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Gas and Fluids in Marine Sediments:

Gas Hydrates, Mud Volcanoes, Tectonics, Sedimentology and Geochemistry in Mediterranean and Black Seas

Fifth Post-Cruise Meeting of the Training Through Research Programme and International Congress
Amsterdam, The Netherlands
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PREFACE

The Congress on "Gas and Fluids in Marine Sediments" was also the post-cruise and annual meeting of the international Training Through Research Programme (TTR), an activity of the IOC Floating University Project. These annual TTR meetings generally take the form of workshops in which TTR research themes and results are discussed and to which special guests are invited to provide additional expertise through their participation.

In July and August of 1996, the Russian research vessel *Gelendzhik* successfully carried out the sixth TTR expedition (TTR-6) with research in the eastern Mediterranean Sea and the Black Sea. The theme of the congress arose naturally from this expedition because of the degree of attention paid to the phenomena of gas and fluid venting through the seafloor, sampling and mapping of gas-charged sediments and gas hydrates (including the first gas hydrates sampled from the Mediterranean Sea), and associated mud volcanoes and occurrences of mass sediment movement.

The congress included, therefore, a number of presentations on data analysed in connection with the TTR-6 expedition, especially by students whose research is dependent on the TTR programme. There were also a number of invited presentations on this theme by scientists other than TTR-6 participants. Among these invited scientists were participants from previous TTR expeditions, scientists involved with the organization and coordination of the TTR programme, a number of special guests, and local students and scientists with an interest in the research. This is in keeping with the open nature of a programme which is continuously evolving.

The organization of this report reflects the congress schedule. Thus the abstracts are in the order in which the presentations were given. Annex I contains the programme showing the titles and authors of presentations, along with the division into different sessions and the chairmen of the sessions. The abstracts follow the same sequence in this report and are likewise grouped thematically under the same headings as the different sessions. The participants are listed in Annex II in alphabetical order by country.

This was the second post-cruise meeting to be held at the Centre for Marine Earth Sciences (Geomarine Centre) of the Free University of Amsterdam (the first was in 1994). Previous meetings have been held in Moscow (1993 and 1996) and in Cardiff (1995). In some respects this reflects the number of students that have been involved from the places mentioned, because it is traditionally the students who have organized the meetings. However, participants in the programme have come from all the Mediterranean countries of Europe as well as from central and northern European countries and beyond. This has always been a function of interests in the particular research planned for a given year. During the meeting there was discussion of plans for future TTR research.

The following report of the congress has been produced by members of the Congress Organizing Committee, whose members, in alphabetical order, are Arie Jan Doets, Jorijntje Henderiks, Ewald Iking, Twan Kleeven (Chairman), Enno van der Schans, and John Woodside.

The congress would have been impossible without the generous support of a number of organizations. We are very grateful for financial support from the Intergovernmental Oceanographic Commission (IOC) of UNESCO, the Netherlands Foundation for Geosciences (Stichting GOA), Shell Nederland bv, Elf Petroland bv, Koninklijk Nederlands Geologisch Mijnbouwkundig Genootschap (KNGMG), and the Free University Funds (Stichting Het Vrije Universiteitsfonds Amsterdam). GeoVusie, the student organization within the Faculty of Geology, contributed in a number of ways to the success of the congress.

Amsterdam, January 1997 — The Congress Organizing Committee

ABSTRACTS

SESSION 1: SEISMICS AND SEDIMENTATION OF THE BLACK SEA

An Abrupt Drowning of the Black Sea Shelf

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During latest Quaternary glaciation, the Black Sea became a giant freshwater lake. The surface of this lake drew down to levels more than 100 m below its outlet. When the Mediterranean rose to the Bosporus sill at 7,150 yr BP, saltwater poured through this spillway to refill the lake and submerge, catastrophically, more than 100,000 km^2 of its exposed continental shelf. The permanent drowning of a vast terrestrial landscape may possibly have accelerated the dispersal of early neolithic foragers and farmers into the interior of Europe at that time.

An Extensive Fluid Flux and Associated Phenomena on the Crimean Continental Margin: An Overview

M. Ivanov[1], J.M. Woodside[2], A. Limonov[1], and the Shipboard Scientific party of ANAXIPROBE/TTR-6 cruise, leg 2.

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Investigations carried out in summer 1996 on the SE Crimean continental margin within the UNESCO/IOC Training-through-Research Programme with the Russian *R/V Gelendzhik* have led to the discovery of a new area of the extensive fluid flux in the Black Sea.

Acoustic methods of the investigations, including single-channel seismic profiling, bathymetric mapping with a Simrad EM12S multibeam echosounder, and a seafloor study with the MAK-1 deep-towed sidescan sonar, equipped with a 4.9 kHz profiler, revealed numerous seafloor structures related to fluid seepages (mud volcanoes, pockmarks, mud flows from open fissures, etc.). The sedimentary sequence in the seismic and bottom profiler records is also characterized by a variety of acoustic anomalies.

Bottom sampling with a large diameter gravity corer confirmed the presence of the active fluid flux through the seafloor in the study area. Most of the cores contained the elevated concentrations of hydrocarbon gases, gas hydrates, crust and concretions of diagenetic carbonates with a light carbon isotope composition. Bacterial mats were found at three sampling sites at a depth of about 2000 m, in a zone of hydrogen sulphide pollution.

The hydrocarbon gases from some sampling sites have a significant admixture of heavy hydrocarbons, up to iso-hexane, and do not show any relation to the amount and composition of organic matter in the host sediments. This can testify to their thermogenic origin and migration toward the upper part of the sedimentary sequence.

Structure of Sedimentary Cover in the Sorokin Trough (South of the Crimea) and Related Mud Volcanism

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The Sorokin Trough is a large (150 by 50 km), SW-NE trending basin situated on the Crimean lower continental slope and rise. It is filled with the Maikopian (Oligocene-Lower Miocene) Formation that is largely represented by clay sediments forming numerous elongated diapiric structures. For 20 years, since the pioneering seismic works in this trough, it has been widely accepted that diapiric folds are arranged in line with the general trend of the trough, merging with the corresponding diapiric belts in the southern Kerch and Taman Peninsulas. The data obtained during the TTR-6 Cruise have shown that this is far from the reality.

The diapiric folds in the trough have a complex structure. They are grouped into diapiric zones, with a length of from 12 to 40 km and a width of from 2 to 10 km. Each zone consists of 1 to 4 diapiric ridges. In turn, each ridge is complicated by individual diapirs or mud volcanoes. In this respect they are similar to diapiric structures in the Taman Peninsula known from drilling. Four types of mud volcanoes were distinguished in the trough:
(1) conical or dome-like mounds; (2) collapsed structures; (3) flat-topped structure of "Barbados type" (only one example found); and (4) fissure eruptions of mud breccia. The last type has not been reported before.

It was revealed that the structural trends of the diapiric zones change along the seismic lines, from SW-NE in the west to almost N-S in the east, being controlled by uplifts in the underlying Cretaceous-Eocene rocks. The formation of the diapirs is thought to have been related to tectonic compression from the south.

Geological Features of the Paleo- Don/Kuban Deep-Sea Fan According to the Results of the Seismic Study on the Pallas Uplift (Northeastern Black Sea)

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The upper and middle parts of the Don-Kuban Deep-Sea Fan were studied during the 6th cruise of *R/V Gelendzhik* within the framework of the TTR programme in 1996. The seismic data were processed on a SUN Sparcstation by Seismic Unix software. The processing included the following procedures: spherical divergence corrections, band pass filtering, predictive deconvolution, and migration.

The Palaeocene-Eocene Pallas Uplift, located at a depth of more than 2.5 km below the seafloor, is covered by Oligocene-Quaternary sediments. The main part of this sequence is represented by Quaternary sediments of the palaeo-Don/Kuban Deep-Sea Fan, made up of several lobes onlapping each other. The lobes, which are complicated by channels and levees, form a thick accumulative structure with a complex relief. It can be supposed that the time when the palaeo-Kuban River was most active in building the fan was the Late Wurm, because at that time the palaeo-Kuban River flowed directly into the Black Sea, and the sea-level was 70-110 m lower than now. This led to an increase of erosional processes by the river. Now, when the Kuban River enters the Sea of Azov, the accumulation of sediments in the fan is small.

A strong diffracting reflector is visible on all seismic profiles. The reflector has a regional character, but it is better visible in the eastern part of the study area, where it roughly follows the sea bottom relief. There are two possible explanations of this phenomenon: it could be either the base of a gas hydrate stability zone or a surface of erosion with a rough topography.

Reference

Naukova Dumka, 1982. Geology of the Ukraine shelf. History and study methods. Kiev, pp.97-108. (in Russian).

Recent Sedimentary Processes in the Sorokin Trough (Black Sea Basin)

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The Sorokin Trough is located east of the Crimea (the northern part of the Black Sea) and was studied during the 6th Training-through-Research Cruise using a set of geological and geophysical methods. The data collected during this cruise together with some results of the previous expeditions carried out by Moscow State University in 1988-89, have been used for this work.

The continental margin is made up of large volumes of Quaternary hemipelagic sediments, turbidites and delta-fan deposits. A few channel-levee systems were discovered by previous and recent seismic data and detailed bathymetric survey. There are two systems of channels and ridges in the northern part and there is one in the western part of the study area. In the northern part of the study area big lobes are seen (upper fan), which split up into several small ones towards the south (middle fan). The distal part of the fan has hummocky relief (lower fan).

The Holocene Turbiditic Sedimentation on the Crimean Slope and Rise Referred to the Yalta Deep-Sea Fan Formation

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Two cores taken during the second Leg of the TTR-6 Cruise aboard *R/V Gelendzhik* recovered three major lithostratigraphic units of the Black Sea Holocene sediments (Ross and Degens, 1974). The first and the second units were complicated with abundant muddy and silty turbidite layers of different thickness that were sandwiched in between laminated sediment. The presence of these turbidites considerably increased the thickness of the Holocene sediments. Besides these cores, sampling data of the previous cruises were included in the present study, and a total of 72 cores taken from the area was analyzed with the purpose to investigate Holocene turbidites' behaviour and distribution. Detailed stratigraphy of the Black Sea sediments allowed the timing of turbiditic events to be established.

Thickness and sedimentation rate distribution of the upper two lithostratigraphic units were mapped. The maps obtained display two local depocentres of Holocene turbiditic sedimentation. One of them was formed within a time interval of 1635-7540 yr BP (Jones and Gagnon, 1994) and the corresponding sedimentation rate was 80 cm/kyr. The second depocentre located upslope from the first one belongs to a time interval of from 1635 yr BP until present (Jones and Gagnon, 1994), and a sedimentation rate of 50 cm/kyr was calculated. These maxima are referred to deep-sea fan formation resulting from activity of several canyons coming from the area of Yalta Bay and cutting through the slope. The presence of these depocentres is explained by the upslope migration of the fan, caused by the Holocene sea-level rise. The fan development is controlled by a growing clay diapiric ridge well-expressed in the sea-bottom morphology as an elongated rise of 170 m in height. This ridge probably caused the turbiditic flow to shift to the southwest in the beginning of the Holocene and is also a barrier for recent turbiditic flows, preventing those from spreading further onto the abyssal plain. Insignificant shelf width and high seismicity of the region are invoked to explain the existence and modern activity of the Yalta deep-sea fan. Considering earthquake events as a trigger mechanism for turbiditic flows, it is suggested that such events, leading to the initiation of turbiditic flow capable of reaching the abyssal plain, can occur approximately every 90 years.

References

Ross D. A. and Degens E. T., 1974. Recent sediments of The Black Sea. In: The Black Sea - geology, chemistry, E.T. Degens and D.A. Ross, editors, AAPG Memoir Vol. 20, Tulsa, Oklahoma, USA, pp. 183-199

James G. A. and Gagnon A. R., 1994. Radiocarbon chronology of Black Sea sediments. Deep-Sea Research, Vol. 41. No. 3. pp. 531-557.

SESSION 2: GAS AND GAS HYDRATES IN THE SEDIMENTS OF THE BLACK SEA

The Occurrence of Gas Hydrates in Sediments of Eastern Mediterranean Mud Domes as inferred from ODP Leg 160 Pore Water Results

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The occurrence of gas hydrates in marine sediments has been inferred from seismic and pore water observations, and has in a number of cases been demonstrated by their actual recovery. Two mud dome structures have been sampled during Leg 160 in the eastern Mediterranean. The pore waters of one of these, namely Milano Dome, clearly demonstrate the massive presence of gas hydrates at relatively shallow depths in the sediment. The deep pore waters of the other, Napoli Dome, indicate that gas hydrates are unlikely to be present, whereas some observations from very shallow (< 1 mbsf) pore waters suggest that some gas hydrates must also be present here. In the case of Milano Dome, it is likely that a massive cap of gas hydrates is overlying natural gas that cannot escape due to the shape of this cap.

At the conditions prevailing in the two mud domes (Milano and Napoli Domes, water depth 2 km, brine interstitial waters, bottom water temperatures of around 14°C, and the usual geothermal gradient) most of which may be identical to those of the numerous other mud domes in the eastern Mediterranean, gas hydrates can only be stable at relatively shallow sediment depths. At Milano Dome they already occur within the first meter of sediment up to at least 40 m sediment depth (de Lange and Brumsack, 1996, 1997). This is one of the very few places in the world where gas hydrates in the marine realm occur so close to the sediment/water interface. The total quantity of methane contained within and captured below gas hydrates at Milano Dome alone is estimated to be greater than $5*10^9$ m^3 methane. Very recently rapidly increasing bottom water temperatures have been observed both in the western and eastern Mediterranean (Bethoux et al., 1994; Roether et al., 1996). Clearly, such increasing temperature would rapidly lead to the destabilization of the aforementioned shallow gas hydrates. Large quantities of methane can be hazardous in different ways :
a. Ship wreckage (the emission of only 1 m^3 of methane at 2 km water depth results in a gas volume of 200 m^3 near the surface)
b. Methane is an important greenhouse gas (30 times more powerful than CO_2).
Some of the World methane hydrate findings, and their inferred composition will be discussed; subsequently, some of the mud-dome pore water results of ODP leg 160 to the eastern Mediterranean is discussed in relation to the inferred presence of gas hydrates.

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Carbonate Nodules: Mineralogical and Isotopic Characteristics of the Authigenic Carbonates (Black Sea)

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This paper focuses on the study of mineralogical and isotope composition of the authigenic carbonates from nodules and crusts sampled in morphologically different parts of the Black Sea (continental slope, rise, and abyssal plain) at water depths of 300-2200 m. Most of the samples were obtained last summer during the TTR-6 cruise on board the *R/V Gelendzhik* within the framework of the UNESCO-IOC TTR programme.

The major part of the authigenic carbonate inclusions was found in the cores noted for higher content of hydrocarbon gases. All of the inclusions can be roughly divided into two types. The first type is a green-coloured thin crust with a thickness of up to 0.5 cm. The second type is represented by different kinds of nodules. The second type also contains nodule-like inclusions with shells and their fragments cemented by carbonate.

From all of the samples, thin sections were made and analyzed, and an X-ray powder diffraction analysis within a whole interval of Bragg angles was carried out. The mineralogical analysis of the nodules and crusts shows that the so-called "complex" carbonates, such as aragonite, high-Mg calcite 15, and dolomite, predominate over the normal calcite. In some thin sections authigenic pyrite was found either as individual crystals or as large fields of globules.

Carbon stable isotopic analysis was carried out according to the standard procedure described by McCrea (1950). The carbon dioxide for this analysis was released by the reaction of the carbonates with 100% H_3PO_4 at 25°C. The results are given in per mil deviation from the PDB standard.

Two groups of the inclusions were distinguished on the basis of isotopic data. One of them has $\delta^{13}C$ values ranging from -5.89 to +1.81 per mil which is normal for marine carbonates. These data show that this carbonate formation might be controlled by pore waters and caused by precipitation from a water solution. The analysis of the composition of the pore waters also suggests that this mechanism is responsible for the origin of this carbonate assemblage.

The other group, which contains samples from the gas-saturated cores, is characterized by negative $\delta^{13}C$ values (from -27.6 to -34.31 per mil). These carbonates were obviously formed under the influence of hydrocarbon gas, which was oxidized in a sulphate-reducing zone due to microbial activity. In addition, carbonate build-ups with similar mineralogical and isotopic compositions were recently reported in association with the gas seepages in the western part of the Black Sea (Ivanov et al., 1991; Shnukov et al., 1995).

Therefore, the results of this investigation suggest the conclusion that hydrocarbon gas is responsible for the precipitation of carbonate inclusions in the study area as a result of methane oxidation by sulphate reducing bacteria in an anaerobic diagenetic zone of sediments.

References

Ivanov, M.V., Polikarpov, G.G., Lein, A.Yu., Galchenko, V.F., Yegorov, V.N., Gulin, S.B., Gulin, M.B., Rusanov, I.I., Miller, Yu.M., Kuptsov, V.I., 1991. Biogeochemistry of carbon cycle in the region of methane gas emission in the Black Sea. Docl. Russ. Acad. Nauk, Volume 320, N5, pp 1230-1235.

Shnyukov, E.F., Sobolevskii, Y.V., Kutnii, V.A., 1995. Unusual carbonate buildups on the northwestern Black Sea continental slope: a possible consequence of the earth entrails degasation. Lithology and Mineral Resources, N5, pp 451-461.

Distribution and Composition of Hydrocarbon Gas in the Seabed Sediments of the Sorokin Trough (South-Eastern Part of the Crimean Margin)

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A study of the distribution and composition of gas from seabed sediments of the Sorokin Trough was carried out on the data collected on the 6th Training-Through-Research cruise in 1996. During the cruise a total of 15 cores was taken from this region. Twelve of them were noted for gas saturation which is already indicative of an abnormal general level of gas content in the sediments of the area. About 200 samples from 6 cores were collected for analyses of content and composition of gas and organic matter for a comprehensive geochemical study to determine a probable source of this gas. Cores which recovered mud breccia and mud breccia with hemipelagic sediments were investigated.

The gas measurements revealed that most of the cores are characterized by a methane predominance over other gases. In cores BS-284G, BS-288G, and BS-292G it accounts for 97.7%-99.9% of the total of hydrocarbons. The negligible content of homologues was observed in the cores BS-288G and BS-292G where gas hydrates were found. The core BS-284G recovered laminae of mud breccia and hemipelagic sediments; and the mud breccia layers there show an increase in content of C^{2+}. In the core BS-296G (Dvurechensky mud volcano) methane constitutes 58.1% in its uppermost part and increases up to 99.4% downwards while the total content of C^{2+} decreases from 42% at the top to 0.5% at the bottom.

In contrast, in the core BS-293G (Kazakov mud volcano) methane content is generally lower than that of its homologues. Methane decreases there downwards from 92.2% to 1.5% and the content of C^{2+} increases with the depth to 98.5%.

The determination of the total organic carbon (TOC) content shows a range from 0.3% to 2.4%. Its higher values correspond to the hemipelagic sediments. In the mud breccia layers the values of TOC remain the same and their distribution along the cores there does not have any relation to the gas content.

All of the above suggests the influence of fluid inflow in all of the studied cores. The gas from the cores BS-293G and BS-296G is likely to be thermogenic according to its composition. In the core BS-284G the methane homologues, found in mud breccia layers, can be brought there with the breccia itself and trapped by underlying hemipelagic sediments. Otherwise, a lateral gas migration through the mud breccia layers is required. The lack of homologues relative to the methane in the cores which contained gas hydrates can probably be explained either by a pure methane inflow from some source, or by the fact that methane easily forms hydrate crystals while the heavier homologues keep on migrating through the sedimentary column. The lack of correlation between composition and distribution of hydrocarbon gases and TOC content is also evidence for fluid inflow in all investigated cores.

Distribution and Nature of Gas Hydrate Accumulations on the Continental Slope of the Crimea from the Geophysical Standpoint

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An area of mud diapirism located on the continental slope of the Crimea peninsula (northern part of the Black Sea) was investigated in 1996 during the 6th TTR expedition within the framework of the UNESCO-IOC "Floating University" project. The area is known for numerous gas vents, and gas hydrates were reported several times in the sampled seabed sediments.

During the cruise 4 single-channel seismic lines and 3 lines of the MAK-1 deep-tow side scan sonar were made along the large area of mud diapirism within the Sorokin trough elongated from southwest to northeast. A sampling programme was also carried out and in 5 cores gas hydrates were observed. Since all of the cores were taken from the area covered by MAK-1 sonographs and rather close to a seismic line (at a distance of 1.2-2.0 km), an analysis could be made of the geophysical data with the possibility to look for any indications both of gas hydrate accumulations and of gas inflow from some deeper structures probably connected with them, from which conclusions about the distribution of gas hydrate accumulations and their probable nature within the studied area can be inferred.

All of the sites where gas hydrates were sampled are located above the flanks of mud diapirs. Nothing looking like a BSR (bottom simulating reflector) can be observed on the seismic record. This, together with the fact that in the other cores gas hydrates were not found, led to the conclusion that gas hydrates in the area are distributed as local accumulations rather than as a continuous layer. On the other hand, both the sonographs and the record of the MAK-1 subbottom profiler over the sites where gas hydrates were sampled are evident for gas seepages there. Furthermore, the seismic record has many indicators for gas migration below these zones, such as acoustic voids, bright spots, local zones of decreased amplitude of the bottom reflection caused by decreased acoustic impedance contrast, etc.

All the above suggest that the gas hydrate accumulations in the study area are local and associated with active gas vents. Therefore, gas for the hydrates has likely not been formed in situ, but migrated from some deeper source through faults and feeder channels of small mud volcanoes, precipitating gas hydrates within the hydrate stability zone.

SESSION 3: NEOTECTONICS OF THE MEDITERRANEAN SEA (PART I)

Extension in Collision: Constraints from Numerical Models of Mediterranean Basins

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We present the results of a number of tectonic modelling studies carried out recently by the Amsterdam Tectonics Group on the formation and evolution of Mediterranean basins. We review differences and similarities in the modes of basin formation and their implication for the record of vertical motions and the associated stratigraphic record.

Key factors appear to be the pre-rift rheology of the lithosphere and the interplay of simultaneously operating tectonic processes effecting the stress field in the basins.

Better understanding of these processes is of fundamental importance for obtaining better predictions on the coupling of deeper lithosphere processes and geological processes at or near the surface.

References

Cloetingh, S., and Burov, E., 1996. Thermomechanical structure of European continental lithosphere: constraints from rheological profiles and EET estimates. Geophys. J. Int., 124, 695-723.

Cloetingh, S., Wees, J.D. van, Beek, P.A. van der and Spadini. G., 1995. Role of pre-rift rheology in kinematics of extensional basin formation: constraints from thermomechanical models of Mediterranean and intracratonic basins. Marine and Petroleum Geology, vol. 12, nr. 8, 793-807.

Cloetingh, S., d'Argenio, B., Catalano, R., Horvath, F., Sassi, W., (Eds), 1995. Interplay of extension and compression in basin formation: Tectonophysics, vol. 252.

Spadini, G., Cloetingh, S. and Bertotti, G., 1995. Thermo-mechanical of the Tyrrhenian Sea: Lithospheric necking and kinematics of rifting. Tectonics, vol. 14, no. 3, 629-644.

Spadini, G., Bertotti, G., Cloetingh, S., 1995. Tectono-stratigraphic modelling of the Sardinian margin of the Tyrrhenian Sea. Tectonophysics, 252, 269-284.

Spadini, G and Cloetingh, S., 1996. Thermo-mechanical modelling of Black Sea basin formation, subsidence and sedimentation. AAPG Memoir in press.

The Anaximander Mountains in their Geological Context

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The Anaximander Mountains lie at the junction between the Hellenic Arc and the Cyprus Arc where the Mediterranean Ridge meets the Florence Rise. The three principal mountains in the complex rise from depths of around 2000 to 2500 m to peaks at about 700 m (Anaximenes Mountain), 900 m (Anaxagoras Mountain), and 1200 m (Anaximander Mountain); but surrounding depths can reach more than 4000 m to the west (Rhodes Basin) and 3000 m to the north (Finike Basin). Each mountain in the group has a different form from the others: Anaximenes is a curved ridge of steeply dipping (about 25°) sedimentary strata, Anaximander is a north tilted (at about 4°) tabular block, and Anaxagoras comprises a broken NW- SE ridge on a broader plateau of rough relief.

Results from the ANAXIPROBE project indicate that the mountains are a southward-rifted and foundered continuation of the southwestern Turkish Tauride mountains to the north. Samples from the eastern part of the complex (Anaxagoras) are similar to those from the Antalya Nappes complex directly to the north (e.g. ophiolites), and samples from further west are similar to the Bey Daglari mountains to the north (e.g. middle Miocene flysch facies). This is the first direct evidence to support the interpretation of Nesteroff et al. (Nesteroff *et al.* 1977) and to refute other ideas such as that of Rotstein and Ben-Avraham (1985) that the mountains are continental plateau from the south.

The mountains are separated by faults and are undergoing independent movement and deformation. They are caught up in the relative northeastward movement of the African plate with respect to the Aegean and Anatolian microplates, resulting on the one hand in transpression along the Pliny Trench and the extension of this transform boundary into southwestern Turkey and, on the other hand, in the compression of the Mediterranean Ridge against the Florence Rise. Locally, northeastward compression of Anaximenes against Anaxagoras mountain has resulted in the tilting and bending of Anaximenes to the northwest and the development of a fold belt in the Antalya Basin to the northeast of Anaxagoras. Because of resistance of northeastward movement of the mountains, deformation of Anaximenes Mountain is accompanied by underthrusting of this block beneath Anaximander Mountain which is being uplifted as a result.

The history of the mountains follows that of the Taurides up until late Miocene when the development of the western Turkish grabens got underway and the relative direction of plate movement between African and Eurasian started shifting from north-south to northeast-southwest with the initiation of the Aegean/Anatolian microplates. Final rifting of the southern region of the southwestern Taurides took place in the Pliocene after the Pliny-Strabo transpressive boundary was well established; thus the Messinian evaporites are very thin or absent throughout the Anaximander region. At this time the Anaximander mountains were effectively transferred to the African plate to be pushed back against Turkey and the Florence Rise since Pliocene time.

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References

Nesteroff, W.D., Lort, J., Angelier, J., Bonneau, M., and Poisson, A., 1977, Esquisse structurale en Méditerranée orientale au front de l'arc Égéen. in (B. Biju-Duval and L. Montadert, eds.) "International Symposium on the Structural History of the Mediterranean Basins", Éditions Technip, Paris, 241-256.

Rotstein, Y., and Ben-Avraham, Z., 1985, Accretionary processes at subduction zones in the eastern Mediterranean. Tectonophysics, 112:551-561.

Interpretation of Seismic Data from the Anaximander Mountains

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Seismic data were obtained by the *N/O l'Atalante* within the context of the ANAXIPROBE programme in 1995, and processed on the TTR-6 cruise, Leg 1, 1996. The Anaximander Mountains area is located south of Antalya, Turkey, and consists of three principal mountains: Anaximander in the west, Anaxagoras in the east, and Anaximenes in the southeast.

A fold belt is located to the east of Anaxagoras. In between Anaximander, Anaximenes and Anaxagoras lies a lobe-like structure. Both these phenomena appear to have formed under compressional stresses, while the mountains themselves can be interpreted as the result of extensional stresses.

Evaluation of the Gravity and Magnetic Data of Anaximander Mountains

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The boundary between the African and the Eurasian plates is delineated by the Hellenic arc and Pliny-Strabo trench in the west and the Cyprus arc and a diffuse fault system probably associated with the Amanos fault in the east. Within the context of the ANAXIPROBE project it has been tried to determine the origin of the Anaximander Mountains: whether they are the foundered southern part of Turkey, a northward-collided part of the African plate, or an upthrust block of the neo-Tethyan seafloor.

Both the 1991 *Gelendzhik* and 1995 *l'Atalante* gravity and magnetic data are considered in this evaluation within the context of the general tectonic framework of the eastern Mediterranean. Free-air gravity anomalies indicate a crustal discontinuity running directly through the middle of the mountains. Free-air gravity anomalies decrease towards the Rhodes basin (northwest), the Finike basin (north) and the south side at the eastern mountains. These are partly correlatable with water depths. The Bouguer gravity anomaly pattern differs considerably from the free-air anomalies. The western mountains area has high values. The gravity value difference across the gradient zone between the eastern and western mountains, is about 150 mGal.

The magnetic data of the region is rather patchy and this suggests a complex block structure. There is a magnetic low in the middle of the area. There is only a very distinguishable magnetic anomaly to the northeast (west of Antalya Bay, near the Turkish coast) which is most probably associated with the ophiolites in this region.

Several data processing and modelling operations were carried out on the data. Two dimensional sections were produced and modelled in order to determine the crustal structure in the area.

Eratosthenes Seamount: Collision-Related Crustal Processes in the Eastern Mediterranean Sea in the Light of Post-Cruise Results from Leg 160

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The preliminary results of drilling of the Eratosthenes Seamount can now be refined by post-cruise studies. Eratosthenes Seamount is a crustal fragment in the process of collision with the convergent margin to the north, of which Cyprus is part. A transect of four holes was drilled: one on the crest of the seamount, one on its upper slope, one on its lowermost slope and one on the lower Cyprus margin. Overall, the Eratosthenes drilling demonstrated an interesting tectonic-sedimentary history extending back to the Early Cretaceous. Early sedimentation (i.e., pre- Aptian; Premoli-Silva et al., in press) occurred in shallow-water on a carbonate platform, and was overlain by deep water pelagic carbonate of Upper Cretaceous (Coniacian-Maastrichtian) and Palaeocene-Middle Eocene age, including minor chert and laminated organic-rich sediments, with non-sequences and much reworking of biota (Site 967). Overlying Miocene shallow-water carbonates (dated using benthic fossils) were recovered at two sites (965, 966). However, Miocene platform sediments are absent at one site (967), where there is instead a complete Messinian-Pliocene boundary succession including abundant Paratethyan ostracods (S. Spezzaferri, pers. com.). There is evidence of faulting and rapid subsidence of Eratosthenes in the Early Pliocene, with the accumulation of matrix-supported breccias. Water depths increased further during the Late Pliocene to Early Pliocene, to a maximum depth today of around 2500 m. Messinian and Plio-Pleistocene sediments were drilled on the lower Cyprus margin (Site 968) and record contrasting palaeoenvironments and tectonic setting with a "lagu mare" environment. The results of drilling of Eratosthenes can be interpreted in terms of flexurally induced faulting and collapse related to loading by an over-riding Cyprus active margin to the north. The collision of the Eratosthenes Seamount can be integrated into a picture of progressive collision of the African and Eurasian plates in the Eastern Mediterranean region. Different areas range from fully collisional since the Miocene in the Bitlis suture zone to the east, to areas of incipient collision, notably the Cyrenaica Promontory of North Africa, and other areas where collision is only just beginning, as in the Ionian Sea and the Herodotus Basin. An important general aspect of collision is the initial effects of loading by the over-riding thrust load. ODP Leg 160 provided important evidence of the effects of such collision in the case of the Eratosthenes Seamount. In addition, collision of the seamount clearly has a bearing on the focused Plio-Quaternary uplift of the Troodos ophiolite.

Age and Diagenetic Characteristics and the Implication of Some of the Core Samples from the Anaximander Mountains and Finike Trough, the Eastern Mediterranean

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Petrographic and age determinations of some rock fragments from cores and dredges collected during the TTR cruise in July, 1996 from the Anaximander Mountains and Finike Trough area in the Eastern Mediterranean revealed some interesting results. A limestone sample, belonging to the toe of the western Taurus shelf edge on the northern margin of the Finike Trough was a bioclastic limestone, consisting of rudists, echinoderms, mollusks and benthic foraminifera shell fragments. Its age was determined to be Coniacian to Santonian (Upper Cretaceous) based on such age-diagnostic planktonic foraminifera as *Dicarinella primitiva* and *D. cf. Concovata*. It also contained abundant age-diagnostic nannofossils and benthic foraminifera. This limestone correlates with the Bey Daglari Formation of the western Taurus mountains which was mapped in the field and penetrated by drill-holes to the north of the Finike Trough . Correlation was based both on the age and facies characteristics of the limestone sample. Another piece, defined visually as a diagenetic coated crust, and belonging to the Anaximander Mountains, was a biocalcarenite containing 15 percent pyrite which was oxidized to hematite and limonite.

A shale breccia, recovered from a mud volcano near the Anaximander Mountains was dated to be Middle to late Miocene. Such rocks could be correlated with the Tertiary clastic sediments found onshore along the coast of the central Taurus mountains in the area. Some other age determinations from the shale samples collected gave such age ranges as early to Middle Miocene to Pliocene based on their palynomorph contents.

The analysis of pelagic carbonate mud collected, showed a micritic matrix made up of Mg-and Ca calcite and consisting of abundant coccolithic shell fragments and planktonic foraminifera. Mg-calcite in the micrite indicates in situ marine cementation.

SESSION 4: NEW RESEARCH DEVELOPMENTS WITHIN TTR

The Alboran and the South Balearic Basins: Insights from Ongoing Survey

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The basins beneath the Alboran and South Balearic Seas , in the western Mediterranean, are generally identified as originated by extension at the site of a former (late Cretaceous to Palaeogene) collisional orogen and developed within a convergence plate tectonic setting since the early Miocene. Several intra-mountain depressions and corridors within the Betic and Rif Orogens (currently known as Betic or Rifean "Neogene Basins") contain Miocene marine sediments similar to those that fill the Alboran and western South Balearic basins, which indicates that during the Miocene these basins spread out N-S beyond the present limits of the Mediterranean Sea.

Geophysical data provide constraints on regional crustal thinning and configuration from the surrounding chains (Betics and Rif) to the Alboran Sea (from 38-35 km in the Internal Betics and Rif to about 16-14 km beneath the Alboran Sea) and suggest a steady W to E decrease in lithospheric thickness from the West Alboran basin to the South Balearic basin (from 60-90 km in the west to about 35-40 km in the east, at the transition to the South Balearic Sea; Polyak et al., 1996). There is no witness for the existence of Cenozoic oceanic lithosphere at the Betic-Rif-Alboran region. Multichannel deep seismic data, however, suggest the presence of oceanic crust east of 1° W meridian in the South Balearic basin (Comas et al., in press). Accurate geophysical data concerning the South Balearic basin are more scarce than those from the Alboran basin.

Recent ODP drilling (Leg 161, Comas, Zahn, Klaus et al., 1996) confirms the presence of continental crust and the north-south continuity of the stretched Alboran Domain (the internal complexes of the Betic-Rif Orogen) beneath the West Alboran basin. The metamorphic basement sampled below middle Miocene sediments at Site 976 belongs to units of the Alpujarride Complex cropping out in the western Betic Cordillera. East of 4° W meridian most of the basement highs at the central and eastern Alboran Sea and in the western South Balearic basin appears to be formed of volcanic edifices, as revealed by dredging and diving data; notwithstanding, the nature of the whole basement at these eastern regions, is unknown.

A more than 6 km-thick lower Miocene (Burdigalian) to Pleistocene sedimentary sequence occurs in the West Alboran basin; however, in the central Alboran Sea, South and East Alboran basins and western South Balearic basin the sedimentary cover is thinner (less than 3.5 km) and most of the sediments are formed of upper Miocene and Plio-Quaternary deposits. Messinian evaporite developed in the South Balearic basin (salt domes beneath the abyssal plain) , which thins towards the north and south margins and disappear towards the west to the Alboran basin. No direct sample information exists about specific ages of pre Messinian sediments in East Alboran and South Balearic basins.

The structure of the Alboran Sea basin, lying to the east of the Gibraltar Arc, resulted from superimposed extensional and compressional tectonic stages in basin evolution. Rifting and progressive exhumation of the Alboran Domain took place at least from the early Miocene. Early stages of crustal stretching correlate with an early Miocene transgression (about 21-19 Myr BP). A prominent middle to late Miocene rifting (from about 16-14 Myr BP to about 11-10 Myr BP) is identify in the seismic record of the West Alboran basin and has been constrained by ODP drilling. Generalized early Miocene and late-Serravallian-to-Tortonian magmatism, as well as notable mud diapirism in the West Alboran basin, have likely resulted from these extensional processes. This rifting, which is connected to large-scale extension detachments known in Betics and Rif, ceased during the late Miocene (about 10 Myr ago). Patterns of Miocene extension, as well as areal distribution of metamorphic basement units and sedimentary sequences are consistent with an asymmetric WSW directed extensional detachment system to produce crustal thinning. According offshore and onshore data the West Alboran basin is located on the hanging wall of a major crustal detachment. Since the late Miocene, NE-SW trending folds, NE-SW and NW-SE directed strike-slip faults, and tectonic inversions of former extensional faults caused a major contractive deformation in this basin. Structures indicate a NNW/N directed compression during the Pliocene and Pleistocene. ODP Sites 977, 978 (both in the East Alboran basin) and 979 (at the southern flank of the Alboran Ridge) drill through latest Miocene to Pleistocene post-rift sequences that are concerned by compression.

Post-Miocene tectonics caused a major reorganization of the whole region which resulted in prominent N-S shortening of the Alboran Basin and uplifting of surrounding areas. Conspicuous wrench-fault lineaments at the southern margin of the South Balearic basin and at the limit between the Alboran and South Balearic basin, as well as significant NE-SW directed extension in both the West Alboran and the western South Balearic basins took place at these times. Messinian to Recent structures are consistent with late Neogene to Present Africa Europe convergence plate kinematics and are thought to involve crustal boundaries.

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References

Comas, M.C., Zahn, R., Klaus, A, et al. (1996). Leg 161- Western Mediterranean. Init. Repts. of Ocean Drilling Program, 161: 1-638 Washington (U.S. Government Printing Office).

Polyak, B.G., Fernàndez, M., Khutorsky, M.D., Soto, J.I., Basov, I.A., Comas, M.C., Kain, V. Ye., Alonso, B., Apagova, G.V., Mazurova, I.S., Negredo, A., Tochitsky, V.O., de la Linde, J., Bogdanov, N.A. and Banda, E. (1996). Heat flow in the Alboran Sea (the Western Mediterranean). Tectonophysics.

Comas, M.C., Dañobeitia, J.J., and Alvarez Marrón, J. (in press). Crustal reflections and structure in the Alboran Basin: Preliminary Results of the ESCI-Alboran Survey. Rev. Soc. Geol. España.

Large Submarine Slides of the Faeroe Margin: Sidescan Sonar and Seismic Interpretation

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High resolution seismic profiles collected by NIOZ/DGU from the NE Faeroer margin during the ENAM programme, showed large scale sliding of the middle and lower continental slope, affecting sediments of presumed Pliocene and Quaternary age. The TOBI sidescan sonar lines recorded during the *R/V Pelagia* ENAM cruise in 1995 were selected on the basis of the interpretation of these seismic profiles and core studies, and complement the data base obtained so far with detailed seabed morphology and bathymetry.

Analysis of the internal reflection patterns within the basaltic basement, showing seaward dipping reflectors, has indicated that the study area covers the continent to ocean transition zone between the Faeroe Islands and the Norwegian Basin. The basin subsidence was initiated in this area.

On the upper part of the slope, the present day situation seems to be a continuation of the stable depositional environment established during the Pleistocene. Contourite sediments cover slumps and debris flows on the upper slope.

On high-resolution seismic profiles of the area northeast of the Faeroer Islands, four seismic sequences are identified. They are separated by regional unconformities formed by major changes in the palaeoceanography.

The upper limit of the Oligocene and Miocene outcrops coincides with the flat bottom of a recent deep water channel. Since the Miocene, the deep-water current has been active and differential deposition has taken place. Slides appear to have involved only sediments from Mid-Miocene to Recent age. Evidence for bottom current activity in Miocene-Pleistocene times is seen as numerous internal unconformities in the sequences III, IV on the seismic records.

The shallow middle slope slides are abundant and are represented by extensive areas of irregular topography composed of discharged blocky, disturbed debris. In plan view this discharged debris is arranged into wide-spread overlapping lobes. They have hummocky relief on top as seen on TOBI and echosounder records.

Slumping takes place at about 1500 m depth contour, and is most strongly seen in the middle part of the study area. Slumping seems to have taken place a number of times, as the lower margin exhibits a number of stacked chaotic apparently slumped intervals. A major slide scar appears at 1500 m water depth having a 225-310 m steep cliff-slope. It is probably covered by recent sediments in the western part of the studied area. The basin floor below the escarpment is characterized by slumped material. Swarms of block trails are observed downslope.

Interpretation of sidescan sonar data indicates that the slope on the continental margin north of the Faeroe Islands has been unstable also within the youngest geological time.

Corsaires: Challenges for Coring the European Margins

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Many years of successful high-resolution reflection seismic profiling and shallow coring by various teams along most European margins, either in the framework of MAST programmes or other international or national projects, have yielded several extremely promising geological objectives, impatiently waiting for 'groundtruthing'. Quite a few of these targets could be addressed by drilling vessels of opportunity, in particular geotechnical vessels, provided some funds are available when the opportunity shows up. Building such opportunities is a major objective of the EC MAST3 concerted action CORSAIRES (CORing Stable And Instable Realms in European Seas Project).

Though the drilling funds could not be readily obtained from the EC yet, a number of preparatory tasks are being carried out within the framework of the concerted action scheme. Some of them contribute to stimulate technological developments, other ones to pave the way for long-range concerted European research actions in strategic themes such as gas hydrates, and many "political" messages are being prepared and conveyed for promoting the case of ocean drilling in Europe.

But for addressing the short term objectives, helping to structure the already identified scientific priorities and the interested scientific communities is a task on its own. This structure is being developed around "core groups", coinciding with the identified regional and/or thematic main areas of interest. A Nordic Core Group (Faeroer-Shetland cluster), a Celtic Core Group (Porcupine Bight - Celtic Sea cluster), an Iberic Core Group (SW Portuguese margin cluster), a French-Italian Mediterranean Core Group and an Eastern Mediterranean Core Group are being shaped, as well as a thematic Core Group about Gas Hydrates. These Core Groups will strengthen the case for drilling these objectives, in further updating and documenting the sites and carrying out site surveys, in assessing priorities, etc.

There is a clear opportunity for synergy between the TTR and CORSAIRES programmes in this field, not the least as CORSAIRES has also been entrusted a task of education at sea, around the coring and core data processing issues.

Sedimentary Processes and Pathways on Glaciated and Non-Glaciated Margins of the Northeast Atlantic

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PONAM, ENAM and other European projects have sponsored extensive surveys of the slope and rise of the northeast Atlantic using the GLORIA long range sidescan sonar, the TOBI medium range sidescan sonar and high resolution seismic profilers. This provides a plan view perspective on the downslope and alongslope distribution of coarse sediments.

Non-glaciated slopes are dominated by channelised turbidite systems with volume of input as the major control. Highest input systems (the giant submarine fans) with distributary channels, low maximum gradients and high sinuosities, are not found in the area. Low input systems (which are typical for the slopes from north of Ireland and to the south) have tributary canyons, sometimes with a single leveed channel. Their gradients are relatively high and sinuosities low. Sand transport is common and sands are sorted into channel deposits and sandy lobes at the channel mouths. Such channel mouth lobes are recognised in the Bay of Biscay but are as yet little studied.

In high latitudes, fast flowing ice streams draining large areas produce large arcuate fans such as the Bear Island Fan and the North Sea Fan. They have a shelf edge bulge and gentler gradients, built up mainly from frequent muddy debris flows. Smaller drainage areas produce smaller, steeper fans, usually with smaller debris flows. Five major sites of large and infrequent slope failures are mapped off the glaciated margins of Europe, including the area north of the Faeroes, the Storegga Slides and the Traenadjupet Slides. None of these processes appear to be able to sort out sands effectively. However there are probable turbidite channels on the slopes of East Greenland. They have low levees, and are prone to be very long. They are associated with slopes without fast flowing shelf edge ice streams. Such channels do appear to have thick sand deposits.

Sands are also transported by relatively strong alongslope currents. Such sand movement in the deep sea is more common than previously supposed. It occurs in deep sea straits, such as the Straits of Gibraltar and the Faeroe Bank Channel. It also occurs in some boundary currents such as the poleward flows sweeping the upper slope west of Scotland and Norway. Sidescan sonar has effectively mapped such strong contour currents. The architecture of the resulting sandy contourite deposits is still poorly known.

Reference

Dowdeswell, J.A., Kenyon, N.H., Elverhoi, A., Laberg, J.S., Hollender, F.-J., Mienert, J. and Siegert, M.J. 1996 Large-scale sedimentation on the glacier-influenced Polar North Atlantic margins: long-range side-scan sonar evidence. Geophysical Research Letters, 23, 3535-3538.

SESSION 5: NEOTECTONICS OF THE MEDITERRANEAN (PART II)

Palaeotectonic Setting of the Mesozoic-Early Tertiary SW Antalya Complex in the Light of Results from the Anaximander Seamount

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Dredging of the Anaximander Seamounts is reported to have revealed a range of rock type that are similar to Mesozoic-Early Tertiary units of the Antalya Complex exposed onshore in SW Turkey. The purpose of this talk is briefly to review mostly published information, and to illustrate the geology and structure of the area with field slides. The Mesozoic-Early Tertiary allochthonous rocks of the Antalya Complex are exposed on both flanks of the Isparta angle, a former seaway that separated two opposing carbonate platforms. The SW area is reconstructed as a passive margin to a large carbonate platform (Bey Daglari), passing out into an oceanic basin to the SE, part of the southerly Neotethys that includes Cyprus, Hatay (Turkey) and Baer Bassit (Syria) during the Mesozoic. The SW Antalya Complex comprises a number of

N-S tectonic units (zones) from west to east, as follows: 1. The Bey Daglari Zone comprises Lower Jurassic to Early Tertiary carbonates, mainly neritic, overlain by ophiolite-related clastics related to final Miocene thrust-emplacement. 2. Kumluca Zone: an imbricate fan of deep-water slope and basinal sediments of Upper Triassic to Upper Cretaceous age; 3. Godene Zone: Thick mainly Upper Triassic basaltic volcanics of WPB to MORB type, overlain by Triassic to Late Cretaceous deep-water sediments, especially ribbon radiolarites. The Godene Zone is cut by steeply-dipping anastomosing strands of serpentinite, that include highly dismembered Upper Cretaceous ophiolitic rocks and minor amphibolite. The Godene Zone also contains Upper Palaeozoic basement rocks and Mesozoic carbonate platform rocks. 4. The Kemer Zone is dominated by Ordovician to Permian basement sedimentary units overlain by Mesozoic carbonate platform units. Lastly, the Tekirova zone comprises the deeper intrusive parts of an Upper Cretaceous ophiolite, unconformably overlain by Late Cretaceous ophiolite-derived clastics. The SW Antalya Complex is restored as the rift and passive margin of part of the large Bey Daglari carbonate platform to the west, a microcontinent within Neotethys. This margin was deformed and imbricated in the Late Cretaceous-Early Tertiary in a strike-slip dominated regime; it was however only finally emplaced in the Palaeocene-Eocene and Miocene, in part coeval with palaeorotation of the westerly limb of the Isparta angle. Uplift has mainly taken place in Plio-Quaternary time and the present topography is dominated by important N-W trending mainly down-to-the-east normal faults, that are also seen disappearing offshore towards the Anaximander Seamount, as determined by Clare Glover (unpublished Ph.D. thesis, Edinburgh, 1996). It is likely that the margin of the Bey Daglari platform formerly extended southwards into the Anaximander Seamount area, where it would have been terminated by a more east-west trending passive margin segment that linked with the southerly Neotethys south of Crete.

Marine Geology of the Medriff Corridor, Mediterranean Ridge

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A 300 km long transect (Medriff Corridor) across the Mediterranean Ridge was investigated by the members of the MEDRIFF consortium (part of the EU - MAST II research programme). Swath mapping of the sea bottom, seismic profiling and side scan sonar imaging preceded the collection of 31 sediment cores (with a maximum of 10 m of sediment recovery) during the *Urania* '93 and *Discovery* D206 cruises. The Mediterranean Ridge is an accretionary complex subject to continent/continent collision and containing an important evaporitic body, partially responsible for the presence of the newly discovered deep sea brine lakes (Urania, l'Atalante and the Discovery basins).

Most sediment cores have a pelagic facies, with biogenic marls as dominant lithology and sapropels and tephras as minor, isochronous lithologies. A combination of isochronous lithologies and calcareous plankton biochronology permits high resolution stratigraphic correlations. Pelagic facies sediments are Middle Pleistocene to Holocene in age. Two cores associated with mounds located along thrusts contain a matrix-supported mud breccia of deep provenance, Burdigalian-Langhian in age, similar to that characteristic of the Mediterranean Ridge diapiric belt (Cita et al., 1995). The newly discovered brine lakes originated from the submarine dissolution of the Messinian evaporites and are different in the various basins. The sedimentary record strongly differs from basin to basin. These brine lakes are very young (35000 years old or less). A drastic change in sedimentation rate recorded in the Discovery Basin suggests that basin collapse was sudden and followed by progressive development of basin anoxia. Some cores were analysed with a prototype multisensor for P-wave velocity, magnetic susceptibility and density. Sapropels show up as abrupt decreases in P-wave velocity and density whilst tephras as sudden increases in magnetic susceptibility. Mud breccia displays P-wave velocities greater than pelagic marls, with peaks related to lithic clasts. Anoxic sediments have high P-wave velocities; peaks are associated with gypsum crystals.

Diatoms from the Sapropel Layers of the Anaximander Mountains Area (Eastern Mediterranean)

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Diatoms were studied from four cores 197G, 224G, 226G, and 228G taken in the Anaximander Mountains area. The sapropel and oxidized layers were investigated mainly. Uneven diatom distribution in the sediments was established. Diatoms were not found even after maceration with heavy liquid in S1 and some oxidized layers from 197G, in any sapropels from 224G, in S1 and two lowest sapropel (S4?, S5?) from 226G, in S1 and S3 from core 228G. A paucity of diatom frustule occurs in S4 from 197G and in the upper sapropel layer of section 4 from 226G, that could be S4 as well. A great abundance and diversity of diatoms was revealed for S5 from 197G and 228G, and for the lower sapropel of section 4 from 226G. The latter seems to be also S5 because of similarity of diatom flora with that in S5 of 197G and 228G.

The planktonic marine forms prevail in the assemblage. The well-preserved *Rhizosolenia calcar-avis* is the most abundant. *Thalassionema nitzschioides, Thalassiothrix frauenfeldii, T. longissima, Hemiaulus hauckii, Thalassiosira oestrupii, Bacteriastrum* sp. are common. Such assemblage is typical for a warm-water deep basin with normal marine salinity. The abundance of diatom valves in S5 is a result of a great diatom productivity in that time.

Eastern Mediterranean Carbonates: Petrographical and Diagenetic Case Study on TTR-6 223D Dredge (Offshore SW Turkey)

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A detailed petrographic and diagenetic investigation of carbonates recovered by dredge TTR-6-223D (Eastern Mediterranean, offshore SW Turkey) reveals similarities in age and lithofacies with the Mesozoic carbonates found onshore in the Susuz Dag / Bey Daglari complexes and the Çatal Tepe Unit of the Antalyan Nappes complex, all part of the Western Taurids, SW Turkey. The carbonate breccia facies is believed to be part of slope deposits supplied by a carbonate platform, that is presently part of the autochthonous Bey Daglari and Susuz Dag units, and this was the dominant depositional setting up to the Oligocene, before the Miocene flysch facies covered it completely.

A paragenetic sequence, with at least 8 events following deposition, has been identified in analyses using plane (polarized) light and cathodoluminescence microscopy. Diagenetic investigations suggest the precipitation of calcite cements out of meteoric fluids after a (Alpine?) tectonic phase fracturing the Upper Senonian (Campano-Maastrichtian) Globotruncana pelagic facies, and prior to the redeposition of the same facies as clasts in the carbonate breccia. Observations could be related to the emergence of part of the Susuz Dag complex during the Oligocene, which is associated with karstification and erosional processes.

References

Bathurst, R.G.C., 1971. Carbonate sediments and their diagenesis. Developments in sedimentology 12. Elsevier, Amsterdam, 658 pp.

Gutnic, M., Monod, O., Poisson, A. et Dumont, J.F., 1979. Géologie des Taurides Occidentales (Turquie). Mémoires de la Société Géologique de France, N. S., T. LVIII, Mémoire No. 137, pp 1-112, 2 cartes.

Machel, H.G., Mason, R.A., Mariano, A.N. and Mucci, A., 1991. Causes and Measurements of Luminescence in Calcite and Dolomite. In: C. E. Barker and O. C. Kopp (Editors), Luminescence Microscopy and Spectrometry: Qualitative and Quantitative Applications. Soc. Econ. Paleontol. Mineral. Short Course Notes 25: 9-25.

Reeder, R. J., 1991. An Overview of Zoning in Carbonate Minerals. In: C. E. Barker and O. C. Kopp (Editors), Luminescence Microscopy and Spectrometry: Qualitative and Quantitative Applications. Soc. Econ. Paleontol. Mineral. Short Course Notes 25: 77-82.

Palaeoclimatic Changes over the Last 130 Ky in the Anaximander Mountains Area (Eastern Mediterranean)

Alexander Sautkin

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Deep-sea core TTR-197G in the Eastern Mediterranean, from the area of Anaximander Mountains (35° 00.1'N, 29° 30.3E', water depth 2595 m, total length 386 cm), was chosen for a quantitative analysis of calcareous nannofossils.

Pelagic sediments recovered by the core include several regional markers: tephras Z2 (15 cm bsf), Y5 (122 cm) and probably Y2 (70 cm); sapropels identified by their assemblages of planktonic foraminifera and calcareous nannofossils, as S1 (31-36 cm), S4 (265-268 cm), S5 (287-320 cm); and probably oxidized sapropel S3 (218-219 cm). The lower part of the core (from 133,5 cm to the bottom) belongs to the *Emiliania huxleyi* Zone, and the remaining upper part of the core to the *E. huxleyi* Acme Zone. The Acme Zone was determined by the predominance of *E. huxleyi* (34,5 %) in the coccolith assemblages. Each sapropel layer in the core is characterized by a specific assemblage of calcareous nannofossils. Changes in abundance of some coccolith species through the core permit me to reconstruct the climatic changes during the last 130 kyr. In pelagic non-sapropelic sediments, Miocene-Pliocene redeposited nannofossils are observed, and their species composition was also studied.

SESSION 6: MUD VOLCANOES

A Model for Acoustical Backscatter from Mud Volcano Breccia

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A heuristic model for acoustic backscatter from rock clasts in mud volcano breccia was developed for the explanation of the contrast in backscatter intensity between areas covered by mud breccia and normal pelagic and hemipelagic sediments. Input parameters for the model are: velocity of clasts and matrix of mud breccia, density of clast and matrix, attenuation of sound in the matrix of mud breccia, volume percentage of clasts, parameters of clasts size distribution function. Since estimates of clasts size distributions in mud breccia are currently unavailable, a log-normal law was used for modelling.

Experimental data on backscattering strength from Novorossiysk mud volcano from the western flank of the Mediterranean Ridge derived from SIMRAD EM12 multi-beam echo sounder data were compared with the results of input parameters. Good fit with experimental data was observed for a realistic value of clasts volume percentage (15-20 %) and a mean clast-radius of 1 cm. Small amounts of clasts (5%) appear to be able to produce significant backscatter. Scattering of sound by nodules of gas hydrates was examined in frames of the same model used for rock clasts. The scattering effect of gas hydrates appears to be lower than that of rock clasts due to lower impedance contrast between matrix and inhomogeneities.

Features of the Black Sea Mud Volcanoes and Mud Diapirs according to Seismic Data

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Mud volcanoes and mud diapirs were important targets of the TTR programme from its very beginning. During the 1991-1995 cruises two areas of mud volcanism were investigated: an area in the central part of the Black Sea and an area in the central part of the Mediterranean Ridge. In 1996 the investigations were spread into two new areas: new mud volcanoes were discovered in the Eastern Mediterranean near the Anaximander Mountains thanks to sidescan data and geological sampling, though on seismic records these mud volcanoes were quite indistinguishable. The area to the south of the Crimea Mountains was known as an area of mud diapirism thanks to 1970-s, 1980-s seismic investigations. During the last TTR cruise new seismic and sidescan data were obtained, and by these data and geological sampling, new mud volcanoes were discovered. It is interesting to compare the seismic images of mud volcanoes and mud diapirs of the last area with those of the central Black Sea and of the Mediterranean Ridge.

In the central part of the Black Sea - on the abyssal plain - we know a limited number of randomly distributed huge mud volcanoes, mostly with well shaped, quite symmetrical cones and with feeder channels, which can be observed on seismic records very well. They broke almost vertically through the thick, well stratified and hardly faulted sedimentary sequence. The roots of these volcanoes are so deep, that we have never observed them on seismic records. We can't surely say, that we have observed mud diapirs or diapiric folds here, either.

In the Mediterranean Ridge, to the contrary, sediments are so heavily folded and faulted, that mud volcanoes can be noticed on seismic profiles only after detailed analysis. It is difficult to establish the form and size of the feeder channel, and the depth of the roots, although the volcanoes seem to have a very shallow structure.

The area to the south of the Crimea Mountains is situated on the foot of the continental slope. The sedimentary sequence, according to single channel seismic data, is well stratified and in some places is noticeably folded. Many mud diapirs and diapiric folds are visible on seismic records at comparatively small depths (0.2-0.5 km). Some of the diapirs seem to break through the stratified sediments completely to the sea floor. On the top of some of diapirs or on the flanks one can notice vertically stretched zones of chaotic reflections, accompanied by small dome like structures on the bottom surface. So these zones can be interpreted as feeder channels of mud volcanoes. Sidescan surveying and geological sampling confirmed these assumptions - mud breccia, gas saturated sediments and gas hydrates were found at the sampling sites. It is worth noticing that for their geometric characteristics in this area the mud volcanoes can be considered as intermediate between the central Black Sea and the Mediterranean Ridge mud volcanoes: their roots are situated at comparatively shallow depths and are visible on the seismic records. Therefore, a detailed study of this area may provide the possibility to understand the mud volcanism phenomenon as a whole.

ODP Leg 160 Mud Volcanic Samples in the Context of the TTR Data on the Mediterranean Ridge Mud Volcanism

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Mud volcanism on the Mediterranean Ridge has been the object of intensive investigations during "Floating University" (TTR) expeditions in 1993, 1994 and 1995 (*R/V Gelendzhik* and *R/V Professor Logachev* cruises). As a result, a large data base has been built up on the lithology of mud volcano deposits exposed on sea-floor or overlain by a thin veneer of Holocene ooze (Limonov et al., 1996). The ODP holes drilled during Leg 160 within the Olimpi Area, one of the most studied mud diapiric areas of the Mediterranean Ridge, have allowed us for the first time to look deeper into the mud volcanoes and to analyse some peculiarities of their development since Pliocene time (Emeis et al., 1995).

The composition of buried mud breccias recovered during ODP Leg 160 were found to be rather typical of the Olimpi area as determined from the earlier TTR investigations. No significant differences from mud breccia exposed on the sea-floor were observed.

Most of the mud breccia clast types previously described for exposed mud breccia flows of the Olimpi area were found in the ODP samples. No new types were observed in the buried and older mud breccia. Mudstones are prevalent among rock fragments of the mud breccia samples recovered by ODP as well as in exposed Olimpi mud breccia. Micrites, fossiliferous micrites, and packed biomicrites are as widespread among lithoclasts of the limestone group as in the youngest mud breccia flows. The different sandstone fragments observed in ODP mud breccia samples probably correspond to the subfeldspathic lithic wackes and lithic arenites previously described for the Olimpi area (Akhmanov, 1996). The crystalloclasts have probably all resulted from disintegration of different rock fragments within the mud breccia. The set of crystalloclasts corresponds completely to component compositions of the lithoclasts. Quartz grains, plagioclase grains, K-feldspar grains, and muscovite are from the subfeldspathic lithic wackes and the lithic arenites. Monocrystals of calcite are from rocks of the limestone group or as fragments of calcite cement of the lithic arenites. The crystalloclasts observed in mud breccia samples are usually less than 0.25 mm and never more than 0.5 mm in size. This corresponds to grain-size parameters of the lithoclasts described for the Olimpi mud breccia (Akhmanov,1996). Bioclasts of a mud breccia, probably, also have resulted from disintegration of rock fragments within mud breccia. Most of them are from carbonate rocks, rich in skeletal components.

The Olimpi mud breccia matrix examined in ODP Leg 160 samples and TTR samples is similar and mainly composed of smectite and mixed-layered (illite/smectite with prevalent smectite layers) clay minerals (40-65%), kaolinite (15-30%), and illite (10-30%). The lack of significant downhole variation in mud breccia composition suggests that the source formations for the mud breccia have not changed since at least Late Pliocene.

References

Akhmanov G.G., 1996. Lithology of Mud Breccia Clasts from the Mediterranean Ridge. Mar. Geol., 132: 151-164.

Emeis K.C., Robertson A., Richter C., and Shipboard Scientific Party Leg 160, 1995. ODP Preliminary Report 60, 89 pp.

Limonov A.F., Woodside J.M., Cita M.B., and Ivanov M.K., 1996. The Mediterranean Ridge and Related Mud Diapirism: A Background. Mar. Geol., 132: 7-19.

Mud Breccias of the Mediterranean Ridge: Lithological Findings on the Deformed Sediments Composing the Accretionary Prism

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During the 5th Training-Through-Research Cruise on board the *R/V Professor Logachev*, three new mud domes were discovered on the Mediterranean Ridge in an area south of Crete (33-34°N, 25-26°E). These mud volcanoes were sampled using gravity cores and a TV-controlled grabber. The majority of the clasts found in the mud breccias of the Dublin- and Stoke-on-Trent mud volcanoes are mudstone fragments. Calcarenites, sandstones, marls, breccias and gypsum were also recovered. Some clasts show signs of deformation, others are massive, laminated or bioturbated. Study of washed residue, thin sections and smear slides shows that the ages vary from upper Cretaceous to Present. At least two eruptive stages were identified and the Stoke-on-Trent mud volcano probably still is active.

ORETECH lines ORE-35 and ORE-36 were used to determine the positions of the cores and grab and their relation to each other. DSDP-sites (125-131) and ODP-sites (965-973) were used to make a comparison between the clasts found in the mud volcanoes and rock types recovered by drilling elsewhere in the Levantine and Ionian basins. Using these correlations and the descriptions, a more thorough stratigraphic section than before was sketched. The sediments show wave dominated deposits, shallow water deposits below wave base, turbidites and pelagics. Our conclusion of at least two shallowing periods in a deep basin agrees with observations elsewhere in the region. There is a regression after the Cretaceous and one at the end of the Miocene. These fluxes are caused by tectonic and climatic changes and are followed by transgressive periods.

Processes of Mud Volcanism on the Mediterranean Ridge in the Regional Tectonic Evolution of the Southerly Neotethys Ocean

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Drilling the Milano and Napoli mud domes on the Mediterranean Ridge during ODP Leg 160 (Sites 970/971) provides insights into processes of mud volcanism. (Kopf and Robertson, 1997). Eruption of largely mud debris flows began prior 1.5 Myr BP, based on biostratigraphic evidence. Both mud volcanoes evolved through a distinct cycle. Early extrusion built up cones of clast-rich debris flows and turbidites, overlain by pelagic sediments, and then followed by successive eruptions of matrix-supported debris flows containing fewer clasts. Both layering and gradational changes are indicated by core observations and formation microscanner data . Upbuilding was accompanied by subsidence to form peripheral moats that still exist in the case of Napoli. The location of the mud volcanoes near the rear part of the Mediterranean Ridge accretionary wedge is critically dependent on collision with the Cyrenaica Peninsula of North Africa to the south. This collision resulted in backthusting of the evaporite-bearing accretionary wedge against a rigid backstop of Cretan continental crust to the north. This backthrusting allowed egress of fluid-and gas-rich muds (probably overpressured) from depth, probably from within the decollement zone. Many of the clasts and some of the matrix material, however, are more likely to have originated from the overlying accretionary wedge. The most probable genesis of lithified clasts is by physical plucking and/or hydraulic fracturing by rising overpressured muds, followed by upward migration and seafloor extrusion of multiple debris flows. Combined results from permeability and shear strength tests, grain size analyses, study of sedimentary textures,and estimates of the viscosity of mud volcanic deposits provide further clues to eruptive processes. Together with side-scan sonar images a quantitative estimate of the mud efflux related to tectonic shortening can be made.

Petrographic studies of clasts and matrix within debris flows making up the Milano and Napoli mud volcanoes drilled south of Crete (ODP Sites 970 and 971) provide insights into the palaeo-tectonic setting of the Eastern Mediterranean (Sea of Crete area) during Upper Oligocene-Upper Miocene (Robertson and Kopf, 1997). Lithified clasts are mainly quartzose sandstones (litharenites), siltstones, calcarenites (both shallow-and deep-water) and pelagic carbonates. Biostratigraphic evidence indicates mainly Middle Miocene ages for fossiliferous clasts, with older microfossils being reworked. Textural evidence (e.g. grading, sorting, grain alignment) suggests the clastic lithologies are turbidites. Sources of the sandstones were mainly plutonic igneous (plutonic quartz, exsolved feldspar, microcline, augite) and metamorphic (polycrystalline quartz, schist, muscovite, foliated biotite). Well-rounded quartz grains are seen as aeolian derived. Provenance was ultimately from the Precambrian basement of North Africa. Contrasting, texturally immature lithic sandstones include serpentinite, basalt, radiolarian chert and sphene, of probable ophiolitic origin, material that is inferred to have been derived from the higher thrust sheets of Crete or adjacent orogenic areas, prior to Plio-Pleistocene erosion and extensional downfaulting of the South Aegean. Shallow-water-derived carbonates were redeposited as calciturbidites, derived from both margins. Contrasting provenances are also indicated by X-ray diffraction of the matrix. Abundant kaolinite has a presumed Nile source, while illite and chlorite are seen as being mainly Eurasian derived. The matrix of the mud debris flows includes numerous small clasts of unfossiliferous claystone and shard-like fragments, showing pseudo-lamination, micro-shearing and cross-cutting veinlets, features that are taken as evidence of high strain and high fluid pressure during matrix formation. Evidence of rare calcite-filled veins and breakage of quartz grains in serpentinite-bearing sandstone clasts are also indicative of some deformation prior to mud volcanism, possibly related to formation of an early accretionary wedge. However, there is no evidence within the clasts of pervasive tectonic deformation (e.g. cleavage, stylolites, or flattening of competent grains), which places constraints on the mode of mud volcanism.

Finally, the history of the mud volcanism can be integrated into the regional tectonic history of the south Aegean, including the development of the North African continental margin to the south, and the closure of Neotethys to the north. Subduction of Mesozoic ocean basins to the north (i.e., Pindos ocean) culminated in emplacement of nappes in Crete; the subduction zone then jumped southwards to initiate the present subduction system south of Crete, building up an accretionary wedge from Late Oligocene? onwards. However, mud volcanism was not initiated until the accretionary wedge began to collide with the North African passive margin, initiating backthrusting and providing zones of egress for mud volcanism.

Turbidites around an Active Fault Scarp Downfan of the Valencia Channel Mouth, Northwest Mediterranean

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Side-scan sonar images from the lower Valencia Fan show that turbidite bedforms (chevrons) vary around a small fault scarp. The variation of the bedforms suggests that the thickness of the current that deposited the turbidite must have been at least 10 m. This agrees with the flow thickness of 9.5 m calculated from bedforms interpreted as antidunes upcurrent from the fault scarp. The fault scarp was not high enough to cause changes in flow vector but was enough to change the nature of bedforms, from chevrons on the hanging wall to smooth bed on the footwall. The distribution of these features were compared with observations of three experimental currents which were partially blocked by an obstacle on the tank floor. In an experiment using a suspension of silicon carbide sediment, up to 40% of the flow was blocked by the obstacle, causing the current to slow, thicken and deposit a greater sediment thickness than in a comparable experiment without an obstacle. Obstacle height to flow depth ratio is an important factor controlling the behaviour of flow over the obstacle and hence the resulting character of turbidite distribution.

ANNEX I

'GAS AND FLUIDS IN MARINE SEDIMENTS'

CONGRESS PROGRAMME
FIFTH TTR POST-CRUISE MEETING

Free University, Amsterdam
January 27-29, 1997

Monday 27 January

Free University of Amsterdam
Faculty of Earth Sciences
Room D107

09:15-10:15 Registration of Participants

10:15-10:30 Opening

Section 1 **Seismics and Sedimentology of the Black Sea**
chairman: John Woodside

10:30-11:30 **William Ryan:** An Abrupt Drowning of the Black Sea Shelf

11:30-11:50 *Break*

11:50-12:20 **Michael Ivanov:** An Extensive Fluid Flux and Associated Phenomena on the Crimean Continental Margin: an Overview

12:20-12:50 **Anatoly Limonov:** Structure of Sedimentary Cover in the Sorokin Trough (South of Crimea) Related to Mud Volcanism

12:50-13:10 **Anna Volkonskaya**: Geological Features of the Palaeo-Don/Kuban Deep-Sea Fan According to the Results of the Seismic Study on the Pallas Uplift (Northeastern Black Sea)

13:10-14:25 *Lunch*

14:25-14:45 **Elena Kozlova**: Recent Sedimentary Processes in the Sorokin Trough (Black Sea)

14:45-15:05 **Andrei Ahkmetzhanov**: The Holocene Turbiditic Sedimentation on the Crimean Slope and Rise Referred to the Yalta Deep-sea Fan Formation

Section 2 **Gas and Gas Hydrates in the Sediments of the Black Sea**
chairman: Anatoly Limonov

15:05-15:35 **Gert de Lange**: The Occurrence of Gas Hydrates in Sediments of Eastern Mediterranean Mud Domes as Inferred from ODP Leg Pore Water Results

15:35-15:55 *Break*

15:55-16:15 **Irina Belenkaya**: Possible Influence of Hydrocarbon Gas on the Geochemical Environment in Sediment and the Origin of the Authigenic Carbonate Minerals

16:15-16:35 **Alina Stadnitskaya**: Distribution and Composition of Hydrocarbon Gas in the Seabed Sediments of the Sorokin Trough (Southeastern Part of the Crimean Margin)

16:35-16:55 **Serguei Bouriak:** Distribution and Nature of Gas Hydrate Accumulations on the Continental Slope of the Crimea from the Geophysical Standpoint

17:00 *Icebreaker in the "Tuinzaal"*

19:00 **TTR Executive Committee Meeting**

Tuesday 28 January

Free University of Amsterdam
Faculty of Earth Sciences
Room D107

Section 3 **Neotectonics of the Mediterranean, Part I**
chairman: Serguei Bouriak

10:00-10:30 **Sierd Cloetingh:** Extension in Collision: Constraints from Numerical Models of Mediterranean Basins

10:30-11:00 **John Woodside and Jean-François Dumont:** The Anaximander Mountains in their Geological Context

11:00-11:20 *Break*

11:20-11:40 **Twan Kleeven:** Interpretation of Seismic Data From the Anaximander Mountains Processed on TTR-6-cruise, Leg 1, Preliminary Results

11:40-12:10 **Mustafa Ergün:** Evaluation of the Gravity and Magnetic Data of Anaximander Mountains

12:10-12:40 **Alastair Robertson:** Tectonic Setting of the Eratosthenes Seamount in the Light of Leg 160

12:40-13:10	**Süleyman Turgut:** Age and Diagenetic Characteristics and Implications of Some of the Core Samples From the Anaximander Mountains and Finike Trough, the Eastern Mediterranean
13:10-14:25	*Lunch*
Section 4	**New research developments in TTR** chairman: Michael Ivanov
14:25-14:55	**Michael Marani:** Recent Swath Mapping Results from the Tyrrhenian Sea
14:55-15:25	**Menchu Comas:** Alboran and South Balearic Basins: Insights from Ongoing Survey
15:25-15:45	**Ekatharina Akentieva:** Large Submarine Slides of the Faeroe Margin: Side Scan Sonar and Seismic Interpretation
15:45-16:05	*Break*
16:05-16:35	**Jean-Pierre Henriet:** CORSAIRES: Challenges for Coring the European Margin
16:35-17:05	**Jean Mascle:** The next PRISMED-II Cruise, January-February 1998
17:05-17:35	**Neil Kenyon:** Sedimentary Processes and Pathways on Glaciated and Non-glaciated Margins of the North East Atlantic
18:00	**TTR Executive and Scientific Committees Meeting: Discussion on TTR Plans**

Wednesday 29 January

Free University of Amsterdam
Faculty of Earth Sciences
Room D107

Section 5	**Neotectonics of the Mediterranean, Part II** chairman: Jan van Hinte
10:00-10:30	**Alastair Robertson:** Palaeotectonic Setting of the Mesozoic-early Tertiary SW Antalya Complex in the Light of Results from the Anaximander Seamount
10:30-10:50	**Giovanni Aloisi de Larderel:** Marine Geology of the Medriff Corridor, Mediterranean Ridge
10:50-11:10	**Svetlana Gablina:** Diatoms from the Sapropel Layers of the Anaximander Mountains Area (Eastern Mediterranean)

11:10-11:30	*break*
11:30-11:50	**Jorijntje Henderiks:** Eastern Mediterranean Carbonates: Petrographical and Diagenetic Case Study on TTR-6 223D Dredge (Offshore SW Turkey)
11:50-12.10	**Alexander Sautkin:** Palaeoclimatic Changes over the Last 130k Years in the Anaximander Mountains Area (Eastern Mediterranean)
Section 6	**Mud Volcanoes** chairman: Twan Kleeven
12:10-12:30	**Roman Almendinguer:** A Model for Acoustical Backscatter from Mud Volcano Breccia
12:30-13:00	**Valery Gainanov:** Features of the Black Sea Mud Volcanoes and Mud Diapirs, According to Seismic Data
13:00-14:15	*lunch*
14:15-15:35	**Grigorii Akhmanov:** Odp Leg 160, Mud Volcanic Samples in the Context of the TTR Data on the Mediterranean Ridge Mud Volcanism
15:35-15:55	**Karin van der Zel:** Mud Breccia of the Mediterranean Ridge, Lithological Findings on the Deformed Sediments Composing the Accretionary Prism
15:55-16:15	*break*
16:15-16:45	**Alastair Robertson:** Processes of Mud Volcanism on the Mediterranean Ridge in the Regional Tectonic Evolution of the Southerly Neotethys Ocean
16:45-17:05	**Stephen Morris:** Turbidites Around an Active Fault Scarp Downfan of the Valencia Channel Mouth, Northwest Mediterranean
16:45-17:30	General Discussion, Questions, Additional Presentations
17:30	**Closing of the Congress**

<u>Thursday 30 January</u>

Departure 09:00	**Excursion through Holland:** The Influence of Man on the Geology in the Netherlands

ANNEX II

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1	CCOP-IOC, 1974, Metallogenesis, Hydrocarbons and Tectonic Patterns in Eastern Asia (Report of the IDOE Workshop on); Bangkok, Thailand, 24-29 September 1973 UNDP (CCOP), 138 pp.	E (out of stock)
2	CICAR Ichthyoplankton Workshop, Mexico City, 16-27 July 1974 (UNESCO Technical Paper in Marine Sciences, No. 20).	E (out of stock) S (out of stock)
3	Report of the IOC/GFCM/ICSEM International Workshop on Marine Pollution in the Mediterranean; Monte Carlo, 9-14 September 1974.	E, F E (out of stock)
4	Report of the Workshop on the Phenomenon known as 'El Niño'; Guayaquil, Ecuador, 4-12 December 1974.	E (out of stock) S (out of stock)
5	IDOE International Workshop on Marine Geology and Geophysics of the Caribbean Region and its Resources; Kingston, Jamaica, 17-22 February 1975.	E (out of stock) S
6	Report of the CCOP/SOPAC-IOC IDOE International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific; Suva, Fiji, 1-6 September 1975.	E
7	Report of the Scientific Workshop to Initiate Planning for a Co-operative Investigation in the North and Central Western Indian Ocean, organized within the IDOE under the sponsorship of IOC/FAO (IOFC)/UNESCO/EAC; Nairobi, Kenya, 25 March-2 April 1976.	E, F, S, R
8	Joint IOC/FAO (IPFC)/UNEP International Workshop on Marine Pollution in East Asian Waters; Penang, 7-13 April 1976.	E (out of stock)
9	IOC/CMG/SCOR Second International Workshop on Marine Geoscience; Mauritius, 9-13 August 1976.	E, F, S, R
10	IOC/WMO Second Workshop on Marine Pollution (Petroleum) Monitoring; Monaco, 14-18 June 1976.	E, F E (out of stock) R
11	Report of the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions; Port of Spain, Trinidad, 13-17 December 1976.	E, S (out of stock)
11 Suppl.	Collected contributions of invited lecturers and authors to the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions; Port of Spain, Trinidad, 13-17 December 1976.	E (out of stock), S
12	Report of the IOCARIBE Interdisciplinary Workshop on Scientific Programmes in Support of Fisheries Projects; Fort-de-France, Martinique, 28 November-2 December 1977.	E, F, S
13	Report of the IOCARIBE Workshop on Environmental Geology of the Caribbean Coastal Area; Port of Spain, Trinidad, 16-18 January 1978.	E, S
14	IOC/FAO/WHO/UNEP International Workshop on Marine Pollution in the Gulf of Guinea and Adjacent Areas; Abidjan, Côte d'Ivoire, 2-9 May 1978.	E, F
15	CPPS/FAO/IOC/UNEP International Workshop on Marine Pollution in the South-East Pacific; Santiago de Chile, 6-10 November 1978.	E (out of stock)
16	Workshop on the Western Pacific, Tokyo, 19-20 February 1979.	E, F, R
17	Joint IOC/WMO Workshop on Oceanographic Products and the IGOSS Data Processing and Services System (IDPSS); Moscow, 9-11 April 1979.	E
17 Suppl.	Papers submitted to the Joint IOC/WMO Seminar on Oceanographic Products and the IGOSS Data Processing and Services System; Moscow, 2-6 April 1979.	E
18	IOC/UNESCO Workshop on Syllabus for Training Marine Technicians; Miami, U.S.A., 22-26 May 1978 (UNESCO reports in marine sciences, No. 4 published by the Division of Marine Sciences, UNESCO).	E (out of stock), F, S (out of stock), R
19	IOC Workshop on Marine Science Syllabus for Secondary Schools; Llantwit Major, Wales, U.K., 5-9 June 1978 (UNESCO reports in marine sciences, No. 5, published by the Division of Marine Sciences, UNESCO).	E (out of stock), E, S, R, Ar
20	Second CCOP-IOC Workshop on IDOE Studies of East Asia Tectonics and Resources; Bandung, Indonesia, 17-21 October 1978.	E
21	Second IDOE Symposium on Turbulence in the Ocean; Liège, Belgium, 7-18 May 1979.	E, F, S, R
22	Third IOC/WMO Workshop on Marine Pollution Monitoring; New Delhi, 11-15 February 1980.	E, F, S, R
23	WESTPAC Workshop on the Marine Geology and Geophysics of the North-West Pacific; Tokyo, 27-31 March 1980.	E, R
24	WESTPAC Workshop on Coastal Transport of Pollutants; Tokyo, Japan, 27-31 March 1980.	E (out of stock)
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26	IOC Workshop on Coastal Area Management in the Caribbean Region; Mexico City, 24 September-5 October 1979.	E, S
27	CCOP/SOPAC-IOC Second International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific; Nouméa, New Caledonia, 9-15 October 1980.	E
28	FAO/IOC Workshop on the effects of environmental variation on the survival of larval pelagic fishes. Lima, 20 April-5 May 1980.	E
29	WESTPAC Workshop on Marine Biological Methodology; Tokyo, 9-14 February 1981.	E
30	International Workshop on Marine Pollution in the South-West Atlantic; Montevideo, 10-14 November 1980.	E (out of stock) S
31	Third International Workshop on Marine Geoscience; Heidelberg, 19-24 July 1982.	E, F, S
32	UNU/IOC/UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the context of the New Ocean Regime; Paris, France, 27 September-1 October 1982.	E, F, S
32 Suppl.	Papers submitted to the UNU/IOC/UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the Context of the New Ocean Regime; Paris, France, 27 September-1 October 1982.	E
33	Workshop on the IREP Component of the IOC Programme on Ocean Science in Relation to Living Resources (OSLR); Halifax, 26-30 September 1963.	E
34	IOC Workshop on Regional Co-operation in Marine Science in the Central Eastern Atlantic (Western Africa); Tenerife, 12-17 December 1963.	E, F, S
35	CCOP/SOPAC-IOC-UNU Workshop on Basic Geo-scientific Marine Research Required for Assessment of Minerals and Hydrocarbons in the South Pacific; Suva, Fiji, 3-7 October 1983.	E
36	IOC/FAO Workshop on the Improved Uses of Research Vessels; Lisbon, Portugal, 28 May-2 June 1984.	E
36 Suppl.	Papers submitted to the IOC/FAO Workshop on the Improved Uses of Research Vessels; Lisbon, Portugal, 28 May-2 June 1984.	E
37	IOC/UNESCO Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs; Colombo, 8-13 July 1985.	E
38	IOC/ROPME/UNEP Symposium on Fate and Fluxes of Oil Pollutants in the Kuwait Action Plan Region; Basrah, Iraq, 8-12 January 1984.	E
39	CCOP (SOPAC)-IOC-IFREMER-ORSTOM Workshop on the Uses of Submersibles and Remotely Operated Vehicles in the South Pacific; Suva, Fiji, 24-29 September 1985.	E
40	IOC Workshop on the Technical Aspects of Tsunami Analysis, Prediction and Communications; Sidney, B.C., Canada, 29-31 July 1985.	E
40 Suppl.	First International Tsunami Workshop on Tsunami Analysis, Prediction and Communications, *Submitted Papers;* Sidney, B.C., Canada, 29 July - 1 August 1985.	E
41	First Workshop of Participants in the Joint FAO/IOC/WHO/IAEA/UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region (WACAF/2); Dakar, Senegal, 28 October-1 November 1985.	E
43	IOC Workshop on the Results of MEDALPEX and Future Oceanographic Programmes in the Western Mediterranean; Venice, Italy, 23-25 October 1985.	E
44	IOC-FAO Workshop on Recruitment in Tropical Coastal Demersal Communities; Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986.	E (out of stock) S
44 Suppl.	IOC-FAO Workshop on Recruitment in Tropical Coastal Demersal Communities, *Submitted Papers;* Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986.	E
45	IOCARIBE Workshop on Physical Oceanography and Climate; Cartagena, Colombia, 19-22 August 1986.	E
46	Reunión de Trabajo para Desarrollo del Programa "Ciencia Oceánica en Relación a los Recursos No Vivos en la Región del Atlántico Sud-occidental"; Porto Alegre, Brazil, 7-11 de abril de 1986.	S
47	IOC Symposium on Marine Science in the Western Pacific: The Indo-Pacific Convergence; Townsville, 1-6 December 1966.	E
48	IOCARIBE Mini-Symposium for the Regional Development of the IOC-UN (OETB) Programme on 'Ocean Science in Relation to Non-Living Resources (OSNLR)'; Havana, Cuba, 4-7 December 1986.	E, S
49	AGU-IOC-WMO-CPPS Chapman Conference: An International Symposium on 'El Niño'; Guayaquil, Ecuador, 27-31 October 1986.	E
50	CCALR-IOC Scientific Seminar on Antarctic Ocean Variability and its Influence on Marine Living Resources, particularly Krill (organized in collaboration with SCAR and SCOR); Paris, France, 2-6 June 1987.	E
51	CCOP/SOPAC-IOC Workshop on Coastal Processes in the South Pacific Island Nations; Lae, Papua-New Guinea, 1-8 October 1987.	E

No.	Title	Languages
52	SCOR-IOC-UNESCO Symposium on Vertical Motion in the Equatorial Upper Ocean and its Effects upon Living Resources and the Atmosphere; Paris, France, 6-10 May 1985.	E
53	IOC Workshop on the Biological Effects of Pollutants; Oslo, 11-29 August 1986.	E
54	Workshop on Sea-Level Measurements in Hostile Conditions; Bidston, UK, 28-31 March 1988	E
55	IBCCA Workshop on Data Sources and Compilation, Boulder, Colorado, 18-19 July 1988.	E
56	IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Cleveland, Australia, 24-30 July 1988.	E
57	IOC Workshop on International Co-operation in the Study of Red Tides and Ocean Blooms; Takamatsu, Japan, 16-17 November 1987.	E
58	International Workshop on the Technical Aspects of the Tsunami Warning System; Novosibirsk, USSR, 4-5 August 1989.	E
58 Suppl.	Second International Workshop on the Technical Aspects of Tsunami Warning Systems, Tsunami Analysis, Preparedness, Observation and Instrumentation. *Submitted Papers*; Novosibirsk, USSR, 4-5 August 1989.	E
59	IOC-UNEP Regional Workshop to Review Priorities for Marine Pollution Monitoring Research, Control and Abatement in the Wider Caribbean; San José, Costa Rica, 24-30 August 1989.	E, F, S
60	IOC Workshop to Define IOCARIBE-TRODERP proposals; Caracas, Venezuela, 12-16 September 1989.	E
61	Second IOC Workshop on the Biological Effects of Pollutants; Bermuda, 10 September-2 October 1988.	E
62	Second Workshop of Participants in the Joint FAO-IOC-WHO-IAEA-UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region; Accra, Ghana, 13-17 June 1988.	E
63	IOC/WESTPAC Workshop on Co-operative Study of the Continental Shelf Circulation in the Western Pacific; Bangkok, Thailand, 31 October-3 November 1989.	E
64	Second IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Phuket, Thailand, 25-31 September 1989.	E
65	Second IOC Workshop on Sardine/Anchovy Recruitment Project (SARP) int he Southwest Atlantic; Montevideo, Uruguay, 21-23 August 1989.	E
66	IOC *ad hoc* Expert Consultation on Sardine/Anchovy Recruitment Programme; La Jolla, California, U.S.A., 1989.	E
67	Interdisciplinary Seminar on Research Problems in the IOCARIBE Region; Caracas, Venezuela, 28 November-1 December 1989.	E (out of stock)
68	International Workshop on Marine Acoustics; Beijing, China, 26-30 March 1990.	E
69	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Leningrad, USSR, 28-31 May 1990.	E
69 Suppl.	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; *Submitted Papers*; Leningrad, USSR, 28-31 May 1990.	E
70	IOC-SAREC-UNEP-FAO-IAEA-WHO Workshop on Regional Aspects of Marine Pollution; Mauritius, 29 October - 9 November 1990.	E
71	IOC-FAO Workshop on the Identification of Penaeid Prawn Larvae and Postlarvae; Cleveland, Australia, 23-28 September 1990.	E
72	IOC/WESTPAC Scientific Steering Group Meeting on Co-Operative Study of the Continental Shelf Circulation in the Western Pacific; Kuala Lumpur, Malaysia, 9-11 October 1990.	E
73	Expert Consultation for the IOC Programme on Coastal Ocean Advanced Science and Technology Study; Liège, Belgium, 11-13 May 1991.	E
74	IOC-UNEP Review Meeting on Oceanographic Processes of Transport and Distribution of Pollutants in the Sea; Zagreb, Yugoslavia, 15-18 May 1989.	E
75	IOC-SCOR Workshop on Global Ocean Ecosystem Dynamics; Solomons, Maryland, U.S.A., 29 April-2 May 1991.	E
76	IOC/WESTPAC Scientific Symposium on Marine Science and Management of Marine Areas of the Western Pacific; Penang, Malaysia, 2-6 December 1991.	E
77	IOC-SAREC-KMFRI Regional Workshop on Causes and Consequences of Sea-Level Changes on the Western Indian Ocean Coasts and Islands; Mombasa, Kenya, 24-28 June 1991.	E
78	IOC-CEC-ICES-WMO-ICSU Ocean Climate Data Workshop Goddard Space Flight Center; Greenbelt, Maryland, U.S.A., 18-21 February 1992.	E
79	IOC/WESTPAC Workshop on River Inputs of Nutrients to the Marine Environment in the WESTPAC Region; Penang, Malaysia, 26-29 November 1991.	E
80	IOC-SCOR Workshop on Programme Development for Harmful Algae Blooms; Newport, U.S.A., 2-3 November 1991.	E
81	Joint IAPSO-IOC Workshop on Sea Level Measurements and Quality Control; Paris, France, 12-13 October 1992.	E
82	BORDOMER 92: International Convention on Rational Use of Coastal Zones. A Preparatory Meeting for the Organization of an International Conference on Coastal Change; Bordeaux, France, 30 September-2 October 1992.	E
83	IOC Workshop on Donor Collaboration in the Development of Marine Scientific Research Capabilities in the Western Indian Ocean Region; Brussels, Belgium, 12-13 October 1992.	E
84	Workshop on Atlantic Ocean Climate Variability; Moscow, Russian Federation, 13-17 July 1992.	E
85	IOC Workshop on Coastal Oceanography in Relation to Integrated Coastal Zone Management; Kona, Hawaii, 1-5 June 1992.	E
86	International Workshop on the Black Sea; Varna, Bulgaria 30 September - 4 October 1991.	E
87	Taller de trabajo sobre efectos biológicos del fenómeno «El Niño» en ecosistemas costeros del Pacífico Sudeste; Santa Cruz, Galápagos, Ecuador, 5-14 de octubre de 1989.	S only (Summary in E, F, S)
88	IOC-CEC-ICSU-ICES Regional Workshop for Member States of Eastern and Northern Europe (GODAR Project); Obninsk, Russia, 17-20 May 1993.	E
89	IOC-ICSEM Workshop on Ocean Sciences in Non-Living Resources; Perpignan, France, 15-20 October 1990.	E
90	IOC Seminar on Integrated Coastal Management; New Orleans, U.S.A., 17-18 July 1993.	E
91	Hydroblack'91 CTD Intercalibration Workshop; Woods Hole, U.S.A., 1-10 December 1991.	E
92	Réunion de travail IOCEA-OSNLR sur le Projet « Budgets sédimentaires le long de la côte occidentale d'Afrique » Abidjan, Côte d'Ivoire, 26-28 juin 1991.	F
93	IOC-UNEP Workshop on Impacts of Sea-Level Rise due to Global Warming. Dhaka, Bangladesh, 16-19 November 1992.	E
94	BMTC-IOC-POLARMAR International Workshop on Training Requirements in the Field of Eutrophication in Semi-Enclosed Seas and Harmful Algal Blooms, Bremerhaven, Germany, 29 September - 3 October 1992.	E
95	SAREC-IOC Workshop on Donor Collaboration in the Development of Marine Scientific Research Capabilities in the Western Indian Ocean Region; Brussels, Belgium, 23-25 November 1993.	E
96	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Zanzibar, United Republic of Tanzania, 17-21 January 1994.	E
96 Suppl. 1	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; *Submitted Papers* 1. Coastal Erosion; Zanzibar, United Republic of Tanzania 17-21 January 1994.	E
96 Suppl. 2	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; *Submitted Papers* 2. Sea Level; Zanzibar, United Republic of Tanzania 17-21 January 1994.	E
97	IOC Workshop on Small Island Oceanography in Relation to Sustainable Economic Development and Coastal Area Management of Small Island Development States; Fort-de-France, Martinique, 8-10 November, 1993.	E
98	CoMSBlack '92A Physical and Chemical Intercalibration Workshop; Erdemli, Turkey, 15-29 January 1993.	E
99	IOC-SAREC Field Study Exercise on Nutrients in Tropical Marine Waters; Mombasa, Kenya, 5-15 April 1994.	E
100	IOC-SOA-NOAA Regional Workshop for Member States of the Western Pacific - GODAR-II (Global Oceanographic Data Archeology and Rescue Project); Tianjin, China, 8-11 March 1994.	E
101	IOC Regional Science Planning Workshop on Harmful Algal Blooms; Montevideo, Uruguay, 15-17 June 1994.	E
102	First IOC Workshop on Coastal Ocean Advanced Science and Technology Study (COASTS); Liège, Belgium, 5-9 May 1994.	E
103	IOC Workshop on GIS Applications in the Coastal Zone Management of Small Island Developing States; Barbados, 20-22 April 1994.	E
104	Workshop on Integrated Coastal Management; Dartmouth, Canada, 19-20 September 1994.	E
105	BORDOMER 95: Conference on Coastal Change; Bordeaux, France, 6-10 February 1995.	E
105 Suppl.	Conference on Coastal Change: Proceedings; Bordeaux, France, 6-10 February 1995	E
106	IOC/WESTPAC Workshop on the Paleographic Map; Bali, Indonesia, 20-21 October 1994.	E
107	IOC-ICSU-NIO-NOAA Regional Workshop for Member States of the Indian Ocean - GODAR-III; Dona Paula, Goa, India, 6-9 December 1994.	E
108	UNESCO-IHP-IOC-IAEA Workshop on Sea-Level Rise and the Multidisciplinary Studies of Environmental Processes in the Caspian Sea Region; Paris, France, 9-12 May 1995.	E
108 Suppl.	UNESCO-IHP-IOC-IAEA Workshop on Sea-Level Rise and the Multidisciplinary Studies of Environmental Processes in the Caspian Sea Region; *Submitted Papers*; Paris, France, 9-12 May 1995.	E
109	First IOC-UNEP CEPPOL Symposium; San José, Costa Rica, 14-15 April 1993.	E
110	IOC-ICSU-CEC Regional Workshop for Member States of the Mediterranean - GODAR-IV (Global Oceanographic Data Archeology and Rescue Project) Foundation for International Studies, University of Malta, Valletta, Malta, 25-28 April 1995.	E

No.	Title	Languages
111	Chapman Conference on the Circulation of the Intra-Americas Sea; La Parguera, Puerto Rico, 22-26 January 1995.	E
112	IOC-IAEA-UNEP Group of Experts on Standards and Reference Materials (GESREM) Workshop; Miami, U.S.A., 7-8 December 1993.	E
113	IOC Regional Workshop on Marine Debris and Waste Management in the Gulf of Guinea; Lagos, Nigeria, 14-16 December 1994.	E
114	International Workshop on Integrated Coastal Zone Management (ICZM) Karachi, Pakistan; 10-14 October 1994.	E
115	IOC/GLOSS-IAPSO Workshop on Sea Level Variability and Southern Ocean Dynamics; Bordeaux, France, 31 January 1995.	E
116	IOC/WESTPAC International Scientific Symposium on Sustainability of Marine Environment: Review of the WESTPAC Programme, with Particular Reference to ICAM Bali, Indonesia, 22-26 November 1996.	E
117	Joint IOC-CIDA-Sida (SAREC) Workshop on the Benefits of Improved Relationships between International Development Agencies, the IOC and other Multilateral Intergovernmental Organizations in the Delivery of Ocean, Marine Affairs and Fisheries Programmes; Sidney B.C., Canada, 26-28 September 1995.	E
118	IOC-UNEP-NOAA-Sea Grant Fourth Caribbean Marine Debris Workshop; La Romana, Santo Domingo, 21-24 August 1995.	E
119	IOC Workshop on Ocean Colour Data Requirements and Utilization; Sydney B.C., Canada, 21-22 September 1995.	E
120	International Training Workshop on Integrated Coastal Management; Tampa, Florida, U.S.A., 15-17 July 1995.	E
121	Atelier régional sur la gestion intégrée des zones littorales (ICAM); Conakry, Guinée, 12-22 décembre 1995.	F
122	IOC-UNEP-PERSGA-ACOPS-IUCN Workshop on Oceanographic Input to Integrated Coastal Zone Management in the Red Sea and Gulf of Aden Jeddah, Saudi Arabia, 8 October 1995.	E
123	Second IOC Regional Science Planning Workshop on Harmful Algal Blooms in South America; Mar del Plata, Argentina, 30 October - 1 November 1995.	E/S
124	GLOBEC-IOC-SAHFOS-MBA Workshop on the Analysis of Time Series with Particular Reference to the Continuous Plankton Recorder Survey; Plymouth, U.K., 4-7 May 1993.	E
125	Atelier sous-régional de la COI sur les ressources marines vivantes du Golfe de Guinée ; Cotonou, Bénin, 1-4 juillet 1996.	F
126	IOC-UNEP-PERSGA-ACOPS-IUCN Workshop on Oceanographic Input to Integrated Coastal Zone.	A
127	IOC Regional Workshop for Member States of the Eastern Pacific GODAR-V (Global Oceanographic Data Archaeology and Rescue Project); Cartagena de Indios, Colombia, 8-11 October 1996.	A
128	Atelier IOC-Banque Mondiale-Sida/SAREC-ONE sur la Gestion Intégrée des Zones Côtières ; Nosy Bé, Madagascar, 14-18 octobre 1996.	A, F