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SEDIMENTARY BASINS OF THE MEDITERRANEAN AND BLACK SEAS

4th Post-Cruise Meeting
Training-through-Research programme

Abstracts

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Introduction

The International conference on "Sedimentary Basins of the Mediterranean and Black Seas" dedicated to the 5th Anniversary of the UNESCO-ESF Training Through Research Programme (TTR) was organized by UNESCO-MSU Research and Training Center in Marine Geology and Geophysics (Geology Faculty, Moscow State University, MSU) and held in Moscow and Zvenigorod (Russia) from 29 January to 3 February 1996.

About 100 scientists and students from 10 countries participated in the conference. At the plenary session at Moscow State University and at thematic sections in Zvenigorod about 50 oral presentations were made. They were based mostly on data obtained during five scientific cruises in the Mediterranean and Black Seas organized by the TTR Programme between 1991 and 1995. A meeting of the Programme's Executive Committee and two round table discussions were held during the conference to discuss the future of the programme.

The opening remarks made by the Vice-Rector of MSU Prof. V. Trofimov were followed by that of the Dean of the Geology Faculty, Prof. B. Sokolov. The opening speakers commented upon the importance of the TTR Programme, which in recent years has become one of the most dynamic and successful marine geoscience-related research and training programmes in the Mediterranean-Black Sea region. The success of the programme derives to a large extent from the scientific achievements as reflected in numerous scientific publications and presentations at various scientific fora: it also arises from a strong educational component, resulting from its "Floating University" facility. This aspect has stimulated the growth of a new generation of young scientists actively working in the field of marine geology and geophysics, which is in agreement with the main objectives of UNESCO, and in particular those of the TEMA programme of the Intergovernmental Oceanographic Commission (IOC).

Topics of scientific research for 1996-2000 were outlined during a two-day round table discussion (see below) which aimed at determining the direction of the programme scientifically and geographically over the next five years and getting plans completed early in order to secure funding. Among them are the continuation of the study of mud volcanoes and related fluid venting through the seafloor, deep sea depositional systems, neotectonics of collision zones, processes at straits, and catastrophic geological events in the Eastern Mediterranean. A new Scientific Committee was established for this new phase of the programme, and a new Executive Committee was appointed. The preparation of a special publication collating the presentations made at the post-cruise meeting was planned.

TTR Executive Committee:

M. Comas (Spain)
M. Ivanov (Russia)
R. Kidd (United Kingdom)
M. Marani (Italy)
J. Woodside (the Netherlands)
UNESCO/IOC liaison officer

TTR Scientific Committee:

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M. Ergun (Turkey)
J.P Foucher or J. Mascle (France)
N. Kenyon (United Kingdom)

G. Kullenberg (UNESCO/IOC representative)
A. Limonov (Russia)
A. Maldonado (Spain)
J. van Hinte (the Netherlands)
Additional members to be confirmed.

Proposed targets for 1996 to 2000 Research Programme (not exclusive):

1996 Anaximander Mountains and Florence Rise (eastern Mediterranean) and Black Sea: to complete work from 1995 on mud volcanoes and deep sea sedimentation;
1997 Atlantic Ocean and western Mediterranean Sea: studies of straits and tectonics of SW Balearic Basin and E Alboran Sea/eastern Mediterranean (Antalya Basin/Adana Basin);
1998 Catastrophic Events: to study Homogenite and north African margin sedimentary processes;
1999 Mud diapirs and mud volcanism, tectonics of Mediterranean Ridge and Black Sea;
2000 Anoxic basins and Danube Fan.

Acknowledgments

The Organizing Committee of the conference would like to thank the following organizations for the generous support, necessary funding, and other facilities they provided for this meeting: UNESCO; the Intergovernmental Oceanographic Commission (IOC) of UNESCO; Russian Foundation for Fundamental Research (RFFR); Ministry of Science and Technological Policy of the Russian Federation; Moscow State University and its Geology Faculty; Institute of Lithosphere of the Russian Academy of Sciences, Prof. N. Bogdanov; national funding sources in France, Italy, the Netherlands, Spain, and the UK, from which travel and accommodation of some of the participants was covered.

For further information:

Expressions of interest in participating in the TTR cruises, and proposals for further research targets should be addressed to UNESCO/IOC (fax: +33 1 4056 9316, e-mail: g.kullenberg @unesco.org) or to the TTR Coordination office (attn. J. Woodside, fax: +31 20 646 2457, e-mail wooj@geo.vu.nl).

PLENARY SESSION

TTR PROGRAMME: MAIN SCIENTIFIC RESULTS

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Over the past 5 years the Training Through Research programme has developed a leading position in research into the nature of mud volcanoes on the Mediterranean Ridge and in the Black Sea, and it has made substantial contributions as well in the field of deep-sea sedimentation and the neotectonic evolution of the Mediterranean. Mud volcanoes have been found in many different areas along the Mediterranean Ridge, indicating that they are not just a limited local phenomenon but significant agents for the mixing of sediments in accretionary prisms. Degassing and venting of fluids was observed during TTR-3 on Napoli. Although activity is rather low level at the moment, there is evidence for more far reaching eruptions which can carry larger blocks of sediment over a kilometre from the volcano. Observations and their interpretation in this mud volcano field were confirmed in general by ODP Leg 160 drilling on Milano and Napoli mud volcanoes.

The Black Sea mud volcanoes occur in an entirely different setting to those of the Mediterranean, which provides useful insights, through comparison, into mechanisms of mud volcanism. Five were studied in detail including a new and recently active one that was discovered during TTR-3. Methane seepage at the sea floor around this mud volcano is inferred from unusual sea floor features, long and narrow criss-cross lines, interpreted as carbonate encrusted fractures. During a neotectonic study of the Cyprus Arc in 1991, it was demonstrated that there is no distinct plate boundary but a broader zone of distributed deformation. This is somewhat similar but not as advanced as the deformation zone in south-eastern Turkey and Syria. The eastern part of the Cyprus Arc is deforming along specific zones located in a broad belt between the Kyrenia-Misis structure and the West Tartus Rise at the north edge of the Levantine Basin; and the Anaximander Mountains at the junction of the Cyprus Arc with the Hellenic Arc are several large blocks absorbing the plate motions from both arcs. The middle portion of the Cyprus Arc is colliding with the Eratosthenes Seamount on the outer edge of the African Plate. The seamount is breaking up as it is thrust beneath the southern margin of Cyprus in the north and thrust beneath the Nile Cone in the south. Thus the deformation arising from plate convergence here involves geological elements extending half way across the eastern Mediterranean.

In the far western part of the Mediterranean lies another collision zone within the Alboran Sea. Here the active tectonics are observed to control the course of the Andarax Canyon system. In its upper course, the canyon follows the Serrata fault zone, in the middle part it diverges down slope until it encounters a down-to-the-north fault which causes the canyon to turn to the south-east, making a 90 degree change in course across the continental slope. Not only has faulting controlled the direction of the canyon but observed meanders are inferred to have been formed when the slope was less steep and later tilted tectonically. Although the canyon is not currently active as a conduit for material to reach the deep basin from the shelf, it is locally active as inferred from channel scouring and erosion of slumps which have entered the channel from the sides. The Rhone canyon system, in contrast to the Andarax, is larger and surprisingly dynamic. The neofan, a sandy lobe which developed from deposits of a recently avulsed channel, is undergoing active erosion. Large unfilled scours, channel switching, terrace-cutting, and so on are evidence from TTR-2 that this is so. The eroded material is probably deposited in the deep Algero-Provencal basin. Bedforms observed at the edge of the abyssal plain during the TTR-4 investigation into the destination of the eroded sediments suggest a low velocity flow regime in which is energy is dissipating rapidly.

West of Sardinia, distal Var bedforms were inconclusively investigated during TTR-4. Interfering currents from the Sardinia margin may be a cause of this. Beyond the coarse canyon deposits on the Sardinia and south-west Corsica rise there was evidence from areas

of ripping up of thin superficial sediment layers that strong currents are present. Rip-up clasts were retrieved in cores from the deeper basin to the west.

The Stromboli canyon in the south-eastern Tyrrhenian Sea appears to be very active also, most likely because of strong currents and unstable margins. A mixture of hemipelagic and volcaniclastic sediment from the slopes is carried out into the Marsili Basin. Some volcanic sediment from Stromboli is carried directly north into the basin where it drapes the volcanic basement topography.

These are but a few of the highlights of five years of research. Evidence of the growing success of the programme is clear from the exponential increase in papers accepted into international journals between 1992 and 1996, in which year we will publish a special issue of Marine Geology on the subject of the Mediterranean Ridge Diapiric Belt. During the same time the number of abstracts/presentations at a variety of international congresses has maintained a fairly stable level in the double digits, indicating that the research results are being circulated widely prior to publication. It is especially gratifying that a significant number of presentations are made by younger researchers from the programme - more than half, when post-cruise meetings are considered.

This success has three principal reasons. It is in part a function of the broad level of international interest in the research programme which has resulted in a very active ESF network and co-operative proposals for funding of joint activities. It is also a result of the unique integration of students and young scientists with experienced experts in a way which optimises both the educational and research aspects.

Finally, the programme has benefited from a certain flexibility and ability to react quickly to promising research results by rapid follow-up with tools suitable to the scientific goals.

GEOLOGICAL AND GEOPHYSICAL EVIDENCE FOR THE HOLOCENE SPECIAL EVENT RECORDED IN THE EASTERN MEDITERRANEAN DEEP-SEA RECORD

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Extended geological and geophysical exploration of basinal settings in different areas of the eastern Mediterranean documented the existence of a several meters thick Holocene mud layer, typically showing a graded basal part.

The timing of the event producing this peculiar deposit can be determined with a certain accuracy, and is compatible with the gigantic exposition of Santorini "Bronze Age" eruption 3500 ys BP, which supposedly produced a strong seismic sea wave or tsunami. Order of magnitude calculations demonstrated that the wave speed was sufficient to induce erosion of the bottom and liquefaction of the soft unconsolidated sediments draping the deep-sea floor in wide areas of the Ionian Basin.

Over 50 deep-sea cores recovered and investigated in the last 20 years record this event, which is materialised by a fine grained "homogenite" layer, up to more than 24 m thick (in the Sirte Abyssal Plain area).

Several depositional models have been identified, based on thickness, composition, carbonate content and sedimentary structures of the deposit, and related to setting and source areas.

MUD VOLCANISM IN THE DEEP MEDITERRANEAN AND BLACK SEAS, ITS ORIGIN AND GEOLOGICAL ROLE

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Mud volcanism is widespread in different geological settings all over the world, but it is yet poorly studied in deep-sea environments. It is known from literature that mud volcanoes are common features for deep sedimentary basins and thick accretionary complexes. They are often associated with oil and gas fields and seeps and acoustic anomalies on seismic sections. Different fluids and especially hydrocarbon gases play a very important, probably critical part of their origin. The compulsory conditions for the mud volcanism development are as follows:
(i) the presence of a deep source of hydrocarbon gases;
(ii) gas traps in sedimentary sequence;
(iii) good caprocks not allowing gas to diffuse through pores and microfractures;
(iv) overpressure below a caprock due to fast sedimentary burial of a gas trap or owing to lateral tectonic stress resulting in thrust pattern;
(v) triggering mechanism allowing the gas energy to be realised through catastrophic eruption or a series of weak eruptions.

The relationship of mud volcanic activity to the presence of hydrocarbon gas was established directly or indirectly (both onshore and offshore) for all mud volcanoes, which were studied in detail.

During the investigations within the TTR programme, direct evidence for gas seeps or gas-saturated mud breccia from mud volcanoes was found in the Kerch and Taman Peninsulas, deep Black Sea (MSU, Yuzhmorgeologiya, Tredmar, and Vassoevitch mud volcanoes), and on the Mediterranean Ridge (Napoli and Stoke-on-Trent mud volcanoes). Rare analyses of gas composition suggest that gas consists mostly of methane, its homologies, and H_2S. Carbon isotopic composition, as a rule, shows a mixed origin for these gases, implying the presence of thermogenic gas from a deep source. The presence of thermogenic gas is also inferred from the ration of methane to its homologies (heavy hydrocarbon gases). It seems to be very important to reveal the sources for these hydrocarbons that could explain not only their role in the mud volcanism process but give insight into hydrocarbon potential for a sedimentary basin.

All mud volcanoes can be roughly separated into 5 types: (1) mud volcanoes forming a classical cone-like construction, with well-displayed mud flows and small craters (Yuzhmorgeologiya, Novorossiysk, and Toronto); (2) mud volcanoes having well-expressed wide craters (more than 1 km in diameter) (Napoli, MSU); (3) mud volcanoes related to negative relief features (depressions on the seafloor or lakes on land) (Tredmar); (4) complex structure with numerous craters within a single field (Gelendzhik mud volcano plateau); and (5) buried, or dormant mud volcanoes (in the Cobblestone-3 area and in the UN area on the Mediterranean Ridge).

Onshore mud volcanoes have generally similar characteristics. The morphology of mud volcanoes seems to reflect their origin and, first of all, physical properties of mud breccia and its fluid saturation. According to our data, mud volcanoes with large diameter craters and mud volcanoes with collapse structure are characterised by much more intensive gas outflow and by higher saturation of mud breccia with gases

The following set of geochemical analyses was carried out for the investigation of organic matter: determination of the content of total organic carbon (TOC); determination of the mobile part of organic matter by a semi-quantitative fluorescent analysis; Rock-Eval pyrolysis, quantitative definition of bitumen with the help of cold and hot extraction's with chloroform, the study of the composition of bitumen with the help of chromatography.

The executed analyses show that the organic matter content in mud breccia from the Black Sea mud volcanoes is much higher than that from the Mediterranean mud volcanoes. The quantity of mobile components of organic matter is also higher in the Black

Sea mud volcanoes. The results of the Rock-Eval pyrolyses demonstrate that the rocks containing organic matter have generally a medium to high potential of source formations but they did not reach "the oil window" according to the classification of Tissot and Welte. In all cases T_{max} was below 430°C, and the composition of organic matter and the degree of its maturation suggest that it could produce mainly gaseous hydrocarbons.

Of course, these hydrocarbon gases are only a part of gases, which can percolate through craters. This part of hydrocarbon gases could strongly affect the geochemical environments in periods between catastrophic eruptions, when the channel for the migrating hydrocarbons is opened above the main caprock. We still know almost nothing about the possible sources of deeper gases, whose part is believed to be still more important in the origin of mud volcanoes.

SECTION 1: TECTONICS

ODP LEG 161 DRILLS THE WESTERN MEDITERRANEAN

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Leg 161, the second in two Ocean Drilling Program legs in the Mediterranean Sea, drilled a transect of six sites in the western Mediterranean. Sites 974 (Tyrrhenian Basin) and 975 (Menorca Rise, South-Balearic Basin) were dedicated to paleoceanography and Sites 976, 977, 978, and 979 (Alboran Basin) focused on tectonic goals but also involved paleoceanographic studies. Paleoceanographic and tectonic objectives are connected in that the tectonic evolution of the Alboran Sea basin is a central theme for understanding the history of the Mediterranean Atlantic gateway that conditioned the Messinian desiccation and the water-circulation in the western Mediterranean from 5.0 My ago. Major paleoceanographic objectives of Leg 161 in the western Mediterranean were: (1) the presence of sapropels and timing of sapropel deposition; (2) the gradients for physical, chemical, and biological factors during periods of sapropel formation; (3) the pattern of sedimentation (sapropels being only one extreme) to reconstruct the region's environmental and climatic history; (4) the dynamics of water circulation through cycles of high productivity and bottom-water anoxia and the hydrography of inflowing Atlantic waters during the last 5.0 My; and (5) the environmental conditions during the end of the Messinian evaporite deposition and the re-establishment of the open-marine system during the earliest Pliocene or latest Miocene.

The main focus of the tectonic program during Leg 161 was on the understanding of the dynamics, kinematics, and deformation of the continental lithosphere that led to the development of Mediterranean extensional basins in Miocene collisional settings. Principal tectonic objectives of drill-sites in the Alboran Sea basin were: (1) the type of crust and nature of the basement; (2) the character, magnitude and timing of extensional faulting; (3) the postrift deformation - latest Miocene to Holocene folding, strike-slip faulting and collapse of the basin; (4) the role of magmatism and volcanism during the synrift and post-

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rift tectonic evolution; and (5) the synrift versus postrift subsidence and the pattern of total tectonic subsidence.

During Leg 161 a total length of 3.9 km of sediment and rock cores were collected from nearly 1 km below the sea floor. Most of the sediments recovered represent stratigraphic sequences extending more than 5 million years back in time to the Miocene /Pliocene boundary - just following the time when the Mediterranean dried up. Sedimentation rates of these sequences varied between 3-4 cm/ky in the Tyrrhenian and South-Balearic Basins, and 15-30 cm/ky in the Alboran Basin. APC (Advanced Piston Cores) and XCB (Extended Core Barrel) drilling at multiple offset holes ensured continuous recovery of Pliocene-to-Pleistocene sequences at all of Leg 161 sites. At each site, composite ("spliced") sections were constructed from multiple offset holes to provide a complete, continuous, and undisturbed stratigraphic record utilising overlapping intervals of cores from the different holes. Distinctive features were correlated between cores from each hole and depth-shifted to meters composite depth to produce single composite section.

One of the most intriguing paleoceanographic results of Leg 161 was the discovery of sapropels-discrete dark, organic-carbon-rich layers believed to reflect distinct changes in Mediterranean climate and marine biological production in the western Mediterranean. Sapropel and organic-rich layers were recovered in all three western Mediterranean basins: 36 sapropels at Site 974 (Tyrrhenian Sea), 38 sapropels at Site 975 (Balearic Sea), and up to 40 organic-rich layers at Sites 976, 977, and 979 (Alboran Sea). Drilling results demonstrated that in the western Mediterranean, sapropel formation was minor during the Pliocene and started in the earliest Pleistocene, at about 1.8 Ma. They contain between 0.8 and 2.5% organic carbon; maximum concentrations of >6% organic carbon were found in the Tyrrhenian Sea.

At Site 975 (Menorca Rise) two cycles of Messinian evaporites were recovered below earliest Pliocene/Miocene(?) carbonate-rich sediments. These sediments presumably represent the "Lago Mare" facies typically found in the eastern Mediterranean, and also recovered at Site 974 (Thyrrenian Basin), which may well represent the transition from restricted to open marine conditions in the western Mediterranean. At the Alboran Sea sites, time-equivalent sections are presented as turbidite facies with strong terrestrial contributions (Site 976) or as deep-sea (?) channel facies (sandy gravel; Sites 977 and 978). No evaporite series were encountered in the Alboran Sea, therefore, Alboran sites are thought critical to determine the history of the Atlantic-Mediterranean gateways.

Site 976 penetrated through the Pleistocene/Miocene sequence of the Western Alboran Basin and cored 258.97 m of high-grade metamorphic rock down into two basement holes. Basement samples consist of high-grade schist and gneiss, with minor amounts of marble, and dikes and migmatitic segregation of granitic material, which yielded information on the origin and evolution of the Alboran Sea basin. Metamorphic conditions of these rocks indicate that these rocks underwent a significant decrease in pressure accompanied by constant or possible increasing temperature. Drilling demonstrates that the basement beneath the Alboran Basin is formed by rocks of continental origin that have undergone exhumation and decompression. Logging at these holes, that included a spectacular suite of Quad-Combo, Formation Micro Scanner (FMS), Bore Hole Televiewer (BHT) and Geochemical Tool (GLT), will help to fill gaps in basement recovery and to know the spatial orientation of metamorphic and tectonic structures.

Sites 977 and 978 in the Eastern Alboran Basin and Site 979 in the Southern Alboran Basin cored through a zone of post-Messinian compressional structures within the sedimentary sequence, yielded information on the age and nature of the later stages of tectonic reorganisation of the Alboran basin. At these sites drilling demonstrates the age and character of the M-reflector which correspond to a lowermost Pliocene, erosional and angular unconformity.

Leg 161's discovery of sapropels in the western Mediterranean will require strong revisions of the paleoceanographic concepts that relate sapropel formation to mechanisms that affect only the eastern Mediterranean basins. Drilling results in the Alboran Sea are expected to have immediate applications in establishing geodynamic models on the origin and evolution of Mediterranean-type back-arc extensional basins.

A NEOGENE EXTENSIONAL BASIN IN COLLISIONAL SETTING: TECTONIC RESULTS OF ODP LEG 161 IN THE ALBORAN SEA

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Among the Mediterranean convergent boundaries, the Paleogene to Neogene collision between the Eurasian and African plates at the westernmost Mediterranean Sea has resulted in a broad region of distributed deformation rather than a discrete plate boundary. This broad region comprises the Betic, Rif, and Tell Cordilleras linked across the Gibraltar Arc, and includes the extensional basins that form the Alboran and South Balearic Seas. The apparent paradox of extensional basin formation and crustal stretching during the collision of the Eurasian and Africa plates has been a long-standing problem in Mediterranean tectonics.

The Alboran Sea basin was formed during the early to middle Miocene by extension at the site of a former (late Cretaceous to Paleogene) collisional orogen. The basin is floored by extended continental crust, and developed behind an arcuate thrust belt (Gibraltar Arc) that was tectonically active before and during extension in the basin. Geophysical data indicate that the basin is floored by thinned crust (from about 24 to 10 km), and multichannel seismic profiles image a complex structure involving basement and more than 6 km-thick early Miocene (Burdigalian) to Pleistocene sedimentary sequences. The present-day structure of the basin resulted from superimposed extensional and compressional tectonic stages. The Miocene extension directions in the basin, and those of the coeval thrusting in the surrounding orogenic belt are not clearly related to the relative motion of Eurasian and African plates.

For tectonic purposes, the Ocean Drilling Program targeted the Alboran Sea as the optimum area to study the origin of the western Mediterranean "back-arc" basins. The prime tectonic objective of Leg 161 (Sites 976, 977, 978 and 979) in the Alboran Basin was to determine the response of the crust to compressional and extensional forces, and to better understand the kinematics and deformation of the Mediterranean continental lithosphere particularly in regard to: a) the origin of extensional basins developed on former collisional orogens, b) the dynamics of the collapse of collisional ridges resulting in extensional basins surrounded by arc-shaped orogenic belts, and c) actual or sub-actual collisional processes. Furthermore, the impressive amount of geological and geophysical data on this region provides valuable information about the brittle and ductile deformation of the crust, on the magmatism in rifting processes, and on the role of upper mantle in crustal modification and lithosphere evolution, altogether considered essential to complement and constrain any drilling's tectonic results.

Site 976 was drilled on a basement horst in the Western Alboran Basin and sampled, beneath the sedimentary sequence, 259 m (669.7-928.7 m bsf) and 50.53 m (652.08-702.5 m bsf) of high-grade metamorphic rocks in two holes (976B and 976E). The contact between the basement and the overlaying sediments is sharp and has an irregular topography produced by faulting. Drilling at Site 976 discovered that the basement of the Alboran Basin is formed of a sequence of metamorphic rocks composed of : (1) high-grade schist (dark-grey graphitic schist with biotite, sillimanite aggregates, and andalusite and garnet porphyroblasts); (2) gneiss (medium-gray felsic gneiss, with biotite, feldspar, plagioclase, sillimanite, andalusite, and blue green cordierite porphyroblasts); (3) migmatitic gneiss (medium grey felsic biotite-cordierite sillimanite-andalusite-gneiss with irregular veins and patches of light gray, weakly foliated or unfoliated granite with biotite and tourmaline); (4) marble (very pale green, gray or white crystalline dolomite marble and calcite marble, with minor amounts of phlogopite and chlorite); (5) calc-silicate rock (banded rocks with thin layers of calcite or dolomite, garnet, plagioclase, green calc-silicate minerals including diopside and calcic amphibole); and (6) granite (discrete pieces of light gray to white, fine-grained hypidiomorphic granular leucogranite with biotite and tourmaline, probably in the form of dikes). Foliation in schist and gneiss shows evidence of penetrative ductile defor-

mation that produced a suite of small-scale structures and fabrics and was followed by extensive brittle fracturing. The metamorphic sequence is also cut by numerous zones of fault-breccia and fault-gouge that mark zones of brittle faulting. In the upper 40 m of basement some fault breccias are formed by highly angular metamorphic clasts in a matrix of Miocene sediments. Some left-lateral oblique slip along discrete faults is suggested by striae on subvertical fault-planes cross-cutting the basement rocks. Preliminary shipboard estimates of P-T conditions suggest that the high grade schist underwent a decrease in pressure accompanied by constant or possibly increasing temperature. Migmatite gneiss and gneiss also indicate a late superimposed high-T metamorphism under low P-conditions with granite formation. The metamorphic history of basement rocks at Site 976 is most easily explained by tectonic exhumation of middle crustal rocks. These basement rocks closely resemble high-grade metamorphic rocks belonging to the Alpujarride Complex of the western Betic Cordillera (Spain), particularly those neighbouring the Ronda peridotite massif. Drilling results at Site 976 confirm the continental nature of the crust beneath the Alboran Sea by sampling these metamorphic rocks, and constrain the age of extensional episodes in the basin by recovering late middle-Miocene sediments on the top of a basement horst.

Sites 977 and 978 lie in small strike-slip fault-bounded sub-basins south and north of the Al-Mansour seamount (Eastern Alboran Basin), and drill through a post-rift sequence (latest Miocene to Pleistocene) that can yield information on the subsidence history and tectonic evolution of the transition from Alboran toward the South Balearic Basin. Site 979 (South Alboran Basin, between the Alboran Island and the Moroccan coast) penetrates through a zone of folds within the Pliocene-Pleistocene sequence on the flank of the main compressional uplifted feature of the Alboran Sea - the Alboran Ridge. Comparing seismic data and drilling results suggests that tectonic activity including uplifting by folding and/or faulting of the Alboran Ridge occurred from the upper Pliocene to the Holocene. High sedimentation rates at these regions suggest that active subsidence and sedimentation were coeval with the recent contractive reorganisation of the Alboran Basin. No volcanic or volcanoclastic material was found at these Sites. Ultimately, drilling results at Sites 977, 978 and 979 provide the data base needed to establish the history of post-Miocene subsidence and/or uplifting of the southern and eastern Alboran region and to constrain the age of the deformation during later stages of contractive reorganisation of the Alboran Basin as a whole.

Geophysical, geological and drilling constrains on the Alboran Basin and underlying lithosphere will allow the discriminating of current geodynamic models for the tectonic evolution of the westernmost Mediterranean.

STRUCTURAL RELATIONSHIP BETWEEN THE SEA OF MARMARA BASIN AND THE NORTH-ANATOLIAN FAULT ZONE

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The North-Anatolian Fault (NAF) zone is a 1500 m long seismically active right-lateral strike-slip fault, extending almost up to the Greek mainland in the west, takes up the relative motion between the Turkish block and Black Sea plate. The Sea of Marmara lies along the western part of the NAF and shows characteristics of subsidence. In this area pure strike-slip motion of the fault zone changes into extensional strike-slip movement responsible for the creation of these basins of the Sea of Marmara and the North Aegean. The northern half of the sea of Marmara is interpreted as a large pull-apart basin. This basin is subdivided into smaller three basins separated by strike-slip fault segments of uplifted blocks trending northeast-southwest. The basinal blocks are covered by the horizontally well-layered syn-transform sedimentary sequences. The uplifted blocks have been made up by the lower syn-transform sedimentary sequences suffered compressional stresses. All the blocks are subsiding and are undergoing vertical motions and rotations relative to one

another. The uplifted blocks have the positive Bouguer gravity anomaly. According to the gravity interpretation there is a relative crustal thinning under the Sea of Marmara. The northern side of the Sea of Marmara has the distinctive deep rooted magnetic anomaly which is dissected and shifted southward by the strike-slip faults. The southern shelf areas of the Sea of Marmara are dominated by short wavelength magnetic anomalies of shallow sources.

STRATIGRAPHY AND TECTONIC INTERPRETATION OF THE PRE-PLIOCENE DRILLING RESULTS OF THE ERATOSTHENES SEAMOUNT, ODP LEG 160, EASTERN MEDITERRANEAN

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Following on from the site survey work carried out by TTR3, drilling on the Eratosthenes Seamount (Eastern Mediterranean) during ODP Leg 160 has provided the first conclusive evidence of what underlies a Plio-Pleistocene cover and allows an interpretation of the history of the seamount, prior to its collision with the Cyprus margin, to be made. Cretaceous carbonates, initially shallow-water biosparites with algae and mollusc fragments followed by Maastrictian deeper-water nannofossil chalks, are overlain unconformably by similar deep-water, Middle Eocene, bioturbated chalks. An unconformity also divides these sediments from shallow-water biosparites and biomicrites of probable Early Miocene age. On the flank of the seamount a calcrete-like horizon containing dolomite and ostracods indicating a lagoonal or continental deposition was found overlying these marine carbonates. A matrix-supported breccia containing shallow-water carbonate clasts marks the base of the Plio-Pleistocene succession of nannofossil ooze which is frequently interbedded with (ca. 80) organic-rich layers. A set of (mainly normal) faults cross-cutting the seamount has been interpreted as being related to its break up on collision and incipient subduction. Faults and fractures were also observed in the cores, and the breccia at the base of the Pliocene is thought to have been generated by active faulting associated with a coeval subsidence event. Both the Eocene and Upper Cretaceous rocks recovered are overprinted by a weak shear fabric, and the lowermost interval of breccia is thought to have tectonic origin. The Eratosthenes seamount is thought to have been part of a shallow-water carbonate platform associated with the African passive margin in pre-Upper Cretaceous times. Tectonic subsidence and pelagic sedimentation followed, interrupted by at least two periods of non-deposition or uplift and erosion as the seamount moved northwards. Collision with the Eurasian Plate and the Messinian drawdown probably resulted in Miocene shallowing and exposure. The subsidence event at the base of the Pliocene marks the re-establishment of open marine conditions and the beginning of break up and subduction, a process which is continuing today.

MAIN MORPHOLOGICAL FEATURES OF THE UN AREA

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During the 5th Training Through Research (TTR) cruise of the UNESCO-TREDMAR programme in August 1995, the eastern part of the Mediterranean Ridge was investigated by geological and geophysical methods. It was intended to study the ridge segments to the east of the Olimpi area which was examined on the TTR-3 cruise.

The 5th TTR cruise of the R/V Professor Logachev focused on the discovery of new mud volcanoes on the Mediterranean Ridge accretionary complex. Previously, the Olimpi area was mapped on the basis of the correlation observed between the back-scattering level

and the sampling data. All discovered mud volcanoes appeared on the sidescan sonar sonographs as large irregular patches with high backscatter. The same strategy was applied on the 5th TTR Cruise but not all of the dark patches clearly seen on the OKEAN and O.R.E.tech sonographs, which were supposed to be mud volcanoes, were confirmed by sampling data.

The purpose of this work is to look at the morphology and to compare the backscattering pattern, bathymetry, and bottom sampling results. The O.R.E.tech mosaic and bathymetric map have been made by R. Almendinguer and P. Shashkin.

Mud volcanoes, pockmark zone, fault scarps, and folds can be distinguished in the United Nations area. The mud volcanoes on the United Nations Rise differ from those in the Olimpi area by their morphology. They are expressed as seafloor depressions. The United Nations Rise mud volcanoes have no typical dome-like structure as in the Olimpi area. It is very difficult to recognise them with confidence on the profiler sections. The mud volcanoes in the United Nations area are situated on intersections of east-northeast and west-northwest-trending faults. This could be caused by the presence of zones with enhanced permeability for fluids. This is also confirmed by numerous pockmarks aligned along these faults. The analysis of the morphology and structure of the United Nations Rise allows us to conclude that this area belongs to the Inner Deformation Front of the Mediterranean Ridge.

SHALLOW STRUCTURE OF THE EASTERN SEGMENT OF THE MEDITERRANEAN RIDGE DEDUCED FROM SEISMIC AND SIDESCAN SONAR DATA

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Combined geological interpretation of sidescan sonar and seismic data collected during the 5th "Training-through-Research" cruise in 1995 allowed the following conclusions to be drown:

(1) The study region can be clearly subdivided morphologically and structurally into three areas: the United Nations Rise, the inner part of the Mediterranean Ridge, lying east on of the UN Rise, and its crestal part.

(2) The U.N. Rise is characterised by very complex topography and structure. It is framed by a system of faults probably of strike-slip nature. Plio-Quaternary sediments on the Rise are very thin, and the Messinian evaporites are absent or their thickness is below the resolution of the seismic method.

(3) The structure of the Rise is dominated by large sinistral strike-slip faults. The structural peculiarities suggest that the Rise is a part of the Inner Deformation Front of the Mediterranean Ridge. The complicity of its structure can be explained by the location at the kink point, where the general trend of the Mediterranean Ridge sharply changes, and by a probable tectonic escape from west to east.

(4) The U.N. Rise is notable for its mud volcanism. Two recent and several dormant mud volcanoes were found within the Rise. The recent mud volcanoes (Dublin and Stoke-on-Trent) are located at the southern boundary of the Rise (southern boundary of the Deformation Front), and the dormant mud volcanoes are observed onward the Deformation Front. The gradual southward extension of the Deformation Front seems to have caused the successive dying out of mud volcanism in this area.

(5) The inner part of the Mediterranean Ridge east of the U.N. Rise shows the absence of the Deformation Front. Its structure is defined by a saw-tooth-like pattern of sinistral strike-slip faults, which belong to the regional shear zone of the Strabo Trench.

(6) The crestal part of the eastern Mediterranean Ridge is generally characterised by SW-NE structural trends. The latitudinal structural trends, which should be expected from the general pattern of the tectonic stress distribution in this area caused by the plate convergence, are of minor importance. Such a pattern might have been brought about by a progressive southward arching of the Hellenic Arc, leading to the anticlockwise rotation of the structural trends on the eastern Mediterranean Ridge.

(7) The Messinian evaporites are present everywhere in the study area around the U.N. Rise, their thickness gradually increasing toward the east. In places, these evaporites are exposed on the seafloor, giving rise to brine pools. The alternation of tectonic deformation styles in the evaporites along the ridge implies that they are composed of different lithologies: competent and incompetent. The presence of the rather thick plastic evaporites is one of the reasons for the absence of mud volcanism on the Mediterranean Ridge east of the U.N. Rise.

TRANSITION ZONE BETWEEN THE RIFTED SICILIAN/CALABRIAN MARGIN AND THE MARSILI OCEANIC-LIKE BASALTIC CRUST.

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The Marsili basin is a small oceanic basin which extends for 80,000 km^2 reaching a depth of 3600 m. It is located in a back-arc setting behind the Calabrian arc and above the NW-subducting Adriatic-Ionian plate. The results of the Ocean Drilling project (ODP) Leg 107, well 650, have shown that the Marsili is a very young basin (1.9-1.7 Ma in its western side). Well 650, showed in addition that the Marsili basin experienced, from its origin, a very high subsidence rate, about 700 m/Ma; a value three times larger than that of the oceanic crust in ridge zones. In the middle of the Marsili basin the homonymous volcanic edifice is present, with a N-S trend and an elevation of 3000 m above the surrounding basinal plain. This work is based on the data acquired in June 1994 by an international group which investigated the Marsili basin and its eastern margin with the Russian Research Vessel "Gelendzhik" within the framework of the UNESCO-ESF "Training Through Research-Floating University" Network. The data consist of 560 km of multichannel seismic reflection profiles acquired with an Airgun source and with a 12-channels seismic cable. In the same period a high resolution survey, using a deep towed Side Scan Sonar (MAK-1) was carried out. These data have been integrated with seismic profiles already available from the Marine Geology Institute of Bologna, Italy. The resulting comprehensive data set covers the Sicilian/Calabrian continental slope, the Marsili basin and the submerged volcano.

From the analysis of the profiles an important difference in the features of the acoustic basement of the continental slope arises. In the upper slope, the basement presents weak reflections and is affected by extensional faults bounding rotated blocks; this area has been interpreted to be the result of the stretching of the margin during the rifting stage. In the lower slope, on the contrary, the acoustic facies of the basement changes drastically being represented by hyperbolic reflections. A similar facies characterises the basement of the Marsili oceanic basin. These data point to the existence of a transition zone between the continental rocks in the upper slope and the oceanic basement in the Marsili basin. This transition zone coincides with the lower slope where the acoustic basement lacks sedimentary cover and the MAK-1 data show the presence of outcropping rocks. This work defines the width of this transition zone and aims to make clear its relationships with the area floored by basaltic oceanic-like crust in the Marsili basin and with the stretched continental margin.

TECTONIC PROCESSES OF THE MEDITERRANEAN RIDGE AS DEDUCED FROM MULTICHANNEL SEISMIC REFLECTION PROFILING

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Multichannel seismic reflection data were acquired across several areas of the Mediterranean Ridge (M.R.), in the eastern Mediterranean Sea, during the MCS Prismed survey (March 1993). Their processing and integration with previous results (seismic pro-

filing, swath bathymetry, sonar) have facilitated the study of the overall deformation pattern of the area, which includes, along a North-South cross section, three distinct major structural domains facing various forelands:
(a) Within the Western and Eastern Mediterranean Ridge branches, Messinian evaporite-bearing formations, deposited in deep oceanic basins, some 5 my ago, play a dominant part in the present structural deformation of the outer accretionnary wedge. Within the outer Ionian MR, Messinian (lower evaporites) are clearly acting as the main "decollement" level, while the top of these formations operate as a disharmonic layer below relatively thin Plio-Quaternary sediments. The present-day MR tôe appears to be affected by ductile-flow deformation. Most of the accreted outer wedge results from progressive piling up (and associated thrusting) of Messinian and overlying Plio-Quaternary sediments. The change in structural style between the western and the eastern MR domains is critically dependant upon convergence parameters between the MR and its associated forelands as well as on variation in sediment thickness. Westwards, a frontal convergence induces a series of low dipping seaward thrusts accommodating a high amount of shortening. Eastward, a more oblique convergence leads to lower shortening rates, and to steep reverse faulting. Within the Herodotus abyssal plain, the onset of deformation is clearly related to variations of the foreland sedimentary supply. In this area, thick Plio-Quaternary deposits (related to the nearby Nile deep sea fan) induce high amplitude and large wavelenght folding, and reverse faulting;
(b) Within the central Mediterranean Ridge domain (the axial and shallowest part of the Mediterranean Ridge) evidences of mud diapiric and mud volcanoes are numerous; back-thrusting towards the inner domain is well imaged. Facing the Libyan margin, this axial domain displays spectacular mud volcano fields, and appears wider and shallower.
(c) The apparently less-deformed inner MR, which may represent a series of former fore-arc basins now progressively gliding over the Aegean continental margin, is bounded towards the north by the Hellenic trench system. Beneath the Ionian inner area, continental crust velocities have previously been recorded indicating the presence of a potential backstop. Within the Levantine region, this area is made of a series of disconnected and uplifted basement blocks (Strabo seamounts), which may also act as potential backstops.

We believe that, the overall MR north-south structural arrangement, and its clear west-east lateral variation, are related to the progressive collision of the accreted feature against the Libyan margin promontory. This event, which may have initiated some 6 to 5 million years ago, has probably induced: (a) a strongly differentiated paleogeography during the Messinian leading to further lateral structural variations of the outer domain ; (b) an incipient strain partitioning between the central Mediterranean Ridge and the Hellenic Trench system.

NEOTECTONIC DEFORMATION OF THE ANAXIMANDER MOUNTAINS OBSERVED FROM EM12D MULTIBEAM DATA

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Inferences from new geophysical data from the region of the Anaximander Mountains south of the Lycian Promontory in south-west Turkey suggest crustal extension there similar to that in western Turkey and the eastern Aegean. As the Aegean has extended outward (and in this area south-eastward), the position of the transpressive plate boundary between the Aegean and the African Plates has shifted principal activity from the Strabo to the Pliny Trench, transferring rifted material to the African Plate where it is in the process of being forced back against the Anatolian Plate to the north. The Rhodes Basin to the north-west of the mountains has a thin stretched crust, inferred to have originated by rifting, as suggested by high Bouguer gravity anomalies and great depth (> 4000 m); and the Finike Basin to the north of the mountains is an extensional basin with clear fault boun-

daries, separating the Anaximander Mountains from southern Turkey. The Anaximander Mountains are large faulted and tilted blocks originally geologically contiguous with south-western Turkey. Rock fragments obtained from one of the mountains show similarities to rocks mapped in Turkey. The mountains are being pushed north-eastward towards the Antalya Basin where a large fold belt is forming in response to this compression; and at the same time they are being pushed northwards against Turkey, causing tilting of two of the mountains up to 20 degrees to the north-west, folding of one of the mountains against another, and extrusion of a large lobe of sediments between them. These post Miocene horizontal and vertical movements of the mountains are a response both to their south-eastward rifting and to compression between the African and Anatolian Plates along the Florence Rise. Thus, the structure of the Anaximander region reflects its origin by rifting, but the neotectonics result from the plate convergence.

SECTION 2: DEEP-SEA DEPOSITIONAL SYSTEMS

THE HOLOCENE-UPPER PLEISTOCENE SANDS AND SILTS OF THE MARSILI BASIN (THE TYRRHENIAN SEA). PATHWAYS OF TRANSPORTATION, COMPOSITION AND POSSIBLE SOURCES

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Sidescan sonar data combined with sedimentological investigations allow to define silt and sand transportation paths into the Marsili Basin. Main sediments transportation pathways are clearly seen on side-scan sonar (10 and 30 kHz) images combined with bathymetric data.

Nine cores were taken in the Marsili Basin during the TTR-4 cruise; they contain about 70 sandy and silty layers. Totally, 83 samples were studied by optical methods for the definition of their mineralogical composition. Normally, sand and silt layers have been deposited by different types of gravity flows or as tephra. More often, they are turbidites, but sometimes grain-flow deposits and debrites. The main components of sands and silts are volcanic glasses, which can be divided into felsic and mafic, according to their composition. The most common are felsic glasses that mainly are either fragments of andesitic, sometimes ryolythic pumices or shards of the same composition. The amount of such felsic glasses is about 90%. Mafic glasses are usually represented by fragments of sideromelan. Felsic glasses are the main components for almost all sandy layers, but sometimes sands have another composition. Such sandy layer have been described in the cores obtained from the area located close to the Marsili Smt. Fragments of the mafic glasses are usually represented by sideromelan, and they are the principal components of these sands. Additionally to volcanogenous components, the typical terrygenous ones, such as, quarts, biotite, chlorite, epidot, garnet, rutil, fragments of different rocks and others were found. These components can present either an admixture or a bulk material of the turbidites.

On the basis of the side scan sonar and sedimentological data, some conclusions about the sources for sands and silts and paths of their transportation can be drawn. Eroded volcanogenous rocks of the islands of the Eolian Arc are the principal source of sands and silts of the Marsili Basin. The Stromboli Canyon is the main pathway for coarse volcanic material, such as pumice fragments and felsic glasses. It is estimated to supply more than 80% sandy and silty material.

The Marsili Smt can be the source of black sand layers, which have been described in almost all cores from the adjoining area, particularly in core 127G. Coarse material coming down from slopes of this seamount could be originated during submarine volcanic eruptions through granulation of pillow rims and then transported by gravity flows. The traces of these gravity flows can be observed on the side-scan sonar images. Thus, such layers of "black sands" can be good markers of submarine volcanic activity.

The main amount of terrigeneous sands and silts is transported from the shelf zone off Calabria. Also, there is evidence of subordinate sands and silts transportation from the area of the South Apennines. Such subordination is a result of sediments trapping in the low gradient deeps occurring on their way.

THE DANUBE DEEP-SEA FAN. MAIN FEATURES AND ORIGIN

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Several large accumulative bodies are distinguished in the sedimentary cover of the Black Sea margin. The formation of these bodies is a result of rever activity, such as that of the Danube, Don, Kuban, and others. The Danube Deep-Sea Fan system is a largest of the above-mentioned accumulation systems.

The Danube Deep-Sea Fan was investigated by Russian research vessels in 1986-1988 and 1994. Single-channel seismic profiling and echosounder were used for the recognition of its structure and development. Typical seafloor features were sampled by gravity corer.

On the basis of seismic, echosounder and coring data, some conclusions can be drawn about the structure of the central part of the Danube Deep-Sea Fan and the sedimentation character of this area.

The Pleistocene-Holocene sequences of the Danube Deep-Sea Fan, unconformably overlying the well-stratified pre-fan sediments, are formed by the alternation of bedded and semi-transparent acoustic units with a gradual lateral transition between them. Such a complex acoustic pattern is the result of facies change connected with the channel-levee system and their lateral migration. The channel facies are developed rather well with typical depositional and erosional features.

To characterise the channel facies distribution it should be noted that they appear upward in sequence and are at first shifted to the northeast and then back to the southwest. This shift is mainly a result of the channel migration and formation of the new channel generation caused by sediment overfilling of the old valley. The supplied sediments broke through a levee and formed a new channel orthogonally to the old one and a new lobe began to grow on the continuation of this new channel. The L- shaped channels formed in such a way are the remarkable feature of the Danube Deep-Sea Fan.

Sometimes new channels were formed probably as the continuation of new canyons located on the continental slope. These canyons, in turn, were a result of sediment paths' changes taking place on the adjoining shelf. From seismic profiles it is clearly seen that the Danube Deep-Sea Fan has a typical of deep-sea fans cyclic structure. Each cycle is formed by channel facies and overlying them are thin, well-stratified sediments. A total of seven such channel generations can be difined in the sequence of the fan. This cyclicity is likely to be connected with sea-level changes taking place during the Pleistocene glacial and interglacial stages.

Such correlation with Pleistocene climatic changes gives us an opportunity to date the Danube Deep-Sea Fan. Thus, the lower seismic member was probably formed in the Early-Middle Pleistocene including four glacial stages. The upper member is likely to have been formed in the Middle-Late Pleistocene with three glacial stages. The Holocene sediments of the Danube Deep-Sea Fan checked by coring demonstrate a typical post-glacial sequence, which is characterised by the almost complete absence of turbidites or deposits of other gravity flows. However, some exceptions can be found.

Evidence of gravity flows was found in cores taken from the recently incised channel. The cycles with gradual bedding were described from that place but all of them are made up of redeposited hemipelagic material (for example, fragments of sapropel) and originating right in the channel. Also, at the same place some unusual sediments, such as relativity thick (about 70 cm and more) layers of diatom ooze, were discovered. The diatom ooze layers are rather common sediments in the Black Sea, but their thickness does not exceed 0.1 m. In this case they could be redeposited because of their enlarged thickness. From this fact, some kind of gravity flow can be proposed as a mechanism of their redeposition.

MODELLING TURBIDITE HYDROCARBON RESERVOIRS: HOW BEST TO USE MODERN GEOPHYSICAL AND ANCIENT OUTCROP DATA

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Many oilfields in the northern North Sea are found in Tertiary sandy turbidite systems. The architecture of these fields is often complicated, and the commercial hydrocarbon sector, in the absence of closely-spaced wells on a number of these fields, has had many problems modelling them. Over the past ten years, much interest has thus been shown in analogue studies by field-based geologists, to aid this modelling. However this modelling has been surprisingly unsuccessful for many of the fields. This presentation uses a field example from western California, and examples of other parts of turbidite systems from around the Mediterranean, to show how modelling problems can occur. Methods are outlined on the use of modern and ancient data, from TREDMAR cruises in the western Mediterranean and similar onshore basins, for modelling reservoirs of the kind seen in the northern North Sea.

SEDIMENTARY PROCESSES AND DEPOSITS ON A STEEP CANYONED MARGIN: WEST OF CORSICA AND SARDINIA

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Although densely canyoned margins are common, their associated sedimentary deposits are poorly known. The deposits in such areas are expected to be of coarse calibre and so are likely to form reservoirs for hydrocarbons. The steep Corsica/Sardinia slope and the rise leading to the NE Balearic abyssal plain are studied from 6.5 kHz, 12 kHz and 30 kHz sidescan sonar data, high resolution profiles and sediment cores. Most of the data was obtained during the 4th TTR Cruise from the R/V *Gelendzhik*.

Small, mountainous drainage basins feed tributary canyons. Canyon floors are mapped as high acoustic backscatter which corresponds to scour holes, rippled gravel sheets and rock. The area between canyons is also extensively affected by mass wasting processes. Individual sandy lobes, deposited on the continental rise, between the canyon mouths and the very flat Balearic abyssal plain, are identified as being associated with characteristic patterns of moderate and low acoustic backscatter. The associated patterns resemble longitudinal braid bars in plan view. First indications are that these braid bar like patterns are imaged at the distal edge of the sandy lobes. Medium to coarse sand with mud clasts, in bodies up to 2.5 m thick, were recovered from the sandy lobes.

SEDIMENT TRANSPORT PROCESSES IN AND AROUND STROMBOLI CANYON, SE TYRRHENIAN SEA

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In 1994 two oceanographic cruises on board the research vessels *Gelendzhik* and *Urania* were conducted in the southeastern most part of the Tyrrhenian Sea with the aim of investigating mechanisms of transport and redistribution of sediments in small ocean basins, in this case the Marsili Basin, part of the Tyrrhenian Sea back-arc configuration. Sediment

input into the basin is mainly from the Stromboli Canyon which represents the primary conduit through which sediments coming from the basin margin and upper slope are transported towards deep basin environments. The split sediment cores were scanned by a Multi-sensor core logger (MSCL) to establish a correlatable stratigraphy. Two hundred and fifty six samples taken from 13 of the recovered cores were analysed for: (i) turbidity current flow characteristics: by grain-size analysis on a wide size range (0.68 μm-2 mm), using a combination of SediGraph 5000ET and sieving; (ii) sediment provenance: by investigation of sand fraction composition, smear-slides and chemical composition of glasses. Three source types were identified:
(i) "volcanic-derived" containing lapilli, volcanic rock fragments and minerals, and lava fragments (derived from the Eolian arc);
(ii) "terrigenous", containing minerals and rock fragments from metamorphic terrains (Calabria and Sicily);
(iii) "mixed turbidites" containing a mixture of volcanic, terrigenous and bioclastic components. Volcanic glass is observed in all deposits. Data from magnetic susceptibility, obtained with the MSCL, together with the sediment classification and the biostratigraphy allowed correlations between cores and reconstruction of turbidity current flow paths which demonstrate their interaction with topography at the fault-controlled bend in the Stromboli Canyon near the Lametini Smts area. The sediment record in the studied cores suggests that flows reaching this bend either (I) are reflected back at the foot of Lametini Smts, generating a cloud of sediments which collapses and moves laterally along the foot of the slope; (ii) cross the saddle which divides the two volcanic crests of the Lametini Smts; or (iii) are channelised and follow the Canyon towards the deep Marsili Basin.

DEPOSITIONAL SYSTEMS OF THE CORSO-LIGURIAN BASIN

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The deep-marine depositional systems of the Corso-Ligurian basin are characterised by narrow steep gradient slopes in the upper fan regions, and relatively flat middle and lower fan regions. The deep-marine systems on the western slopes of Corsica and Sardinia are incised by numerous submarine canyons and gullies. The larger canyons, such as the Ajaccio Canyon, are the source regions for sandy depositional lobes. Sidescan and high-resolution seismic data suggest that the submarine fans developed at the base of the slope do not contain submarine channel features. The clastic deposits downslope of the canyon mouths appear detached in nature. The canyon mouths in the region may be areas of significant breaks in slope, and also candidate areas for hydraulic jump phenomena. The detached deposits also exhibit an enigmatic backscatter pattern similar to patterns described from the Orinocco Fan and Umnak Fan. This paper also illustrates possible sedimentological causes for the backscatter pattern.

PREDICTION OF THICKNESS VARIATIONS IN EXPERIMENTAL TURBIDITES IN FRONT OF TOPOGRAPHIC FEATURES

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Experiments were designed using spreading, high concentration turbidity currents to aid the prediction of location of thickness variations in turbidites around obstacles. In the rock record, thickness variation would be on a scale not resolvable from geophysical records although representing as much as a 2-fold increase. The mass and thickness of sediment generally increases abruptly upstream of the obstacle forming a ridge (c.f. Alexander and

Morris, 1994). The experiments discussed here investigate the relationships between sediment pattern and obstacle position, orientation and flow composition. The distance from source, obstacle angle and sediment grain size were varied independently. In experiments where the obstacle was perpendicular to mean flow direction, the sediment ridge curved around the sides. In experiments with varying obstacle angle, the ridge showed an angular relationship to the obstacle. The ridge represents the terminal position of a hydraulic jump that operated in the flow in front of the obstacle and its position was controlled by flow discharge patterns. We also plan to present results of experiments in progress that aim to show flow behaviour over the area of sediment thickening.

Reference:

ALEXANDER, J., AND MORRIS, S., 1994, Observations on experimental, nonchannelized, high-concentration turbidity currents and variations in deposits around obstacles, *Journal of Sedimentary Research*, A64, 899-909

SECTION 3: PELAGIC AND HEMIPELAGIC SEDIMENTATION

RHYTHMIC-BEDDED UPPER CENOMANIAN SEDIMENTS IN THE CRIMEA: CLIMATIC RESPONSE TO ORBITAL FORCING

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This paper presents the results of a study of three limestone couplets in deep-shelf deposits of the middle-Cenomanian of the Crimea (Ukrania). The mechanisms triggering these alternations have been the subject of intense debate and have been widely attributed to climatic variations due to Milankovitch periodicity resulting to fluctuating productivity and terrigenous runoff. This study suggests that, in this regional setting, variations in solar insolation triggered two different basin regimes resulting in different deposits. Wet climatic phases resulted in higher input of terrigenous sediments and fresh water causing water stratification and higher productivity in the photic zone. During dry climatic phases, terrigenous sediment and fresh water input decreased and water stratification and eutrophic conditions ceased to exist. At three sections, we studied a stratigraphic interval of three limestone couplets, a massive bed and a time-equivalent bentonite, with a focus on one section. All couplets consist of a thick light bed and a thin dark bed. Light deposits are characterised by high calcium carbonate content and a low clay content, conversely, dark deposits contain relatively low amounts of calcium carbonate and high amounts of terrestrial detritus. Bioturbation studies show that a transition zone between these two end members is small or even absent. These observations support a hypothesis in which alternating wet and dry climatic phases trigger the deposition of these bedding couplets. The light interval is also characterised by oligotrophic conditions in the photic zone and a relatively good bottom water oxygenation in contrast to the eutrophic and stagnant conditions during the dark interval.

SEQUENCE BOUNDARIES IN THE WESTERN MEDITERRANEAN

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The 1994 TTR Cruise to the Balearic Abyssal Plain north-east of Menorca collected seismic reflection profiles that show unconformities and lapout structures apparently related to salt dome movements. These sequence boundaries around different salt structures proved to correlate. We interpret the tuned, spasmodic movements to be related to glacial/ interglacial sea level fluctuations. During periods of lowstand, material is eroded from the

continental shelf and deposited in the deep sea, loading the Miocene salts which causes more active diapirism. ODP site 372 and the seismic lines made for exploring the site were used for defining the Pliocene-Quaternary boundary and dating the cycle terminations.

DIATOMS FROM THE LATE QUATERNARY SEDIMENTS IN THE EASTERN MEDITERRANEAN AND AEGEAN SEA

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Diatoms are very sensitive to the smallest changes of environments such as water temperature and salinity, basin depth, contents of nutrients, and others. Therefore, they can be used for the reconstruction of conditions of sediment accumulation, paleoecological environments of a basin and for conclusions about paleogeographical peculiarities of the basin and adjoining land. Established paleoecological features of diatom assemblages quite often have a climatostratigraphical significance. From this point of view it will be very interesting to use diatom studies for the stratigraphy and paleoenvironmental reconstructions for the Pleistocene and Holocene in the Mediterranean. Furthermore, it is the unique basin, which was subjected by numerous hydrological and climatic changes. Diatoms from Quaternary bottom deposits of the Mediterranean Sea in general are rather poorly investigated. The literature on the diatoms from the Upper Pleistocene and Holocene sediments of the Eastern Mediterranean is sparse, and absent for the Aegean sea. Cores of the bottom deposits of the Aegean Sea were obtained during the cruise of the R/V *Moscow University*, which was organised by the Department of Lithology and Marine Geology of the Moscow State University in 1991. Core 31 (40° 06.5'N; 25° 15'E; water depth 490 m) and core 32 (40° 31.7'N; 25° 13.3'E; water depth 1400 m) are located within the North Aegean Trough (near Lemnos Island). Core 31 (length 142 cm) consists of green sapropelic mud (in the upper part), which is probably sapropel S1, and clayey mud in the lower part. In this core the richest diatom flora was established. There are 177 species and varieties. There is a difference in species amount and composition of assemblages between sapropel and clayey mud. Marine diatoms predominate in all deposits, but their percentage is 72-90% in the sapropel layer and 63-79% in the other parts of the core. The content of brackish-marine forms decreases gradually towards the top of the core. But a sharp increase of both fresh-water diatoms (up to 11%) and brackish-water ones (up to 15%) are observed just below S1. Littoral species make up a large part of the assemblage, especially in the upper part of the sapropel (up to 78%). *Grammatophora marina* and *G. oceanica* are most abundant here. Among planktonic forms, neritic diatoms play a main role. *Thalassionema nitzschioides*, various *Chaetoceros* (mainly spores) and oceanic *Thalassiosira oestrupii* prevail in the sapropel layer. These species are common in the upwelling zone. Thus, the diatom assemblage from core 31 shows that the originally brackish-water basin gradually became a normal marine one. However, there was a short episode of salinity decrease just before the sapropel accumulation. This may be evidence of the invasion of the Black Sea water. This input caused a great supply of nutrients that conduced to the diatom blossom and the sapropel formation. Core 32 (length 129 cm) consists of grey clayey mud with sandy layers and biodetritus. There are 107 species. Judging by diatom assemblage, there were no changes in salinity when the sediments were deposited, because the percentage of all diatom groups is almost constant through the core. Marine planktonic, mainly neritic species prevail. The percentage of benthic diatoms is 18-38%. As core 32 is located in the deep part of the trough, it seems that it consists of the Upper Holocene deposits younger than the sapropel. Thus, there was a normal marine basin not far from the coast at that time. It is considered that the sapropel formation took place under relatively deep-water conditions. According to the diatom assemblage, sapropel S1 of core 31 at first was also formed in deep water. But the abundance of benthic species at the top of the sapropel could be evidence of a more shallow

basin. But more likely this is connected with the core location on a steep slope and close to land. Littoral forms could be supplied by the turbidity currents. A large quantity of the reworked diatoms (in general *Aulacosira praegranulata*) both above and below the sapropel is a result of the same cause. The loss of reworked species in the sapropel may be explained by rapid accumulation. Thus, owing to the diatom analysis, paleoecological changes of the environment and sedimentation features in the Aegean sea on the boundary of the Pleistocene and Holocene were established, which can be connected to the change of paleo-geographical conditions at that time.

Similar features were found for the core of bottom deposits from the Sallum Gulf (Libyan margin) in the Eastern Mediterranean. Core C-91/1 (32° 06.6'N, 25° 14.1'E; water depth 1020 m) was obtained in a similar way. The sequence of sediments is typical of this part of the sea. Fresh-water species are also rather numerous in the investigated diatom assemblage. Deposits were divided into four units on the basis of the taxonomic and ecological structure of diatom assemblage. Two first of them were distinguished in the lithologically homogeneous horizon. I - In the first unit, planktonic neritic species living in desalting parts of the sea not far from the coast prevail. Brackish-water forms have got a maximum distribution here. These data allow us to attribute this unit to the warm Middle Würm. Ice thaw during deglaciation promoted a global rise of the sea-level, that was reflected in the diatom assemblage. II - In the second unit, the quantity and diversity of diatoms is reduced. Littoral species are most abundant. The abundance of marine forms is minimum. It could be the influence of the Late Würm glaciation, that has resulted in the sea-level fall and appearance of the adverse for diatom development conditions. III - The third is sapropel S-1, which accumulated during the Holocene climatic optimum. The increase of diversity of diatom mainly of benthic forms is observed here. Nevertheless, neritic species prevail quantitatively. Oceanic diatoms play a more significant role. Generally marine diatoms typical of the modern Mediterranean sea predominate here. IV - brackish-water species are completely absent, and among marine ones the oceanic forms prevail. This interval can be attributed to the Middle-Upper Holocene. Thus, the following similar features of the investigated diatom assemblages are established: rather lean diatom assemblage with prevalence of littoral species in the Upper Pleistocene sediments; a sharp increase of species diversity and abundance with prevalence of marine oceanic and neritic forms in the Holocene deposits; plenty of fresh-water, littoral and reworked diatoms, that is probably connected to the core locations.

ORBITALLY-FORCED UPPER CENOMANIAN DEPOSITS ON THE CRIMEAN PENINSULA, UKRAINE: CLIMATIC CONTROL ON CM-SCALE

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Analysis on stable isotopes, carbonate content and biofacies of 3 Middle Cenomanian limestone-marl couplets from the Crimea, Ukraine indicates that water column stratification caused by enlarged river influx is the most likely cause for the changes found in the sedimentological signal. A lowering of the $\delta^{18}O$ values and increase of the Cu and V content, as well as an enrichment in pyrite suggests that during the deposition of dark beds, the water column is highly stratified, leading to anoxic or dysoxic circumstances at the bottom and lower carbonate production. During deposition of the lighter beds, the water mass is better mixed, resulting in higher carbonate production and well-oxygeninated bottom water. The resulting gradual pattern of black and white layering can almost fully be ascribed to mixing due to bioturbation, and hides the original signal of a thin dark layer and thick white layer in one couplet. This implies that during a 21 Ka precession cycle as is present in this sediment only a short period is favourable for the deposition of dark beds and the well-mixed water circumstances dominate the major part of the cycle. By correlating the studied beds to European basins a good time resolution might be possible, but due to an unknown hiatus in the basal part of the Middle Cenomanian, this remains trivial.

NETHERLANDS INDIAN OCEAN PROGRAMME: TRACING A SEASONAL UPWELLING IN THE INDIAN OCEAN

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The Netherlands Indian Ocean Programme (1990-1995) was organised by The Netherlands Marine Research Foundation (SOZ) of The Netherlands Organisation of Scientific Research (NWO). The objective of the Netherlands Indian Ocean Programme (NIOP) is "to study the effect, on a spatial and temporal scale, of the monsoon on the climate system in the northern Indian Ocean". One of the 5 projects within the programme is "Tracing a monsoon induced upwelling system". It is based on an extensive data and sample set collected during the five cruises within the NIOP 1992/93 in the upwelling areas off Somalia and in Yemen. Extreme changes were found in productivity and related measures of ocean climate driven by ocean circulation and vertical mixing in response to monsoonal atmospheric forcing. This allows for a modern-analogue approach to paleoproductivity on a geological time scale. Analysis of planktonic foraminifera is the main tool of the research. However it is a multidisciplinary study as it also involves sedimentology, geochemistry, isotopic analysis, etc.

Three PhD projects are recently carried out at the Free University (Amsterdam) using the wide range of samples representing a vertical "section": from shallow to deep plankton, sediment traps representing upwelling and non-upwelling seasons, sediment samples from box- and piston-cores. The study is to be done in order to estimate present day primary biological production in the area, fluxes and accumulation processes, paleofluxes and preservation stages.

Size fraction analysis of planktonic foraminifera was done as a pilot study to find a way of getting the most sufficient and complete information from planktonic foraminiferal assemblages and to figure out the most important parameters which can be used as indicators of the climatic changes. The study shows:

- there is only one size-break in the abundance and composition which occurs in about all samples around 125 m. For the fractions >100 μm, 40 - 60% of all specimens occurs in the fraction 100-125 μm. During the upwelling season, one of the most abundant species in this size-fraction is *T. quinqueloba.*, associated with minor *G. vivans*, *G. uvula* and *T. humilis*. These important indicators are obviously missing in previous studies based on >125 or certainly in >150 μm counts (e.g. CLIMAP);
- the upwelling indicator *G. bulloides* is present in the size-range 125 - 300 and has a peak abundance between 150 and 250 . During the non-upwelling season it is present in low numbers and has a wider size spectrum;
- *G. tumida* and *G. menardii* dominate in the fractions > 355-400 μm of the upwelling samples while these size intervals yield high frequencies of *G. aequilateralis* , *P. obliquiloculata* and *G. trilobus/sacculifer* during non-upwelling periods.

The top of box-core 905B, located under the core of upwelling and below the sediment traps, reveals a strong imprint of the upwelling assemblage.

Some interesting information was obtained as a result of the study of 3 box-cores. Both production and preservation signals in the planktonic foraminifera assemblages found in the sediments differ considerably from one box-core to another. It is related to the core locations and water depth. Analyses of C_{org}, $CaCO_3$ and isotopes are in progress, thus there is more information expected.

FORAMINIFERAL ANALYSIS OF SAPROPEL S5, CORE TTR5-188G, EASTERN MEDITERRANEAN

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Deposition of a sapropel in general is determined by the conditions in the upper part of the water column. The aim of this study is to find out more about the paleoceanographic parameters of the upper water layer during deposition of S5. Sapropel S5 was recovered in core TTR5-188G and was sampled during the 5th TTR cruise on the R/V *Professor Logachev*. Core TTR5-188G is located on the Mediterranean Ridge, south of Crete. The 27 cm thick sapropel was continuously sampled every cm for the quantitative study of planktonic foraminifera assemblages and oxygen and carbon isotope analysis. In total, 24 samples have been washed, sieved and split. For every sample 200 specimens of planktonic foraminifera were counted and identified in a fraction of 125 - 500 μm. Also the abundance of pteropods, radiolaria and pyritised burrows was determined. Twenty specimens of *Globigerinoides ruber* were selected from each sample for oxygen and carbon isotope analysis.

SEDIMENTATION PROCESSES AND PROVENANCE OF THE SEDIMENT OF A DEEP-SEA PISTON-CORE (APNAP T86 CRUISE - MIDDLE ATLANTIC RIDGE)

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T86-8P was the eighth piston core raised from the APNAP cruise in 1986. The area investigated by the cruise was situated on the western side of the Middle Atlantic Ridge and the position of the core is 42°13'43"N and 25°39'45"W at 3218 m water depth. The aim of the work was to define the provenance of the sediments (and the sources) and thus to contribute to an explanation, with different models of transport, of the complicated processes in which the deep sea sediment is involved. For this reason 57 samples were taken at different depths (every ~15 cm) through the complete core (858 cm long) and several analyses were made: dry bulk density, carbonate content, grain-size (free carbonate and total), stable isotopes, clay minerals, polarizing microscope analyses on slides. By correlating the results obtained, it was possible to extrapolate interesting data like interpolated age, sedimentation rate, mass accumulation rate. The core, that covers an age of about 565 Ky, clearly shows the correlation between glacial/interglacial periods and the correspondent variations in colour, grain size, carbonate content, and density of the sediment. In spite of the scarce sampling, particular attention was given to the individuation of the Heinrich layers (H1-H3) and two samples show satisfactory characteristics (higher amount of terrigenous material coarser than 180 μm, high detritic carbonate and a lower productivity of organic material). The study of the fluctuations in the mass accumulation rate of the insoluble material shows the most interesting results: a higher input of coarse sediment at the end of the glacial periods while the finer fraction is recorded with a maximum at the beginning of them. Besides, all the sandy units show the presence of millimetric grains and centimetric dark pebbles thus demonstrating that ice-rafting is the only process able to transport such a coarse material. Following these data, it was possible to define models for the provenience of materials and sedimentation processes. The first model proposed assumes that the icebergs (at this latitude the only supplier of glacial deposits) were a mixture of fine and coarse material and had a shift southward in accordance with the southern boundary of the ice pack and thus with the advancement of the glacial period. Therefore the oldest MAR peak of finer material represents the melting of icebergs, which started northward, and the discharge of lithic material that is subsequently selected by bottom currents which push the finer fraction southward and leave the coarser one as deposit. With the advancement of the glacial period the polar front position was

shifted southward and coherently also the melting of icebergs, whose material is deposited following the same criterion as before (record in the core of the younger MAR peak for the coarser material). The second model is divided into two events: the first assumes that the older MAR of finer fraction is related to the eolian transport, bearing in mind that during the beginning of each glacial period, the eolian activity should be much stronger and the amount of windblown material greater. In normal conditions the earth wind system is distributed by the uppermost easterly winds between 60^0 and 90^0 lat. and the high pressure line at about 60^0 N. This boundary in the glacial period should be shifted southwards to 45^0-50^0 N and consequently the limit of the easterly winds. The second event that characterises this model is the "time lag effect" at the end of the glacial cycle. In this way the sediment of the icebergs (mainly coarse) will be released when all the ice masses are melted (peak for the sandy fraction). Nevertheless, a third model based on the combination of the previous ones is reliable.

CARBONATE PLATFORM-TO-BASIN CORRELATIONS OF PALEOCEANOGRAPHIC EVENTS

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Carbon-isotope chemostratigraphy has permitted "facies breaking" correlation between the paleoceanographic record of deep-water basinal sediments and paleo-environmental changes recorded in shallow-water carbonate platform deposits. Furthermore analysis of the stratigraphic position and shape of each $\delta^{13}C$ spike has provided independent evidence with respect to sedimentation rates, as well as distinctly marking unconformities.

As part of a Mid Cretaceous Sea Level Project the Friuli region in northeastern Italy was studied. The aim of the project is to reconstruct the successions of alternating transgressive and regressive sediment deposition and test whether these cycles reflect global sea level changes (eustacy). The emphasis has been placed upon the correlation of shallow carbonate platform deposits with the adjacent basin. Geochemical analyses were integrated with sedimentologic analyses and biostratigraphy, resulting in an overall high-resolution framework. Positive spikes in bulk-rock marine carbonate $\delta^{13}C$ analyses from the Early Aptian and the Cenomanian/Turonian boundary have been identified and correlated in carbonate platform and adjacent basin sediments.

The carbon-isotope analyses illustrate that positive carbonate $\delta^{13}C$ excursions of the Lower Aptian Oceanic Anoxia Event (or OAE) are very well developed in basin deposits (Val Cismon section), and can be traced into the platform-margin (Monte Cavallo section) and platform-interior (Val Cellina section) facies.

The Cenomanian/Turonian OAE is also accompanied by a positive carbonate $\delta^{13}C$ excursion in the basin and platform-margin facies. The correlation of black marls in the basin with pelagic muds on the platform-margin is interpreted as the record of a relative sea level rise. A shift towards very negative carbonate $\delta^{13}C$ values in the lithologies of the platform-margin and platform-top sections is due to diagenetically overprinting by exposure events.

References:

FOUKE,B.W., BUIJS,G.J.A., DUIZENDSTRA,O., ORDELMAN,W., NEDERBRAGT,A.S., PODLACHIKOV,Y.Y., SCHINDLER,U., SALVADOR,G.L., AND SCOTT,R.W., 1995, Carbonate platform-to-basin correlations of paleoceanographic events. In press.

ORDELMAN,W., 1995, Sedimentology and lithostratigraphy of the Friuli Platform Margin in Monte Tremol, Southern Alps, Northern Italy. Internal report, Vrije Universiteit, Amsterdam.

SECTION 4: MUD VOLCANISM

LITHOLOGICAL AND FABRIC VARIATIONS OF OLIMPI AREA MUD BRECCIA SAMPLED FROM ODP LEG 160

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Two mud volcanoes from the Olimpi mud diapiric field, located in the central part of the Mediterranean Ridge, were drilled during ODP Leg 160 in May 1995. Thirty-seven samples of mud breccia and hemipelagic sediments from cores taken at sites 970 and 971 were studied in thin sections with the aim of recognition structural features and examining the relationship between clasts and matrix.

Three types of mud breccia were observed and the peculiarities of their genesis were investigated on the basis of two main indications: structure and set of clasts.

(1) "Ordinary" mud breccia is represented by a very poorly-sorted, matrix-supported, massive, structureless, non-layered, non-graded mixture of clay matrix and abundant clasts which vary in composition, shape, size, and roundness. The clast size varies in studied samples from 0.01 to 10 mm, but they are mostly between 0.1 and 2 mm. There is no orientation to the clasts. The matrix of ordinary mud breccia consists of calcite, clay minerals illite and smectite, and fine silt-sized grains of quartz and feldspar. Mud breccia of this type dominates, forming the central parts of mud breccia flows.

Clasts include all types of rock fragments already described for the Olimpi mud breccia sampled during the TTR-3 cruise of the R/V "*Gelendzhik*" (Akhmanov, 1996).

Fragments of mudrocks are predominant among the clasts. They are tabular or bladed, very thinly laminated, soft, and plastic. Shape and structure of some mudrock fragments imply a plastic deformation of the fragments within the mud breccia. Sizes of mudrock fragments vary chiefly from 0.5 to 10 mm. Mostly, these mudrocks consist of Fe-illite and corrensite. Particles of Fe-illite show strict orientation that results in almost simultaneous extinction of the entire fragment under examination. The same paragenesis of Fe-illite with corrensite and the similar illite morphology are known for mudrocks within some terrigeneous-carbonate-evaporite sequences (Drits and Kossowskaya, 1991).

Fragments of micrites are very abundant as well. They are massive, structureless, rounded, and sometimes rich in organic matter. Their prevalent size is 1 to 3 mm. There are also fossiliferous biomicrites composed of Globigerina in a micritic calcite matrix with clay admixture.

Siltstones, fine-grained sandstones with clayey matrix and fine-grained sandstones with calcite cement are also present as mud breccia clasts. They are structureless, massive, different in shape, and usually angular. Their predominant size is 1 to 3 mm.

Quartz grains are prevalent among crystalloclasts. They vary in shape, size, and roundness. Plagioclase grains and K-feldspar grains are less abundant. They are usually less than 0.1 mm in size. Altered grains are commonly rounded whereas relatively "fresh" grains are subangular. In addition, monocrystals of calcite, rare muscovite and glauconate grains were observed also. All crystalloclasts have resulted from disintegration of different rock fragments within mud breccia.

(2) "Organized" mud breccia displays a preferred orientation for the bladed grains and clasts. Deformation of soft, plastic fragment of clay and mudrocks is common. Breccia of this type is associated with the lower and upper parts of mud breccia flows. Usually this breccia shows an increase in carbonate content towards the contact because of partial blending with high carbonate adjacent deposits. In contrast to poorly sorted "ordinary" breccia, sorting of this breccia also increases towards the contact. Large clasts are almost absent. Grains up to 2 mm in size dominate.

(3) One type of the mud volcanic facies observed in the samples from ODP Leg 160 is not really a mud volcano breccia although it originated from mud breccia. Intervals of such deposits were interpreted as coarse-grained turbidites during ODP Leg 160 shipboard

investigation. These deposits are represented by clast-supported facies and show fine planar lamination. Some samples are graded. There is a preferred orientation to the clasts. In contrast with "ordinary" breccia facies, relatively good sorting is observed, especially in the fine grained samples. These structural and textural features imply transportation of material by gravity flow, possibly, by turbidity current. At the same time, composition of these deposits is similar to "ordinary" mud breccia composition. These deposits have been formed probably by gravity flows transporting material from normal breccia. This material was sorted during transportation and redeposited as local turbidites not for away from a source area such as the mud volcano crater or upper slope, for example. These "redeposited" breccias were described for intervals around 170 m bsf of the outer flanks of the Milano mud volcano (hole 970 A) and the Napoli mud volcano (hole 971 B). They might be related to some period of tectonic activity in the area.

Mud breccia formation is believed to begin at the depth of sedimentary source deposits, it continues during upward migration through overlaying rocks, and does not finish after deposition on surface. Composition of the mud breccia matrix is changed in time with assimilation of clasts. Investigations of clasts-matrix contacts, matrix texture and composition in thin sections were carried to characterise the tendencies of different clast types to disintegrate and to take part in matrix formation. With regards to their behaviour in the matrix, the mud breccia clasts can be arranged into a series from the least to the most stable: soft and plastic clayrocks and mudrocks, micrites and fossiliferous micrites, siltstones, sandstones, bioclasts, fragments of calcite cracks, feldspar grains, mica, calcite grains, chalcedony, polycrystalline quartz grains, monocrystalline quartz grains. Mud breccia matrix composition is closely related to the set of clasts and to their compositions.

References:

AKHMANOV G.G. 1996. Lithology of mud breccia clasts from the Mediterranean Ridge. Marine Geology (in press).

DRITS V.A., AND KOSSOWSKAYA A.G, 1991 Clay minerals: mica, chlorites. Trudy Akad. Nauk SSSR, vol. 465. Moscow: Nauka, pp. 174. (in Russian)

MUD VOLCANOES OF THE KERCH PENINSULA. GENERAL REVIEW

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The Kerch Peninsula is an area where mud volcanoes are widespread. They have been in the focus of many scientists for a long time. A recent field trip aimed to study mud volcanoes of the Kerch Peninsula was organised by the UNESCO Centre for Marine Geology and Geophysics of MSU in co-operation with the Ukrainian State Institute of Mineral Resources in June 1995. This field trip was a part of the investigations of onshore and submarine mud volcanism conducted within the framework of the TTR Programme.

Mud volcanoes of the Kerch peninsula are connected with clay diapir structures and are usually located at their tops. Three types of the mud volcanoes can be distinguished. Differences between these types depend on the character of their activity. The mud volcanoes whose activity has an explosive character are referred to the first type. Short periods of activity are separated by long passive periods. The Dzhau-Tepe mud volcano is a typical example of this type. It is a hill 60 m high built up from radially spreading mud flows with the length of 40 to 400 m. It represents the biggest mud volcano of the Kerch peninsula. The second type, on the contrary, can be characterised by a relatively weak and continuous activity. Mud volcanoes, belonging to this type, have different morphological expressions. Numerous vents minutely spitting out small amounts of gassy mud, are very common. This type is strongly effected by the presence of water saturated layers in the upper part of a sedimentary sequence. This type was investigated in the Bulganak mud volcanoes area. The typical mud volcano of the third type called Dzhard- zhava is located in the eastern part of the peninsula and represents a hill of about 15 m high and 300 m across.

It demonstrates a transitional type of mud volcanic activity with the features of both above mentioned types. The eruptive periods are replaced by weak activity periods in this case. The differences between these types can be generally explained by the peculiarities of the host formation and the evolution of the mud volcanoes.

Onshore mud volcanoes are quite comparable with deep-sea ones. Usually the former shows a varying morphology. The later has better preserved meso-relief features because of the absence of erosive agents such as wind, running water, etc.

MUD VOLCANOES OF THE TAMAN PENINSULA (WESTERN CAUCASUS). MORPHOLOGY, STRUCTURE AND LITHOLOGICAL COMPOSITION.

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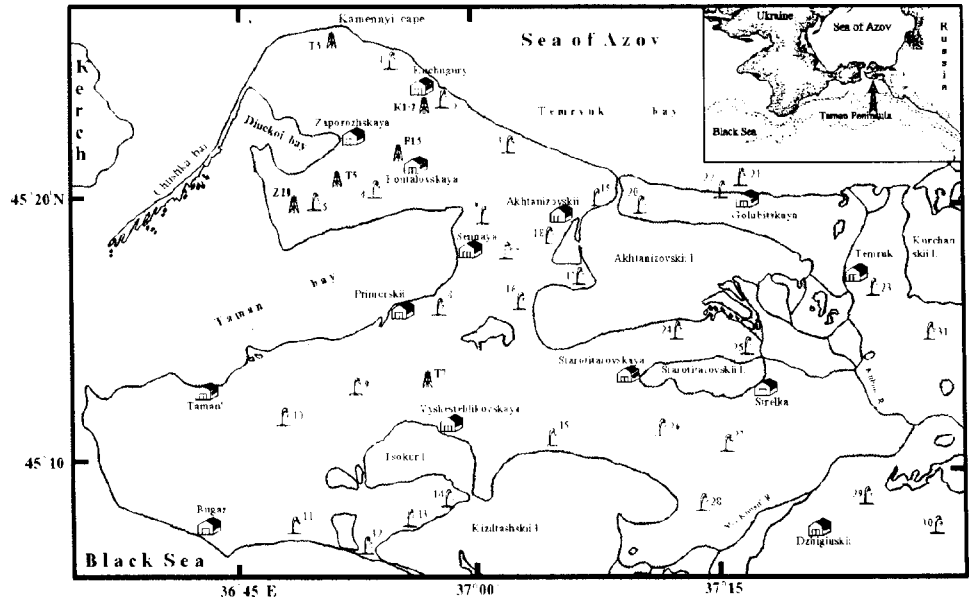
In summer 1994 a geological field trip was carried out, within the framework of the TTR programme, on the Taman Peninsula (Fig. 1) with the main goal to investigate the mud volcanoes: their location, activity, morphology and lithology of the erupted products. Several mud volcanoes and well-cores were studied and sampled during the expedition for comparison and identification of the rock fragments from the mud volcano breccia.



Legend

Mud volcanoes

1. PecloAzovskoe
2. Kuchugurskii
3. Tizdar
4. Fontalovskii
5. Gorelaya mountain
6. Puchina
7. Tsymbaly-Vostochnue
8. Shopurskii
9. Chirkova mountain
10. Karabetova mountain
11. Peklo Chernomorskoe
12. Bugazskii
13. Polivadina
14. Severo-Kiziltashskii
15. Vyshesteblievskii
16. Sennoi
17. Borisa I Gleba mountain
18. Akhtanizovskii
19. Severo-Akhtanizovskii
20. Sopka
21. Temryukskii
22. Golubitskii
23. Miska
24. Severo-Neftyanoi
25. Dubovyi rynok
26. Yuzhno-Neftyanoi
27. Kamyshevatskii
28. Girlyanyi
29. Dzhiginskii
30. Raznokol'skii
31. Gnilaya mountaim

Drill holes

K1;2 - Kuchugury 1 & 2
T3 - Taman 3
T5 - Taman 5
T7 - Taman 7
F15 - Fontalovskaya 15
720 - Zaporozhskaya 20

Fig. 1. Location map of the Taman mud volcanoes and drill holes

Structurally, the Taman region is situated on the connecting zone of the Caucasus and Crimean folded belts; as well, it is characterised by its complicated geological and tectonic structure, manifestating faults of various scales, by the presence of thick clay deposits of the Maikopian Formation and by other factors which are responsible for diapirism and mud volcano activity in the area under study.

The differences in activity of mud volcanoes were revealed in the field work results. The modern eruptions of Taman mud volcanoes are characterised by weak activity with eruption of liquid and gas saturated breccia sometimes with oil pellicles. Ancient ones are mainly characterised by explosive eruptions, as demonstrated by the morphology of mud volcanoes (existence of circular bank around the crater, formed by products of eruptions and destruction of the mud volcano upbuilding) and by the presence of a great deal of coarse rock fragments in the mud volcano breccia. In addition it was noted that at the present time, active mud volcanoes are situated in the northern part of the Taman Peninsula whereas the extinct ones are mainly located in the southern part.

Lithological analysis of the rock fragments from mud volcano breccia permits the distinguishing of the main clasts lithotypes and conglomerates with different rock fragments, such as limestones, siderites, sandstones, and volcanic rocks. Sandstones are very widespread in the mud volcano breccia; they are mainly glauconite-quartz, quartz - feldspar and polymictic sandstones. Silt- and claystones are characterised by enrichment of organic matter and pyrite and could be dated back to the Oligocene-Lower Miocene time. The carbonate rock fragments play an important role in the composition of the breccia; usually these are limestones, dollostones, micrites and siderites.

Finally, through studying of the lithological composition of rocks from the well-cores drilled on the Taman Peninsula, comparison with rock fragments carried out by mud volcanoes and with published data, one can define the ages of these rock fragments, which is vary from the Cretaceous to the Miocene time.

References

SHNYUKOV E.F., SOBOLEVSKIYI Y.V. ET AL., 1986. Mud Volcanoes of the Kerch-Taman Area. An atlas. 147 p. (in Russian).

CHSHERBA I.G., 1994 The Paleogene basin of the Caucasus.. Byull. Moscovskogo Obchshestva Ispytatelei Prirody. Otd. Geol. V. 69, N 3, pp. 71-80. (in Russian).

INVESTIGATIONS OF THE MUD VOLCANOES AT THE EASTERN EXTENSION OF THE MEDITERRANEAN RIDGE

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The Mediterranean Ridge is the largest structural element of the Central and Eastern Mediterranean, stretching from the Calabrian rise in the west to the Florance Rise in the east over a distance of some 1500 km. The Ridge is of the order of 150-300 km wide and has an arcuate convex southward shape. The Mediterranean Ridge is a young structure which originated as a result of the African and Eurasian plates convergence. But there are numerous hypotheses varying from a midocean ridge to a giant olistostrome. On the Mediterranean Ridge several mud volcanoes have been discovered and the Plio-Quaternary sediments and the Messinian evaporites were defined from seismic reflection profiles. One of the main goals of the TTR5 cruise, carried out by number methods including high resolution seismic profiling, was to investigate the characteristics of mud volcanoes, the

distribution of the Messinian evaporites, and to map the sea floor structures. At the same time the high resolution seismic data were confirmed with other geo-acoustic methods as side scan sonars (short-ORETECH and long range-OKEAN) and subbottom sampling. The target area was from a point 150 km south-east of Crete, NW to a point 50 km south of Anaximander Mountains. The area of investigation is designed to run parallel to the Mediterranean Ridge is situated between the northern and southern deformation fronts of the ridge. The water depths vary from about 1800 to 3000 m in the study area. The data was pre-processed on board (band-pass filtering, horizontal stack and attenuation level) and predictive deconvolution. The preliminary results of the seismic lines gave some clues to the reflection characteristics. Some mud volcanoes were discovered at the most western part of the target area. Some V-shaped and outcropped M-reflectors were observed.

MUD VOLCANISM ON THE MEDITERRANEAN RIDGE

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During two cruises of the "Training-through-Research" Program (1993 and 1995), several mud volcanic areas were discovered on the crest of the Mediterranean Ridge in an area south of Crete. These areas were investigated with seismic lines and OKEAN, MAK-I and ORETECH side-scan sonars. The mud volcanoes were also sampled with a gravity core and a TV-controlled grabber. These different areas are compared, and both their place on the Mediterranean Ridge and the structural features in their neighbourhood are taken into account. I compare flow directions, depth of the mud volcanoes, the composition of the mud breccia (clasts and matrix) and the relation between the mud volcanoes and the occurrence of brine pools and pockmarks. Difference are considered to be due to the heights of the mud volcanoes which are probably related to tectonic processes in the area.

FLUID VENTING FROM MUD DIAPIRIC STRUCTURES: THE EXAMPLE OF THE MUD DIAPIRIC FIELD SEAWARD OF THE DEFORMATION FRONT OF THE BARBADOS ACCRETIONARY COMPLEX AT 14° N

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Numerous mud volcanoes and diapirs pierce in the southern part of the Barbados accretionary complex. The underthrusting of sediment below the wedge and the thick muddy turbidites from the Orinoco R. allow the development of overpressured and undercompacted zones from which diapirs and mud volcanoes originate. Mud volcanoes have also developed in several areas of the abyssal plain seaward of the deformation front of the wedge, presumably as a result of a large fluid flow coming from the wedge along the decollement. The mud volcano field at 14°N is one of these areas. Submersible dives in this field brought evidence of fluid venting from all explored structures whatever their types: conical mounds, large diapirs, and mud pies. All have chemosynthetic bivalve communities and most have large amounts of carbonate sedimentation. Heat budgets estimated for the Atalante and Cyclops mud volcanoes indicate volumes of expelled fluids of 40,000 m^3/yr. and 5,000 m^3/yr. respectively. Assuming that the fresh water component of the expelled fluids comes from the dissociation of gas hydrates, 8,000 kg of methane could be released per day by the Atalante mud volcano alone. Fluid and gas venting may remain active even through periods of quiescence of mud expulsion. Moreover, diffuse fluid flow at rates of between 2 and $10x10^3$ m^3/yr. through sediments surrounding mud volcanoes results in fluid fluxes through the seafloor even larger than those channelled through mud volcanoes.

MUD VOLCANISM ON THE MEDITERRANEAN RIDGE - INSIGHTS FROM THE MILANO AND NAPOLI MUD DOMES (ODP LEG 160)

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The presence of mud volcanoes in different areas on the Mediterranean Ridge accretionary complex was initially documented by several Italian expeditions (Cita, et al. 1981; 1989; Camerlenghi, et al. 1992). Two contrasting mud dome structures in the Olympi mud diapir field (Milano dome, Site 970; Napoli dome, Site 971; cf. Emeis, Robertson, Richter, et al., in press; see Fig. 1 for location) were drilled during the recently completed ODP Leg 160, to test two hypotheses: whether they formed as mud diapirs (i.e. intrusion), or as mud volcanoes (i.e. extrusion). New seismic data and the results of scientific drilling support the hypothesis of an eruptive origin of the mud volcano deposits, although the source of the mud is still elusive. The Milano mud volcano dates from at least ca. 1.75 Ma, and is now, apparently dormant, whilst there is evidence of episodic activity at Napoli from 1.5 Ma to the present day. This suggests that mud volcanoes have a much greater longevity than previously supposed. A transect of holes was drilled from the adjacent hemipelagic deep-sea sediments, across the flanks, to the crestal area of each of the structures (Fig. 2). The dominant sediment type is matrix-supported muds and mud breccias, interbedded and interfingering with deep-sea hemipelagic sediments. On the flanks of both volcanoes, inclined intervals of clast-supported gravels and sands are overlain by matrix-supported, clast-rich muds, interpreted as multiple debris flows. By contrast, more silty and sandy intervals characterise the crestal areas (Fig. 2). The mud volcano deposits contain variable quantities of clasts (cf. Flecker and Kopf, in press), which are dominantly mudstones, and claystones of Plio-Quaternary age. Upper Cretaceous, Oligocene and Early Miocene microfossils were found in the clasts, but are considered having been reworked, as biostrata of Miocene age is also present. Pore fluid chemistry at Napoli and to a lesser extent at Milano, indicates proximal halite, presumably of Messinian age. Hydrocarbon gas (predominantly methane) is actively venting from the Napoli structure, and gas is also present in the Milano mud volcano crestal-sediments and elsewhere on the Mediterranean Ridge (Cita et al. 1995). In addition, methane hydrates (clathrates) were discovered for the first time in the Mediterranean in the crestal sediments of the Milano dome.

References:

CAMERLENGHI, A., CITA, M.B., HIEKE, W., AND RICCHIUTO, T.S., 1992. Geological evidence of mud diapirism on the Mediterranean Ridge accretionary complex. Earth Planet. Sci. Lett., 109:493-504.

CITA, M.B., RYAN, W.F.B., AND PAGGI, L., 1981. Prometheus mud- breccia: An example of shale diapirism in the Western Mediterranean Ridge. Ann. Geol. Pays Hellen., 30:543-570.

CITA, M.B., CAMERLENGHI, A., ERBA, E., MCCOY, F.W., CASTRADORI, D., CAZZANI, A., GUASTI, G., GIAMBASTIANI, M., LUCCHI, R., NOLLI, V., PEZZI, G., REDAELLI, M., RIZZI, E., TORRICELLI, S., AND VIOLANTI, D., 1989. Discovery of mud diapirism in the Mediterranean Ridge - A preliminary report. Boll. Soc. Geol. It., 108:537-543.

CITA, M.B., WOODSIDE, J.M., IVANOV, M.K., KIDD, R.B., LIMONOV, A.F., ET AL., 1994. Fluid venting, mud volcanoes and mud diapirs in the Mediterranean Ridge. Rend. Fis. Acc. Lin. Roma, 5: 159-169.

EMEIS, K.-C., ROBERTSON, A.H.F., RICHTER, C., et al., in press. Proc. ODP, Init. Repts., 160, College Station, TX (Ocean Drilling Program).

FLECKER, R. AND KOPF, A., in press. Clast and grain size analysis of sediment recovered from the Napoli and Milano mud volcanoes, ODP Leg 160 (Eastern Mediterranean). In: Emeis, K.-C., Robertson, A.H.F., Richter, C., et al., 1996. Proc. ODP, Init. Repts., 160, College Station, TX (Ocean Drilling Program).

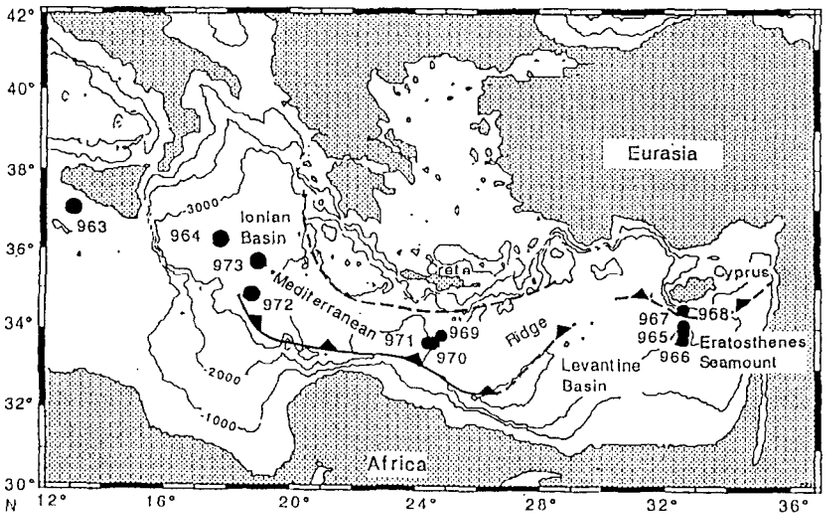

Fig. 1: Outline map of the Eastern Mediterranean showing the location of the Milano (Site 970) and Napoli (Site 971) mud volcanoes drilled during Leg 160.

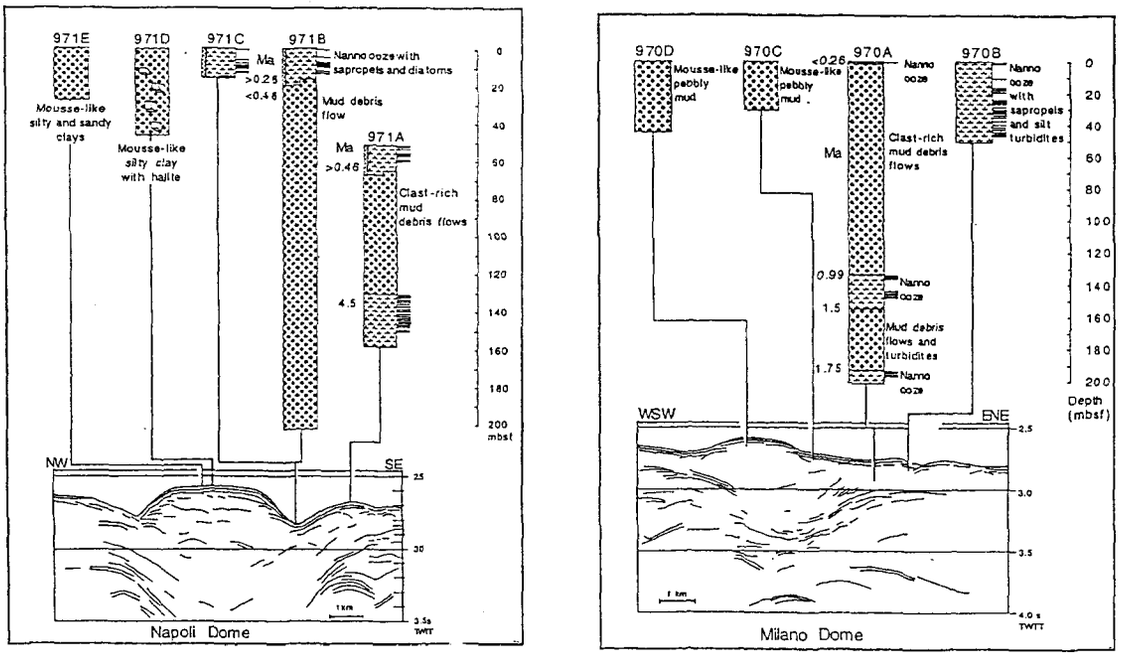

Fig. 2: Summary of the lithostratigraphy of the Milano (Site 970) and Napoli (Site 971) mud volcanoes drilled during ODP Leg 160. The seismic reflectors visible within the two mud structures are shown below. Note the presence of inward-dipping reflectors beneath both flanks of Napoli and the WSW-side of the Milano.

MUD BRECCIAS OF THE MEDITERRANEAN RIDGE

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After the discovery of mud volcanoes during the TTR-5 cruise in an area south of Crete (33-34^0 N and 25-26^0 E), gravity cores and a TV-controlled grabber were used to collect mud breccias. Mud breccias were sampled in the area of the Dublin and Stoke-on-Trent mud volcanoes to determine the age and origin of the rocks picked up during an eruption to relate them to the history of the Mediterranean Ridge and mud volcano activity. The majority of the clasts are found to be mudstone fragments. Calcarenites, sandstones, marls, breccia and gypsum were also recovered. Some clasts show signs of deformation, others are massive, laminated or bioturbated. Further study of smearslides and residue from the matrix, and thin sections and residue of the clasts is planned. To correlate the mud volcanoes, Oretech, seismic lines and eventually ODP-sites will be studied.

SECTION 5: FLUIDS IN MARINE SEDIMENTS AND GEOCHEMISTRY

ON RESULTS OF PORE WATER STUDIES, EASTERN MEDITERRANEAN

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Eighteen core samples, frozen aboard at a temperature of -12^{0}C, were available for the author for pore water studies from the TTR-5 cruise. The pore water was squeezed out with a steel screw press with double-side water diversion. Chemical analyses were made after the samples have been diluted with distilled water at a ratio of 1:10. Concentration of chloride-ion was determined by argentometric titration, sulfateion by the weight method through the use of precipitation with barium chloride and total alkalinity by titration with lean solution of hydro-chloric acid. Eh and pH were determined with the use of the EV-74 potentiometer. In the samples taken at sites 169G, 170G, 179G, 187G and 195G, the following changes of concentrations were noted: chloride-ion - from 18.7 g/kg to 67 g/kg, sulfate-ion - from 2.1 g/kg to 20 g/kg, total alkalinity - from 0.1 g/kg to 0.5 g/kg, Eh - from -280 mV to -155 mV, pH - from 7.57 to 8.27. The most obvious regularities were observed in the chloride-ion distribution. It is possible to distinguish three types of chlorinity variabilities through the section. Type I is characterised by a constant chloride-ion content, which is similar to that in the sea water. Such a distribution was observed at Site 179G situated on the mud flow of the Stoke-on-Trent mud volcano. Type II is observed in the sections of sites 169G and 187G, where pelagic sediments were penetrated, and perhaps at site 195G. It is characterised by a downsection increase in chlorinity with a gradient of up to 153.7 (mg/kg)/cm. Such type of the distribution is explained by the vertical diffusion of chlorides. It seems reasonable to note that in both sites the increase in methane concentration is observed downsection where the depth of its highest gradient coincides with that for chlorinity (A.V.Egorov, personal communication). Type III was noted at site 170G, where a slump breccia was recovered. There is no noticeable increase in chlorinity downsection down to a depth of 240 cm. At a depth of 268 cm, chloride-ion content rises, and that is probably related to water flow in the interbeds of sand in the interval of 268-288 cm. b.s.f. Therefore, there is no sites situated within zones of fluid seepages, otherwise there would be a high chlorinity without chloride concentration gradient should. The above mentioned also refers to the situation at Site 179G. Because the chloride diffusion coincides with the diffusion of methane, it can be supposed that the deep source for both components are gas-brine fluids. Perhaps, at site 170G a sub-lateral offshoot of such fluid associated with hypothetical zones of highest permeability (sand interbeds) was penetrated. The studies of pore water and geothermic studies would be necessary in marine geological investigations.

I am grateful for the samples afforded by A.V.Egorov. I also thank N.A. Kuz'micheva for chemical analyses and to G.D. Ginsburg for the constructive discussion.

References:

REZNIKOV, A.A., MULIKOVSKAYA, YE.P., AND SOKOLOV, I.YU., 1963. Methods of Analisis of Natural Water. Leningrad: Geoltechizdat (in Russian)

Information report on the 5th international expedition under the UNESCO "Floating UnIversity" Programme. St.-PetersBurg, PMGRE (Polar Marine Geological Exploration Expedition), 1995 (in Russian, unpublished).

CARBONATE MINERAL ASSEMBLAGE IN BOTTOM SEDIMENTS FROM THE UNITED NATIONS AREA, EASTERN MEDITERRANEAN RIDGE.

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The objective of this investigation was to study of the carbonate mineral assemblage in bottom sediments from the United Nations rise and the adjacent areas of the Mediterranean Ridge, which are characterised by intensive hydrocarbon fluids. A variety of authigenic minerals, first of all dolomite, calcite and sulphides were observed during the visual core description and microscopic study of smear slides and thin sections. In one sample (170G) a large field of well-crystallised dolomite was described. In some thin sections, an almost complete replacement of organic detritus by sulphides and a filling of a foram shell interior with pyrite and markasite were observed. 23 samples from 13 sites taken in the water depth ranging from 2180 m to 2470 m were selected for defining the composition of carbonate minerals from some characteristic levels below sapropel S1 and above sapropel S6. All of the samples were analysed in powder test by X-ray method with the Co-target in the limited interval of the Bragg angles (25.04Θ-55.04Θ). The analysis was carried out in an automatic mode, with IBM PC based data processing. Methods of this kind are sufficient for exact identification of carbonates composition, but they do not provide the quantitative evaluation of carbonate content. Generally in our samples four types of calcite and three types of dolomite were found. "Normal" calcite (d_{104}=3.0357A) is present in all of the analysed cores. In most of the samples, the high-Mg calcite and "complex" carbonates (with various amounts of Ca, Mg, Fe in their lattice) were identified. Side by side with the ordinary ratio of the carbonate minerals, high-Mg calcite (d_{104}=3.006A) predominance over the "normal" calcite is also frequent (172G, 185G, 184G and 175G). The composition of dolomite is variable as well. Besides the ordinary dolomite (d_{104}=2.889A), we also observed some varieties with abundance of $CaCO_3$ (d_{104}=2.90A) and $FeCO_3/MgCO_3$ (d_{104}=2.90A). These dolomites in all of the samples where they were found, are characterised by a very unstable crystal structure, that may be caused by Ca^{2+}, Mg^{2+} and Fe^{2+} being arranged disorderly (170G, 175G, 169G, 185G and 177G). Distribution of "complex" carbonates and dolomites correlates with higher concentrations of hydrocarbon gases and bitumen in sediments. The geochemical investigation of organic matter and hydrocarbon gases shows that the predominance of wax - asphalthenous components is observed in the upper parts of cores 168G ,169G , 170G , 175G and 172G (Egorov et al. , this book; Stadnitskaya, this book). The share of the light hydrocarbon gases in the composition of the bitumen increases downward along all cores. The composition and degree of transformation of bitumen indicate its allochthonous nature and possible origin from a deep source of hydrocarbon gas. In the lowest parts of the cores higher concentrations of gases, mainly methane were observed. Sediments with such distribution of bitumen and gases concentration are characterised by an abundance of $MgCO_3$ ($FeCO_3$) and unstable crystal structure for the carbonate minerals. The obtained results are in line with similar investigations, which were carried out on the Cascadia margin (Ritgen et al.,1987), in the Gulf of Mexico (Ferrel et al., 1994) and other regions. Such a rare assemblage of carbonate minerals in the subsurface

sediments of the deep-water basin as well as the unusually high contents of $MgCO_3$ may be explained by the following reasons:

1. Precipitation at higher temperature . The temperature of near bottom water in this area of the Mediterranean Sea is much higher then the normal for this depth which is equal to 13 C (Marta Estrada, 1984). Additionally, the temperature of the water can be risen in the gas vents areas because of upgoing flows of hot fluids from depth, which were noted, for example, in the mud volcano area of the Barbados accretionary complex (Le Pichon X. et al., 1990).
2. High input of the methane - derived CO_3 into sediments

$$CH_4+SO_4^{2-} = HS + HCO_3^- + H_2O$$

This process could give rise to local development of anoxic conditions around hydrocarbon seeps, caused by HS^- reduction to H_2S with the hydrogen from the organic matter in deposits. The presence of authigenic Fe-sulphides in sediments and the strong smell of H_2S in some cores may be taken as indirect evidence.
3. Supersaturation of pore water with $MgCO_3$ which may occur by being brought to the surface by fluids from the Messinian evaporite layer, lying at a small depth in the area.

References:

ESTRADA, M. and others, 1994, Life and Productivity of the Open Sea, in: Western Mediterranean.

FERRELL, E.,1994, Mineral assemblages occurring around hydrocarbon vents in the northern Gulf of Mexico, Geo-Marine letters, 14.

LE PICHON, X., 1990, Mud volcano field seaward of the Barbados accretionary complex: a submersible survey, J. Geophys. Res.

RITGER, 1987, Methane-derived authigenic carbonates formed by subduction-produced pore-water expulsion along the Oregon/Washington margin, Am. Bulletin, v.98, p.147-156.

BRIGHT SPOTS ON THE TTR-5 SEISMIC PROFILES: IS IT REALLY GAS?

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On seismic sections obtained during the TTR-5 cruise of the R/V *Professor Logachev*, a number of bright spots were observed. These local acoustic anomalies of significantly increased reflectivity, relatively to the rest of the seismic section, are associated with the notable negative relief of the M-reflector, and are observed directly above the evaporitic layer. The bright spots are better seen after the low frequency band-pass filtering (V. Gainanov, personal communications), i.e. they are characterised by a lower frequency spectrum. These acoustic anomalies have been assumed to indicate gas saturations, however there are no reliable evidence, except for the increase in the reflected wave amplitudes. On the other hand it is well-known that seismic amplitudes are affected by both geometric and lithologic features of reflecting layers, and therefore, bright spots are a function of not only pore fluid saturations, but also of layer thickness and surrounding rock type. Thickness of the layer is an important factor here due to possible interference of the reflected wave components. Therefore, amplitude analysis alone is not sufficient to define realistically whether there is gas saturation of a layer or not. This work aims to check the nature of the bright spots mainly by means of the reflected wave analysis in frequency domain. Computer simulation of the seismic direct problem will be carried out in order to find out the most probable cause for the bright spots, and construct the most reliable model for their origin in the area.

SHALLOW GAS VENTS OFFSHORE BULGARIA

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The existence of gas vents and permanent gas seeps along the Bulgarian Black Sea coast has been known for many years. Based on the geological-geophysical data obtained in 1980s, numerous acoustic anomalies, such as acoustic turbidity, bright spots, enhanced reflections, etc., which are an indication of the presence of gas in marine sediments, are discovered almost everywhere offshore Bulgaria. Water column anomalies and seabed pockmarks have also been localised.

Acoustic turbidity is related mainly to Holocene gas-charged sediments, which are widespread in the central parts of the shelf and on the uppermost continental slope. The presence of gas in these sediments is connected with a very high rate of sedimentation and intensive processes of transformation of the accumulated organic matter. Similar acoustic features are registered in deeper horizons in buried paleodeltaic bodies.

Bright spots and their shallow counterpart - enhanced reflectors - are discovered predominantly on the northern shelf. They are irregularly scattered both laterally and vertically. Usually they occur at 16-20, 45-60 and 85-105 ms (TWTT) below seabed. Most probably they are result of free gas under anomalous pressure, trapped in shelly-sand layers.

Seabed pockmarks are discovered along the periphery of the southern shelf and uppermost continental slope at water depths from 95 to 250 m. A total of 305 pockmarks have been localised within an area of more than 100 km^2 (2-5 km wide and 41 km long). Both within the pockmarks zone and in the neighbourhood, the specific reflections in the water column on the echosounder and shallow seismic records suggest that there is the release of free gas from the seabed. This suggests that some of the pockmarks are active at present. The main triggering mechanism for the pockmark formation is assumed to be earthquakes and slope processes.

Natural gas seeps occur at numerous sites in the aquatic area along the Bulgarian Black Sea coast. Some of them has been known to the old fishermen at least since the end of the 1940s. More than 2500 seeps are known now, which occur at water depths between 4 and 15 m and it is assumed that there could be more than 5000 seeps. Most of the gas seeps are situated in areas with known or possible shallow gas fields and most probably they are result of gas migration along fault zones.

HYDROCARBON GASES CONNECTED WITH MUD VOLCANOES AND VENTS ON THE MEDITERRANEAN RIDGE.

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During two Training-Through-Research UNESCO-sponsored cruises (1993 and 1995) a number of mud volcanoes and fluid vents on the Mediterranean Ridge were discovered. Hydrocarbon gas composition was investigated for four of them (mud volcanoes: 1 - Napoli (33° 43.47'N, 24° 41.13'E), 2 - Stoke-on-Trent (33° 28.8'N, 25° 35.1'E), 3 - Dublin (33° 37.66'N, 25° 46.00'E) and 4 - fluid vent (34° 03.2'N, 26° 46.0'E). Gases for the analysis were extracted from mud breccia and sediment by the "head-space"degassing method and by free degassing (for Napoli mud volcano).In gas samples light hydrocarbon (C_1-C_4) contents and isotopic composition of methane $\delta^{13}C$ were determined. Very high gas contents in Napoli mud breccia was observed in the form of intensive free degassing. We estimate gas contents as more then 1000 cm^3/kg. Analyses of this gas were made in the AGIP laboratory and were made available to us by courtesy of M.B. Cita. The principal component of the gas sample is methane, ethane content is about 7,5%, there are only traces

of propane; $\delta^{13}C$ for methane is 37,1‰. For the Dublin mud volcano, very low (~10×10^{-4} cm^3/kg) gas concentration was determined. We beleive this mud volcano to be presently inactive. Gases from the Stoke-on-Trent mud volcano breccia and the fluid vent sediments are very similar in spite of significant distance between them. Gas content is about 1 cm^3/kg, ratio of sum of C_2, C_3, C_4 to C_1 is about 2%; $\delta^{13}CH_4$ is about -55‰. For both these stations a predominance of i-C_n over n-C_n is observed. We suppose that these gases have the common source. From genetic point of view the discussed here gases must be considered as thermogenic: high temperature condition (>150^0 C) for Napoli gas formation and low temperature condition (~90^0 C) for others. Isotopic composition falls into limits of topical values of isotopic composition for onshore mud volcanoes.

GAS COMPOSITION AND ORGANIC GEOCHEMISTRY INVESTIGATIONS OF EASTERN MEDITERRANEAN RIDGE SEDIMENTS DURING THE TTR-5 CRUISE.

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Bottom sediments and mud volcano breccia were investigated using a set of methods. (1) Degassing of the sampled sediments and chromatographic measurements of concentration of hydrocarbon gases: C_1, C_2, $C_{2''}$, C_3, $C_{3''}$, i-C_4, n-C_4; sampling gas phase for isotopic analysis of methane carbon $\delta^{13}C_1$. (2) Sampling of sediments for total organic carbon (TOC) content determination. (3) Sampling of wet sediments (frozen at -12^0 C) for pore water analysis: SO_4^{2-}, Cl^-, HCO^{3-}, pH. (4) Sampling of sediments for luminescent organic carbon analysis. (5) Sampling of sediments for bituminological analysis of organic carbon using hot extraction.

All of the investigated stations can be divided into three groups on the basis of their setting: (1) normal (background) station; (2) mud volcanoes and (3) site of fluid venting. For normal stations the main features are strong lithological control (through sapropel layers) of both the contents of hydrocarbon gases and TOC and their composition. For example, TOC contents in sapropel varies between 2% and 7% , but for marls it varies from 0,15% to 0,9%. In sapropel we observe the sharp increase in heavy (C_2 - C_4) hydrocarbon gases contents; in general, gas contents for normal station being low (<100×10^{-4} cm^3/kg). Salt composition of pore water is not regular, and we did not observe the decrease in SO_4^{2-} concentration with depth, which is typical of sediments of intercontinental seas.

A station from the active Stoke-on-Trent mud volcano is characterised by high gas concentration, significant contents of methane homologues, the almost complete absence of unsaturated hydrocarbon gases, and abundant i-C_4 for n-C_4. Isotopic composition of methane carbon is about -55‰ by PD. standard. Concentration of TOC is low, but the salt composition is similar to that from a normal station.

The core on the venting side taken rather far away from the active mud volcano zone has a gas concentration increasing with depth (4 cm^3/kg at 4 m) and its composition is similar to that for gas from the Stoke-on-Trent mud volcano. Concentration of TOC is low. Salt concentration has an almost linear increase with depth.

ORGANIC CARBON PRODUCTION AND PRESERVATION IN MARINE SEDIMENTS

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Quaternary and recent sediments of semi-enclosed marine basins contain cycles of organic-rich and poor sediments. High-resolution geochemical and sedimentological analyses were carried out on such sediments recovered in cores from the Eratosthenes Seamount, eastern Mediterranean. Organic chemical determinations included carbon and nitrogen by thermal elemental analysis and biogenic opal content by sequential leach extraction. Inorganic analyses included Ba, Cr, Cu, Mn, Ni, P, Sr, U, V and Zn determinations effected by XRF and ICP techniques. The genesis of organic-rich layers remains controversial. Two main models are purported; decreased oxygen concentrations resulting in enhanced organic preservation or an increase in photic zone productivity leading to an increased organic flux to the sea floor. The data generated were interpreted with respect to these two models. Geochemical proxies were used to consider the two main formational models. Despite some problems with remobilisation under depleted oxygen conditions, barium can be used as a proxy for past productivity. Redox sensitive trace metals have been used as proxies for depleted oxygen conditions. Thus Cu, Ni, U and V seemed to be useful proxies; in contrast the behaviour of Cr and Zn seemed to be controlled by detrital processes, undermining their use as a proxy. The two organic-rich horizons studied exhibit different geochemical signatures. These indicate that S1 organic-rich layer was deposited, following an productivity increase, in an oxygenated water column. The overlying manganese marker bed is a diagenetic feature marking the original upper boundary of S1. The older S5 was deposited during increased productivity in depleted oxygen conditions. This study has demonstrated that anoxic conditions are not required a priori for organic-rich sediments to accumulate.

COMPOSITION OF ORGANIC MATTER AND HYDROCARBON GAS FROM RECENT SEDIMENTS OF THE UN AREA, EASTERN MEDITERRANEAN RIDGE

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During the 5th TTR cruise of the R/V *Professor Logachev*, a total of 562 samples of seabed sediments from 19 cores were collected from the UN Rise area. The water depth was 1739-2800 m. The core recovered varied in length from 1 to 4 m.

Geochemical investigations consisted of fluorescent analysis of extractable organic matter (EOM) (106 samples), determination of total organic carbon content (50 samples), bitumenological analysis (106 samples), determination of the organic carbon concentration (50 samples), gas-liquid chromatography (176 samples) of the bitumen for the determination of hydrocarbon composition of organic matter, and gas chromatography for detecting concentrations of hydrocarbon gases (methane and its homologues). Concentration of the organic carbon in cores 168G, 169G varies in a wide range: from 0.1% in grey and brown marls to 6.9% in sapropel layers.

The fluorescent analysis of EOM was the first geochemical study carried out. The cores 166G, 167G, 168G, 169G, 170G, 172G, 175G, 178G and 179G being examined by this method allowed us to define a few different types of bitumoids according to their composition: wax-asphalthenes, oil-wax with higher concentration of oils, and oils. The oil and oil-wax bitumen seem to be allochthonous. They were found mainly in the cores taken from the fault zones and mud volcano area (169G, 170G, 172G, 175G, 178G, 179G).

For determination of hydrocarbon composition of the organic matter with gas-liquid chromatography, EOM cores 172G (the crater of the Dublin mud volcano) and 166G (a pelagic core) were taken and analysed. Peaks corresponding to the n-alkanes were observed

on the chromatograms of all of the samples. In core 172G they are presented by C_{18} - C_{35}, with the maximum for C_{26}, where they also reach there maximum. On the chromatograms for core 166G n-alkane peaks were attributed to C_{18} - C_{29}, and an increase in the baseline of chromatogram was observed in the record in much higher part. These two cores are also very different according to the results of the fluorescent analysis of EOM and gas chromatography: in the core from the Dublin mud volcano (172G) much more methane homologues were found, relative to that in the pelagic core (166G).

In general, the main result of the geochemical investigations is that the cores from the active areas differ from the pelagic cores. These difference are as follows:

1. Composition of EOM: oil-wax and oils are predominant in the cores from the active areas, while in the pelagic cores wax-asphalthenes and asphalthenes prevail.
2. Content of EOM: 0.01-0.42% in the pelagic cores, 0.01-5.41% in the cores from the active areas.
3. Molecular composition of EOM: it is high-molecular in the pelagic cores, and low-molecular in the cores from the active zones.

Composition and content of hydrocarbon gases: the gas was defined as thermogenic in the cores taken from the active areas, and as biogenic in the pelagic cores (A. Egorov, this book).

It seems to be rightful to conclude that all the above mentioned differences between the cores taken from the active areas (fault zones, mud volcanoes) and the pelagic cores are most likely caused by the impact of upgoing fluids in the active areas. This is also corroborated by the fact that, it is observed the unusual ratio of carbonate minerals and high content of $MgCO_3$ in the sediments from core 172G, which is abnormal for recent marine deposits (I.Belen'kaya, this book). Therefore, the results of the geochemical analysis may be taken as evidence of the hydrocarbon inflow from deep sources.

THE INORGANIC GEOCHEMISTRY OF A MEDITERRANEAN RIDGE MUD BRECCIA

S. Wakefield and G. O'Sullivan
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A shallow penetration core from the Napoli Dome within the Olimpi Mud Volcano field has been characterised geochemically. The sediment can be considered to be essentially a mixture of a carbonate-rich, aluminium-poor component with a carbonate-poor, aluminium-rich one. This major lithological variation controls the geochemistry of Sr and Mn (carbonate associated) and of Fe, Zn, Si and Ni (aluminium associated). Other minor elements e.g. Cu, Rb, V, and Zr show a surface enrichment in the hemipelagic veneer at the top of the core while Mo and As are enriched sub-surface in association with sulphides. Organic carbon and nitrogen show clear decreases with depth but differential diagenesis degrades the organic matter such that the C/N ratio increases with depth from 9 to 18. Linked to this organic material is a massive peak of barium, an order of magnitude above background, centred on a nitrogen poor horizon at 31 cm with a C/N ratio of 29. Pore water Si and P profiles increase with depth to 200 μM and 31 μM respectively indicating that this mud breccia facies is a potential source of nutrients to the Mediterranean Sea.

SECTION 6:

GEOPHYSICAL METHODS, EQUIPMENT AND DATA PROCESSING

PROCESSING TOBI SIDESCAN SONAR DATA FROM AROUND THE FAEROES

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A deep tow sidescan sonar survey of two areas around the Faeroe Islands was carried out with the 30 kHz TOBI system in 1995, as part of the EC funded ENAM programme.

A mosaic was made of an area of giant submarine slides on the margin north of the Faeroes. Mass flow deposits on the upper slope are partially covered by recent deposits that are presumed to be contourites and only the trace of the headwall is present at the seafloor. The slide complex on the lower slope is younger and better defined. It has a steep, irregular headwall, up to 300 m high, below which is a zone of very large intact blocks. Below the block zone there are several types of debris flows, some with a longitudinal flow fabric. The base of the slide has many 10-15 km long tracks with individual outrunner blocks at the end.

An area south west of the Faeroes was investigated to check on the sites of cores taken for study of the history of overflow water from the Norwegian Sea and to investigate the transport paths of the overflow water. Areas of increased bottom current activity were mapped as stronger acoustic backscatter and several types of sedimentary bedforms. Proven pathways include a clockwise circulation around at least a part of Bill Bailey Bank and Lousy Bank.

Post cruise processing was carried out at the Southampton Oceanography Centre in order to improve the shipboard images. The steps in the processing include correcting for the distortion of the image along the path of the vehicle that is due to the varying speed of the vehicle over the ground. Missing swath lines are repeated in order to account for the varying distance covered. Time varying gain (TVG) is applied, to make allowances for the drop off in signal strength with increasing range, using shading correction files.

As TOBI operated in relatively shallow water (average depth of about 2 km) the data is corrupted by a sea surface reflection. A procedure for suppressing it is applied to the data before slant-range correction. Speckle noise has been removed using a small median difference kernel and line dropouts have been removed using a ratio of two box-car filters, each with appropriate thresholding techniques.

PROCESSING AND INTERPRETATION OF SEISMIC AND SIDESCAN SONAR DATA OBTAINED DURING THE TTR4 CRUISE IN NORTHWESTERN PART OF ALGERO-PROVENCAL BASING

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During the 3rd Leg of 4th TTR cruise, geophysical and geological investigations were carried out in the area of the distal part of the Rhone Deep-Sea Fan and assumed Valencia Fan. The geophysical investigations included 6-channel seismic profiling combined with the OKEAN long-range sidescan sonar and MAK-1 deep-towed sidescan sonar surveys. Processing of the seismic and OKEAN data was carried out in order to improve its quality and to obtain records for more detailed interpretation. Seismic data were processed on a Sun Sparc 2 workstation using the Seismic Unix software (Colorado School of Mines), and the OKEAN data were processed on an IBM PC using a software developed by the

UNESCO Centre for Marine Geology and Geophysics. The OKEAN data processing resulted in a digital mosaic of the sonographs, plotted.

The data interpretation was aimed to reveal features related to the Valencia Channel depositional system. Sedimentary bodies filling erosional valleys are the most prominent features observed on the seismic sections. Three generations of the erosional valleys were distinguished. Two ancient valleys are filled with sediments, and the modern one forms the seafloor surface. The overall thickness of the sedimentary bodies filling the ancient valleys, is about 70 ms (TWTT) or about 60 m. The lateral limits of the uppermost sedimentary body are well correlated with the margins of a lobe-shaped structure seen on the OKEAN mosaic.

Analysing these data one can draw the conclusions that erosion and redeposition of material are the prevailing processes in the investigated area. The Valencia Fan was not found in the investigated area, and probably this fan could be located to the south of investigated area, in the central part of the Balearic Abyssal Plain.

SOME SEISMIC PROFILING RESULTS OF THE 1995 TTR CRUISE.

V. Gainanov
Faculty of Geology, Moscow State University, Moscow, Russia

Seismic profiling was carried out during the TTR-5 cruise by a single channel method with 2 air guns. The processing included the gain control, deconvolution and band-pass filtering. Although the area is known as unfavourable for seismic profiling because of very strong faulting and folding, some interesting results have been obtained. The areas of several degree tectonic dislocations can be distinguished on the seismic profiles; salt diapirs, several faults and folds are seen. The structures similar to mud volcanoes are seen on some of the seismic profiles. Their comparison with the seismic images of the well-known Black Sea and Eastern Mediterranean mud volcanoes confirms that these structures are mud volcanoes or mud diapirs. According to seismic data the central parts of some of these structures are covered by gas hydrate layers, and the underlying sediments are saturated with gases.

METHODS OF SEISMIC PROFILING AND DATA PROCESSING DURING THE TTR-5 CRUISE

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During the TTR-5 cruise, seismic profiling was carried out with two air gun sources Pulse-5 and hydrophone streamer PSS-12; digital system was used for data recording and real time processing on IBM PC AT 486. In order to achieve the highest signal-to- noise ratio four channels of 12-channel seismic streamer were connected in parallel as a single one. The bubbling effect was decreased by using two sources operating simultaneously.

The main task for digital processing of seismic data was to achieve the highest signal-to-noise ratio and to present data in a more convenient form for interpretation. It included the following procedures: reading data from disk; adjusting the profile to a common time delay; horizontal sliding window smoothing; predictive deconvolution; band-pass filtering; selecting optimum output parameters; printing the paper copies.

The above mentioned procedures resulted in getting rid of the random noise in frequency band differing from that of the signal with the help of band-pass filtering. In the frequency band corresponding to the signal, the signal-to-noise ratio was significantly increased by horizontal sliding window smoothing. Predictive deconvolution being applied allowed us to shorten the pulse duration, which in turn enhanced the resolution of the wave field in time, improved correlation of reflectors and made structural unconformities and faults better seen.

Annex

4th UNESCO/IOC/ESF Post-Cruise Meeting
"Sedimentary Basins of the Mediterranean and Black Seas"
marking the 5th Anniversary of the Training Through Research Programme
29 January - 3 February 1996
Moscow - Zvenigorod, Russia

PROGRAMME:

Moscow, Hotel "Uzkoe"

29 January

17:00 - 20:00 Registration of participants
20:00 Welcoming Party

30 January

Moscow State University, Main Building
Plenary Session:

10:00 Opening
Salutatory address by Prof. V.T. Trofimov, Vice-Rector of Moscow State University
Salutatory address by Prof. B.A. Sokolov, Dean of Geology Faculty
10:20 A.E. Suzyumov, V.T. Trofimov: 5 years of the "Floating University"
10:40 J.M. Woodside, M.K. Ivanov, A.F. Limonov: TTR Programme: main scientific results
11:20 Coffee break
11:50 M.K. Ivanov: Mud volcanism, its origin and geological role
12:20 M.B. Cita: Geological and geophysical evidence for the Holocene special event recorded in the Eastern Mediterranean deep-sea record
12:50 Lunch
14:30 V.E. Khain: The new tectonic map of Europe and peculiarities of the Alpine Belt structure
15:00 J.E. van Hinte: Looking for ways to measure change in Earth's major carbon reservoir
15:30 Discussions
16:30 Coach leaves Main Building of MSU for Zvenigorod

31 January

Section 1: Tectonics
Conveners: Prof. J. Mascle, Dr. A. Limonov

10:00 J. Mascle and E. Chaumillon: Tectonic processes of the Mediterranean Ridge as deduced from multichannel seismic reflection profiling
10:20 A. Limonov: Shallow structure of the eastern segment of the Mediterranean Ridge deduced from seismic and sidescan sonar data

10:40 R. Flecker, A. Kopf, A. Robertson, J. Woodside, S. Spezzaferri, Y. Mart, M.-J. Jurado, and the Scientific Party of ODP Leg 160: Stratigraphy and tectonic interpretation of the Pre-Pliocene drilling results of the Eratosthenes Seamount, ODP Leg 160, Eastern Mediterranean

11:00 M. Ergun and E. Ozel: Structural relationship between the Sea of Marmara basin and the North-Anatolian Fault Zone

11:20 - 11:40 Coffee break

11:40 J. Woodside: Neotectonic deformation of the Anaximander Mountains observed from EM12D multibeam data

12:00 E. Kozlova, E. Akentieva: Main morphological features of the United Nations area

12:20 M. Comas and ODP leg 161 Scientific Party: A Neogene extensional basin in collision setting: tectonic results of ODP Leg 161 in the Alboran Sea

12:40 M. Comas, R. Zahn, A. Klaus, and ODP Leg 161 Scientific Party: ODP Leg 161 drills the Western Mediterranean

13:00 - 15:00 Lunch

Section 2: Deep-Sea Depositional Systems
Conveners: Prof. A. Maldonado, Dr. B. Cronin

15:00 N. Kenyon, J. Clark, J. Millington: Sedimentary processes and deposits on a steep canyoned margin: west of Corsica and Sardinia.

15:20 A.Maldonado: The post-Messinian opening of the strait of Gibraltar: growth patterns of the Alboran Sea and Gulf of Cadiz controlled by paleoceanographic events.

15:40 B. Cronin: Modelling turbidite hydrocarbon reservoirs: how best to use modern geophysical and ancient outcrop data.

16:00 A. Akhmetjanov, P. Shashkin: The Holocene-Upper Pleistocene sands and silts of the Marsili Basin (Tyrrhenian sea). Pathways of transportation, composition and possible sources.

16:20 - 16:40 Coffee break

16:40 R. Lucchi, R. Kidd: Sediment transport processes in and around Stromboli Canyon, SE Tyrrhenian Sea

17:00 S. Morris and J. Alexander: Predication of thickness variations in experimental turbidites in front of topographic features.

17:20 A. Akhmetjanov, M. Ivanov, V. Arkhipov: The Danube Deep-Sea Fan: main features and origin

17:40 Meeting of the TTR's Executive Committee

1 February

10:00 - 14:00 Field trip and local sightseeing tour.

14:00 - 15:00 Lunch

Section 3: Pelagic and Hemipelagic Sedimentation
Conveners: Prof. M.B. Cita, Prof. J. van Hinte

15:00 S. Gablina: Diatoms of the Late Quaternary sediments of the Eastern Mediterranean and Aegean Sea.

15:20 S. Kortekaas: Foraminiferal analysis of sapropel S5, core TTR5-188G, Eastern Mediterranean.
15:40 W. Ordelman: Carbonate platform-to-basin correlations of paleoceanographic events.
16:00 - 16:30 Coffee break
16:30 Round Table: The future development of the TTR Programme

2 February

Section 3 continued

10:00 E. Iking: Orbitally-forced Upper Cenomanian deposits on the Crimean Peninsula, Ukraine: climatic control on cm-scale.
10:20 H. van den Bosch: Rhythmic-bedded Upper Cenomanian sediments in the Crimea: climatic response to orbital forcing.
10:40 E. Ivanova: Netherlands Indian Ocean Programme: tracing a seasonal upwelling in the Indian Ocean.
11:00 A. Mazzini: Sedimentation processes and provenance of the sediment of deep sea piston-core (APNAP T86 cruise - Mid Atlantic Ridge).
11:20 E. Felser and J. van Hinte: Sequence boundaries in the Western Mediterranean.
11:40- 14:00 Free discussions
14:00 -15:00 Lunch

Section 4: Mud Volcanism
Conveners: Dr. N. Kenyon, Dr. J.-P. Foucher

15:00 M. Cita: Mud diapirism in the Eastern Mediterranean: where we are now.
15:20 J.-P. Foucher: Fluid venting from mud diapiric structures: an example of the mud diapiric field seaward of the Barbados Accretionary complex at 14°N.
15:40 A. Kopf, R. Flecker, A. Robertson, J. Woodside, H. Brumsack, A. Cramp, and the Shipboard Scientific Party, ODP Leg 160: Mud volcanism on the Mediterranean Ridge - insights from the Milano and Napoli mud domes (ODP Leg 160).
16:00 G. Akhmanov, J. Woodside, and Shipboard Scientific Party, ODP leg 160: Lithological and fabric variations of Olimpi area mud breccia samples from ODP Leg 160.
16:20 - 16:40 Coffee break
16:40 E. Felser: Mud volcanism on the Mediterranean Ridge.
17:00 C. van der Zel: Mud breccias of the Mediterranean Ridge.
17:20 A. Akhmetjanov, O. Krylov, E.Basov, E. Kozlova, G. Akhmanov, and A. Stadnitskaya: Mud volcanoes of Kerch Peninsula: general review (field trip 1995).
17:40 E. Basov and L. Meisner: Mud volcanoes of the Taman Peninsula (western Caucasus). Morphology, structure and lithological composition.
19:00 Dinner
20:00 Round Table: Homogenites and other evidences for catastrophic events in the Eastern Mediterranean.

3 February

Section 5: Fluids in Marine Sediments and Geochemistry
Conveners: Dr. M. Ivanov, Dr. L. Dimitrov

10:00 G. O'Sullivan, S. Wakefield: Organic carbon production and preservation in marine sediments.
10:20 C. Corselli: Macrofauna communities sustained by chemosynthesis.
10:40 A. Stadnitskaya: Composition of organic matter and hydrocarbon gas from recent sediments of the UN area, Eastern Mediterranean Ridge.
11:00 I. Belen'kaya: Carbonate mineral assemblage occurring around hydrocarbon vents in the United Nations area, Eastern Mediterranean Ridge.
11:20 - 11:40 Coffee break
11:40 S. Wakefield, G. O'Sullivan: The inorganic geochemistry of a Mediterranean Ridge mud breccia.
12:00 L. Dimitrov: Shallow gas vents offshore Bulgaria.
12:20 D. Abezgauz: On the results of pore water studies, Eastern Mediterranean.
12:40 A. Egorov and M. Ivanov: Hydrocarbon gases connected with mud volcanoes and vent of the Mediterranean Ridge.
13:00 A. Egorov, A. Stadnitskaya, and D. Abezgauz: Gas composition and organic geochemistry investigations of Eastern Mediterranean Ridge sediments during the TTR-5 cruise.
14:00 - 15:00 Lunch

Section 6: Geophysical Methods, Equipment and Data Processing
Conveners: Dr. J. Woodside, Dr. M. Ergun

15:00 V. Gainanov: Some seismic profiling results of the 1995 TTR cruise.
15:20 S. Bouriak: Bright spots on the TTR-5 seismic profiles: is it really gas?
15:40: R. Almendinguer: Processing and interpretation of seismic and sidescan sonar data obtained during TTR-4 cruise in the northwestern part of the Algero-Provencal basin.
16:00 E. Akentieva, Tj. van Weering, and N. Kenyon: Processing TOBI sidescan sonar from around the Faeroes.
16:20 A. Volkonskaya: Methods of seismic profiling and data processing used in the TTR-5 cruise.
16:40 - 17:00 Coffee break
17:00 Round Table: Planning the 1996 TTR Cruise programme
19:00 Dinner and Farewell party.

4 February

Departure of the participants from Zvenigorod to Moscow