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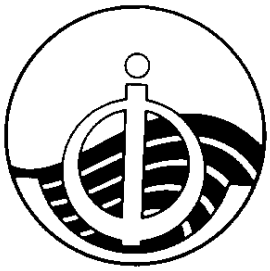

Geological processes on European continental margins

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

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PREFACE

The International Conference "Geological Processes on European Continental Margins (TTR-9 Post-Cruise Meeting)" was held from 31 January to 3 February 2000, at the Faculty of Sciences (University of Granada, Spain). This meeting brought together over 40 participants from 9 countries (Denmark, Italy, Morocco, Portugal, Russia, Spain, Tunisia, UK and USA). 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.

The Conference was divided into four scientific sessions:

- Geological Processes on the Atlantic Margin
- Fluid Venting, Mud Diapirism and Volcanism
- Sedimentary Processes and Climate Changes in the Western Mediterranean
- Tectonics and Structure of the Western Mediterranean

In total some 30 oral presentations and 15 poster presentations were made during the first three days of the meeting. The primary focus of the Conference was to present data and preliminary results of the 9th International scientific expedition of the UNESCO/IOC "Training-Trough-Research" ("Floating University") Programme. The TTR-9 cruise (June-July, 1999) was dedicated to investigations of slope processes, tectonics, sedimentation, fluid flow, mud diapirism and volcanism in the Northeast Atlantic and the Western Mediterranean. The Conference also provided the opportunity to present data and results from previous TTR cruises and other research undertaken within the Marine Geosciences on European continental margins.

The Conference started with the Inaugural Session. Mr. E. Salvo Tierra opened the meeting on behalf of the Government of Andalucia, and Dr. F. Verdegay welcomed the participants on behalf of the Rector of the University of Granada. Mr. A. E. Suzyumov addressed the meeting on behalf of Mr. P. Bernal, Executive Secretary of the Intergovernmental Oceanographic Commission (IOC) at UNESCO. Dr. Fernando Gonzalez Caballero welcomed the participants on behalf of the Faculty of Sciences and Dr. M. Comas on behalf of the Organizing Committee.

During the scientific sessions of the Conference nine areas studied during the TTR-9 cruise were highlighted: Faeroes Margin, Rockall Trough, Portuguese Margin, Gulf of Cadiz, Alboran Sea and Balearic Basin. Evidence of very strong bottom currents and recent sliding off the Faeroe Islands, discovered during the TTR-9 cruise, was discussed. Attention was drawn to the sedimentary processes on the Portuguese margin. New mud volcanic areas discovered in the Gulf of Cadiz and the Alboran Sea were highlighted, with eight mud volcanoes confirmed by bottom sampling. The results of gas hydrate studies discovered for the first time in the Gulf of Cadiz were presented. Chemosynthetic biocommunities and authigenic mineralization, associated with hydrocarbon vents, found in several TTR-9 study areas were discussed. An overview was given of basement volcanic and methamorphic rocks, recovered during the cruise, allowing better linking of complex marine-land geology in the Alboran Sea and Balearic Basin.

The discussions around the posters and lively debates at coffee time and beyond created a very stimulating intellectual atmosphere. All participants expressed great satisfaction with the Conference, as having fully achieved its objectives and facilitated fruitful contacts.

On the fourth day a field trip to the Natural Park of Sierra Nevada and the Alpujarra Region was organized, sponsored by the Government of Andalucia. The trip covered outcrops along the western termination of the Sierra Nevada mountain range and its transition to the Granada Basin, filled with Miocene-to-Recent sediments. Recent structures related to mountain uplift and basin formation, extensional fault zones active during the Middle to Upper Miocene and metamorphic rocks of the Alpujarride and Nevado-Filabride complexes were also visited on the southern slope of the Sierra Nevada mountain range.

During the Conference plans for future TTR research were discussed and, on 31 January, a meeting of the TTR Executive Committee was held at the Faculty of Sciences, which considered a number of items related to the organization of the TTR-10 cruise (summer 2000), as well as the publication policy of TTR data.

The Conference programme was set up by the Organizing Committee:

- Prof. Dr. Menchu Comas (Chair),
- Dr. J. Miguel Azanon
- Dr. Francisca Martinez-Ruiz (Secretary)
- Dr. Mario Sanchez-Gomez
- Dr. Juan-Ignacio Soto

The book of abstracts was compiled by the above Organizing Committee, and was further edited by Dr. G. G. Akhmanov (Moscow State University) with the assistance of Dr. A. E. Suzyumov (UNESCO) for the present Report. English editing was undertaken by Ms. J. Cheftel (UK). The Report layout reflects the Conference schedule; thus the abstracts are in the order in which the presentations were given. Annex I contains the programme with titles and authors of presentations, divided into the different sessions and chairpersons. The abstracts are similarly grouped thematically under the same headings as the different sessions. Participants are listed in Annex II in alphabetical order by country.

The Conference was organized by the Instituto Andaluz de Ciencias de la Tierra (CSIC and the University of Granada) and co-sponsored by UNESCO/IOC, the Government of Andalucia and the University of Granada. The Conference Secretariat was established at the Instituto Andaluz de Ciencias de la Tierra, CSIC and the University of Granada, Campus Fuentenueva – Faculty of Sciences, 18002-GRANADA, Spain.

ABSTRACTS

Introduction

GOALS AND PRINCIPLE RESULTS OF THE TTR-9 CRUISE

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The principal aim of the TTR-9 cruise was a further study of geological processes on the deep-water European continental margins.

New acoustic records and sampling data prove that slope instability of the Eastern Faeroe margin is more widespread than it was previously thought. A wide range of mainly longitudinal current induced bedform types has been observed, representative of both low and high bottom current speeds. The presence of very coarse deposits provides further evidence for strong current activity in the area, especially on steep escarpments in the southern part of the Faeroe-Shetland channel.

Sedimentary processes and seabed facies were studied in two areas of the Rockall Trough. The acquisition of seabed samples, underwater video lines and sub-bottom profiler images provided unexpected data with respect to the current dynamics and local morphology.

The broad development of contourite deposits on the Portuguese margin, speculated from old GLORIA data, was not fully confirmed. Areas for their potential development lie north and west of the Vigo Seamount, and in the basin located between the continental slope and the Porto Seamount, as can be interpreted from the 3.5 kHz hull-mounted profiler data. At these locations, relatively thick stratified packages, sometimes with wavy internal reflectors, were recognized below the seafloor, resembling characteristic contourite deposits. Offshore Lisbon, seismic and long-range sidescan sonar surveys showed the development of a canyon system deeply incised into the continental slope. The most prominent feature is related to the Setubal canyon, which appears to be the major conduit of turbidity currents far into the Tagus abyssal plain.

The existence of mud volcanoes in the Gulf of Cadiz, suggested by scientists from the Naval Research Laboratory (USA) on the basis of sidescan sonar and multibeam bathymetry surveys of the area in 1992, was fully confirmed. At least four regions of mud volcanism and clay diapirism were identified: Western Moroccan Field (WMF), Middle Moroccan Field (MMF), Eastern Moroccan Field (EMF), and Spanish–Portuguese Field (SPF). All these fields have differences in the recent activity of mud structures and in mud breccia composition. In most active mud volcanoes of MMF strong hydrocarbon fluid escape, methane clathrates, hemosynthetic organisms and isotopically light gas-related carbonates have been discovered. The EMF gravity core samples confirmed the existence of 3 mud volcanoes, while seismic and sidescan sonar data suggested that there are at least 5 more mud volcanoes and 4 diapiric ridges. It is believed that carbonate mud mounds were developed on top of some buried mud structures.

The relationship between seafloor morphology and tectonics, in actively deforming sectors of the Alboran Sea and the South Balearic Basin, has been studied with an extensive set of methods. Two new mud volcanoes, named Granada and Marrakech, associated with a mud

diapiric field, have been discovered on the Moroccan margin of the Alboran Sea. A collection of rock clasts from mud volcanic breccia contains unique information on the lithology and age of deep sedimentary strata, allowing a preliminary geological reconstruction of the sedimentary sequence. The OKEAN imagery obtained from the Balearic Basin showed a variety of processes taking place in this part of the margin. Basement outcrops, canyon system and slope instability features were all successfully mapped.

Geological Processes on the Atlantic Margin

MORPHOLOGY AND SEDIMENTARY PROCESSES OF THE SLOPE WEST OF PORTUGAL

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The OKEAN long-range sidescan sonar and a 3.5kHz profiler have been used to map some critical parts of the continental slope west of Portugal. Gardner and Kidd (1983, 1987), and Roberts and Kidd (1984) predicted that, on the basis of sediment waves and drifts mapped with GLORIA long-range sidescan sonar and profilers, there have been deep currents fashioning the margin over a long period. However, our remapping with higher resolution data suggests that deeper parts of the slope, west of central Portugal, have no convincing mud waves. Some of the areas of mud waves on the deep margin off North Africa have also been reinterpreted, and are now believed to be due to downslope flow processes.

The mapping of the canyons west of Lisbon shows that the higher backscattering floors are present only at the foot of the slope, except at the mouth of the Setubal Canyon. The canyon has a strongly backscattering floor beyond the limit of our survey, which is almost at the edge of the abyssal plain. A single deep towed medium-resolution sidescan sonar line was obtained, with the TOBI system, in the critical zone beyond the base of the slope. Both sediment waves and scour pits were observed, which is in keeping with the extra energy expected from a hydraulic jump in the turbidity currents.

PROCESSING OF MULTI-CHANNEL SEISMIC DATA COLLECTED ON THE PORTUGUESE MARGIN DURING THE TTR-9 CRUISE

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One of the aims of the investigation on the Portuguese margin during the TTR-9 Cruise was a study of the deep-water sand deposits (turbedites and contourites), which are of interest as modern analogues of deepwater oil and gas reservoirs. The slope stability, and the mechanisms and scales of sedimentary migration on the continental slope were also studied.

Nine lines were shot in this region with the 12-channel seismic system of the Netherlands Geological Survey. The received data is characterized by sufficient quality in the shallow-water part of the area, but in the deep-water part only the seafloor surface is visible.

Pre-processing analysis of the records revealed problems of a clipped signal and a too small Common Deep Point (CDP) multiplicity, which made most standard processing procedures not applicable to the data.

Clipping of the highest signal amplitudes was caused by a misfit in the dynamic ranges of the recorded signal and the analog-digital converter. To eliminate this effect, sinus-interpolation of the clipped parts of the wavelet was used.

The calculation of the CDP co-ordinates revealed that only 3-fold CDP multiplicity could be achieved, while for a significant improvement of the signal-to-noise ratio with stacking, at least 6-fold multiplicity is needed.

Time-variant stacking was used in order to increase the signal-to-noise ratio in deeper parts of the records, improving penetration without reducing the resolution in the shallowest parts of the seismic section. The algorithm involved CDP stacking of the shallowest parts of seismic traces, while at depth, pads consisting of several adjacent CDPs were used for summing, instead of single points. The size of the pads gradually increased with depth.

This allowed a significant increase in seismic penetration, without losing resolution in the upper parts of the seismic sections.

INFERRED SHALLOW GAS ACCUMULATIONS ON THE MOROCCAN CONTINENTAL MARGIN (GULF OF CADIZ) ACCORDING TO GEOPHYSICAL DATA OF THE TTR-9 CRUISE

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An area of mud volcanism and diapirism located in the Gulf of Cadiz was investigated in July 1999, during the TTR-9 expedition of the RV “Professor Logachev”, within the framework of the UNESCO-IOC “Floating University” project.

Over 550 km single channel seismic and 3.5 kHz subbottom profiler data, and 15,000 km^2 of OKEAN 9 kHz sidescan sonar and 160 km^2 of OREtech 30 kHz sidescan sonar data were collected in the area. Ground-truthing information for the sidescan was obtained from nineteen gravity cores, 2 grab samples and 6 hours of video imaging were collected during the cruise.

Three regions of mud volcanism and diapirism were identified during the cruise: Western Moroccan Field (WMF), Middle Moroccan Field (MMF) and Eastern Moroccan Field (EMF). In the WMF, diapiric structures represented long, sinuous ridges on the seafloor. Sedimentary basins have formed adjacent to these ridges. In the MMF, OREtech sidescan data, grab samples and gravity core samples confirm the existence of two mud volcanoes (Yuma and Ginsburg). Methane hydrate was recovered from the Ginsburg. In the EMF, gravity cores confirm the existence of 3 mud volcanoes (Kidd, Adamastor, TTR), and seismic and sidescan sonar data suggest that there are at least 5 more mud volcanoes, and maybe 4 diapiric ridges.

Analysis of the processed seismic lines reveals the existence of numerous bright spots (local high amplitude reflections of reversed polarity), which are probably indicators of shallow gas accumulations. Located at 1300-1800 ms TWT subbottom depth, these gas accumulations are associated with the flanks of mud volcanoes and probable clay diapirs, suggesting fluid migration at depth through the mud volcano feeder channels or through the weak zone at the edge of diapiric bodies.

Spatial distribution of the inferred shallow gas accumulations seems to follow the general direction of deep faults reported in the area by A. Maldonado (1999).

LITHOLOGICAL CHARACTERISTICS OF HOLOCENE–LATE PLEISTOCENE SEDIMENTS FROM CARBONATE MOUNDS OF THE PORCUPINE SEABIGHT BASIN

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In 1997, the 7th cruise of the TTR programme was carried out in the North Atlantic. The region of carbonate seabed mounds in the Porcupine Seabight was sampled; sediments from these mounds mainly consist of the breakdown of abundant and relatively fast growing coral *Lophelia petrusa* and *Madrepora oculata*. The influence of global temperature changes on the growth and development of corals and reefs was studied. Four cores were investigated in detail: AT2G, AT16G (on the top of mounds), AT3G (from a moat) and AT7G (distant from all mounds). Forty intervals from different lithologies were sampled in these cores for X-ray and thin-section analyses. Clear mineralogical and lithogenetic control of sedimentary thickness, higher in interglacial periods on the mound surfaces due to increasing micrite and coral detritus, was revealed. Two different hypotheses of the carbonate mound origins were considered: due to close association with active hydrocarbon seepage; or as a result of bottom current activity. The absence of gas in sediments from Porcupine carbonate mounds indicates that the origin of these mounds is not related to gas seeps. On the contrary, reduced thickness and the presence of different lithologies suggest a more active sedimentary environment at the mounds. Layered succession, as described above, forms as a result of a continuous supply of biogenic detrital material that is subsequently re-deposited by bottom currents. In this case, bottom currents could supply nutrients for the growth of coral patches and re-deposited detritus. Migrating coral colonies over mound surfaces could result from changing hydrological conditions, such as migrating bottom currents. Coral patches can sometimes be a source of coral detritus covering the mound surfaces.

LITHOLOGY OF BOTTOM SEDIMENTS FROM THE BEAR ISLAND REGION (NORWEGIAN SEA)

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This work is mainly based on data collected during the TTR-8 cruise of the RV “Professor Logachev” in the area off Bear Island, Norwegian Sea, with some data from the 1996 cruise in the same area also included. Samples were analyzed with a series of sedimentological methods, including detailed description, and grain-size and mineralogical analyses of the clay fraction. The following types of sediments were identified: hemipelagic sediments, mud breccia of the Haakon Mosby mud volcano, diapiric material, and redeposited sediments. Each type is characterized by a specific grain-size and mineralogical composition of the clay fraction.

Among the grain-size parameters, the empirical distribution and cumulative curves appeared to be the most informative. The general shape of the distribution curves provides information about the genesis of the studied deposits. The steepness of the cumulative curves shows the degree of transformation of the material. The presence of illite/smectite mixed-layer minerals in the clay fraction is the evidence for the transformation of sediments during redeposition. These parameters revealed distinct sets of characteristics typical of the Haakon Mosby mud volcano breccia, diapiric material and hemipellagic sediments. Through comparison of their characteristics with those of redeposited sediments of unknown origin, the most probable sources of redeposited sediments and the degree of their transformation could be inferred.

DEEP-SEA SEDIMENTATION IN THE TAGUS ABYSSAL PLAIN (W. IBERIA): SEDIMENT TRANSPORT AND TECTONIC CONTROL

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The most recent Pleistocene sedimentation (120 kyr) on the Tagus Abyssal Plain consists of turbidity events alternating with pelagic units. The detailed correlation of 6 piston cores (average 8 m long), constrained by oxygen isotope, Heinrich events and foraminiferal stratigraphy, indicate that these originate from more than one point source, located eastward, in the Portuguese Margin (Lebreiro, 1995). Some turbidites are exclusive of the southern cores, whereas others are present only in the northernmost cores. Some of the turbidite flows correlate with glacial-interglacial transitions, while others were probably triggered by slope instabilities or seismic activity. The most recent turbidite unit can be related to the 1755 Lisbon earthquake, by comparison with the dating of a similar flow (Thomson and Weaver, 1994) in the Horseshoe Abyssal Plain.

The sediment conduits, along the Lisboa and Setúbal canyons, are clearly visible in the bathymetry, and Gloria (Teixeira and Monteiro, 1997) and OKEAN (Kenyon *et al.*, 1999; this meeting) mosaic interpretations. The tectonic control of the main conduits is evident in the recently acquired multichannel seismic profiles (TTR9 cruise), where a lobe-type geometry can be observed in the uppermost unit. A preliminary seismic stratigraphy was defined, based on the correlation with the area's seismo-stratigraphic units defined by Mougenot (1988). The seismic profiles clearly show the fault control of the Setúbal and the Lisboa canyons. These faults appear to correspond to the offshore continuation of the onshore Late Variscan faults, which were reactivated during Mesozoic rifting episodes and, more recently, in the Cenozoic, during basin inversion associated with the SE–NW Africa–Eurasia convergence. A small shallow compressive structure is observed in one of the seismic profiles (PSAT 117), probably related to the present-day stress field (Ribeiro *et al.*, 1996), with a compression oriented in a WNW–ESE direction.

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IRON IN SEDIMENTS AS AN INDICATOR OF DEPOSITIONAL ENVIRONMENTS (AN EXAMPLE FROM THE BARENTS SEA AND WESTERN MOROCCAN FIELD)

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The chemical and phase condition of iron in bottom sediments reacts sensitively to sedimentation environments and post-sedimentation changes. This information is useful for paleoreconstruction and forecasting climate change.

To this end, the Late Holocene sea-bottom sediments of different climatic zones (Barents Sea and Western Moroccan field) were investigated. The samples of the bottom sediments were studied using chemical analysis, thermography and Mossbauer (57Fe) spectroscopy. Processes influencing iron formation in sediments are:

- Oxidation-reduction conditions of sedimentation dependent on temperature and bacterial activity;
- Post-sedimentation changes dependent on the interaction of sediments with pore waters, bacterial decay and their metabolic products.

The majority of these processes are dependent on climatic changes. The Barents Sea is characterized by a cold polar climate, with low temperatures in the bottom sediments and water (+3 to -2°C). All processes occur at low velocity in this environment. The Western Moroccan field is characterized by higher temperatures in bottom sediments and water (+12 to +15°C).

These areas are distinguished by different chemical reaction velocities and iron form distributions. In Barents Sea bottom sediments, a first phase of sulfide formation – hydrotroilite – was registered. Hydrotroilite was not found in Western Moroccan field bottom sediments, which is related to the high chemical reaction velocities, and iron sulfide is present in a more ordered form – marcasite.

Thin layers of iron hydroxides were found in the bottom sediments of both regions. The origins of these layers are different; in northern areas a slower sedimentation rate formed compressed pure organic matter layers, which exist in almost the whole area. We suppose that this depended on global or regional climatic changes at the time, which are clearer in northern rather than southern areas.

SEDIMENTATION PATTERNS ON THE NORTH–EAST ATLANTIC MARGIN

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A new map of the overall patterns of sedimentation along the NE Atlantic continental margin is presented. The margin displays a wide range of sediment transport systems with both alongslope and downslope processes, but can be subdivided into three provinces.

Off most of the NW African margin, south of 26°N, upwelling produces elevated accumulation rates, though there is little fluvial input. This area is subject to infrequent but large-scale mass movements, giving rise to debris flows and turbidity currents. The latter traverse the slope and deposit thick layers on the abyssal plains, while debris flows deposit on the continental slope and rise.

From the Atlas Mountains northwards to 56°N the margin is less prone to mass movements, but is cut by a large number of canyons that also funnel turbidity currents to the abyssal plains. The presence of a lithospheric plate boundary off SW Iberia is believed to have led to high rates of sediment transport to the deep sea. Even larger quantities of coarse sediments

have fed the canyons and abyssal plains in the Bay of Biscay as a result of drainage from melting icecaps. Bottom currents have built sediment waves off the African and Iberian margins, and created erosional furrows south of the Canaries. The Mediterranean outflow is a particularly strong bottom current near the Straits of Gibraltar, depositing sand-and mudwaves in the Gulf of Cadiz.

North of 56°N the margin is heavily influenced by glacial and glaciomarine processes active during glacial times, which built glacial trough-mouth fans such as the North Sea Fan, and left iceberg scour marks on the upper slope and shelf. Over a long period, especially during interglacials, this part of the margin has been greatly influenced by alongslope currents, with less influence by turbidity currents than on the lower latitude margins. Mass movements are again a prominent feature, particularly off Norway and the Faeroes. Some of these mass movements have occurred during the Holocene, though high glacial sedimentation rates may have contributed to the instability.

TECTONICS AND DEPOSITION IN THE DEEP-WATER AREA ADJACENT TO PORTO AND VIGO SEAMOUNTS

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Three submarine mountains are located on the northwestern Portuguese margin: Porto, Vigo, and Vasco da Gama Seamounts. The region adjacent to Porto and Vigo Seamounts was surveyed during Leg 2 of the TTR9 cruise. The aim of this survey was to collect geophysical data concerning deep-sea sediment bodies. These were previously recognized in the study area and were believed to consist predominantly of bottom-current deposits (contourites). Sources of data for this study included: OKEAN side-scan sonar, 3.5 kHz hull-mounted profiler, seismic reflection acquisition systems, and three sediment cores collected on the D. Carlos Valley, between the two seamounts.

The interpretation of a mosaic of side-scan (OKEAN) sonar data did not clearly reveal the existence of broad sediment waves in the surveyed area. In the D. Carlos Valley, the sea floor consists of a wide flat region punctually interrupted by linear features interpreted as fault scarps. The same acoustic character was recorded in the area between Porto Seamount and the continental slope. A complex system of gullies was observed on the slope and on the flanks of the seamounts. Some of these erosional features continue over the gentle continental rise, forming minor feeder channels of submarine canyons.

Seismic reflection data was obtained in parallel with the OKEAN scanning. Two main Tertiary basins are seen on the seismic data overlying Mesozoic units. The basins are fault-bounded and form two distinct Tertiary depocentres located between the studied seamounts. No important sediment wave accumulations can be identified within the Tertiary units. Seismic packages with wavy geometry are occasionally seen east of the Porto and Vigo Seamounts, always with a limited lateral extent. Gravitational processes (slumps and slides) dominate the toe of the continental slope, as proved by the existence of mounded and chaotic seismic packages. Profiler data (3.5 kHz) seems to underline the absence of extensive sediment waves: the depth of penetration is poor throughout the surveyed area, with the exception of areas where seismic data revealed possible sediment wave zones.

Core sampling on the D. Carlos Valley between both seamounts was poor, perhaps revealing the presence of compact turbiditic sands over the cored zones. This assumption seems to

be valid, since the D. Carlos Valley constitutes a bypass area of turbiditic sediments derived from the Vigo, Porto and Aveiro submarine canyons.

Preliminary results obtained on Leg 2 of the TTR9 cruise do not confirm the existence of broad contouritic sediments, both east of the Porto Seamount and in the D. Carlos Valley. However, the survey did not include the areas north and south of the referred submarine features. Therefore, the presence of important sediment wave accumulations in these regions cannot be excluded.

Fluid Venting, Mud Diapirism and Volcanism

THE CRETACEOUS-NEOGENE SEDIMENTARY HISTORY OF THE EASTERN MEDITERRANEAN: AN UPDATE FROM A STUDY OF RECENT MUD VOLCANIC DEPOSITS

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Mud volcanic deposits (mud breccia) of the Mediterranean Ridge sharply differ from the surrounding pelagic sediment, and are composed of very poorly sorted silty sandy clay (mud breccia matrix), with significant gravel admixture (mud breccia clasts). Clay mineral compositions of the matrix and clast lithologies vary for different mud volcanic areas of the Eastern Mediterranean. Large mud breccia clasts are represented by a wide variety of fragments of Early Cretaceous – Early Neogene sedimentary rocks of different lithology and genesis.

Among mud breccia clasts of the Cobblestone 3 mud volcanic area, 16 main types of rocks were defined (Akhmanov *et al.*, 1998). Rock fragments observed in mud volcanic deposits of the Olimpi / Prometheus 2 Area are represented by 12 main lithologies (Akhmanov, 1996). Mud breccia clasts from the UN Rise Area can be grouped into 12 main rock types. Some lithologies, such as micrite, fossiliferous micrite and various mudstones are common among the mud breccia clasts in all studied mud volcanic areas, indicating that some sedimentary series, through which the mud volcanoes erupted, extend through the whole Eastern Mediterranean. Most mud breccia clast types represented by various detritic carbonate and siliciclastic rocks are peculiar to certain mud volcanic areas and were not found in others. They reflect peculiarities of the source formation lithology, tectonic setting, and geological evolution in different parts of the Eastern Mediterranean.

Mud volcanic deposits provide important information about the composition of deep-seated series and can be used for revealing the evolution of the Eastern Mediterranean. Mud breccia clasts are most informative (Akhmanov and Woodside, 1998), and the optimum scheme for their study includes:

(a) detailed lithological description of every mud breccia clast recovered;
(b) determination of lithotypes, groups of clasts of the same lithology – presumably fragments of the same series;
(c) lithotype studies in thin sections, grain-size and XRD analyses, other precise methods of paleontological investigation; correction of determined groups of rocks, if required, according to new data obtained;
(d) lithotype genesis interpretation;
(e) determination of assumed paragenetic association, the main sedimentary units through which mud volcanoes erupted, on the basis of the lithological peculiarities of determined groups of

rocks, paleontological data and genetic interpretations (rocks of similar lithologies, dated with the same age interval and deposited in the same environment, consist of one unit); and

(f) organization of the determined units in stratigraphic order; reconstruction of the whole sedimentary succession and interpretation of the region's geological evolution.

The results of the mud breccia study suggest that a deep-sea basin has been present in the Eastern Mediterranean at least from the Aptian. The Aptian-Albian was characterized by a sea level fall, a wide deltaic front was being formed on the North African continent and thick flyshoid series were being deposited at the Pelagonian continental rise to the south. A large amount of terrigenous material was being supplied into the basin. The finest particles could reach its deep-sea parts. Serving as a settling basin for terrigenous clayey material, at the end of the Early Cretaceous, a relatively narrow deep-water gulf of the southern Neotethyan basin existed in the western sector of the Eastern Mediterranean. Thick clayey series accumulated there.

In the Late Cretaceous the gulf enlarged, sea level rose, terrigenous input into deep part of the basin decreased and carbonate pelagic sedimentation became predominant.

The regional tectonic re-arrangement of the Neotethyan basins occurred at the end of the Late Cretaceous. The closure of the Pindos basin to the north, the narrowing of the strait in the Isparta Angle and the strait north of Arabia, and the continuing closure of the Northern Neotethys probably led to the re-arrangement of waterways, causing an intensive water circulation within the Neotethyan basins. This resulted in the formation of condensed horizons of foraminiferal sand, in narrow parts of the basin on local highs. In deep parts of the basin pelagic sedimentation remained prevalent.

The Paleogene time was characterized by diminishing basin areas and their probable separation caused by tectonic activation. Within dissociated basins the specific depositional environments were set up in accordance to local geological and hydrological conditions. The regression in the western part of the basin led to deposition of thick terrigenous siliciclastic series of deltaic-prodeltaic sediments. The eastern part of the basin was characterized by a predominant carbonate pelagic sedimentation and bottom-current activity.

In the Miocene several turbidite systems were widely developing in the region, with predominant carbonate pelagic sedimentation. Turbiditic sedimentation in the western sector of the basin was characterized by a supply of carbonate detritus mixed with siliciclastic terrigenous material. In the central part of the basin thick clastic terrigenous and detrital carbonate series have been deposited separately. Siliciclastic material supplied into the central part of the basin was carried out mainly by the paleo-Nile, shifting gradually to the east, while the Eocene carbonate series of North Africa were the main source of carbonate turbidite deposition. Besides, the Miocene tectonic activation led to episodic re-deposition of pelagic material within the basin, forming very fine-grained mostly carbonate basinal turbitides.

In general, the configuration of the Eastern Mediterranean basin has changed significantly during its geological evolution since the Cretaceous, gradually approaching its present contours. Beside global sea-level fluctuations, local tectonic movements within the basin have affected the style of sedimentation.

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MORPHOLOGY OF SEAFLOOR MUD VOLCANOS ON THE MOROCCAN MARGIN

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Complex interactions between the Iberian and African plates since the Triassic in the Gulf of Cadiz, Alboran Sea and adjacent Moroccan continental margin have created an interesting puzzle for both sedimentologists and structural geologists. The Marine Physics Branch of the Naval Research Laboratory in cooperation with the Hawaii Mapping Research Group (HMRG) and the Naval Oceanographic Office (NAVOCEANO) conducted a sidescan sonar and multibeam bathymetry survey of the Gulf of Cadiz and Western Moroccan continental margin in 1992. Several seafloor structures believed to be methane hydrate related mud volcanoes were identified during the cruise and it was clear that further sub-bottom information and groundtruthing was needed to better understand the genesis and development of these structures.

Data collected onboard the RV "Professor Logachev" during Leg 2 of the Training Through Research cruise 9 (TTR9), in July 1999, has provided additional critical scientific information. Over 550 km of 6 channel seismic and 3.5 kHz subbottom profiler data, 15,000 km^2 of OKEAN 9 kHz sidescan sonar and 160 km^2 of OREtech 30 kHz sidescan sonar data were collected in the area of interest. Ground-truthing information for the sidescan was obtained from nineteen gravity cores, 2 grab samples and 6 hours of video imaging collected during the cruise.

Three regions of mud volcanism / diapirism were identified during the cruise. They are referred to as the Western Moroccan Field (WMF), Middle Moroccan Field (MMF) and Eastern Moroccan Field (EMF) for simplicity. In the WMF the diapiric structures were identified as long, sinuous ridges. In the MMF, OREtech sidescan data, grab samples and gravity core samples confirmed the existence of two mud volcanoes (Yuma and Ginsburg). In the EMF, gravity core samples confirmed the existence of 3 mud volcanoes (Kidd, Adamastor, TTR) and seismic and sidescan sonar data suggest that there are possibly 3 more mud volcanoes and 4 diapiric ridges. In addition, a possible BSR was observed in the seismic records

RECOGNITION OF AN ANCIENT MUD VOLCANO IN THE MALABATA AREA (NORTH–WESTERN RIF, MOROCCO)

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The subsurface deposits recognized by an experimental well with three galleries and GEO3 and SB3 bore holes, conducted by the Société Nationale d'Etudes du Détroit (SNED) in the framework of the "Linked Project across the Strait of Gibraltar» in areas of Malabata close to Tangier (North–Western Rif, Morocco), have a chaotic aspect and a predominantly clayey matrix (70 – 90% of the total volume). Scarce stratigraphic data indicate Lower Cretaceous, Upper Cretaceous and ? Eocene ages (Feinberg, 1994), and some clasts appear similar to Oligo–Miocene deposits of the Rif chain.

Two conflicting views were suggested as explanations for the texture and organization of these deposits. The first hypothesis (Chraibi *et al.*, 1995) proposes the existence of an oblique fault between the Lower and Upper Cretaceous successions, while the second hypothesis (Hamoumi, 1995) interprets these deposits as a post-Cretaceous wildflysch.

Re-examination of the sedimentological (facies, petrography and mineralogy) and geochemical data of these deposits (SNED, 1985, 1992, 1994 ; Hamoumi, 1994 a & b, 1995), from the results obtained in the last few years on gas hydrates and recent mud volcanoes (Gonthier *et al.*

1994 ; Cita *et al*,1996 ; IOC technical series, 1997; IOC workshop report 129, 1997 ; Ginsburg & Soloviev, 1998 ; Akhmanov & Woodside, 1998 ; and Results of the TTR9 1999) suggests a deposition by argilokinetic processes and fluid circulation, and expulsion during mud volcano activity.

These deposits correspond to a poorly sorted matrix supported by a mixture of clay matrix including clasts that vary in size (millimeter to hectometer scale), shape (rounded to angular) and lithology (red mudstone, gray mudstone, grey mudstone, silty mudstone, siltstone, calcareous sandstone, micaceous sandstone, calcarenite, calcareous siltstone, limestone). Moreover, they exhibit the typical composition, texture, features and structure of a mud volcanic deposit, as follows:

- the presence of several kinds of clays (gray, greenish, green and red) in the matrix that can be sometimes mixed in the same level;
- the aspect of the matrix clays that exhibit crumbly texture, glossy shard like fragments showing micro shearing, calcareous fragments and soft sediments deformations;
- the existence of calcite veins in the matrix clays and many clasts;
- the co-existence of polygenic clasts: 1) brown concretions, 2) crystalloclasts, gravels, pebbles and blocks realized from the disintegration of old deposits known to be from the Rif chain successions, 3) clasts realized during hydrate precipitation such as polymictic clasts (composed of red clay matrix and angular calcareous fragments, of splintery clay matrix and siltstone gravels or of sandstone pebble coated with massive clay), structureless limestone clasts with calcareous veins, and poorly consolidated siltstone or mudstone clasts;
- the mixture of sediments of different ages;
- the lack of grading and often of preferred orientation;
- the existence of levels with lenticular bedded structures;
- the degree of the weathering maturity of the sediments;
- the existence of authigenic minerals (smectite, vermiculite, calcite and pyrite);
- the chemical changes (alteration, dissolution and recrystallization) and the breakage that affects microfossils,
- the organic matter rich levels;
- the discovery of gas (methane) during drilling in GEO3 (at 147 m) and SB5 (at 180 m); and
- the discovery of low chlorine water in the Malabata well (Chraibi *et al.*, 1995).

This phenomenon is not necessarily limited to the south margin of the strait of Gibraltar, mud volcanic deposits could also exist in the north margin. This is suggested by: 1) the discovery of gas in the Al Marshal and S3 Pista de Betis drill holes, 2) the existence of Upper Cretaceous blocks in a Lower Miocene matrix in the Al Marchal bore hole, and 3) the difficulty to establish relationships between superimposed deposits of different ages, recognized from the petroleum drillings north of Tarifa (Durand Delga, 1993)

The Malabata mud volcano can be integrated in the regional tectonic history of the alpine Rif chain. It probably initiated during Miocene times. More detailed studies must be conducted in order to define the extent, age and geodynamic context of this phenomenon and its relationship with the recent mud volcanoes (Marrakech, Granada and Ginsburg) uncovered in the Moroccan margin (TTR 1999).

The discovery of mud volcano in the present marine environment of many regions of the world and the numerous data obtained from their investigations, offer us a new genetic model for poorly sorted sediments that are interpreted usually by gravity flow processes. It is thus necessary to take in account this important phenomenon when interpreting ancient deposits.

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TECTONIC ASPECTS OF MUD VOLCANO ORIGINS: COMPARISON OF THE SEISMIC DATA FROM THE MEDITERRANEAN RIDGE AND THE GULF OF CADIZ

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The Mediterranean Ridge and the Gulf of Cadiz mud volcano areas were studied during the TTR-3, TTR-5, TTR-9 and PRISMED-II cruises. Both of these areas are located at the boundary between the Eurasian and African plates where subduction takes place.

A comparison between the Mediterranean Ridge mud volcanoes, in the Olimpi area and the United Nations Rise, and those in the Gulf of Cadiz using seismic and acoustic data demonstrates that they have a rather similar surface morphology but are quite different in seismic sections. On the sea floor they are represented as either isometric or slightly elongated structures, with a diameter of hundreds of meters to several kilometers. Some of them are characterized by extensive mudflows.

On seismic sections the Gulf of Cadiz mud volcanoes, cut through adjacent stratigraphic units and vertical feeder channels, can be traced. In contrast, the deep structure of the Mediterranean mud volcanoes is not visible or rather complicated. This difference could be explained by the structure of host sediments and their formation mechanisms.

The sedimentary layers in the Gulf of Cadiz are almost horizontal and disturbed by occasional normal faults. On the Mediterranean Ridge the sedimentary sequence is broken extensively by normal, reverse and strike-slip faults, and thrusts. Because the fault planes may intersect in different directions and may have different dips, the feeder channels must be extremely complex and hence totally invisible on seismic sections.

In the Gulf of Cadiz the major factor in the formation of mud volcanoes is the lithostatic pressure of rather thick overlying sediments, although some lateral tectonic compression takes place as well. The principle mechanism responsible for the Mediterranean Ridge mud volcanoes' origin is lateral tectonic compression.

PHYSICAL PROPERTIES OF ROCK CLASTS FROM MUD BRECCIA OF THE YUMA MUD VOLCANO (GULF OF CADIZ).

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Physical properties provide important information about rock composition, texture and diagenetic alterations. This work is a first attempt to estimate some physical parameters of deeply buried strata in the Gulf of Cadiz area, studying a rather limited amount of rock fragments erupted onto the seafloor in the Yuma mud volcano crater.

In the first stage of the study, all rock clasts from Yuma mud breccia were subdivided into three main groups – claystone, sandstone and limestone – and their thin sections described in detail in under a polarizing microscope. The claystones are composed mainly of kaolinite and chlorite, with carbonate and siliciclastic admixture. The sandstones are medium to fine-grained and consist mainly of quartz grains, plagioclase and feldspar, cemented with carbonate and clay minerals. The limestones are of two types: crystalline and biodetritic.

Bulk grain density, and total and effective porosity were determined for all rocks. The claystones have the lowest values of bulk density (1.67 – 1.87 g/cm^3) and accordingly the highest values of total porosity (25.0 – 31.6%). The bulk density of the sandstones varies from 2.17 to 2.40 g/cm^3, and their effective porosity is 8.11 – 22.7%. The crystalline limestones have higher values of bulk density (2.5 – 2.83 g/cm^3) and lower values of effective porosity (about 5%) than biodetritic limestones (2.43 – 2.58 g/cm^3 and 10.5 – 21% respectively).

The very low values of bulk density in the claystones imply incipient catagenetic alternations. However, the processes of cementation in sandstones and re-crystallization in limestones have significantly limited the effective inter-granular rock porosity, which is expected at this low stage of alteration.

The data obtained suggest that only sandstones and biodetritic limestones can be considered as potential reservoirs for hydrocarbons.

ROCK CLAST LITHOLOGY IN MUD VOLCANO BRECCIA FROM THE GULF OF CADIZ

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The material investigated came from a large sample of mud volcanic deposits, which were taken during the TTR-9 cruise of the RV "Professor Logachev" from the Yuma mud volcano (Gulf of Cadiz) with a TV-controlled grab sampler. The study of rock clasts from the mud breccia was developed according to a method elaborated by G. G. Akhmanov (1999) for the Mediterranean Ridge mud volcanoes, based on material collected during several TTR cruises.

According to their visual (macroscopic) lithological description (composition, structure and texture) rock clasts were subdivided into groups. Study in thin sections under a polarizing microscope allowed the definition of 17 main groups. The genetic indicators of studied rocks suggest a deep-sea environment during their accumulation. Rocks of similar lithology and deposited in the same environment were grouped in 12 sedimentary units. On the basis of

lithological investigations and micropaleontological studies, reconstruction of the sedimentary succession, broken up by volcanic mud, was made.

The inferred reconstruction was mainly represented by limestones, claystones and sandstones. Most pelagic limestones are of the Miocene-Pliocene age. The sandstones, possibly from turbidity deposits, were formed during the Eocene and Miocene in the Gulf of Cadiz. The position in the sequences and the genesis of shallow water deposits and slumped units is questionable. The data introduced above provide additional light on the geological history of the Gulf of Cadiz area.

GEOCHEMICAL INVESTIGATION OF ORGANIC MATTER IN ROCK CLASTS FROM MUD VOLCANO BRECCIA (GULF OF CADIZ AND ALBORAN SEA)

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Mud volcanism is known to be clear evidence for fluid venting. This phenomenon is widespread in the world, both onshore and offshore, and is common in deep sedimentary basin and accretionary complex environments. Gas saturating mud breccia consist mostly of methane, and in many cases of heavier homologues. The chemical and isotopic composition of hydrocarbon gas suggests its thermogenic origin (Stadnitskaya, 1996; Egorov, 1996). The main aim of this work was to find source rocks for thermogenic gases formed due to the destruction of kerogen in sedimentary sequences.

During the research, a collection of more than 60 rock clast samples from mud volcano breccia (in the Gulf of Cadiz and Alboran Sea mud volcanic areas) was analyzed using Rock-Eval pyrolazer and fluorescent methods. A few samples, the richest in organic matter, were selected for more detailed investigation, such as gas chromatography (GC), gas chromatography – mass-spectrometry (GC–MS) and infrared analysis.

The rock clast organic matter generally belongs to immature and low maturity kerogen, of types II and III (according to Tissot and Welte, 1984). The organic carbon content varies in different areas, depending on the environmental conditions during sedimentation. The immaturity and poor oil / gas potential of the samples may indicate that the source of thermogenic gas lies in deeper layers, which are represented in almost all rock clasts found in the mud breccia. The samples richest in organic matter however, show good and excellent potential for gas and oil production.

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HYDROCARBON GAS DISTRIBUTION IN MUD VOLCANIC DEPOSITS OF THE GULF OF CADIZ: PRELIMINARY RESULTS

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Hydrocarbon gas composition and distribution were analyzed for a number of mud volcanic sites located within the Gulf of Cadiz, discovered during TTR-9 cruise of the RV "Professor Logachev". The study was aimed at distinguishing the origin of gas from the area of active fluid flux and gas venting investigated. Of particular interest were the content, behavior and correlation between individual hydrocarbons along the cores, in order to infer possible migration mechanisms in relation to a deep source.

Hydrocarbon gas concentrations were measured using gas chromatography for C_1–C_5, including both saturated and unsaturated components. The determination of Total Organic Carbon (TOC) content was also carried out, from samples taken at the same intervals as those for gas analysis.

According to the gas measurement results, the area investigated is characterized by a relatively high background gas content (in comparison with previously studied areas in the Eastern Mediterranean and Black Sea). Reference Core AT-201G shows methane concentrations ranging from $112x10^{-4}$ ml/l to 0.9 ml/l and 33 – $97x10^{-4}$ ml/l for its homologues. Hydrocarbon concentrations in cores from the mud volcanoes are, in most cases, close to the background values. However, cores taken from the Yuma and Ginsburg mud volcanoes (AT-203G and AT-208G), located in the central part of the area, have abnormal methane concentrations (up to 292 ml/l).

In Core AT-208G, gas hydrates were recovered within the interval 97 – 118 cm bsf. The results of the gas analysis imply that the gas-hydrate layer might be thicker than it was described. Between 40 cm and 120 cm bsf, the methane concentration rapidly increases from 3 to 292 ml/l, and then decreases down to 53 ml/l.

Mud breccia of Core AT-203G underwent extensive gas-driven self-extrusion, but gas hydrates were not observed. However, the concentration and distribution of hydrocarbon gas suggest that gas hydrates could also be present there. In the uppermost 40 cm the methane concentration dramatically increases from 1 to 87 ml/l.

The homologues of methane in both cores are also characterized by very high concentrations. For instance, in Core AT-208G the sum of C_{2+} ranges from 0.002 to 6 ml/l and in Core AT-203G from 0.004 to 6 ml/l. The distribution of hydrocarbon gas in these cores is very chaotic.

The cores are also characterized by a predominance of saturated, rather than unsaturated, hydrocarbon gas. The value of C_nH_{2n+2}/C_nH_{2n} ranges from 3 to 25, which indicates a thermogenic source. Migration processes were identified using the iC_4/nC_4 ratio. The predominance of iC_4 suggests focused upward migration, and the predominance of nC_4 characterizes diffusion processes. Cores AT-203G and AT-208G clearly demonstrate the presence of two migration mechanisms, where focused upward migration is the principal one. Extremely low values of unsaturated components (C_2H_4 and C_3H_6) imply slow microbiological processes probably caused by a rapid hydrocarbon flow.

GAS-RELATED CHANGES IN PORE WATER CHEMICAL COMPOSITION: APPLICATION TO AUTHIGENIC CARBONATE FORMATION (TTR-9, GULF OF CADIZ)

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Authigenic carbonate precipitation and pore water composition in highly gas-saturated sediments of the Yuma and Ginsburg mud volcanoes were investigated in the deep-water area of the Gulf of Cadiz during the TTR-9 cruise.

Newly formed diagenetic carbonate-cemented aggregates associated with tubeworm communities occur at the aerobic-anaerobic sediment zone near the sea bottom. The cement present is mainly aragonite, however low values of magnesium calcite and dolomite were also observed. The low 13C values (as low as –30.03 ‰ PDB) in aragonite indicate that some of its carbon is derived from methane oxidation. SEM analysis shows that carbonate crystals are associated with biofilm media, and round-shaped micro-organisms have been observed in the carbonates.

The pore water analysis shows low values of SO_4^{2-} and SO_4^{2-}/Cl^- in sediments where diagenetic carbonates occur. Bacterial sulfate reduction could favor the precipitation of the carbonate phase. Elevated Mg/Ca ratios may have provoked the crystallization of aragonite instead of calcite. The low clorinity compared to the high Cl^- concentration of sub-bottom waters points to gas hydrate dissolution.

A number of laboratory analyses of the pore water chemical composition were performed; optical microscope study, SEM analysis, determination of carbonate carbon isotope values and X-ray powder diffraction in the whole interval of Bragg angles.

The origin of diagenetic carbonates is discussed.

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HYDROCHEMICAL FEATURES OF GAS HYDRATE-BEARING MUD VOLCANOES, OFFSHORE MOROCCO

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The study area is located on the Moroccan continental margin (Gulf of Cadiz). This region was investigated in July 1999 during the 9-th international expedition on board the RV “Professor Logachev” within the framework of the UNESCO-IOC Training Trough Research Programme. A number of mud volcanoes were discovered in data collected by seismic profiling and OREtech deep-towed combined sidescan sonar and 5-kHz subbottom profiler. Gas hydrates have been sampled with a gravity corer from one of the mud volcanoes (namely, Ginsburg mud volcano). Elemental and isotopic analyses of about 50 samples of pore water were carried out. The results of these analyses affirm considerable variations in chlorinity, the Mg/Cl ratio and the isotopic composition of oxygen and hydrogen in water. Gas hydrate-bearing intervals of sediments recovered from the Ginsburg mud volcano are characterized by low (to 450 mM) chlorinity. We suspect gas hydrates also occur in sediments from the Yuma mud volcano based on the low

(relative to ocean water) chlorinity in the pore water. Our data suggest that the chemical composition (chlorinity, Mg/Cl ratio etc.) of the mud volcano water is similar to the composition of pore water from pelagic sediments. A distinct correlation between the chlorinity (gas hydrate index) and the isotopic composition of the water was revealed. The oxygen became heavier with decreasing chloride concentration and increasing gas hydrate content, which correlates with isotopic fractionation during gas hydrate formation. In this case hydrogen becomes lighter, which is in contrast with available insights. The reason for this phenomenon has yet to be explained. The object of this investigation is unique due to the fact that this is the first discovery of gas hydrates in this region.

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THE AGE OF ROCK CLASTS FROM THE YUMA MUD VOLCANO BRECCIA ON THE BASIS OF A FORAMINIFERA STUDY (GULF OF CADIZ, NE ATLANTIC)

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Foraminiferal assemblages from rock clasts of the mud volcano breccia, collected during TTR-9 cruise of the RV "Professor Logachev"(June – July, 1999), were investigated. The sample of mud breccia was taken by a TV-Grab system at Station TTR9-AT209Gr located on top of the Yuma mud volcano, in the southeastern part of the Gulf of Cadiz.

Thirty-seven samples with different lithological characteristics were studied. The samples were disintegrated, washed and sieved through a 50 μm sieve. They were then separated into two size fractions: >100 μm and 50 – 100 μm. Professor V. A. Krasheninnikov of Geological Institute of RAS helped with the determination of foraminiferal taxa in size fractions >100 μm. Foraminiferal tests were found in twenty-one samples. Twelve of these were characterized by richer foraminiferal assemblages and were selected for dating.

All studied samples can be subdivided into two groups on the basis of their age. The first age group is characterized by following planktonic foraminiferal species: *Globigerina eocaena, G. hagni, Globigerinatheka subconglobata micra, Acarinina bullbrooki and A. soldadoensis soldadoensis*. These are typical of the upper part of the Lower Eocene and the lower part of the Middle Eocene (Bolli *et al.*, 1985). In the second age group, the following planktonic foraminiferal species were defined: *Globigerina nepenthes, Globorotalia menardii, Praeorbulina glomerosa circularis, Globorotalia praemenardii, Globoquadrina dehiscens, Globorotalia siakensis* and *G. scitula praescitula*. This assemblage is typical of the Miocene in general (Bolli *et al.*, 1985; Krasheninnikov, 1973).

All above-mentioned samples contain stenohaline planktonic foraminiferal species, suggesting that the corresponding rocks were deposited in a marine basin with normal salinity. The samples of some lithotypes contain only benthic agglutinated foraminiferal species typical of a deep-water environment.

The results of the lithotype dating show that, in the Yuma mud volcano, breccia rock clasts are represented by Middle/Lower Eocene and Miocene lithological varieties.

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MICROPALEONTOLOGICAL INVESTIGATION OF ROCK CLASTS FROM MUD VOLCANIC DEPOSITS IN THE ALBORAN SEA

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Lithological and micropaleontological investigations were carried out on deposits from a mud volcano discovered during TTR-9 cruise of the RV "Professor Logachev" (June – July, 1999). The mud volcano (named Granada) was found on the Moroccan margin of the West Alboran Sea (lat. 35˚33 N, long. 04˚37 W) at a water depth of 580 m.

Two gravity cores (258G and 259G) were taken from the top of the Granada mud volcano. These cores recovered mud breccia deposits with numerous rock clast fragments of different lithologies, and an average size of 2 – 3 cm. The rock clasts were subdivided into seven lithological groups: 1) limestone (11 samples), 2) detritic limestone (3 samples), 3) clay (7 samples), 4) claystone (6 samples), 5) siltstone (5 samples), 6) marlstone (4 samples) and 7) sandstone (3 samples).

Assemblages of calcareous nannofossils were studied in all rock clast samples and in the mud breccia matrix. Four samples of the matrix were analyzed and their assemblages found to be abundant, moderately preserved and diversified. The dominant species include Upper Cretaceous coccoliths – *Micula decussata, Cribrosphaerella ehrenbergi, Predicoshaera cretace.* Neogene coccoliths (*Discoaster sp, Pontosphaera multipora)* and Recent coccoliths (*Emiliania huxleyi, Gephyrocapsa sp, Rhabdosphaera claviger)* are less abundant.

The majority of rock clasts (27 samples) from the mud volcano are from the Upper Cretaceous. The most abundant species are *M. decussata, C. ehrenbergi, Arkhangelskiella sp, P. cretacea, Rhagodiscus angustus, Stradneria crenulata, W. barnesae, Eiffelithus turriseiffelii, Tranolithus phacelosus, Gartnerago obliquum, Manivitella pemmadoidea, Glaukolithus diplogrammus.* The common occurrence of *Arkhangelskiella sp.* is indicative of the Campanian–Maastrichtian age (CC18-CC26, Cretaceous coccoliths zone), and the presence of *Thierstenia ecclesiastica* and *G. obliquum* indicative of the Turonian–Santonian age (CC10-CC19).

Paleocene and Eocene species were observed in five rock clast samples. In particular, *Cruciplacolitus tenuis, Ellipsolithus bolii, Chiasmolithus conseuetus, C. solitus, Neochiastozigus sp, Discoaster multiradiatus, Toweius emines* and *Campylosphaera eodela* were identified. These species indicate the Paleocene–Early Eocene age (NP 4, NP9 – NP10, Nannoplankton Paleogene zone).

Two samples of the rock clasts contain poorly preserved Neogene coccoliths and discoasters. *Discoaster cf. D. drugii, Discoaster cf. D. deflandrei, Helicosphaera sp, Coccolithus pelagicus* and *Pontosphaera multipora* species were identified in them. The discoaster shapes suggest the Miocene age.

The Granada mud volcano is located in the southern part of the widespread mud-diapiric province, in the West Alboran Sea adjacent to the Early Miocene sedimentary depocenter (Comas *et al.*, 1999). This province involves sediments from lithological units overlaying the basement complex in the West Alboran Sea. These units represent olistostromes and are composed of over-pressured and under-compacted shales dating from the Early Miocene (Aquitanian?–Burdigalian) (Comas *et al.*, 1999). The Granada mud volcano is probably rooted in these lithological units. The Upper Cretaceous and some Paleocene–Eocene nannofossil species could be derived from clastic materials, which belong to the olistostromes.

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FLUID SEEPS ASSOCIATED WITH SALT/SHALE GRAVITATIONAL SPREADING ALONG THE GULF OF CADIZ CONTINENTAL SLOPE

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Deformations observed on multifold seismic lines with high-resolution seismic equipment (Sparker and Geopulse) along the shelf and slopes of the Gulf of Cadiz (Iberian Atlantic margin) provide geometric evidence for salt-related fault families. The plastic layers involved in these processes are Triassic salt and under-compacted Early–Middle Miocene plastic marls (known generically as the "Gualdalquivir allochton"), along which the front of the advancing Betic-rifian accretionary wedge overthrust into the Gulf of Cadiz during Late Tortonian times.

Asymmetric extensional arrays consist predominantly of listric growth faults that dip basinward and sole out into a salt weld. These are accompanied by symmetric fault arrays, mainly over the crests of reactive diapirs. Extensional faults are formed by basinward advancement of the salt and its overburden, with associated subsidence of mini basins.

Basinward advancement of the shelf sequence is balanced by salt extrusion and contractional fault families on the upper slope, mainly basinward-vergent thrusts that ramp from a salt detachment. Salt bodies along toe-thrusts close to (primary and/or secondary) welds that surfaced on the sea floor and supplied salt tongues: arcuate lobes of salt advancing basinward.

Large seafloor pockmarks identified at water depths less than 400 m are related to extensional structures due to reactive diapirism, such as keystone or crestal faults, which provide avenues for the moderate vertical flux of hydrocarbon gases (mainly composed of biogenic methane) and fluids (brine). In water depths greater than 500 m, injection of sediment-rich fluids along the contractional toe-thrust structures results in the construction of relief structures, probably mud volcanoes and mound-like carbonate build-up, as reported on the Gibraltar Strait at depths between 600 and 800 m. Sub-bottom injection underthrusting non-consolidated sediments also occurs, forming small mud/salt laccoliths.

We infer that this system called the "Cadiz Salt Nappe", evolved since the Late Tortonian by gravitational spreading and sliding of mobile shales and salt stocks, providing avenues for fluid expulsion (including brine, oil, gases and fine sediment) to the continental slope surface along the Gulf of Cadiz, which shows similar flow patterns to those reported on accretionary wedge settings by contractional structures.

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DIAPIRS AND MUD VOLCANOES IN THE GULF OF CADIZ, MOROCCAN SECTOR: INTERPRETATION OF SEISMIC AND SIDE-SCAN SONAR DATA

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Seafloor structures identified during a previous geophysical survey (The Marine…, 1992) were investigated using a single channel seismic acquisition system, and 9 kHz OKEAN and 30 kHz OREtech side-scan sonars, as part of the research programme undertaken in the Gulf of Cadiz during the RV "Professor Logachev" TTR-9 cruise. The aim of the investigation was to gain a

better understanding of the genesis and development of the seafloor structures, believed to be methane hydrate-related mud volcanoes.

Interpretation of the seismic and side-scan sonar data suggests that the seafloor structures are connected to piercing bodies in which the internal reflection pattern is characterized by the absence of coherent acoustic impedance contrasts. In addition, several diapiric bodies with a similar (transparent) reflection pattern were identified. Based on the morphology of the diapiric and volcanic structures and the strata geometries adjacent to these, the study area was classified into three regions: Eastern Moroccan Field (EMF), Middle Moroccan Field (MMF) and Western Moroccan Field (WMF). The existence of five mud volcanoes was confirmed by shipboard chemical analyses of sediment samples taken from cores collected in EMF and MMF (see this volume). Three of these were identified in the EMF – two of them 2 km diameter, sub-circular volcanoes in association with a NW-SE trending diapiric ridge. In the MMF two 4 km diameter, individual sub-circular volcanoes surrounded by a moat collapse structure were identified. The WMF was characterized by long, sinuous NW-SE trending ridges similar to that in the EMF. However, the structures in this area were much steeper and the area is the most topographically varied. This suggests that the structures are older or have been active for a relatively longer time. The NW-SE alignment is seen as being related to the NW-SE compression along the Moroccan margin.

Due to the low resolution of the seismic data, it is impossible to identify the source layer of the diapirs and volcanoes, and to see to what extent the source material is associated with, or masks, other structures such as underlying faults. Results of research (Rodero *et. al.,* 1999) undertaken adjacent to this study area suggest that only sediments of Quaternary (Pleistocene) age are being resolved. Stratal geometries indicate that all diapiric and volcanic structures show movement prior to deposition of the deepest interpreted unit of Quaternary age and that growth has continued until present day.

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DIAPIRS AND RELATED STRUCTURES IN THE MUD-VOLCANO AREA OF THE WEST ALBORAN BASIN

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One of the objectives of the BASACALB cruise (TTR-9 Leg 3) was to survey the diapir province of the West Alboran Basin. Two mud-volcanoes called Granada and Marrakech together with several mud diapirs were discovered. Gravity cores taken on top of the Granada mud-volcano recovered mud breccia of over-pressured expelled material (cores 258G and 259G).

Geological and geophysical data indicate that the Alboran Basin was formed by extensional processes in a collisional plate-tectonic setting. Plate-motion reconstruction of the Eurasian and African plates shows that this segment of the plate boundary experienced a roughly 200 km N–S convergence between the middle Oligocene to the late Miocene, followed by about 50 km of NW–SE convergence from the latest Tortonian (9-8 Ma) to present-day. Extension in the

basin was coeval with thrusting and shortening in the peripheral Betic and Rif mountain belts. Extensional systems were active from the Early Miocene (about 22 Ma) to the Late Tortonian (about 9 Ma), since then, contractional deformation in the basin has produced reverse and strike-slip faults and E–W folds.

During the BASACALB cruise (TTR-9 Leg 3) the mud volcano area of the southwestern Alboran Basin was surveyed by single-channel seismic and side-scan sonar (OKEAN) profiling. Four gravity cores were taken in the area and a mud-volcano was sampled in the West Alboran Basin for the first time. Commercial MCS lines crossing the area have been used to determine the age of the three seismic units distinguished in the area. Unit I (the uppermost) and Unit II are characterized by strong parallel reflectors of variable amplitude, and have locally lateral thickness variations as well as a wedge geometry. These two units are separated by an erosional or angular unconformity seen as a high-amplitude reflector. Unit II is less reflective than Unit I and has widely spaced high-amplitude reflectors, as well as several internal angular unconformities. Unit III is semi-transparent with spaced sub-parallel to low amplitude scattered reflectors. The Pliocene–Quaternary boundary is probably situated inside Unit III, as is suggested by correlation with commercial MCS lines and ODP Leg 161 data. Maximum thickness of the seismic units is achieved between diapirs. Towards the highs the reflectors show an on-lap geometry and the units decrease in thickness. Mud diapirs generate non-cylindrical folds with anticline culmination coinciding with the diapir highs and encased synclines between them. Lateral mud flow, at least during the Quaternary, produces steep anticline culmination and hang basins in the anticline depressions and synclines. Preliminary seismic interpretation of the BASACALB cruise (TTR-9 Leg 3) data suggests that discovered mud-volcanoes are displaced from diapir culmination.

Sedimentary Processes and Climate Changes in the Western Mediterranean

TEMPESTITE TO TURBIDITE DEPOSITION IN POST-EVAPORITIC MESSINIAN SEDIMENTS OF THE GAFARES AREA (ALMERIA, SE SPAIN)

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Messinian sequences are exceptionally well exposed in many on-land basins of southeast Spain (e.g. Sorbas, Vera, Fortuna), allowing precise assessments of the sedimentary record and palaeoenvironmental evolution of the Mediterranean, under pre- to post-desiccation conditions. Gafares, located between Níjar and Carboneras, is one of these sites where the post-evaporitic deposits are particularly well represented. In this report we present preliminary data of these sediments from a section east of Gafares.

The Messinian evaporitic and post-evaporitic units of the studied section constitute a continuous sequence up to about 200 m thick. Selenitic gypsum beds characterize the evaporitic unit, while conglomerates, sands, silts and marls represent the post-evaporitic unit. The evaporitic unit gradually changes up sequence to post-evaporitic deposits, due to progressive thinning of the selenitic gypsum beds and a concomitant thickening of the siliciclastic intercalations.

The terrigenous intervals of the lower part of the transitional zone between the two units are massive silty background sediments and sand beds interspersed with a conspicuous planar bedding. The sand beds show many sedimentary structures: thin horizontal lamination; trough and planar cross lamination; wavy lamination; hummocky cross-bedding; normal grading; and

channeled basal contacts. Water-scape structures are also very common. All these sedimentary features indicate these sediments can be attributed to storm deposits.

Marls and silts, with planktonic and benthic foraminifera, dominate the upper part. Intensively bioturbated (*Chondrites*) sand beds, showing partial or complete Bouma sequences, are intercalated between the marls. This material is interpreted as turbidite deposited in a deep-sea fan. Slumps and other structures indicating syn-sedimentary deformations are recognized in the transitional zone between the tempestite to turbidite dominant parts of the unit.

The sedimentary record of the studied section suggests a deepening trend, from a shallow platform affected by storms to deep-basinal marine settings. Over-abundance of *Chondrites* in many sand beds indicates that sedimentation took place under anaerobic conditions. Syn-sedimentary deformation was probably related to the uplift of Sierra Cabrera, the Betic basement north of the study area. In fact, the interspersed conglomerates and coarse-grained sands are made up of metamorphic cobbles and boulders from this relief. A similar deepening trend in the marine post-evaporitic deposits of the Sorbas basin has been proposed. In addition, the presence of foraminifera in Gafares confirms that the marine reflooding of the Mediterranean after desiccation occurred during the Messinian, prior to the long-assumed “Early Pliocene deluge” hypothesis.

THE BOTTOM OF UPPER MESSINIAN EVAPORITES OBSERVED WITHIN DIAPIRS OF THE SOUTH BALEARIC BASIN, ACCORDING TO SEISMIC DATA

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An area of salt diapirism located in the South Balearic Basin was investigated in 1999 during TTR-9 expedition within the framework of the UNESCO-IOC “Floating University” project. Several single-channel seismic lines were made along this area. Data show the presence of high-amplitude reflections inside the diapiric folds, which generally follow the diapir topography.

Qualitative 3D modeling demonstrates that these reflections could be side-echoes from other diapirs, located aside from the seismic lines. However, the fact that they are all located virtually symmetrical to the main diapirs, makes this assumption questionable.

Migration of the seismic data allowed the elimination of diffraction hyperbolas, which complicated the reflections, and at the same time to obtain better information about their real shape. It appeared to be a continuous interface, rather than separate reflections, and was interpreted as a boundary between upper Messinian evaporites, represented mainly by gypsum and dolomite, and the underlying salt layer.

OXYGEN AND PRODUCTIVITY PROXIES IN ALBORAN AND SOUTH-BALEARIC SEDIMENTS: IMPLICATION FOR PALEOCLIMATIC RECONSTRUCTIONS

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The cyclic deposition of sapropels and organic-rich layers has been well documented in the Mediterranean. The origin of such organic carbon enriched deposits has been widely discussed and different hypotheses have been proposed to establish their origin. Two main conflicting models have been argued for decades: the anoxia model showing that sapropels resulted from

stagnation and basin anoxia, and the productivity model that suggests increased productivity at time of sapropel deposition. Discussion has been mainly focused on productivity and oxygen proxies. However, some classical indicators of productivity are not always well preserved, thereby biasing productivity signals. Advances in this field and the search for more refractive chemical indicators have demonstrated that barium (Ba) has a strong biogenic association. Ba in sedimentary solid phases has therefore been proposed as a productivity proxy. Nevertheless, the use of Ba as a record of productivity depends on Ba carriers and possible diagenetic remobilization. Ba can only be a reliable productivity proxy if it occurs as barite crystals, resulting from biogenic activity, and if the Ba record is well preserved (Paytan *et al.*, 1996).

Analyses of the most recent sapropel layer (S1) in the eastern Mediterranean revealed that the original sapropel corresponds to a Ba-enriched interval, thicker than the visible sapropel, and that the Ba-carriers of excess Ba are biogenic barite crystals. Barite is therefore evidence enhanced productivity during sapropel formation, thus indicating that the S1 sapropel origin is related to an increase in biogenic production rather than the preservation of organic carbon (Martinez-Ruiz *et al.*, 2000). Paleoredox indicators point to restricted oxygenated bottom waters, not anoxic conditions. Climate change involving enhanced humidity and precipitation / run-off led to higher nutrient supply and therefore increased productivity. In contrast, analyses of the most recent organic rich layer (ORL 1) in the Alboran Sea revealed a different record of these environmental changes, since no Ba enrichment is recognized. Although good Ba preservation might be expected with increased mass accumulation rates, solid-phase Ba is not effectively preserved in sediments that have undergone suboxic diagenesis, since post-depositional processes may have caused mobilization and alteration of the original geochemical record (McManus *et al.*, 1998). Different oxygen conditions at a time when the ORL 1 deposition and post-depositional alteration may have both contributed to a different geochemical record. Changes in oxygenation and diagenetic conditions from East to West are poorly understood due to the sapropel-record gap between the Alboran Sea and the eastern Mediterranean. Addressing this problem the BASACALB cruise (TTR-9 Leg 3) recovered an excellent sapropel layer in this area. Analyses of the recovered sapropel interval revealed a well-preserved Ba profile, which confirms particular oxygen conditions at a time of deposition and / or diagenesis restricted to the Alboran Sea basin.

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PALAEOENVIRONMENTAL SIGNIFICANCE OF BENTHIC FORAMINIFERAL ASSEMBLAGES IN THE LOWER PLIOCENE CONTINENTAL PLATFORM DEPOSITS OF THE ALMERÍA-NÍJAR BASIN (SE SPAIN)

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Changes in benthic foraminiferal assemblages in lower Pliocene deposits of the Almería-Níjar basin (SE Spain) were studied. The Almería-Níjar basin is bound by Sierra Alhamilla and Sierra Cabrera to the N, Sierra de Gádor to the W, and Serrata de Níjar-Sierra de Gata to the east.

The Pliocene deposits can be divided into two non-conformable units: the lower unit is of Early Pliocene to lowermost Late Pliocene age, and the upper unit is Late Pliocene. In this report, we focus on foraminiferal assemblages of the lower unit, which represent a shallowing upward sequence from outer shelf blue-grey clays at the bottom of the sequence, deposited below the storm wave base, to shallow inner shelf deposits affected by storm waves at the top.

A qualitative binary cluster analysis reveals three different foraminiferal assemblages, which in turn reflect the aforementioned shallowing trend. The foraminiferal assemblage at the bottom of the sequence is dominated by *Cassidulina neocarinata* (50%), a microfossil assemblage corresponding to the deepest deposits formed under anaerobic sea-floor conditions. Shallow facies at the top of the section are characterized by *Ammonia*, *Florilus*, *Criboelphidium* and *Elphidium*. Foraminiferal assemblages of the middle shelf facies are highly diversified, predominantly *Florilus boueanum*, *Elphidium sp*, *Lenticulina calcar*, *Cibicides sp* and *Asterigerinata planorbis.*

Within this general environmental trend, two minor shallowing cycles can be differentiated. In the middle of the sequence, the boundary between the two cycles can be inferred, based on a substantial microfossil assemblage change and on the coincidence of a species diversity maximum and a planktonic / benthic (P / P+B) ratio peak. Nonetheless, upwelling currents and / or over-abundance of nutrients due to continental outflow could also contribute to increased diversity and P / P+B ratio.

Finally, a quantitative Q-mode cluster analysis allows the identification of benthic foraminiferal subgroups controlled by different environmental factors, regardless of their depth distribution. Thus, a foraminiferal assemblage dominated by *Bulimina*, *Hopkinsina*, *Cassidulina* and *Brizalina* characterizes anaerobic conditions. On the other hand, the abundance of *Elphidium*, *Criboelphidium* and *Cibicides*, a typically epiphytic foraminiferal assemblage, can be correlated with the presence of an algal covered sea-bottom.

RECORD OF CLIMATIC VARIATIONS IN THE UPPER MIOCENE PELAGIC MARLS IN THE SORBAS BASIN (ALMERIA, SE SPAIN)

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Changes in lateral facies from Messinian marginal carbonates into pelagic marls can be physically traced in 3 well-exposed sections of the Sorbas Basin, SE Spain. This has allowed the constraining of the palaeoenvironmental context of carbonate deposition with oxygen and carbon isotope analysis on foraminiferal tests from coeval marls.

At the basin margins, an uppermost Tortonian to lowermost Messinian temperate carbonate unit (bryomol and rhodalgal facies) is overlain by two successive Messinian reef units, comprising coral and Halimeda bioherms and fringing Porite reefs respectively. All these units change into basinward silty marls and marls. ^{18}O values of both planktonic and benthic foraminifera from the temperate carbonate unit are higher than those from the overlying reef carbonate units. This decrease in ^{18}O, together with an increase in subtropical species in planktonic foraminiferal assemblages, suggests a rise in sea-surface temperatures in the transition from temperate to reef-carbonate deposition.

^{13}C values from planktonic foraminifera indicate a parallel decrease in sea-surface productivity from temperate to reef units. During the formation of reef carbonates, carbon isotope signatures and benthic foraminiferal assemblages point to a poorly oxygenated bottom and marked stratification of the water column, disturbed by water mixing and high productivity in several intervals.

Tectonics and Structure of the Western Mediterranean

TECTONICS AND BASIN/PLATFORM STRUCTURES OF THE TUNISIAN MEDITERRANEAN CONTINENTAL MARGIN

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The northeastern margin of Tunisia is bounded by the Mediterranean Sea and comprises the gulfs of Tunis and Hammamet to the North and the Gulf of Gabès to the South. In onshore regions, Mesozoic and Cenozoic sedimentary series crop out in Northern Atlas zones.

The main geological investigations are based on petroleum well and reflection seismic data. The geological and geophysical studies carried out on this margin, with seismic stratigraphy and isopach andisochron structural mapping of Mesozoic and Cenozoic horizons, reveal the tectonics and the basin / platform structures, as well as the stratigraphic infilling sequence.

These results show a tectonic structural framework characterized by a deep-seated flower structure with strike-slipfault corridors East–West, North–East, South–West and North–South. These faults distribute the Mesozoic and Cenozoic sedimentary cover according to the spatial and temporal basin / platform organization of grabens, rim synclines, folds and synclines.

Along the major strike-slip fault corridors alkaline intrusive and extrusive magmatic rocks encountered in the outcrops and petroleum wells accompanied transtensive and transpressive fault reactivation from the Triassic to the Miocene. Triassic salt diapirism appears in the northern and more or less in the western parts of the Sahel area, whereas clay intrusives and diapirs characterize thick Neogene deposits in the eastern and northern offshore zones. A tentative 3D-basin model shows the relationship between fault and basin / platform structures.

These results enabled the recognition of spatially and temporally reactivated and avorted transform margins in Tunisia.

REGIONAL CONTEXT OF THE METAMORPHIC ROCKS SAMPLED DURING THE BASALCALB CRUISE (TTR9-LEG3)

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The basement of the Alboran basin is mostly composed of metamorphic units belonging to the Alboran Crustal Domain, which also crops out in the Betic and Rif Cordilleras. The metamorphic units are grouped, in ascending order, into the Nevado-Filabride, Alpujarride and Malaguide complexes, each one showing independent polyphasic tectonometamorphic histories. Marine sedimentation started in the lower Miocene, while metamorphic units were rapidly exhumed. However, at the same time, the Alboran Domain was superimposed on the Iberian and Maghrebian Domains, in a westward motion, giving rise to the Gibraltar Arc.

One of the objectives of the BASALCALB cruise (TTR9-Leg3) was to sample possible metamorphic rocks of the Alboran Domain in residual highs and escarpments. The basement was sampled by dredging (Site 265D) a topographic high *ca.* 30 km NE of ODP Site 976, in a NNE–SSW horst structure of the northern West Alboran Basin. The recovered sample is a medium grained gneiss with synkinematic muscovite and a mylonitic foliation defined by K-feldspar

porphyroclast. A small, sheared, black, fine-grain metapelite was also dredged in Site 266D on the Djibouti Bank, 50 km southeast of Site 265D.

The gneiss sampled at site BA-265D is similar to rocks belonging to the upper Alpujarride units (named Sebtide in the Rif), probably from the Jubrique or Blanca groups, which are respectively placed over and beneath a near-continuous slab of mantle-derived peridotite. Metapelitic rocks like those drilled at ODP Site 976 and on the BASACALB cruise, crop out *ca.* 55 km towards the northwest, in the Marbella area, and also further southwest towards the Ceuta and Cabo Negro peninsulas (Southern margin of the Alboran Sea, Rif Cordillera). In these regions, gneissic and high-grade metapelithic rocks occur within strongly attenuated units affected by thick shear zones with regional N–S stretching lineation, and are frequently covered by lower Miocene marine sediments. Above these shear zones, kilometric peridotite slabs and overlying Alpujarride and Malaguide units occur in both northern and southern margins of the Alboran Sea. However, in the Ceuta peninsula almost in the middle of the Gibraltar Arc, the peridotite slab is reduced to a few meters thick, forming extensional horses. Tectono-metamorphic data from the Alboran Domain of the Betic and Rif cordilleras suggest that the peridotite slab was previously thicker and dismembered in discrete bodies by N–S extensional shear zones, during the lower Miocene. Meanwhile, the underlying tectonic units were plastically extended beneath a crustal-scale extensional detachment, through melting during their exhumation. Findings from basement dredging during the BASALCALB cruise (TTR-9 Leg 3) may also support this tectonic interpretation.

PLIO-QUATERNARY CONTRACTIVE REORGANIZATION ALONG THE SERRATA–CARBONERAS FAULT ZONE, NE ALBORAN BASIN

J. Rodríguez-Fernández, J. M Azañon, J. M Martínez-Martínez

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An important fault zone striking approximately N45E, on average 15 km wide and 50 km long, crosses the Gulf of Almeria (NE Alboran Sea), and continues on land a further 40 km in the same NE direction. The Sabinar and Pollux volcanic banks, and the Cabo de Gata volcanic massif are bound by the fault zone in the SE, and the Gador, Alhamilla and Cabrera Sierras bound by the fault zone in the NW. The most conspicuous strand corresponds to the so-called the Serrata-Carboneras Fault Zone (SCFZ). Analysis of several seismic lines from offshore areas and some commercial wells, among other regional geological data, reveals the main characteristics and amorphism of this fault system.

Onshore, the left lateral strike-slip movement of the SCFZ is well documented, with several periods of activity from the Upper Miocene to the present. The fracture zone was bound parallel to a subsiding trough, from the Messinian to the Upper Pliocene. This trough was then deformed and inverted in a transpressive regime to become a significant positive lineament known as La Serrata, 350 m above sea level. The relief gradually decreases towards the Southwest and the fault zone continues beneath the sea.

In the offshore area, the SCFZ downthrows the basement to the NW and is bound by a trough where Messinian sediments occur on the basement surface. Pliocene to Holocene sediments sealing the fault are thicker in the hanging wall and indicate coeval faulting activity. Seismic profiles imaging the fault morphology and its relationship with overlying sediments reveal the contractional character of this fault.

Pliocene to Holocene sediments are strongly faulted, this faulting affects the sea-floor, thus indicating that tectonic activity continued untill present.

STRUCTURE OF THE PALOMARES AND MAZARRON MARGINS (SE SPAIN)

J. I. Soto[(1)], M. C. Comas[(1)], J. M. Azañón[(1)], J. M. Martínez-Martínez[(1)], M. Sánchez-Gómez[(2)], BASACALB cruise (TTR-9 Leg 3) Scientific Party

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The transition from the Alboran to the South-Balearic Basin in the western Mediterranean is marked by an increase in water depth from a western, shallow (< 2000 m) and rough seafloor with several ridges and sea-mounts made of locally outcropping basement rocks, towards a deep abyssal plain (≈ 2600 m). This transition is especially sharp along the northern and southern margins of the western South Alboran Basin, characterized by the occurrence of steep slopes and deeply incised sub-marine canyons. The seafloor morphology in this area probably reflects a change in the nature of the crust and its amorphous style. Deep seismic reflection profiling, heat-flow and gravity data recently collected in the region suggest a remarkable eastward decrease in the thickness of the mantle lithosphere (60–90 to 35–40 km) and a concurrent crustal thinning (14–16 to 10–12 km). Local seismic refraction velocities seem to be consistent with a transitional and thin continental to oceanic crust, in the western South Balearic Basin. A Messinian salt diapirism is ubiquitous in this basin and has been generally linked to the presence of an oceanic crust.

One of the main objectives of the BASACALB cruise (TTR-9 Leg 3) was to study the upper crustal structure of the transition from the Alboran to the South Balearic Basin and the Palomares and Mazarrón margins (eastern Betic Cordillera). Shallow seismic profiling and side-scan sonar (OKEAN) imaging show two steep linear escarpments (trending NNE–SSW and EW) incised by narrow canyons connected to onshore seasonal water channels. Down-slope, deep fans, massive rock-falls and rock-slides are clearly seen, and probably triggered by recent high angle faulting. Most of these faults cut the Plio-Quaternary seismic units, control seafloor features and continue onshore with recent major strike-slip faults. Residual highs made of volcanic (e.g. Maimonides) or metamorphic rocks, as revealed through dredging, occur at the base of the Mazarrón and Carboneras margins near the transition to the abyssal plain. This is consistent with the occurrence of an abrupt change in the nature of the crust, towards the South-Balearic Basin. High angle normal faults, with a probable strike-slip component and active during the Plio-Quaternary, are responsible for most of the present day morphology of these margins and the uplift of the eastern Betic Cordillera, and overall probably enhanced the subsidence of the South-Balearic Basin.

A TECTONIC OVERVIEW OF MUD DIAPIRS AND RELATED MUD VOLCANOES IN THE ALBORAN BASIN

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Analyses of seismic reflection data carried out during the last decade within the Alboran Sea have revealed evidence of significant mud diapirism in the West Alboran Basin (WAB), contrary to earlier literature inferring that these diapirs were formed by “Messinian salt”. The mud diapir province is developed in a region where there is major sedimentary accumulation (up to 8 km thick) in the Alboran Basin.

The large diapir province involves sediments from the lowermost sequences of the Alboran sedimentary cover, seismic Unit VI and the base of the overlying seismic Unit V. The diapirs themselves comprise under-compacted and over-pressured material from these units.

According to seismic stratigraphic correlation with data from the commercial well (Alboran A-1), off the coast of Spain, Unit VI corresponds to older marine deposits overlying the metamorphic basement of the Alboran Domain, late Aquitanian?–Burdigalian age, and consists of olistostromes containing diverse clastic material and under-compacted shales. Seismic Unit VI can be correlated with inland complexes composed of clays and detrital deposits containing olistostromes. The overlaying seismic Unit V consists of middle Miocene (Langhian) deposits made of under-compacted shales at the base, passing upwards into graded sand-silt-clay turbidite.

The original geometry of the over-pressured lithosome forming Unit VI was deformed by complex coupled diapiric and fluid-flow processes, which lead to highly diverse structures. Two distinct major stages of active mud diapirism are identified, each one punctuated by several events of mud-flux activity. The older stage is of particular interest, as it reflects the process of widespread crustal extension that affected the Alboran Basin during the middle and late Miocene (between about 18 and 9 Ma ago). Mud diapirism occurred along the WAB depocenter for a long time and was characterized by widespread tectonic subsidence. The limits of the mud diapir province run parallel to basement highs and are related to major extensional faults in the Wab. Diapirism initiated on the bottom of basement half-grabens. The extension direction is perpendicular to the axes of the mud diapir province, consistent with a W–SW extension affecting the WAB at that time.

The youngest stage of active diapirism is post-Messinian, and affects limited areas of the WAB diapir province, where important piercing diapirs rising from the sea floor prevail and mud volcanoes are developed. We propose that pulses of contractional tectonics may have repeatedly triggered mud diapirism during this youngest stage, at times when the subsidence history has been considered as either thermal or flexural. Pliocene to Pleistocene — or Recent — mud diapirs and related structures, and mud-volcanoes like those discovered during the BASACALB cruise (TTR-9 Leg 3), are found to be generally consistent with the noticeable submeridian contraction and roughly E–W transtension in the Alboran Basin; which is coeval to the general uplift at the basin margins (i.e. in the Betics and Rif) from the Pliocene.

EXTENSIONAL STRUCTURES IN THE MAZARRÓN MARGIN AND ONSHORE AREA (BETICS, SE SPAIN)

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Major structures observed in the eastern Betics, north of the Mazarrón margin, result from extensional and compressional processes operating since the Miocene to the present. Tectonic lineaments in the eastern Alboran basin and western South Balearic basin, which generally affect the whole brittle part of the crust, are sites of seismogenic faults related to recent episodes of strike-slip and extensional or compressional tectonic evolution. The aim of this study is to compare the onshore structures with those inferred from geomarine data.

Analyses of a mosaic composed by OKEAN long-range sidescan sonar profiles, collected onboard the RV “Professor Logachev” during Leg 3 of Training Through Research-9 cruise, and several commercial multichannel seismic profiles reveal the existence of major faults controlling the margin physiography. Faults can be grouped into two sets with NW–SE and E–W strike. Faults showing similar characteristics have also been recognized onshore, in the coastal area located between Cabo de Palos and Mazarrón. They are listric normal faults with SSE and SW hanging-wall transport that cuts across a down-section of the basement rocks in the Alboran basin. These faults cut late Tortonian large-scale open folds affecting Serravallian extensional detachments, which were involved in the attenuation of the Miocene Alboran basin basement (Martínez-Martínez and Azañón, 1997).

The morphology of the coastal line between Almería and Cabo de Palos is mainly conditioned by the most recent faults. In the multichannel seismic profile across the Mazarrón margin, these faults seem to cut the Pliocene seismic unit. In the onshore region around Almería, faults with similar structural features were dated as Pliocene (Rodríguez-Fernández and Martín-Penela, 1993).

References:

Martínez-Martínez, J. M. and Azañón, J.M. (1997). *Tectonics*, 16, 2, 205-225.
Rodríguez-Fernández, J. and Martín-Penela, A. J. (1993). *Geodinamica Acta* (Paris), 6, 4, 255-270.

MAJOR FINDINGS ON THE NATURE OF ACOUSTIC BASEMENT ROCKS IN THE ALBORAN AND SOUTH BALEARIC BASINS FROM THE BASACALB CRUISE (TTR-9, LEG 3)

J. M. Fernández-Soler[(1)], J. M. Azañón[(1)], M. Sánchez-Gómez[(2)], J. I. Soto[(1)], J. M. Martínez-Martínez[(1)] and BASACALB cruise (TTR-9 Leg 3) Scientific Party

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Preliminary data obtained from hard rock samples recovered during the BASACALB cruise (TTR-9 Leg 3, RV "Professor Logachev", July 1999) in the Alboran and South Balearic basins are reported here. Their acoustic basement was thought to be partly composed of Neogene volcanic rocks, which are widespread in SE Spain and N Morocco, as well as in the Central and Eastern Alboran basins, where a much more limited amount of data was available. Several dredging sites were planned to sample selected topographic highs and escarpments, in order to determine the extent and age of volcanic activity. Some of the dredging sites were intended to provide samples of the Alboran Basin metamorphic basement already studied in ODP Site 976.

For most of the sampling in the Alborán Sea, dredging was difficult due to the widespread existence of Mn-oxide and biogenic crust on the rock surfaces. The dredges provided some volcanic and metamorphic clasts, together with abundant corals and / or Mn-rich biogenic crusts.

A residual high between the Xauen Bank and Alboran Island (TTR9-263D) provided few clasts of hyaloclastic basaltic andesite, with a variable degree of alteration. These are composed of microphenocrysts of plagioclase, pyroxene and Fe-Ti oxides in a microlitic groundmass. Preliminary petrographical, geochemical (XRF, ICPMS) and isotopic data indicate a low K calc-alkaline affinity, intermediate between the classical calc-alkaline province of Cabo de Gata in SE Spain and the depleted tholeiitic basalts and andesites of the Alboran sea-floor.

A deformed gneissic rock (TTR9-265D) was recovered from a basement high in the West Alborán Basin, situated in the NE–SW trending basement horst of ODP Site 976. The rock is composed of K-feldspar, plagioclase, biotite, tourmaline (schorl variety), minor muscovite and quartz. Preliminary phase relations and thermobarometry estimates from this sample indicate pressure conditions of *ca.* 5.4–6 kbar during melting and deformation, in agreement with the PT conditions of 5–7 kbar and 700°–750°C inferred for gneissic rock melting in ODP Site 976. In an isolated high SE of the Djibouti Bank, a small fragment of a cataclastic fine-grained rock (TTR9-266D) was recovered and probably represents a foliated cataclasite from a fault zone. Several ortho-gneissic rocks (TTR9-271D) were dredged from a steep and deep high at the base of the Mazarrón escarpment, just near the transition to the abyssal plain of the South Balearic Basin. The samples are slightly deformed ortho-gneisses with K-feldspar, plagioclase and biotite phenocrysts, together with scarce interstitial tourmaline and quartz.

These samples, in spite of their small size and scarcity, provide the opportunity for further studies on the nature of the transition from the Alboran Basin to the oceanic crust of the South Balearic Basin, together with the age of regional volcanic activity.

ANNEX I

CONFERENCE PROGRAMME

MONDAY, JANUARY 31

9:00 – 10:00 Registration

10:30 Opening

Introduction

11:45 GOALS AND PRINCIPLE RESULTS OF THE TTR-9 CRUISE
M. Ivanov, N. Kenyan, T. Nielsen, A. Wheeler, J. Monteiro, J. Gardner, M. Comas, G. Akhmanov, A. Akhmetzhanov, and Scientific Party of the TTR-9 cruise

Geological Processes from on the Atlantic Margin

Chairperson: M. Comas

12:30 MORPHOLOGY AND SEDIMENTARY PROCESSES OF THE SLOPE WEST OF PORTUGAL
N. H. Kenyon, J. H. Monteiro, F. Abrantes, R. B. Wynn

12:50 PROCESSING OF MULTI-CHANNEL SEISMIC DATA COLLECTED ON THE PORTUGUESE MARGIN DURING THE TTR-9 CRUISE
A. Grachev

13:10 INFERRED SHALLOW GAS ACCUMULATIONS ON THE MOROCCAN CONTINENTAL MARGIN (GULF OF CADIZ) ACCORDING TO GEOPHYSICAL DATA OF THE TTR-9 CRUISE
E. I. Petrov

TUESDAY, FEBRUARY 1

Fluid Venting, Mud Diapirism and Volcanism

Chairperson: M. K. Ivanov

9:00 THE CRETACEOUS-NEOGENE SEDIMENTARY HISTORY OF THE EASTERN MEDITERRANEAN: AN UPDATE FROM A STUDY OF RECENT MUD VOLCANIC DEPOSITS
G. G. Akhmanov, A. F. Limonov, M. K. Ivanov, M. B. Cita, I. Premoli, E. Erba

9:20 MORPHOLOGY OF SEAFLOOR MUD VOLCANOS ON THE MOROCCAN MARGIN
J. M. Gardner

9:40 RECOGNITION OF AN ANCIENT MUD VOLCANO IN THE MALABATA AREA (NORTH–WESTERN RIF, MOROCCO)
N. Hamoumi

10:00 TECTONIC ASPECTS OF MUD VOLCANO ORIGINS: COMPARISON OF SEISMIC DATA FROM THE MEDITERRANEAN RIDGE AND THE GULF OF CADIZ
A. L. Volkonskava

10:20 PHYSICAL PROPERTIES OF ROCK CLASTS FROM MUD BRECCIA OF THE YUMA MUD VOLCANO (GULF OF CADIZ)
E. J. Suslova

10:40 ROCK CLAST LITHOLOGY IN MUD VOLCANO BRECCIA FROM THE GULF OF CADIZ
D. O. Ovsyannikov, A. Yu. Sadekov

Chairperson: J. M. Gardner

11:30	GEOCHEMICAL INVESTIGATION OF ORGANIC MATTER IN ROCK CLASTS FROM MUD VOLCANO BRECCIA (GULF OF CADIZ AND ALBORAN SEA) *E. Kozlova, J. Gardner, F. Baudin, C. Largeau*
11:50	HYDROCARBON GAS DISTRIBUTION IN MUD VOLCANIC DEPOSITS OF THE GULF OF CADIZ: PRELIMINARY RESULTS *A. Stadnitskaia. M. Ivanov, J. Gardner*
12:10	GAS-RELATED CHANGES IN PORE WATER CHEMICAL COMPOSITION: APPLICATION TO AUTHIGENIC CARBONATE FORMATION (TTR-9, GULF OF CADIZ) *I. Belenkaya, D. Goncharov*
12:30	HYDROCHEMICAL FEATURES OF GAS HYDRATE-BEARING MUD VOLCANOES, OFFSHORE MOROCCO *L. L. Mazurenko, V. A. Soloviev, J. M. Gardner*
12:50	THE AGE OF ROCK CLASTS FROM THE YUMA MUD VOLCANO BRECCIA ON THE BASIS OF A FORAMINIFERA STUDY (GULF OF CADIZ, NE ATLANTIC) *A. Yu. Sadekov, D. O. Ovsyannikov*
13:10	MICROPALEONTOLOGICAL INVESTIGATION OF ROCK CLASTS FROM MUD VOLCANIC DEPOSITS IN THE ALBORAN SEA *A. Saoutkine*

Sedimentary Processes and Climate Change in the Western Mediterranean

Chairperson: J. Monteiro

15:00	TEMPESTITE TO TURBIDITE DEPOSITION IN POST-EVAPORITIC MESSINIAN SEDIMENTS OF THE GAFARES AREA (ALMERIA, SE SPAIN) *J. Asuirre, I. M. Sanchez-Almazo*
15:20	THE BOTTOM OF UPPER MESSINIAN EVAPORITES OBSERVED WITHIN DIAPIRS IN THE SOUTH BALEARIC BASIN, ACCORDING TO SEISMIC DATA *A. M. Bobrov*
15:40	LITHOLOGY OF BOTTOM SEDIMENTS FROM THE BEAR ISLAND REGION (NORWEGIAN SEA) *V. Krupskaya, I. Andreeva*
16:00	OXYGEN AND PRODUCTIVITY PROXIES IN ALBORAN AND SOUTH BALEARIC SEDIMENTS: IMPLICATION FOR PALEOCLIMATIC RECONSTRUCTIONS *F. Martinez-Ruiz and BASACALB cruise (TTR-9 Leg 3) Scientific Party*
16:20	LITHOLOGICAL CHARACTERISTICS OF HOLOCENE–LATE PLEISTOCENE SEDIMENTS FROM CARBONATE MOUNDS IN THE PORCUPINE SEABIGHT BASIN *L. L. Mazurenko*

WEDNESDAY, FEBRUARY 2

Tectonics and Structure of the Western Mediterranean

Chairperson: N. H. Kenyon

9:00	TECTONICS AND BASIN / PLATFORM STRUCTURES OF THE TUNISIAN MEDITERRANEAN CONTINENTAL MARGIN *M. Bedir, N. Boukadi, F. Zargouni*
9:20	TECTONICS AND DEPOSITION IN THE DEEP-WATER AREA ADJACENT TO PORTO AND VIGO SEAMOUNTS *T. Alves, J. H. Monteiro, L. M. Pinheiro, F. Teixeira, T. Cunha, R. G. Janus*

9:40	REGIONAL CONTEXT OF METAMORPHIC ROCKS SAMPLED DURING THE BASALCALB CRUISE (TTR9-LEG 3) *M. Sánchez-Gómez, J. M. Azañón, J. I. Soto*
10:00	PLIO-QUATERNARY CONTRACTIVE REORGANIZATION ALONG THE SERRATA-CARBONERAS FAULT ZONE, NE ALBORAN BASIN *J. Rodriguez-Fernandez, J. M. Martínez-Martínez, J. M. Azanon*
10:20	STRUCTURE OF THE PALOMARES AND MAZARRON MARGINS (SE SPAIN) *J. I. Soto, M. C. Comas, J. M. Azañón, J. M. Martínez-Martínez, M. Sánchez-Gómez, BASACALB cruise (TTR-9 Leg 3) Scientific Party*
10:40	A TECTONIC OVERVIEW OF MUD DIAPIRS AND RELATED MUD VOLCANOES IN THE ALBORAN BASIN *M. Comas, J. I. Soto, and BASACALB cruise (TTR-9 Leg 3) Scientific Party*

Chairpersons: M. Comas and M. Ivanov

11:30	FINAL DISCUSSION
13:15	PRIZES FOR THE BEST STUDENT ORAL AND POSTER PRESENTATIONS

THURSDAY, FEBRUARY 3

9:00	FIELD TRIP TO THE NATURAL PARK OF SIERRA NEVADA AND THE ALPUJARRA REGION

POSTER PRESENTATIONS
(Alphabetical listing by first author)

EXTENSIONAL STRUCTURES IN THE MAZARRON MARGIN AND ONSHORE AREA (BETICS, SE SPAIN)
J. M. Azandn, J. M. Martinez-Martinez, J. Rodriguez-Fernandez, J. I. Solo,and BASACALB cruise (TTR-9 Leg 3) Scientific Party

FLUID SEEPS ASSOCIATED WITH SALT/SHALE GRAVITATIONAL SPREADING ALONG THE GULF OF CADIZ CONTINENTAL SLOPE
M. C. Fernandez-Puga, L. Somoza, A. Lowrie, A. Maestro, R. Leon, V. Diaz del Rio

MAJOR FINDING ON THE NATURE OF BASEMENT ROCKS OF THE ALBORAN AND SOUTH BALEARIC BASINS FROM THE BASACALB CRUISE (TTR-9, LEG 3)
J. M. Femandez-Soler, J. M. Azanon, M. Sanchez-Gomez, J. I. Soto, J. M. Martinez-Martinez,and BASACALB cruise (TTR-9 Leg 3) Scientific Party

PHYSICAL PROPERTIES OF SEDIMENTS FROM MOROCCAN MUD VOLCANOS IN THE EASTERN ATLANTIC
J. Gardner, B. Sawyer, N. Rasul

PROCESSING OF MULTI-CHANNEL SEISMIC DATA COLLECTED ON THE PORTUGUESE MARGIN DURING THE TTR-9 CRUISE
A. Grachev

RECOGNITION OF AN ANCIENT MUD VOLCANO IN THE MALABATA AREA (NORTH–WESTERN RIF, MOROCCO)
N. Hamoumi

DEEP-SEA SEDIMENTATION IN THE TAGUS ABYSSAL PLAIN (W IBERIA): SEDIMENT TRANSPORT AND TECTONIC CONTROL
L. M. Pinheiro, S. Lebreiro, T. Cunha, P. Terrinha, F. Teixeira, H. Monteiro, F.C. Teixeira, T. Alves, R. Janus

PALAEOENVIRONMENTAL SIGNIFICANCE OF BENTHIC FORAMINIFERAL ASSEMBLAGES IN THE LOWER PLIOCENE CONTINENTAL PLATFORM DEPOSITS OF THE ALMERIA-NIJAR BASIN (SE SPAIN)
A. B. Perez-Munoz, R. Marquez-Crespo, J. Yesares-Garcia, I. M. Sanchez-Almazo, J. Aguirre

INFERRED SHALLOW GAS ACCUMULATIONS ON THE MOROCCAN CONTINENTAL MARGIN (GULF OF CADIZ) ACCORDING TO GEOPHYSICAL DATA OF THE TTR-9 CRUISE
E. L. Petrov

DIAPIRS AND MUD VOLCANOES IN THE GULF OF CADIZ, MOROCCAN SECTOR: INTERPRETATION OF SEISMIC AND SIDE-SCAN SONAR DATA
M. Rank, J. M. Gardner

RECORD OF CLIMATIC VARIATIONS IN THE UPPER MIOCENE PELAGIC MARLS IN THE SORBAS BASIN (ALMERIA, SE SPAIN)
J. M. Sanchez-Almzo, B. Spiro, J. C. Braga, J. M. Martin

DIAPIRS AND RELATED STRUCTURES IN THE MUD-VOLCANO AREA OF THE WEST ALBORAN BASIN
A. Talukder, M. Comas, J. I. Solo, BASACALB cruise (TTR-9 Leg 3) Scientific Party

IRON IN SEDIMENTS AS AN INDICATOR OF DEPOSITIONAL ENVIRONMENTS (AN EXAMPLE FROM THE BARENTS SEA AND WESTERN MOROCCAN FIELD)
Yu. V. Volkova, G. N. Goncharov

SEDIMENTATION PATTERNS ON THE NORTH–EAST ATLANTIC MARGIN
P. P. E. Weaver, R. I. B. Wynn, N. H. Kenyon

ANNEX II

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

No.	Title	Languages	No.	Title	Languages	No.	Title	Languages
	The Indo-Pacific Convergence; Townsville, 1-6 December 1966							
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	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	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	49	AGU-IOC-WMO-CPPS Chapman Conference: An International Symposium on 'El Niño'; Guayaquil, Ecuador, 27-31 October 1986.	E	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	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	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	51	CCOP/SOPAC-IOC Workshop on Coastal Processes in the South Pacific Island Nations; Lae, Papua-New Guinea, 1-8 October 1987.	E	51	CCOP/SOPAC-IOC Workshop on Coastal Processes in the South Pacific Island Nations; Lae, Papua-New Guinea, 1-8 October 1987.	E
52	SCOR-IOC-UNESCO Symposium on Vertical Motion in the Equatorial Upper Ocean and its Effects upon Living Resources and the Atmosphere; Paris, France, 6-10 May 1985.	E	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	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	53	IOC Workshop on the Biological Effects of Pollutants; Oslo, 11-29 August 1986.	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	54	Workshop on Sea-Level Measurements in Hostile Conditions; Bidston, UK, 28-31 March 1988.	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	55	IBCCA Workshop on Data Sources and Compilation, Boulder, Colorado, 18-19 July 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	56	IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Cleveland, Australia, 24-30 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
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58	International Workshop on the Technical Aspects of the Tsunami Warning System; Novosibirsk, USSR, 4-5 August 1989.	E	58	International Workshop on the Technical Aspects of the Tsunami Warning System; Novosibirsk, USSR, 4-5 August 1989.	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	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	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	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	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	60	IOC Workshop to Define IOCARIBE-TRODERP proposals; Caracas, Venezuela, 12-16 September 1989.	E	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	61	Second IOC Workshop on the Biological Effects of Pollutants; Bermuda, 10 September-2 October 1988.	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	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	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	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	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	64	Second IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Phuket, Thailand, 25-31 September 1989.	E	64	Second IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Phuket, Thailand, 25-31 September 1989.	E
65	Second IOC Workshop on Sardine/Anchovy Recruitment Project (SARP) in the Southwest Atlantic; Montevideo, Uruguay, 21-23 August 1989.	E	65	Second IOC Workshop on Sardine/Anchovy Recruitment Project (SARP) in the Southwest Atlantic; Montevideo, Uruguay, 21-23 August 1989.	E	65	Second IOC Workshop on Sardine/Anchovy Recruitment Project (SARP) in the Southwest Atlantic; Montevideo, Uruguay, 21-23 August 1989.	E
66	IOC ad hoc Expert Consultation on Sardine/Anchovy Recruitment Programme; La Jolla, California, U.S.A., 1989	E	66	IOC ad hoc Expert Consultation on Sardine/Anchovy Recruitment Programme; La Jolla, California, U.S.A., 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)	67	Interdisciplinary Seminar on Research Problems in the IOCARIBE Region; Caracas, Venezuela, 28 November-1 December 1989.	E (out of stock)	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,	E	68		E	68		E

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	China, 26-30 March 1990.	
69	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Leningrad, USSR, 28-31 May 1990.	E
69 Suppl.	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Submitted Papers; Leningrad, USSR, 28-31 May 1990.	E
70	IOC-SAREC-UNEP-FAO-IAEA-WHO Workshop on Regional Aspects of Marine Pollution; Mauritius, 29 October - 9 November 1990.	E
71	IOC-FAO Workshop on the Identification of Penaeid Prawn Larvae and Postlarvae; Cleveland, Australia, 23-28 September 1990.	E
72	IOC/WESTPAC Scientific Steering Group Meeting on Co-Operative Study of the Continental Shelf Circulation in the Western Pacific; Kuala Lumpur; Malaysia, 9-11 October 1990.	E
73	Expert Consultation for the IOC Programme on Coastal Ocean Advanced Science and Technology Study; Liège, Belgium, 11-13 May 1991.	E
74	IOC-UNEP Review Meeting on Oceanographic Processes of Transport and Distribution of Pollutants in the Sea; Zagreb, Yugoslavia, 15-18 May 1989.	E
75	IOC-SCOR Workshop on Global Ocean Ecosystem Dynamics; Solomons, Maryland, U.S.A., 29 April-2 May 1991.	E
76	IOC/WESTPAC Scientific Symposium on Marine Science and Management of Marine Areas of the Western Pacific; Penang, Malaysia, 2-6 December 1991.	E
77	IOC-SAREC-KMFRI Regional Workshop on Causes and Consequences of Sea-Level Changes on the Western Indian Ocean Coasts and Islands; Mombasa, Kenya, 24-28 June 1991.	E
78	IOC-CEC-ICES-WMO-ICSU Ocean Climate Data Workshop Goddard Space Flight Center; Greenbelt, Maryland, U.S.A., 18-21 February 1992.	E
79	IOC/WESTPAC Workshop on River Inputs of Nutrients to the Marine Environment in the WESTPAC Region; Penang, Malaysia, 26-29 November 1991.	E
80	IOC-SCOR Workshop on Programme Development for Harmful Algae Blooms; Newport, U.S.A. 2-3 November 1991.	E
81	Joint IAPSO-IOC Workshop on Sea Level Measurements and Quality Control; Paris, France, 12-13 October 1992.	E
82	BORDOMER 92: International Convention on Rational Use of Coastal Zones. A Preparatory Meeting for the Organization of an International Conference on Coastal Change; Bordeaux, France, 30 September-2 October 1992.	E
83	IOC Workshop on Donor Collaboration in the Development of Marine Scientific Research Capabilities in the Western Indian Ocean Region; Brussels, Belgium, 12-13 October 1992.	E
84	Workshop on Atlantic Ocean Climate Variability; Moscow, Russian Federation, 13-17 July 1992	E
85	IOC Workshop on Coastal Oceanography in Relation to Integrated Coastal Zone Management; Kona, Hawaii, 1-5 June 1992.	E
86	International Workshop on the Black Sea; Varna, Bulgaria, 30 September – 4 October 1991	E
87	Taller de trabajo sobre efectos biológicos del fenómeno «El Niño» en ecosistemas costeros del Pacífico Sudeste; Santa Cruz, Galápagos, Ecuador, 5-14 de octubre de 1989.	S only (summary in E, F, S)
88	IOC-CEC-ICSU-ICES Regional Workshop for Member States of Eastern and Northern Europe (GODAR Project); Obninsk, Russia, 17-20 May 1993.	E

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	China, 26-30 March 1990.	
69	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Leningrad, USSR, 28-31 May 1990.	E
69 Suppl.	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Submitted Papers; Leningrad, USSR, 28-31 May 1990.	E
70	IOC-SAREC-UNEP-FAO-IAEA-WHO Workshop on Regional Aspects of Marine Pollution; Mauritius, 29 October - 9 November 1990.	E
71	IOC-FAO Workshop on the Identification of Penaeid Prawn Larvae and Postlarvae; Cleveland, Australia, 23-28 September 1990.	E
72	IOC/WESTPAC Scientific Steering Group Meeting on Co-Operative Study of the Continental Shelf Circulation in the Western Pacific; Kuala Lumpur; Malaysia, 9-11 October 1990.	E
73	Expert Consultation for the IOC Programme on Coastal Ocean Advanced Science and Technology Study; Liège, Belgium, 11-13 May 1991.	E
74	IOC-UNEP Review Meeting on Oceanographic Processes of Transport and Distribution of Pollutants in the Sea; Zagreb, Yugoslavia, 15-18 May 1989.	E
75	IOC-SCOR Workshop on Global Ocean Ecosystem Dynamics; Solomons, Maryland, U.S.A., 29 April-2 May 1991.	E
76	IOC/WESTPAC Scientific Symposium on Marine Science and Management of Marine Areas of the Western Pacific; Penang, Malaysia, 2-6 December 1991.	E
77	IOC-SAREC-KMFRI Regional Workshop on Causes and Consequences of Sea-Level Changes on the Western Indian Ocean Coasts and Islands; Mombasa, Kenya, 24-28 June 1991.	E
78	IOC-CEC-ICES-WMO-ICSU Ocean Climate Data Workshop Goddard Space Flight Center; Greenbelt, Maryland, U.S.A., 18-21 February 1992.	E
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88	IOC-CEC-ICSU-ICES Regional Workshop for Member States of Eastern and Northern Europe (GODAR Project); Obninsk, Russia, 17-20 May 1993.	E

No.	Title	Languages
89	IOC-ICSEM Workshop on Ocean Sciences in Non-Living Resources; Perpignan, France, 15-20 October 1990.	E
90	IOC Seminar on Integrated Coastal Management; New Orleans, U.S.A., 17-18 July 1993.	E
91	Hydroblack'91 CTD Intercalibration Workshop; Woods Hole, U.S.A., 1-10 December 1991.	E
92	Réunion de travail IOCEA-OSNLR sur le Projet « Budgets sédimentaires le long de la côte occidentale d'Afrique » Abidjan, côte d'Ivoire, 26-28 juin 1991.	E
93	IOC-UNEP Workshop on Impacts of Sea-Level Rise due to Global Warming. Dhaka, Bangladesh, 16-19 November 1992.	E
94	BMTC-IOC-POLARMAR International Workshop on Training Requirements in the Field of Eutrophication in Semi-enclosed Seas and Harmful Algal Blooms, Bremerhaven, Germany, 29 September-3 October 1992.	E
95	SAREC-IOC Workshop on Donor Collaboration in the Development of Marine Scientific Research Capabilities in the Western Indian Ocean Region; Brussels, Belgium, 23-25 November 1993.	E
96	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Zanzibar, United Republic of Tanzania, 17-21 January 1994.	E
96 Suppl.	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Submitted Papers 1. Coastal Erosion; Zanzibar, United Republic of Tanzania 17-21 January 1994.	E
96 Suppl	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Submitted Papers 2. Sea Level; Zanzibar, United Republic of Tanzania 17-21 January 1994.	E
97	IOC Workshop on Small Island Oceanography in Relation to Sustainable Economic Development and Coastal Area Management of Small Island Development States; Fort-de-France, Martinique, 8-10 November, 1993.	E
98	CoMSBlack '92A Physical and Chemical Intercalibration Workshop; Erdemli, Turkey, 15-29 January 1993.	E
99	IOC-SAREC Field Study Exercise on Nutrients in Tropical Marine Waters; Mombasa, Kenya, 5-15 April 1994.	E
100	IOC-SOA-NOAA Regional Workshop for Member States of the Western Pacific - GODAR-II (Global Oceanographic Data Archeology and Rescue Project); Tianjin, China, 8-11 March 1994.	E
101	IOC Regional Science Planning Workshop on Harmful Algal Blooms; Montevideo, Uruguay, 15-17 June 1994.	E
102	First IOC Workshop on Coastal Ocean Advanced Science and Technology Study (COASTS); Liège, Belgium, 5-9 May 1994.	E
103	IOC Workshop on GIS Applications in the Coastal Zone Management of Small Island Developing States; Barbados, 20-22 April 1994.	E
104	Workshop on Integrated Coastal Management; Dartmouth, Canada, 19-20 September 1994.	E
105	BORDOMER 95: Conference on Coastal Change; Bordeaux, France, 6-10 February 1995.	E
105 Suppl.	Conference on Coastal Change: Proceedings; Bordeaux, France, 6-10 February 1995	E
106	IOC/WESTPAC Workshop on the Paleographic Map; Bali, Indonesia, 20-21 October 1994.	E
107	IOC-ICSU-NIO-NOAA Regional Workshop for Member States of the Indian Ocean - GODAR-III; Dona Paula, Goa, India, 6-9 December 1994.	E
108	UNESCO-IHP-IOC-IAEA Workshop on Sea-Level Rise and the Multidisciplinary Studies of Environmental Processes in the Caspian Sea Region; Paris, France, 9-12 May 1995.	E
108 Suppl.	UNESCO-IHP-IOC-IAEA Workshop on Sea-Level Rise and the Multidisciplinary 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
111	Chapman Conference on the Circulation of the Intra-Americas Sea; La Parguera, Puerto Rico, 22-26 January 1995.	E
112	IOC-IAEA-UNEP Group of Experts on Standards and Reference Materials (GESREM) Workshop; Miami, U.S.A., 7-8 December 1993.	E
113	IOC Regional Workshop on Marine Debris and Waste Management in the Gulf of Guinea; Lagos, Nigeria, 14-16 December 1994.	E
114	International Workshop on Integrated Coastal Zone Management (ICZM) Karachi, Pakistan; 10-14 October 1994.	E
115	IOC/GLOSS-IAPSO Workshop on Sea Level Variability and Southern Ocean Dynamics; Bordeaux, France, 31 January 1995	E
116	IOC/WESTPAC International Scientific Symposium on Sustainability of Marine Environment: Review of the WESTPAC Programme, with Particular Reference to ICAM, Bali, Indonesia, 22-26 November 1994.	E
117	Joint IOC-CIDA-Sida (SAREC) Workshop on the Benefits of Improved Relationships between International Development Agencies, the IOC and other Multilateral Inter-governmental Organizations in the Delivery of Ocean, Marine Affairs and Fisheries Programmes; Sidney B.C., Canada, 26-28 September 1995.	E
118	IOC-UNEP-NOAA-Sea Grant Fourth Caribbean Marine Debris Workshop; La Romana, Santo Domingo, 21-24 August 1995.	E
119	IOC Workshop on Ocean Colour Data Requirements and Utilization; Sydney B.C., Canada, 21-22 September 1995.	E
120	International Training Workshop on Integrated Coastal Management; Tampa, Florida, U.S.A., 15-17 July 1995.	E
121	IOC-EU-BSH-NOAA-(WDC-A) International Workshop on Oceanographic Biological and Chemical Data Management, Hamburg, Germany, 20-23 May 1996.	E
122	IOC-EU-BSH-NOAA-(WDC-A) International Workshop on Oceanographic Biological and Chemical Data Management, Hamburg, Germany, 20-23 May 1996.	E
123	Second IOC Regional Science Planning Workshop on Harmful Algal Blooms in South America; Mar del Plata, Argentina, 30 October - 1 November 1995.	E, S
124	GLOBEC-IOC-SAHFOS-MBA Workshop on the Analysis of Time Series with Particular Reference to the Continuous Plankton Recorder Survey; Plymouth, U.K.,4-7 May 1993.	E
125	Atelier sous-régional de la COI sur les ressources marines vivantes du Golfe de Guinée ; Cotonou, Bénin, 1-4 juillet 1996.	E
126	IOC-UNEP-PERSGA-ACOPS-IUCN Workshop on Oceanographic Input to Integrated Coastal Zone Management in the Red Sea and Gulf of Aden. Jeddah,	E

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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
111	Chapman Conference on the Circulation of the Intra-Americas Sea; La Parguera, Puerto Rico, 22-26 January 1995.	E
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117	Joint IOC-CIDA-Sida (SAREC) Workshop on the Benefits of Improved Relationships between International Development Agencies, the IOC and other Multilateral Inter-governmental Organizations in the Delivery of Ocean, Marine Affairs and Fisheries Programmes; Sidney B.C., Canada, 26-28 September 1995.	E
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120	International Training Workshop on Integrated Coastal Management; Tampa, Florida, U.S.A., 15-17 July 1995.	E
121	IOC-EU-BSH-NOAA-(WDC-A) International Workshop on Oceanographic Biological and Chemical Data Management, Hamburg, Germany, 20-23 May 1996.	E
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125	Atelier sous-régional de la COI sur les ressources marines vivantes du Golfe de Guinée ; Cotonou, Bénin, 1-4 juillet 1996.	E
126		E

No.	Title	Languages	No.	Title	Languages	No.	Title	Languages
	Saudi Arabia, 8 October 1995.							
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	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	127	IOC Regional Workshop for Member States of the Caribbean and South America GODAR-V (Global Oceanographic Data Archeology and Rescue Project); Cartagena de Indias, Colombia, 8-11 October 1996.	E
128	Atelier IOC-Banque Mondiale-Sida/SAREC-ONE sur la Gestion Intégrée des Zones Côtières ; Nosy Bé, Madagascar, 14-18 octobre 1996.	E	128	Atelier IOC-Banque Mondiale-Sida/SAREC-ONE sur la Gestion Intégrée des Zones Côtières ; Nosy Bé, Madagascar, 14-18 octobre 1996.	E	128	Atelier IOC-Banque Mondiale-Sida/SAREC-ONE sur la Gestion Intégrée des Zones Côtières ; Nosy Bé, Madagascar, 14-18 octobre 1996.	E
129	Gas and Fluids in Marine Sediments, Amsterdam, the Netherlands; 27-29 January 1997.	E	129	Gas and Fluids in Marine Sediments, Amsterdam, the Netherlands; 27-29 January 1997.	E	129	Gas and Fluids in Marine Sediments, Amsterdam, the Netherlands; 27-29 January 1997.	E
130	Atelier régional de la COI sur l'océanographie côtière et la gestion de la zone côtière ;Moroni, RFI des Comores, 16-19 décembre 1996.	E	130	Atelier régional de la COI sur l'océanographie côtière et la gestion de la zone côtière ;Moroni, RFI des Comores, 16-19 décembre 1996.	E	130	Atelier régional de la COI sur l'océanographie côtière et la gestion de la zone côtière ;Moroni, RFI des Comores, 16-19 décembre 1996.	E
131	GOOS Coastal Module Planning Workshop; Miami, USA, 24-28 February 1997	E	131	GOOS Coastal Module Planning Workshop; Miami, USA, 24-28 February 1997	E	131	GOOS Coastal Module Planning Workshop; Miami, USA, 24-28 February 1997	E
132	Third IOC-FANSA Workshop; Punta-Arenas, Chile, 28-30 July 1997	S/E	132	Third IOC-FANSA Workshop; Punta-Arenas, Chile, 28-30 July 1997	S/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	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	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	134	IOC/WESTPAC-CCOP Workshop on Paleogeographic Mapping (Holocene Optimum); Shanghai, China, 27-29 May 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	135	Regional Workshop on Integrated Coastal Zone Management; Chabahar, Iran; February 1996.	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	136	IOC Regional Workshop for Member States of Western Africa (GODAR-VI); Accra, Ghana, 22-25 April 1997.	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	137	GOOS Planning Workshop for Living Marine Resources, Dartmouth, USA; 1-5 March 1996.	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	138	Gestión de Sistemas Oceanográficos del Pacífico Oriental; Concepción, Chile, 9-16 de abril de 1996.	S	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	139	Sistemas Oceanográficos del Atlántico Sudoccidental, Taller, TEMA;Furg, Rio Grande, Brasil, 3-11 de noviembre de 1997	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	140	IOC Workshop on GOOS Capacity Building for the Mediterranean Region; Valletta, Malta, 26-29 November 1997.	E	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	141	IOC/WESTPAC Workshop on Co-operative Study in the Gulf of Thailand: A Science Plan; Bangkok, Thailand, 25-28 February 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	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	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	143	Geosphere-biosphere coupling: Carbonate Mud Mounds and Cold Water Reefs; Gent, Belgium, 7–11 February 1998.	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	144	IOC-SOPAC Workshop Report on Pacific Regional Global Ocean Observing Systems; Suva, Fiji, 13-17 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	145	IOC-Black Sea Regional Committee Workshop: 'Black Sea Fluxes' Istanbul, Turkey, 10-12 June 1997.	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	146	Living Marine Resources Panel Meeting, Paris, France, 23-25 March 1998.	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	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	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	148	IOC/WESTPAC International Scientific Symposium – Role of Ocean Sciences for Sustainable Development Okinawa, Japan, 2-7 February 1998.	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	149	Workshops on Marine Debris & Waste Management in the Gulf of Guinea, 1995-97.	E	149	Workshops on Marine Debris & Waste Management in the Gulf of Guinea, 1995-97.	E
150	First IOCARIBE-ANCA Workshop Havana, Cuba, 29 June-1 July 1998.	E	150	First IOCARIBE-ANCA Workshop Havana, Cuba, 29 June-1 July 1998.	E	150	First IOCARIBE-ANCA Workshop Havana, Cuba, 29 June-1 July 1998.	E
151	Taller Pluridisciplinario TEMA sobre Redes del Gran Caribe en Gestión Integrada de Áreas	S	151		S	151		S

No.	Title	Languages
	Costeras Cartagena de Indias, Colombia, 7-12 de septiembre de 1998.	
152	Workshop on Data for Sustainable Integrated Coastal Management (SICOM) Maputo, Mozambique, 18-22 July 1998	E
153	IOC/WESTPAC-Sida (SAREC) Workshop on Atmospheric Inputs of Pollutants to the Marine Environment Qingdao, China, 24-26 June 1998	E
154	IOC-Sida-Flanders-SFRI Workshop on Ocean Data Management in the IOCINCWIO Region (ODINEA project) Capetown, South Africa, 30 November-11 December 1998.	E
155	Science of the Mediterranean Sea and its applications UNESCO, Paris 29-31 July 1997	E
156	IOC-LUC-KMFRI Workshop on RECOSCIX-WIO in the Year 2000 and Beyond, Mombasa, Kenya, 12-16 April 1999	E
157	'98 IOC-KMI International Workshop on Integrated Coastal Management (ICM), Seoul, Republic of Korea 16-18 April 1998	E
158	The IOCARIBE Users and the Global Ocean Observing System (GOOS) Capacity Building Workshop, San José, Costa Rica, 22-24 April 1999	E
159	Oceanic Fronts and Related Phenomena (Konstantin Federov 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