**Intergovernmental Oceanographic Commission**

Workshop Report No. 197

# Geosphere-Biosphere coupling processes: the TTR interdisciplinary approach towards studies of the European and North African margins

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

Marrakech, Morocco
2 – 5 February 2005

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**UNESCO 2005**

IOC Workshop Report No. 197
Paris, 15 April 2005
English only

**Abstract**

The annual international post-cruise meeting and research Conference on 'Geosphere-Biosphere Coupling Processes: the TTR interdisciplinary approach towards studies of the European and North African margins' was organized by the Intergovernmental Oceanographic Commission (IOC) of UNESCO and its Training-through-Research (TTR) programme together with the Geosphere-Biosphere Coupling Processes Consortium of the universities and research institutions of Morocco (GBCP-Morocco) and Ghent University (Belgium). It considered the results of the TTR14 (2004) cruise to the Gulf of Cadiz and the Mediterranean Sea, results of some other TTR cruises carried out at the European and North Atlantic margins and in the Central Atlantic, and other national and international projects relevant to subjects of the TTR research. The Conference had dual but complementary tasks: to discuss the most recent achievements in interdisciplinary research mostly on ocean margins and to provide students, including Ph.D. students, with a forum to present and discuss their research results. It had yet another target: to contribute in a wider sense to capacity building in countries of the South.
The Conference took place in Marrakech, Morocco (2-5 February 2005). The meeting brought together nearly 70 participants from sixteen countries: Belgium, France, Germany, Greece, Ireland, Italy, Morocco, the Netherlands, Norway, Portugal, Russia, Saudi Arabia, Senegal, Spain, Switzerland and the United Kingdom. Attending were researchers and students with different specialties (geology, sedimentology, geophysics, geochemistry, microbiology, biology, etc.) and research interests falling in the area of the conference themes. In total 37 oral and nine poster presentations were made grouped around several themes like mud volcanoes, fluid venting, carbonate mounds, slope processes, geohazards etc.

(SC-2005/WS/11)

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# PREFACE

The annual international post-cruise meeting and research Conference on 'Geosphere-Biosphere Coupling Processes: the TTR interdisciplinary approach towards studies of the European and North African margins' was organized by the Intergovernmental Oceanographic Commission (IOC) of UNESCO and its Training-through-Research (TTR) programme together with the Geosphere-Biosphere Coupling Processes Consortium of the universities and research institutions of Morocco (GBCP-Morocco: Mohammed V – Agdal Univrsity, Rabat; Caddi Ayad Universiy, Marrakech; Abdel Malek Saadi University, Tangier) and Ghent University (Belgium). It considered results of the TTR14 (2004) cruise to the Gulf of Cadiz and the Mediterranean Sea, results of some other TTR cruises carried out at the European and North Atlantic margins and in the Central Atlantic, and other national and international projects relevant to subjects of the TTR research. (For more details see the TTR web site: www.ioc.unesco/ttr).

The Conference had dual but complementary tasks: to discuss the most recent achievements in interdisciplinary research mostly on ocean margins and to provide students, including Ph.D. students, with a forum to present and discuss their research results. By this, the Conference also contributed to the tasks of the recently approved European project on Hotspot Ecosystem Research on the Margins of European Seas (HERMES). It had yet another target: to promote the TTR approach in the Third World countries, especially in Africa, and thus to extend training-through-research operations that have been carried out for the last 14 years at the European, North American and North African margins to other areas, and to contribute in a wider sence to capacity building in countries of the South.

The Conference took place in Marrakech, Morocco (2-5 February 2005) following the invitation from the GBCP-Morocco Consortium and as the follow up to the decision of the November 2004 meeting of the TTR Executive Committee.

The TTR annual conferences are of particular value to students and scientists involved in the programme as they enable participants to present and discuss results of studies shortly after a cruise, to agree on further data processing and to orient joint research. For the students, it is an integral part of their training in science. It is also an opportunity to present the results to the international scientific community, and to facilitate co-ordination with other relevant national or international research initiatives.

The meeting brought together nearly 70 participants from sixteen countries: Belgium, France, Germany, Greece, Ireland, Italy, Morocco, the Netherlands, Norway, Portugal, Russia, Saudi Arabia, Senegal, Spain, Switzerland and the United Kingdom. Attending were researchers and students with

*Conference participants at the opening session, 2 February 2005* different specialties (geology, sedimentology, geophysics, geochemistry, microbiology, biology, etc.) and research interests falling in the area of the conference themes.

The meeting was opened by N. Hamoumi, Chairperson of the Organizing Committee (University Mohammed V - Agdal, Rabat) who welcomed the participants on behalf of the Organizing Committee. The participants were welcomed in Morocco and specifically in Marrakech by M. Knidiri, President of the 'Association Le Grand Atlas' (Marrakech), M.F. Hamouda, Central Director of the 'Office National des Eaux Potables' (Rabat) and El H. Boumaggard (on behalf of the Rector, University Cadi Ayyad, Marrakech). N. Kenyon (TTR Co-ordinator, UK) welcomed the participants on behalf of the TTR programme; J-P. Henriet made an introductory presentation on the tasks of the GBCP-Morocco Consortium; A. Suzyumov welcomed the participants on behalf of the IOC.

Two Certificates of Appreciations issued by the IOC and signed by P. Bernal, Assistant Director-General of UNESCO for IOC, were delivered to J-P. Henriet (Ghent University) and T. van Weering (The Royal Dutch Institute for Sea Research) for their long-term contributions to the IOC.

In total 37 oral and nine poster presentations were made grouped aroud several themes like mud volcanoes, fluid venting, carbonate mounds, slope processes, geohazards etc.

The Prize Committee (J-P. Foucher - Chair, M. Marani and A. Wheeler - Members) was established to select three best papers presented at the Conference by the students. The first Conference prize was awarded to V.H. Magalhães (Portugal), the second one to D. Titkova (Russia) and the third one to A. Foubert (Belgium).

On 5 February a geological trip under the theme "The Ourika Valley (High Atlas of Marrakech, Morocco): a natural geological section through typical intracontinental chain" was organized. It was efficiently guided by H. Ouanaimi and K. Taj-Edine, in co-operation with N. Hamoumi.

The closing remarks were given by: N. Hamoumi who on behalf of the Scientific and Organizing Committees expressed satisfaction with the results of the Conference; N. Kenyon, who summarized the TTR progress and sincerely thanked the organizers on behalf of the conference participants and the TTR programme; E. Bileva and D. Titkova who expressed gratitude to the organizers and the TTR executives on behalf of the students; and J-P. Henriet, who in addition to the expression of gratitude to the local organizers also indicated the future opportunities and interest for the Moroccan researchers and students to be fully involved in the GBCP activities.

The Honorary Committee supervised the Conference and provided valuable support, in a number of ways. The Conference programme was set up by the Scientific Committee while the Organizing Committee was responsible for the local arrangements. Efficient secretarial assistance was provided by a group of students from Mohamed V - Agdal University. (See Annex I). For the present Report, the original book of abstracts was further edited. Annex II contains the Conference programme and Annex III list of participants.

On 3 February the TTR Executive Committee met at an open session. M. Ivanov presented plans and timetable for the TTR15 cruise (2005) to the Gulf of Cadiz, the Tyrrhenian and Black Seas. Some other research proposals, for future TTR work, were presented and discussed as well, such as at the Mid-Atlantic Ridge, the Nile Delta and the Red Sea.

**Acknowledgements**

It was for the first time since the establishment of the TTR programme in 1991 that a TTR post-cruise meeting took place outside Europe. This became possible thanks to efforts and financial support from many co-sponsors in and outside Morocco. Among the Moroccan sponsors were the 'Association Le Grand Atlas' (Marrakech), 'Institut National de la Recherche Halieutique' (INRH, Rabat), 'Office National des Hydrocarbures et des Mines' (ONHYM, Rabat), 'Office National des Eaux Potables' (ONEP, Rabat), 'Ministère de l'Agriculture, du Développement rural et des Pêches maritimes - Département des pêches maritimes' (Rabat), '). 'L'Institut Supérieur des Travaux Publics' (ISTP, Marrakech) provided, free of charges, the meeting room and other facilities. Many international participants got travel support from their national sources and/or the European programmes and projects. The Government of Flanders (The Kingdom of Belgium) supported the Conference through the Flanders-IOC project 'Geosphere-Biosphere Coupling Processes in the Ocean - the Training-through-Research approach towards Third World involvement'. The Intergovernmental Oceanographic Commission (IOC) of UNESCO provided support through its Capacity-Building programme. All contributions in whatever form and size provided are most sincerely acknowledged.

# Abstracts

## Carbonate mounds, corals, carbonates

### DECRYPTING THE MESSAGE OF CARBONATE MOUNDS: FROM OUTCROP TO OCEAN DRILLING

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Carbonate-rich mounds are prominent ecosystems throughout the Earth's history, and their frequently prolific development, at discrete instants in time and locations in space, may reflect basic strategies of Life in shaping and controlling the composition of the ocean and of the atmosphere. The pace had been set by the stromatolitic mud-mounds in Precambrian times, which provided for all the Earth's atmospheric oxygen.

The decline in stromatolites in Late Precambrian times coincided with the rise of calcified cyanobacteria which, in association with the upcoming metazoans, played an important role in the development of mud-mounds. The fossil record argues for the complex interplay between abundant mound-building calcified microbes and a variety of benthic invertebrates, which may have played an ancillary role in mound construction. Still, catching the broad picture of mound provinces build-up from the fossil record has frequently been eluded by the fragmentary nature of outcrops.

Exciting new observations in the present ocean on recent mound provinces along the West-European and Moroccan margin yield an unprecedented opportunity to study carbonate mound clusters and provinces in 4D, conveying the holistic picture which is essential to interpret the role of mound formation and termination as a basinal process, in a changing ocean.

The EU FP5 GEOMOUND project, closely associated with TTR, ECOMOUND, and ACES and relayed in recent years by projects such as MoundForce, GeNesis, EURODOM and HERMES, has quantified the carbon sink represented by giant mound provinces in Porcupine and Rockall Basins, and elicited their broad basinal setting and their link to large-scale fluxes of matter and energy. It has led to the discovery of patterns of stacked or spatially associated, also potentially seep-controlled structural, sedimentological, geophysical and geochemical features, within the realm of the large mound provinces. Mound research has also led to the discovery of true present-day, prolific hotspots in ecosystem diversity, like the Thérèse mound cluster in the Belgica mound province, which provocatively neighbour barren mound settings.

Mounds and mound provinces are no doubt complex systems, which owe their genesis and spectacular growth to a complex woven of internal and external controls, modulated by biogenic feedback processes and process relays, only to resolve through a holistic approach and through ocean drilling. A first drilling action, in the framework of IODP, is coming closer than ever. It will unlock the mysteries of Challenger Mound, on the Irish margin (Fig. 1).

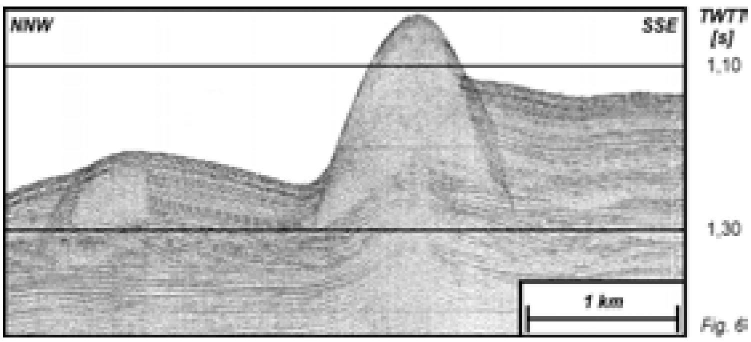


*Fig. 1. Challenger Mound, Belgica mound province: target of the first oceanic mound drilling project (May 2005)*

# CARBONATE MOUNDS AND REEFS OF THE ROCKALL TROUGH AND GULF OF CADIZ; MOUNDFORCE PROGRESS

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Giant carbonate mounds occur between 600-1200 m water depth along both the SE and SW margins of Rockall Trough. The mounds rise 5 to 350 m above the surrounding seafloor and have diameters at their basis of up to 5km. Buried mounds, at relatively shallow depth below the seafloor are also found. Both individual and complex clusters of mounds are recognized. At the SE Rockall Trough margin mostly single mounds are present. Clustered mound complexes occur mainly at the SW margin. Smaller and individual, sometimes buried mounds are found at the upper slope in an area adjacent to large sediment waves at the SW margin.

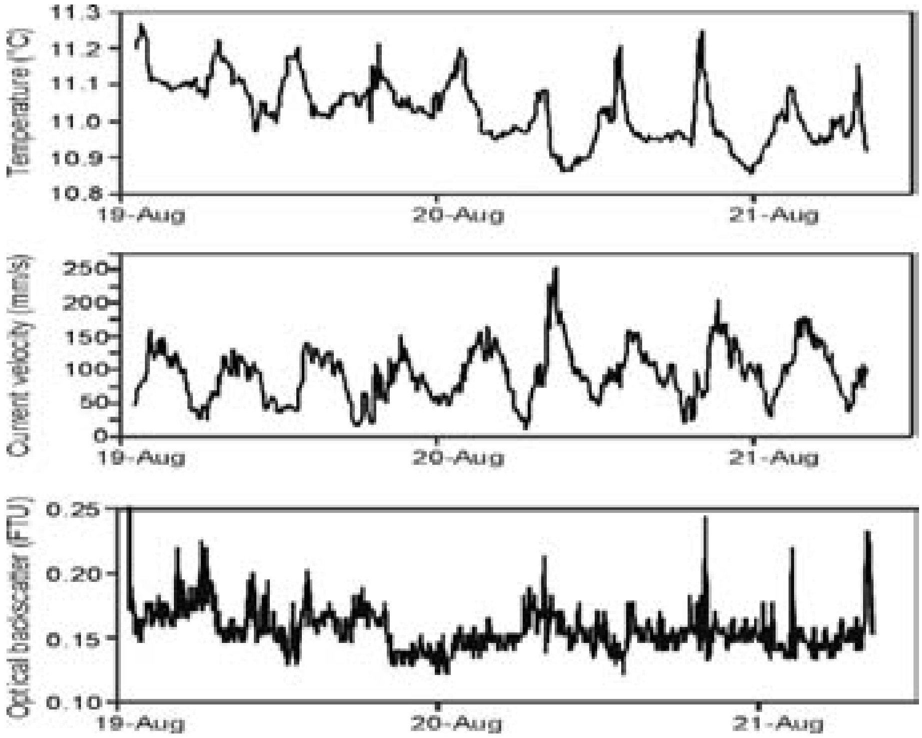


*Fig.1. Near sea bed hydrographic data measured over a period of 2.5 days near a carbonate mound at Pen Duick Escarpment, Gulf of Cadiz, by the BOBO benthic lander. The tidal signal in the current velocities and water temperature is easily recognised. Suspended sediment concentration (optical backscatter), is related to current velocity, and thus the tidal cycle*

Seabed imagery (photography and video surveys) indicates that cold water corals (mainly *Lophelia pertusa* and *Madrepora oculata*) are abundant at and near to the summit of most of the mounds at the SW Rockall Trough margin. On the mounds at the SE margin much less living coral is found. The sediments at the lower flanks of the mounds consist of foraminiferal sand with coral and other biogenic carbonate debris and minor amounts of siliciclastic material. In between the mounds the seabed is often covered with ice rafted material (sand to boulders), indicating the absence of substantial deposition during the Holocene in these areas. The focussing of the tidal currents in between the mounds results in enhanced current velocities and thus non-sedimentation or even erosion. In contrast to this, the 3-dimensional coral framework at the mound summits acts as a sediment trap, thus enhancing sediment deposition on the mounds.

Near bed hydrodynamic and water column data collected by a series of repeated CTD and BOBO lander deployments identified forcing of mound morphology by strong bottom currents and internal waves (Fig. 1). So far no evidence has been provided for the role of gas or fluid flow in early phases of development of the mounds.

Mound morphologies in the Gulf of Cadiz are quite different and are related to a strongly different tectonic setting, favouring mud diapirism and development of mound structures, some of which actively vent gases of thermogenic and biogenic origin (Ivanov et al., 2000, Stadnitskaya et al., unpublished data). This mud volcanism is found associated with authigenic carbonate formation, and, locally deep water corals on mound tops.

A comparison of the hydrodynamic situation of the two areas shows that in both the Rockall Trough Margin Mound area and in the Gulf of Cadiz, forcing of coral growth may well be the result of a combination of the presence of internal waves and high current velocities, favouring enhanced particle and thus food supply to and over the mound tops. The latter is shown in the relationship between near-bed current velocities and water temperature against optical backscatter, measured by a short term BOBO lander, deployed near the mounds.

## CORAL BUILD-UPS OF THE STRAITS OF GIBRALTAR: DEPOSITIONAL MODELS AND CONTROL

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The existence of coral build-ups in the Strait of Gibraltar has been suspected after the recognition of coral fragments in the sediments sampled during numerous oceanographic cruises (SECEG, 1987 - 1994). But it is only during the cruise of the R/V *Rift* with the *Argus* submersible (Linked Project across Strait of Gibraltar, "Projet Liaison Fixe à travers le Détroit de Gibraltar") that coral build-ups were recognized visually (SNED, 1994; Shimkus *et al.*, 1995).

The re-examination of the video records and photographs of the sea floor collected during the *Rift-Argus* cruise completed by the results of previous works (Alvarez & al., 1995 ; Hamoumi & Jbilou, 1995; Jbilou and Hamoumi, 1995; Sandoval *et al.*, 1995; Sanz *et al.*, 1991; Shimkus *et al.*, 1995) allows to precise depositional models, control and the timing of the evolution of these build-ups.

The coral build-ups develop at depths lower than 300 m on tops of topographic highs. They show many karstified generations separated by thin carbonate crusts. Some living colonies often appear above the dead colonies and the total thickness of the build-ups range from 1 to 10 m. A dense benthic fauna lives in association with these coral bioherms. The deepest areas (northern channel, southern channel and eastern basin) are characterized by two types of deposits:

- accumulations of coral debris and other biogenic fragments mixed with bioclastic sands or carbonated mud,
- authigenic carbonate crusts coating the bottom surface and including bioclasts (corals, bryozoans, pelycipodes and gastropods) and well rounded, non-sorted (from sand size to boulders) clastic terrigenous material.

The main ahermatypical: corals sampled during the *Garcia Del Cid* 93 cruise (Alvarez *et al.*, 1995) and the *Rift-Argus* cruise (SNED, 1995; Shimkus *et al.*, 1995), represent several generations with ages ranging in the interval from late Miocene to the recent: *Corallium rubrum, Desmophyllum cristagalli, Dendrophyllia cornigera*, *Dasmosmilia, lymari (Pourtales)*, *Madrepora oculata (Linne), Lophelia pertusa*, *Caryophyllia cyathus (Ellis a. Solender), Errina aspera (Linne)* and *Monomyces pigmaea*.

The development and evolution of these coral build-ups have been controlled by the interplay between autogenic and allogenic processes: glaciation and tectonics. Intrabasin processes include reworking by currents and biological factors. Changes in climate and glacial mass influence the rate and the nature of sediments' supplies and relative sea level fluctuations. The facies reflect a complex history where evolution of the depositional system may be considered in terms of several phases:

(1) Initiation of the Strait of Gibraltar due to extensional tectonics during Tortonian - Pliocene followed by a transgression.

(2) Falling of the sea level related to the first glacial stage at the end of the Pliocene resulted in bottom erosion and leaded to cutting alluvial valleys and progradation of fluvial supplies.

(3) Rising of the sea level due to glacier retreat during the interglacial Donau/Günz combined with a compressive tectonic event during the lower Pleistocene allowed the water depth over the

topographic high to be sufficient for the development of coral build-ups. The topographic highs acted as isolated platforms where no terrigenous input. The Atlantic flows cooled by the ice melting waters induced the reduction of the thermal gradient between the surface and the bottom waters, which favoured convection currents and led to the oxygenation of the deep waters. The first colonies of corals got settled on the borders of these platforms exposed to ascending currents rich with nutrients.

(4) Falling of the sea level related to the glacier advancement (Günz) and an extension event induced meteoric alteration of the coral build-ups that resulted in karstification and the spreading of fluvial deposits.

The last two phases (3 and 4) repeated again three times during the middle and upper Quaternary in relation with the advancement and retreat of the glacier stages (Mindel, Riss and Würm) of the middle and upper Pleistocene. In the beginning of the eustatic rise, coastal conditions allow the precipitation of a carbonate crust on the dead corals and when the sea level is high enough, a new generation of coral starts growing on an isolated platform. The subsequent sea level fall induces the destruction of a part or the totality of the new build-ups by meteoric alteration

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## GEOSPHERE FLUID VENTING, SEABED CHARACTER AND HYDRODYNAMIC CONTROLS OF COLD-WATER CORAL BIOHERMS: THE DARWIN MOUNDS, NE ATLANTIC

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Cold-water corals are widespread along the European continental margin and form bioherms, carbonate mounds and reefs measuring up to several hundred metres tall. Over the past few years, considerable research effort has been focussed on defining the formation processes and environmental controls on mound growth. Despite early indications of a relationship between fluid venting (cold seeps) and cold-water coral carbonate mounds, subsequent work has found little support for this premise with the role of hydrodynamic processes stressed.

This presentation reviews work on cold-water coral mounds in the northern Rockall Trough margin (Darwin Mounds) (Fig. 1) where evidence for both fluid venting and hydrodynamic processes plays in important role in the formation and subsequent development of the Darwin Mounds.

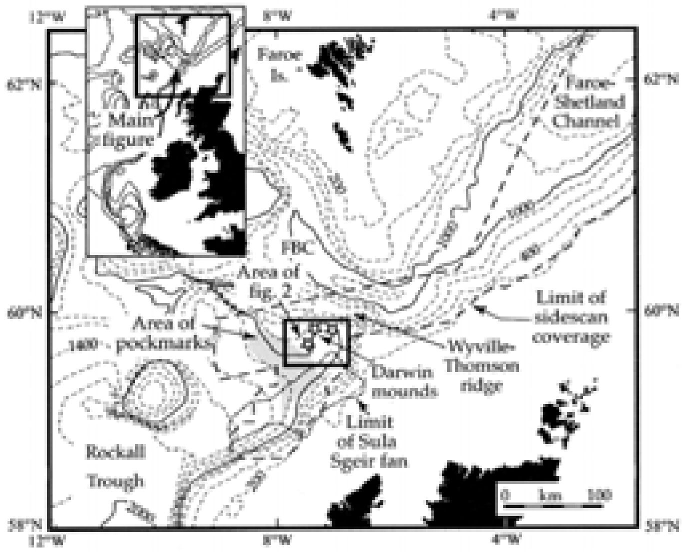
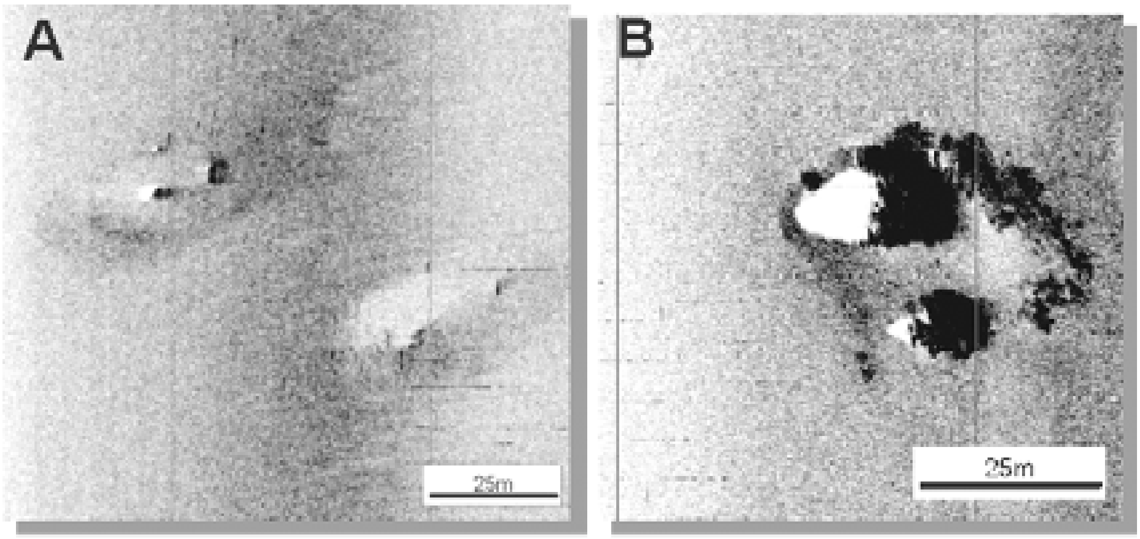



*Fig. 1 Location of the Darwin mounds in the northern Rockall Trough. Abbreviation: FBC, Faroe Bank Channel. Insert shows location of the study area to the north of the UK (from Masson et al., 2003)*



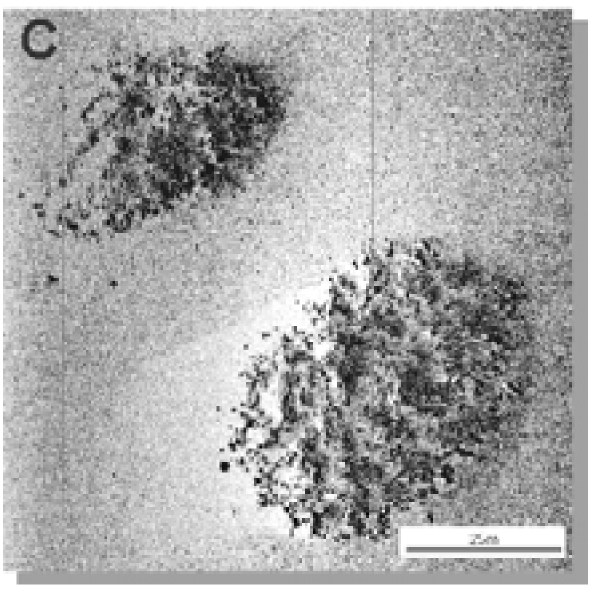




Fig. 2. Seabed features observed in the Darwin Mounds area A: pockmarks, B: partially coral-colonised pockmarks, and C: Darwin Mounds with high back-scatter (black) indicative of coral colonisation. A-C represents a south-north transition.

Evidence of sub-surface fluid escape in the Darwin Mounds areas is apparent in the form of pockmarks and sand volcanoes. These are thought to be the result of fluid-escape due to sub-surface overpressuring. These features are progressively colonised by cold-water coral with transitional examples of uncolonised pockmarks, partially colonised pockmarks and coral mounds imaged. These observations support a geological control on mound formation.

A lack of methane-seep related phenomena suggests that fluid escape may provide an appropriate substrate for coral colonisation thereby dictating the morphology of the mounds although it may be unrelated to coral colony food supply. Once established, the coral framework baffles sandy sediment allowing the mounds to grow. Changes in morphology from circular to ovoid and increases in mound height reflect increases in bedload sand transport supporting a hydrodynamic control on mound growth after seep-controlled mound initiation.

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## THE «TUBOTOMACULUM»: A FOSSIL RECORD OF CORALS

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The "tubotomaculum" occurs in the upper Cretaceous to Miocene argillaceous formation ("argile varicolore") at the base of the numidian flysh succession in the western peri-Mediterranean alpine orogenic belt. They have been considered for a long time as enigmatic geological bodies and still now there is many controversial hypothesis about their origin and mode of genesis: epigenous burrows and coprolite (Durand Delga, 1955), epigenous burrows for the cylindrical shape and, fecal pellets, mud fragments, authigenic iron grains or particular concretions of manganese and iron oxides (Pautot *et al.*, 1975) .

In the western Rift belt of Morocco, the tubotomaculum occurs in the "argiles à tubotomaculum" formation which represents the slope or the prodelta deposit of the slope delta numidian succession of oligo - miocene age (Hamoumi *et al.*, 1995). Sedimentological study of these tubotomaculum using macroscopic (visual) description, petrologic and mineralogical studies (thin and polished section), X - Ray diffraction on bulk sediment and chemical analysis, allows their identification for the first time as fossil corals epigenized and coated by Fe and Mn oxides.

These Tubotomaculum are dark brown to black ferromanganese bodies composed of a core and a bumpy cortex. Their sizes range from 1 to 4 cm in diameter and 2 cm to 10 cm in the length. They can be assigned to various shape classes: conical, trochoidal, pyramidal cylindrical, twisted, dendroid and irregular that may be compared to the morphology of some scleratinia: *Fungia, Acropora Formosa, Thamnasteria, Caryophyllia clava, Dictuophyllia, Rennensismilia, Dendrophillia, Pocillopora, Siderastrea scotica.*

Observation of cross longitudinal and transverse sections and thin sections with the naked eye show in almost all the tubotomaculum that the cortex displays several successive dark brown or black layers.

Study of thin section under polarising microscope allows to recognise specific morphological structures that characterise coral skeleton such as: corallites, septa, dissepiments and rounded septal dentation. It also leads to recognition of prevalent iron mineral with sparse detrital quartz and phyllite, veins of calcite and oxidized matrix. The iron oxide is identified in polished section as microcrystalline goethite.

X-ray diffraction revealed the manganite together with goethite and hematite in the cortex and goethite in the core and the peripheral layer of the cortex.

Chemical analyses using spectrometry show significant difference among the core and the cortex, the highest concentration of Mn is located in the cortex (13,2%), the core has low concentrations: 8%

and 6, 40%. While Fe content follows an inverse trend, the highest concentrations are located in the core (36% and 35, 32%) and the cortex displays lower value (30, 68%).

On the base of the Mn/Fe ratio, these encrustations appear to be associated with the hydrothermal field (Bonatti et al; 1972). Such encrustation grows at the interface sediment/seawater in areas characterized by hydrothermal activity of a spreading centre or local volcanic/hydrothermal activity, low sedimentation rate, reduced organic activity and a well oxygenated water column.

These ferromanganese fossil corals recorded the long and complex history of the "Bassin maghrebin" (Bouillin, 1986) between the African and European plates. During Cretaceous, the extensional tectonics was prevalent and thus induced a falling of sea level during a global period of high sea level (Salhi *et al.*, 1995). This may result in the degradation of the Jurassic and Cretaceous bioherms. The coral fragment was then completely replaced by Fe and Mn oxides during a long diagenetic evolution under the combination of hydrothermal activity related to the continuing rifting, active subsidence and low rate of sedimentation. The occurrence of hydrothermal activity is supported by the existence of chimneys, metalliferous crust and pyrite in the western Rif Cretaceous succession. This evolution was favoured by the modification of oceanic circulation related to colder flow at the Eocene. During Oligo-Miocene the ferromanganese fossil corals were resedimented in a delta slope.

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## CHEMICAL AND ISOTOPIC EVIDENCE FOR SOURSE OF CARBON AND FORMATION OF CARBONATE BUILT-UPS IN THE GULF OF CADIZ

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Fluid escape of hydrocarbon-rich fluids is one of the phenomena for the Gulf of Cadiz. Marine geological explorations have shown the presence of authigenic carbonate deposits in the areas of active fluid seepage through the seafloor.

The material for this work was obtained during TTR11, 12 and 14 cruises in the Gulf of Cadiz. The set of geological and geophysical studies was performed, including side scan sonar survey, underwater TV and bottom sampling. During these investigations a number of carbonate built-ups was sampled. Two main groups of them were recognized. The first group is represented by irregular carbonate slabs and chimneys and their fragments. Carbonate built-ups of the second group are represented by cemented mud breccia.

During my study the investigations were based on petrography and geochemical studies: thin section description, X-ray diffraction (XRD) analysis and analysis of stable isotopes: $^{13}C$, $^{18}O$ and $^{87}Sr$ in order to determine composition and origin of the studied carbonate crusts.

The carbonate built-ups of the first group have porous, vesicular and very oxidized surface. All samples show an evidence of biological activity around. Sponges, corals, hydrozoa, tube worms and bacterial mats are abundant on their surface. The inner channels and pores are free of sediments. The chimneys and slabs are mainly composed of ankerite and dolomite with admixture of iron-oxides. On the thin section we see their microcrystalline structure with some amount of organogenic features.

The brownish gray carbonate crusts of the second group are predominantly isometric in shape with vesicular and porous surface. In thin sections almost all samples show massive structure and insignificant amount of organogenic features. Micritic calcite cement binds together the fine fraction of the matrix and centimeter (or less) generally clay clasts of different roundness. According to the interpretation of XRD analysis the crusts are composed mainly of aragonite or Mg-calcite with some content of ankerite, carbonate and dolomite. The presence of ankerite and dolomite is probably caused by the admixture of iron oxides in the crust composition. Mineralogy of the carbonate cement is controlled by the concentration of $SO_4^{2-}$ in pore waters. Strong concentrations of $SO_4^{2-}$ in the sediment will inhibit the precipitation of Mg calcite, enhancing instead of precipitation of aragonite (Burton, 1993).

Stable isotopes ($^{13}C$, $^{18}O$) data for all studied samples show the evidence of methane-derived carbon in the carbonate built-ups (Fig. 1). So carbon is mainly derived from the oxidation of methane into $CO_2$. Consequently $CO_2$ reacts with the aqueous solution from which carbonate ultimately precipitates. Thus studied carbonate built-ups are formed as micrite-cemented concretions in the sediment pore space of carbonate-rich sedimentary environments.

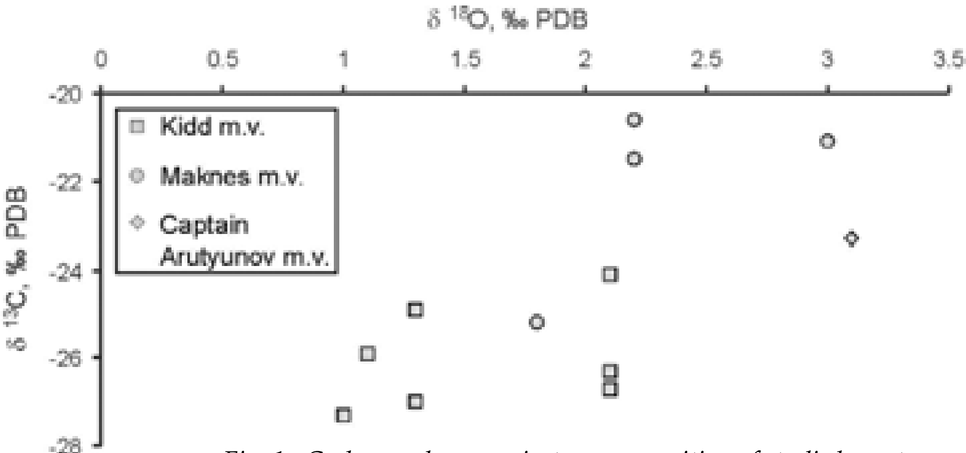


*Fig. 1. Carbon and oxygen isotope composition of studied crusts*

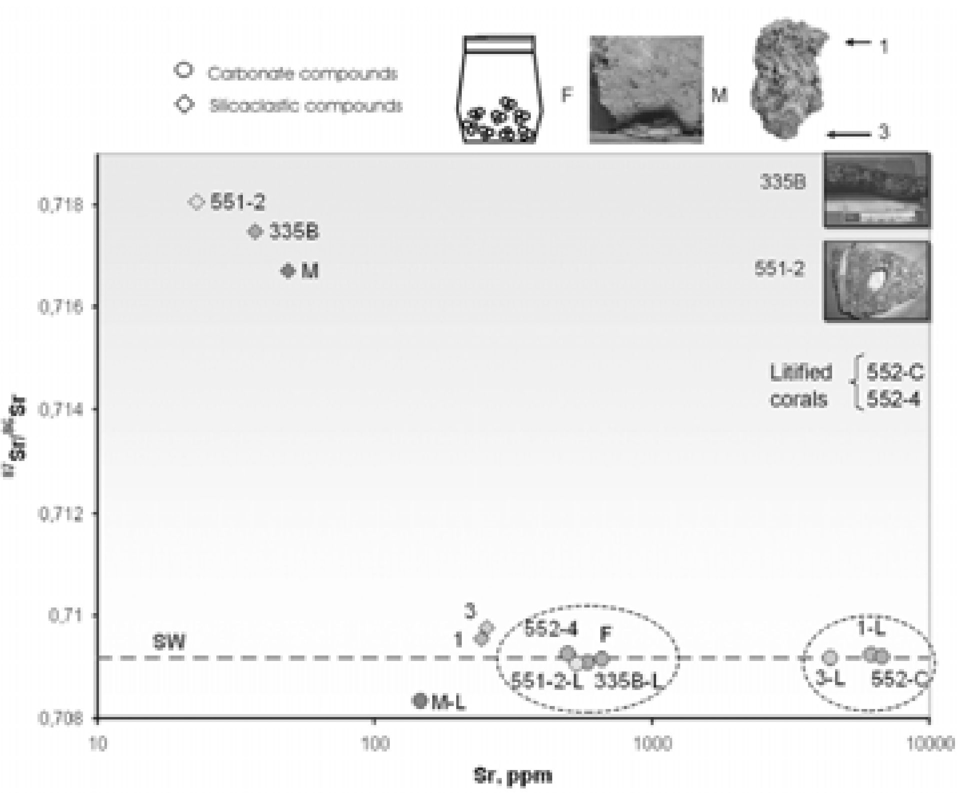


*Fig. 2. Strontium isotopic composition of studied samples*

Strontium isotope analyses were performed for 8 samples (Fig. 2). The strontium isotopic composition of carbonate minerals of studied samples reflects the strontium isotopic composition of the water in which they formed (Hess et al., 1986). The measured values of the ratio of strontium-87 to strontium-86 are undistinguishable from values for contemporaneous seawater. So all studied samples were formed at quaternary period. According of the concentration of strontium the carbonate built-ups of the first group were recrystallized.

Therefore:

1. According to their composition and strontium isotope measurements the studied carbonate crusts have the recent origin;
2. Authigenic carbonates are the result of microbially-mediated processes of oxidation of methane in the areas where hydrocarbon-rich fluids are seeping;
3. The carbonate built-ups of the first group were recrystallized.

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## AUTHIGENIC CARBONATE CHIMNEYS AND CRUSTS FROM THE GULF OF CADIZ: BIOMARKER EVIDENCE OF ARCHAEA MEDIATING ANAEROBIC OXIDATION OF METHANE

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The study of authigenic carbonate chimneys and crusts in the Gulf of Cadiz has been an objective of several cruises of the TTR program: TTR11 Leg3 in 2001 (Kenyon et al. 2002), TTR12 Leg 2 in 2002 (Kenyon et al. 2003) and TTR14 Leg 1, in 2004). On the cruises we collected and identified different types of authigenic carbonates: dolomite crusts, dolomite nodules, chimneys or filled burrows and aragonitic slabs or pavements. Dolomitic samples were found along the Guadalquivir diapiric ridge (GDR), the Formoza Ridge (Díaz-del-Río et al. 2003; Magalhães et al. 2003), on sedimentary structures associated with the outflow of the Mediterranean water (MOW) and on some mud volcanoes and mud diapirs located on the pathway of the MOW. Aragonitic pavements were associated with several mud volcanoes (Jesus Baraza, Ginsburg, Mercator, Faro and Hesperides), but some of them were not under influence of the MOW.

Petrographic and XRD studies of (I) dolomitic samples showed, that they consists of microcrystalline dolomite cements with subordinate high and low magnesium calcite and (II) a detrital and pelagic fraction composed mainly of quartz and minor feldspar, clays, bioclasts of planktonic foraminifera (globigerinoids), ostracods, and pellets. Crusts of iron and manganese oxides cover some of the carbonate samples. Even carbonates from the same chimney show variations in dolomite/calcite ratios along radial and longitudinal profiles. Tabular to nodular precipitates consisting mainly of aragonite also contain mud breccia clasts cemented by micrite, shell fragments, clasts from previous generations of crusts and detrital quartz, clays and bioclasts of planktonic foraminifera.

Authigenic carbonates yielded $\delta^{13}C_{carbonate}$ values indicating methane as major carbon source with ratios as low as -46.9 ‰ PDB and $\delta^{18}O_{carbonate}$ as high as +6.5‰ PDB. Likewise, the crusts and chimneys can be interpreted as record of extensive methane seepage in this particular area of the Gulf of Cadiz.

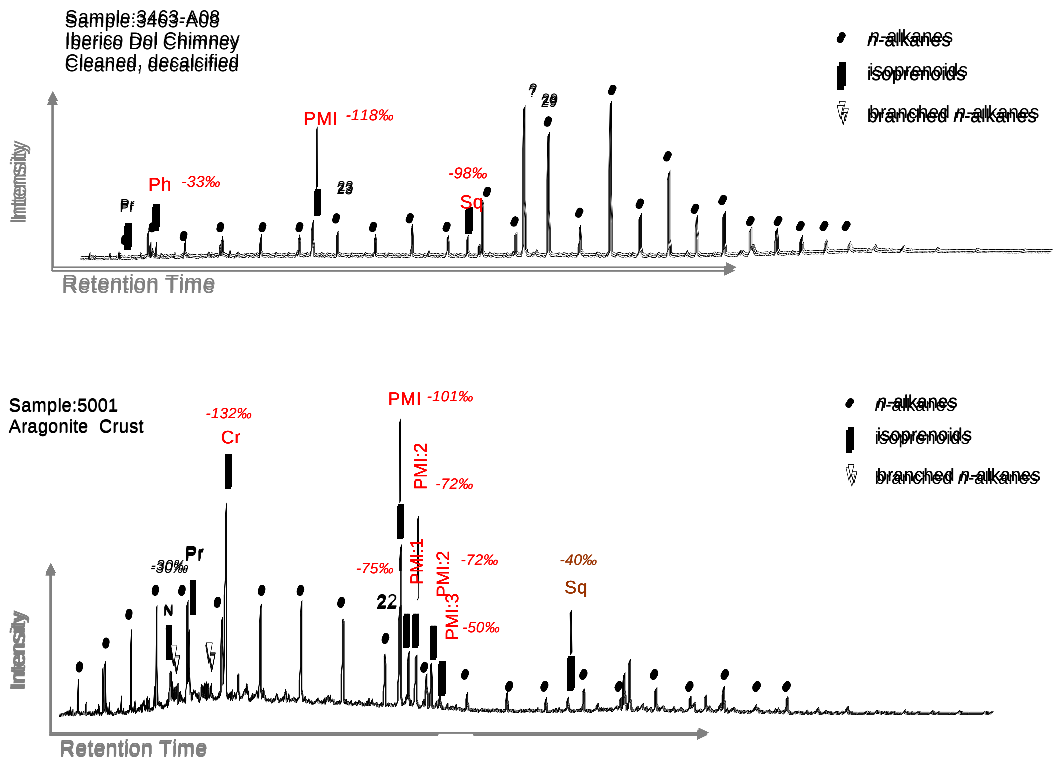


*Fig. 1. Hydrocarbons fraction gas chromatograms of a dolomite chimney (on top) and of an aragonite pavement (bottom). Isotopic compositions of individual biomarkers are presented in $\delta^{13}C$ ‰ relative to PDB.*

Specific $^{13}C$-depleted lipid biomarkers (Fig. 1) have been identified in two chimney slabs. These biomarkers include tail-to-tail linked acyclic isoprenoids such as PMI (2,6,10,15,19-pentamethyleicosane) and squalane (2,6,10,15,19,23-hexamethyltetracosane). These compounds derive from archaea involved in the anaerobic oxidation of methane (AOM). The aragonite crusts showed even better preserved biomarker patterns in comparison with the chimney dolomites. PMI ($\delta^{13}C$ value: -101‰) is accompanied by unsaturated derivatives with 1 to 3 double bonds (PMIΔ; -75‰). Isotopically-depleted PMI is representing the most widespread and persistent hydrocarbon biomarker for AOM-performing archaea. Further analysis of alcohol and fatty acid biomarker fractions are in progress.

These results are substantiated by SEM observations (Fig. 2), which confirm that microbial activity has played an important role in carbonate authigenesis at methane-seeps in the Gulf of Cadiz.

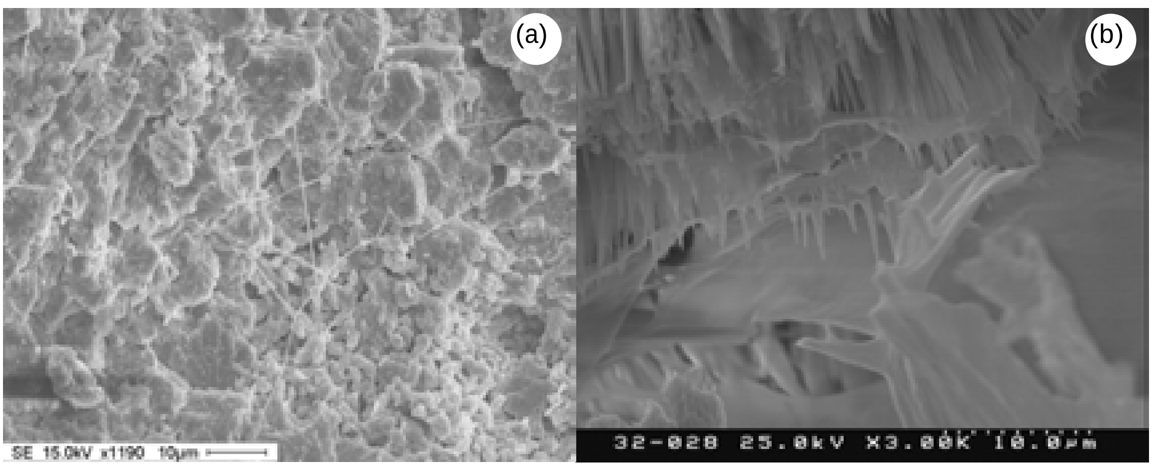


*Fig. 2. SEM images revealing microbial activity indicators.*
*(a) dolomite chimney, (b) aragonite pavement*

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## PHENOMENON OF ANKERITE MINERALIZATION IN THE GULF OF CADIZ

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During the 1st Leg of TTR14 cruise the new sea mound covered by carbonate chimneys and crusts were discovered in the Gulf of Cadiz close to Gibraltar Strait at the depth of 300-500 m. The similar mounds during last years were studied in the Gulf of Cadiz (Iberico, Formoza Ridge) (Kenyon et al., 2001; Diaz-del-Rio et al., 2003). Chimneys from all of these fields show similar petrographic characteristics, being mainly formed by authigenic carbonates with distinctive contents of Fe-Mg (ankerite, dolomite and Mg-calcite).

In the dredges AT550-551D at the depth of 368-445 m the massive carbonate chimneys, crust, coral debris and big amount of biological samples were recovered. The dead corals were replaced by authigenic carbonates of different mineralogical composition. Four stages of carbonate replacement in corals were recognized and studied by following set of methods: macro and microscopical description, X-ray diffraction analysis (XRD), analysis of stable isotopes $^{87}Sr$, measurement of total amount of calcite/dolomite.

Four stages of mineralogical transformations from aragonite to ankerite $Ca(Fe,Mg)(CO_3)_2$ documented. Initial aragonite and calcite in coral (stage I) are replaced by calcite and dolomite (stage II) forming mineralogical assemblage consists of aragonite (70%), calcite (15%), Mg-calcite (10%), dolomite (5%). Than it changes into ankerite (80%) calcite (10%) and Mg-calcite (10%) (stage III) and finally - into ankerite with small admixture of calcite (stage IV). According to XRD analysis and description of thin-section goethite appears on the third stage. At the last stage this mineral covered all septal walls of corals and rich 30% from common bulk.

The origin of ankerite-dolomite minerals has been much debated. Ankerite and dolomite authigenic carbonates are typically associated with pore fluids in the deepest formation zone with suitable thermal condition more than 200°C. Another possible scenarios for crystallizing of $Ca(Fe,Mg)(CO_3)_2$ can related to bacterial fermentation in the cold seeps and crystallization of dolomite on boundary between water masses with different salinities (Stakes et al., 1999; Greinert at al., 2001; Kuznetsov, 2002).

We believe that replacement of aragonite by ankerite mainly related to changing of water composition with increasing of $Mg^{2+}$ and $Fe^{2+}$ ions due to influence of Mediterranean Outflow.

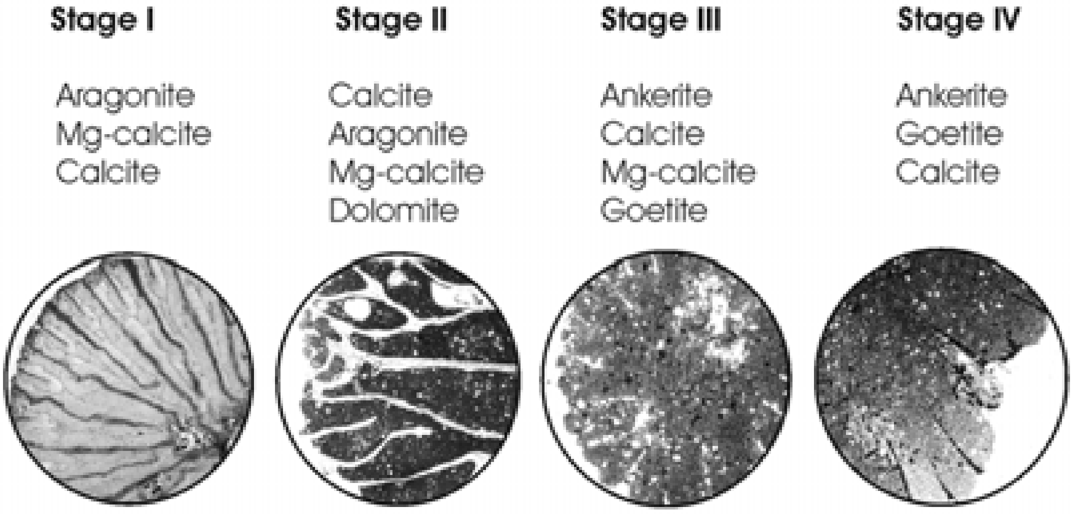


*Fig. 1. Four stages of mineralogical transformation from aragonite to ankerite*

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## CARBONATE CHIMNEYS FORMATION IN THE GULF OF CADIZ

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This work provides an attempt to understand the nature of hydrocarbon-derived carbonate chimneys in the Gulf of Cadiz, which have been studied since 2001 with the R/V *Professor Logachev*. During the TTR14 cruise Leg 1 the new sea mounds covered by carbonate chimneys were found. The new location was studied using a dredge, TV-grab, underwater camera and MAK-1 sidescan-sonar.

Carbonate chimneys research are based on studies of the tectonic, sedimentological and oceanographic history of the area and also seismic, sampling, underwater camera observation results taken in different areas where these chimneys have been discovered (including TTR14 Leg 1 area). X-ray diffraction (XRD) analysis, analysis of stable isotopes (carbon and oxygen) and thin section slides were made.

All chimneys are mainly composed of authigenic carbonates (ankerite and Mg-calcite) with abundant iron oxides and quartz. $\delta^{13}C$ values vary from -20,2‰ to -48,3‰ PDB. It means that carbonate chimneys were formed from thermogenic hydrocarbons. These results are similar to those published by Spanish researchers (Diaz-del-Rio et al., 2003)

The main purpose of this research was to find gas-source rocks, according to several criteria. These criteria include methane-oxidation scheme of carbonate chimneys forming, simplified burial (paleotemperature) history diagram and research of rock fragments from mud breccia, which were divided into groups with different oil-source potentional during previous TTR cruises in the Gulf of Cadiz. After the above-mentioned analysis was made, two main layers where identified: the upper Cretaceous and lower Miocene as probable gas-source rocks. Also it was important to understand how a well-known but badly-studied olistostrome (accretionary) complex and mud diapirs (where a big number of chimneys where found) influenced on hydrocarbon forming and migration.

Studying hydrocarbon-derived carbonate chimneys might be essential for understanding the problem of hydrocarbon fluid venting in the Gulf of Cadiz.

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## COMPOSITION AND AGE STRUCTURE OF METHANE DERIVED CHIMNEYS IN THE GULF OF CADIZ (TTR14)

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During TTR 14 cruise on RV *Professor Logachev* in the Gulf of Cadiz hydrocarbon derived chimneys were surveyed by TV controlled grab system and sampled. In total three chimneys were investigated. We present results from the Uranium- Thorium dating, the trace element ratios Mg/Ca, Sr/Ca and Ba/Ca and $\delta^{18}O$ and $\delta^{13}C$ in order to determine the age and the conditions of chimney growth. Sampling site is situated in a tectonically active region at the front of the Betic-Rifian Arc, which is characterized by diapirism, mud volcanism, hydrocarbon venting and pockmarks. In the northern sector large amounts of carbonate chimneys have been found along diapiric ridges, which are composed mainly of dolomite and high magnesium calcite.

MC-ICP mass spectrometry (VG Axiom) was used for Uranium- Thorium dating, whereby the Uranium isotope ratios were determined and the age of the carbonate chimneys was calculated. The measurements show, that the chimneys grew during a period of low sea level about 10 000 years ago. We assume, that the rate of venting increases due to pressure release at the onset of glacial phases. Age determinations in cross sections reveal, that the chimneys grew from the inside to the outside in a very brief time span. Oxygene and carbon isotope analyses performed on a MAT 252 with Carbo Kiel II device points to the participation of methane in the growth process. Therefore, we can draw the conclusion of the occurrence of methane and presumably of gas hydrates.

# GEOFLUID PUMPING IN CARBONATE MOUND SYSTEMS: A FACTOR FOR GROWTH AND STABILISATION?

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The origin and growth of carbonate (mud) mounds is a heavily debated subject in recent discussions. Currently the growth of carbonate mounds is being hypothesised as driven by an external flux of nutrients with optima in regions of upwelling deep ocean waters and at boundaries between different water masses, thus high primary production.

Despite the fact that the locations where large coral build-ups occur, seem to coincide with the large hydrocarbon provinces in the North-East Atlantic, the theory that hydrocarbon seepage is a driving internal force for carbonate mound growth has been questioned. However, it is known that corals and other benthic sessile organisms require a hard substrate to settle on and attach to. In this line of thought it seems reasonable to propose hydrocarbon seepage as a trigger event which leads to carbonate crust hardground formation at or near the sediment surface, rendering the seafloor a hospitable place for colonization by organisms.

Indeed, the discovery of small carbonate mounds in an area on the Moroccan margin, boasting giant mud volcanoes revives the idea that deep fluids could influence – at least partly – the distribution of carbonate mounds – (!) only the initial stage of seafloor preparation (hardground formation) but not the successive growth fase – since the mounds are adjacent to large mud volcanoes. Moreover, carbonate crusts have been dredged from this mound area and these give evidence of methane-related formation through carbon stable isotope analyses.

Furthermore, it is know that carbonate mound growth is almost exclusively occurring on topographic elevations, such as ridges, fault scarps… At the Pen Duick Escarpment in the El Arraiche mud volcano field off-shore Morocco; carbonate mounds are located at the top of the fault-bounded cliff. This fact has always been regarded as a confirmation that external import of nutrients is the only driving force of growth since 'the highest on the elevation, the more food' seemed logical and it explained the mostly vertical growth style of the mounds. However, high current velocities versus low settling velocities of particles in the ocean don't necessarily impose
an advance for hill- or mound top residing organisms, but it is rather the suffocation by sediments at the lower parts that is the controlling factor.

We want to propose a new model for onset, growth and stabilization (due to formation of carbonate crusts cementing coral debris and sediments) of carbonate mud mounds: a scarp or hill on the seabed subject to rather strong currents will develop zones of high pressure at the lows of the slopes and low pressure areas at or near the summit. This pressure effect would create a fluid migration from deeper layers to the top of the structure. An enhanced migration of reduced chemical compounds at an uncolonized scarp or hill towards the surface will promote cementation of the sediments leading to hardground formation, suitable for subsequent settling.

Fluid rise also would result in cementation of a coral rubble framework for existing mounds, eading to stabilization. It will also enhance the food supply for microbial communities. This in turn can boost species diversity, both mega- and microfauna. So, in this view, the pumping of fluids in carbonate mound systems, driven by external currents, is responsible for different processes.

Currently, modelling of internal fluid motion in function of fluid velocity and topography is ongoing and will be applied to real-life study cases, in the first place at ocean margins.

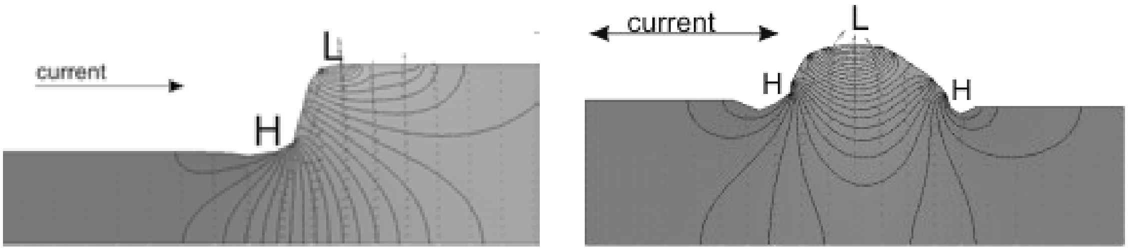


*Fig. 1. Pore pressure differentiation over an obstacle (left: ridge, right: mound) due currents. The pore pressure will induce pore fluid migration (Darcy) towards the top of the structure*

# PEN DUICK ESCARPMENT ON THE MOROCCAN MARGIN: A NEW MOUND LAB?

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The recent discovery of cold water corals and carbonate mounds in the Gulf of Cadiz (R/V Belgica, 2002 and TTR12, 2002) offered challenging perspectives for a comparative study of deep water carbonate build-ups and associated ecosystems along the European and the N-African margin, respectively Porcupine Basin (SW of Ireland) and the Moroccan margin (El Arraiche mud volcano field).

The Porcupine Basin was already the focal point of several cruises and multi-disciplinary studies whereas some very interesting regions in the southern part of the Gulf of Cadiz were almost unexplored. This lack in information formed the rationale for a detailed study along the Atlantic margin of Morocco. For this study, recent cruises (R/V Sonne, 2003, R/V Marion Dufresne, 2004 and TTR14, 2004) have gathered gravity cores, CALYPSO piston cores and CASQ-cores for (1) a better understanding of the mound build-up in the Gulf of Cadiz, (2) comparison of the mounds in a mud volcano setting with the mound-constructions in Porcupine Seabight and (3) a detailed comparison of on-mound records and off-mound records.

At the Pen Duick Escarpment in the El Arraiche mud volcano field off-shore Morocco, carbonate mounds are located at the top of a fault-bounded cliff. Their occurrence on such a topographic elevation implies that periodical high currents and enhanced food-supply could have provided adequate conditions for the extensive growth of deep-water corals. However, at recent times no live coral is observed on the mounds. The mounds are mainly constructed by reef-forming deep water scleractinians. The main framework building species Lophelia pertusa, Madrepora oculata and Dendrophyllia sp., only were represented by dead specimen. These corals seem to be the driving factor of the mound construction by baffling sediments and alternating with periods of increased sediment deposition. The composition of the framework building corals reflects in some cases the alternating depositional environment. A large number of shell-bearing invertebrates formerly inhabiting the different econiches provided by the coral framework are found in the sediment throughout the entire core. The preliminary analysis of these macrobenthic associations also reflects several environmental changes over the time span reported in the core.

Even as during the preliminary study only few thyasirid clams, known to life in symbiosis with sulfide-oxidizing bacteria have been found in the sediments, the findings were clearly limited to certain parts of the core and might indicate an anoxic environment.

Diagenetic processes, playing an important role in mound build-up, are reflected in changing preservation stages of the coral framework and are responsible for early-stage cementation of the sediments in some parts of the core. Moreover, the sulphate profiles acquired from measurements of porewater on- and off-mound, indicate that anaerobic methane oxidation may play an important role in deep sulphate reduction. Indeed, the occurrence of small carbonate mounds in an area where large mud volcanoes are witnessing of fluid escape and where adequate conditions for the development of gas hydrates are observed, the importance of methane-fluxes in the past can't be neglected and possibly play an important role in mound-initiation.

## ACOUSTIC SEAFLOOR OBSERVATIONS AND CARBONATE SEDIMENTOLOGY OFF MOROCCO: INITIAL RESULTS

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In 2002, the Moroccan Margin was probed with side-scan sonar and deep-tow camera systems and intensively sampled with a range of techniques, during the TTR12 cruise, after the Cadipor cruise had discovered the extensive El Arraiche mud volcano field, boasting the largest submarine mud volcanoes ever seen and deep-water mound structures at a fault-bounded cliff. During TTR14 Leg 1, the Moroccan Margin was surveyed further south with seismics, side-scan sonar and multiple sampling techniques, in search for fluid escape features in order to estimate the extent of activity and tectonic relations.

Acoustic imaging with side-scan sonar and subbottom profiler revealed the presence of mud volcanoes and (carbonate) mounds. The former are proved by high reflectivity fields with concentric structure patterns, the latter hinted by small circular features, occurring at slope tops and associated with sidesweeps on the subbottom profiler image. Yet again, the Moroccan Margin is proven to be an interesting laboratory for the study of fluid escape features of different types. The inferred mounds and mud volcanoes will be studied in more detail in upcoming fieldwork.

Related with these fluid sources, carbonate crusts and "chimneys" are often observed. Carbonate crusts and "chimneys" from different settings in the Gulf of Cadiz and the Moroccan Margin collected during the TTR12, TTR14 and other cruises are being analysed with a range of techniques in order to reveal processes related to the origin, growth and diagenesis of these structures.

Carbonate crust and chimney samples from Pen Duick Escarpment, Fez mud volcano (Moroccan Margin) and other mud volcanoes are available for analysis. Techniques used include petrographic analysis, stable isotope analysis (C, O, S, Fe, Sr), U/Th dating, scanning electron microscopy and XRD.

The goal of the study is to move towards a detailed analysis of (amongst others) the origin and mineralogy dolomite fraction in the samples, nature of the included Fe, formation of cracks observed in chimneys, dating and growth phases of chimneys and other phenomena.

## THE EC HERMES PROGRAMME

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HERMES (Hotspot Ecosystem Research on the Margins of European Seas) is an EC programme designed to gain new insights into the biodiversity, structure, function and dynamics of ecosystems along Europe's deep-ocean margin. It represents the first major attempt to understand European deep-water ecosystems and their environment in an integrated way by bringing together expertise in biology, geology, and physical oceanography, so that the relationship between biodiversity and ecosystem functioning can be understood. Study sites will extend from the Arctic to the Black Sea and include open slopes, where landslides and deep-ocean circulation affect ecosystem development, and biodiversity hotspots, such as cold seeps, cold-water coral mounds, canyons and anoxic environments, where the geosphere and hydrosphere influence the biosphere through escape of fluids, presence of gas hydrates and deep-water currents. These important systems require urgent study because of their possible biological fragility, unique genetic resources, global relevance to carbon cycling and possible susceptibility to global change and man-made disturbances.

The programme starts in April 2005 and TTR is one of 36 academic partners.

# Mud volcanoes, gas hydrates, cold seeps

## GEOPHYSICAL EVIDENCE OF GAS HYDRATE PRESENCE IN SHALLOW MUD VOLCANOES (EL ARRAICHE MUD VOLCANO FIELD, MOROCCAN MARGIN)

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The Mercator and Fiuza mud volcanoes of the El Arraiche mud volcano field on the Moroccan continental margin bear a subsurface bottom simulating reflector (BSR) with negative polarity on high resolution seismic profiles (Cadipor cruise, R/V Belgica, May 2002). This is the first observation of a submarine BSR at very shallow depth of 400 meter and even less.

We interpret this BSR as the base of a gas hydrate stability zone. Based on modelling with pore water salinity and gas hydrate composition from nearby deep-water mud volcanoes (e.g. Ginsburg MV), we found that gas hydrates could -theoretically- be stable. The stability of the gas hydrates is favoured because of the presence of a high fraction (20%) of higher order hydrocarbons ($C_{2+}$). This composition is also likely in the Mercator and Fiuza mud volcano gasses since thermogenic gasses are fuelling the mud volcanoes.

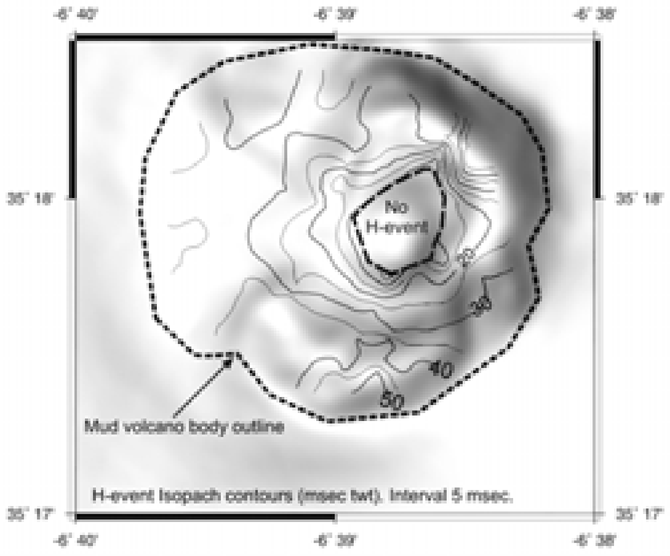


*Fig. 1: Depth map (msec twt) of the H-event below the mud volcano surface*

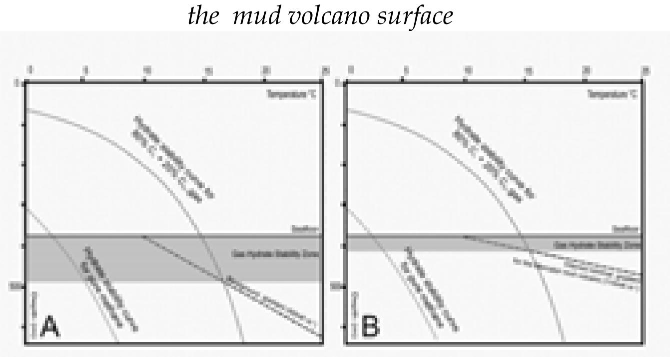


*Fig. 2: Gas hydrate stability graphs for Cadiz gas hydrate (Mazurenko et al., 2003) and methane (for comparison) in case of normal geothermal gradient (A) and minimal inferred heatflow in Mercator mud volcano (B)*

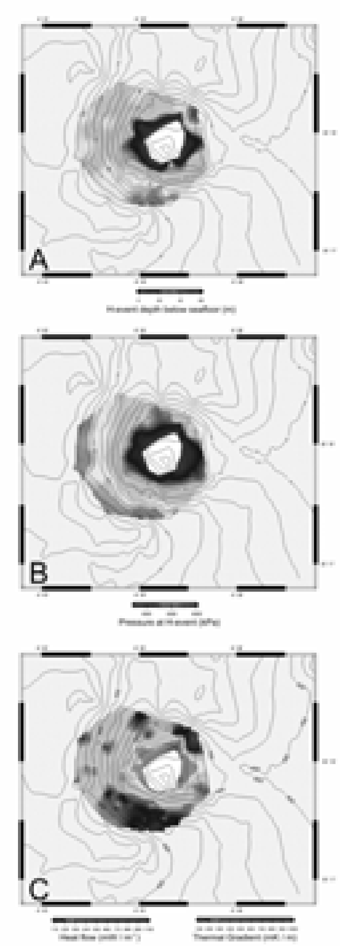


*Fig. 3: H-event depth below seafloor (in meter), pressure distribution at the H-event surface and inferred heatflow*

The BSR in the Mercator mud volcano was mapped out in 3 dimensions on a high resolution narrow spacing seismic grid. The gas hydrate stability zone in the Mercator mud volcano is thickening away from the mud volcano's crater to thicknesses up to 60 m. In the crater itself, no BSR is observed. The inferred thermal gradient and heath flow fields show a concentric pattern around the mud volcano's crater, typical for heath diffusion away from the warm central feeder pipe. Calculated heath flow values (inferred values go over 1 W $m^{-2}$) are typical for more active mud volcanoes and thus suggest that the Mercator mud volcano is actively venting fluids. The heat flow distribution suggests that the hydrate stability field in the crater is obliterated by focussed vertical migration of deep warm fluids.

## ORIGIN AND ACTIVITY OF GIANT MUD VOLCANOES ON THE MOROCCAN MARGIN

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The mud volcanoes of the El Arraiche mud volcano field (Moroccan Margin) are related to an extensional tectonic setting and their occurrence is strongly controlled by structural features. Anticlinal ridges, related to deep normal faults, have been eroded at the crest while onlapping sediments started to cover these structures. Since the ridges anticlinal form is related to the presence of rotated blocks in the subsurface, fluid migration along lystric faults bounding these blocks, has caused the mud volcanoes activity. Assuming a tectonic pulse, expressed as divergence caused by basin subsidence, activity of the different mud volcanoes has started in a rather short time lapse during the Late Pliocene. Subsequent periods of mud volcano activity are also related to basin subsidence.

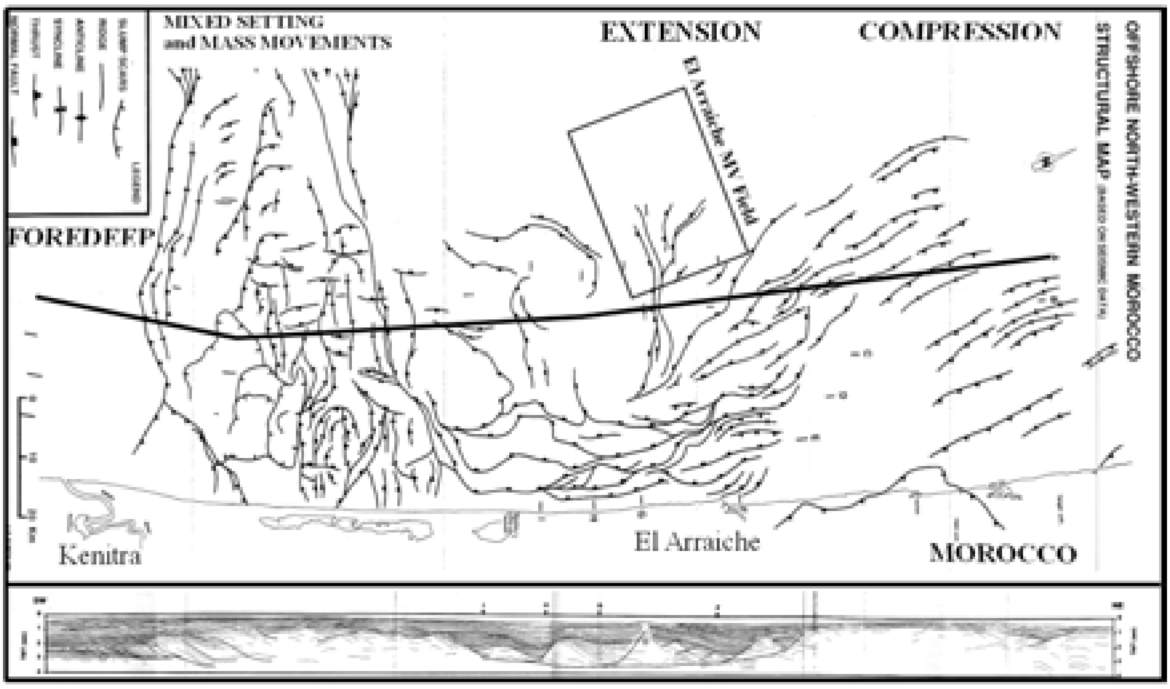


*Fig. 1. Structural setting of the Moroccan margin, after Flinch (1993)*

Both the Al Idrisi and Mercator mud volcanoes are occurring at or near an anticlinal ridge crest. The loss of mass below these mud volcanoes has been compensated by collapse underneath the mud volcanoes, expressed by many small normal faults around the mud volcanoes and dipping reflections of the substratum and the oldest unit. The Gemini MV – Pen Duick Escarpment area is more complex: the seafloor and basement are offset by two normal faults lining a large collapse area. Along the western part, carbonate mounds are present. At the east extension of the fault and south of the second faults, the area is overlain by the Gemini mud volcano and fault offsets also decrease eastwards. A structural control on the location of the Fiúza mud volcano is not resolved. Analysis of the timing of activity of the different mud volcanoes has shown that their activity is not exactly simultaneous; however times of activity and periods of calm could be resolved and concurred between the different mud volcanoes. This is assumed to indicate differences in tectonic activity throughout the Late Pliocene – Quaternary, as indicated by basin subsidence.

Erosional moats are very significant at the present seafloor. Throughout the history of the mud volcanoes' activity, these moats appear since the mud volcanoes must have had a considerable volume already. The direction of the moats also hint a strong E-W directed (tidal) current.

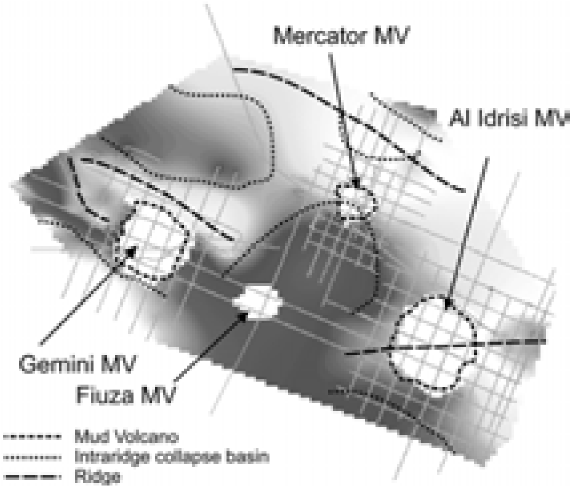


*Fig. 2: Basement map of the El Arraiche mud volcano field, showing the relation of the mud volcanoes to ridge structures. Field with is ~30 km.*

**Reference**

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## HYDROCARBON GASES FROM THE MUD VOLCANIC DEPOSITS OF THE GULF OF CADIZ AREA

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During the TTR14 (Training-through-Research) cruise Leg 1 (in the Gulf of Cadiz) new data on hydrocarbons were obtained. Both known mud volcanoes and newly discovered ones were investigated. Bottom deposits were taken to study: molecular and isotopic composition of hydrocarbon gases, pore water composition and total organic carbon content (TOC). Basing on the geophysical and geochemical data, relatively active and passive mud volcanoes were distinguished. Passive mud volcanoes are covered by hemipelagic sediments and have very low (about 0.01 ml/l) concentrations of hydrocarbons in volcanic deposits. Sulphate content of pore water samples does not change much with the depth. Sulphate reduction zone (SRZ) usually does not observed in sediments recovered by gravity corer (3-6 m). In active mud volcanoes methane concentration in deposits samples reaches 130 ml/l. Deposits recovered from these mud volcanoes are represented by high gas saturated mud breccia. Concentration of the heavy homologues of methane is larger than in passive ones ($C_1/C_{2+}$ ratio is about 10-20). Moreover, carbon isotopic values for methane vary from –49 to –

37.2‰ PDB and do not change much with the depth. Sulphate content in mud volcanic deposits decreases very fast with the depth (from 80 until almost 0 mM/l at the first 10 - 30cm).

The Captain Arutynov mud volcano was first studied during the TTR12 cruise in 2002. Based on the previous data (Blinova and Bileva, 2003) gas mostly consists of methane ($C_1/C_{2+}$ about 300) with concentration up to 126 ml/l. However hydrocarbons till pentane were detected but their concentration does not exceed 0.01 ml/l. Carbon isotopic composition of methane is about –48.54‰ PDB and reaches –79.08‰ PDB in the upper part. Cores taken in the TTR14 cruse are characterized by the same values. Gas mixture consists of methane with concentration up to 90 ml/l. $\delta^{13}C$ of methane about –49.62‰ PDB along the core (Fig. 1). Gas hydrates found in this mud volcano consist of pure methane (94%) with some admixture of heavy hydrocarbons (ethane, propane and butylenes) in total

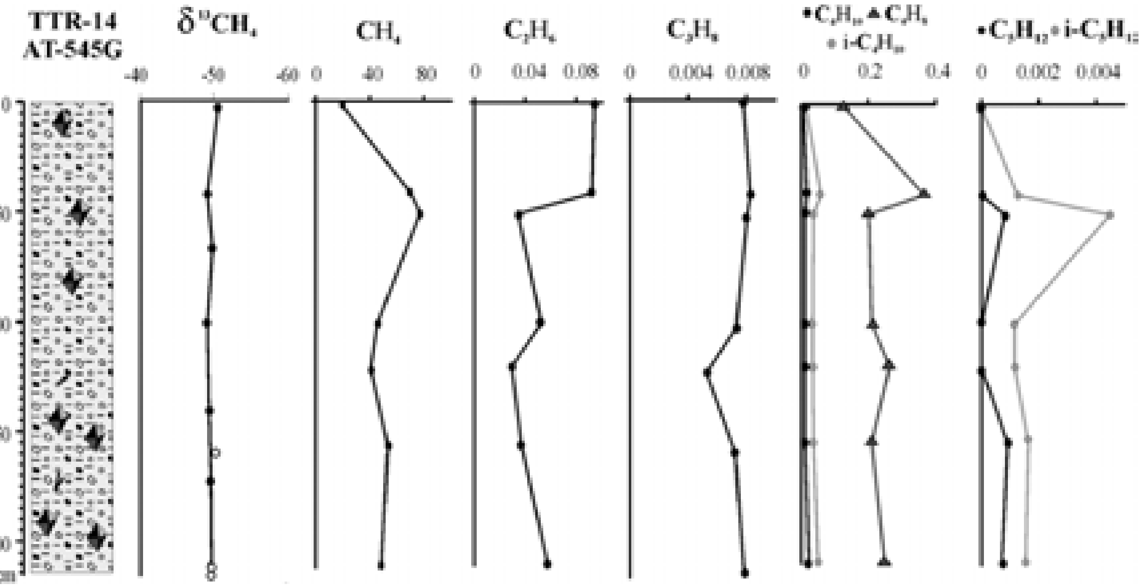


*Fig. 1. Gas composition from the mud volcanic deposits of the Captain Arutynov mud volcano. $\delta^{13}C$ $CH_4$ - ‰ PDB, white dots are $\delta^{13}C$ of methane from gas hydrates. Hydrocarbons composition is presented in ml/l*

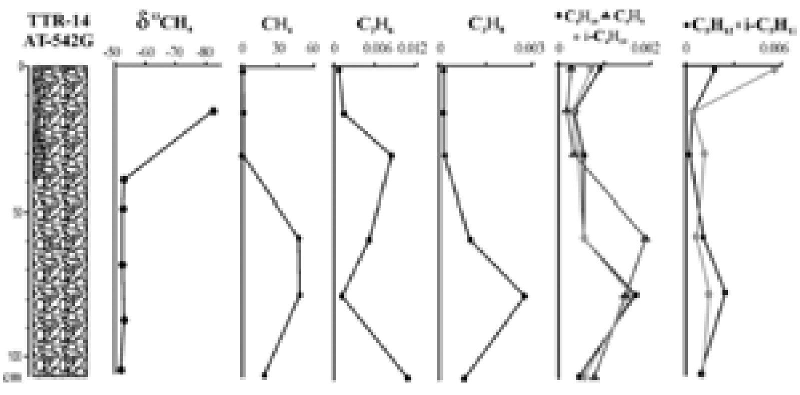


*Fig. 2. Gas composition from the mud volcanic deposits of the Meknes mud volcano. $\delta^{13}C$ $CH_4$ - ‰ PDB. Hydrocarbons composition is presented in ml/l*

less than 0.1% and non-hydrocarbons ($CO_2$, $N_2$ and He) – about 5.9%. $\delta^{13}C$ of methane is close to the isotopic values from sediments (from –49.01 to –50.03‰ PDB), $\delta^{13}C$ of ethane is –25.27 ‰ PDB.

The Meknes mud volcano founded in the southeast part of the Gulf of Cadiz is also characterized by high methane concentration (up to 48 ml/l). But isotopic values are lighter (about –52.66‰ PDB and reach –82.53‰ PDB in the upper part). Probably microbial activity is higher in the Meknes than the Captain Arutynov mud volcano (Fig. 2).

Several differences between the western and the eastern mud volcanoes in the Gulf of Cadiz were established based on study of molecular and isotopic composition of hydrocarbon gases. Mud volcanoes from the western part (Bonjardim and Carlos Ribeiro) are characterized by similar gas composition with high concentration of heavy hydrocarbons (wet gas). This gas is probably generated

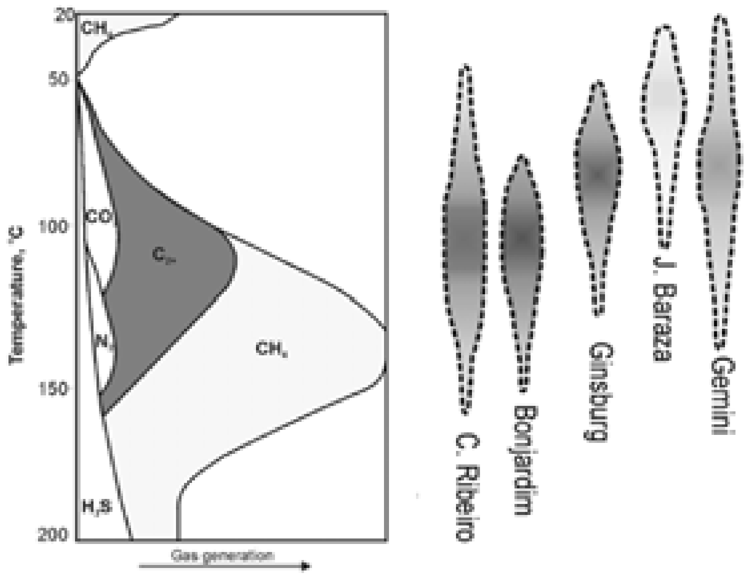


*Fig. 3. Hydrocarbon gas generated scheme from the different mud volcanoes from the Gulf of Cadiz area. Dotted lines show "oil window" zone*

in the upper and central parts of the "oil window" (Fig. 3). $\delta^{13}C$ of methane samples from the sedimentary sequence changes from –50.2 to –64.3‰ PDB. Initial carbon isotopic composition of methane, which was not affected by subsurface biogenic degradation, can be assumed as from -46 to -50 ppm PDB conformably.

Mud volcanoes from the central and eastern parts of the basin are characterized by more diverse molecular and isotopic composition of the gas. Most probably such gas was originated from the immature organic matter, above the "oil window" zone.

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## SEDIMENTOLOGICAL STUDY OF THE MOROCCAN FIELD MUD VOLCANIC DEPOSITS, GULF OF GADIZ

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Sedimentological study based on X-Ray diffraction and petrographic analysis was performed on samples collected at the Moroccan margin in the Gulf of Cadiz during TTR9 (1999) and TTR10 (2000) cruises on board of the R/V *Professor Logachev*, in order to precise mineralogical composition of mud volcanic deposit and to identify the parent rocks.

Study under polarising microscope of thin sections of some of the mud breccia clasts collected by a TV-grab sampler from the crater of the Yuma mud volcano (AT209Gr, TTR9) lead to the recognition of four main groups of rocks:

- volcanic rocks: porphyritic basalt;
- volcanoclastic rocks;
- limestones: biomicrite, biomicrite with stromatolites, sparititic limestones, bioclastic limestone;
- mixed siliciclastic/carbonate rocks: silty biomicrite, sandy biomicrite, sandy allochemic limestone, muddy bioclastic limestones.

These petrofacies are possibly not representative of all the clasts of the Yuma mud volcano because only a part of the clasts collected was studied in Morocco. However some conclusions may be done:

- the mud breccia clasts are comparable to those collected in Al Idrissi mud volcano (Merrouane *et al.*, 2003 ; Merrouane, 2004);
- the siliciclastic and carbonate components of limestones and mixed siliciclastic/carbonate rocks indicate that the rock clasts reflect desintegration from lithological units that may be compared to those outcroping onshore in the Cretaceous to Oligo-Miocene successions of the western Rif belt and the Gharb basin;
- the volcanic rocks may be related to the Triassic basalt.

X-Ray mineralogical study of the sediments collected by gravity cores during TT10 from the Jesus Baraz mud volcano (AT230, AT231), a carbonate mound (AT232, AT233), a diapir (AT234), the Rabat (AT235) and Ginsburg (AT236, AT237, AT238) mud volcanoes, revealed the following:

- the mineralogical composition mainly consists of calcite, quartz, muscovite, dolomite, smectite, chlorite and kaolinite with admixture of halite, hematite, albite or microcline in some cases;
- the Ginsburg deposits and mud breccia of the other core shows a significant increase in the smectite content;
- kaolinite is more abundant in marly sediments when no feldspar exists and in mud breccia even when feldspar does exist.

Such mineralogical composition is known in the Eocene and Oligo-Miocene successions of the Rif belt. However the variation noted in the amount of kaolinite and smectite contents reflects the existence of authigenic smectite and kaolinite related to the alteration processes during the mud volcano activity.

Thus it remains to study more samples from mud volcanoes and to develop a more detailed analysis in order to: 1) complete this preliminary work, 2) identify all the lithological units reworked by the mud volcano and 3) better understand the structural organisation of the Moroccan margin subsurface and the alteration processes associated with mud volcano activity.

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## GAS HYDRATE STABILITY AND SEABED FEATURES IN DEEP-WATER ENVIRONMENTS WEST OF IRELAND

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The formation and dissociation of gas hydrates in response to changes in sea level and/or water temperatures has global implications for continental slope stability and for climate change. Here we present a first assessment of the potential occurrence of gas hydrates in relation to shallow sedimentary features on the deep-water continental margin west of Ireland, using data (multibeam bathymetry and bottom water temperatures) obtained during the Irish National Seabed Survey (INSS) across depths of 200-4500 m (Zone 3, 450,000 $km^2$). Theoretical modelling of hydrate stability, both for present-day conditions and for conditions approximating a glacial-stage, was accompanied by reconnaissance-level observations of the seabed using 3D-visualisation techniques.

The hydrate stability zone was modeled using gridded bathymetry and bottom water temperatures acquired during the INSS, plus regional geothermal gradients from an IODP dataset. For present-day conditions, the stability zone is present below depths of 500 ± 50 m, in thicknesses of up to 587 m below seabed. For glacial-stage conditions (sea level -100 m, bottom water temperatures – 2°C), the stability zone is present below depths of up to 400 m and is up to 250 m thicker.

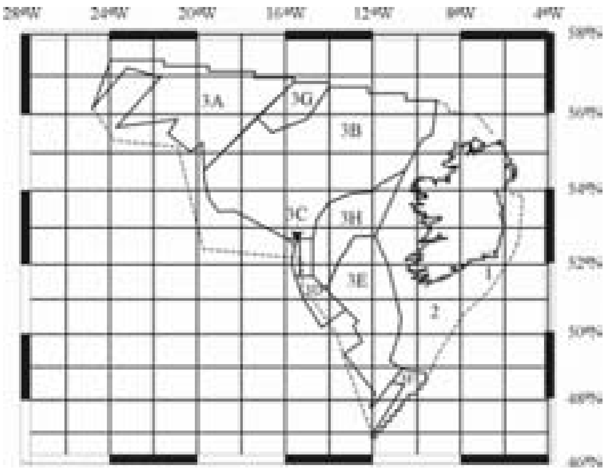


*Fig. 1. Location of INSS Zone 3*

The increase in thickness reflects greater sensitivity of hydrate stability to small changes in temperature (colder bottom waters) than to pressure (shallower water depths). A net release of hydrate is implied for the transition from glacial to interglacial conditions, with maximum impact within the 'critical wedge', i.e. along the upper limit of the stability zone in slope depths of 400-1000 m.

The seabed across INSS Zone was 'explored' within gridded subsets of the raw multibeam data, affording resolution up to tens of metres; selected INSS 3.5 kHz echosounder profiles were also examined. Four categories of seabed feature were recognised that may be indicative, directly or indirectly, of gas/fluid escape. *Pockmarks* >100 m in diameter are recognised at several locations in depths of 300-900 m. *Mounds* (up to 300 m high and several kilometres across) occur across depths of 300-3000 m and include known carbonate mud-mounds as well as volcanic cones. *Scarps* marking the headwalls of slides are common on the steep (>3°) slopes flanking the Rockall Trough and Porcupine Seabight, in depths of 500-1500 m. *Canyons* are mainly restricted to the eastern slopes of the Rockall Trough and Porcupine Seabight, although some broad channels occur west of the Rockall Bank. The INSS database offers scope for further investigations of the possible presence and nature of fluid escape structures and their relation to gas hydrates, for which more detailed seismic and sampling will be required within several areas of interest. *Acknowledgement*: This project was funded by the Geological Survey of Ireland, who also provided access to the INSS data, we thank the staff of the Seabed Survey and Marine sections for their help at various stages, especially Michael Geoghegan, Eibhlin Doyle, Xavier Monteys and Archie Donovan.

## THE FAUNAL ASSEMBLAGE OF THE MEKNÈS MUD VOLCANO (NORTH AFRICAN MARGIN OFF MOROCCO). PRELIMINARY RESULTS OF THE TTR14 CRUISE IN THE GULF OF CADIZ

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The North African margin of the Gulf of Cadiz was explored during the TTR14 cruise (July-August 2004) and several known mud volcanoes and new structures were sampled. The Meknès mud volcano centred at 34º 59.1'N 7º 4.4'W at a depth of 700m (crater), was probably the most interesting new structure found. The sampling included a deep-towed TV line (from the southern flank, crossing the crater to the northwestern flank), four gravity cores (two in the flanks and two inside the crater) and one TV-assisted grab (also inside the crater).

The data from the video observations were processed using multivariate analysis and the interpretation of the results allowed discriminating three different sections where changes in the geological setting were clearly accompanied by changes in the benthic community. The first section was characterized by numerous patches of dead coral and coral rubble covered by abundant sessile fauna including large sponges and soft corals; different species of mobile fauna (crustaceans, echinoderms and fish) were recorded; the sediment was highly bioturbated by different kinds of burrows and tracks and. The second section, spanning the crater, showed a heavily disturbed greenish mud breccia with scattered clasts as well as a striking large number of empty shells of the gastropod *Neptunea contraria* and a very low density of living megafauna (mostly fish swimming or standing near the bottom). Finally in the third section, the benthic assemblage showed an intermediate abundance mostly of sessile fauna covering the few patches of dead coral and many carbonate crusts and clasts.

The core samples were taken for sediment analysis but nevertheless permitted to record the presence of Siboglinidae pogonophorans in the crater sampling stations. On the other hand, the grab sample provided abundant biological material showing that despite the apparent desolation of the crater the sediments are inhabited by a wealthy assemblage of small sized animals that are not visible in the video images. Over 40 different families of invertebrates were retrieved from a subsample (ca. 20 l) of the sediments collected by the grab. Most of the species (65%) are crustaceans, mostly amphipods and isopods, followed by polychaetes (17%). The other groups (cnidarians, molluscs, echinoderms, etc) yielded fewer species. Chemosynthetic fauna was represented by Solemyid bivalves (cf. *Acharax* sp.) and abundant Siboglinid pogonophoran worms (*Siboglinum* sp.). Among the crustaceans the most abundant were phoxocephalid and caprellid amphipods, cirripeds (*Verruca* sp.) and the small crab *Cymonomus granulatus*.

## COMMON CHEMOSYNTHETIC SPECIES IN THE GULF OF CADIZ: UPDATED SPATIAL DISTRIBUTION

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Communities of benthic animals associated with cold seeps have been discovered recently at several locations on active and passive continental margins of the Pacific and Atlantic Ocean (reviewed by Olu-Le Roy *et al.*, 2004). Cold seep communities are sustained by massive methane-rich fluid expulsion resulting from hydrocarbon or hydrate dissociation, generally without sulfide, that can nevertheless be produced in the sediment by consortia of methanotrophic archaea and sulfate reducing bacteria. This environment is colonized by macroinvertebrates such as pogonophoran worms, sponges and bivalves hosting endosymbiotic chemoautotrophic bacteria that use enzymatic oxidation of reduced compounds as their basic energy source (Sibuet and Olu, 1998).

In the Gulf of Cadiz the most common chemosynthetic species are the pogonophoran worm *Siboglinum* sp. and the solemyid bivalve *Acharax* sp. Other pogonophoran worms (*Polybrachia* sp. and *Oligobrachia* sp.) and the bivalve *Lucinoma* sp. were also recovered occasionally. The distribution of the chemosynthetic species in the Gulf of Cadiz is given based on the data collected during the TTR cruises in the Gulf of Cadiz (TTR9, 10, 11, 12 and 14).

*Siboglinum* sp. is the most widespread species (Fig. 1) with the highest number of individuals collected at the Moroccan sector, especially in mud volcanoes showing evidence of relatively recent seeping activity (e.g. Captain Arutyunov, Yuma, Kidd). The other pogonophoran species only occurred at the deeper mud volcanoes in the Portuguese sector (e.g. Bonjardim).

Variations in the density of pogonophoran worms can be related to the intensity or chemistry and regularity or persistence of fluid emissions in seepage area (Sibuet and Olu, 1998).

Most *Acharax* sp. specimens were collected during the TTR14 cruise. These bivalves were especially abundant in the Kidd mud volcano but were also found in the Yuma, Meknès and Fiúza mud volcanoes (Fig. 2). The size-frequency distribution of the specimens collected in Kidd mud volcano shows the occurrence of distinct size classes, including recently settled individuals, and suggests the presence of a well-established and reproducing population. During previous cruises these bivalves were also found in Ginsburg and Jesus Baraza mud volcanoes and in Pen Duick Escarpment. Living lucinids are rarely collected despite the frequent occurrence of empty shells.

Studies on these species will be pursued namely by stable isotope analysis. Specimens of *Siboglinum* sp. and *Acharax* sp. were prepared for analyses of $\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$. This is a useful approach to unravel trophic interaction and study the methanotrophy or sulfide oxidation by symbionts in seep and vent *taxa* (Levin *et al.*, 2000).

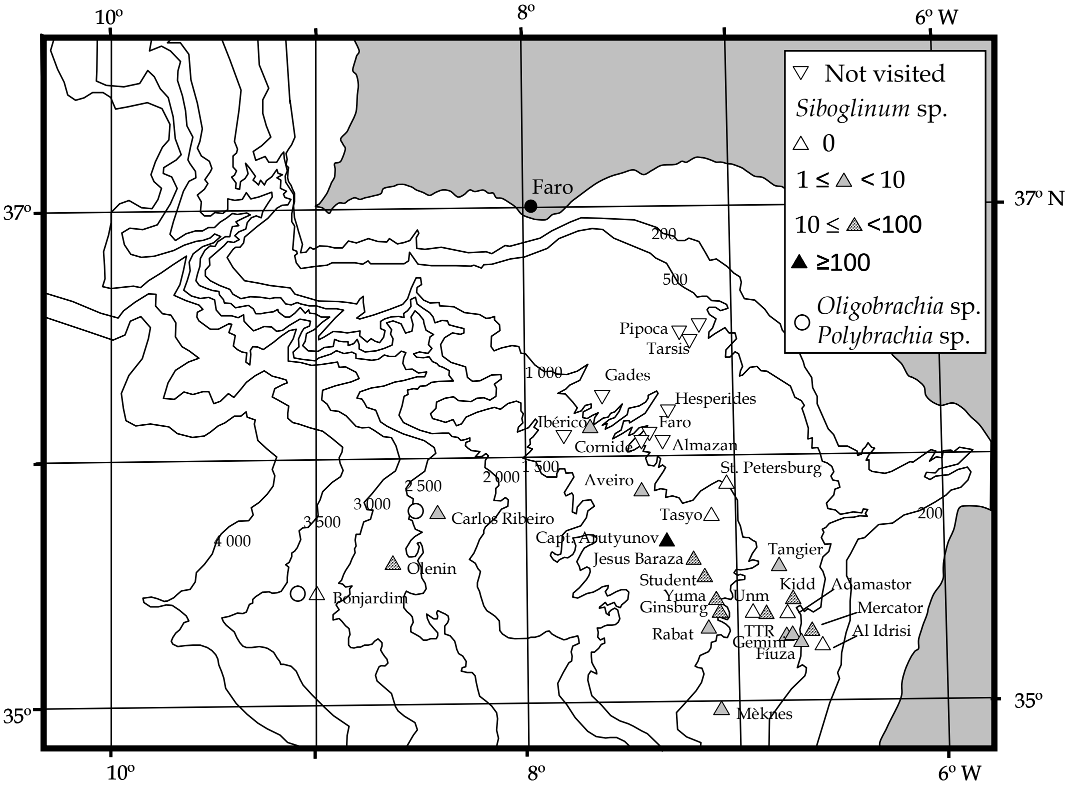


*Fig. 1. Pogonophora distribution in Gulf of Cadiz*

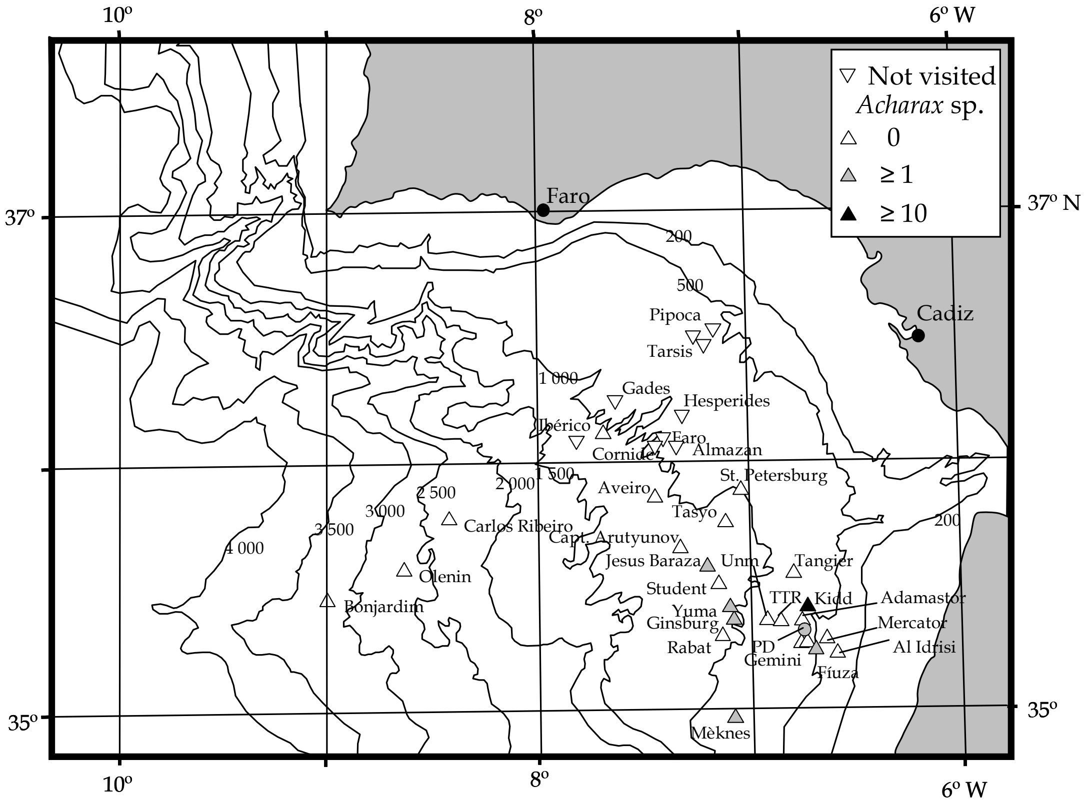


*Fig. 2. Acharax sp. distribution in Gulf of Cadiz*

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## PHYSICAL PROPERTIES OF "EXOTIC" SANDSTONES FROM MUD VOLCANIC DEPOSITS IN THE MOROCCAN MUD VOLCANIC PROVINCE (MOROCCAN CONTINENTAL MARGINE, THE GULF OF CADIZ)

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During the TTR12 cruise (2002) large amount of sandstones' fragments were observed on TV-lines AT34 and AT39 across the Al Idrissi and Mercator mud volcanoes. Three dredging stations were done. Collected sandstones (from 0.1x0.05x0.05 m to 0.3x0.2x0.1 m in size) were not typical for mud volcanic deposits, so were called "exotic". In the MSU laboratories dating and thin section description of the sandstones were performed. They were described as Late Miocene-Pleistocene coarse- to fine-grained sandstones and siltstones with admixture of foraminifera and biodetritus cemented by poikilitic calcite. Collected rocks were determined as similar to the Late Miocene-Pleistocene sandstones of the Rharb basin of Morocco (Akhmanov *et al.*, 2003) (Fig. 1).

During the TTR14 cruise fragments and slabs of similar medium- to fine-grained sandstones with foraminifera were observed and retrieved from the Kidd and Fiuza mud volcanoes. Collected rocks have size about 0.2x0.1x0.05 for fragments and 0.5x0.5x0.2 m for slabs. Dating and thin section description of the sandstones was performed. These sandstones are analogous with "exotic" sandstones from the Al Idrissi and Mercator mud volcanoes.

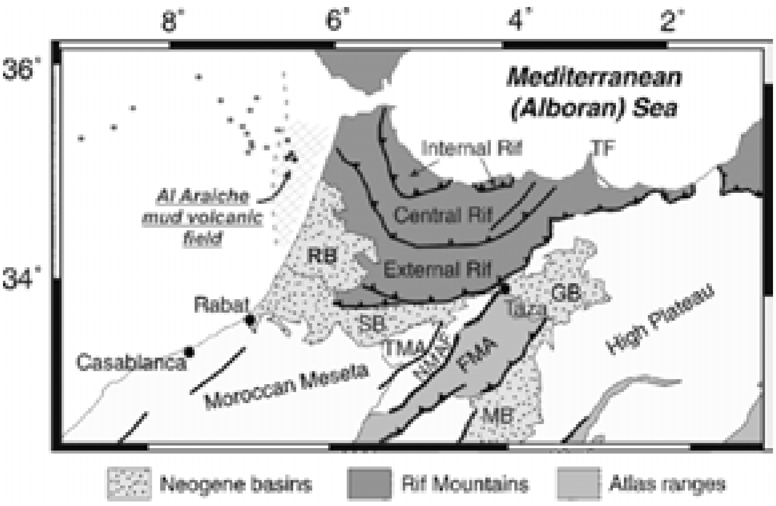


*Fig. 1. Offshore continuation of Rharb Basin according the results of the Al Araiche mud breccia study (after Akhmanov* et al.*, 2003). Map of northern Morocco is after Gomez et al., 2000. RB = Rharb basin, GB = Guercif basin, FMA = folded Middle Atlas, TMA = tabular Middle Atlas, NMAF = north Middle Atlas fault, SB = Saiss basin, MB = Missour basin, TF =Cape Trois Fourches*

Several sandstone samples from the Kidd (AT-528Gr), Fiuza (AT-566D), Al Idrissi (AT-412D) and Mercator (AT-409D) mud volcanoes were selected for laboratory studies of their physical properties by a set of methods:- granulometric composition
- total carbonate content
- porosity measurement
- density measurement
- determination of permeability.

According to the laboratory results sandstones from the Kidd and Fuisa mud volcanoes have the sorting coefficient from 1.5 to 1.8 (well-sorted) by the Trask scale. An average grading is 0.4 mm.

The sorting coefficient of sandstones from the Al Idrissi and Mercator mud volcanoes are changing in rage between 1.3-1.5 (well-sorted) by the Trask scale. An average grading is 0.41 mm. Carbonate content analysis shows that samples from the Kidd and Fuisa mud volcanoes contain about 45-48% of calcite, and some of them more then 50%, that could be explained by development of calcite veins. Rocks from the Al Idrissi and Mercator mud volcanoes content 20-25% of carbonates. Samples from stations AT-528Gr and AT-566D have bulk density about 2.45 g/cm$^3$; samples from AT-412D and AT-409D stations have density 2.48 g/cm$^3$. Such differences in densities can be explained by the density difference between calcite and quartz: 2.5 g/cm$^3$ and 2.65 g/cm$^3$ accordingly. Porosity of all samples is from 4.8 to 19.8%. An average value of permeability for these samples is about 3 mD. The permeability of these rocks is related to their fracturing. Not fractured plugs have the permeability less then 1 mD, while the fractured plugs have permeability up to 13 mD. In spite of the fact that the studied samples have some differences in their physical properties, we can conclude about their similar nature.

Late Miocene–Pleistocene sandstones were described as reservoirs for gas in the Rharb basin, Morocco (Pratsch, 1995). The studied rocks have low reservoir properties for hydrocarbons accumulation. Due to the low porosity and permeability these rocks can form good capping for hydrocarbon traps at the Moroccan continental margin in the Gulf of Cadiz.

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## SEA FLOOR EXPRESSION OF SEDIMENT EXTRUSION AND INTRUSION AT THE EL ARRAICHE MUD VOLCANO FIELD, GULF OF CADIZ

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The El Arraiche mud volcano field was discovered during the CADIPOR survey by the RV *Belgica* in May 2002 in the Moroccan Atlantic margin in the Gulf of Cadiz. It consists of 8 mud volcanoes of varying size and shape just below the shelf edge. The largest mud volcano in the field (Al Idrissi mud volcano) is 255 m high and 5.4 km wide, the smallest we observed is only 500 m wide and 25 m high. The morphology of the mud volcanoes consist of, from base to top: a moat around part of the base of the mud volcano cone, an irregular slope characterized by radial outward sediment flows, terraces and/or depositional sediment flow escarpments (lobe fronts), a crater depression or a flat top, and a central dome.

The 2002 surveys by the RV *Belgica* and the RV *Professor Logachev* yielded detailed swath bathymetry over the entire area, dense grids of high-resolution seismic data, very high-resolution deep-tow sub bottom profiles, side scan sonar mosaics over the major structures, selected video lines, TV-grabs, dredge samples and gravity cores.

The large amount of sea floor data and the clear shape of the larger mud volcanoes prompted us to focus on the morphology of the mud volcano cones. Although mud volcanoes are prominent features in the submarine sea-scape little attention has yet been given to their small-scale morphology. Mud volcanoes in their broadest sense refer to any extrusion of mobilized sediment. Mud volcanoes *sensu* *strictu* are cone-shaped with central vents. They are often considered as a sedimentary analog of stratovolcanoes, built by stacked sediment flows issued from a central crater or subsidiary vents at the flanks. The morphology of mud volcanoes *sensu stricto* is thus largely attributed to extrusion processes whereas the effect of intrusive processes remains unclear. High-resolution seismic profiles provide little information about the internal structure of a large mud cone, due to acoustic blanking. We can in this case only deduce formation processes from the information available at the surface.

On the basis of the observations we conclude that these large cone-shaped mud volcanoes result from a combination of intrusive and extrusive processes. Sediment flow deposits on the slopes range between two end-members. Flows with low yield strength (type I) extend to the base of the slope and create a steepening convex slope profile with a low overall slope angle (5° - 6°). Flows with a high yield strength (type II) freeze on the steep slope and create an irregular slope profile with almost constant slope angle (8° - 10°). Within the crater, several vents issue fluidised sand and small debris flows that consist of mud breccia with cm to m-sized clasts in a mud matrix. The extrusive sediment flows shape the surface of the mud volcano but in this study we also observe morphological elements that do not appear to correspond solely to extruded sediment deposits and may be partly result from sediment intrusion processes. The central dome and the concentric pattern of continuous terraces and steps on the slope are interpreted to result from different phases of uplift by sediment intrusion, each possibly followed by collapse due to degassing or dewatering. Intrusive processes may involve shallow-seated diapirism caused by density re-equilibration within the thick pile of remoulded mud volcano sediments or uplift and volumetric expansion by injection of sedimentary dykes.

## ACTIVE BRINE SEEPAGE THROUGH THE SEABED OF THE NILE DEEP SEA FAN (EASTERN MEDITERRANEAN)

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We primarily report observations of active brine seepage in the western part of the Nile deep sea fan (Eastern Mediterranean). Observations were mainly made during the NAUTINIL expedition of the French research vessel *L'Atalante* with submersible *Nautile* in September-October 2003. The NAUTINIL observations were complemented by sediment and fluid sampling, heat flow measurements and high resolution sediment profiling during the MIMES expedition of the Dutch research vessel *Pelagia* in June-July 2004. Several sites of the Nile delta and deep sea fan, showing three different types of potential fluid emission, were identified initially from their acoustic signature in EM300 multibeam data from cartographic surveys made during the FANIL expedition in 2000 (Loncke et al, 2004). One of the sites, a zone in the western sector of the Nile deep sea fan known as the Menes caldera, at a depth of 3000 meters, discharges brines at a temperature of around 50°C. Measured salinities of the brines are up to 311 °/°°. These brines form pools and lakes on the seafloor

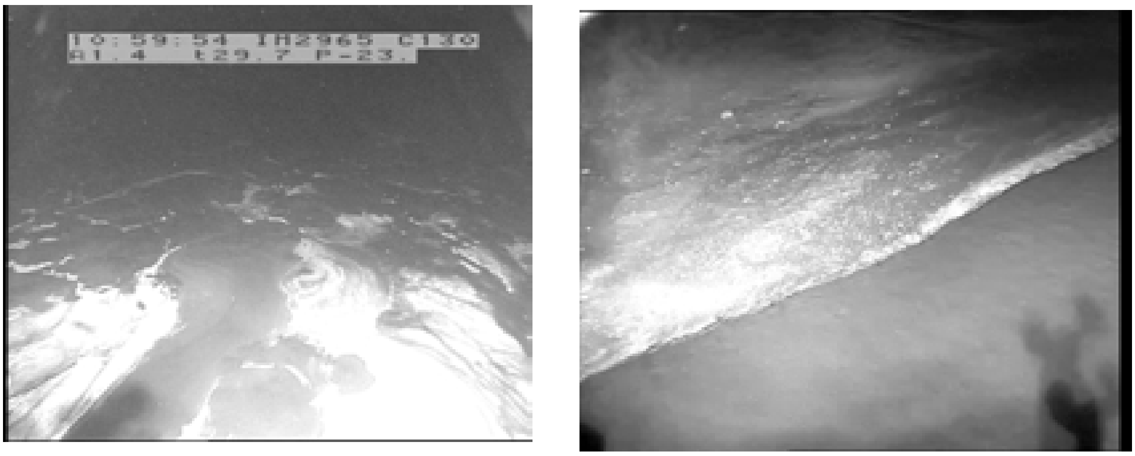

*Fig. 1. Brine flows carrying white microbial filaments at the edge of Chefren mud volcano. Photographs taken from submersible* Naurile *during the Nautinil 2003 expedition.*

with dimensions reaching several dozens of meters on the mounts 'Cheops' and 'Chefren' situated in the interior of the Menes caldera. The thickness of the brine accumulation filling up the crater on top of 'Chefren' exceeds 200 m. Brine overflows were observed at several locations at the edge of the crater. These overflows appear to trigger episodic sediment failure and turbiditic currents. Intense microbial activity is observed around the brine lakes and at secondary brine vents on the flank of the mount. Corresponding to a second type of fluid seepage, the mud volcanoes named 'Isis', 'Osiris', and 'Amon', in the eastern sector of the Nile fan at depths around 1000 meters, are characterized by elevated temperatures in the upper muddy sediments (more than 40°C at 9 meters below the seafloor in the centers of Isis and Amon) and intense degassing. The third type of fluid emissions is from a field of 'pockmarks' in the central part of the Nile fan at depths around 2000 meters. Submersible observations made in several of the pockmarks found thick carbonate crusts and chemosynthetic seep fauna (vestimentiferan worms and bivalves) associated with the methane seeps. Side scan sonar records during MIMES demonstrated active degassing.

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## CONTRIBUTION OF HIGH-INTENSITY GAS SEEPS IN THE BLACK SEA TO METHANE EMISSION TO THE ATMOSPHERE (CRIMEA)

P. Van Rensbergen[1] & the CRIMEA Project Members

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The CRIMEA project focuses on the transfer of methane from the seafloor through the water column and into the atmosphere from submarine high-intensity methane seeps and gas outbursts in the Black Sea. Methane outbursts at the sea floor occur in various locations in the Black Sea and generate large (sometimes up to 1000 m high!) ascending methane bubble plumes in the seawater. In some cases these methane plumes reach the sea surface and emit methane directly into the atmosphere. The project focuses on two study areas, each characterised by different methane venting processes, and by a different geological and oceanographic setting. Study Area I occurs at the shelf edge in the NW Ukrainian part of the Black Sea, at water depths of 100-250 m, mostly in the upper oxic water layer. Many active high-intensity seeps are documented in this area. This shallow site occurs outside the stability field of gas hydrates; the subsurface methane migration is directly controlled by the underlying margin geology, unaffected by hydrate-forming processes. Study Area II occurs in the abyssal Black Sea, in the lower anoxic water layer, at water depths of about 2100 m. In this area hydrocarbon gas emission is related to active mud volcanism and hydrate formation and dissociation processes in the subsurface. The project applies an integrated, multidisciplinary approach, addressing: 1. the origin of the methane seeps and outbursts, especially the role of hydrate formation and dissociation in the subsurface; 2. the methane flux from the seafloor, in the water column, at the anoxic-oxic interface and at the sea surface to the atmosphere; 3. the study of the physical, chemical and microbiological processes related to the methane release at the sea floor and its ascent through the water column, in order to (i) quantify the methane losses and transformations, (ii) document associated physical and chemical changes in the water mass, (iii) investigate the role of methanotrophic bacteria in the water column, and (iv) quantify the net methane flux from the sea floor to the atmosphere; 4. the significance of the methane outbursts as an mediator of regional atmospheric change.

To measure and model all involved processes the CRIMEA project makes use of state-of-the-art technology from different disciplines and for various applications. The experimental work will be completed by modelling the physical and chemical processes in the water column connected to methane ascent in plumes, and by modelling the atmospheric effects of methane release related to these outbursts.

The CRIMEA project is funded by the EC in the framework of FP5 - environment and sustainable development program, topic: sudden climate changes (Contract No. EVK2-2001-00322).

# The Alboran Sea tectonics and geophysics

## PRELIMINARY RESULTS OF TTR14 LEG 2 ON THE SE IBERIAN MARGIN (PALOMARES AND CARTAGENA MARGINS)

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The UNESCO-IOC Training Through Research Program conducted a survey to investigate two segments of the SE Iberian Margin- the Palomares and Cartagena margins- during TTR14 operations onboard the R/V *Professor Logachev* (Leg 2, August, 2004). The survey attained the Palomares and Cartagena margins, which are thought as brusque crustal boundaries tailored by major faults-zones that separate the thinned continental crust of the Alboran Basin and eastern Betic Cordillera, and the oceanic crust of the Balearic-Algerian basin.

TTR14 Leg 2 (SEIMAR Cruise) aimed to better know the shallow crustal structure of these margin segments to determine constraints from tectonic and sedimentary processes in the SE Iberian Margin development during recent times (post-Messinian). Furthermore, the survey encompasses the E-W transition between the East Alboran and the western Balearic-Algerian basins, just at the southern prolongation of the Palomares margin. Data acquisition consists of high-resolution seismic reflection profiling (3000 l air-gun source and 250 m long streamer, recorded till 2-3 s.t.w.t. beneath sea floor) and side-scan sonographs (long range OKEAN, and ultra high resolution MAK-1 deep towed side scan sonar) (Fig. 1).

SSW trending continental slope of the Palomares margin, drive out by two major submarine canyons- the Aguas-Almazora and the Gata canyons-, which give way down slope to meandering channels and turbidite fans. Significant portions of both canyons were imaged by high-resolution MAK-1 sonographs. Gravity flows and turbidite pathways appear originally controlled by submarine relief from residual volcanic-seamounts in the margin, and Quaternary to present-day active faults.

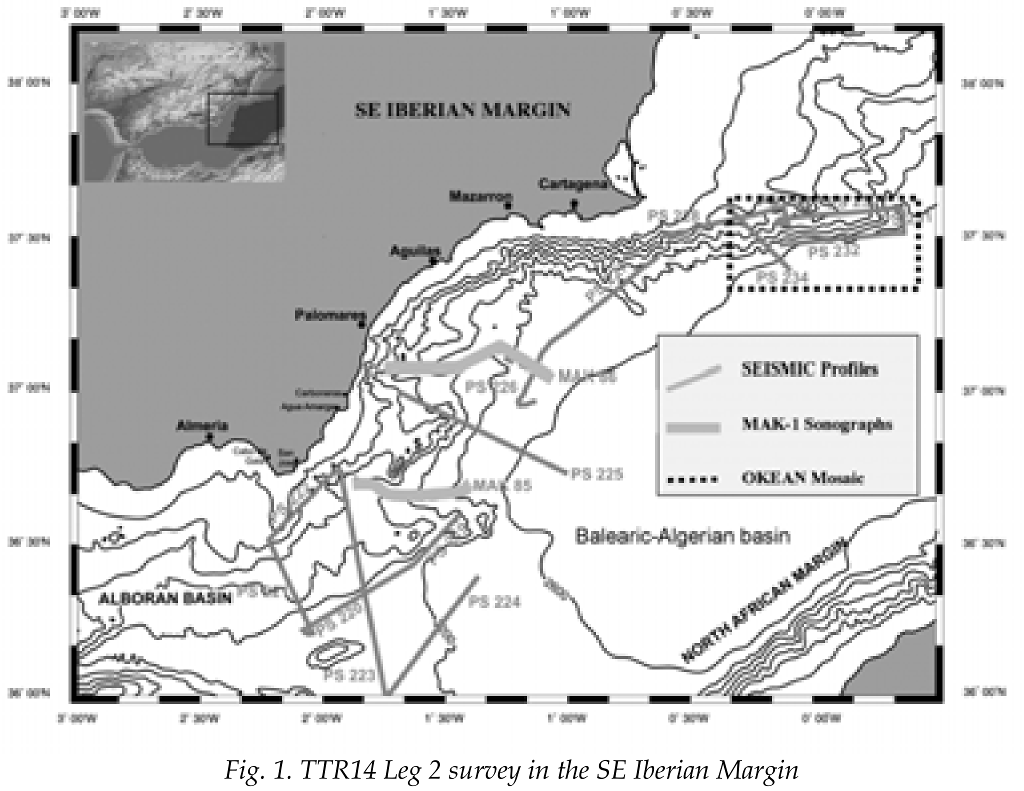


*Fig. 1. TTR14 Leg 2 survey in the SE Iberian Margin*

Contour currents, over-imposed to turbidite flows, may also have influenced sediment dispersal along the Palomares margin. The Cartagena Margin, to the contrary, appears depleted of well-developed turbidite systems shaping the slope, but denotes steep fault-plains conditioning slope inclines. The steep slope of the Cartagena Margin corresponds to the Mazarron Escarpment (trending E-W), which mainly represents a sediment-bypassing area. The Mazarron Escarpment shows strong erosion features (gullies and incised canyons), and denotes ubiquitous mass wasting structures and slide processes. OKEAN sonographs and seismic profiling (from TTR9 and TTR14 surveys) imaged a major slide deposit, the Cartagena Slide, occupying an area of several $km^2$ at the eastern Mazarron Escarpment.

The transition between the East Alboran and Balearic-Algerian basins corresponds to very thin continental crust (less than 13 km thick and typify by the occurrence of volcanic edifices) and concurrent lithosphere thinning in the Alboran Basin, given way to the east to the Balearic-Algerian oceanic crust. Shallow structures in this crustal transition denote that compressive tectonics processes dominate at post-Messinian times. High-resolution seismic profiles crossways ODP Sites 977 and 978, acquired by TTR14 Leg 2 on the drilled area, assent to stratigraphy correlations of borehole data and ODP sampled sequences (Messinian to Holocene sediments) throughout the entire seismic network in the region.

Main results from the TTR14 Leg 2 validate that both the Cartagena and Palomares margins are highly deformed segments of the SE Iberian Margin. Shallow structures mostly result from post Messinian contraction and recent, or even active, wrench tectonics that in turn drives sedimentary and mass wasting processes. Strike-slip faults, with local extensional and compressive slip components, influence the sea floor morphology. Seismic data also allow us setting up the limits of the Messinian-salt diapirs at the cutting edge of both margins, which may indicate the presence of underlying oceanic crust just bordering the margins, and occupying a wider area than suspected before the cruise.

Integrating TTR 14-Leg 2 results with available data set in the region (TTR9 and TTR12 results, among others) will illustrate the shallow and deep-seated processes shaping the SE Iberian Margin, and the Post-Miocene to present-day kinematics affecting the westernmost Mediterranean margins.

Besides the geophysical survey in Fig. 1, TTR14 Leg 2 also attained gravity-core sampling at a transect from the East Alboran to Balearic-Algerian basins. Ongoing geochemical and sedimentological work on Holocene pelagic sediments recovered in core samples will address climate reconstructions in the westernmost Mediterranean during the last 20.000 years.

[3] *TTR14 Leg 2 Scientific Party: F. Fernandez-Ibáñez; D. Gallego; M. Garcia-Garcia; F.J. Jiménez-Espejo; G. Marro; N. Mhammdi; F. Martinez-Ruiz; M.J. Roman-Alpiste M.J.; O. Romero; M. Sánchez-Gomez; H. Vanneste; and Moscow State University TTR14 participants.*

*Contribution from Projects REN2002-12095-E (ESF Euromargin WESTMED), REN 2001-3868-CO3-01 and REN2003-09130-CO2-01 (R & D National Plan of the Ministry of Education & Science and FEDER funding, Spain).*

## RECENT TECTONICS IN THE TRANSITION BETWEEN THE EAST ALBORAN AND BALEARIC-ALGERIAN BASINS

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Geophysical survey carried out during TTR14 (Leg 2) onboard R/V *Professor Logachev* on the SE Iberian Margin provided rewarding geophysical and geological data to characterize the shallow structure of the transition between the East Alboran and Balearic-Algerian basins. This zone corresponds to a transition between a thinned, continental crust (floored the East Alboran Basin; <1400 m water depth) and a probable oceanic crust at the Balearic-Algerian Basin (>2000 m water depth) (Comas *et al.*, 1997) and is marked by several volcanic highs (Maimonides, Al-Mansur, and Yusuf). The Plio-Quaternary sedimentary cover at the transition has a rather equal thickness (≈ 1 km) and were drilled by the Ocean Drilling Program at Sites 977 and 978. The deep Balearic-Algerian Basin and the individualized basins occurring between volcanic highs at the East Alboran Basin are bounded by steep strike-slip faults with local extensional and compressive slip components. The deep Balearic-Algerian Basin has pervasive salt-diapir structures that fold underlying sedimentary sequences.

Seismic profiles acquired during TTR14 Leg 2 in the transition between the Alboran and Balearic-Algerian basins, south of Cabo de Gata apron, show sharp thickness variations of the post-Messinian sediments, providing important constraint for depicting recent tectonic processes. Seismic profiles show narrow networks of closely spaced high-angle faults with both normal and reverse components, interpreted as fault zones.

Faults at this crustal transition affect the seafloor and extend with a steep dip from the acoustic basement crosscutting the entire Plio-Quaternary sequence. Fault zones are characterized by chaotic seismic facies comprising lens-shaped bodies with a continuous, parallel seismic fabric. This geometry, commonly observed in major fault zones (e.g. Rutter *et al.* 1986; Faulkner *et al.* 2003), lend to anostomosing pattern of high-strain domains accounted from master-fault displacements. In seismic profiles, high-strain domains appear with chaotic-seismic fabric that bound lenses of less-deformed sediments with layered seismic facies. Chaotic seismic-fabric strands can be interpreted as fault damage zones formed by pervasive fracturing processes resulting in breccia and gouge seams, associated to joints and shear fractures. Away from the fault zones, wall-rock sediments may show drag folds induced by faulting. These damage zones are thought brittle shear zones where rapid strain rates occur during seismic events.

From available seismic profiles data and seafloor images, is rather difficult to precise the sense of displacement associated to these fault zones; however, there are some observations that suggest they would have an important horizontal fault-displacement. Namely, the high-dip of the fault zones and their anastomosed internal structure, the probable change in orientation of the individual fault plains inside the fault zones, the changes of strike and sense of dip, and the observation of reverse and normal-sense of displacements in related faults. Collectively, these observations point out for a dominat strike-slip character of the fault zones, with minor dip-slip components. The thickness of most of the fault zones (in cases ≈30 km wide) suggests that they could accommodate large crustal displacements.

Brittle shear zones, affecting the entire Quaternary sediments and the sea-floor surface, may represent structures from present active tectonic. The seismicity in the area is characterized by a shallow, upper crust earthquake distribution, in agreement with the shallow depth of the brittle-ductile transition in the region (<15 km); thus suggesting the seismogenic character of some of these structures (see Fernandez-Ibañez, this volume). Earthquakes may have triggered the ubiquitous slumps and steep relief in the region.

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*Contribution from Projects REN2002-12095-E (ESF Euromargin WESTMED) and REN 2001-3868-CO3-01 (R & D National Plan of the Ministry of Education & Science and FEDER funding, Spain)*

# CRUSTAL SEISMICITY IN WESTERN MEDITERRANEAN MARGINS: THE BETIC-RIF-ALBORAN REGION

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The Alboran Sea (Westernmost Mediterranean) is located in the inner part of an arcuate Alpine orogenic belt comprised by the Betic and Rif, connected through the Gibraltar Arc. The boundary between the African and Eurasian plates in the Betic-Rif-Alboran region is a large zone of distributed deformation and strain partitioning with simultaneous extension and lithospheric attenuation. The distribution of local seismicity is characterized by scattered seismic swarms at shallow crustal depths, which spread out over a broad area of plate convergence deformation (Fig. 1). Focal depth distribution of earthquakes shows that most of seismicity is located in the crust (86%), and preferentially in the upper, brittle crust (90% of the crustal seismicity at ≤15 km).

A three dimensional rheological model has been developed in the region to characterize the brittle-ductile transition (BDT) in the upper crust; calculating a multiple set of regularly-spaced strength profiles based on a synthetic 3D lithospheric structure that gathers most of the available geological and geophysical data. Additionally, data from geodetic measurements of crustal deformations and earthquakes focal mechanisms have been used to validate the boundary conditions that govern the rheological model. Predicted rheological domains in the crust, either brittle or ductile, agree with focal depth distribution of crustal earthquakes in the westernmost Mediterranean (Fig. 1, next page); moreover, the scarce micro-seismicity located in the lithosphere mantle (<14%) is also in agreement with these results. Most of the seismicity tends to nucleate in the brittle domains, up to the BDT, resulting in a gap between uppermost crustal and lithosphere mantle intermediate seismicity. In spite of seismic swarms that seem to depict active faults, it is needed to apply relative location methods to constrain the prolongation in depth of active faults.

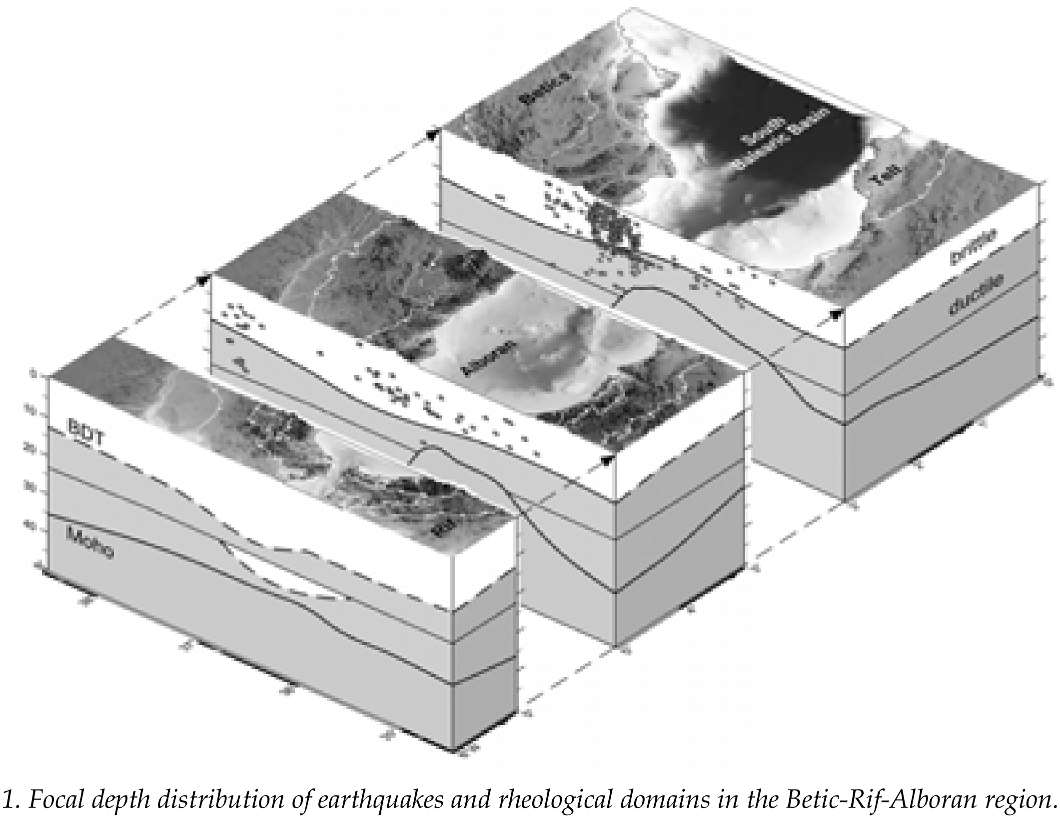


*Fig. 1. Focal depth distribution of earthquakes and rheological domains in the Betic-Rif-Alboran region. Please notice that most of the seismicity tends to nucleate in the brittle domains, above to the BDT (Brittle-ductile transition)*

This sort of comparison between the rheological modelling results and the distribution of seismicity in the Spanish and Moroccan margins of the Alboran Sea, and in the basin itself, could be useful to constrain the strain velocity field related to the Africa and Eurasia plate convergence in the Western Mediterranean. This type of study in the Betic-Rif-Alboran region deserves to integrate the geometry and timing of active faults, to unravel the link between these structures and active, mountain uplift and coeval subsidence processes.

*Contribution from Projects REN2002-12095-E (ESF Euromargin WESTMED) and REN 2001-3868-CO3-01 (R & D National Plan of the Ministry of Education & Science and FEDER funding, Spain)*

## MORPHOLOGY AND SHALLOW STRUCTURE OF TWO SE IBERIAN MARGIN SEGMENTS (PALOMARES AND CARTAGENA MARGINS, WESTERN MEDITERRANEAN)

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The Palomares and Cartagena margins are two near perpendicular segments of the SE Iberian Margin that flank to the W and NW the Balearic-Algerian basin. Shallow structures and morphological features of both margins were investigated during TTR9 Leg 3 (1999) and TTR14 Leg 2 (2004) surveys by acquiring side-scan sonar images (OKEAN and MAK1 systems), and high-resolution seismic lines.

The Palomares Margin trends NNE-SSW adjacent to the Eastern Betic chain and parallel to the Palomares Fault onshore (Fig. 1a). The physiography of this margin denotes a narrow platform and a large slope, with very complex relief due to the occurrence of gullies, submarine canyons (Gata, Alias, and Almanzora canyons) and channels, and volcanic seamounts (Maimonides and Abubacer highs). The shelf in the Palomares Margin has average amplitude of 5 km, which goes from 15km in the Cabo de Gata platform to less than 1km at the head of the mentioned canyons. To the east, in the transition toward the Cartagena Margin the shelf gets values of about 10km. Slope and base-of-slope domains have an average width of 55 km with inclination variations ranging from around 3º in the southern margin and up to 11º in the transition to the Cartagena Margin. The Maimonides and Abubacer highs are the expression of the Miocene volcanic activity, well known in the Rift and Betics Chains and in the Alboran Sea basin. The Maimonides High, E-W elongated, has an extension of roughly 650 $km^2$ and altitude of about 1200m being limited to the south by a N70E directed escarpment. To the north the high is staked out by the course of the Gata Canyon. The Abubacer High, SW-NE elongated, has an extension of almost 400$km^2$ and altitude of about 1200m. Dredging of volcanic rocks during TTR9 cruise demonstrate the volcanic nature of both seamounts. Sediments mostly bury volcanic rocks in Abubacer. The Gata and Alias-Almanzora turbidite systems developed from incised canyons and gullies in the inner shelf to channels (meandering or braided) in the base slope, getting way to turbidite lobes in the deep- basin (small deep sea fans). The Gata system, to the east of Cabo de Gata, has a longitude of 79 km and runs between the Maimonides and Abubacer highs in the lower slope. Two deeply incised canyons (Alias and Almanzora canyons), developed from the inner shelf to the upper slope, head the Alias-Almanzora system; the two canyons coalesce at 1600 m depth in the Alias-Almanzora Channel. Rivers feed both canyons from the Spain coast (Fig. 1). The Alias-Almanzora system is 49 km in length, and its down-slope channels have meandering features. Erosion by canyons affects mainly the Plio-Quaternary sequence, and locally attains Late Messinian sediments. Sedimentary source-to-sink processes dominated for shaping the Palomares Margin seafloor.

The Cartagena Margin runs with E-W direction from the Palomares Margin to the west, until 0º 30' meridian. Shelf width varies from 2.5 km near Cabo Tiñoso to 8-13 km to the east of the Balearic Promontory Platform (Fig. 1). The steep inclined Mazarron Escarpment, more than 100 km long and with average amplitude of 15 km, corresponds to the upper slope in the margin. Sea floor morphology in the Escarpment denotes strong erosion processes resulting in numerous gullies,

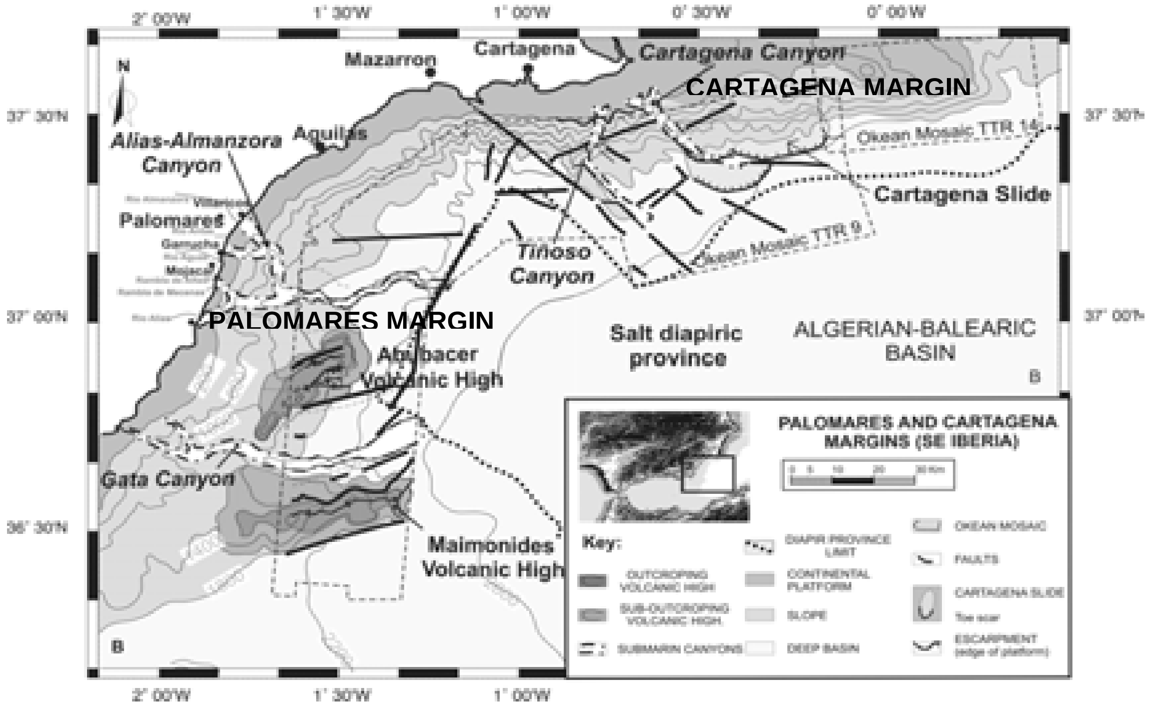


*Fig. 1. Morphodynamic and tectonic map of the Palomares and Cartagena margins*

discrete canyons and sediments bypassing areas lending to exposures of the acoustic basement at the seafloor. Mass wasting and slumping processes seem to be widespread in this margin, as demonstrated by the presence of slide deposits everywhere. The main expression of the strength of the slide processes is the Cartagena Slide, discovered in the side scan OKEAN sonographs. In the OKEAN images, the Cartagena Slide elongate parallel to the Mazarron Escarpment, and can be follow from the upper slope (500 m depth below sea level) to the deep basin (2600 m depth below sea level at the toe scar), reaching an extension of about 415 km² (Fig. 1). Sediments affected by the slide may be as older as late Pliocene to Pleistocene in age, according seismic images of the basal master-detachment. Detached sediment ridges and sediment streams can be seen in the Cartagena Slide.
Basin plain morphology at the foot of both margins is characterized by bulges, furrows and discrete troughs originated by Messinian-salt diapiric processes lending to pierced salt diapirs that occasionally reach the sea-floor, as shown in the seismic profiles.

Major shallow structures affecting the sea floor of the margins are faults, with normal or reverse slip, and strike-slip components commonly (Fig. 1). Seismic profiles indicate that shallow deformation mainly results from contraction and recent, or even active, wrench tectonics processes occurred during the Pliocene and Quaternary times. In the Palomares Margin, a major NNE-SSW fault paralleling the inland strike-slip Palomares Fault appears bounding the lower margin to the west. Interpretations from widespread complex faulting seen in the seismic profiles suggest the entire Palomares Margin may belong to the seawards prolongation of the Palomares Fault Zone. The E- W directed Mazarron Escarpment exposes the Cartagena Fault Zone, which in seismic profiles is imaged as staked high-angle faults with normal to reverse slip, shaping the margin slope. Transverse NW-SE normal to reverse faults, with obvious horizontal components, deform the lower-margin basin-plain boundary in the Cartagena Margin. Seismic profiles indicate that salt tectonics is the main processes deforming the Plio-Quaternary sequences in the deep basin off the margins.

Recent or sub-recent active tectonics from faulting processes, which in turn produced uplift of the Iberian continental shelf and tectonic subsidence in the Balearic-Algerian basin, may have resulted in earthquakes causing extensive mass wasting processes in the region, among other the triggering of the Caratagena Slide. The limits of the Messinian-salt diapir province (Fig. 1) appear just at the cutting edge of both SE Iberian margin segments, and seem to correspond to major crustal-fault boundaries.

*Contribution from Projects REN2002-12095-E (ESF Euromargin WESTMED) and REN 2001-3868-CO3-01 (R & D National Plan of the Ministry of Education & Science and FEDER funding, Spain)*

# INTERPRETATION OF THE TTR14 SEISMIC DATA IN THE EASTERN ALBORAN BASIN

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Eastern Alboran Basin was the area of investigations during Leg 2 of the TTR14 cruse. Six seismic lines were made (PS219MS-PS224MS), two of them crossed the ODP hole 978. The PS223MS and PS224MS lines crossed an interesting structure that contains very strong reflection factor (bright spots) (Fig. 1.). These features were assumed to prove gas presence in the Miocene structures composed of gravel to sandy gravel sediments.

We attempted to define an origin of the structures observed on the PS223MS and PS224MS profiles; tried to explain the nature of the bright spots; constructed a 3D model of the investigated area and improved the space imagination of some of the underwater features. Initially this Miocene structure was supposed to be a fluid trap. However, no boundaries belonging to this structure, which would change the signal polarity are recognized.

Different log measurements were performed at ODP 977 site, including acoustic logs. Unfortunately there are no log data at the ODP 978 site, that is why log data were prolonged from the ODP 977 well according to lithology and taking into account the same conditions of the sedimentary

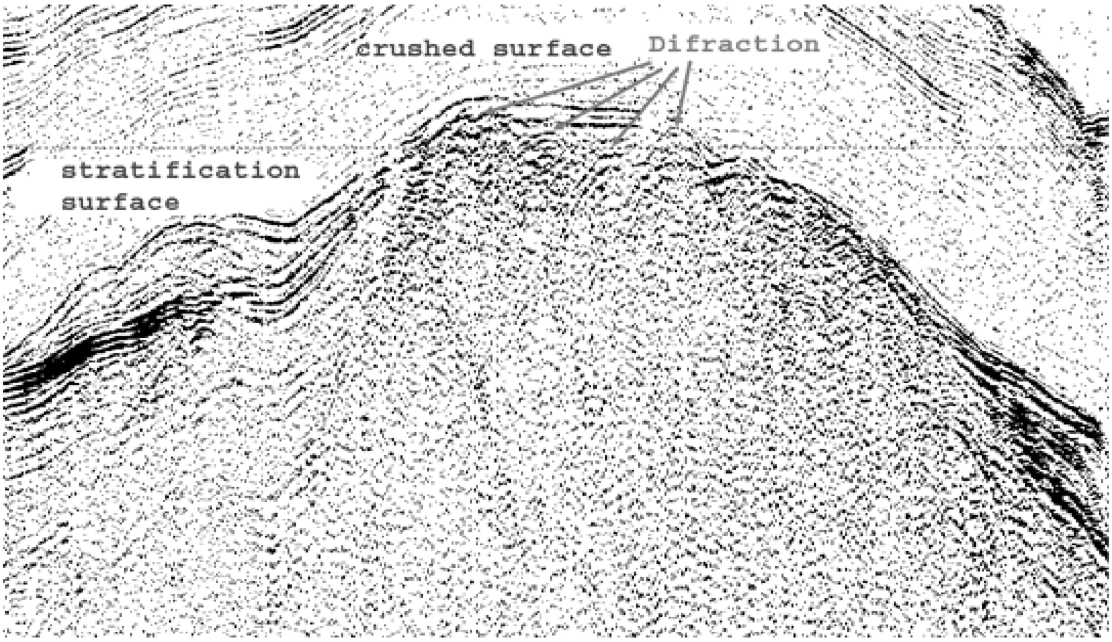

*Fig. 1. Bright spots on the seismic profile PS224MS*

rock forming. This allowed to construct velocity laws for both wells separately and then to recalculate them to the Time-Depth curves (velocity increases from approximately 1500 m/s at the top of the hole to 2300 m/s at the bottom). Then seismic and top formation data were represented in the time scale. Initially four main litho-stratigraphic units of Miocene to Pleistocene age recovered from ODP data (units 1-4 from the top to the bottom of the sedimentary sequence) were indicated on the seismic profiles and boundaries were traced in the investigated area. As a result 3D surfaces of the main geological units (Fig. 2.) and also thickness maps were constructed. Values of the acoustic wave interval velocity were given for each formation. Thus the investigated area was characterized by acoustic properties and time-cross-section was transformed into the depth-cross-section. Then the 3D surface of the Miocene was built, and a better space imagination allowed to assume the sliding origin of the studied body (a landslide). Hence we supposed that because of these slide movements very good M-reflector was crushed. As a proof of this one can observe a lot of diffraction features on the interested surface (Fig. 1.). Hence the bright spots features can be explained as the remains of the stratified medium with a good reflectivity property.

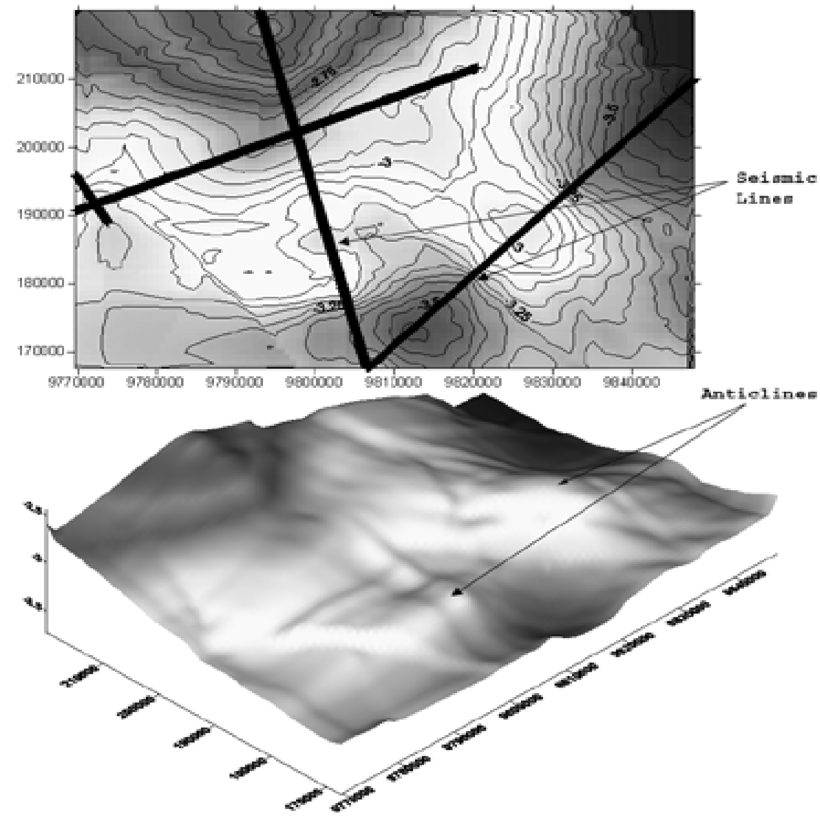


*Fig. 2. Contour map and 3D surface of the Miocene sandy gravel formation*

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## STRATIGRAPHIC AND TECTONIC EVOLUTION OF THE MOROCCAN MEDITERRANEAN MARGIN: LATE MIOCENE TO RECENT

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This study is based on the analysis of multi-channel seismic lines obtained by an oil company (BRPM) and core sampling on the Moroccan Mediterranean margin, taken during several cruises (Alb1983, Alb1986 & Strakov1994). The interpretation of the seismic profiles combined with the coring results shows the diachronism between the West Alboran Basin (WAB), the East Alboran Basin and the South Alboran Basin. In fact the most ancient sediments are lower Miocene in age, in the Western Alboran Basin, and upper Miocene in the South Alboran Basin. The Alboran Ridge constituting the most prominent NE-SW linear relief across the Alboran Sea interrupts a thick sedimentation (over 8 km) in basins, and emerges locally forming the small Alboran Island and banks like Xauen Bank formed by close folds trending ENE-WSW.

The distribution of the different sedimentary facieses is controlled by hydrodynamic (Atlantic-Mediterranean exchange) and glacio-eustatic factors, morphostructural inheritance and lithology of the outcropping geological formations. Textural and mineralogical studies coupling with planktonic foraminifera studies are used in order to distinguish between a marine and continental origin for sedimentary components and provide a type sequence of the upper Pleistocene-Holocene in this key area of the Mediterranean Sea. The sedimentological, mineralogical and micropalentological records show a good correlation with climato-eustatic changes.

# The Tyrrhenian Sea studies

## CONTRASTING SEDIMENTATION STYLES IN THE HISTORY OF BACKARC BASINS: A COMPARISON OF RECENT DEPOSITION IN THE VAVILOV AND MARSILI BASINS (RESULTS OF CRUISES TTR 4 AND 12)

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The Tyrrhenian Sea is centred by the the Vavilov and the Marsili deep sea basins that represent two separated structural elements. The Vavilov basin, the oldest backarc basin of the Tyrrhenian supra-subduction system, formed around 6 Ma ago behind a volcanic arc that is presently dismembered. Successively, the roll-back of the subducting slab caused the activation, around 2 Ma ago of the Marsili back-arc basin and of the presently active Aeolian volcanic arc to the southeast. The Vavilov and Marsili basins thus, represent successive stages in the evolution of back-arc basins, and are therefore characterized by different tectonic and volcanic regimes and by contrasting margin settings. In order to evaluate how the differences in these parameters, that are amongst the major factors that control sedimentary processes, influence the style of the sedimentary infill of the Marsili and Vavilov basins, the acquisition and interpretation of detailed multibem morphobathmetric data, of long range and deep towed sidescan sonar images, of high- and very-high resolution seismic lines and seafloor sampling has been undertaken. These data allow to reconstruct the depositional processes at the scale of the basin fill and to decipher the smaller scale depositional architectural elements that compose the recent depositional systems of the two basins.

The Vavilov basin is divided by the Vavilov Seamount and by the Gortani Ridge into a western and eastern sub-basin. It is bounded to the west by the D'Ancona Ridge and by the De Marchi seamount that represent structural barriers to the Sardinia Valley, the main submarine sedimentary pathway that collects siliciclastic sediments from the Sardinian passive margin. Thus, the main sedimentary entry points are located on the northern and eastern sides of the Vavilov basin where submarine canyons and slope failures that dissect the structurally controlled intraslope basin of the Campanian and Pontian margin, can directly feed sediments to the deep abyssal plain. In fact, in the eastern sub-basin, adjacent to base of the Campanian slope, the high resolution seismic data show that small depositional lobes are present at the mouth of the major canyons that at times continue as very small relief channels in the basin floor. The main salient features of the recent sedimentary infill of the Vavilov basin are, however, 4 basin-wide Acoustic Transparent Layers (ATLs). The two lowermost ATLs lie between 50 and 10 m below the seafloor; they have a cumulative thickness in the range of 45 m, with only slight thickness variations over the small-scale intrabasinal highs (tens of metres) and abrupt terminations against the hundreds of metres high basin-bounding structural blocks. The two uppermost ATLs are thinner, and are present over two distinct depocentres in the eastern and western sub-basin; they thin considerably over the small-scale intrabasinal highs and gradually pinch out towards the structural highs that bound the basin. Similar ATLs found in the deep portions of the Mediterranean Sea have been interpreted as megaturbidites triggered and emplaced by a variety of genetic and depositional processes. The presence of the basin-wide ATLs in the Vavilov area, highlight therefore that whatever the entry point, sedimentary processes consisting of flows that are capable of spreading and depositing over the whole basin are responsible for much of its recent sedimentary infill. However, the differences in the distribution, in the geometry of terminations and in the interaction with small scale intrabasinal highs, that distinguish the 4 ATLs point to variable characteristics of the flows responsible for the ATLs' deposition. The volume of the deepest ATL is around 150 $km^3$. ATLs with similar volumes have already been reported in the deep basins of the Eastern and the Western Mediterranean Sea in very different geodynamic settings. As a consequence, the finding in the Vavilov Basin further strengthens the evidence that ATLs are a common element of the recent stratigraphic successions of the deep-sea evidence that ATLs are a common element of the recent stratigraphic successions of the deep-sea basins of the Mediterranean region, regardless of the structural and geodynamic context of the different basins and of the genetic processes.

The Marsili backarc basin is flanked by the active Aeolian arc and by the uplifting Apenninic and Calabrian arc. The main morphologic feature of the Calabrian margin is the Stromboli Canyon that runs in the axial part of the Gioia Basin and cuts through the Aeolian Arc and reaches the Marsili Basin. It funnels a large input of siliciclastic and volcaniclastic material that enters the western portion of the Marsili basin through a single entry point. As a result, a deep-sea fan spans almost the whole western portion of the Marsili basin, with a length of 40 km and a width of 20 km. Much of the fan is characterized by a strongly reflective, rough seafloor highlighting that it is mainly floored by coarse-grained sandy or gravelly material and by highly disorganised depositional bodies with small lateral continuity as confirmed by the highly variable sedimentary facies observed in the cores. Different architectural elements characterize the deep-sea fan. To the south, a leveed channel is evident down to a depth of around 3200 m where it connects to a convex upward body interpreted as a depositional lobe. The lobe has a length of around 9 km and a width of around 4,5 km and is evident down to a depth of 3300 m. Its surface is characterized by a highly reflective seafloor resulting from the juxtaposition of single small upward convex acoustic transparent bodies with a width of 1 km and a thickness of around 2-3 m that can represent the single depositional units that make up the lobe and coincide with high backscattering lobate features in the sidescan sonar data. The central portion of the fan is occupied by a braided valley that connects upslope with the Stromboli canyon and reaches the deeper portion of the basin down to a depth of 3400 m. It has a maximum width of 4.5 km and is characterized by intrachannel longitudinal bars, by marginal terraces and by depositional levee on both sides. The braided valley feeds a depositional lobe that in the distal portion of the fan interacts with tectonic features at the base of the Marsili volcano. In the northern portion of the fan, another main channel is present; it has well developed levees with a well layered sequence, indicative of finer-grained material as compared with the other architectural elements that compose the Marsili fan. This channel ends at a depth of around 250 m where a channelised lobe made up of coarse grained material is present.

## DEEP-SEA TRANSPORT AND DEPOSITION OF THE MATERIAL DERIVED FROM THE 30/12/02 FLANK COLLAPSE OF STROMBOLI ISLAND

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One of the objectives of the TTR14 cruise was the study of the flanks and deeper portions of the Stromboli/Marsili sedimentary system in order to characterise the transport and depositional processes acting on the material derived from the flank collapse that affected Stromboli volcano in December 2002. The research represents an important component of the *tsunami* hazard assessment that is being undertaken by the Italian Civil Protection authority.

The investigated areas comprised the northern submerged flanks of Stromboli volcano, facing the major sector of flank instability of the Island, Sciara del Fuoco and the deep-water zones of the Stromboli canyon, running at the base of the volcano.

About 200 km of MAK deep-tow SSS were acquired in the area. On the basis of the MAK results, three TV camera tows were planned to investigate the deep canyon axis; the base of the Stromboli edifice and the median flank characteristics of the volcano. Following sampling targeted 14 sites utilising TV-controlled grab, box, gravity and Kasten corers and dredging.

An important unexpected result was the discovery, and sampling, of an extensive pillow lava field at the base of the volcano. The analyses of these samples offer important information on the petrography of the deeper magmas of Stromboli which are at the base of the largest explosive eruptions of Stromboli due to their high volatile content.

However, the most outstanding result of the investigations was the recognition on the MAK lines and subsequent TV run of part of the debris avalanche deposits derived from the collapse event. The deposits are positioned between 1550 m and 2000 m on the flank of the Stromboli edifice and about 5 to 7 km from the coastline.

The TV images showed that the deposit consists of a disorganised body made up of numerous decimetric blocks amidst larger blocks within a matrix of black volcaniclastic sand. The volcanisclatics are more abundant over the distal edges of the deposit, where they become organised into ripple-sized bedforms down slope. The limits of the debris avalanche are represented by sharp contacts with a hemipelagic sediment covered seafloor characterised by spoke burrows and sedimented, older blocky deposits. TV-controlled grab samples consist of numerous angular black lava blocks. The blocks display bimodal characteristics, being either massive or scoriaceous. The absence of rounded clasts suggests a deposit generated directly by proximal subaerial flows, without evidence of any permanence in the coastal zone. Macroscopically, the lavas are analogous to the eruptive products emitted by Stromboli shortly before and after the collapse event.

The definition of the processes of displacement of the collapsed material represents a fundamental component for understanding the dynamics of generation of the destructive tsunami that resulted from the landslide.

Comparison of multibeam bathymetric data-sets collected before and after the collapse reveals three principal areas of accumulation which reach maximum thicknesses of ~15 m. In addition, a zone of deficit, or removal of material stretches 3 km offshore the Sciara del Fuoco, probably due to erosion caused by the passage of the debris avalanche. The approximate volumes involved are 28±4 million m3 of deposits and 4±1 million $m^3$ of erosion, and compatible with the estimated volume of the material removed by the landslide.

## FLANK FAILURE AND VOLCANICLASTIC DEPOSITION AT STROMBOLI VOLCANO (AEOLIAN ISLANDS, ITALY)

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Stromboli, the northernmost volcanic island of the Aeolian archipelago in southern Italy (Fig. 1), is the sub-aerial part of a much larger volcanic edifice, which rises from a depth of approximately 2000 m to an elevation of 924 m above sea level (a.s.l.). In the last 13.000 years Stromboli volcano was affected by several flank collapses, whose traces are well-exposed in the horseshoe-shaped depression on the NW side of the island called Sciara del Fuoco (SdF). On December 30, 2002, a flank collapse of a 15-20 Million $m^3$ of SdF, provoked a tsunami causing significant damage to buildings on the eastern coast of the island up to 10m a.s.l.. The Sciara del Fuoco and its ubmarine prosecution acts as a manifold for mild explosive activity and episodic flank collapse events, creating a deep-sea fan covering almost the whole eastern portion of the Marsili basin. The marine environment, being the ultimate depositional site of landslide and related sediment-gravity flows, can be the best repository of information about collapse events. This implies that the deep-sea depositional systems surrounding Stromboli Island can constitute a good archive of information concerning the recent history of the volcano.

Deep-sea fan covers almost the whole eastern portion of the Marsili basin. The marine environment, being the ultimate depositional site of landslide and related sediment-gravity flows, can be the best repository of information about collapse events. This implies that the deep-sea depositional system surrounding Stromboli Island can constitute a good archive of information concerning the recent history of the volcano. A first data acquisition in the areas sur-rounding the island of Stromboli and the Marsili basin was undertaken during VST2002 (September 2002) cruise. Sampling sites were chosen and planned on the basis of a preparatory geophysical set of multibeam echo-sounder data, deep-towed sidescan sonar images and seismic lines available at the Institute for Marine Geology of Bologna and collected during VST2002 cruise. Deposits sampled by the one meter long core collected on the Strom-boli canyon right side it (VST02-16 unico) consisted in a sequence of a thin, fine grained mud layers alternating with thick layer of black volcaniclastic sand rich in glass fragments with a chemical composition compatible with Stromboli volcano. The sedimentary structures and the geochemical affinity between these samples and the products of the last 5 ky activity suggests they likely represent landslide related sediment-gravity flows.

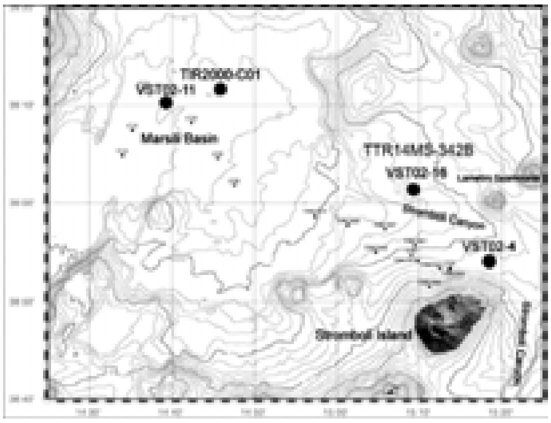


*Fig. 1. Location map of sampling sites in the area surrounding Stromboli*

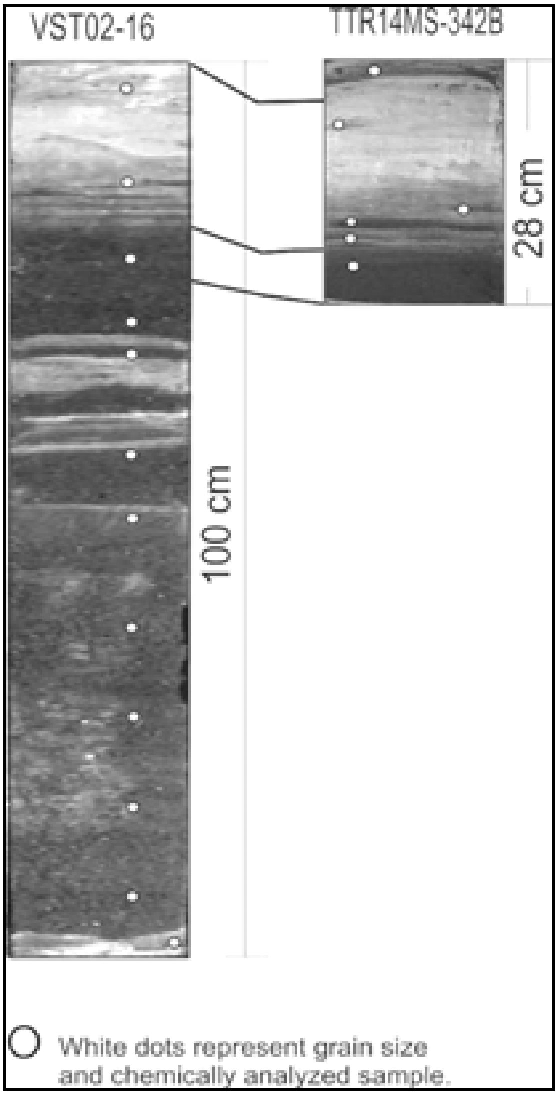


*Fig. 2. Comparison between VST02-16 (sampled in September 2002 before 30 December 2003 flak failure event) and TTR14MS-342B (sampled in September 2004 after the event); to notice difference in the 3-4 upper cm of TTR14MS-342B*

TTR14 MS cruise data acquisition was lead in the same location, two years after the December 30, 2002, flank collapse. One of the main goals of this cruise was to assess the occurrence of a new volcaniclastic layer and in this case too make a comparison of this with older deposits (Fig. 2). Sampling attempts by gravity and box coring were mainly unsuccessful probably as a result of the coarse-grained nature of deposits; only one sample recovered about 28 cm box coring. The sedimentary succession closely resembles VST2002 sample excepts in the topmost part where a new 3-4cm thick layer of mid-coarse, uncompacted, fresh volcani-clastic sand with thin lenses of muddy-sand sealed by a <1cm level of silty-mud occur.

Preliminary study (sedimentary structures, grain size, component and SEM-EDAX microanalysis, Fig. 3) conducted at the Dipartimento di Scienze della Terra of Pisa University, reveals great affinity with VST2002 samples and chemical composition of pyroclastic products of the present activity of Stromboli suggesting that this sample represents the distal sediment to of the December 30, 2002, flank collapse.

Further works will allow us to best characterize samples and compare them with our data in order to define a physical and sedimentological model for flank failure related volcaniclastic depo-sitional events.

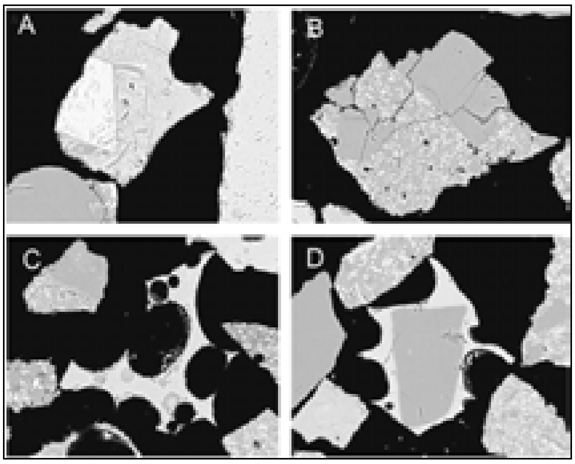


*Fig. 3. Ash, scoria and lava fragments analyzed with SEM-EDS Philips XL 30 EDAX DX 4; a,b, litics, very crystallized lavas fragments; c,b, no altered/crystallized glass shards with recent Stromboli chemical composition.*

# PLANKTONIC FORAMINIFERA ASSEMBLAGES: AN INDICATOR OF PLEISTOCENE – HOLOCENE PALEOENVIRONMENTAL CHANGES IN SOUTHEASTERN SARDINIA MARGIN AND IN STROMBOLI BASIN

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A quantitative analysis of planktonic foraminifera assemblages was carried out on the sediments of three cores TTR14 MS 317G (39º23'27N, 10º00'48E), TTR14 MS 324G (39º33'14N, 10º08'44E) and TTR-14 MS 331B (38º53'55N, 15º18'28E) located respectively at the southeastern margin of Sardinia and in Stromboli basin (Fig. 1). The cores were recovered during the Training-throughResearch TTR14 Cruise Leg 4 (2004) in the Tyrrhenian Sea on board the R/V *Professor Logachev*. This study of planktonic foraminifera allows to reconstruct the paleoenvironmental evolution during the Pleistocene-Holocene period in the areas.

On the southeastern Sardinia margin, the planktonic foraminifera are dominated by a subpolar assemblage represented generally by *Globigerina bulloïdes* (12 to 25%) and *Néo-globoquadrina pachyderma dextral* (5 to 20.8%). This assemblage shows high percentages of the cold-water species *Globorotalia scitula* (5%), reflecting an intensification of cold conditions which can be related to a glacial stage.

The winter Subtropical assemblage represented by *Globorotalia inflata* (7 to 15%) and *Globorotalia truncatulinoïdes* (0.1 to 7%) never exceeds 26% in this area, while the summer subtropical assemblage represented by *Globigerinoïdes ruber* and *Globorotalia rubescens* reaches 32%.

The tropical assemblage (*Globigerinoïdes trilobus* and *Globigerinoïdes sacculifer*) becomes more important from the base to the top of the cores TTR14-MS317G and TTR14-MS324G, testifying the exchange and mixture of cold and warm water. The existence of ostracoda (1.5%) and benthic foraminifera (2%) reflects favourable conditions: high oxygenated environment and important nutrient availability.

In the Stromboli basin, the occurrence of high percentage of winter subtropical assemblage (36%) and warm-water species (21 to 23%), reflects the Holocene assemblage. The increase in *Globorotalia inflata* (18%), the high percentage of the warm-water species *Globorotalia truncatulinoïdes* (14%) and the scarcity of the cold-water species *Globorotalia scitula* (1%), indicate interglacial climatic conditions. On the other hand, the abundance of *Globorotalia inflata* and *Globorotalia truncatulinoïdes* indicates a renewed, oxygenated and nutrient rich environment where there is a mixture of cold and warm water. The summer sub-tropical assemblage dominated by *Globigerinoïdes ruber* (8 to 9%) shows a low percentage (13%). The tropical assemblage (*Globigerinoïdes trilobus* and *Globigerinoïdes sacculifer*) reaches 6% along the core TTR14-MS331B. The scarcity of ostracoda (0.75%) and benthic foraminifera (1%) seems to be controlled by the lithological nature (sandy clay and sand).

This study demonstrates that the Paleo-climatic and paleoenvironmental changes during the Pleistocene – Holocene period related to quaternary glaciation control the planktonic foraminifera assemblages, on the Southeastern Sardinia margin and in the Stromboli basin.


*Fig. 1. Overview map with location of the studies cores*

# PETROGRAPHY AND CHEMICAL COMPOSITION OF MAFIC LAVAS FROM THE SUBMARINE PART OF STROMBOLI VOLCANO (AEOLIAN ARC)

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Stromboli is the northernmost volcanic island of the Aeolian archipelago, located in the southeastern part of the Tyrrhenian Sea. Volcanism on Stromboli is famous for its exceptional persistence in the level of activity. Current activity at Stromboli occupies three main craters located at 750 m a.s.l. within the Sciara del Fuoco, a horseshoe-shaped depression on the NW flank of the volcano (Rosi, 2000). The last voluminous eruption of Stromboli took place in 2003 but this volcano is still active at present.

The NW underwater slope of Stromboli was studied in 2004 during the TTR14 cruise. A set of instruments, including a deep-towed side scan sonar, digital underwater TV, TV-controlled grab and a dredge were used. On the basis of the received acoustic data three TV lines were performed. A lot of volcanic rocks including some pillow-lavas indicating an underwater eruption were observed on the record. Several sampling stations were done on the basis of the TV data. Many volcanic rock samples were retrieved on board, with some pillow-lavas among them.

A laboratory study of rocks included petrographic description, chemical analysis for major and trace elements (XRF method), and microprobe research. The study of thin sections showed all volcanic rocks are potassic trachybasalts with a porphyritic texture. Phenocrysts comprise Ti-augite, olivine, and plagioclase. Microlites of a potassic feldspar are present in the groundmass, together with common plagioclase, olivine, clinopyroxene, and Ti-magnetite.

On most diagrams the volcanics of Stromboli are rather different from other magmatic rocks of the Aeolian arc (Hornig-Kjarsgaard *et al.*, 1993; Rottura *et al.*, 1991), mainly due to higher alkali content, and may be subdivided into at least two series with different alkalinity. It could be related to a contribution from a deeper and enriched magma source (or sources) probably due to somewhat thicker lithosphere under the northern part of the archipelago. Studied samples have lower $SiO_2$ and higher MgO contents than most of Stromboli volcanics. It can be explained by a more primitive nature of the first one.

Composition of phenocrysts and the groundmass were studied by microprobe at the Petrology department (Geological faculty, MSU) on CAMSCAN electron microscope with Link AN 10000 analyzer. Most of the phenocrysts have normal oscillatory zoning, but some pyroxenes have inverse zoning. Variation diagrams for phenocrysts, groundmass, and bulk rock compositions infer the minor role of olivine fractionation during magma evolution. Primary melt inclusions in phenocrysts will be the subject of further research.

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# BACKSCATTER CAPABILITY OF MAK-1M SIDE-SCAN SONAR IN THE EASTERN SARDINIA MARGIN (TTR14 CRUISE LEG 4)

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The Sarrabus Canyon on the Eastern continental margin of Sardinia (Western Tyrrhenian Sea) was an object of investigations during the TTR14 cruise Leg 4. Eight 30 kHz MAK-1M profiles were performed in the area and a mosaic compiled. One 100 kHz MAK-1M line was done across this mosaic. Sonograms obtained in the study area showed queer change of backscattering: from very strong near the track to low in a distance aside the track (Fig. 1). According to the bottom sampling results in the places with very strong backscattering on the profiles, the gravel layer was discovered at depth of 50-90 cm below the seafloor, covered by water-saturated mud.

The gravel layer is characterized by very strong backscattering. Mud has low backscattering properties. Thus, a presence of mud layer overlaying gravel body can explain the artefact that backscattering characteristics relate to a distance from the track.

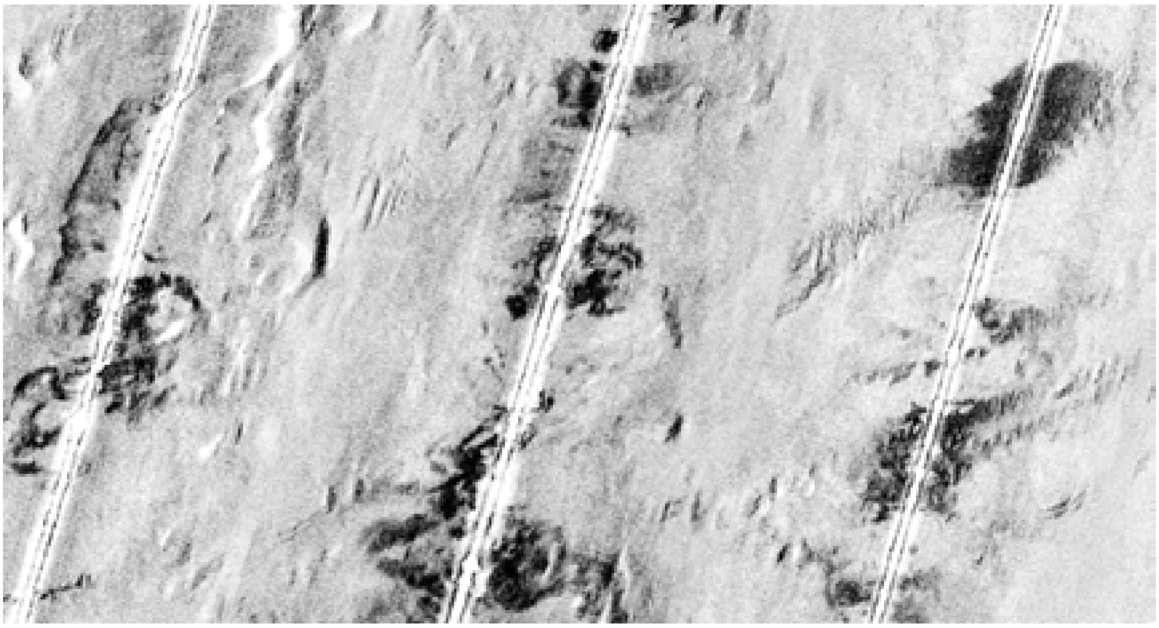

*Fig. 1. Fragment of the MAK-mosaic.*

First supposition concerns an appearance of a head wave, which spreads on the bottom surface starting with definite angle approach (or hade) (Fig. 2). Thus, the wave does not reach the gravel surface. Hades were calculated for MAK lines of different frequencies. For example, for line MAK125MS (30 kHz frequency) the hade is 60°, angle approach is 30°, distance from the track is 176 m. For line MAK123MS (100 kHz frequency) the hade is 45°, angle approach is 45°, distance from the track is 48.5 m.

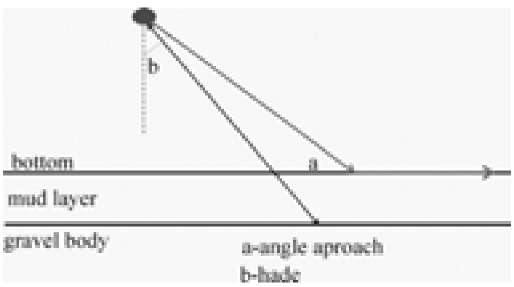


*Fig. 2. Appearance of the head wave.*

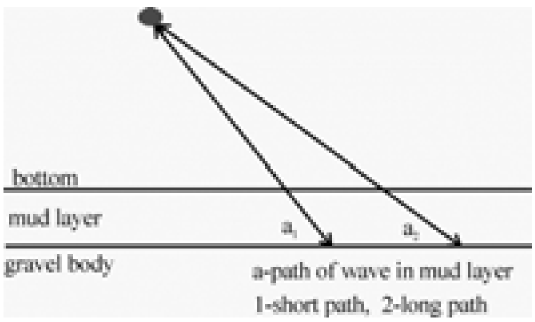


*Fig. 3. Wave attenuation in the mud layer*

The second supposition concerns a wave's attenuation in mud layer (Fig. 3). When the hade is small, the path, which the wave passes through the mud layer is short. Consequently, the wave reaches the gravel surface and reflects from it. Path of the wave in the mud layer increases depending on increasing of the hade. When this path reaches definite value, the wave does not reach the gravel surface. For example, the length of this wave path is 112 cm for line MAK120MS (30 KHz frequency).

This path could be exactly count only in place of bottom sampling . Suppose this path constant in all queer places it is possible to recount inclined path to vertical thickness in other places.

Low backscattering near the track can be explained by changing of geological properties. Accordingly, models of gravel surface for places where strong backscatter changes into low are presented (Fig. 4).

Thus, the fact of backscattering changing could be explained from different points of view: wave's attenuation and appearance of the head wave. Appearance of the head wave takes place on different hades. Value of a hade depends on frequencies of MAK lines.

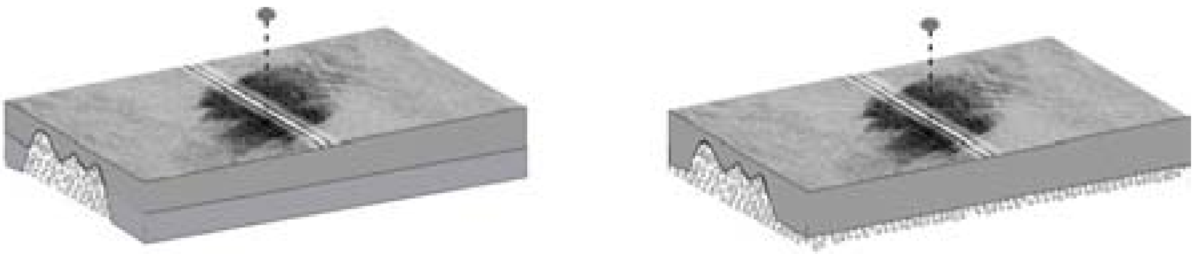

*Fig. 4 Two models of gravel surface: left - the gravel body covered by two layers with different properties; right - the gravel body covered by one mud layer*

# Sands, slides, canyons & turbidite systems

## SPECULOBE – A NEAR-OUTCROP SCALE STUDY OF A MODERN DEEP-WATER SAND LOBE AT THE END OF A GRAVITY FLOW CHANNEL

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An 8 km long active sand lobe at the end of a channel has been discovered in a small basin, with a floor at 1500m, in the Gulf of Cadiz, eastern Atlantic Ocean (Habgood et al., 2003). Capacities of the Training-Through-Research Programme of UNESCO-IOC provided an excellent opportunity to study this feature as a modern reservoir analogue for the interpretation of outcrop and 3D seismic imagery during hydrocarbon exploration. The SPECULOBE project was set up in collaboration with Shell International, Exxon Mobil and the UK-TAPS group.

The lobe is small enough that we were able to map it in its entirety using a high-resolution sidescan sonar (100 kHz) and a seismic profiler (5 kHz) that were towed near to the seabed during TTR11 and 12 cruises. The resulting plan view pattern is spectacularly detailed and comprises a complex bifurcating system of multiple, narrow sinuous channels. The profiles have enabled isopachs of lobe thickness to be drawn at 2m intervals.

Massive sand has been recovered up to 8 m thick but because of the complexity of the lobe and the questions about flow processes that have been raised, further core sampling was needed.

In the year 2004 the project went into the second phase during which the key elements of the lobe system identified on the geophysical data were to be calibrated by piston corer bottom sampling. The sites were selected in order to address issues of reservoir facies characterization as well as general aspects of gravity flow processes and deposits. The coring has been successfully executed as a part of the RRS Charles Darwin cruise CD166 during which a total of 11 piston cores were collected. The coring confirmed the widespread character of the sandy deposits within the lobe. The uniform nature of the sandy layer made it difficult for the piston corer to penetrate and resulted in several bent barrels. Although sand in some of the cores appears to be flown-in, its uniform character suggests the absence of heterogeneities in the original sequence. Cores from the lobe fringe recovered deposits that are believed to be from individual flows. Their homogeneous character and sharp upper and lower contacts indicate the rheology typical for debris flows. Sands with graded bedding were also recovered in the system in the by-pass area dominated by erosional channels.

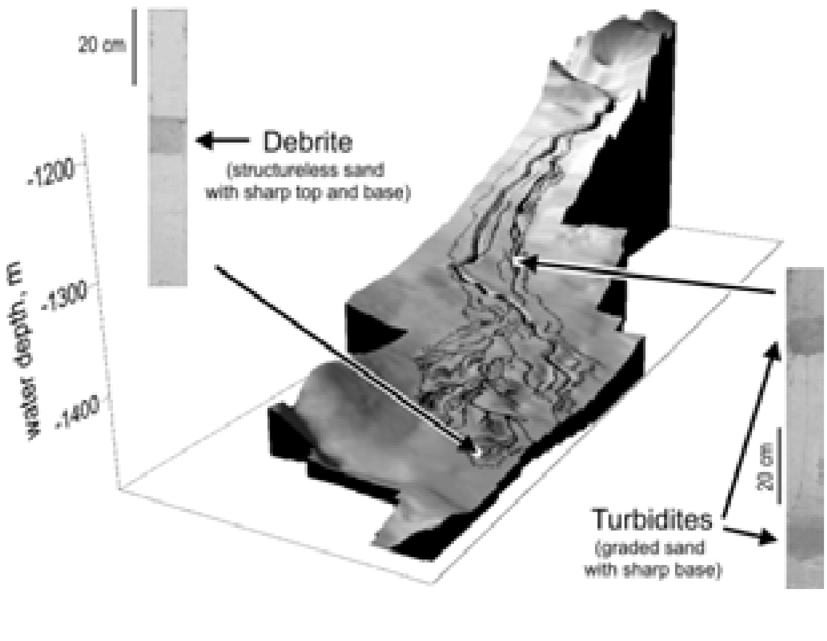


*Fig. 1. Active sand lobe system in the Gulf of Cadiz studied by TTR in 2001-2002. Recent sampl-ing cruise CD166 onboard RRS Charles Darwin confirmed the widespread presence of sandy debris flow deposits in the depositional area of the lobe. As predicted, turbidites were found in the by-pass area.*

**Reference**

Habgood E.L., Kenyon N.H., Akhmetzhanov A., Weaver P.P.E., Masson D.G., Gardner J. & Mulder T., 2003. Deep-water sediment wave fields, contourite sand channels and channel mouth sand lobes in the Gulf of Cadiz, NE Atlantic. *Sedimentology*, **50**: 483-510.

## THE ANDØYA CANYON OFFSHORE NORWAY – PROCESSES OF CANYON GROWTH

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Located on the steepest part of the Norwegian continental slope the Andøya Canyon represents a 30 km long, up to 20 km wide and 1100 m deep V-formed incision. The canyon has been studied using high-resolution seismic data, deep-towed side-scan records, short cores and multi-beam echo-sounder data. The headwall is about 7 km long and has an up to 20° gradient. It forms the present shelf break at about 200 m water depth and is located only 10 km from the coastline. The thalweg is up to 1 km wide and its gradient is 5° or less. A tributary valley joins the canyon where the thalweg reaches 1100 m water depth. The uppermost part of the canyon has an incised axial channel originating close to the shelf break. The eastern sidewall of the canyon is the steepest and has a gradient of up to 20°. It is dominated by a number of straight and shallow, parallel to subparallel gullies up to 100 m in width. The gullies are erosional features that originate at or near the shelf break and can be followed to the base of the canyon where some of the gullies have adjusted to thalweg base level, others terminate on top of an up to 150 m high escarpment defining the eastern boundary of the thalweg. Several deeper and wider incisions characterised the western sidewall. The largest is a 2.5 km wide, amphitheatre formed slide scar. Within the slide scar small, elongated highs probably represents sediment ridges that moved for some distance and then stopped. On the lower part of the continental slope the western sidewall is dominated by a large slide scar, up to 8 km wide and 400 m deep that feed into the canyon. In this area the eastern sidewall is characterised by a 10 km wide incision also indicating a large sediment failure. In summary, the canyon shows a very complex morphology probably related to a variety of gravity driven processes responsible for the canyon growth. The timing, frequency and origin of events within this canyon are presently not known.

## THE EIVISSA SLIDES IN THE WESTERN MEDITERRANEAN SEA: MORPHOLOGY, INTERNAL STRUCTURE AND THEIR RELATION WITH FLUID ESCAPE FEATURES

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After obtaining full coverage of swath bathymetry data in 1995 and very-high resolution acoustic profiles in 2001 (Lastras et al., 2004), four small, <0.4 km$^3$ and 16 km$^2$, submarine landslides (Table 1) in the Eivissa Channel area, between the Iberian Peninsula and the Balearic Islands, western Mediterranean Sea, were revisited in August 2004 in order to obtain side-scan sonar data using the MAK-1M deep-towed acoustic system available onboard R/V *Professor Logachev*. New data, higher in resolution than swath bathymetry, show two main features previously undetected within these submarine landslides: (1) a series of linear detached blocks oriented perpendicularly to the slide

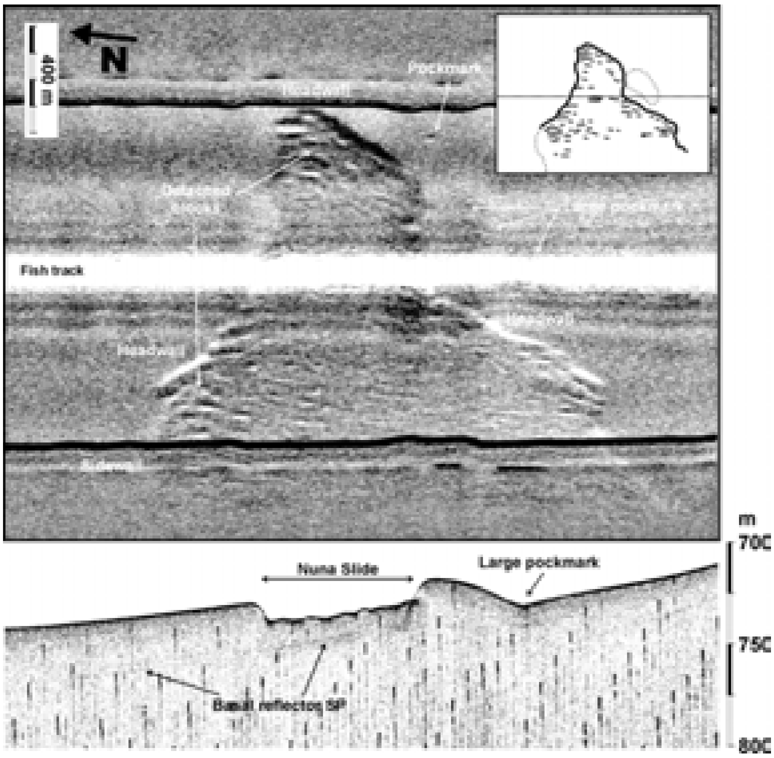


*Fig. 1. MAK-1M sonograph (upper part) across the Nuna slide headwall scar and 5 kHz acoustic profile (lower part) along the fish track, showing detached blocks within the slide mass, and a large pockmark very close to the headwall corresponding to that described by Lastras et al. (2004). Inter-pretation of the sonograph is also provided. Note that the sonograph is in inverted gray-scale.*

**Table 1.** General characteristics of the four slides in the Eivissa Channel.

| Slide name | Location | | Water depth (m) | Slope Angle (º) | Scar Height (m) | Maximum thickness (m) | Area (km²) | Volume (km³) |
|---|---|---|---|---|---|---|---|---|
| | Lat N | Lon E | | | | | | |
| Ana | 38º38′30″ | 0º49′00″ | 635-815 | 1.6 | 30 | 44 | 6.0 | 0.14 |
| Joan | 38º41′00″ | 0º47′30″ | 600-870 | 2.5 | 20 | >25 | 16.0 | 0.40 |
| Nuna | 38º43′15″ | 0º47′30″ | 675-860 | 3.0 | 50 | 50 | 10.3 | 0.31 |
| Jersi | 38º47′30″ | 0º47′15″ | 755-905 | 1.9 | 15 | 45 | 7.9 | 0.19 |

movement and located in the uppermost part of the slides (Fig. 1), and (2) arcuate regular positive relieves oriented also perpendicularly to the slide movement and located in the depositional lobes ofsome of the slides. The first have been have been interpreted as extensional ridges suggesting a retrogressive post-failure evolution of the slides, while the second are compression ridges related to plastic deformation of the sediment during movement. Moreover, new data show that fluid escape features are even more widespread in the Eivissa Channel than previously though, where dozens of less than 20 m in diameter pockmarks have been identified.

**Reference**

Lastras G., Canals M., Urgeles R., Hughes-Clarke J.E., and Acosta J., 2004. Shallow slides and pockmark swarms in the Eivissa Channel, western Mediterranean Sea. *Sedimentology,* **51**: 837–850.

# TURBIDITY CURRENT PROCESSES AND DEPOSITS IN THE AGADIR CHANNEL AND BASIN OFFSHORE NW MOROCCO: INITIAL RESULTS OF CD166

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A new UK-TAPS (Turbidite Architecture and Process Studies) cruise in late 2004 visited the deep-water Agadir Channel and Basin offshore Morocco. This cruise was funded by NERC and a consortium of four oil companies (ExxonMobil, BHPBilliton, ConocoPhillips and Shell Morocco). The main aim was to understand gravity flow processes and deposits at a basin-wide scale. Data collected included two multibeam bathymetry surveys and a total of 50 piston cores - see figure below for location map of Agadir Basin (box), multibeam survey lines (dark shading) and location of piston cores (dots). Previous techniques outlined in Wynn et al. (2002) enabled turbidite and debris flow deposits in these cores to be correlated across the whole basin.

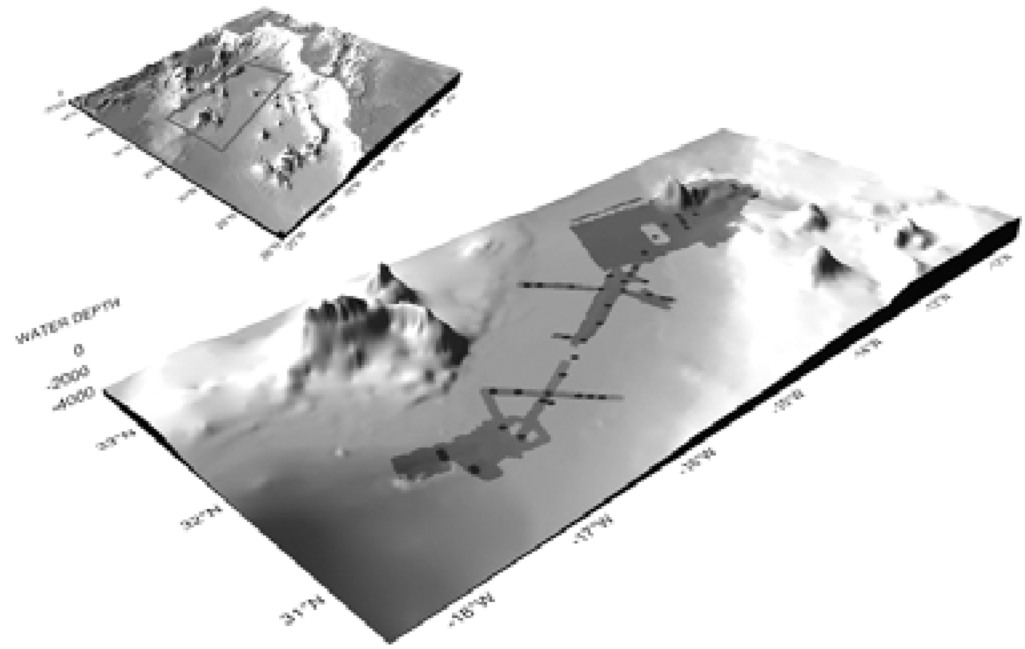


*Fig. 1. Location map of the Agadir Basin (box), multibeam survey lines (dark shading) and piston cores (dots)*

Initial results show that turbidites sourced from the Moroccan margin flow down the Agadir Channel and turn a sharp 90$^{o}$ bend before entering the basin. Significant erosion occurs on the outer part of this bend. Turbidite deposits preserved in the channel mouth are often discontinuous and truncated by erosional scours and hiatuses. Overall the channel mouth is characterised by high complexity and abundant cut-and-fills. Beds deposited in the basin display a wide range of deposit volumes and bed geometries. One of the flows contained both debris flow and turbidity current phases, leading to development of a turbidite-debrite 'sandwich' bed. Two major volcaniclastic flows are preserved in the basin fill, and have been correlated with major landslides on the flanks of the Canary Islands. New cores show that across the basin these turbidites consistently contain multiple stacked sub-units. The consistent pattern of this facies suggests it is not a function of local flow reflection or flow surging, and instead may relate to multi-stage failure of the source landslide.

**Reference**

Wynn, R.B., Weaver, P.P.E., Stow, D.A.V., and Masson, D.G. (2002). Turbidite depositional architecture across three interconnected deep-water basins on the Northwest African margin. *Sedimentology*, **49**: 669-695.

## ANALYSIS OF THE QUARTZ GRAINS SURFACE FEATURES PRESENT IN THE CADIZ BAY SEDIMENTS (SW OF SPAIN)

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### INTRODUCTION AND METHODS

The studies of quartz grains exoscopy made by several authors (Krinsley and Doornkamp, 1973, le Ribault, 1975 and Torcal and Tello, 1992 among others) show the utility of this technique as tool of recognition of the superficial and morphological characteristics of grains. This technique also provide data about the mechanisms of transport and deposit undergone by these grains during the sedimentary process.

The detailed analysis of different associations of superficial textures, and their superposition can indicate different stages that have taken place in the evolution of the grain. This analysis provide very interesting information about the sedimentary evolution of the materials and their origin.

In this work, the superficial textures of quartz grains present in Cadiz bay sediments are analyzed. The objective is to determine the different stages of their evolution, from the associations of identified textures. Also, the objectives of this study are included in a general context of the transference continent-ocean study.

The study zone occupies the central part of the littoral of Cadiz Gulf, between parallel 36º25´ and 36º38´ North and meridians 6º09´ and 6º18´ West (Fig.1).The superficial sediments extraction has been made with Van Veen Drag. The sample position was determined by Differential Global Position System (DGPS). The sampling stations were collected in 1997 on board of *Tartesos* I and *Tartesos* II of the University of Cadiz. The grain size analysis was carried out by sieving. The mineralogical composition was studied by X-ray powder diffraction (XRD). Textural analysis of surface features of the quartz grain was performed with a JOEL SEM.

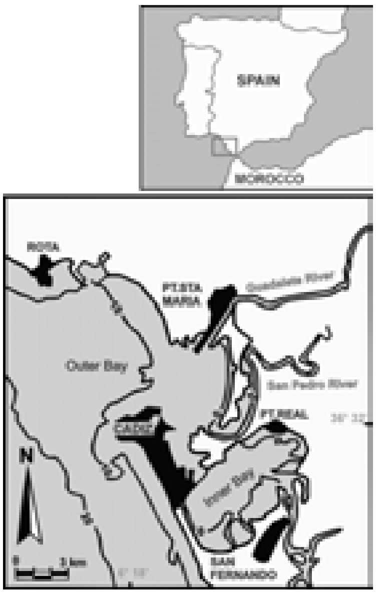


*Fig. 1. Geographical map of the studied zone*

### Sedimentary Facies

The superficial sediments present in Cadiz bay are siliciclastic nature. The most important mineral is the quartz, which indicates siliciclastic character of these sediments, and its origin from sources area rich in this mineral. Its content is high, with average values of 50%, and maximums of 75% in sandy facies, the lowest values (25%) are given/occur in muddy bottoms.

From granulometric point of view, in the inner bay, mud and sandy-mud predominate. In the outer bay, the sand is the dominant fraction especially in the littoral zone, while the fins sediments (muddy-sand) occupy the central and oriental part of Cadiz bay. In this last sector, the gravel appears near rocky shoals.

### Morphologies and Micro-Features of Quartz

The principal mechanical and chemical surface textures that appear in quartz grains, have been differentiated on the basis of a combination of terminologies used by Margolis and Krinsley (1974) and Torcal and Tello

(1992). Under a morphologic point of view, three types of quartz grains have been distinguished (Achab et al, 1999): angular xenomorphic, rounded xenomorphic and sub-rounded-subangular xeno-morphic (Fig. 2 & Table 1).

(a) Angular Grains. - They are characterized by the predominance of angular conchoidal fractures of different size and development. Other mechanical marks are: grooves, chattermark trails and reworking conchoidal fract-ures. The chemical marks appear as oriented etch and solution pits, that can affect to previous features. The primitive surface can be observed, this one appears polished.

(b) Rounded Grains. - Their characteristic textures are the upturned plates and the arcuate steps that evidence an important eolic action. Present oriented etch and solution pits and some reworking or polished conchoidal fractures.

(c) Subrounded-subangular Grains . - They Show old mechanical marks (conchoidal fractures and grooves) widened by dis-solution. Present a gener-alized polish of grains sur-face, in which old marks are observed as upturned plates and oriented etch and solution pits.

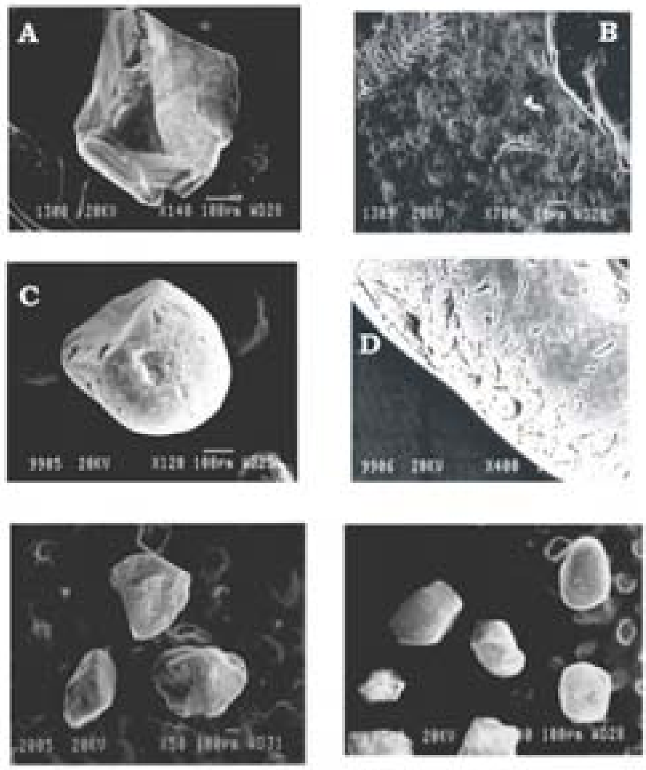


*Fig. 2. Scanning electron micrographs of quartz grains. A) Angular grains with conchoidal fractures; B) Detail of the previous grain, note chattermark trails, mechanical Vs, arcuate steps and solution signs; C) Rounded grain with reworking conchoidal fractures and arcuate steps; D) Detail of the previous grain, note arcuate steps, grooves and solution signs; E and F) See of different morphological types of quartz grain, note the prevalence of subrounded-subangular grains.*

**Table 1.** Surface features and morphologies in different types of quartz grains

| Surface features | Morphologies | | |
|---|---|---|---|
| | Angular quartz | Rounded quartz | subrounded-subangular quartz |
| Angula conchoidal fractures | *** | | * |
| Reworking conchoidal fractures | * | *** | ** |
| Mechanical V-forms | * | * | ** |
| Grooves | ** | ** | ** |
| Arcuate steps | * | ** | * |
| Oriented Vs | | * | |
| Oriented etch pits | ** | ** | ** |
| Solution pits | * | ** | ** |
| Chattermark trails | ** | ** | |
| Silica globules | | | * |
| Pulished surface | ** | ** | ** |

*: scarce, **: abundant, ***: very abundant

**Evolutionary Phases**
The study of surface textures associations present in xenomorphic grains indicates a multicyclical character. Considering the different works of quartz exoscopy, realized in the study zone by diverse authors (Torcal, 1989, Moral Cardona et al 1997 and Achab et al, 1999); the possible evolutionary phases undergone by these grains and the transport mechanisms of deposit have been differentiated. The principal stages can be synthesized as it follows:
(1) First stage represented by the predominance of mechanical and/or Aeolian textures like, upturned plates, arcuate steps and grooves;
(2) Second stage marked by the presence of conchoidal fractures formed in environments of high mechanical energy, related to fluvial channels or to reworking processes in coastal zones type beach;
(3) One laste stage represented by the predominance of chemical marks (oriented etch and solution pits) that affects old mechanical marks. These textures according to the cases can be originated in edaphic environments, intertidal zones, etc.

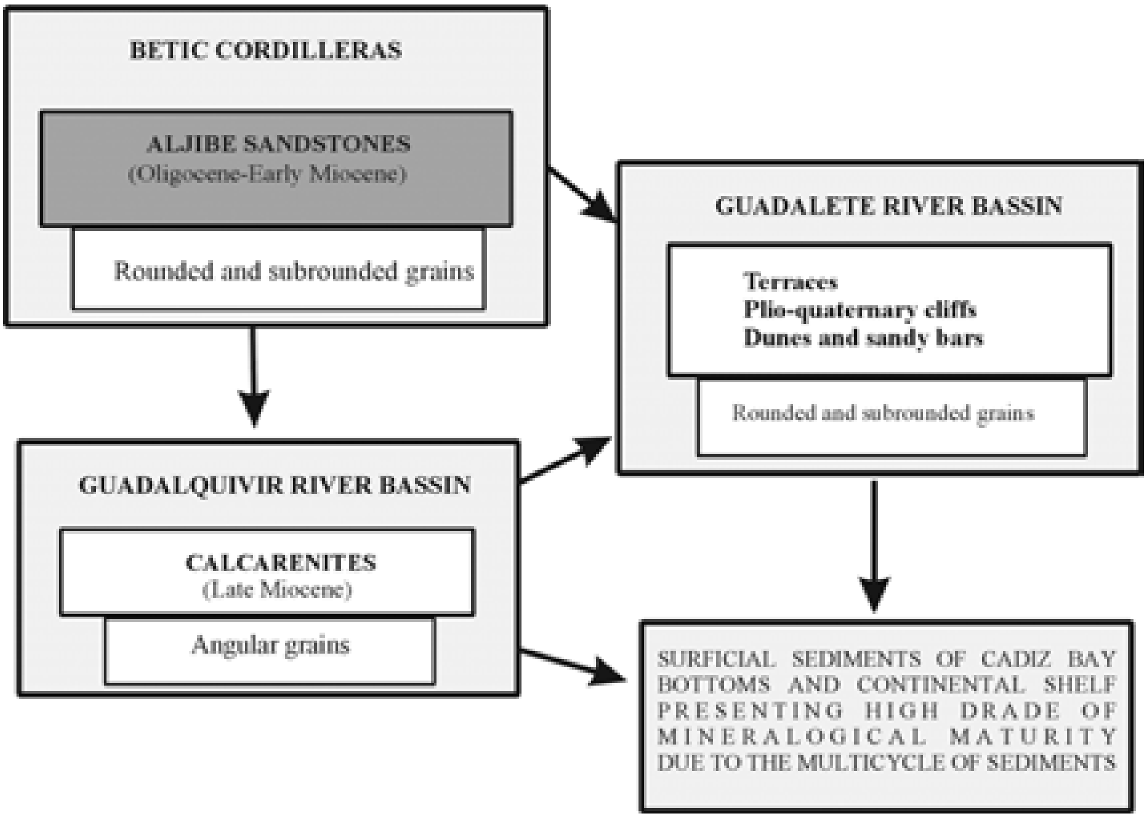


Fig. 3. Explanatory sketch of the origin of different morphological types of quartz grains present *in superficial sediments of Cadiz Bay*

**Origin of Quartz Grains**
The possible continental areas and sources of contributions/supplies of different morphological quartz grains to Cadiz Bay bottoms, have been established (Figs. 3, 4), and are the following (Achab and Gutierrez Mas, 2002):
(a) From the *Aljibe* sandstones (Oligocene-Early Miocene), constituted by more of 90% of quartz and in which predominate rounded and sub-rounded (Moral Cardona, 1997 and Achab,2000). These materials can arrive to Cadiz bay through Guadalete river and reworked sediments.
(b) From the calcarenites of Late Miocene. It is of calcareous sandstone, with 40% of quartz, that contain angular grains with sharp conchoidal fractures. Great part of grains that show these characters, correspond to grain of reworked *Aljibe* sandstone (Moral Cardona, 1997, Achab, 2000). These grains appear widely in it basin and reach the Cadiz bay bottoms through Guadalete river.
(c) Another source of contributions is the plio-quaternary coastal cliffs and the coastal dunes, these last, can provide/gives by erosion during storm events, mineral grains of variable maturity and morphology, and with different degree of reworking.

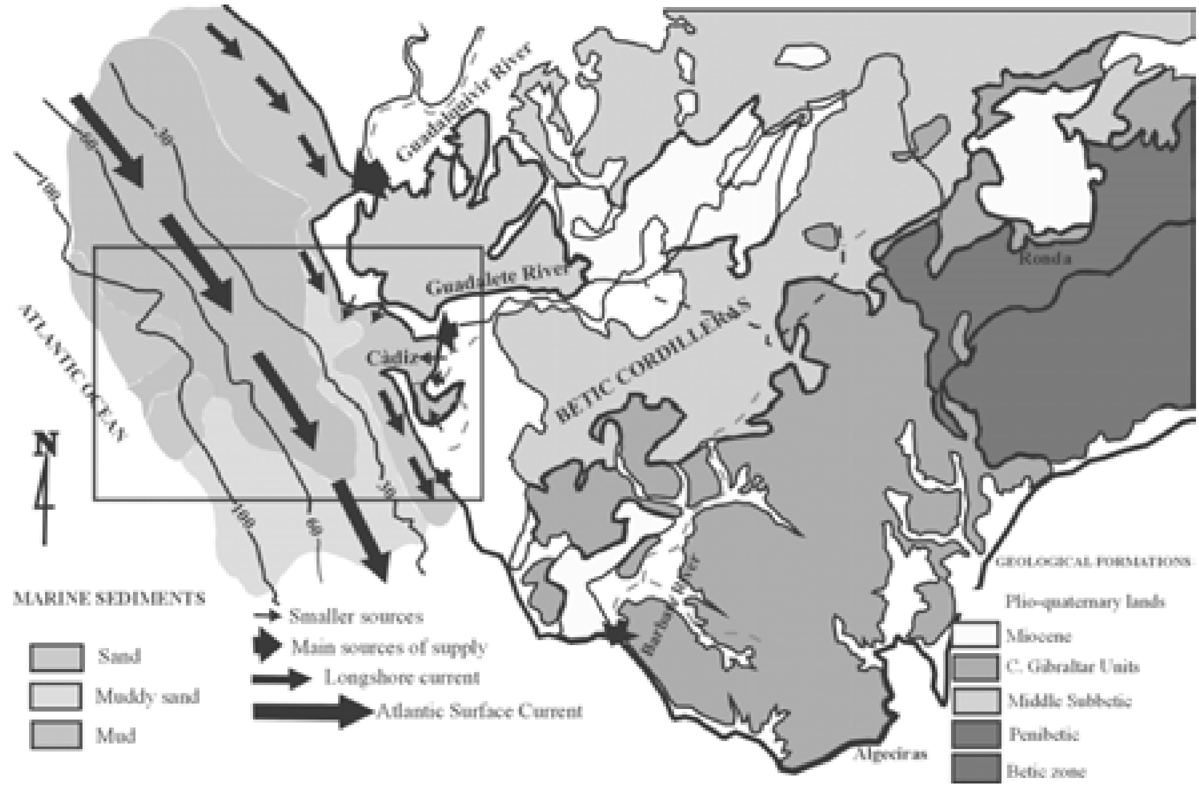


*Fig. 4. Main continental areas and supply sources of sediments to Cadiz Bay*

**Acknowledgements**
This research has been financed under project Sea-98-0796 of the Comision Interministerial de Ciencias y Tecnologia (CICYT)-Spain.

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# Studies in the Central Atlantic Ocean

## SURVEYING THE FLANKS OF THE MID-ATLANTIC RIDGE: EXAMPLES OF GEOSPHERE-BIOSPHERE COUPLING IN DEEP-SEA AREAS OF THE NORTH ATLANTIC

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As the Training-Through Research (TTR) programme is increasingly concerned about Geosphere-Biosphere coupling processes and their relation to marine environments, previous TTR cruises have led to important discoveries in deep-water areas of the North Atlantic Ocean. During Leg 5 of the TTR12 cruise, new seismic reflection and OKEAN (9.5 kHz) sidescan sonar data were acquired and used to characterise the seismic stratigraphy and structure of the region south of the Azores Islands, North Atlantic Ocean (Fig. 1). The new data provided constraints on the tectono-sedimentary evolution of deep-ocean basins located on the flanks of slow spreading ridges, particularly those SE of the Azores hotspot (North African Plate). TTR12-Leg 5 also allowed the collection of significant biological and petrological samples in areas where the Mid-Atlantic Ridge (MAR), adjacent abyssal hills and major seamounts have an important control on seabed and oceanographic processes.

South of the Azores, thick sedimentary sequences (>1.0 s two-way travel time) correlated with units in the Madeira Abyssal Plain (ODP Sites 950-952) overlay an irregular basement generated by a combination of volcanic and tectonic processes. Similarly to the Madeira Abyssal Plain, three main Cenozoic depositional events are recognised and signed by distinct seismic megasequences.

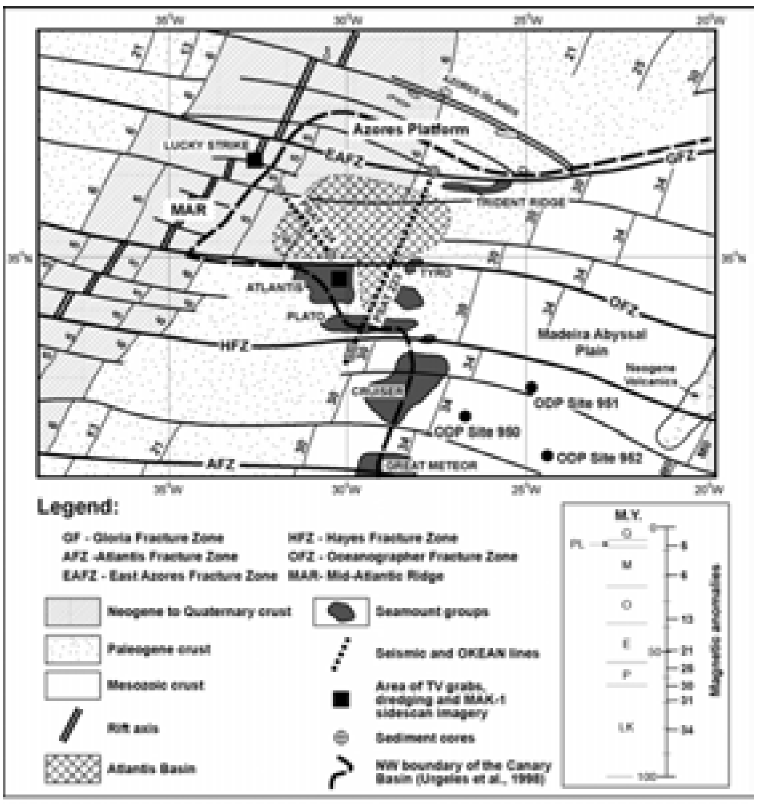


Figure 1

*Fig. 1. Location of the study area and adjacent sea floor features in relation to the MAR and underlying oceanic crust. Magnetic data taken from Emery and Uchupy (1984) and Müller and Roest (1992). Figure taken from Alves et al. (2004).*

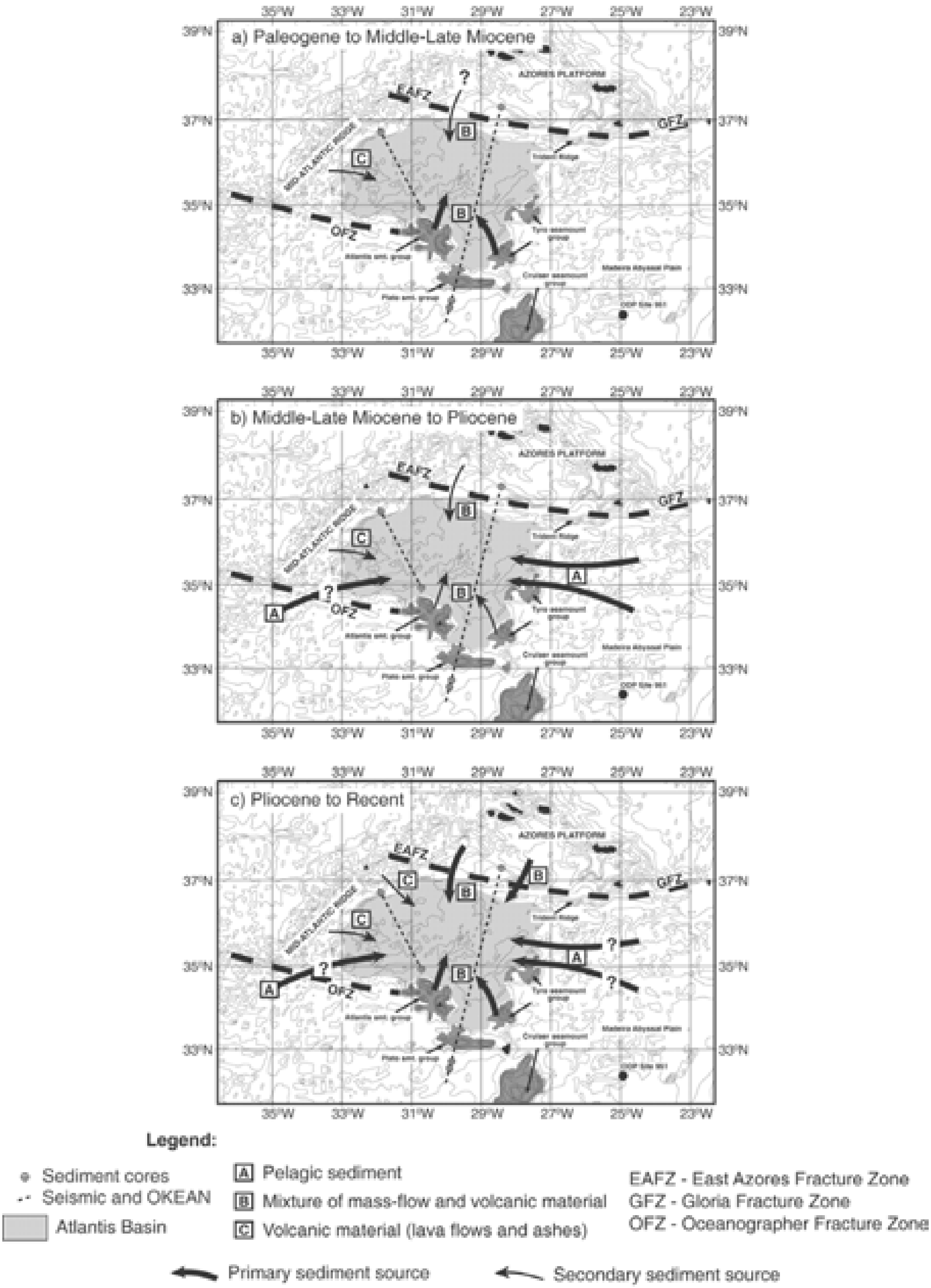


*Fig. 2. Diagram representing the relative importance of regional sediment sources to the gradual filling of the Atlantis Basin. From Alves et al. (2004)*

The moderate deformation of the sedimentary units and the structural fabric of the underlying oceanic crust shown on seismic and sidescan data suggest the existence of a complex tectonic setting prominent abyssal hills west of 30ºW change into a segmented oceanic crust denoting an extensional/transtensional tectonic regime east of the latter meridian. Such change may reflect the increasing importance of MAR-related processes (i.e. volcanism, hydrothermalism) in shaping the sea-floor topography towards the MAR and Azores hotspot.

When compared with the Hawaii, Marquesas (Pacific Ocean) and La Rèunion (Indian Ocean) hotspot centres, the seismic stratigraphy of the study area presents striking differences. Similar units to those of Hawaii and La Rèunion can only be identified at the base of the interpreted seismic sequences (megasequence A), suggesting that erosion of adjacent volcanic islands was the predominant sedimentary process prior to the Middle Miocene. However, in the latter part of the Miocene and during the Quaternary, pelagic sedimentation interrupted by episodic gravity flows became relatively more important (Alves et al., 2004). Thus, evidence is taken from seismic data that distinct sediment sources fed the basin at different times, a character most likely influenced by the progressive growth of the Azores Plateau and by the dismantling of the Atlantis-Plato-Great Meteor seamount groups with time (Fig. 2).

We consider that the significance of the Canary Islands volcanism in the depositional history of the Atlantis Basin should be further investigated, particularly due to the similar seismic stratigraphy between units in the Madeira Abyssal Plain and in the study area. Also, new seismic, well, geochemical and geophysical information on the Atlantis Basin should help constraining the events that led to the formation of the Azores Platform and adjacent seamount groups. Conversely, biological composition (and variety) in the study area should be investigated in order to better characterise the living resources of the Azores Exclusive Economic Zone.

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## PETROGENESIS OF LAVAS FROM THE LUCKY STRIKE SEGMENT, AZORES REGION, 37°N ON MID-ATLANTIC RIDGE

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**Geological Setting**

The 65-km Lucky Strike segment is located on the Mid-Atlantic Ridge, southwest of the Azores Triple Junction, between 37º00′ N and 37º35′N. The morphology of the longitudinal axial depth profile of the segment is characterized by a topographic high located at the middle part of the segment. The axial depth ranges from 1650 m on the central topographic high to greater than 3000 m at the intersections with the northern and southern offsets that delimit the segment. The morphology, with a well-defined axial rift valley, is characteristic of the Mid-Atlantic Ridge. Rectangular in shape, the rift valley of this segment has a nearly uniform width of 11 km between the rift valley walls. A prominent feature of the Lucky Strike segment is the large seamount in the centre of the rift valley that forms a broad platform extending nearly across the rift valley. This central topographic high is made up of a composite volcano that is 13 km long, 7 km wide, and 430 m high, and is divided into two parts separated by a N-S valley. The western part is an elongated narrow ridge while the eastern part has a semi-circular shape with three volcanic cones at its summit, predominantly constituted by scoriaceous breccia. The Lucky Strike hydrothermal site is located in the depression located between these three cones. The central part of this depression is occupied by an inactive lava lake, 300 m in diameter, made of fresh non- vesicular lobate, and sheet flows. The topography, crustal thickness and basalt chemistry of this segment of the MAR rift valley are strongly influenced by its proximity to the Azores hot spot.

**Results**

New major and trace element, and Nd-Sr isotopic, data on samples from the Lucky Strike segment are presented. The samples were recovered during TTR12 cruise, on board of the Russian R/V *Professor Logachev*. All samples studied are enriched mid-ocean ridge basalts (E-MORB), but different degrees of enrichment are identified. Considering the relationship among various incompatible trace elements, Lucky Strike basalts have been subdivided into three distinct compositional groups: In Group 1, the lavas have the highest La/Sm, La/Yb, Nb/Zr, Nb/Y, Zr/Y, $K_2O/P_2O_5$, $K_2O/TiO_2$, $^{87}Sr/^{86}Sr$ and the lowest $^{143}Nd/^{144}Nd$ ratios, are spatially restricted to the central part of the axial volcano, are highly vesicular, and are plagioclase phyric. These lavas have a degree of enrichment between those of E-MORB and OIB. Group 3 lavas have the smallest La/Sm, La/Yb, Nb/Zr, Nb/Y, Zr/Y, $K_2O/P_2O_5$, $K_2O/TiO_2$, $^{87}Sr/^{86}Sr$ and the highest $^{143}Nd/^{144}Nd$ ratios, were collected throughout the Lucky Strike segment (from 37º12,0′ to 37º27,3′ in latitude), are almost aphyric to plagioclase microphyric, and present REE and multi-element patterns typical of E-MORB. Group 2 lavas have chemical characteristics intermediate between those of groups 1 and 3 in terms of trace and isotope compositions, producing continuous, and regular trends in different element ratios that link the lavas from the previous two groups. Thus, these lavas have the maximum dispersion in the different element or element ratios, and present an enrichment degree between those of group 1 and 3 lavas.

**Discussion**

Extensive low-pressure crystal fractionation (olivine + clinopyroxene + plagioclase), reaching a maximum of 50%, is the main differentiation process controlling the chemical evolution among the magmas precursors of lavas from group 3. Also extensive, accumulation processes, essentially involving plagioclase and clinopyroxene, have exerted the main control on the major and compatible trace element concentrations in the magmatic precursors of group 1 basalts. Incompatible trace element abundances in these group 1 basalt progenitors were little influenced by accumulation. Modelling based on incompatible trace element ratios, together with the Sr and Nd isotopic data, exclude the possibility of different degrees of partial melting, from an homogeneous mantle, as the explanation for the existence of different chemical signatures in the basalts from groups 1 and 3. This suggests derivation of these two magma types from distinct enriched parental magmas. Good fits of calculated mixing lines to the chemical data , demonstrate that mixing is probably an important process for the Lucky Strike tholeiites, involving an N-MORB type source end-member and an enriched one, similar to that assumed to generate the group 1 basalts.

The assumption of a heterogeneous mantle is consistent with the analytical data obtained. These heterogeneous domains (the source of group 1 lavas), are highly enriched in trace incompatible elements and have, at the same time, higher Sr and lower Nd isotopic ratios, when compared to a typical E-MORB. The coupled relationship between enriched radiogenic isotopic characteristics and elevated incompatible trace abundances, indicates time integrated enriched domains, meaning they are ancient, and may occur as blobs or streaks (Hanson, 1997; Fitton & James, 1986; Saunders et al., 1988; Weaver, 1991). It is reasonable to view the mantle beneath the Lucky Strike segment as heterogeneous, having small, yet recognizable, domains of these enriched components (that could be a clinopyroxene-type lithology), that are dispersed non-uniformly in the ambient enriched mantle source (enriched spinel lherzolite, E-MORB type).

An initial enriched melt, produced by low partial melting, will have to migrate into the crust, individually, to a small magma chamber where it will stay long enough to develop the plagioclase phenocrystals, found in group 1 lavas. Fractionation and accumulation processes will control the magma differentiation in a such high-level small crustal magma chamber. The focused magma directly on the top of the volcanic complex, in the centre of the plateau, will produce the three volcanic cones corresponding to the basalts from group 1. Continuous, and at the same time extensive, melting in the Lucky Strike mantle source will start to melt the E-MORB mantle source, and the magmas produced will be less enriched. With time and higher melting fractions, the magmas will gradually become more similar to those produced by melting only the E-MORB mantle source. This means that the proportion of the incompatible element-enriched heterogeneities in the melt will decrease with further melting as a result of dilution. During this interval, lavas from group 2 will be generated, initially more enriched in character (similar to group 1 lavas) and at the end less enriched (similar to group 3 lavas). At a certain point, the enriched domains would be exhausted and only melting the E-MORB mantle source would occur thus generating the magma precursors of group 3 lavas. Different progressions through the crust, with variable extents of crystal fractionation (up to 50%), will create group 3 lavas from, the most common in the Lucky Strike segment, according to the sampling performed to date. This model implies the existence of intermittent, possibly relatively small, magma chambers. In summary, the geochemical consequence of melting a heterogeneous source is to produce mixing relationships in the melts between the ambient enriched end-member and the highly enriched component, primarily achieved through processes of variable degrees of melting.

The assumption of clinopyroxene-rich lithologies in the enriched domains is supported by data obtained in this current study but not included in this report. They show very high Ca/Al ratios (up to 0.90) in glass, which is unusual for MORB. These also show a high-Ca composition of olivine and the crystallisation of clinopyroxene (low-Al Cr-diopside). This model indicates that much of the magmatic activity in Lucky Strike region is separated in time and space.

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# Methods and applications

## USING GIS SOFTWARE FOR UNIFICATION OF THE TTR DATA

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Since 1991 the UNESCO/IOC Training-through-Research cruises have been carried out annually in the World Ocean. Forteen TTR cruises (1991-2004) gathered great amount of different types of data - seismic, acoustic, geological, geochemical and lithological.

When analyzing data in any particular region, we face the challenge of inconvenience in accessing different types of data. For example, when we use data from TTR14, it is useful to also add in the analyses the corresponding data from the previous cruises. Also, when studying one type of data, e.g. seismic profiles, it is useful to have fast access to lithological and other data. This is not the case for the time being.

The solution of this problem is in creating the TTR GeoInformation System (Fig. 1), which includes geodatabases that include different types of collected data.

The purposes of the information system and geodatabases are:

- To allow a faster access to any TTR data;
- To allow plotting on a map any types of data, evaluating relations between them (e.g., to illustrate how TV-profiles correspond to mosaics).

The main task of these databases is their convenience. A user should be able:

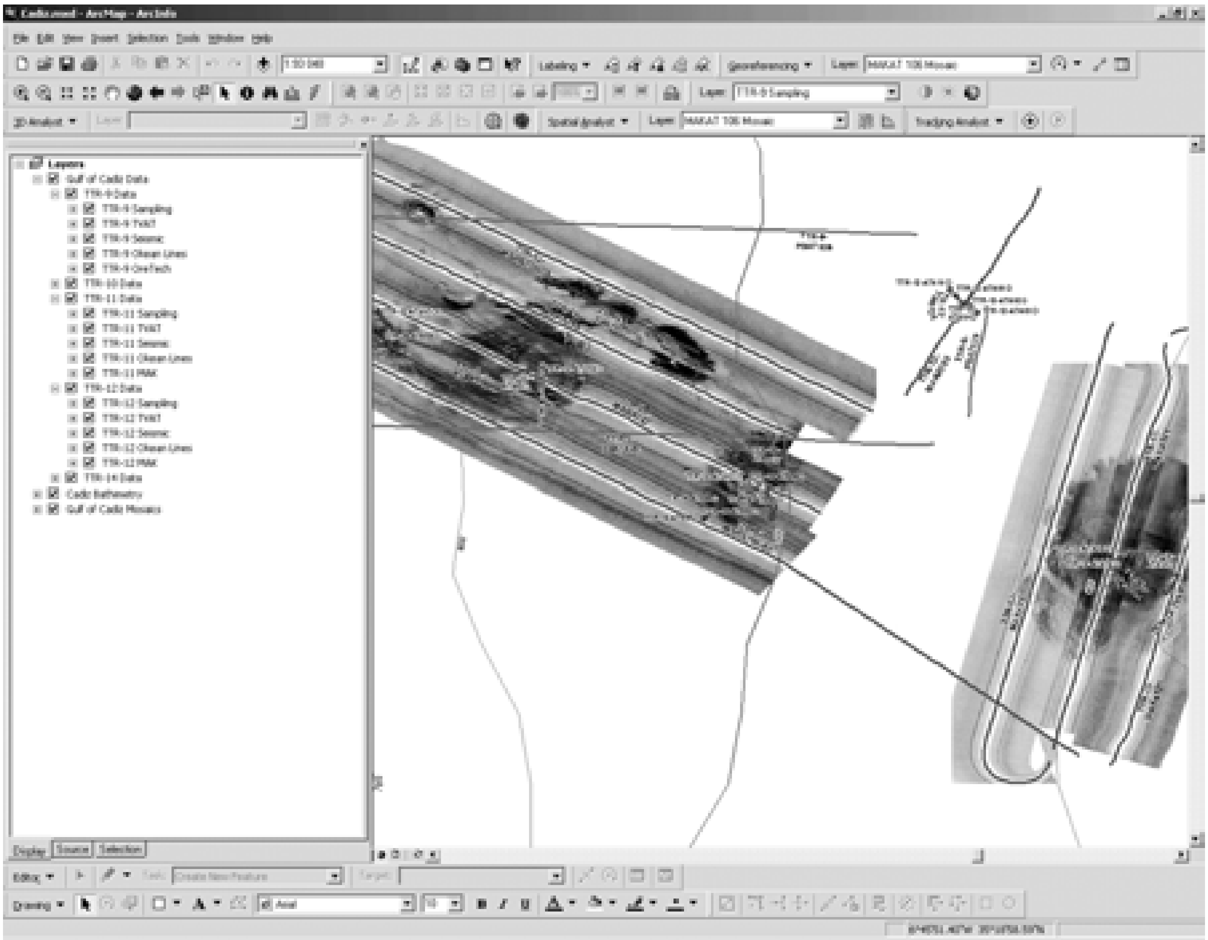

*Fig. 1. Example of interposition of various data using GIS*

- to browse, view and analyze large amounts of different data;
- to update databases with acquired data straightway aboard a research ship for further analyses;
- to provide a user-friendly system adapted to minimal user's knowledge.

The principles of architecture of these geodatabases are based on separating data by different attributes: region/location, year of acquisition, and type of data. Priority of sorting is the regional attribute. Every "region" includes databases, sorted by years, and every yearly database includes features, sorted by types of data. Besides geographical information, geodatabases must include links to graphical information, e.g. lithological columns, photos, results of analyses of sampling stations, key screenshots of underwater TV etc. The key purpose of this work is to define a standard, to develop database structure, summarizing all types of TTR data in one user-friendly GeoInformation system with a possibility of updating it during every cruise.

These geodatabases include:
- geographical information of seismic, acoustic, underwater TV lines, position of sampling stations;
- time marks for these lines (10 min points);
- seismic and acoustic profiles;
- screenshots from underwater television;
- lithological columns and photos of sampling stations;
- most important MAK mosaics with reduced resolution.

Geodatabases are built with ESRI software ArcGIS Desktop.

The future work will include building and regular updating geodatabases for different regions where TTR has made or will make studies, i.e. Gulf of Cadiz, Mediterranean Sea, Black Sea, North Atlantic Margin.

## RESOLUTION ENHANCEMENT OOF MARINE SEISMIC TTR14 DATA WITH USE OF WAVELET ANALYSIS

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The target of this work is seismic data resolution improvement. The purpose is to increase the resolution of marine seismic data from the TTR cruises. The method is based on basic function expansion of the input signal. High frequency fades with depth like an exponent function, therefore geological media can be presented as a low-frequency filter. That is why the seismic signal spectrum shifts to the lower frequency area with depth and the shape of registered signal becomes smoother. More accurately the law of filtration can be defined from the analysis of the wavelet spectrum (Fig. 1).

The spectrum calculation is based on a definition of the signal's cross-correlation function and basic functions (wavelets). The maximum of the cross-correlation function corresponds to concurrence of signal form, amplitude and wavelet. This maximum determines a signal form (wavelet) at the depth.

The next stage of processing is an expansion of seismic traces in earlier defined wavelets. In places where the form of wavelet and useful signal coincide, the maximum of expansion coefficient is

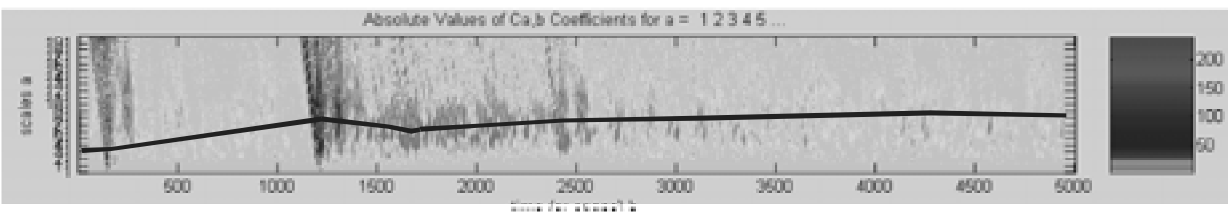


*Fig. 1. Wavelet spectrum of signal*

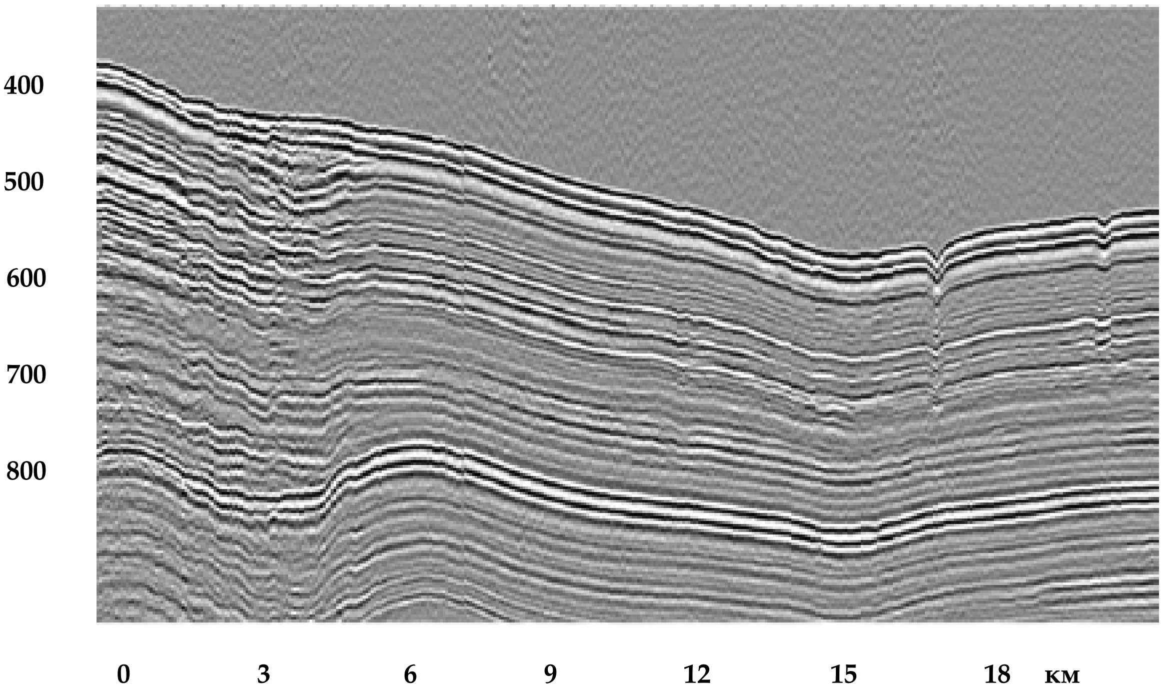


*Fig. 2. Part of a seismic line before data processing*

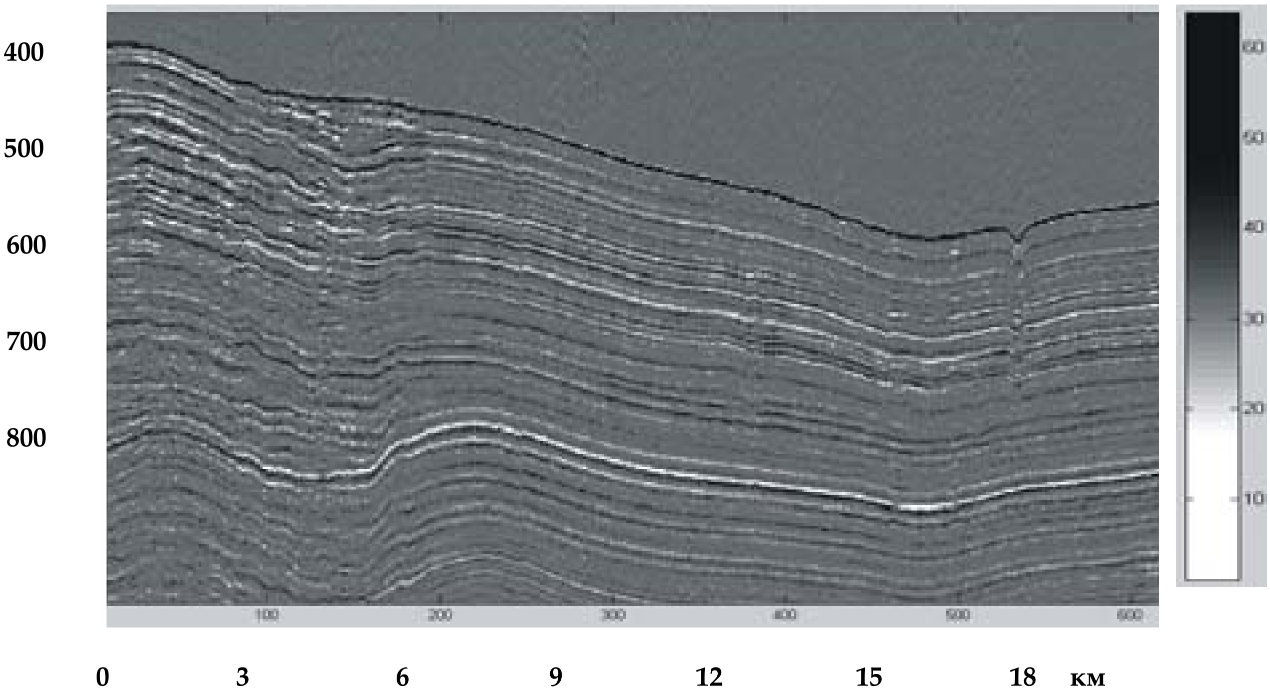


*Fig. 3. The same part of a seismic line after basis pursuit transform*

observed. In places where useful signal is low or absent, the values near zero are observed. Thus the useful signal is underlined more precisely and noise is smoothed (Fig. 3).

The standard deconvolution procedure increases both noise and as well as useful signal. The calculated expansion coefficients are physically close to reflection coefficients. Such expansion is made on several wavelets (from different depths). In zones of strong absorption the maximum of coefficients corresponds to the smoothest wavelet expansion. The profile of coefficients was of higher resolution than unprocessed one. This can help structural interpretation and especially with identification of thin layers. Also changes of reflection coefficients on this profile can be easy determined. It can be helpful with rock properties change evaluation. Further processing includes synthetic seismogram calculation based on the received coefficients.

The method allows to enhance resolution of seismic records and to smooth the random noise level.

# AN EXAMPLE OF ANCIENT DEEP SEA DEPOSITS STUDY BY MODERN SEISMIC METHODS

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The aim of this work is to study ancient marine deposits using full range of modern seismic methods, such as attribute analysis, acoustic inversion and AVO. This work was done using data from a group of Western Siberian oilfields. Three main horizons were targets for production for the last 15 years. But as a result of exploration work in this area it was discovered that besides main productive layers also a number of oil-saturated layers, the so called "Achimov section", are present. Earlier these layers considered to be unprofitable for the oil industry. At the same time, the Achimov section is 200-500 meters deeper than the deepest productive horizon, so usually wells did not penetrate it. Now, as a result of oil prices rise, production from these layers have become profitable. And a decision was made to explore this section.

The following data were used for this work: logs from 90 exploration and 10 production wells, with good spatial distribution (approximately 10 km between wells), 3D seismic data (900 km$^2$) and results of acoustic inversion and the AVO analysis. Unfortunately in the center of this group of oilfields is an area without seismic coverage, so this zone was not used for the analysis. At the present moment more than 1000 production wells are drilled at this oilfield, but, as it was mentioned above, only small part of them penetrated the Achimov section.

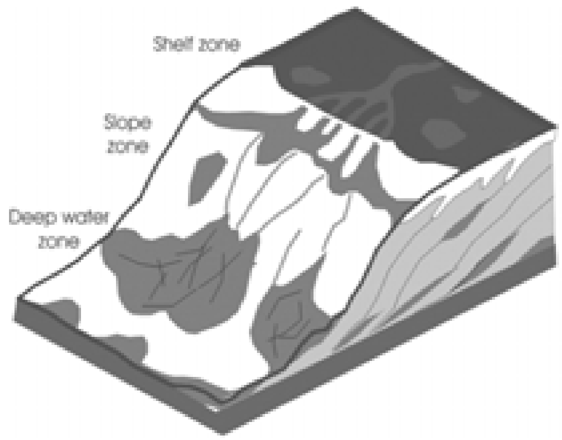


*Fig. 1. Achimov sands depositional system*

The main task for this work was to evaluate such reservoir properties as sand thickness and zones of best porosity, which will be used for 3D geological modeling, and as a result, these data will be the basis for the future Achimov drilling program.

According to the previous investigations of nearby oil fields a depositional model for the Achimov sediments was built. (Fig. 1). This section was deposited in a relatively shallow basin and can be divided into three parts: a shelf zone, a slope zone and a deep-water zone. Each of these parts has its own properties, and identification of these zones will help to calculate the reservoir properties.

With the help of the Acoustic Inversion analysis the Achimov section was subdivided into two separated oil saturated layers: Ach1 and Ach2. Also on the Acoustic Inversion data it is clearly seen that sand bodies have very good lateral continuity and big (up to 40m) thickness in comparison to upper layers.

Later the Acoustic Inversion data was used for attribute analysis and geological model construction.

Analysis of Ach2 layer showed that this area can be subdivided into two main parts – a slope zone and a deep-water zone. During the timeslice analysis such features as channels and zones of folding in the transition area were identified. In these channels an increased sand thickness can be expected. The width of these channels is 50-150 meters.

Two seismic events were picked up in the zone of Ach2 presence. Detailed analysis showed that time thickness of a section between these two reflectors has good correlation (correlation coefficient 0.94) with a gross thickness of Ach2 layer. At the same time the gross thickness of this layer can be correlated with the net sand thickness of Ach2 layer (correlation coefficient 0.74). On the net sand thickness map of Ach2 layer it can be clearly seen a zone with big thickness of sand. This can be a target for future drilling.

Ach1 layer has a more complicated structure than Ach2. All three zones – shelf, slope and deep water can be found there. Detailed understanding of the location of these parts can help to evaluate their reservoir properties.

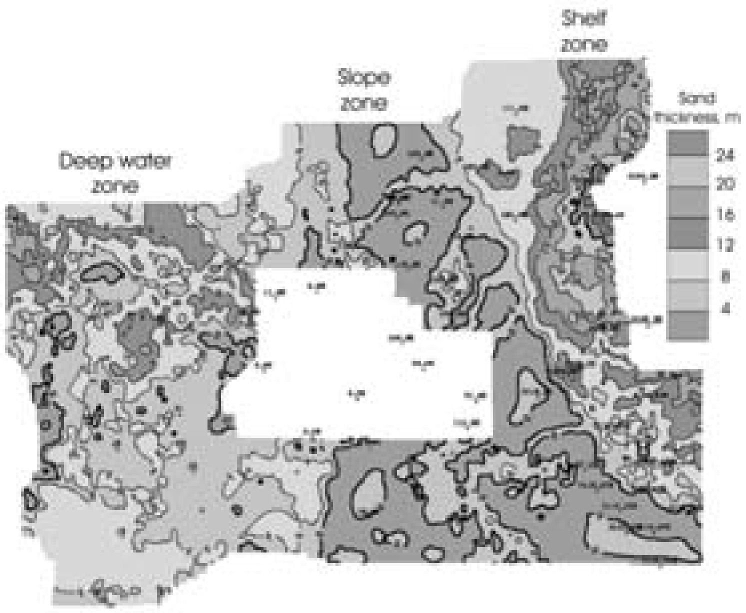


*Fig. 2. Ach1 net sand thickness map*

During the timeslice analysis of Ach1 layer such features as a shelfbreak, zones of folding in the transition area and a fan were identified and contoured. The shel-fbreak was identified as a boundary between two areas of different seismic patterns. The fan is presented on seismic records as a zone of a “mixed” seismic record, it was also proved by the well control.

During the attribute analysis a good correlation (correlation co-efficient 0.77) was found between net sand thickness and maximum peak amplitude on seismic. This allows building a net sand thickness map (Fig. 2), where all main zones, which were listed above can be clearly identified.

As a result of this work two deepest productive layers of the oilfield were analyzed and two net sand thickness maps for future geological modeling were built, some features which can be zones of increased sand thickness and, consequently, targets for future drilling were identified.

## APPLICATION OF PRIMARY COMPONENT ANALYSIS (PCA) TECHNOLOGY FOR SEISMIC BASED RESERVOIR CHARACTERIZATION

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PCA - primary component analysis - is one of the common mathematical techniques widely used in all fields of science. There are different ways to apply it in geology and geophysics. If we are talking about seismic based methods, these are cluster analysis and neural nets.

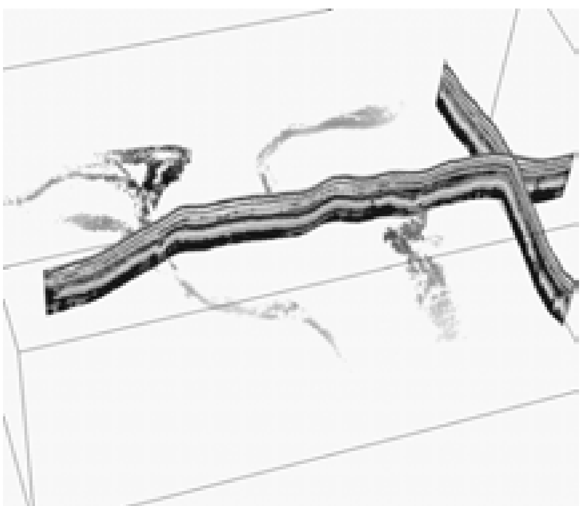

*Fig. 1. Channel bodies in 3D space, field A*

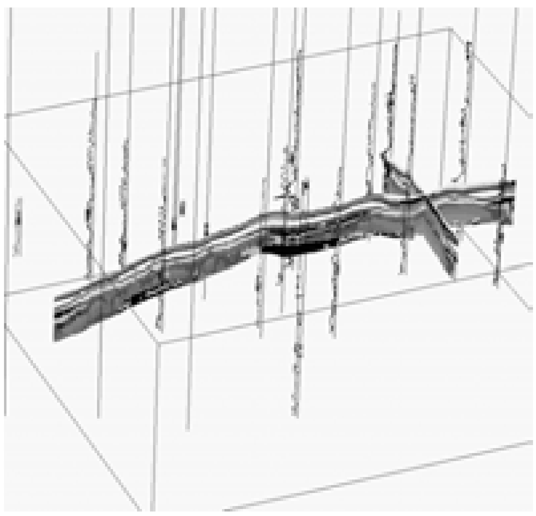

*Fig. 2. Cluster cube, field B*

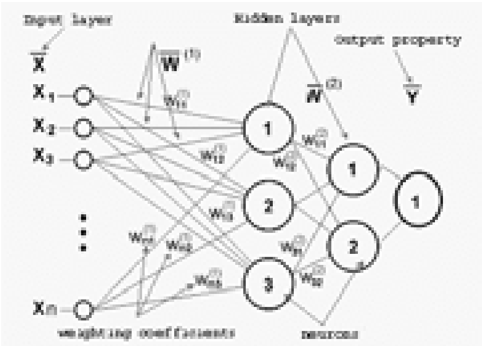


*Fig. 3 Neural nets. Calculating scheme.*

The PCA technique transforms seismic data into PC (primary component) space, after that first n PCAs are kept. The purpose is to discard PCs, which are caused by noise and decrease the number of space dimensions.

To group similar waveform seismic data (which we consider will have the same geological effect) into clusters we use a k-mean clustering algorithm.

In neural nets we use PC values as an input to "train" nets in well's point with the known properties. We make prediction of a certain property on those nets for the whole PCA-transformed seismic cube.

The PCA technique was applied to three Western Siberia oil fields. At field A clustering on PCA-transformed seismic has given an opportunity to define channel bodies in 3D space (Fig. 1).

After that it is easy to distribute different properties (porosity, permeability etc.) separately in channels and bearing strata applying the Sequential Gaussian Simulation (SGS) method.

At field B, we used a cluster cube (Fig. 2) calculated using the same PCA technique. We make cloud transform procedure to receive the porosity cube. In this method we have porosity values known in wells for each point. The obtained cube was used as a soft trend in the Collocated Cokriging SGS.

At the third field we "trained" neural nets on PC values and made a prediction of porosity (Fig. 3). Then we used that porosity as a soft trend in the Collocated Cokriging SGS as above.

## ANALYSIS OF SIDE SCAN SONAR ARTEFACTS BASED ON TTR14 CRUISE DATA

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During processing and interpretation of side scan sonar data of the 14$^{th}$ Training Through Research (TTR14) cruise a problem of amplitude artefacts on shallow water sonograms was faced (Fig. 1). Analysis of these data showed that an artefact appears when the sea bottom depth is less than 900 m. Moreover, depending on area and part of a profile these artefacts have different representations.

In general the shape of artefacts can be described as "stripe" (enhanced amplitude), parallel to the first arrival of a backscattered signal. The first stripe appears on all sonograms and the second and the third stripes are seen in some parts of sonograms.

The subject of this work is to determine a reason of stripe's appearance and to propose a method to eliminate this problem. The first stripe is reflection from the water surface (Fig. 2a). It is received in a slant direction (27°÷35°) and is related to the directional diagram of the antenna. The second and the third stripes are reflections from the bottom and water surface (Fig. 2b, c). Such a model is confirmed by the fact that the difference between the third and the second stripe's arrival time is equal to the difference between the second and the first stripes' arrival time and this difference is equal to TWT from the sonar to the bottom. These differences are approximately the same on all sonar profiles.

There are two possible reasons of appearance of the stripes: 1) bottom morphology – the second and the third stripes appear at the side of a steeper slope; 2) enhanced reflectivity – the second and the third stripes appear on places with high reflectivity. Appearance of artefacts is not related to the

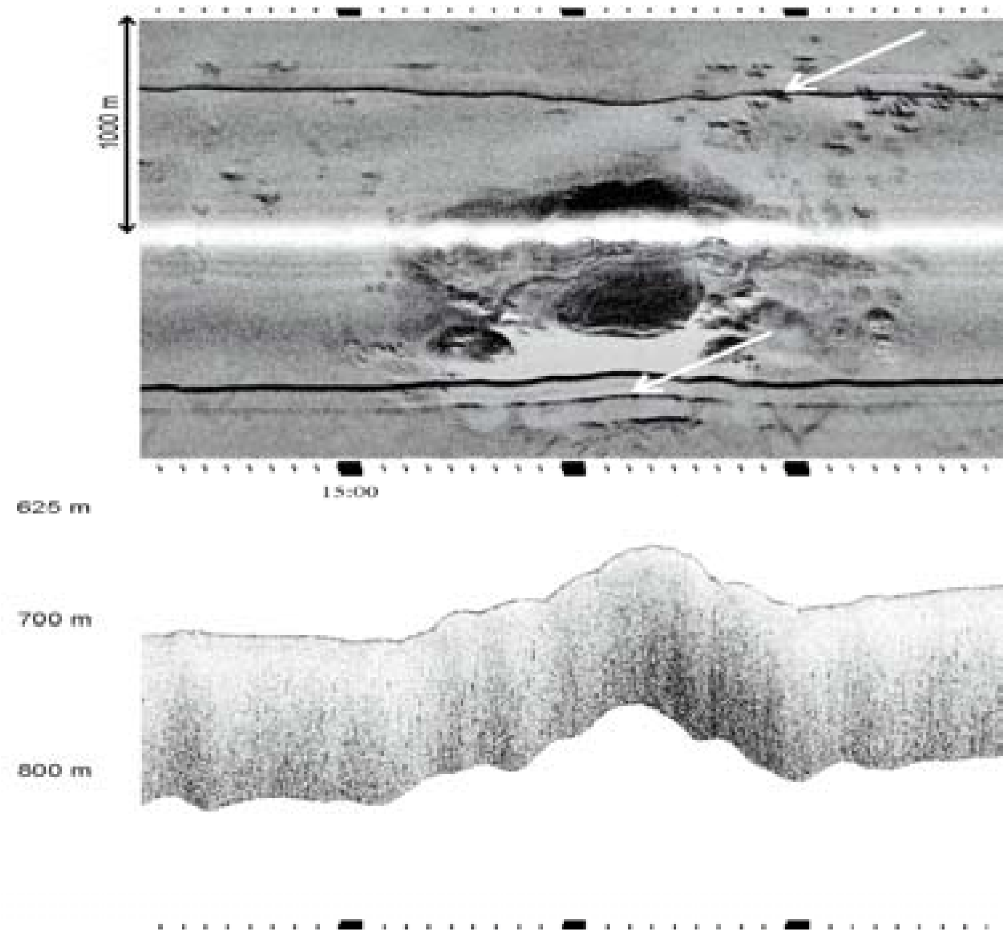


*Fig. 1. Fragment of line MAK-AT110 with artefacts (shown by arrows)*

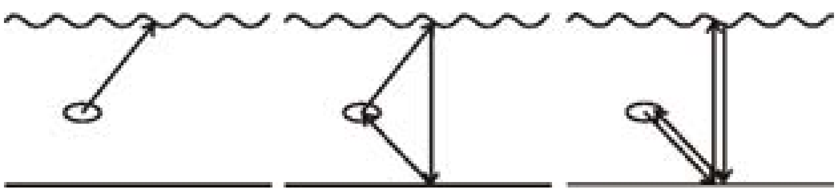


*Fig. 2. Trajectory of waves*

sonar's roll. Thus, if it is known that the reflectivity is constant along the survey line the three stripes show changes in bottom topography, and if topography is constant the three stripes show changes in the reflectivity.

It is impossible to eliminate these artefacts during acquisition of the data. An algorithm of decreasing the enhanced amplitudes and increasing quality of data during the data processing has been suggested. It implies the following steps: 1) to take a trace on a flat part of a profile (a standard trace with the first stripe); 2) to calculate an etalon trace (a suspected trace in this place without stripes, for example, if the depth is higher than 900 m); 3) to mark on each trace time of the first arrival of the stripe; 4) to calculate the difference between the standard and the etalon traces equal to the value of an amplitude of a signal reflected from the water surface; 5) to subtract this value from each trace on a profile (subtracting begins from a marked time). The resulted sonogram has no stripes and amplitude at time of the stripe is approximately equal to the real amplitude of a backscattered signal.

# Climate changes

## THE LAC MBAWANE (CAP VERT) MICROFAUNAS (FORAMINIFERA, OSTRACODES) AND SEA-LEVEL FLUCTUATIONS IN THE UPPER HOLOCENE ALONG THE NORTH SENEGAL COASTLINE

R. Sarr*, B. Sarr, El H. Sow & C.A.K. Fofana

*Département de Géologie, Faculté des Sciences et Techniques, Université Cheikh Anta Diop de Dakar, Sénégal.*
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The Lac Mbawane is an inter dune depression located NE of the Cap Vert peninsula, along the great coast of Senegal. It lies on a North-South direction and is connected with an old hydrographical system of rivers linking the Lac Tanma to the submarine canyon of Kayar (Fig. 1). The lake is placed at about one km from the Atlantic Ocean and stays dry during most of the year. The aim of this work is to study lithological and micropaleontological (foraminifera, ostracodes) composition of a core of 6 m depth located SE of the lake and to discuss on recent depositional environment and climatic fluctuations in the area.

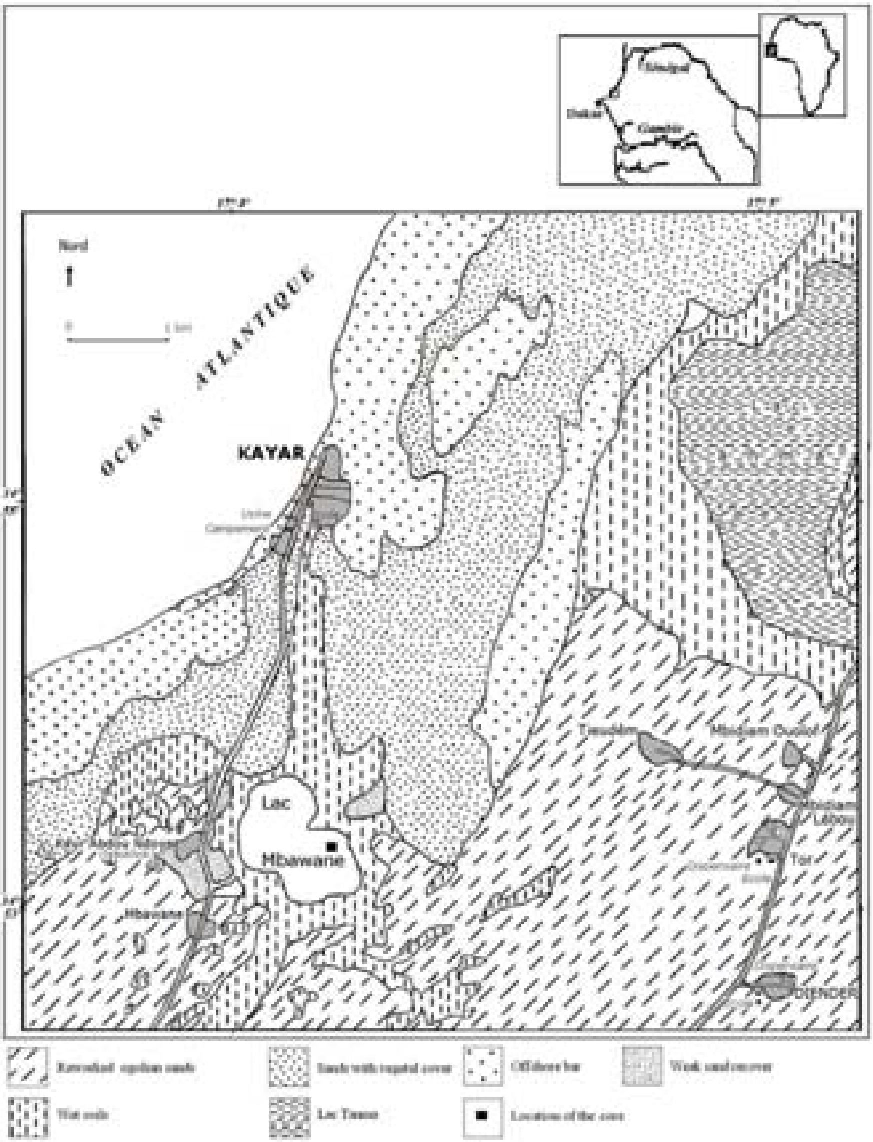


*Fig. 1: Geographic map of the Lac Mbawane area.*

Percentage of lutites and sands of the core allow distinguishing two units in the section: argillaceous mud at the base (600 to 320 cm) and argillaceous sandy mud with levels of shells at the top (320 to 00 cm). There is evidence of correlation between sand and shell levels that correspond to old coastlines because shells are broken and belong to bivalves of littoral or opened lagoon environments.

Foraminifera is the better represented group and comprise 13 species: *Ammonia parkinsoniana* (d'Orbigny), *A. tepida* (Cushman), *Cribroelphidium articulatum* (d'Orbigny), *Elphidium advenum* (Cushman), *E. gunteri* Cole, *E. williamsoni* Haynes and *Quinqueloculina* cf. *pulchella* d'Orbigny are the most frequent of them ; they are associated with some *Nonion* spp., *Pararotalia* sp., undetermined miliolids and rare planktonic foraminifera (*Globigerina* spp.).

Four associations named A, B, C and D can be evidenced in the section:

**Association A** (600 to 400 cm) shows evolution from weakly diversified population (3 species) dominated by *A. parkinsoniana* at the lower part, to more diversified species of lagoonal and marine (*Nonion* sp. and *Globigerina* sp.) characteristic at the upper level. It evidences increasing of the sea-level and evolution of Lac Mbawane from confined to opened lagoon (Ausseil-Badié, 1983; Debenay *et al.*, 1987) .

The monospecific **association B** (400 to 330 cm) is very rich of *A. parkinsoniana* and is related to a confined lagoon with poor nutriments under dry climate.

**Association C** (330 to 230 cm) with 6 species is also dominated by *A. parkinsoniana* and characterise a confined lagoon with weak marine connection.

**Association D** (320 to 70 cm) is also a monospecific *A. parkinsoniana* and evidences confined lagoon under dryer climate. There is no foraminifer encountered at the top of the core.

Exceptional and discontinuous ostracode fauna comprises *Aglaiella* sp. 1 Pinson, *Cyprideis nigeriensis* Omatsola, *Leptocythere* sp. 1 Pinson, *Neomonoceratina iddoensis* Omatsola, *Pseudocytherura calcarata*, *Ruggieria tricostata* Omatsola et *Xestoleberis* sp. 2 Pinson. They are distributed at three discontinuous levels on the core:

**Association 1** (sample 595-590 cm) yields *Leptocythere* sp. 1 Pinson and *Xestoleberis* sp. 2 that characterise opened lagoon with algal cover of the bottom (Pinson, 1980; Carbonel *et al.*, 1983).

**Association 2** (315 to 260 cm) comprises *N. iddoensis,* characteristic of lagoon with mangrove (Peypouquet, 1977; Pinson, 1980; Riffault, 1980; Rouvillois, 1982; Debenay *et al.*, 1990), and marine inner shelf species as *Pseudocytherura calcarata, Ruggieria tricostata* and *Aglaiella* sp. (Omatsola, 1970 and 1972; Pinson, 1980; Riffault, 1980).

**Association 3** (sample 75-70 cm) is composed of monospecific *C. nigeriensis* with dissolved valves. It evidences a closed lagoon without link with the sea.

At the top of the core (70 to 00 cm) there is no ostracode encountered.

Results of lithologic and microfaunal studies allow reconstituting sea-level and climatic fluctuations in the Lac Mbawane area (Fig. 2):

- In the first stage Lac Mbawane evolved progressively to an opened lagoon (associations A and 1) after the most important marine intrusion recorded along the core ;
- The second stage corresponds to a confined lagoon (association B), which marine connection is interrupted by offshore bar and characterise dryer climate ;
- The third corresponds to a week opened lagoon which was bordered by mangrove under more wet climate (associations C and 2) ;
- The forth step corresponds to a confined lagoon isolated from the sea (associations D and 3) by offshore bar under dryer climate ;
- Afterwards, Lac Mbawane evolved entirely in continental condition passing progressively from permanent to a seasonal lake. This has been evidenced by the diatom study led by Fofana (2004) who identified between 60 and 10 cm mainly freshwater species. The lack of all microfossil groups at the top of the core (10 to 00 cm) characterise the seasonal stage of Lac Mbawane under dryer climate that affected the Sahel area since this time. There is no radiometric data available on the core but the two marine levels may correspond to the Dakarian (3000 B. P.) and Saint-Louisian (about 2000 B. P.) transgressions recorded along the senegalo-mauritanian coastline at this time (Hébrard, 1972; Elouard *et al.*, 1975 and 1977; Lézine, 1987).

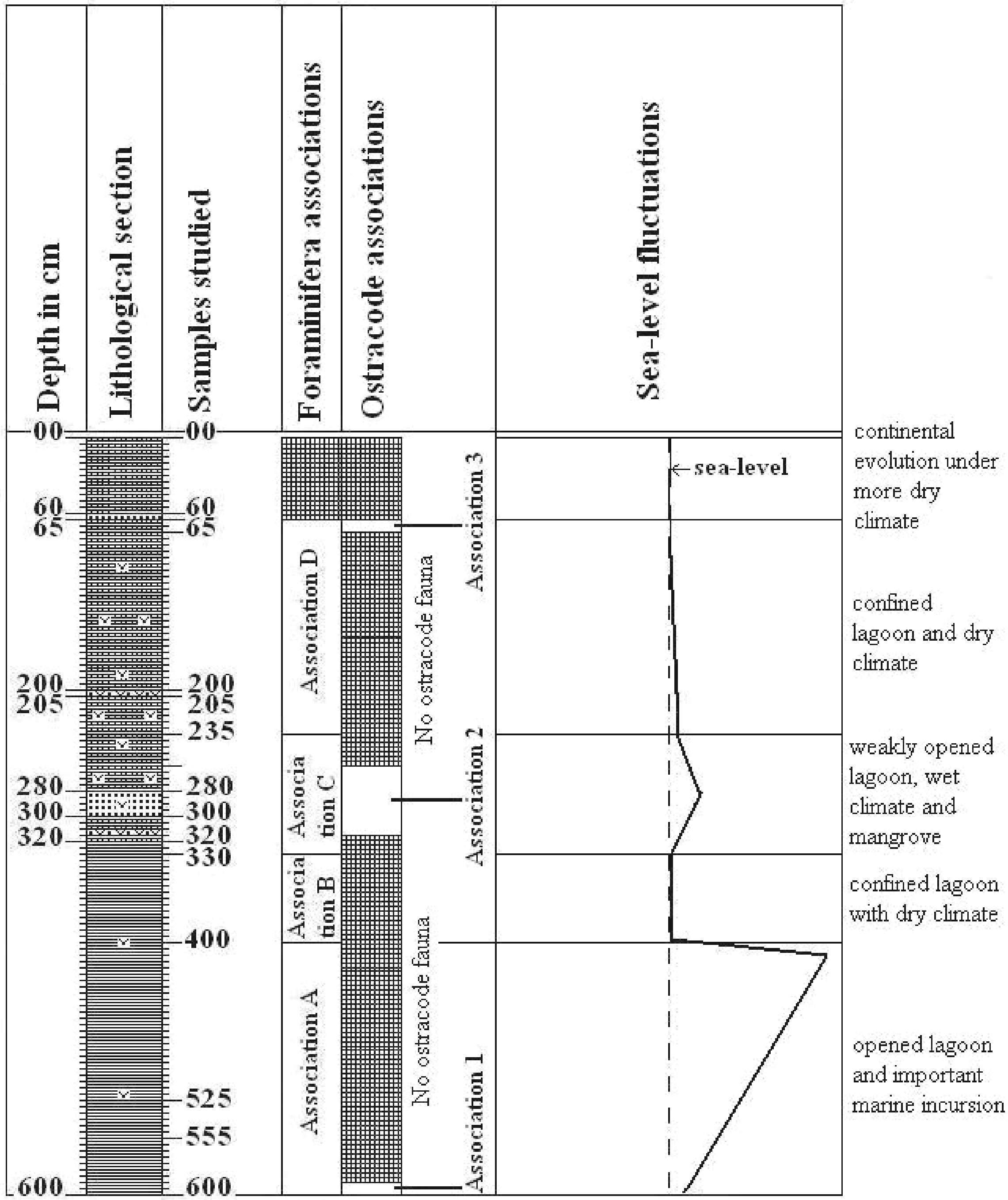


*Fig. 2. Reconstitution of sea-level fluctuations in the Lac Mbawane area during Upper Holocene*

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# ANNEX I

## Conference Committees

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Prof. Kamal TAJ-EDDINE, University Caddi Ayyad, Geology Department, Marrakech
Prof. Naima HAMOUMI, Mohamed V - Agdal University, Geology Department, Rabat

# ANNEX II

# PROGRAMME

**1 February**
Arrival of the participants
Registration

**2 February**

| | |
|---|---|
| 08:30 | Registration |
| 09:00 | Opening |
| 10:00-10:30 | Coffee break |

**Scientific Session 1. Convener: Neil KENYON**

| | |
|---|---|
| 10:30 | M. Ivanov, M. Canals, M. Comas, N. Kenyon, M. Marani, L. Pinheiro and the TTR14 cruise scientific party. MAJOR RESULTS OF THE TTR14 (2004) CRUISE TO THE GULF OF CADIZ AND THE MEDITERRANEAN SEA |
| 11:00 | A. Sungurov. USING GIS SOFTWARE FOR UNIFICATION OF TTR DATA |
| 11:30 | J-P. Foucher. ACTIVE BRINE SEEPAGE FROM THE NILE DEEP SEA FAN |
| 12:20 | N. Kenyon, Ph. Weaver. THE EC HERMES PROGRAMME |
| 12:40 | Discussion |
| 13:00-14:30 | Lunch |

**Scientific Session 2. Convener: Mikhail IVANOV**

| | |
|---|---|
| 14:30 | J-P. Henriet. DECRYPTING THE MESSAGE OF CARBONATE MOUNDS: FROM OUTCROP TO OCEAN DRILLING |
| 15:00 | T.C.E.van Weering, H.de Haas, H.C.de Stigter, F.Mienis, Th. Richter. CARBONATE MOUNDS AND REEFS OF THE ROCKALL TROUGH AND GULF OF CADIZ; MOUNDFORCE PROGRESS |
| 15:20 | N. Hamoumi. CORAL BUILD-UPS OF THE STRAIT OF GIBLALTAR: DEPOSITIONAL MODEL AND ENVIRONMENTAL CONTROL |
| 15:40 | A.J. Wheeler & D.G.Masson. GEOSPHERE FLUID VENTING, SEABED CHARACTER AND HYDRODYNAMIC CONTROLS OF COLD-WATER CORAL BIOHERMS: THE DARWIN MOUNDS, NE ATLANTIC |
| 16:00-16:30 | Coffee break |

**Scientific Session 3. Convener: J-P. FOUCHER**

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|---|---|
| 16:30 | D. Depreiter. ORIGIN AND ACTIVITY OF GIANT MUD VOLCANOES ON THE MOROCCAN MARGIN |
| 16:50 | V. Blinova. HYDROCARBON GASES FROM THE MUD VOLCANIC DEPOSITS OF THE GULF OF CADIZ AREA |
| 17:10 | A. Foubert, L. Maignien, T. Beck, D. Depreiter, D. Blamart & J-P. Henriet. PEN DUICK ESCARPMENT ON THE MOROCCAN MARGIN: A NEW MOUND LAB? |
| 17:30 | D. Praeg, V. Unnithan, P.M. Shannon, N. O'Neill. GAS HYDRATE STABILITY AND FLUID-ESCAPE FEATURES IN DEEP-WATER ENVIRONMENTS WEST OF IRELAND |
| 17:50 | Discussion |

**3 February**

**Scientific Session 4. Convener: Marina CUNHA**

| | |
|---|---|
| 09:00 | E. Bileva. CHEMICAL AND ISOTOPIC EVIDENCE FOR SOURSE OF CARBON IN CARBONATE CEMENT OF MUD BRECCIA IN THE GULF OF CADIZ |
| 09:20 | V.H. Magalhães, D. Birguel, J. Peckmann, L.M. Pinheiro, C. Vasconcelos, J.A. McKenzie, M.K. Ivanov. AUTHIGENIC CARBONATE CHIMNEYS AND CRUSTS FROM THE GULF OF CADIZ: BIOMARKER EVIDENCES OF ARCHAEA MEDIATING ANAEROBIC METHANE OXIDATION |
| 09:40 | E. Kozlova. PSEUDOBIOGENIC ANKERITE ON THE CHIMNEYS RIDGE CLOSE TO GIBRALTAR STRAIT IN THE GULF OF CADIZ |
| 10:00 | A. Shuvalov. CARBONATE CHIMNEYS IN THE GULF OF CADIZ AS A RESULT OF HYDROCARBON VENTING |
| 10:20 | V. Kiselev. RESOLUTION ENHANCEMENT OF MARINE SEISMIC TTR-14 DATA WITH THE USE OF WAVELET ANALYSIS |
| 10:40 | Poster Session and coffee break |

**Scientific Session 5. Convener: Naima HAMOUMI**

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|---|---|
| 11:30 | M.R. Cunha, C.F. Rodrigues, P.R. dos Santos, C.V. de Sá and the TTR14 Leg 1 scientific party. THE FAUNAL ASSEMBLAGE OF THE MEKNÈS MUD VOLCANO (NORTH AFRICAN MARGIN OFF MOROCCO). PRELIMINARY RESULTS OF THE TTR14 CRUISE IN THE GULF OF CADIZ |
| 11:50 | C. F. Rodrigues, M.R. Cunha. COMMON CHEMOSYNTHETIC SPECIES IN THE GULF OF CADIZ: SOME DATA ON THEIR SPATIAL DISTRIBUTION |
| 12:10 | R. Sarr, B. Sarr, El Hadji Sow and A. K. Fofana. LES MICROFAUNES (FORAMINIFERES ET OSTRACODES) DU LAC MBAWANE (CAP VERT) ET LES VARIATIONS DU NIVEAU MARIN DANS L'HOLOCENE SUPERIEUR DU LITTORAL NORD DU SENEGAL |
| 12:30 | N. Hamoumi. THE "TUBOTOMACULUM": A FOSSIL RECORD OF DEEP SEA CORALS |
| 12:50 | Discussion |
| 13:00-14:30 | Lunch |

**Scientific Session 6. Convener: Michael MARANI**

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|---|---|
| 14:30 | A. M. Akhmetzhanov, N.H. Kenyon, E.L. Habgood, C. O'Byrne, M.K. Ivanov and UK-TAPS group. SPECULOBE – A NEAR-OUTCROP SCALE STUDY OF A MODERN DEEP-WATER SAND LOBE AT THE END OF A GRAVITY FLOW CHANNEL |
| 14:50 | J.S. Laberg, S. Guidard, J. Mienert, T. O. Vorren, H. Haflidason and A. Nygård. THE ANDØYA CANYON OFFSHORE NORWAY – PROCESSES OF CANYON GROWTH |
| 15:10 | G. Lastras, M. Canals, B. Dennielou, L. Droz, M. Ivanov, D. Amblas and the TTR-14 Leg 3 Shipboard Scientific Party. THE EIVISSA SLIDES IN THE WESTERN MEDITERRANEAN SEA: MORPHOLOGY, INTERNAL STRUCTURE AND THEIR RELATION WITH FLUID ESCAPE FEATURES |
| 15:30-16:00 | Coffee break |
| 16:00 | TTR EXECUTIVE COMMITTEE OPEN MEETING |

**4 February**
**Scientific Session 7. Convener: Andrey AKHMETZHANOV**

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|---|---|
| 09:00 | F. Gamberi, M. P. Marani. CONTRASTING SEDIMENTATION STYLES IN THE HISTORY OF BACKARC BASINS: A COMPARISON OF RECENT DEPOSITION IN THE VAVILOV AND MARSILI BASINS (RESULTS OF CRUISES TTR4 AND TTR12) |
| 09:20 | M.P. Marani, F. Gamberi, R. Di Roberto. DEEP-SEA TRANSPORT AND DEPOSITION OF THE MATERIAL DERIVED FROM THE 30/12/02 FLANK COLLAPSE OF STROMBOLI ISLAND |
| 09:40 | I. Bouimetarhan, A. Foubert, A. Slimane, J-P. Henriet, M. Ivanov and N. Hamoumi. PLANKTONIC FORAMINIFERA ASSEMBLAGES: AN INDICATOR OF PLEISTOCENE – HOLOCENE PALEOENVIRONMENTAL CHANGES IN SOUTH-EASTERN SARDINIA MARGIN AND STROMBOLI BASIN |
| 10:00 | D. Titkova. PECULIARITIES OF MAK-1M SIDE-SCAN SONAR SIGNAL PENETRATION: CALCULATION ON TTR-14 CRUISE DATA (LEG 4) |
| 10:20 | A. Ovsyannikov. PETROGRAPHY AND CHEMICAL COMPOSITION OF MAFIC LAVAS FROM THE SUBMARINE PART OF STROMBOLI VOLCANO |
| 10:40 | A. Di Roberto, M.Rosi, A.Bertagnini, M.Marani, F.Gamberi. FLANK FAILURE AND VOLCANICLASTIC DEPOSITION AT STROMBOLI VOLCANO (AEOLIAN ISLANDS, ITALY) |
| 11:00-11:30 | Coffee break |

**Scientific Session 8. Convener: Najeeb RASUL**

| | |
|---|---|
| 11:30 | E. Bonatti. TEMPORAL VARIATIONS IN THE GENERATION OF OCEANIC LITHOSPHERE IN THE NORTHERN MID ATLANTIC RIDGE |
| 11:50 | T. M. Alves, T. Cunha, S. Bouriak, A. Volkonskaya, J. H. Monteiro, M. Ivanov and TTR12 Leg 5 Scientific Party. SURVEYING THE FLANKS OF THE MID-ATLANTIC RIDGE: EXAMPLES OF GEOSPHERE-BIOSPHERE COUPLING IN DEEP-SEA AREAS OF THE NORTH ATLANTIC |
| 12:10 | M. Ligi, E. Bonatti. TRANSITION FROM A CONTINENTAL TO AN OCEANIC RIFT IN THE NORTHERN RED SEA: PRELIMINARY RESULTS OF A JANUARY 2005 EXPEDITION |
| 12:40 | I. Kuvaev. AN EXAMPLE OF ANCIENT MARINE DEPOSITS' STUDY BY MODERN SEISMIC METHODS |
| 13:00 | P.L. Ferreira, B.J. Murton & C. Boulter. MAGMATIC PROCESSES BENEATH LUCKY STRIKE SEGMENT, AZORES REGION, 37ºN ON MID-ATLANTIC RIDGE |
| 13:20-14:30 | Lunch |

**Scientific Session 9. Convener: Jean-Pierre HENRIET**

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|---|---|
| 14:30 | I. Uvarov. APPLICAYION OF PCA TECHNOLOGY FOR SEISMIC BASED RESERVOIR CHARACTERIZATION, EXAMPLES FROM WESTERN SIBERIA OIL FIELDS |
| 14:50 | N. Hamoumi, M. Ivanov & J. Gardner. SEDIMENTOLOGICAL STUDY OF THE MOROCCAN FIELD MUD VOLCANIC DEPOSITS, GULF OF GADIZ |
| 15:10 | Report by the TTR14-PCM Prize Committee |
| 15:30 | General discussion |
| 16:00 | Closing |

**5 February**

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|---|---|
| 08:30-19:00 | Geological trip to the High Atlas |

**6 February** Departure of the participants

**POSTERS**

A. Beckstein, A. Eisenhauer, W. Brückmann, J. Fietzke, A. Kolevica, C. Dullo. COMPOSITION AND AGE STRUCTURE OF METHANE DERIVED CHIMNEYS IN THE GULF OF CADIZ (TTR-14)

E. De Boever, D. Depreiter, A. Foubert, B. El Moumni, R. Swennen, J-P. Henriet. ACOUSTIC SEAFLOOR OBSERVATIONS AND CARBONATE SEDIMENTOLOGY OFF MOROCCO: INITIAL RESULTS

D. Depreiter, A. Foubert, J-P. Henriet. GEOFLUID PUMPING IN CARBONATE MOUND SYSTEMS: A FACTOR FOR GROWTH AND STABILISATION?

D. Depreiter, J. Poort, P. Van Rensbergen, J-P. Henriet. GEOPHYSICAL EVIDENCE OF GAS HYDRATE PRESENCE IN SHALLOW MUD VOLCANOES (EL ARRAICHE MUD VOLCANO FIELD, MOROCCAN MARGIN)

F. Fernández-Ibáñez, M. Sánchez-Gómez, G. Marro, M. C. Comas, and J. I. Soto. RECENT TECTONICS IN THE TRANSITION BETWEEN THE EAST ALBORAN AND BALEARIC-ALGERIAN BASINS

F. Fernández-Ibáñez, J. I Soto, and J. Morales. CRUSTAL SEISMICITY IN WESTERN MEDITERRANEAN MARGINS: THE BETIC-RIF-ALBORAN REGION

G. Marro, M.C. Comas. MORPHOLOGY AND SHALLOW STRUCTURE OF TWO SE IBERIAN MARGIN SEGMENTS (PALOMARES AND CARTAGENA MARGINS, WESTERN MEDITERRANEAN)

R.B. Wynn, A.R.H. Akhmetzhanov, B.T. Cronin, P.J. Talling, D.G. Masson, M. Frenz, M. and the CD166 scientific party. TURBIDITY CURRENT PROCESSES AND DEPOSITS IN THE AGADIR CHANNEL AND BASIN OFFSHORE NW MOROCCO: INITIAL RESULTS OF CD166

# ANNEX III
# LIST OF PARTICIPANTS

**Belgium**

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| 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 |
| 89 | IOC-ICSEM Workshop on Ocean Sciences in Non-Living Resources; Perpignan, France, 15-20 October 1990. | E |
| 90 | IOC Seminar on Integrated Coastal Management; New Orleans, U.S.A., 17-18 July 1993. | E |
| 91 | Hydroblack'91 CTD Intercalibration Workshop; Woods Hole, U.S.A., 1-10 December 1991. | E |
| 92 | Réunion de travail IOCEA-OSNLR sur le Projet «-Budgets sédimentaires le long de la côte occidentale d'Afrique-» Abidjan, côte d'Ivoire, 26-28 juin 1991. | F |
| 93 | IOC-UNEP Workshop on Impacts of Sea-Level Rise due to Global Warming. Dhaka, Bangladesh, 16-19 November 1992. | E |
| 94 | BMTC-IOC-POLARMAR International Workshop on Training Requirements in the Field of Eutrophication in Semi-enclosed Seas and Harmful Algal Blooms, Bremerhaven, Germany, 29 September - 3 October 1992. | E |
| 95 | SAREC-IOC Workshop on Donor Collaboration in the Development of Marine Scientific Research Capabilities in the Western Indian Ocean Region; Brussels, Belgium, 23-25 November 1993. | E |
| 96 | IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Zanzibar, United Republic of Tanzania, 17-21 January 1994. | E |
| 96 Suppl. | IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Submitted Papers 1. Coastal Erosion; Zanzibar, United Republic of Tanzania 17-21 January 1994. | E |
| 96 Suppl. 2 | IOC-UNEP-WMO-SAREC lPlanning 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 | lFirst 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 | lChapman Conference on the Circulation of the Intra- Americas Sea; La Parguera, Puerto Rico, 22-26 January 1995. | E |
| 112 | lIOC-IAEA-UNEP Group of Experts on Standards and Reference Materials (GESREM) Workshop; Miami, U.S.A., 7-8 December 1993. | E |
| 113 | IOC Regional Workshop on Marine Debris and Waste Management in the Gulf of Guinea; Lagos, Nigeria, 14-16 December 1994. | E |
| 114 | International Workshop on Integrated Coastal Zone Management (ICZM) Karachi, Pakistan; 10-14 October 1994. | E |
| 115 | IOC/GLOSS-IAPSO Workshop on Sea Level Variability and Southern Ocean Dynamics; Bordeaux, France, 31 January 1995. | E |
| 116 | IOC/WESTPAC International Scientific Symposium on Sustainability of Marine Environment: Review of the WESTPAC Programme, with Particular Reference to ICAM Bali, Indonesia, 22-26 November 1994. | E |
| 117 | Joint IOC-CIDA-Sida (SAREC) Workshop on the Benefits of Improved Relationships between International Development Agencies, the IOC and other Multilateral Intergovernmental Organizations in the Delivery of Ocean, Marine Affairs and Fisheries Programmes; Sidney B.C., Canada, 26-28 September 1995. | E |
| 118 | IOC-UNEP-NOAA-Sea Grant Fourth Caribbean Marine Debris Workshop; La Romana, Santo Domingo, 21-24 August 1995. | E |
| 119 | IOC Workshop on Ocean Colour Data Requirements and Utilization; Sydney B.C., Canada, 21-22 September 1995. | E |
| 120 | International Training Workshop on Integrated Coastal Management; Tampa, Florida, U.S.A., 15-17 July 1995. | E |
| 121 | Atelier régional sur la gestion intégrée des zones littorales (ICAM); Conakry, Guinée, 12-22 décembre 1995. | F |
| 122 | IOC-EU-BSH-NOAA-(WDCA) 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, Saudi Arabia, 8 October 1995. | E |
| 127 | IOC Regional Workshop for Member States of the Caribbean and South America GODAR-V (Global Oceanographic Data Archeology and Rescue Project); Cartagena de Indias, Colombia, 8-11 October 1996. | E |
| 128 | Atelier IOC-Banque Mondiale-Sida/ SAREC-ONE sur la Gestion Intégrée des Zones Côtières ; Nosy Bé, Madagascar, 14-18 octobre 1996. | E |
| 129 | Gas and Fluids in Marine Sediments, Amsterdam, the Netherlands; 27-29 January 1997. | E |
| 130 | Atelier régional de la COI sur l'océanographie côtière et la gestion de la zone côtière ; Moroni, RFI des Comores, 16-19 décembre 1996. | E |
| 131 | GOOS Coastal Module Planning Workshop; Miami, USA, 24-28 February 1997. | E |
| 132 | Third IOC-FANSA Workshop; Punta-Arenas, Chile, 28-30 July 1997 | S/E |
| 133 | Joint IOC-CIESM Training Workshop on Sea-level Observations and Analysis for the Countries of the Mediterranean and Black Seas; Birkenhead, U.K., 16-27 June 1997. | E |
| 134 | IOC/WESTPAC-CCOP Workshop | E |

| No. | Title | Languages |
|---|---|---|
| | on Paleogeographic Mapping (Holocene Optimum); Shanghai, China, 27-29 May 1997. | |
| 135 | Regional Workshop on Integrated Coastal Zone Management; Chabahar, Iran; February 1996. | E |
| 136 | IOC Regional Workshop for Member States of Western Africa (GODAR-VI); Accra, Ghana, 22-25 April 1997. | E |
| 137 | GOOS Planning Workshop for Living Marine Resources, Dartmouth, USA; 1-5 March 1996. | E |
| 138 | Gestión de Sistemas Oceano-gráficos del Pacífico Oriental; Concepción, Chile, 9-16 de abril de 1996. | S |
| 139 | Sistemas Oceanográficos del Atlántico Sudoccidental, Taller, TEMA; Furg, Rio Grande, Brasil,3-11 de noviembre de 1997. | S |
| 140 | IOC Workshop on GOOS Capacity Building for the Mediterranean Region; Valletta, Malta, 26-29 November 1997. | E |
| 141 | IOC/WESTPAC Workshop on Co-operative Study in the Gulf of Thailand: A Science Plan; Bangkok, Thailand, 25-28 February 1997. | E |
| 142 | Pelagic Biogeography ICoPB II. Proceedings of the 2nd International Conference. Final Report of SCOR/IOC Working Group-93; Noordwijkerhout, The Netherlands, 9-14 July 1995. | E |
| 143 | Geosphere-biosphere coupling: Carbonate Mud Mounds and Cold Water Reefs; Gent, Belgium, 7–11 February 1998. | E |
| 144 | IOC-SOPAC Workshop Report on Pacific Regional Global Ocean Observing Systems; Suva, Fiji, 13-17 February 1998. | E |
| 145 | IOC-Black Sea Regional Committee Workshop: 'Black Sea Fluxes' Istanbul, Turkey, 10-12 June 1997 | E |
| 146 | Living Marine Resources Panel Meeting, Paris, France, 23-25 March 1998 | E |
| 147 | IOC-SOA International Training Workshop on the Intregration of Marine Sciences into the Process of Integrated Coastal Management, Dalian, China, 19-24 May 1997 | E |
| 148 | IOC/WESTPAC International Scientific Symposium – Role of Ocean Sciences for Sustainable Development Okinawa, Japan, 2-7 February 1998 | E |
| 149 | Workshops on Marine Debris & Waste Management in the Gulf of Guinea, 1995-97 | E |
| 150 | First IOCARIBE-ANCA Worskshop Havana, Cuba, 29 June-1 July 1998 | E |
| 151 | Taller Pluridisciplinario TEMA sobre Redes del Gran Caribe en Gestión Integrada de Áreas Costeras Cartagena de Indias, Colombia, 7-12 de septiembre de 1998 | S |
| 152 | Workshop on Data for Sustainable Integrated Coastal Management (SICOM) Maputo, Mozambique, 18-22 July 1998 | E |
| 153 | IOC/WESTPAC-Sida (SAREC) Workshop on Atmospheric Inputs of Polluants to the Marine Environment Qingdao, China, 24-26 June 1998 | E |
| 154 | IOC-Sida-Flanders-SFRI Workshop on Ocean Data Management in the IOCINCWIO Region (ODINEA project) Capetown, South Africa, 30 November-11 December 1998 | E |
| 155 | Science of the Mediterranean Sea and its applications UNESCO, Paris 29-31 July 1997 | E |
| 156 | IOC-LUC-KMFRI Workshop on RECOSCIX-WIO in the Year 2000 and Beyond Mombasa, Kenya, 12-17 April 1999 | E |
| 157 | '98 IOC-KMI International Workshop on Integrated Coastal Management (ICM) Seoul, Republic of Korea 16-18 April 1998 | E |
| 158 | The IOCARIBE Users and the Global Ocean Observing System (GOOS) Capacity Building Workshop San José, Costa Rica, 22-24 April 1999 | E |
| 159 | Oceanic Fronts and Related Phenomena (Konstantin Fedorov Memorial Symposium) - Proceedings Pushkin, Russian Federation, 18-22 May 1998 | E |
| 160 | Under preparation | |
| 161 | Under preparation | |
| 162 | Workshop report on the Transports and Linkages of the Intra-Americas Sea (IAS), Cozumel, Mexico, 1-5 November 1997 | E |
| 163 | Under preparation | |
| 164 | IOC-Sida-Flanders-MCM Third Workshop on Ocean Data Management in the IOCINCWIO Region (ODINEA Project) Cape Town, South Africa 29 November-11 December 1999 | E |
| 165 | An African Conference on Sustainable Integrated Management; Proceedings of the Workshops. An Integrated Approach, (PACSICOM), Maputo, Mozambique, 18–25 July 1998 | E, F |
| 166 | IOC-SOA International Workshop on Coastal Megacities: Challenges of Growing Urbanization of the World's Coastal Areas; Hangzhou, P.R. China, 27–30 September 1999 | E |
| 167 | IOC-Flanders First ODINAFRICA-II Planning Workshop, Dakar, Senegal, 2-4 May 2000 | E |
| 168 | Geological Processes on European Continental Margins; International Conference and Eighth Post-Cruise Meeting of the Training-Through-Research Programme, Granada, Spain, 31 January – 3 February 2000 | E |
| 169 | International Conference on the International Oceanographic Data and Information Exchange in the Western Pacific (IODE-WESTPAC) 1999, ICIWP '99 Langkawi, Malaysia, 1–4 November 1999 | Under preparation |
| 170 | IOCARIBE-GODAR-I Cartagenas, Colombia, February 2000 | Under preparation |
| 171 | Ocean Circulation Science derived from the Atlantic, Indian and Arctic Sea Level Networks Toulouse, France, 10–11 May 1999 | E |
| 172 | (Under preparation) | |
| 173 | The Benefits of the Implementation of the GOOS in the Mediterranean Region, Rabat, Morocco, 1-3 November 1999 | E, F |
| 174 | IOC-SOPAC Regional Workshop on Coastal Global Ocean Observing System (Goos) for the Pacific Region, Apia, Samoa, 16–17 August 2000 | E |
| 175 | Geological Processes on Deep-Water European Margins, Moscow-Mozhenka, 28 January-2 February 2001 | E |
| 176 | MedGLOSS Workshop and Coordination Meeting for the Pilot Monitoring Network System of Systematic Sea Level Measurements in the Mediterranean and Black Seas, Haifa, Israel, 15–17 May 2000 | E |
| 177 | Under preparation | |
| 178 | Under preparation | |
| 179 | Under preparation | |
| 180 | Abstracts of Presentations at Workshops during the 7th session of the IOC Group of Experts on the Global Sea Level Observing System (GLOSS), Honolulu, USA, 23–27 April 2001 | E |
| 181 | Under preparation | |
| 182 | Under preparation | |
| 183 | Geosphere/Biosphere/Hydrosphere Coupling Process, Fluid Escape Structures and Tectonics at Continental Margins and Ocean Ridges, International Conference & Tenth Post-Cruise Meeting of the Training-Through-Research Programme, Aveiro, Portugal, 30 January-2 February 2002 | E |
| 184 | (Under preparation) | |
| 185 | (Under preparation) | |
| 186 | (Under preparation) | |
| 187 | Geological and Biological Processes at deep-sea European Margins and Oceanic Basins, Bologna, Italy, 2-6 February 2003 | E |
| 188 | Proceedings of 'The Ocean Colour Data' Symposium, Brussels, Belgium, 25-27 November 2002 | E |
| 189 | Workshop for the Formulation of a Draft Project on Integrated Coastal Management (ICM) in Latin America and the Caribbean (LAC), Cartagena, Colombia, 23-25 October 2003 | E F (electronic copy only) |
| 190 | First ODINCARSA Planning Workshop for Caribbean Islands, Christchurch, Barbados, 15-18 December 2003 | E (electronic copy only) |
| 191 | North Atlantic and Labrador Sea Margin Architecture and Sedimentary Processes - International Conference and Twelfth Post-cruise Meeting of the Training-through-research Programme, Copenhagen, Denmark, 29-31 January 2004 | E |
| 192 | Regional Workshop on Coral Reefs Monitoring and Management in the ROPME Sea Area, Iran I.R., 14-17 December 2003 | E (under preparation) |
| 193 | Workshop on New Technical Developments in Sea and Land Level Observing Systems, Paris, France, 14-16 October 2003 | E (electronic copy only) |
| 194 | IOC/ROPME Planning Meeting for the Ocean Data and Infomation Network for the Central Indian Ocean Region | (under preparation) |
| 195 | Workshop on Indicators of Stress in the Marine Benthos, Torregrande-Oristano, Itay, 8-9 October 2004 | E |
| 196 | International Coordination Meeting for the Development of a Tsunami Warning and Mitigation System for the Indian Ocean within a Global Framework, Paris, France, 3-8 March 2005 | E |
| 197 | Geosphere-Biosphere Coupling Processes: The TTR Interdisciplinary Approach Towards Studies of the European and North African Margins; International Conference and Post-cruise Meeting of the Training-Through-Research Programme, Morocco, 2-5 Febriary 2005 | E |