traced downslope (within the GHSF), some of these layers in several locations seem to terminate at the gliding plane of the slide, that revive the discussion on the possible interrelation between the hydrates and sliding in the area. However, these locations are always deep inside the (either modern or pre-slide) GHSF that makes hydrate dissociation there hardly possible. On the other hand, the assumption of increased liquefaction of these layers, stimulating gas hydrate formation, apparently at the same time would be favorable for sediment failure. This assumption also fits well to the hypothesis of liquefied layers, acting as lubricants below the sliding sediments, suggested by Bugge et al. (1987) as one of the most probable factors stimulating downslope transport of the material displaced by the Storegga Slide.

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CONTOURITES, FLUID TRANSPORT AND FORMATION OF GAS HYDRATE ACCUMULATION (ON THE BASIS OF DSDP-ODP DRILLING RESULTS)

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The properties of sediments containing gas hydrates may play an important roles for gas hydrate distribution. Formation of gas hydrate, beside other factors, is controlled by porosity and permeability. The investigation of gas hydrate accumulation within Blake Outer Ridge (Northwest Atlantic) made us suggest that a link exists between fluid migration processes (and, therefore, also gas hydrate formation) and specific properties of contourites.

Blake Outer Ridge is a sedimentary body accumulated during the Pliocene and Miocene time at very rapid sediment rates (up to 350 m/m.y.). The sediments were deposited by the south-flowing Western Boundary Undercurrent that sweeps southward along the Atlantic Margin (Shipboard Scientific Party, 1972; Gradstein and Sheridan, 1983). Blake Ridge contourites are composed mostly of homogeneous sequence with the minimal variations in properties and lithology. Gas hydrate is inferred to be finely dispersed within the homogenous sediments (Paull, Matsumoto, et al., 1996). However, across the section some heterogeneity was revealed on base of grain-size distribution and sediment composition (Ginsburg et al., 2000; Kraemer et al., 2000). Granulometric analysis of sediments from sites 994, 995, 997 and 1054-1061 ODP has shown the following:

(1) gas hydrate-containing sediments represent interbedding thin layers with a different extent of permeability;

(2) gas hydrate-bearing sediments in the clay-rich Blake Ridge contourite sequence are characterized by the relatively lowered content of fine fractions and the better sorting - i.e. by the better permeability.

The following features has been taken into account:

- gas hydrate accumulation within Blake Ridge is largest and most well investigated and it is associated with bottom current deposits;
- contourites form local, spatially limited bodies;
- contourite accumulation is characterized by high sediment rates, that can be the pre-requisite for formation ascending fluid flow through non steady-state of gravitational consolidation (Ginsburg, Soloviev, 1998).

Through these facts, other areas could be revealed where current-related sedimentation is associated with processes of fluid migration. For this purpose geochemical, lithological and geophysical data from DSDP-ODP were considered. Anomalies of interstitial water composition, sediment saturation by gas, BSR distribution (as an indirect indications of gas hydrate) has been used as an evidence of fluid transport. Several regions of current-related deposition were revealed on the basis of these investigations: Northern-Western Pacific, Eastern Pacific, Antarctica, Northern-Western Atlantic, North Atlantic-Arctic, Northern-Eastern Atlantic. All the regions are located on the bottom current pathways (fig.1). Under action of the Coriolis force the geostrophic currents deviate to the right in northern hemisphere and to the left in southern (Lisitsyn, 1988). In all revealed areas, except for the North Atlantic-Arctic, the indications of fluid transport were found in sediment related to the currents activity.

Thus, in contourite regions conditions favourable for fluid migration are rather common. These processes occur both on passive and active continental margins. It should be noted, however, that in conditions of active continental margins the basic prerequisite of fluid transport are tectonic factors.

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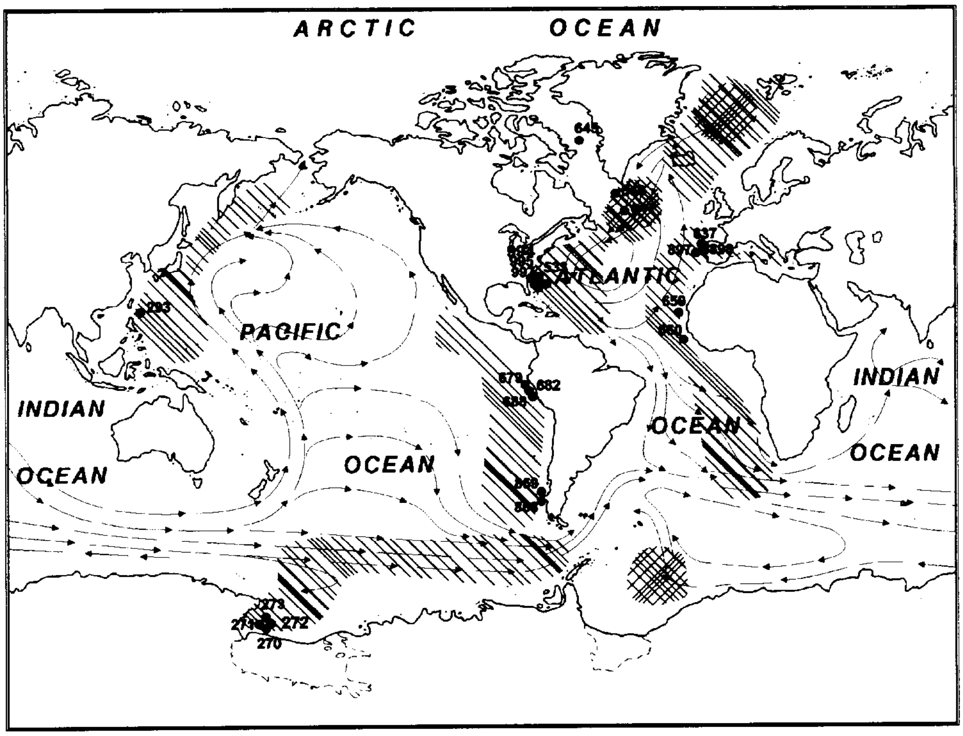

Fig. 1. World Ocean deep current circulation (modified from Pickering et al., 1989). The cross-hatched areas are regions of production of bottom waters. Schematized flow lines for abyssal depth. The hatched areas are regions of current-related sedimentation on DSDP-ODP results; location of DSDP-ODP drilling sites characterized both current-influenced deposition and fluid migration processes (black dots)

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Biosphere - geosphere interaction

MOUNDS IN THE BIOSPHERE.
A MODEST BUT SINCERE HOMAGE TO VLADIMIR I. VERNADSKY AT THE 75TH ANNIVERSARY OF THE PUBLICATION OF 'BIOSFERA' (1926)

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The term 'Biosphere' has been coined rather casually by the Viennese geologist Edward Suess in the very last pages of his pioneering book 'Die Entstehung der Alpen' (1875). He thus assigned the place on Earth's surface where Life dwells, above the 'Lithosphere'. His first citation of the Biosphere in his magnum opus 'Das Antlitz der Erde' - the Face of the Earth (vol. II, 1888) already contained the recognition of two major habitats: one controlled by solar energy, and the other one deprived of light: the abyssal realm, unveiled by the cruise of the Challenger (1872-1876).

But the 'Biosphere' truly unchained as a higher concept in the vision of Vladimir I. Vernadsky, in his master work 'Biosfera', published in Russia in 1926. Life is not a mere superficial shell of the Earth, it is not merely a geological force, it is the geological force at the surface of the Earth, influencing virtually most geological processes. In Vernadsky's vision, the Biosphere is even turning into a new evolutionary state - the 'Noosphere' - through the force of Man and his scientific thought. A concept which would be developed in a spiritual context by Teilhard de Chardin. The Biosphere concept has set the stage for biogeology or geobiology, biogeochemistry, geomicrobiology and other disciplines which are not mere bridging exercises but true novel research avenues. UNESCO has heralded a global societal response on such emerging concepts - linked to growing environmental issues - by launching its " Man and the Biosphere " programme in 1970. New views on Earth 'physiology' emerged in more recent times (Lovelock, 1979; Westbroek, 1991).

Throughout geological times, one of the most spectacular strategies of Life as a geological force has been displayed by mound-shaped habitats on the seafloor, built in various architectural styles and by varying ecological associations. Since the dawn of Life, stromatolites, mud-mounds and coral reefs - whatever the scientific and semantic nuances - have relayed each other in variable patterns as major sites of exchange of matter and energy between the atmosphere, the oceans, Life and the mineral world. They ruled the fluxes of oxygen and carbon dioxide between the ocean and the atmosphere, and the precipitation of carbonates - through processes of Life, for the benefit of Life.

Stromatolites dominated biogenic sedimentation in the Precambrian, and individual 'colonies' of those primitive blue-green algae could reach large sizes, several metres high. For every atom of carbon precipitated in stromatolite rocks, one molecule of oxygen was released in the atmosphere, making our planet's breathable air. In contrast, calcification in our recent coral reefs proves to be a net source of carbon dioxide to the atmosphere. As to 'mud-mounds', which arose in Early Palaeozoic times after the decline of the stromatolites through a new strategic alliance between microbial species and the upcoming metazoa, they still largely elude our attempts to unveil their genesis and 'physiology'. The recent discovery of large provinces of giant mounds in hydrocarbon provinces over the world ocean might yield some clues, and may shed light on the role of mounds in the Biosphere. Some examples are discussed.

In the wake and spirit of its "Man and the Biosphere" venture, UNESCO has a continuing role to play in this quest, through its succesful Training-Through-Research programme.

DEEP-WATER CORAL RESEARCH - PAST AND FUTURE

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The earliest records for *Lophelia pertusa* are from Norwegian waters. In 1755, Pontoppidan refers to it being collected by fishermen and divers and used for medicinal purposes. It was described in 1758 by Linneus and in 1768 by Gunnerus. The growth of fishing in the late 18th to early 20th century provided more records on its distribution from Norway to the Iberian Peninsula. The accumulated data resulted in several publications including Joubin (1922a,b), Dons (1944), Le Danois (1948), Teichert (1958), Fernandez Garcia et al. (1976). Some of these contained ecological observations. In the 1960's interest widened to New Zealand waters where the colonisation strategy of Lophelia was investigated (Squires, 1965). Submersible observations were made in the late 60's and 70's on the Blake Plateau, (Milliman et al., 1967), in the Straits of Florida (Neumann et al., 1977) and on Rockall Bank (Wilson 1979a,b). These provided further models for the colonisation strategies in different environments. Investigations off northern and mid Norway (Stjernsund and Sula Ridge) have provided much new information on the ecology and general geobiology of Lophelia (Freiwald, 1998; Freiwald et al., 1999; Mortensen et al., 1995) and include details of the largest true coral reef in cool temperate waters.

In the early 1990's interest developed in the potential oil prospects north-west of Shetland in the so-called Atlantic Frontier Zone, in the Rockall Trough and on the western slopes of Porcupine Bank. This has generated wide interest in Lophelia, partly in response to inaccurate scare stories about the alleged destructive effects of oil developments on the coral. Many more European Research Institutes and Universities became interested in the general ecology, physiology and genetic variability in Lophelia and this culminated in the start of the European Union ACES (Atlantic Coral Ecosystem Study) project in April 2000. The research commissioned by ACES will concentrate on specific topics including reproductive strategies; growth rates; framework constructing potential; morphological variation; genetic variability; the longevity of the deep-water coral ecosystem; biodiversity; coral behaviour and sensitivity to stress; hydrographic and other factors affecting benthic boundary layer particle dynamics and conservation issues including an appraisal of the destructive effects of extensive continental margin trawling.

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MORE ON MOUNDS

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During the past decade, considerable attention has been paid towards studies of various kinds of mounds, such as mud mounds, serpentinite mounds, carbonate mounds, and the like, both on land and at sea.

During the early phases of the TTR programme, these studies were directed mainly to the Black Sea mud volcanoes, following up on earlier studies carried out by MSU in the 1980's. The Black Sea studies and results culminated in the 1993 cruise to the Black Sea, when detailed MAK sidescan sonar images of a number of mounds were recorded, and were extended a few years later with another leg of R/V *Gelendzhik* .

However, during the 1993 cruise extremely good and new results regarding fluid flow, and mud volcano formation in relation to their tectonic and sedimentary settings, were obtained in the eastern Mediterranean Ridge, and in fact these have set the scene for extensive follow up studies in the second part of the 90's, inclusive of studies with diving vehicles and ODP drilling. Since then, the more recent findings of mud volcanoes and mounds by the international TTR community in the Gulf of Cadiz and off the Moroccan Margin have proven to be of international and outstanding quality.

In addition, since 1997 attention has been paid towards a number of newly observed types of mounds at the NE Atlantic Margin, the carbonate mounds, and to the understanding of their internal and external forcing conditions.

Research carried out by NIOZ in the framework of EU funded research programs over the last years (ENAM, STRATAGEM, ECOMOUND, GEOMOUND) is related to a study of the development of the large carbonate mounds at the SE and SW Rockall Trough Margins. Here giant mounds between 600-1200 m water depth rise 5 to 300 m above the surrounding seafloor and have diameters at their basis of up to 5km. Smaller and individual, sometimes buried mounds are found at the upper slope while, especially at the SW Rockall Trough margin, higher, steeper and individual mounds are found deeper downslope (900-1100 m). At the middle slope the mounds merge into a complex structure and form a cluster with a very irregular upper surface and an apparent lack of internal reflectors (600-1000 m depth). Buried mounds, at relatively shallow depth below the seafloor are also found, and it appears if at least two generations of mounds can be recognized. Internal and external forcing conditions of mound formation, in a variety of tectonic and sedimentary settings will be discussed and highlighted.

THE ACOUSTIC AND SEDIMENTOLOGICAL FACE OF THE SEDIMENTS SURROUNDING THE BELGICA MOUNDS PROVINCE

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Sidescan sonar imagery acquired during the TTR-7 cruise in July 1997 were the first to reveal the presence of a current swept seafloor between 500 and 1200 m on the upper slope of the Eastern Porcupine Seabight (SW off Ireland). Most of these features (parallel grooves, sand sheets and sand waves) were found within the vicinity of coral banks, called the Belgica Mound province. Current speed was estimated up to 100 cm/s flowing northward. The depth interval in which these currents occur coincides with the presence of a core of Mediterranean Outflow Water. Most likely the sharp density contrast between the MOW and the overlying European North Atlantic Water is thought to locally enhance the effects of this contour current.

In this presentation we illustrate and discuss the seismic and sedimentological facies of the drift body surrounding the Belgica Mound province. Therefore, airgun-array and sparker seismic profiles (respectively low- and very high-resolution) are used. We clearly observe the influence of the mounds on the bottom current regime. At present, it is clear that the present-day and past current regime is by far more complicated then generally assumed.

A set of giant piston cores taken within the framework of the ENAM-2 and IMAGES programmes were analysed for their magnetic susceptibility, grainsize distribution, foraminifer and IRD content within the fraction superior to 150 µm. We also investigated the abundance of planktonic foraminifers (e.g. N. pachyderma s.) and the epibenthic foraminifers U. Mediterranea and P. ariminensis. The results suggest the presence of intensified bottom currents, within the MOW core, during climatic warmer periods.

Although the work in this region is within an early stage of investigation, we might add this region to the large inventory of sediment drifts and contourites.

THE FAUNAL COMMUNITY ASSOCIATED TO MUD VOLCANOES IN THE GULF OF CADIZ

M.R. Cunha[1], A.M. Hilario[2], I.G. Teixeira[2], and all the scientific party aboard the TTR-10 Cruise

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The macroinvertebrate faunal community of some of the mud volcanoes in the Gulf of Cadiz was investigated in July 2000 (TTR-10 Cruise aboard the R/V *Prof. Logachev*). A total of 2I gravity core samples were taken in 8 mud volcanoes from the Portuguese, Spanish and Marrocan margins. A quarter of the top layer (approx. 30 cm) of each sample was reserved for biological analysis. Some specimens were also retrieved from a TV-assisted grab sample collected in one of the Marrocan volcanoes. These samples provided a collection of about 150 specimens belonging to more than 20 macroinvertebrate taxa. The specimens are not yet fully identified due to the incipient knowledge of the fauna of the mud volcanoes from this region and to the typical endemicity of chemosynthesis-based benthic communities.

The majority of the specimens collected (56.6%) were assigned to the Pogonophora. These worms, as other symbiont-containing species, rely on methane or sulphide bacterial oxidation and are frequently associated with the expulsion of methane-rich fluids in different geological contexts in passive and active margins. The higher density of pogonophoran tubes was observed in the Bonjardim mud-volcano (Portuguese margin) and in the Marrocan mud-volcanoes while the Spanish margin showed the lowest densities. In the Portuguese volcanoes different kinds of tubes, probably belonging to different species, were recovered and are now being studied by a specialist.

Besides pogonophoran worms only a few other species were retrieved from the core samples. A thyasirid bivalve, probably also a symbiont-containing species, was collected in one of the Portuguese volcanoes and polychaete worms were frequent in the Spanish volcanoes. Most species were collected in the Marrocan margin especially due to the grab sample that included 18 different species, mostly small crustaceans and molluscs but also pycnogonids and echinoderms. Several samples, mostly from the Marrocan margin, also contained pieces of dead coral (*Lophelia* and *Madrepora*) sometimes with attached sessile fauna (mainly cnidarians). Despite the small amount of information given by these very preliminary results, we think that they are enough to prove the interest of further and more thorough biological research in this area.

PETROGRAPHY AND STABLE ISOTOPE GEOCHEMISTRY FROM A RECENTLY SAMPLED CARBONATE CRUST FROM THE GULF OF CADIZ

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The sample consists of a kind of matrix supported conglomerate. Semi-rounded up to 4 cm large pale yellow-brown fine crystalline clasts float in a more beige brown matrix enriched in fossils and penetrated by pogonophores worms. This aspect of the rock is nicely deducible from a 3D-Computerized Tomography reconstruction. A small well-preserved solitary coral was present in the matrix aside shell fragments. The outer surface of the sample is dark brown coloured most likely due to the presence of iron oxi/hydroxides. The clasts typically are characterised by the presence of open or sediment filled cracks. Under transmitted light microscopy there is a marked difference between clasts and matrix. The clasts consist of a network of randomly oriented minute aragonite needles less than 3 µm in length. These aragonite needles become somewhat coarser crystalline where they seem to have filled pores. Well-developed acicular aragonite radiating bushes up to 2 mm in length develop in the cracks. These clasts are very pure in $CaCO_3$. Locally some dolomite rhombs up to 30 µm in diameter can be localised. The latter often occur in clusters. In contrast to the matrix no foraminifera or other bioclasts nor detritals like quartz detritals occur. Also framboidal pyrite is more common in the matrix than in the clasts. This partially can be explained by the fact that the framboidal pyrites preferentially occur as clusters within or next to the foraminifera. In the matrix locally strongly altered fragments, 1-2 mm in size occur. The latter might correspond to altered volcanic ash fragments. Within the matrix some dessication-like (syneresis?) cracks develop around some of the fragments and clasts. Also biomolds and large circular pores relating to worm tubes are present. Intra-foraminiferal porosity is also common. In contrast to the clasts these pores are not cemented.

The one clast analysed displayed a $\delta^{13}C$ value of -22.91% and a $\delta^{18}O$ value of +4.82%. Taking the difference in carbon and oxygen fractionation behaviour between aragonite and calcite into account there is no significant difference in stable isotopic composition with the matrix. The latter varied between -25.30% and -26.86% for $\delta^{13}C$ and between +4.30% and +5.02% for $\delta^{18}O$. However, here it should be mentioned that this signal is slightly diluted by the presence of bioclasts, which make up <5% of the matrix. The latter most likely possess a signal varying for both stable isotopes around 0%.

Similar petrographical observations and stable isotope geochemical signals have been reported from many carbonate crusts collected from oceanic settings, in particular from mud volcanoes (e.g. Matumoto, 1990; Bohrmann et al., 1998; Aloisi et al., 2000). The depleted carbon signature could be indicative for carbonate precipitation within the sulphate reduction diagenetic realm, which is also supported by the existence of framboidal pyrite. However, knowing that these crusts form at the ocean floor it is more likely that a major depleted d13C source is reflected in this signal which became diluted with CO_2 in equilibrium with the atmosphere. In the latter case methane oxidation could be a likely source. The enriched $\delta^{18}O$ signal seems to be typical for carbonate crust formed under these conditions, and is often interpreted in relation to the destabilisation of gas hydrates.

Pelagic and hemipelagic sedimentation

A EUROPEAN DEEP MARGIN RECORD OF THE ICE AGE ORIGIN

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Phanerozoic Earth has known three climate modes which have been referred to as "green-house Earth" with no or just a small ice cap, "doubt-house Earth" with one ice cap and "ice-house Earth" with two ice caps.

This talk will briefly review a large-scale climate change scenario for the Tertiary. After which special attention will be paid to deep continental margin sedimentary sections of the Greenland-Norwegian Seas which reveal a record of the final events that lead to the formation of the northern ice cap and present-day Earth's ice-house conditions.

Dusted data and an old theory will be tested against recent ODP drilling results.

RECENT FORAMINIFERAL ASSEMBLAGES FROM CARBONATE MUD MOUNDS OF THE PORCUPINE BANK (NE ATLANTIC)

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Attention towards studies of the geomorphologic, biological and ecological structure of carbonate mud mounds has strongly increased during the last years, especially these interests after the publications of Hovland (1990, 1994), who proposed an association of these structures with gas or hydrocarbon (methane) seepages. Modern foraminifera, living at and around the mud mounds, are sensitive to microenvironmental conditions, and thus could be good markers of mound growth patterns.

In the present paper we describe species diversity and the distribution of recent benthic foraminiferal assemblages from carbonate mud mounds at the Porcupine Bank (North Atlantic). The material was collected during the R/V *Pelagia* cruise organised by NIOZ in July-August 2000.

Six box-core sampling stations situated along a transect through two carbonate mud mounds were analysed. The benthic foraminifers were studied quantitatively in the fraction >150 um from the top 0.5 cm of the sediments. The foraminiferal taxa were identified according to the classification by Loeblich and Tappan (1988) and at species level by Murray (1973) and Jones (1994). The cluster diagrams were calculated for studies of sample similarity using statistic programme "STATISTICA 5.6".

Seventy-five species in total, belonging to 55 genera of benthic foraminifera were recorded in the area of the investigation. The two sampling sites from the tops of both mounds (with recovered corals branches) are characterised by a foraminiferal assemblage with as dominant (>10%) species *Trifarina angulosa,* subdominant (5-10 %) *Planulina ariminensis, Planorbulina* sp., *Cassidulina laevigata* and minor (2.5-5 %) *Bulimina marginata, Trifarina bradyi, Cibicides rufulgens, Globocassidulina subglobosa, Gyroidinoides orbicularis, Cassidulina obtusa, Melonis barleeanus, Amphicoryna scalaris, Paromalina crassa, Uvigerina* sp. This assemblage is typical for the NE Atlantic continental slope from 500 to 1500 m deep (Weston, 1985).

The sampling sites located on slopes and outside of the carbonate mud mounds are characterised by different and specific foraminiferal assemblages. The taxonomic composition of these samples are quite similar to the "top mound assemblage" but the occurrence of species in assemblage is very different. The main reason for this is the high occurrence of one species in the assemblage (*Trifarina angulosa*-34%, *Cibicides rufulgens* -13.6%, *Cibicidoides pachyderma* 1.1.-13% *Paromalina crassa*-22%, accordingly). The statistic results show that the correlation coefficient between these does not exceed 0.5. These assemblages contain also some shallow-water species: Parafissurina sp. *Oolina hexagona, Quinqueloculina* sp., *Elphidium* sp., *Lagena* cf. *interrupta,* (Murray, 1973), suggesting that they are of allochthonous origin, and result from current induced bottom transport by high velocity near bed currents, and/or sliding of soft sediments of the slope.

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PECULIARITIES OF HEMIPELAGIC SEDIMENTATION AND MASS-WASTING PROCESSES ON THE NORTH-EASTERN FAEROE MARGIN

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The data obtained on the North-Eastern Faeroe continental slope and in the Norwegian sea during TTR-8 cruise (leg 2) are discussed. Mass-wasting deposits are widespread on the North-Eastern Faeroe margin. The formation of large slides in the region started in the Miocene (van Weering et al., 1998). Late Quaternary activity of mass-wasting was reported by Kuijpres et al. (2001). This work is especially focused on the studying of the changes in the depositional environments resulted in the intercalation of mass flow deposits and hemipelagic sediments settled on the North- Eastern Faeroe slope and in the Norwegian basin. Four cores from the slope

(TTR8-AT104-TTR8-AT107) and two cores (TTR8-AT108, TTR8-AT109) from the Norwegian basin were studied in detail in thin-sections, X-Ray diffraction and grain-size analyses were curried out.

Some features related to mass-wasting activity were reported in the lower parts of the cores TTR8-AT104, TTR8-AT106 and TTR8-AT107, situated within the large slide. They are presented by debris flow deposits in the core TTR8-AT104 and by small-scale distortions and inclined boundaries in the cores TTR8-AT106 and TTR8-AT107. Upper intervals of these cores and the core TTR8-AT105 composed mainly of silty clay were initially described as hemipelagic sediments with intercalating bottom current deposits presented by sandy/silty layers. All four cores contain two marl layers with tephra layer in between. During the followed study of the core TTR8-AT105, four layers with abundant gravel particles were observed and hypothetically interpreted as Heinrich layers. Taking into account age of the Heinrich events (Rasmussen et al., 1996) and dating of the tephra (23 ka), carried out by Kuijpers et al. (2001) rates of the sedimentation for the core TTR8-AT105 were distinguished. Rates of the sedimentation for the core TTR8-AT104 were calculated based on the data obtained by Kuijpers et al. (2001). The intervals, which showed abnormally high rates (36.4 cm/ka in the middle part of the core TTR8-AT105, 9.2 and 10.9 in the upper part of the core TTR8-AT104) were assumed to contain mud flow deposits and turbidites. Low activity of the contour currents during glacial periods (Rasmussen et al., 1996) allows to describe some of the graded sandy/silty layers as turbidites.

Two cores collected in the elongated depression of the Norwegian basin contain in their lower parts a 4m thick layer composed of homogeneous clay without bioturbation marks. The whole thickness of the layer as seen on the subbottom profiler record, is approximately 8 meters. Grain size analyses showed, that a distribution of the thin silty admixture down the core has the same trend as in the upper part of homoginite from the eastern Mediterranean (Cita et al., 1996), so this layer was formed by a rapid redeposition of huge values of the sediments and it was reported as a megaturbidite. The overlying hemipelagic clay contained small amount of sandy admixture of foraminifera.

Clay minerals in the studied samples are presented by illite, smectite, chlorite and by mixed-layer clays (illite/smectite and chlorite/smectite). Predominance of illite was observed in the sediments of the Norwegian basin and in the marl and tephra layers from the Faeroe continental slope. All other samples from the slope show predominance of smectite or equal contents of these minerals. Thus two versions of the megaturbidite origin can be supposed: marl from the Faeroe slope was remobilized and seattled in the elongated depression of the Norwegian sea approximately 25000 years BP; redeposition of the sediments of the Norwegian basin could take place before 16000 years BP.

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MICROPALEONTOLOGICAL INVESTIGATION OF ROCK CLASTS FROM MUD VOLCANIC DEPOSITS IN THE GULF OF CADIZ

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Lithological and micropalaeontological investigations were carried out for the mud volcanic deposits from seven mud volcanoes discovered during the TTR-9 and TTR-10 cruses of the R/V *Professor Logachev* (table 1).

A collection of 165 rock fragments of different lithologies from the mud volcanoes was dated using micropalaeontological method. Dating of the rock clasts was based on study of calcareous nannofossils assemblages. Coccoliths assemblages were also analysed in matrix from the mud volcanoes.

The rock clasts may be classified in four main age groups: 1) Upper Cretaceous rocks (21 clasts); 2) Eocene rocks (37 clasts); 3) Miocene rocks (48 clasts) and 4) Pliocene rocks (14 clasts). 45 clasts were free from calcareous nannofossilis therefor they age are remain undefined.

The Upper Cretaceous rocks are found in the following mud volcanoes: Bonjardim, Carlos Ribeiro, Tasyo. It is also, possible that two clasts of marlstones from the mud volcano Rabat are Upper Cretaceous in age (fig. 1a).

Assemblages of calcareous nannofossils indicate that the ages of the rocks range from Santonian to Maastrichtian times. The oldest rock is Santonian mudstone (CC15-CC16). This clast was encountered in the Bonjardim mud volcano. Most of Upper Cretaceous clasts in the collection has Campanian age (CC21-CC23) and Maastrichtian (CC23-CC26) limestones and marlstones (fig. 1c). Mudstones, claystones and sandstones are less common in this collection (fig. 1b).

Upper Cretaceous calcareous nannofossils are moderately or poorly preserved and sometimes diversified. The most abundant species are *Cribrosphaerella ehrenbergii, Microrhabdulus decoratus, Watznaueria barnesae, Micula decussata, M. concava, Arkhangelskiella cymbiformis, Quadrum gothicum, Quadrum trifidium, Q. sissinghii, Predicosphaera cretacea, Manivitella pemmatoidea, Ceratolithoides aculeus, Eiffelithus turriseiffelii, Reinhardtites anthophorus, Stradneria crenulata, Tranolithus phacelosus, Lithraphidites carniolensis, L. quadratus.*

The Eocene rocks are frequently encountered in the collection of the clasts. They are common in the samples from the mud volcanoes Ginsburg, Yuma, Jesus Baraza, Carlos Ribeiro and less common in the mud volcanoes Bonjardim and Rabat. The only one sample in the Tasyo mud volcano was approximately dated as Upper Eocene (fig. 2a).

Coccoliths assemblages are observed in the clasts indicate that the age ranges from Middle to Upper Eocene (NP14?- NP15-NP20), mainly Middle Eocene (NP15-NP17) (fig. 2b). The largest part of the clasts is limestones and marlstones, rock fragments of sandstones, claystones and mudstones are less abundant in the collection of Eocene rocks (fig. 2c).

Eocene coccoliths are fine or moderately preserved and diversified. The most common species are *Reticulofenestra umbilica, Discoaster saipanensis, D. barbadiensis, D. tanii, Cribrocentrum reticulata, Cyclicargolithus floridanus, Dictyococcites bisecta, Ericsonia formosa, Chiasmolithus grandis, Sphenolithus radians, Neococcolithes dubius, Helicosphaera seminulum.*

Miocene rocks make up the largest proportion in the collection of clasts. They are frequently occur in the mud volcanoes Bonjardin, Carlos Ribero, Tasyo, Yuma, Ginsburg and less abundant in Rabat and Jesus Barasa (fig. 3a).

The greater part of the Miocene rock clasts is Lower or Middle Miocene ages (NN1-NN7) (fig. 3b). The Miocene rocks are diversified in lithology. The biggest part of them is claystones and limestones. Sandstones, marlstones, mudstones and siltstones are found in smaller number (fig. 3c).

In general, coccoliths assemblage are poorly preserved and has low diversity. Only a few samples contain fine preserved and diversified Miocene coccoliths assemblages. Typically Miocene coccoliths co-occur with reworked Upper Cretaceous nannofossils and rare with Paleocene and Eocene ones. The commonly encountered Miocene coccoliths are *Reticulofenestra*

Table 1. The mud volcanoes discovered during the TTR-10 cruise

Mud volcano	Geographic coordinates	Water depth, m	Samples of the rock clasts	Samples of matrix
Bonjardim	lat. 35^{0}28'N, long. 9^{0}00'W.	3059	31	4
Carlos Ribeiro	lat. 35^{0}47'N, long. 8^{0}25'W.	2206	21	3
Ginsburg	lat. 35^{0}22'N, long. 7^{0}05'W.	910	28	3
Rabat	lat. 35^{0}19'N, long. 7^{0}8'W.	1060	16	2
Jesus Baraza	lat. 35^{0}35,50'N, long. 7^{0}12'W.	1091	13	2
Yuma	lat. 35^{0}26'N, long. 7^{0}06'W.	986	28	1
Tasyo	lat. 35^{0}46'N, long. 7^{0}07'W.	1105	28	3
		Total:	**165**	**18**

pseudoumbilica, R. gelida, Discoaster druggii, D. variabilis, Sphenolithus heteromorphus, Sphenolithus belemnos, Cyclococcolithus macintyrei.

Pliocene rocks are limited in number. These rocks are only common in the mud volcanoes Jesus Baraza and Tasyo. They are also found in the Rabat mud volcano (fig. 4a).

Most of Pliocene rocks are fragments of various claystones (fig. 4b). At least a portion of these rocks is Lower Pliocene in age (fig. 4c).

Pliocene coccoliths found in the clasts are moderately preserved and co-occur with reworked Upper Cretaceous and Eocene nannofossilis. The following Pliocene species were identified in the clasts: *Gephyrocapsa* sp, *Discoaster assymetricus, Reticulofenestra pseudoumbilica, Cyclococcolithus leptoporus, Helicosphaera kamptneri.*

The mud volcanoes can be subdivided on the basis of the ages of the rocks from mud breccia on the three main groups.

The first group includes two mud volcanoes: Bonjardin and Carlos Ribeiro. Upper Cretaceous, Eocene and Miocene rocks are found in the samples from them.

The second group combines four mud volcanoes: Jesus Baraza, Yuma, Rabat, Ginsburg. Eocene and Miocene-Pliocene rocks are found in these mud volcanoes.

The only one mud volcano Tasyo may be includes in the third group. Miocene - Pliocene and Upper Cretaceous rocks are abundant in this mud volcano.

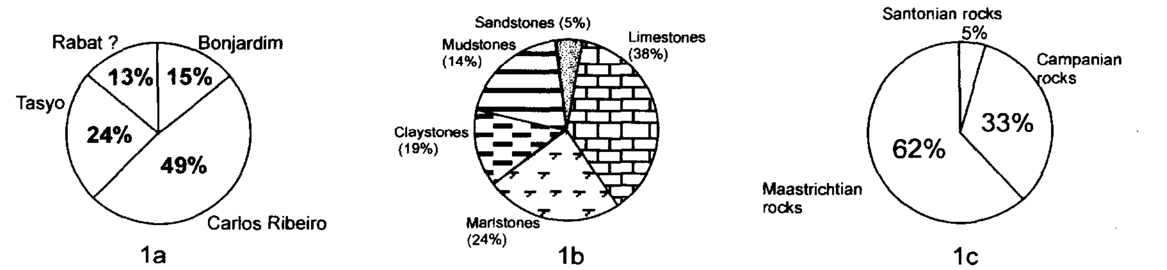

fig 1. Summary information on Upper Cretaceous rocks from mud breccia: (1a) distribution in the mud volcanoes; (1b) lithology; (1c) ages

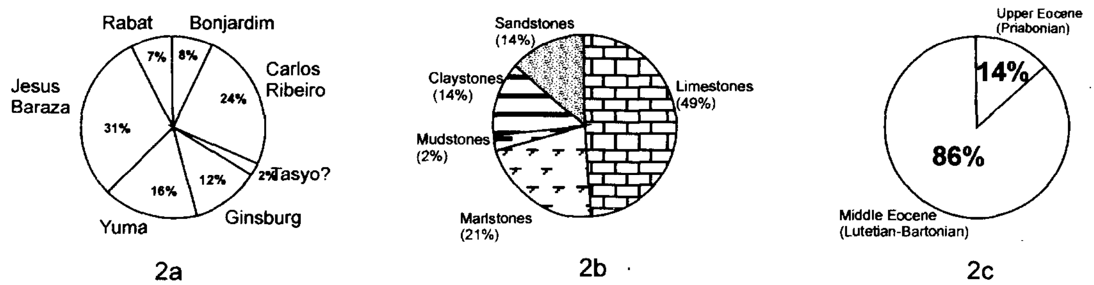

fig 2. Summary information on Eocene rocks from mud breccia: (2a) distribution in the mud volcanoes; (2b) lithology; (2c) ages

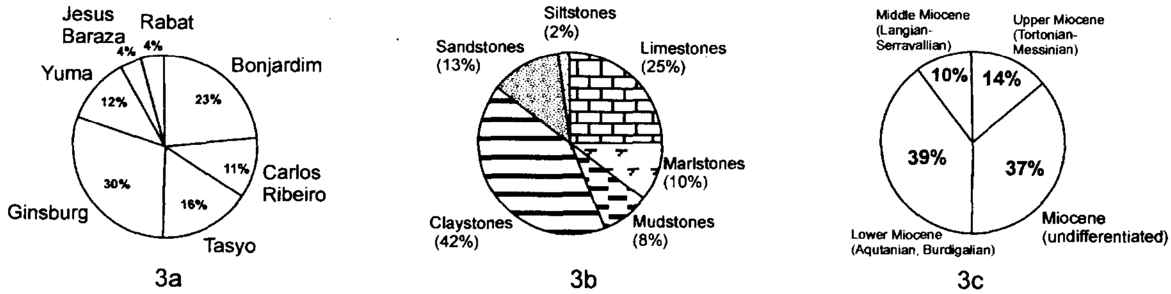

fig 3. Summary information on Miocene rocks from mud breccia: (3a) distribution in the mud volcanoes; (3b) lithology; (3c) ages

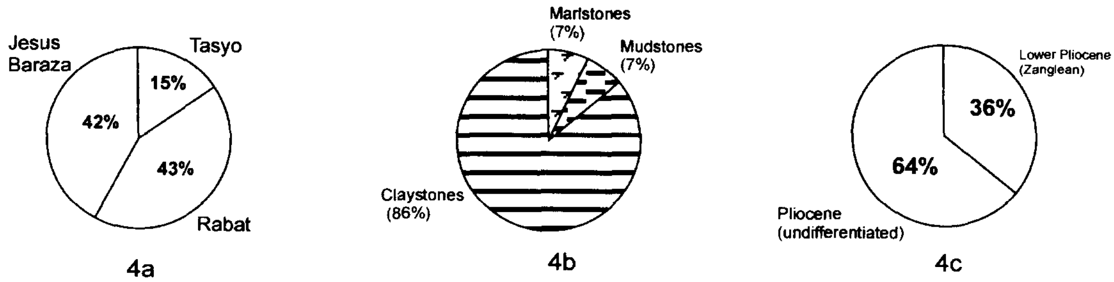

fig 4. Summary information on Pliocene rocks from mud breccia: (4a) distribution in the mud volcanoes; (4b) lithology; (4c) ages

Volcanism and hydrothermal venting of the Mid-Atlantic Ridge

EVOLUTION OF EXPLOSIVE SEAMOUNT VOLCANISM: EVIDENCE FROM 37°N ON THE MID-ATLANTIC RIDGE

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The Lucky Strike segment of the slow-spreading Mid-Atlantic Ridge is characterised by an unusually large central volcanic complex with a history of explosive eruption and hydrothermal activity. This ~65km long, second order ridge segment is centred on 37°17.5'N and 32°16.5'W. At its deepest ends, the segment is ~3200 m deep.

Bathymetry and sidescan sonar imagery together reveal a slow-spreading ridge segment that has a large composite volcanic plateau at its centre. The central volcanic complex comprises a plateau that rises from a mean basal depth of 2200 m. This plateau is 5 km wide (east to west) and 6 km long (north to south). The volcanic plateau comprises up to seven constructional terraces with three conical edifices at its highest point in the centre. The three volcanic cones are relatively old and comprise late-stage fractionated and highly vesicular basalt. The presence of hyaloclastites associated with these cones indicates explosive submarine activity. In between the three central cones is a circular depression of recent volcanic activity and subsidence. To the north and south, the central volcanic complex is characterised by recent and extensive sheet-like flows. To the north and south of these sheet-like flows, the ridge segment contains regions of hummocky flows, as well as more sediment.

Brittle tectonic deformation in the form of fault scarps has recently bifurcated the central volcanic plateau and post-dates the three central cones. This activity forms a north-south trending graben that forms a small valley immediately to the west of the three cones. Subsidence is centred on the volcanic plateau where it has a maximum throw of ~100 m. Extensive sheet flows, to the north and south of the central cones, are retained by the graben walls and post date the start of tectonic subsidence.

The central volcanic complex has geochemical variations that reflect magmatic fractionation processes. The three cones at the top of the volcanic complex, in the centre of the plateau, are enriched in incompatible elements, with up to 300ppm Ba and 300ppm Sr, compared to the plateau that has only 60ppm Ba and 110ppm Sr (Langmuir et al., 1997). The three central cones are also highly vesicular compared with the subjacent plateau. The central depression located between the three cones comprises fresh and vitreous collapsed lobate flows and lava pillars, and has been described as a recently active lava lake (Fouquet et al., 1999). Fouquet (1999) also reports that there are hyaloclastic and volcanic breccias deposited on the flanks of the three cones and around the periphery of the lava lake, that are also host to a vigorous hydrothermal system.

We interpret the central volcanic complex as a composite feature that is the result of an interplay between brittle tectonics and volcanic activity linked to magma evolution and changes in styles of eruption. From the evidence collected by previous studies and the new data collected during cruise TTR-10 leg 2, a model is proposed for the tectonovolcanic evolution of this complex. This model is based on mechanisms of magma buoyancy to control the maximum height of the central volcanic complex. Volcanic eruption is limited and ceases when the height and density of the magma column feeding the top of the volcanic complex is equal to the depth and density of the crust overlying the magma reservoir. Thus the maximum height of the central volcano is achieved when the magma and crust are in isostatic equilibrium.

The oldest lavas form the base of the volcanic plateau and are avesicular, aphyric glassy pillow types. These were erupted relatively slowly forming moderate gradients at their flow fronts that combined to form lobate terraces. At this time, tectonic activity was compensated for by eruption and hence no major graben system was formed. As the plateau grow in height, reaching some 200 m above its base, a reduction in driving force for the magma and hence volcanic activity allowed tectonic strain and subsidence to accumulate. This resulted in the eruption of more fractionated lavas that included large megacrysts of plagiocase.

At the top of the volcanic complex, the three volcanic cones represent the maximum height of the volcano. As they represent isostatic equilibrium between the magma column and crustal depth to the magma chamber, further volcanic eruption either ceased or could only occur if the magma density decreased. In the case of the three cones, magmatic stagnation allowed evolution and plagioclase crystal growth with increasing volatile content. Assimilation of altered crust may also have increased the volatile contents of these magmas. Despite a water depth of 1700 m, the volcanic activity at these three cones was explosive, with the formation of hyaloclastite and volcanic breccias. Lenticular structures in the bedded hyaloclastite recovered from the depression between the three cones, and the coarsening-upwards grading of some layers indicate surge deposition during volcanic explosions. Magma vesiculation, of up to 70% in these lavas, assisted explosive eruption and magma fragmentation causing the hydroroclastic deposits. Evidence of layers of shell debris and oxidised horizons between hyaloclastic layers indicates the explosive activity was sporadic. Concentric faulting of the summits of two of the three cones indicates that gaseous eruption and explosive activity led to partial subsidence of the summit. Although explosive, the volcanic activity at this time was of a low volume.

At some time during the hydroroclastic activity at the three summit cones, tectonic deformation became dominant over volcanic accretion. The result was graben formation and subsidence by at least 100m of the central volcanic complex. Effusion rates rapidly increased resulting in extensive sheet flow formation that partially infilled the newly forming graben. Initially these sheet flows were vesicular and plagioclase phyric, having essential the same composition as the three pyroclastic cones. However, later sheet flows were aphyric and avesicular, reflecting degassing and replenishment by new magma.

Hydrothermal activity has affected mainly the pyroclastic deposits. The younger sheet flows and the lava lake in the central depression are not involved in hydrothermal mineralsation. This indicates that the most intense hydrothermal circulation was established during the period of magma accumulation while and volcanic stagnation. This was also the time of pyroclastic activity and formation of the summit cones.

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EVOLUTION OF THE LUCKY STRIKE ORE FIELD BASED ON PETROLOGICAL STUDIES OF BASALT

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During the second Leg of the 10th "Training Through Research" (TTR-10) cruise in the Atlantic Ocean, the investigation of the Lucky Strike area was carried out with TV-controlled grab, dredge, CTD system, and OREtech deep-towed side scan sonar.

The Lucky Strike ore field is situated in a segment of the Mid-Atlantic Ridge (MAR) rift valley (36-38°N). The field is associated with a depression between three volcanic cones on an elongated volcanic plateau, located in the middle of the axial zone of the Lucky Strike segment (37°17,5'N; 32°16,7'W) (Fouquet et al., 1994).

A number of samples of Mid-Atlantic Ridge Basalt (MARB) were collected both from the field and from adjacent areas. Tops and slopes of volcanic cones, volcanic plateau, depression, and bottom of the rift valley at a distance of up to 20 km from the field were studied. Beside fragments of chimneys of active and inactive black smokers, hydrotermally altered rocks were subsampled. Analysis of thin-sections from the samples of MARB and polished section samples from the sulfide formations were carried out in laboratories of Moscow State University.

The obtained data of this study were compared with the existing dataset (Cannat et al., 1999, Fouquet et al., 1984). The results of this comparison and also interpretation of the deep-towed 30 kHz side-scan sonar line allowed to come to the following conclusions:

- The ore field Lucky Strike is a unique evidence of hydrothermal activity on this segment of MAR.
- The zone of hydrothermal alterations of rocks covers the area of 0.5 km^2 and is associated with a "lava lake" in the depression between three cones. The basalts composing the volcanic cones show no or very little traces of alteration.
- The basalts forming volcanic cones differ strongly from the typical MORB, that testifies to the presence of a different magma chamber.
- Beside the main chamber there are several secondary magma chambers.
- Azores hot spot render a little influence on this segment under condition of slow-spreading zone (Cannat et al., 1999).
- Nowadays the volcanic activity is ceased.

Based on these facts, the prospective scheme of evolution of the Lucky Strike ore field and model of hydrothermal activity were made.

The influence of Azores plume has caused the occurrence of an unusual magma chamber, extremely rich in fluids like H_2O, S, CO, CO_2, and H_2S. After the lava discharge, the pressure in the chamber decreased and the remaining magma started to squeeze out onto the surface, forming subvolcanic bodies. The devastation of the chamber has caused collapsing of the volcanic construction which is currently taking place, thus promoting the increase of the pressure on the underlying rocks.

It is obvious, that in this segment of the rift valley the area of hot volcanic zone is the most weakened one. The increased thermal flow results in the convective movement of the oceanic water which, while passing through the basalts of the second layer of the oceanic crust and through the secondary magma chambers, is getting enriched in elements containing in these rocks. The hydrothermal solutions migrates upward along the most weakened zones. In this case, one of these zones is the main feeder channel of the volcanic structure, as the secondary channels are sealed by subvolcanic rocks. Taking into account, that the zone is located in the depression, it can be suggested that the occurrences of sulfide ore are associated with the "lava lake" and the hydrothermal alterations of the host rocks take place in the peripheral parts of the feeder channel.

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THE FAUNAL COMMUNITY FROM THE LUCKY STRIKE HYDROTHERMAL VENT FIELD

M.R. Cunha[1], A.M. Hilário[2], I.G. Teixeira[2], and all the scientific party aboard the TTR-10 Cruise

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The macroinvertebrate faunal community from the Lucky Strike hydrothermal vent site (Mid-Atlantic Ridge, 37°18'N, 32°16'W) was first reported by Desbruyeres et al. (1994) as a preliminary list following a Nautile dive series during the Diva 2 Cruise. Another preliminary list of 25 invertebrate taxa, was published by Van Dover et al. (1996) and summarises the results of an Alvin dive series in 1993. Since then, a series of new species from this site have been described but others still remain undescribed.

In August 2000, the TTR-10 geological Cruise (Leg 2) at the Lucky Strike vent field also included a biological survey program. A series of 24 TV assisted grab samples taken in the vent field, 8 dredge operations carried out at its surroundings, and one gravity core, provided a collection of over 4000 specimens belonging to about 80 macroinvertebrate taxa which increases considerably the number of taxa cited for this location. One of the most interesting aspects of the collection is the high number of peracaridan species (42% of the identified taxa). The role of these small crustaceans in vent communities is still poorly known because they are seldom collected during submersible dives and are also difficult to see and identify in video footages.

The majority of the specimens (98.7%) were retrieved from the grab samples. The most abundant sample, accounted for 70.3% of the material collected and the two dominant species, the limpet *Shinkailepas* sp. and the mussel *Bathymodiolus azoricus*, accounted for 48.5% of the specimens. However, half of the recorded taxa were only represented by a few individuals (1-3) and in most samples the fauna was poor.

The multivariate analysis performed on the preliminary data matrix showed the high heterogeneity of the samples with estimated similarity values always below 45% (Bray & Curtis similarity index on presence/absence data). Nevertheless, three sample groups were identified in the dendrogram obtained by a UPGMA classification.

The samples from the dredge operations formed a discrete cluster. The community retrieved by this sampler included mainly a wide variety of sponges (77.8% of the specimens collected by this device) and only a few specimens of other taxa. These characteristics are related both to the sampling device and the peripheral location of the samples.

The samples from the grab operations are arranged in two main clusters. The first cluster is formed by the samples taken in very active sites, located very close to the lava lake, that are characterised by a typically rich and diverse hydrothermal vent community. This community is dominated by beds of mytilid mussels (*Bathymodiolus azoricus*) and its commensal polynoid polycahete (*Branchipolynoe seepensis*), limpet and coiled gastropods (e.g.: *Shinkailepas* sp., *Peltospira* spp., *Pseudorimula midatlantica, Protolira valvatoides*), bresiliid shrimps (*Mirocaris fortunata*), ampharetid polychaetes (*Amathys lutzi*) and other species (e.g.: the crab *Segonzacia mesatlantica*, the amphipod *Bouvierella curtirama* and the sea spider *Sericosura heteroscela*). The second cluster is formed by a heterogeneous group of samples taken around the lava lake. In average, only seven specimens were retrieved in each sample, mainly picked from the surface of hyaloclastic rocks and/or pillow lava. The faunal community is much poor comparatively to the one in the first cluster and it is characterised by the presence of sessile organisms (cnidarians and small sponges) and a diversity of vagrant species, mostly amphipods but also isopods, tanaids, and polychaetes, that occurred erraticaly.

The remaining samples, not included in these clusters, were located near the border of the vent field. In some of them no living animals were found, and the others had no more than one to three specimens of small crustaceans, polychaetes or sea urchins.

This analysis is indicative of a spatial pattern in the distribution of the organisms that can be related to an environmental gradient associated with the hydrothermal activity and geological settings within the vent field. The spatial pattern is evident not only by the decreasing number of species and density of the fauna occurring together with the increasing distance to active vents but also by the structural changes in both taxonomic and trophic composition of the faunal community.

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Van Dover, C.L., D. Desbruyeres, M. Segonzac, T. Comtet, L. Saldanha, A. Fiala-Medioni, C. Langmuir (1996). Biology of the Lucky Strike hydrothermal field. *Deep-Sea Research*, 43 (9): 1509-1529.

HYDROTHERMAL GEOLOGICAL MATERIALS FROM LUCKY STRIKE FIELD COLLECTED DURING TTR-10/LEG 2, AZORES, MID ATLANTIC RIDGE

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Introduction

The discovery of black smokers, massive sulphides and vent biota in Mid Ocean Ridges confirmed that the formation of new oceanic crust through seafloor spreading is intimately associated with the formation of metallic mineral deposits at the seafloor. It has been documented that the 350°C hydrothermal fluids discharging from the black smoker chimneys continuously precipitate metal sulphides in response to mixing of high temperature hydrothermal fluids with ambient seawater. The circulation of seawater through the oceanic crust is the principal process responsible for leaching and transport of metals in this environment, which eventually precipitate as massive sulphides at the seafloor or as stockwork and replacement sulphides in the subseafloor. The resulting massive sulphide deposits, which commonly include pyrite, sphalerite and chalcopyrite, can reach considerable size. The Lucky Strike hydrothermal field, located South of the Azores Islands in the Mid Atlantic ridge, results from the different processes described above, has an area of 1 km^2 and is considered as one of the most important sulphide deposits in the oceans (Fouquet, 1997).

During the summer of 2000 was carried out the TTR-10 Cruise. In its Leg 2, based on data obtained by Lustre 1996 Cruise through the ROV Jason images, 35 different areas of the Lucky Strike field were sampled using a tv-grab and a dredge as collection equipment; this sampling programme was essentially carried out in the vicinity of the active vents. The massive sulphide materials, together with metalliferous sediments and alterated rocks collected in the Lucky Strike field constitute a very important record of seafloor hydrothermal activity at mid-ocean ridges.

Geological Setting

The Lucky Strike hydrothermal field is located within the ridge, in a topographic high (water depth is 1700 m), where the axial valley is well defined; in the median eastern part of this segment there are three volcanic cones, made of different rock types (very vesicular pillow-lavas, lobates and hyaloclastites) surrounding a circular central depression where there is a lava lake. The hydrothermal site is located between these three volcanoes.

Hydrothermal Geological Materials - Data and Interpretation

The hydrothermal geological materials collected during TTR-10/Leg 2, may be included in three different groups:

1. Black smoker chimney fragments, with original shape preserved; 2. Massive sulphides (sulphide rubble) that could correspond to ancient chimney structures that were disaggregated, or could alternatively originate from sub-surficial deposits; 3. Materials with different degrees of hydrothermal alteration, mainly made of silica and disseminated sulphides.

1. From the three sites where hydrothermal chimneys were sampled, two were located in inactive areas, and one was very close to an active vent once the collected material was hot - with a temperature of sediments and rocks of about 26°C, measured on the arrival of the tv-grab - and included a very rich faunal community (both in numbers and species). The chimney fragments include two different types: A) Cu-chimneys, with a typical mineralogical zonation with chalcopyrite at the inner and at the bottom of the structures and anhydrite at outer part; B) Ba-Zn chimneys, primarily composed of barite, sphalerite and pyrite (amorphous silica may occur in variable amounts).

The black smoker chimneys are essentially conduits for the escape of high temperature end-members hydrothermal fluids. The fragments collected have a concentric zonation reflecting the sequence of mineral precipitation, not due to chemical gradients but to the decreasing temperature. The sequence of mineral precipitation which attends mixing of these high temperature fluids with cold seawater includes an early assemblage of chalcopyrite, pyrrotite and/or isocubanite (these two minerals present at low concentrations) and anhydrite at high temperatures followed by pyrite, sphalerite and marcassite at lower temperatures. The chalcopyrite-lined orifices and the outer anhydrite-rich wall constitute characteristic features that distinguish many black smoker vents from other chimney structures. However, considering the black smoker temperatures, minerals such as silica or barite are generally lost into the hydrothermal plume. The anhydrite is found at a more external position of the channels, because of its deposition during the initial phase of the chimney formation; this sulphate precipitates from seawater and its solubility increases considerably with decreasing temperature. In some samples it was possible to identify fragile anhydrite layers, easily removed, revealing its instability at low temperatures conditions. Based on the presence or absence of this mineral, and taking into account its retrograde solubility, it is possible to determine the relative ages of the chimneys. All these characteristics are consistent with numerous descriptive models of black smoker chimney formation (Haymon, 1983).

The Ba-Zn chimneys are considered to expel fluids having lower temperature; they are quite porous and are composed by several channels of different diameters. They have complex shapes, that could reflect a change in growth from multiple vent orifices at the base to a narrower vent at the top. These structures rarely have a central, dominating fluid conduit, and diffuse flow of fluid through the chimneys is usually via a porous network of interconnecting channels with diameters of less than a centimetre down to a few millimetres. Sometimes porous interiors are filled with fine grained aggregates of pyrite and sphalerite. Some parts of the chimneys have amorphous silica, which is deposited as colloidal material within the last remaining open spaces as the chimneys become progressively clogged and are gradually cut off from further hydrothermal flow. Barite is another sulphate present and usually precipitates after the sulphides in a later stage. This mineral is frequently associated with sphalerite aggregates coating small cavities, proving that there is a second generation of sphalerite.

2. The massive sulphide rubble form a group of old chimney fragments (without any preserved structure) and, possibly, derived from deposits exposed and later eroded by tectonic movements which are extremely frequent in this type of geotectonic environment. The samples are essentially made of pyrite and chalcopyrite. Sphalerite is also common and always younger than the others; it frequently occurs as crystalline aggregates (exhibiting colomorphic textures) or growth textures in association with pyrite and chalcopyrite. Barite occurs frequently as transparent euhedral crystals in vacuoles closely associated with sphalerite. Pyrite commonly develops colomorphic textures and is also seen as fromboidal or spheroidal aggregates of minute pyrite crystals.

3. The last group of hydrothermal material is represented by different volcanic rocks that were exposed to variable degrees of hydrothermal alteration; the study of different samples in this group has allowed the identification of a continuous evolution from unaltered volcanic rocks to completely silicified and mineralised rocks. Intermediate stages are represented by volcanics with variable degrees of silicification and disseminated sulphide mineralization. These observations allow us to infer that diffuse episodes of hydrothermal discharges could have had an important role in the evolution of the Lucky Strike field.

However, the coexistence of high and low temperature vents may reflect instantaneous zoning during a single protracted hydrothermal episode, or completely separate hydrothermal events (Herzig et al., 1995). All these inferences show that the hydrothermal history in this area is very complex. This becomes even more pronounced if we consider that the development of a vent field is the result of a long series of discrete hydrothermal events, each one having the possibility to create, modify or incorporate (e.g. the sulphide rubble) different sulphide bodies. Considering the lithologic mapping made during the LUSTRE 1996 cruise, and taking into account the sampling made during TTR-10 cruise, it seems that the massive sulphides occupy a considerable area on the Lucky Strike hydrothermal field, corroborating the hypothesis of ancient episodes of hydrothermal activity.

References:

Fouquet, Y., Where are the large hydrothermal sulphide deposits in the oceans? 1997. *Phil. Trans. R. Soc. Lond.*, A 355, 427-441.

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Herzig, P.M. & Hannington, M.D. Polymetallic massive sulfides at the modern seafloor: A review, *Ore Geology Reviews*, 10, 95-115.

Lustre 96 - Lucky Strike Exploration, Final Cruise Report, Woods Hole Oceanographic Institution, 1996.

ANNEX I

CONFERENCE PROGRAMME

SUNDAY, JANUARY 28
Moscow, "Universitetskaja" Hotel

18:00–21:00 Registration of participants

MONDAY, JANUARY 29
Moscow State University, Main Building, 6th floor, room 611

9:15–10:00 Registration of participants

Plenary Session:

10:00 Official opening
Welcoming addresses by:
V.T. Trofimov, Vice-Rector of Moscow State University
B.A. Sokolov, Dean of Geological Faculty
I.F. Glumov, Deputy Minister of Natural Resources, Russia
R.R. Murzin, Head of Marine Department, Ministry of Natural Resources, Russia
V. Zhivago, Yu. Mikhailitchenko, Ministry of Industry, Science and Technology, Russia
P. Bernal, Assistant Director General of UNESCO for IOC

10:30 *A.E. Suzyumov*
TRAINING THROUGH RESEARCH - 10 YEARS OF INTERNATIONAL CO-OPERATION

10:50 *M.K. Ivanov, J.M. Woodside, N.H.Kenyon and TTR Scientific Party*
PRINCIPLE SCIENTIFIC RESULTS OF THE TTR FIRST DECADE

11:40 *E. Bonatti*
WHY THE OCEAN?

12:10 *N.A. Bogdanov*
SOME ASPECTS OF GEOLOGY OF THE ARCTIC SHELF

12:30 *J. Woodside and Shipboard Scientists of the MEDINAUT/MEDINETHProjects*
NAUTILE OBSERVATIONS OF THE EASTERN MEDITERRANEAN MUD VOLCANOES AND GAS SEEPS - RESULTS FROM THE MEDINAUT AND MEDINETH PROJECTS

15:00 Round-city bus tour

TUESDAY, JANUARY 30
Mozhenka, "Zvenigorodskii" Hotel

Section 1: Deep-sea depositional systems and modern analogues of hydrocarbon reservoirs
Convenors: N. Kenyon and B. Cronin

14:40 *N. Kenyon*
CHANNELISED DEEP-SEA DEPOSITIONAL SYSTEMS IN THE MEDITERRANEAN: THE VALUE OF SONAR BACKSCATTER MAPPING

15:00 *A. Akhmetzhanov, N.H. Kenyon, T. Nielsen, E. Habgood, M. Ivanov, J.-P. Henriet, and P. Shashkin*
DEEP-SEA BOTTOM CURRENT DEPOSITIONAL SYSTEMS WITH ACTIVE SAND TRANSPORT ON THE NORTH-EASTERN ATLANTIC MARGIN

15:20 *M. Gee, D. Masson and A. Watts*
PASSAGE OF DEBRIS FLOWS AND TURBIDITY CURRENTS THROUGH A TOPOGRAPHIC CONSTRICTION: SEAFLOOR EROSION AND DEFLECTION

	OF FLOW PATHWAYS
15:40	*I. Kuvaev* GEOLOGICAL STRUCTURE AND MAIN STAGES OF SEDIMENTARY STRATA FORMATION ON WESTERN CONTINENTAL MARGIN OF IRELAND ACCORDING TO SEISMIC DATA
16:00	*H. de Haas, Tj. van Weering, and M. Stoker* DEVELOPMENT OF A SEDIMENT DRIFT: FENI DRIFT, NOTH-EAST ATLANTIC MARGIN
16:20	*B. Cronin, A. Hurst, G.G. Akhmanov, G. Spadini, and P. Rocchini* HIGH RESOLUTION MARINE GEOPHYSICAL DATA AS PROXIES FOR PREDICTION OF RESERVOIR QUALITY AND GEOMETRY IN DEEP-WATER SETTINGS: ANALOGUE DATA FROM MODERN, HIGH AND LOW N:G SETTINGS AND THEIR APPLICATION TO THE SUB-SURFACE

Section 2: Geomorphology and neo-tectonics
Convenors: M. Ergun and A. Limonov

17:00	*J.M. Woodside and Shipboard Scientists of ANAXIPROBE* THE ANAXIMANDER MOUNTAINS REVISITED
17:20	*M. Ergun and E. Z. Oral* CONJUNCTURAL POSITION OF THE ANAXIMANDER MOUNTAINS WITHIN THE EASTERN MEDITERRANEAN TECTONICS
17:40	*A. Volkonskaya, J. Mascle, and C. Huguen* GEOLOGICAL STRUCTURE OF THE UPPER SEDIMENTS IN THE EASTERN PART OF THE MEDITERRANEAN RIDGE
18:00	*A. Limonov* A PARADOX OF THE IONIAN SEA (CENTRAL MEDITERRANEAN): THE LATE MIOCENE-PLIOCENE SHALLOW-WATER BASIN UNDERLAIN BY MESOZOIC OCEANIC CRUST?
18:20	*L. Pinheiro, M. Ivanov, P. Terrinha, L. Matias, J.H. Monteiro, J.P. Henriet and the TTR-10 Leg1 Shipboard Scientific Party* THE SEISMOGENIC ZONE OF THE 1755 LISBON EARTHQUAKE
18:40	*S. Shkarinov* GEOLOGICAL STRUCTURE OF PORTUGUESE MARGIN NEAR THE MARQUES DE POMBAL FAULT AREA ACCORDING TO SEISMIC DATA
19:00	*T. Alves, R. Gawthorpe, D. Hunt, and J. Monteiro* TECTONIC CONTROLS ON THE DEPOSITIONAL AND EROSIONAL PROCESSES OFF WESTERN IBERIA
21:00	Video fragments of TTR expeditions, years of 1991 to 2000

WEDNESDAY, JANUARY 31

Section 3: Diapirism, mud volcanism, and hydrocarbon potential of deep sedimentary basins
Convenors: Tj. Van Weering and D. Miller

10:00	*D. Miller* POSSIBLE HYDROCARBON ASSOCIATED ACOUSTIC FEATURES ON THE CAMPOS BASIN SEAFLOOR, SE BRAZIL
10:20	*L. Pinheiro, M. Ivanov, J. Monteiro, J. Gardner, V. Magalhães, and the TTR-10 Leg1 Shipboard Scientific Party* A NEW MUD VOLCANO FIELD OFF S. IBERIA
11:00	*G. Akhmanov, M. Ivanov, J. Woodside, and M.B. Cita* LITHOLOGY OF DEEP-SEA MUD VOLCANIC DEPOSITS: GENERAL ASSESSMENT OF CURRENT KNOWLEDGE AND FUTURE RESEARCH NEEDS
11:40	*E. Kozlova, F. Baudin, S. Derenne and C. Largeau* GEOCHEMICAL CHARACTERISTICS OF ORGANIC MATTER IN ROCK

	CLASTS FROM MUD VOLCANO BRECCIA (THE GULF OF CADIZ)
12:00	*D. Ovsyannikov, A. Sautkin, and A. Sadekov* LITHOLOGY OF ROCK CLASTS FROM MUD BRECCIA OF THE BONJARDIM MUD VOLCANO (GULF OF CADIZ, NE ATLANTIC)
12:20	*J.P. Herbin, A. Battani, E. Deville, J.P. Houzay, and A. Prinzhofer* METHODOLOGY CONCERNING THE GEOCHEMICAL STUDY OF THE MUD VOLCANOES: FROM THE ONSHORE TO THE DEEP-WATER MARGINS
12:40	*V. Kaulio and V.Soloviev* SCALE ESTIMATION OF MUD VOLCANO DISCHARGE USING MEASURED TEMPERATURE DATA
13:00	*B. Murton and J. Biggs* NUMERICAL MODELLING OF MUD VOLCANOES AND THEIR FLOWS USING CONSTRAINTS FROM THE GULF OF CADIZ

Section 4: Shallow gas, cold seeps and gas hydrates
Convenors: J. Woodside and L. Pinheiro

16:00	*R. León, L. Somoza, M. Ivanov, V. Diaz-del-Rio, A. Lobato, F. J. Hernández-Molina, M.C. Fernandez-Puga, A. Maestro, J. Alveirinho and T. Vazquez* SEABED MORPHOLOGY AND GAS VENTING IN THE GULF OF CADIZ MUD VOLCANO AREA: IMAGERY OF MULTIBEAM DATA AND ULTRA-HIGH RESOLUTION SEISMIC
16:20	*V. Blinova and A. Stadnitskaya* COMPOSITION AND ORIGIN OF THE HYDROCARBON GASES FROM THE GULF OF CADIZ MUD VOLCANIC AREA
16:40	*A. Stadnitaskaia, M. Ivanov, Tj. van Weering, J.S. Sinninghe Damsté, J.P. Werne, R. Kreulen and V. Blinova* MOLECULAR AND ISOTOPIC CHARACTERIZATION OF HYDROCARBON GAS AND ORGANIC MATTER FROM MUD VOLCANOES OF THE GULF OF CADIZ, NE ATLANTIC
17:00	*L. Dimitrov and J. Woodside* DEEP SEA POCKMARK ENVIRONMENTS IN THE EASTERN MEDITERRANEAN
17:40	*G. Çifçi, D. Dondurur and M. Ergün* GAS-SATURATED SEDIMENTS AND THEIR AFFECTS ON SOUTHERN SIDE OF THE EASTERN THE BLACK SEA SEDIMENTS
18:00	*L. Mazurenko, V. Soloviev, M. Ivanov, L. Pinheiro, and J. Gardner* GEOCHEMICAL FEATURES OF GAS HYDRATE-FORMING FLUIDS OF THE GULF OF CADIZ
18:20	*A. Mazzini, I. Belenkaya, J. Parnell, B. Cronin, and H. Chen* EVIDENCE FOR MODERN AND ANCIENT FLUID FLOW IN THE SEAFLOOR CRUSTS: IMPLICATIONS FOR UNDERSTANDING THE PLUMBING OF SUBMARINE SEDIMENTS

THURSDAY, FEBRUARY 1
10:00-13:00 Poster section

Section 4 (continuation): Shallow gas, cold seeps and gas hydrates
Convenors: J. Woodside and L. Pinheiro

15:00	*V. Diaz-del-Rio, L. Somoza, J. Martinez-Frías, F.J. Hernández-Molina, R. Lunar, M.C. Fernandez-Puga, A. Maestro, P. Terrinha, E. Llave, A. Garcia, A. C. Garcia and J.T Vazquez* CARBONATE CHIMNEYS IN THE GULF OF CADIZ: INITIAL REPORT ON THEIR PETROGRAPHY AND GEOCHEMISTRY

15:20	*V. Galaktionov* ACOUSTIC CHARACTERISTICS OF THE BSR AND ADJACENT ENHANCED REFLECTIONS AT THE SOUTHERN EDGE OF THE VØRING PLATEAU AND NORTH-EASTERN PART OF THE STOREGGA SLIDE AREA
15:40	*S. Bouriak* 'SPLIT' BSR AT THE VØRING PLATEAU AND BELOW THE STOREGGA SLIDE DEPOSITS - NEW DATA OF THE TTR-10 CRUISE, AUGUST 2000
16:00	*T. Matveeva* CONTOURITES, FLUID TRANSPORT AND FORMATION OF GAS HYDRATE ACCUMULATION (ON THE BASIS OF DSDP-ODP DRILLING RESULTS)

Section 5: Biosphere - geosphere interaction
Convenors: J.-P. Henriet and J. Wilson

16:40	*J.-P. Henriet* MOUNDS IN THE BIOSPHERE. A MODEST BUT SINCERE HOMAGE TO VLADIMIR I. VERNADSKY AT THE 75TH ANNIVERSARY OF THE PUBLICATION OF 'BIOSFERA' (1926)
17:00	*J. B. Wilson* DEEP-WATER CORAL RESEARCH - PAST AND FUTURE
17:20	*Tj.van Weering, H. de Haas, and H. de Stigter* MORE ON MOUNDS
17:40	*D. van Rooij, M. Kozachenko, A. Wheeler, W. Lekens, and J.-P. Henriet* THE ACOUSTIC AND SEDIMENTOLOGICAL FACE OF THE SEDIMENTS SURROUNDING THE BELGICA MOUNDS PROVINCE
18:00	*M.R. Cunha, A.M. Hilário, I.G. Teixeira, and all the Scientific Party aboard the TTR-10 Cruise* THE FAUNAL COMMUNITY ASSOCIATED TO MUD VOLCANOES IN THE GULF OF CADIZ
18:20	*P. Vermeesch, M. Van Geet, J.-P. Henriet, M. Ivanov, and R. Swennen* PETROGRAPHY AND STABLE ISOTOPE GEOCHEMISTRY FROM A RECENTLY SAMPLED CARBONATE CRUST FROM THE GULF OF CADIZ

FRIDAY, FEBRUARY 2

9:30-14:00	**Field trip and local site-seeing tour**

Section 6: Pelagic and hemipelagic sedimentation
Convenors: J. van Hinte and G. Akhmanov

15:00	*J. van Hinte* A EUROPEAN DEEP MARGIN RECORD OF THE ICE AGE ORIGIN
15:20	*A. Sadekov, H. Stigter, and Tj. van Weering* RECENT FORAMINIFERAL ASSEMBLAGES FROM CARBONATE MUD MOUNDS OF THE PORCUPINE BANK (NE ATLANTIC)
15:40	*J. Mardanjan* PECULIARITIES OF HEMIPELAGIC SEDIMENTATION AND MASS FLOW PROCESSES ON THE NORTH-EASTERN FAEROE MARGIN
16:00	*A.P. Sautkin and D.O. Ovsyannikov* MICROPALEONTOLOGICAL INVESTIGATION OF ROCK CLASTS FROM MUD VOLCANIC DEPOSITS IN THE GULF OF CADIZ

Special session: Volcanism and hydrothermal venting of the Mid-Atlantic Ridge
Convenors: B. Murton and J. Monteiro

16:40	*B. Murton, P. Ferreira, and J.H. Monteiro* EVOLUTION OF EXPLOSIVE SEAMOUNT VOLCANISM: EVIDENCE FROM 37°N ON THE MID-ATLANTIC RIDGE
17:00	*A. Stepanov* EVOLUTION OF THE LUCKY STRIKE ORE FIELD BASED ON PETROLOGICAL STUDIES OF BASALT
17:20	*M.R. Cunha, A.M. Hilário, I.G. Teixeira, and all the Scientific Party aboard the TTR-10 Cruise* THE FAUNAL COMMUNITY FROM THE LUCKY STRIKE HYDOTHERMAL VENT FIELD
17:40	*P. Ferreira, A. Pinto, B. Murton, H. Monteiro, V. Magalhães, E. Salgueiro, C. Lopes, R. Quartau, and A. Stepanov* HYDROTHERMAL GEOLOGICAL MATERIAL FROM THE LUCKY STRIKE FIELD COLLECTED DURING TTR-10/LEG 2, AZORES, MID-ATLANTIC RIDGE
18:00	*P. Shashkin and J.-P. Henriet* GAS AND FLUIDS IN MARINE SEDIMENTS AND RELATED PHENOMENA - EDUCATIONAL CD-ROM
19:00-19:30	Closure of the meeting, prizes for best students oral and poster presentations

POSTER PRESENTATIONS
(alphabetical listing by first author)

V. Kroupskaia and I. Andreeva
GRAIN SIZE COMPOSITION OF THE BEAR ISLAND AREA DEPOSITS AS AN INDICATOR OF THEIR GENESIS

A. Kuijpers, S.R. Troelstra, A. Akhmetzhanov, S. Buryak, M.A. Prins, K. Linthout, M. F. Bachmann, S. Lassen, S. Rasmussen, and J. B. Jensen
THE SOUTHEAST GREENLAND MARGIN: LATE QUATERNARY SEDIMENTARY PROCESSES AND OCEAN CIRCULATION CHANGES

T. Nielsen, T. Bugge, A. Kuijpers, and M. Ivanov
THE OUTCOME OF COLLABORATION BETWEEN TTR AND THE INDUSTRY-BASED FAROESE GEM NETWORK

E. Petrov and TJ. van Weering
3D GEOMETRY OF SEDIMENTARY STRUCTURES IN THE ROCKALL TROUGH AREA

E. Sakvarelidse
THE THERMAL REGIME OF THE CRUST FOR THE WATER AREA OF THE BLACK SEA

L. Somoza, M.K. Ivanov, L. Pinheiro, A. Maestro, A. Lowrie, J.T. Vazquez, J. Gardner, T. Medialdea, and M.C. Fernandez-Puga
STRUCTURAL AND TECTONIC CONTROL OF FLUID SEEPS AND MUD VOLCANOES IN THE GULF OF CADIZ.

E. Suslova and O. Krylov
THE BITUMINOUS CHARACTERISTIC OF MZ - KZ SEDIMENTS FROM TAMAN PENINSULA

A. van der Molen
GRAIN SIZE AND CARBONATE ANALYSIS OF TWO GRAVITY CORES FROM THE WESTERN FAEROE MARGIN

ANNEX II

LIST OF PARTICIPANTS

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5	IDOE International Workshop on Marine Geology and Geophysics of the Caribbean Region and its Resources; Kingston, Jamaica, 17-22 February 1975.	E (out of stock) S
6	Report of the CCOP/SOPAC-IOC IDOE International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific; Suva, Fiji, 1-6 September 1975.	E
7	Report of the Scientific Workshop to Initiate Planning for a Co-operative Investigation in the North and Central Western Indian Ocean, organized within the IDOE under the sponsorship of IOC/FAO (IOFC)/UNESCO/EAC; Nairobi, Kenya, 25 March-2 April 1976.	E, F, S, R
8	Joint IOC/FAO (IPFC)/UNEP International Workshop on Marine Pollution in East Asian Waters; Penang, 7-13 April 1976.	E (out of stock)
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12	Report of the IOCARIBE Interdisciplinary Workshop on Scientific Programmes in Support of Fisheries Projects; Fort-de-France, Martinique, 28 November-2 December 1977.	E, F, S
13	Report of the IOCARIBE Workshop on Environmental Geology of the Caribbean Coastal Area; Port of Spain, Trinidad, 16-18 January 1978.	E, S
14	IOC/FAO/WHO/UNEP International Workshop on Marine Pollution in the Gulf of Guinea and Adjacent Areas; Abidjan, Côte d'Ivoire, 2-9 May 1978.	E, F
15	CPPS/FAO/IOC/UNEP International Workshop on Marine Pollution in the South-East Pacific; Santiago de Chile, 6-10 November 1978.	E (out of stock)
16	Workshop on the Western Pacific, Tokyo, 19-20 February 1979.	E, F, R
17	Joint IOC/WMO Workshop on Oceanographic Products and the IGOSS Data Processing and Services System (IDPSS); Moscow, 9-11 April 1979.	E
17 Suppl.	Papers submitted to the Joint IOC/WMO Seminar on Oceanographic Products and the IGOSS Data Processing and Services System; Moscow, 2-6 April 1979.	E
18	IOC/UNESCO Workshop on Syllabus for Training Marine Technicians; Miami, U.S.A., 22-26 May 1978 (UNESCO reports in marine sciences, No. 4 published by the Division of Marine Sciences, UNESCO).	E (out of stock), F, S (out of stock), R
19	IOC Workshop on Marine Science Syllabus for Secondary Schools; Llantwit Major, Wales, U.K., 5-9 June 1978 (UNESCO reports in marine sciences, No. 5, published by the Division of Marine Sciences, UNESCO).	E (out of stock), E, S, R, Ar
20	Second CCOP-IOC Workshop on IDOE Studies of East Asia Tectonics and Resources; Bandung, Indonesia, 17-21 October 1978.	E
21	Second IDOE Symposium on Turbulence in the Ocean; Liège, Belgium, 7-18 May 1979.	E, F, S, R
22	Third IOC/WMO Workshop on Marine Pollution Monitoring; New Delhi, 11-15 February 1980.	E, F, S, R
23	WESTPAC Workshop on the Marine Geology and Geophysics of the North-West Pacific; Tokyo, 27-31 March 1980.	E, R
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27	CCOP/SOPAC-IOC Second International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific; Nouméa, New Caledonia, 9-15 October 1980.	E
28	FAO/IOC Workshop on the effects of environmental variation on the survival of larval pelagic fishes. Lima, 20 April-5 May 1980.	E
29	WESTPAC Workshop on Marine Biological Methodology; Tokyo, 9-14 February 1981.	E
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31	Third International Workshop on Marine Geoscience; Heidelberg, 19-24 July 1982.	E, F, S
32	UNU/IOC/UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the context of the New Ocean Regime; Paris, France, 27 September-1 October 1982.	E, F, S
32 Suppl.	Papers submitted to the UNU/IOC/UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the Context of the New Ocean Regime; Paris, France, 27 September-1 October 1982.	E
33	Workshop on the IREP Component of the IOC Programme on Ocean Science in Relation to Living Resources (OSLR); Halifax, 26-30 September 1963.	E
34	IOC Workshop on Regional Co-operation in Marine Science in the Central Eastern Atlantic (Western Africa); Tenerife, 12-17 December 1963.	E, F, S
35	CCOP/SOPAC-IOC-UNU Workshop on Basic Geo-scientific Marine Research Required for Assessment of Minerals and Hydrocarbons in the South Pacific; Suva, Fiji, 3-7 October 1983.	E
36	IOC/FAO Workshop on the Improved Uses of Research Vessels; Lisbon, Portugal, 28 May-2 June 1984.	E
36 Suppl.	Papers submitted to the IOC/FAO Workshop on the Improved Uses of Research Vessels; Lisbon, Portugal, 28 May-2 June 1984.	E
37	IOC/UNESCO Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs; Colombo, 8-13 July 1985.	E
38	IOC/ROPME/UNEP Symposium on Fate and Fluxes of Oil Pollutants in the Kuwait Action Plan Region; Basrah, Iraq, 8-12 January 1984.	E
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40	IOC Workshop on the Technical Aspects of Tsunami Analysis, Prediction and Communications; Sidney, B.C., Canada, 29-31 July 1985.	E
40 Suppl.	First International Tsunami Workshop on Tsunami Analysis, Prediction and Communications, *Submitted Papers;* Sidney, B.C., Canada, 29 July - 1 August 1985.	E
41	First Workshop of Participants in the Joint FAO/IOC/WHO/IAEA/UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region (WACAF/2); Dakar, Senegal, 28 October-1 November 1985.	E
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45	IOCARIBE Workshop on Physical Oceanography and Climate; Cartagena, Colombia, 19-22 August 1986.	E
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47	IOC Symposium on Marine Science in the Western Pacific: The Indo-Pacific Convergence; Townsville, 1-6 December 1966.	E
48	IOCARIBE Mini-Symposium for the Regional Development of the IOC-UN (OETB) Programme on 'Ocean Science in Relation to Non-Living Resources (OSNLR)'; Havana, Cuba, 4-7 December 1986.	E, S
49	AGU-IOC-WMO-CPPS Chapman Conference: An International Symposium on 'El Niño'; Guayaquil, Ecuador, 27-31 October 1986.	E
50	CCALR-IOC Scientific Seminar on Antarctic Ocean Variability and its Influence on Marine Living Resources, particularly Krill (organized in collaboration with SCAR and SCOR); Paris, France, 2-6 June 1987.	E
51	CCOP/SOPAC-IOC Workshop on Coastal Processes in the South Pacific Island Nations; Lae, Papua-New Guinea, 1-8 October 1987.	E

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52	SCOR-IOC-UNESCO Symposium on Vertical Motion in the Equatorial Upper Ocean and its Effects upon Living Resources and the Atmosphere; Paris, France, 6-10 May 1985.	E
53	IOC Workshop on the Biological Effects of Pollutants; Oslo, 11-29 August 1986.	E
54	Workshop on Sea-Level Measurements in Hostile Conditions; Bidston, UK, 28-31 March 1988	E
55	IBCCA Workshop on Data Sources and Compilation, Boulder, Colorado, 18-19 July 1988.	E
56	IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Cleveland, Australia, 24-30 July 1988.	E
57	IOC Workshop on International Co-operation in the Study of Red Tides and Ocean Blooms; Takamatsu, Japan, 16-17 November 1987.	E
58	International Workshop on the Technical Aspects of the Tsunami Warning System; Novosibirsk, USSR, 4-5 August 1989.	E
58 Suppl.	Second International Workshop on the Technical Aspects of Tsunami Warning Systems, Tsunami Analysis, Preparedness, Observation and Instrumentation. *Submitted Papers*; Novosibirsk, USSR, 4-5 August 1989.	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
60	IOC Workshop to Define IOCARIBE-TRODERP proposals; Caracas, Venezuela, 12-16 September 1989.	E
61	Second IOC Workshop on the Biological Effects of Pollutants; Bermuda, 10 September-2 October 1988.	E
62	Second Workshop of Participants in the Joint FAO-IOC-WHO-IAEA-UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region; Accra, Ghana, 13-17 June 1988.	E
63	IOC/WESTPAC Workshop on Co-operative Study of the Continental Shelf Circulation in the Western Pacific; Bangkok, Thailand, 31 October-3 November 1989.	E
64	Second IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Phuket, Thailand, 25-31 September 1989.	E
65	Second IOC Workshop on Sardine/Anchovy Recruitment Project (SARP) int he Southwest Atlantic; Montevideo, Uruguay, 21-23 August 1989.	E
66	IOC *ad hoc* Expert Consultation on Sardine/Anchovy Recruitment Programme; La Jolla, California, U.S.A., 1989.	E
67	Interdisciplinary Seminar on Research Problems in the IOCARIBE Region; Caracas, Venezuela, 28 November-1 December 1989.	E (out of stock)
68	International Workshop on Marine Acoustics; Beijing, China, 26-30 March 1990.	E
69	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Leningrad, USSR, 28-31 May 1990.	E
69 Suppl.	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; *Submitted Papers*; Leningrad, USSR, 28-31 May 1990.	E
70	IOC-SAREC-UNEP-FAO-IAEA-WHO Workshop on Regional Aspects of Marine Pollution; Mauritius, 29 October - 9 November 1990.	E
71	IOC-FAO Workshop on the Identification of Penaeid Prawn Larvae and Postlarvae; Cleveland, Australia, 23-28 September 1990.	E
72	IOC/WESTPAC Scientific Steering Group Meeting on Co-Operative Study of the Continental Shelf Circulation in the Western Pacific; Kuala Lumpur; Malaysia, 9-11 October 1990.	E
73	Expert Consultation for the IOC Programme on Coastal Ocean Advanced Science and Technology Study; Liège, Belgium, 11-13 May 1991.	E
74	IOC-UNEP Review Meeting on Oceanographic Processes of Transport and Distribution of Pollutants in the Sea; Zagreb, Yugoslavia, 15-18 May 1989.	E
75	IOC-SCOR Workshop on Global Ocean Ecosystem Dynamics; Solomons, Maryland, U.S.A., 29 April-2 May 1991.	E
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78	IOC-CEC-ICES-WMO-ICSU Ocean Climate Data Workshop Goddard Space Flight Center; Greenbelt, Maryland, U.S.A., 18-21 February 1992.	E
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80	IOC-SCOR Workshop on Programme Development for Harmful Algae Blooms; Newport, U.S.A., 2-3 November 1991.	E
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86	International Workshop on the Black Sea; Varna, Bulgaria 30 September - 4 October 1991.	E
87	Taller de trabajo sobre efectos biológicos del fenómeno «El Niño» en ecosistemas costeros del Pacífico Sudeste; Santa Cruz, Galápagos, Ecuador, 5-14 de octubre de 1989.	S only (Summary in E, F, S)
88	IOC-CEC-ICSU-ICES Regional Workshop for Member States of Eastern and Northern Europe (GODAR Project); Obninsk, Russia, 17-20 May 1993.	E
89	IOC-ICSEM Workshop on Ocean Sciences in Non-Living Resources; Perpignan, France, 15-20 October 1990.	E
90	IOC Seminar on Integrated Coastal Management; New Orleans, U.S.A., 17-18 July 1993.	E
91	Hydroblack'91 CTD Intercalibration Workshop; Woods Hole, U.S.A., 1-10 December 1991.	E
92	Réunion de travail IOCEA-OSNLR sur le Projet « Budgets sédimentaires le long de la côte occidentale d'Afrique » Abidjan, Côte d'Ivoire, 26-28 juin 1991.	F
93	IOC-UNEP Workshop on Impacts of Sea-Level Rise due to Global Warming. Dhaka, Bangladesh, 16-19 November 1992.	E
94	BMTC-IOC-POLARMAR International Workshop on Training Requirements in the Field of Eutrophication in Semi-Enclosed Seas and Harmful Algal Blooms, Bremerhaven, Germany, 29 September - 3 October 1992.	E
95	SAREC-IOC Workshop on Donor Collaboration in the Development of Marine Scientific Research Capabilities in the Western Indian Ocean Region; Brussels, Belgium, 23-25 November 1993.	E
96	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Zanzibar, United Republic of Tanzania, 17-21 January 1994.	E
96 Suppl. 1	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; *Submitted Papers* 1. Coastal Erosion; Zanzibar, United Republic of Tanzania 17-21 January 1994.	E
96 Suppl. 2	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; *Submitted Papers* 2. Sea Level; Zanzibar, United Republic of Tanzania 17-21 January 1994.	E
97	IOC Workshop on Small Island Oceanography in Relation to Sustainable Economic Development and Coastal Area Management of Small Island Development States; Fort-de-France, Martinique, 8-10 November, 1993.	E
98	CoMSBlack '92A Physical and Chemical Intercalibration Workshop; Erdemli, Turkey, 15-29 January 1993.	E
99	IOC-SAREC Field Study Exercise on Nutrients in Tropical Marine Waters; Mombasa, Kenya, 5-15 April 1994.	E
100	IOC-SOA-NOAA Regional Workshop for Member States of the Western Pacific - GODAR-II (Global Oceanographic Data Archeology and Rescue Project); Tianjin, China, 8-11 March 1994.	E
101	IOC Regional Science Planning Workshop on Harmful Algal Blooms; Montevideo, Uruguay, 15-17 June 1994.	E
102	First IOC Workshop on Coastal Ocean Advanced Science and Technology Study (COASTS); Liège, Belgium, 5-9 May 1994.	E
103	IOC Workshop on GIS Applications in the Coastal Zone Management of Small Island Developing States; Barbados, 20-22 April 1994.	E
104	Workshop on Integrated Coastal Management; Dartmouth, Canada, 19-20 September 1994.	E
105	BORDOMER 95: Conference on Coastal Change; Bordeaux, France, 6-10 February 1995.	E
105 Suppl.	Conference on Coastal Change: Proceedings; Bordeaux, France, 6-10 February 1995	E
106	IOC/WESTPAC Workshop on the Paleographic Map; Bali, Indonesia, 20-21 October 1994.	E
107	IOC-ICSU-NIO-NOAA Regional Workshop for Member States of the Indian Ocean - GODAR-III; Dona Paula, Goa, India, 6-9 December 1994.	E
108	UNESCO-IHP-IOC-IAEA Workshop on Sea-Level Rise and the Multidisciplinary Studies of Environmental Processes in the Caspian Sea Region; Paris, France, 9-12 May 1995.	E
108 Suppl.	UNESCO-IHP-IOC-IAEA Workshop on Sea-Level Rise and the Multidisciplinary Studies of Environmental Processes in the Caspian Sea Region; *Submitted Papers*; Paris, France, 9-12 May 1995.	E
109	First IOC-UNEP CEPPOL Symposium; San José, Costa Rica, 14-15 April 1993.	E
110	IOC-ICSU-CEC Regional Workshop for Member States of the Mediterranean - GODAR-IV (Global Oceanographic Data Archeology and Rescue Project) Foundation for International Studies, University of Malta, Valletta, Malta, 25-28 April 1995.	E

No.	Title	Languages
111	Chapman Conference on the Circulation of the Intra-Americas Sea; La Parguera, Puerto Rico, 22-26 January 1995.	E
112	IOC-IAEA-UNEP Group of Experts on Standards and Reference Materials (GESREM) Workshop; Miami, U.S.A., 7-8 December 1993.	E
113	IOC Regional Workshop on Marine Debris and Waste Management in the Gulf of Guinea; Lagos, Nigeria, 14-16 December 1994.	E
114	International Workshop on Integrated Coastal Zone Management (ICZM) Karachi, Pakistan; 10-14 October 1994.	E
115	IOC/GLOSS-IAPSO Workshop on Sea Level Variability and Southern Ocean Dynamics; Bordeaux, France, 31 January 1995.	E
116	IOC/WESTPAC International Scientific Symposium on Sustainability of Marine Environment: Review of the WESTPAC Programme, with Particular Reference to ICAM Bali, Indonesia, 22-26 November 1994.	E
117	Joint IOC-CIDA-Sida (SAREC) Workshop on the Benefits of Improved Relationships between International Development Agencies, the IOC and other Multilateral Intergovernmental Organizations in the Delivery of Ocean, Marine Affairs and Fisheries Programmes; Sidney B.C., Canada, 26-28 September 1995.	E
118	IOC-UNEP-NOAA-Sea Grant Fourth Caribbean Marine Debris Workshop; La Romana, Santo Domingo, 21-24 August 1995.	E
119	IOC Workshop on Ocean Colour Data Requirements and Utilization; Sydney B.C., Canada, 21-22 September 1995.	E
120	International Training Workshop on Integrated Coastal Management; Tampa, Florida, U.S.A., 15-17 July 1995.	E
121	Atelier régional sur la gestion intégrée des zones littorales (ICAM); Conakry, Guinée, 12-22 décembre 1995.	F
122	IOC-EU-BSH-NOAA-(WDC-A) International Workshop on Oceanographic Biological and Chemical Data Management Hamburg, Germany, 20-23 May 1996.	E
123	Second IOC Regional Science Planning Workshop on Harmful Algal Blooms in South America; Mar del Plata, Argentina, 30 October - 1 November 1995.	E, S
124	GLOBEC-IOC-SAHFOS-MBA Workshop on the Analysis of Time Series with Particular Reference to the Continuous Plankton Recorder Survey; Plymouth, U.K., 4-7 May 1993.	E
125	Atelier sous-régional de la COI sur les ressources marines vivantes du Golfe de Guinée ; Cotonou, Bénin, 1-4 juillet 1996.	F
126	IOC-UNEP-PERSGA-ACOPS-IUCN Workshop on Oceanographic Input to Integrated Coastal Zone Management in the Red Sea and Gulf of Aden Jeddah, Saudi Arabia, 8 October 1995.	E
127	IOC Regional Workshop for Member States of the Caribbean and South America GODAR-V (Global Oceanographic Data Archeology and Rescue Project); Cartagena de Indias, Colombia, 8-11 October 1996.	E only
128	Atelier IOC-Banque Mondiale-Sida/SAREC-ONE sur la Gestion Intégrée des Zones Côtières ; Nosy Bé, Madagascar, 14-18 octobre 1996.	E, F
129	Gas and Fluids in Marine Sediments, Amsterdam, the Netherlands; 27-29 January 1997.	E
130	Atelier régional de la COI sur l'océanographie côtière et la gestion de la zone côtière ; Moroni, RFI des Comores, 16-19 décembre 1996.	F
131	GOOS Coastal Module Planning Workshop; Miami, USA, 24-28 February 1997.	E
132	Third IOC-FANSA Workshop; Punta-Arenas, Chile, 28-30 July 1997	S/E
133	Joint IOC-CIESM Training Workshop on Sea-level Observations and Analysis for the Countries of the Mediterranean and Black Seas; Birkenhead, U.K., 16-27 June 1997.	E
134	IOC/WESTPAC-CCOP Workshop on Paleogeographic Mapping (Holocene Optimum); Shanghai, China, 27-29 May 1997.	E
135	Regional Workshop on Integrated Coastal Zone Management; Chabahar, Iran; February 1996.	E
136	IOC Regional Workshop for Member States of Western Africa (GODAR-VI); Accra, Ghana, 22-25 April 1997.	E
137	GOOS Planning Workshop for Living Marine Resources, Dartmouth, USA; 1-5 March 1996.	E
138	Gestión de Sistemas Oceanográficos del Pacífico Oriental; Concepción, Chile, 9-16 de abril de 1996.	S
139	Sistemas Oceanográficos del Atlántico Sudoccidental, Taller, TEMA; Furg, Rio Grande, Brasil, 3-11 de noviembre de 1997.	S
140	IOC Workshop on GOOS Capacity Building for the Mediterranean Region; Valletta, Malta, 26-29 November 1997.	E
141	IOC/WESTPAC Workshop on Co-operative Study in the Gulf of Thailand: A Science Plan; Bangkok, Thailand, 25-28 February 1997.	E
142	Pelagic Biogeography ICoPB II. Proceedings of the 2nd International Conference. Final Report of SCOR/IOC Working Group 93; Noordwijkerhout, The Netherlands, 9-14 July 1995.	E
143	Geosphere-biosphere coupling: Carbonate Mud Mounds and Cold Water Reefs; Gent, Belgium, 7-11 February 1998.	E
144	IOC-SOPAC Workshop Report on Pacific Regional Global Ocean Observing Systems; Suva, Fiji, 13-17 February 1998.	E
145	IOC-Black Sea Regional Committee Workshop: 'Black Sea Fluxes' Istanbul, Turkey, 10-12 June 1997	E
146	Living Marine Resources Panel Meeting, Paris, France, 23-25 March 1998	E
147	IOC-SOA International Training Workshop on the Intregration of Marine Sciences into the Process of Integrated Coastal Management, Dalian, China, 19-24 May 1997	E
148	IOC/WESTPAC International Scientific Symposium – Role of Ocean Sciences for Sustainable Development Okinawa, Japan, 2-7 February 1998	E
149	Workshops on Marine Debris & Waste Management in the Gulf of Guinea, 1995-97	E
150	First IOCARIBE-ANCA Worskshop Havana, Cuba, 29 June-1 July 1998	E
151	Taller Pluridisciplinario TEMA sobre Redes del Gran Caribe en Gestión Integrada de Áreas Costeras Cartagena de Indias, Colombia, 7-12 de septiembre de 1998	S
152	Workshop on Data for Sustainable Integrated Coastal Management (SICOM) Maputo, Mozambique, 18-22 July 1998	E
153	IOC/WESTPAC-Sida (SAREC) Workshop on Atmospheric Inputs of Polluants to the Marine Environment Qingdao, China, 24-26 June 1998	E
154	IOC-Sida-Flanders-SFRI Workshop on Ocean Data Management in the IOCINCWIO Region (ODINEA project) Capetown, South Africa, 30 November-11 December 1998	E
155	Science of the Mediterranean Sea and its applications UNESCO, Paris 29-31 July 1997	E
156	IOC-LUC-KMFRI Workshop on RECOSCIX-WIO in the Year 2000 and Beyond Mombasa, Kenya, 12-17 April 1999	E
157	'98 IOC-KMI International Workshop on Integrated Coastal Management (ICM) Seoul, Republic of Korea 16-18 April 1998	E
158	The IOCARIBE Users and the Global Ocean Observing System (GOOS) Capacity Building Workshop San José, Costa Rica, 22-24 April 1999	E
159	Oceanic Fronts and Related Phenomena (Konstantin Fedorov Memorial Symposium) - Proceedings Pushkin, Russian Federation, 18-22 May 1998	E
160	Under preparation	
161	Under preparation	
162	Under preparation	
163	Under preparation	
164	IOC-Sida-Flanders-MCM Third Workshop on Ocean Data Management in the IOCINCWIO Region (ODINEA Project) Cape Town, South Africa 29 November-11 December 1999	E
165	An African Conference on Sustainable Integrated Management; Proceedings of the Workshops. An Integrated Approach, (PACSICOM), Maputo, Mozambique, 18–25 July 1998	E, F
166	IOC-SOA International Workshop on Coastal Megacities: Challenges of Growing Urbanization of the World's Coastal Areas; Hangzhou, P.R. China, 27–30 September 1999	E
167	Under preparation	
168	Geological Processes on European Continental Margins; International Conference and Eighth Post-Cruise Meeting of the Training-Through-Research Programme, Granada, Spain, 31 January – 3 February 2000	E
169	International Conference on the International Oceanographic Data and Information Exchange in the Western Pacific (IODE-WESTPAC) 1999, ICIWP '99 Langkawi, Malaysia, 1–4 November 1999	*Under preparation*
170	IOCARIBE-GODAR-I Cartagenas, Colombia, February 2000	*Under preparation*
171	Ocean Circulation Science derived from the Atlantic, Indian and Arctic Sea Level Networks Toulouse, France, 10–11 May 1999	E
172	(*Under preparation*)	
173	(*Under preparation*)	
174	IOC-SOPAC Regional Workshop on Coastal Global Ocean Observing System (GOOS) for the Pacific Region, Apia, Samoa, 16–17 August 2000	E

No.	Title	Languages	No.	Title	Languages	No.	Title	Languages
175	Geological Processes on Deep-Water European Margins, Moscow-Mozhenka, 28 January-2 February 2001	E						