

Intergovernmental Oceanographic Commission

Workshop Report No. 191



North Atlantic and Labrador Sea Margin Architecture and Sedimentary Processes

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

Copenhagen, Denmark
29 – 31 January 2004



GEUS

UNESCO

Intergovernmental Oceanographic Commission

Workshop Report, 191

North Atlantic and Labrador Sea Margin Architecture and Sedimentary Processes

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

Copenhagen, Denmark
29 – 31 January 2004

Editors: N. E. Poulsen
A. E. Suzyumov

UNESCO 2004

IOC Workshop Report, 191
Paris, March 2004
English only

Abstract

'North Atlantic and Labrador Sea Margin Architecture and Sedimentary Processes' was the title of an international conference and Post-cruise meeting of the Training-through-Research (TTR) programme of the IOC. It was organized and hosted by the Geological Survey of Denmark and Greenland (GEUS) in Copenhagen (29-31 January 2004) following the decision of the November 2003 meeting of the TTR Executive Committee. The Conference was focussed on the aspects of marine geosciences that were addressed during the 13th TTR marine expedition (TTR-13) and some previous TTR cruises.

The meeting brought together participants from eleven countries: Belgium, Denmark, Germany, Ireland, Italy, the Netherlands, Norway, Portugal, Russia, Switzerland and the United Kingdom. Attending were researchers and students with different specialities (geology, sedimentology, geophysics, geochemistry, microbiology, biology, palaeontology) and research interests falling in the area of the conference themes.

In total 26 oral and three poster presentations were made that reflect the main research directions of the TTR programme, such as mud volcanism, fluid venting and related processes, geosphere-biosphere interactions, tectonics and sedimentation on continental margins and in deep-sea basins.

TABLE OF CONTENTS

Preface.....	1
Abstracts.....	3
TTR-13 CRUISE TO THE NORTH ATLANTIC: REVIEW OF THE RESULTS	
M. Ivanov, N. Kenyon, A. Kuijpers, J.S. Laberg, X. Monteys, T. Nielsen, N.E. Poulsen & TTR-13 Cruise participants.....	3
SURVIVAL GUIDE FOR A GIANT CARBONATE MOUND	
A. Akhmetzhanov, X. Monteys, N.H. Kenyon, V. Huvenne & M.K. Ivanov	6
A VIEW ON MUD VOLCANOES FORMATION IN THE GULF OF CADIZ BASED ON STUDYING MUD BRECCIA CLASTS	
O. Barvalina & E. Sarantsev.....	7
RELICT ICEBERG PLOUGHMARKS ON THE WESTERN GREENLAND MARGIN	
A.B. Belan, L. Abbuehl & A. Kuijpers	9
CARBONATE CRUSTS OF THE NORTH PORCUPINE BANK: MINERALOGICAL COMPOSITION AND ISOTOPIC MEASUREMENTS	
E. Bileva, A. Mazzini & X. Monteys	12
ORIGIN AND COMPOSITION OF CARBONATE CHIMNEYS FROM THE IBERICO MUD MOUND (GULF OF CADIZ)	
V. Blinova, I. Belenkaya, A. Eisenhauer, M. Ivanov & L. Pinheiro.....	13
REGIONAL GEOLOGY, CENTRAL AND SOUTHERN WEST GREENLAND	
J.A. Chalmers.....	14
MEGAFUNA FROM A CANYON BORDERING THE FYLLA STRUCTURAL COMPLEX (SOUTHWESTERN MARGIN OF GREENLAND). RESULTS OF THE TTR-13 CRUISE (LEG 4)	
M.R. Cunha & V. Blinova.....	15
SOUTHERN WEST GREENLAND – SEABED SAMPLING PROJECT 2003. TTR-13 CRUISE LEG 4 AND PART OF LEG 3	
F. Dalhoff, A. Kuijpers, T. Nielsen & N. E. Poulsen.....	16
TURBIDITY CURRENTS AND AGGRADATIONAL CANYON FILL: THE CASE OF THE STROMBOLI CANYON BEND	
F. Gamberi & M. Marani.....	19
SEARCH FOR A HIGH RESOLUTION HOLOCENE RECORD ON THE EIRIK DRIFT, SOUTHERN GREENLAND	
N.H. Kenyon, A. Akhmetzhanov, S. Hunter, A. Kuijpers, E. Rohling, S. Bacon & D.A.V. Stow.....	22
MINERALOGICAL AND GRAIN SIZE ANALYSES OF A RECENT TURBIDITE IN THE LOFOTEN BASIN, NORWEGIAN SEA	
R. Khamidullin & J.V. Laberg.....	22
PRINCIPLE RESULTS OF HARD ROCK SAMPLING ON THE GREENLAND MARGIN	
D. Korost, A. Ovsyannikov & V. Blinova	24
COMPOSITION AND MATURITY OF ORGANIC MATTER IN THE ROCK CLASTS OF MUD VOLCANIC BRECCIA	
E. Kozlova, M. Ivanov, F. Baudin, C. Largeau & S. Derenne.....	24
ASPECTS OF DEEP-WATER BOTTOM CURRENTS IN THE BILL BAILEY BANK AREA, OFFSHORE SW FAEROES	
M. Kruse & L.O. Boldreel.....	26

ARCHITECTURAL ELEMENTS OF A MODERN DEEP-SEA CHANNEL AND SANDY LOBE, NORWEGIAN SEA J.S. Laberg, T.O. Vorren, N.H. Kenyon, M. Ivanov & E.S. Andersen	29
SEDIMENTARY FEATURES OF THE DISTAL ANDØYA SLIDE J.S. Laberg, T.O. Vorren, N.H. Kenyon, M. Ivanov & E.S. Andersen	31
THE UNIQUE CHARACTER OF SUBMARINE VOLCANISM: MARSILI AND PALINURO SEAMOUNTS, TYRRHENIAN SEA M.P. Marani, F. Gamberi, D. Penitenti & TTR-12 Cruise participants.....	33
FEATURES RELATED TO MUD DIAPIRISM IN THE NORWEGIAN SEA I. Mardanian, M. Ivanov, T. Nielsen, A. Kuijpers, T. van Weering, T. Richter & N. E. Poulsen.....	34
CARBONATE MOUNDS AND CARBONATE-PHOSPHATE DEPOSITS IN THE PORCUPINE BANK A. Mazzini, E. Bileva, M. Ivanov, X. Monteys, J. Parnell & B. T. Cronin	35
GIANT CARBONATE MOUNDS ON THE WEST PORCUPINE BANK, IRISH MARGIN, NE ATLANTIC MORPHOLOGY AND DISTRIBUTION X. Monteys	36
THE FAEROE MARGIN: PLIOCENE-QUATERNARY SLOPE INSTABILITY ON THE WESTERN FLANK OF THE FAEROE-SHETLAND CHANNEL T. Nielsen, A. Kuijpers, A. Mathiesen, S. J. Lassen, STRATAGEM WP2 Partners & TTR Shipboard Scientific Parties (TTR 8, 9, 12).....	37
GEOLOGICAL EVIDENCE OF VOLCANIC ORIGIN OF THE SEAMOUNTS ON THE WESTERN AND SOUTH-WESTERN GREENLAND MARGIN A. Ovsyannikov & T. Nielsen	38
EFFECT OF MUD VOLCANO ACTIVITY ON BIODIVERSITY AT SHALLOW TO DEEP WATER MUD VOLCANOES AT THE MOROCCAN ATLANTIC SLOPE AND IN THE GULF OF CADIZ B. Pannemans, M. Cunha, P. van Rensbergen, E. Bileva, J.-P. Henriët, M. Ivanov, L. Pinheiro & S. van Gaever.....	40
GEOCHEMICAL INVESTIGATION OF ORGANIC MATTER IN THE ROCKS FROM OUTCROPS (WESTERN GREENLAND MARGIN) E. Poludetkina, D. Korost, M. Ivanov & T. Nielsen.....	40
DEPOSITIONAL ENVIRONMENT OF THE NORTHERN PART OF THE DAVIS STRAIT HIGH AREA REVEALED FROM LITHOLOGY OF TWO CORES COLLECTED DURING THE TTR-13 CRUISE E.S. Sarantsev	42
DISTRIBUTION AND STABLE CARBON ISOTOPIC COMPOSITION OF BIOMARKERS IN METHANE-RELATED CARBONATES AND MUD VOLCANO SEDIMENTS, THE SOROKIN TROUGH, NE BLACK SEA A. Stadnitskaia, M. Baas, V. Blinova, T.C.E. van Weering, M. Ivanov & J. Sinninghe Damsté.....	43
FLOW TRANSFORMATION IN A CHANNELISED DEBRIS FLOW LOCATED ON THE NORTH-EASTERN ROCKALL TROUGH MARGIN J.D. Stanford, A. Akhmetzhanov, N.H. Kenyon & D.A.V. Stow	43
RECENT DEPOSITS AND DEPOSITIONAL ENVIRONMENT ON THE WEST PORCUPINE BANK, IRISH MARGIN, NE ATLANTIC L.K. Øvrebø & X. Monteys	44

Annex I. Programme

Annex II. List of Participants

PREFACE

'North Atlantic and Labrador Sea Margin Architecture and Sedimentary Processes' was the title of the International Conference and Post-cruise meeting of the Training-through-Research (TTR) programme of the UNESCO's Intergovernmental Oceanographic Commission (IOC). It was organized and hosted by the Geological Survey of Denmark and Greenland (GEUS) in Copenhagen (29-31 January 2004) as the follow up to the decision of the November 2003 meeting of the TTR Executive Committee. GEUS was also among the major sponsors of the 13th TTR marine expedition in summer 2003 whose principal organizer was the UNESCO-MSU Centre for Marine Geosciences at Moscow State University (MSU). The Conference was focussed on the aspects of marine geosciences that were addressed during the TTR-13 cruise (2003) to the North Atlantic and some previous TTR cruises.

In operation since 1991, the TTR programme puts together the advantages of the formal training of undergraduate and postgraduate students and young scientists with the experiences gained in advanced research. Its main operational field is marine geology and geophysics combined in the interdisciplinary way with studies in benthic biology and physical oceanography. The new TTR focus is on studying processes of geosphere-biosphere coupling in high seas (for more details, see the TTR web site, www.ioc.unesco/ttr).

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

The meeting brought together nearly 50 participants from eleven countries: Belgium, Denmark, Germany, Ireland, Italy, the Netherlands, Norway, Portugal, Russia, Switzerland and the United Kingdom. Attending were researchers and students with different specialities (geology, sedimentology, geophysics, geochemistry, microbiology, biology, etc.) and research interests falling in the area of the conference themes.

The meeting was opened by K. Soerensen, the GEUS Vice Director, who welcomed the participants and underlined the interest of the Danish scientists and students in the TTR programme. This was followed by a welcoming address by A. Suzyumov on behalf of the IOC. In total 26 oral and three poster presentations were made.

All the participants expressed great satisfaction with the Conference as having fully accomplished its objectives. The closing remarks were given by: T. Nielsen (GEUS); N. Kenyon (the TTR Co-ordinator, SOC), who summarized the TTR achievements and sincerely thanked GEUS on behalf of the conference participants and the TTR programme; M. Ivanov (MSU), on behalf of the cruise participants; and E. Poludetkina (MSU) who expressed gratitude to GEUS and the TTR executives on behalf of the students.

The Nomination Committee (M. Marani, A. Kuijpers and J.S. Laberg) was established to select three best papers presented at the Conference by the students. The first Conference prize was awarded to E. Poludetkina, the second one to A. Ovsyannikov and the third one to A. Belan.

The Conference programme was set up by the GEUS Organising Committees: Antoon Kuijpers, Tove Nielsen and Niels E. Poulsen. The book of abstracts was compiled by N. E. Poulsen. For the present Report, it was further edited by A. Suzyumov (UNESCO). With the exception of the first introductory one, all other Abstracts are given in the alphabetic order as per the first author. Annex I contains the Conference programme and Annex II list of participants.

On 30 January the TTR Executive Committee met at an open session. M. Ivanov presented the TTR-14 cruise (2004) plans and timetable. N. Kenyon reported on the progress with the TTR involvement in a European project on Hotspot Ecosystem Research on the Margins of Europe (HERMES). J.P. Henriët reported on a project proposal submitted to the Government of Flanders (Belgium) in support of the involvement of Third World countries in the TTR training and research operations.

Acknowledgements

The conference was supported by the Geological Survey of Denmark and Greenland, Bureau of Minerals and Petroleum (Nuuk, Greenland) and the IOC with additional contributions for individual participants' travel from universities of Aveiro (Portugal), Bologna (Italy), Bremen (Germany), Gent (Belgium), Moscow (Russia), Tromsø (Norway), as well as Geological Survey of Ireland and Southampton Oceanography Centre (UK). All these contributions are gratefully acknowledged.



Group of participants at the TTR-13 Post-cruise Conference. From left to right:
Bottom row: M. Ivanov, N. Kenyon, F. Gamberi, M. Cunha, A. Akhmetzhanov, C. Køser, A. Stadnitskaia;
2nd row: T. Nielsen, E. Kozlova, A. Suzyumov, N. Poulsen, V. Blinova, A. Ovsyannikov, E. Sarantsev,
R. Khamidullin, A. Mazzini;
3rd row: J.S. Laberg, F. Dalhoff, L. Abbuehl, A. Lauridsen, M. Marani, A. Belan, D. Korost,
I. Mardanian, M. Kruse;
Top row: J. Chalmers, A. Kuijpers, J.P. Henriët, D. Anthony, E. Poludetkina, O. Barvalina, E. Bileva,
L. K. Øvrebø, X. Monteys, J. Stanford

ABSTRACTS

TTR-13 CRUISE TO THE NORTH ATLANTIC: REVIEW OF THE RESULTS

M. Ivanov¹, N. Kenyon², A. Kuijpers³, J.S. Laberg⁴, X. Monteys⁵,
T. Nielsen³, N. E. Poulsen³ & TTR-13 Cruise participants

¹ UNESCO-MSU Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevy Gory, Moscow 119899, Russia, fu@geol.msu.ru

² Southampton Oceanography Centre, Empress Dock, Southampton, SO14 3ZH, United Kingdom, n.kenyon@soc.soton.ac.uk

³ Geological Survey of Denmark and Greenland, Thoravej 8, DK2400, Copenhagen NV, Denmark, aku@geus.dk, tni@geus.dk, nep@geus.dk

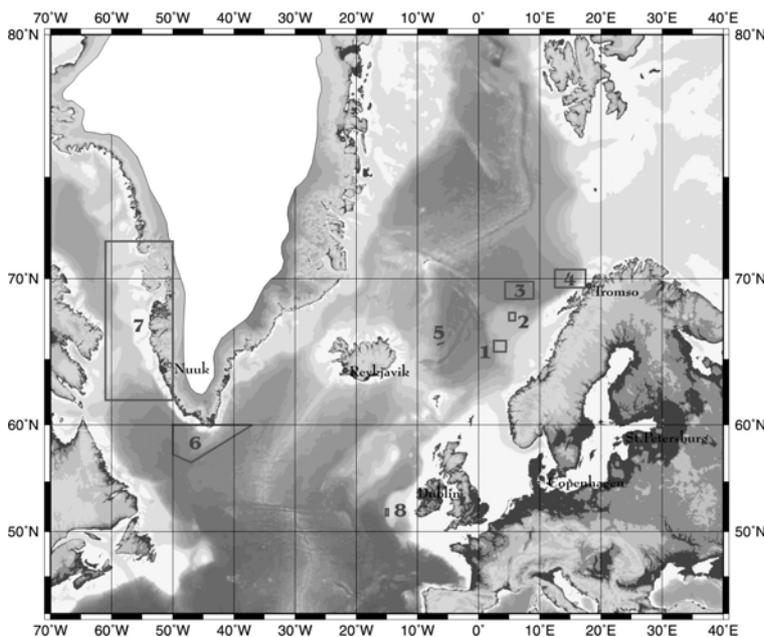
⁴ Department of Geology, University of Tromsø, N-9037 Tromsø, Norway, jan.laberg@ig.uit.no

⁵ Geological Survey of Ireland, Haddington Road, Dublin 4, Ireland, xavier.monteys@dcmnr.gov.ie

The TTR-13 cruise was carried out on board of the R/V *Professor Logachev* (Russia) from 10 July to 24 September 2003. The cruise started and terminated in St. Petersburg (Russia). The first group of international participants embarked in Copenhagen (Denmark) on 13 July. The cruise was divided into 5 legs separated by port calls, where partial exchange of the scientific crew was made. After Copenhagen, the port calls were to: Tromsø (Norway), on 29-30 July; Reykjavik (Iceland), on 5 August; Nuuk (Greenland), on 13 and 30-31 August; Dublin (Ireland), on 14-15 September; and Copenhagen (Denmark), on 21 September. The Co-Chief Scientists of the cruise were:

- Leg 1, 14-29.07: J.S. Laberg, N. Kenyon and M. Ivanov;
- Leg 2, 30.07-4.08: N. Kenyon and M. Ivanov;
- Leg 3, 5-13.08: N. Kenyon, N. Poulsen and M. Ivanov;
- Leg 4, 14-30.08: T. Nielsen, A. Kuijpers and M. Ivanov;
- Leg 5, 31.08-13.09: X. Monteys and M. Ivanov.

An international team of forty-two scientists, post- and undergraduate students from the following nine countries participated: Belgium, Denmark, Georgia, Germany, Ireland, Norway, Portugal, Russia and UK. The participating students were involved in all stages of acquisition and preliminary processing of multi-disciplinary set of geophysical and geological data. Daily seminars, lectures and discussions of the results facilitated high-level on-the-job training of the students and young scientists. The R/V *Professor Logachev* visited eight areas located in the North Atlantic (see the cruise map).



TTR-13 cruise map (1 to 8 – study areas)

Cruise objectives: The objectives of the cruise were two-fold: to conduct detailed interdisciplinary investigations of geological processes on the deep continental margins of Europe and Greenland, and to train students in marine geoscience research. The following scientific themes were addressed during the cruise:

1. Deep-sea depositional systems in the North Atlantic;
2. Neotectonics and down-slope processes on continental margins;
3. Contourites and turbidites in deep-water sedimentary systems;
4. Carbonate mud mounds.
5. Investigation of possible seeps on the Norwegian and Greenland margins.
6. Geological mapping and study of pre-Neogene rocks on the deep South-Western Greenland margin.

Equipment:

In addition to the standard equipment (described below) for geological and geophysical investigations normally used on board the *Logachev*, in the TTR-13 cruise the new vibro-coring equipment was used to sample sandy-gravelly bottom sediments, inaccessible to other coring instruments. This equipment called 'Deep Ocean' can core up to 10 meters of hard sediments. The vibro-corer can work at various depths from 20 to 5,000 meters. It works with TV-cameras that permit to select targets for coring at the sea-bottom and fully control the coring process. Other equipment used for research and training included a single-channel high-resolution seismic system with airgun sources, OKEAN long-range side-scan sonar, a hull-mounted 3.5 kHz profiler, a MAK deep-towed system containing a high- to middle-resolution side-scan sonar and a 5.1 kHz sub-bottom profiler. A 6-m gravity corer, a box corer, a kasten corer, a CTD system, an underwater digital TV camera, a TV-controlled grab and a dredge were also used for more detailed studies.

Principal results:

Norwegian margin

Areas 1 and 2: Vøring Plateau

The main objective on the Vøring Plateau was to investigate inferred complexes of mud diapirs. The Vema diapir field had been studied and a good set of data had been collected. As a continuation of this work, seismic and acoustic studies of the Vigrid (Area 1) and Vivian (Area 2) diapir fields, located on the Vøring Marginal High and the Vøring Basin respectively, were conducted by TTR-13. Airgun seismic lines were run across the above-mentioned fields.

Area 3: Traenadjupet Slide and Lofoten Basin floor

The Traenadjupet Slide off the northern part of Norway covers an area of about 12,000 km². It originates on the continental slope and has a well-defined termination on the lower continental rise. The distal part of the slide was studied in detail with the help of the side-scan sonar, high-resolution profiles and bottom sampling in order to elucidate the sediment failure processes and their ages.

The Lofoten Basin Channel was crossed on the lower slope where it has a thick unit of acoustically laminated sediments on its northern flank. A deep towed line across the distal part of the channel showed erosional features on the channel floor, especially where it cuts through a probable slide deposit. The area beyond the channel, that had proved difficult to sample on this and an earlier cruise, was found by using the vibro-corer to be sandy. A highlight of this study was the discovery of possible sand volcanoes on the channel-mouth lobe.

Area 4: Andøya Slide and Andøya Canyon

The Andøya Slide in the Lofoten Basin covers an area of about 9,700 km². A large set of data was obtained using high-resolution side-scan sonar, onboard profiler and coring. It will help to identify the age of the most recent slide event and to study sediments that overlie the slide deposits. The adjacent Andøya Canyon was investigated with side-scan sonar, TV-system and bottom sampling in order to confirm the types of processes transporting sediments through the canyon and whether they were still active.

Norwegian Basin (Area 5)

On the passage to Reykjavik (Iceland) a seismic and hull mounted profiler line was run across some supposed diapiric structures on the floor of the basin between the Aegir and Jan Mayen Ridge. Diapiric structures were confirmed.

Greenland margin

Area 6: Eirik Ridge

This very thick sedimentary ridge is located at the southern tip of Greenland and is laid down by the long term bottom currents which run along the east Greenland margin. As such it represents an excellent record of the history of global ocean circulation and climate change. Air gun and ship borne seismic profiles were used to determine the best site for obtaining a core that would have a high deposition rate during the Holocene. A deep towed profile was used to get a high resolution acoustic record and two cores were obtained for detailed analysis, and in particular to determine whether there is evidence for high frequency

changes of current speed. This data is a reconnaissance for a further UK research cruise to the area in 2004 that will obtain more cores and undertake current measurements.

Area 7: Labrador Sea and Davis Strait

Principal targets of investigation within Area 7 were chosen on the basis of multi-channel seismic data of the Geological Survey of Denmark and Greenland. Positive (“diapiric-like”) structures on the sea bottom were studied by the single-channel seismic, long-range side-scan sonar, deep-towed side-scan sonar, onboard profiler, underwater TV inspection and by way of bottom sampling. From two of these structures we collected samples that suggest their volcanic and crystalline basement rather than diapiric origin.

The pre-Neogene seabed outcrops were studied on the flanks of canyons and valleys extending from the upper continental slope into the deep-water basin west of the Fylla Bank and in the Davis Strait High area. Lithology of the samples and biological specimens were preliminary identified on board and stored for shipment ashore and further analysis. These further indicated a promising presence of mature bitumen in certain samples.

The areas studied for possible gas or fluid seeping proved to be strongly disturbed by iceberg ploughing, which provided an opportunity for (unexpected) studies of the glacial history of the area. Along with a series of gravity cores from the seep areas a unique sandy-gravelly core was collected with a vibro-corer in the northernmost of the ploughmark areas.

Irish margin

Area 8: Porcupine Bank

A large area of carbonate mounds was studied on the western margin of the Porcupine Bank. Recent depositional environments and processes were investigated using the high-resolution side-scan sonar, underwater TV-system and bottom sampling. Side-scan sonar imagery could be accurately located on the existing swath bathymetry map to give an impressive view of the seafloor. Particular attention was paid to the biology of the mounds and to their relationship with the underlying basement. Several outcrops were identified and sampled for further laboratory studies.



Leg 4 shipboard party and a Greenland iceberg met when surveying Area 6 (collage)

SURVIVAL GUIDE FOR A GIANT CARBONATE MOUND

A. Akhmetzhanov¹, X. Monteys², N.H. Kenyon¹, V. Huvenne¹ & M.K. Ivanov³

¹Challenger Division, Southampton Oceanography Centre, Empress Dock, Southampton, SO14 3ZH, United Kingdom, Andrey.Akhmetzhanov@soc.soton.ac.uk

²National Seabed Survey, Geological Survey of Ireland, Haddington Road, Dublin 4, Ireland, xavier.monteys@dcmnr.gov.ie

³UNESCO-MSU Centre for Marine Geosciences, Geology Faculty, Moscow State University, Vorobjevy Gory, 119899 Moscow, Russia, fu@geol.msu.ru

Much new data on deep-water carbonate build-ups has been collected in recent years from locations along the European Atlantic margin. An early and comprehensive study, conducted by the TTR program in 1997, together with results from major EC research projects (GEOMOUND, ECOMOUND and ACES) suggest that the formation of the mounds is related to several environmental factors, which co-exist on the upper continental slope and support the growth of deep-water corals. It is thought that crucial role in the formation of these complex ecosystems is played by the availability of a suitable substrate and the presence of strong bottom currents (such as along slope boundary currents and internal tides).

Mound morphology can either, be “inherited” from the pre-existing substrate, be “developed” by the prevailing environmental conditions or be a combination of both (Wheeler *et al.*, submitted). However, there is still doubt as to whether any of these scenarios are significant to the establishment of an extensive carbonate mound field.

A detailed study of a large cluster of carbonate mounds fringing the head of the Porcupine Canyon, based on the integration of multibeam data from the Irish Seabed Survey and TTR13 side-scan sonar data, shows that the pre-existing morphology has the primary control over mound distribution and mound shape. The majority of the mounds inherit the pattern of a complex fault system, which has been traced around the canyon head. The faults are usually expressed in the seabed topography as escarpments, up to 50 m high and several km long.

Analysis of the other datasets from the Rockall Trough, together with datasets from Porcupine Seabight, Norwegian margin, Gulf of Cadiz and Florida-Hatteras slope confirms that the existence of topographical highs and breaks in slope of various origins is important for the development and long-time survival of a carbonate mound field. Enhanced turbulence, existing along such features, is believed to provide better food availability than at other suitable settling grounds, such as coarse-grained lag deposits. The example of the Magellan mound field in the northern Porcupine Seabight (Huvenne *et al.*, 2003) shows that lag deposits, in an area swept by strong bottom currents, provided a good substrate for extensive colonisation by cold-water corals and for the growth of many carbonate mounds. However, the absence of significant slope breaks on the relatively flat seabed may have limited food availability, preventing development of larger build-ups able to grow faster than the sedimentation rate. This ultimately led to the extinction of the field.

References

- Wheeler, A.J., Beyer, A., Freiwald, A., de Haas, H., Huvenne, V.A.I., Kozachenko, M. & Olu-Le Roy, K., (submitted). Morphology and environment of deep-water coral mounds on the NW European Margin. - In: Henriot, J.P. & Dullo, W.C. (eds). *Modern carbonate mound systems: a window to Earth history*, Springer-Verlag, Heidelberg.
- Huvenne, V., De Mol, B. & Henriot, J.P., 2003. A 3D seismic study of the morphology and spatial distribution of buried coral banks in the Porcupine Basin, SW of Ireland. *Marine Geology*, **198**, 5–25.

A VIEW ON MUD VOLCANOES FORMATION IN THE GULF OF CADIZ BASED ON STUDYING MUD BRECCIA CLASTS

O. Barvalina & E. Sarantsev

UNESCO-MSU Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevi Gory, Moscow 119899, Russia, fu@geol.msu.ru

The Gulf of Cadiz is characterized by extensive mud volcanism processes. Between 1999-2002, during four research cruises (TTR-9, 10, 11, 12) of the Training-through-Research programme about 20 mud volcanoes have been discovered, most of them have been sampled and the recovered mud breccia studied. This work is based on the material obtained during TTR-9, 10 and 12 cruises. The main objective was to reconstruct sedimentary successions in different parts of the Gulf of Cadiz basing on lithology, content and composition of organic matter in rocks.

Studied were rock fragments from mud breccia from several mud volcanoes: the Bonjardim, Carlos Ribeiro, Captain Arutyunov and Mercator (fig. 1). The first two are situated on the Portugal margin in the south-western part of the Gulf of Cadiz, the third one in the central part of the Gulf of Cadiz, and the fourth one on the Moroccan margin.

Rock fragments were studied in thin sections under polarizing microscope. Dating of some rocks was based on studying calcareous nannofossil assemblages and plankton foraminifers. Then geochemical investigations were carried out using fluorescent analyses (to characterize extractable organic matter (EOM)), determination of total organic carbon (TOC) content, Rock-Eval pyrolysis and gas chromatography of extracted bitumen.

As per lithological investigations, all rock clasts from the mud volcanic breccia were subdivided into several groups. They are mainly represented by limestones, claystones and sandstones.

According to micropaleontological data the age of rocks from mud volcanic deposits of the Bonjardim, Carlos Ribeiro and Captain Arutyunov mud volcanoes varies from the Upper Cretaceous to Pliocene. Clasts from mud breccia from the Mercator mud volcano have the Cenozoic age. Same result was obtained studying rock clasts from the Yuma, Ginsburg, Rabat and Jesus Barasa mud volcanoes, which are situated in the same area (Ovsvyannikov, 2000).

All the Upper Cretaceous rocks are similar in different parts of the Gulf of Cadiz and represented mainly by claystones and bioclastic limestones. The Paleogene sequence is represented only by the Eocene rocks, which were found in every studied mud volcano. Probably, during Paleocene and Oligocene there were interruptions in sedimentary accumulation. The Eocene rocks are represented by different types: clayey-carbonate series in mud breccia from the Bonjardim and Carlos Ribeiro mud volcanoes and clayey-siliciclastic series from the Captain Arutyunov and Mercator ones. Possibly at that period there were a few separated basins in the place of the modern Gulf of Cadiz with different conditions of sedimentation.

The Miocene rocks are similar in different regions of the Gulf of Cadiz. The Lower Miocene rocks are represented mainly by claystones, only in mud breccia from the Bonjardim and Carlos Ribeiro mud volcanoes sandstones of this age were found. The Middle Miocene rocks are represented by different types of limestones. The Upper Miocene rocks are represented by clayey series.

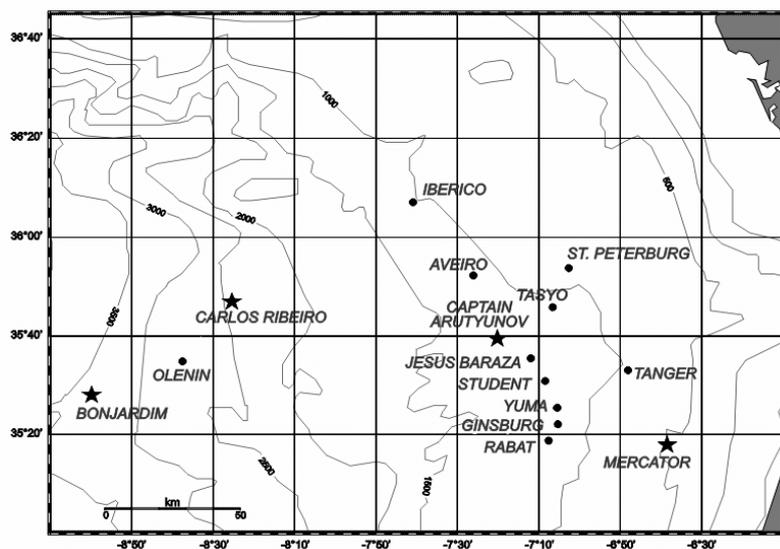


Fig.1. Location map of studied mud volcanoes in the Gulf of Cadiz

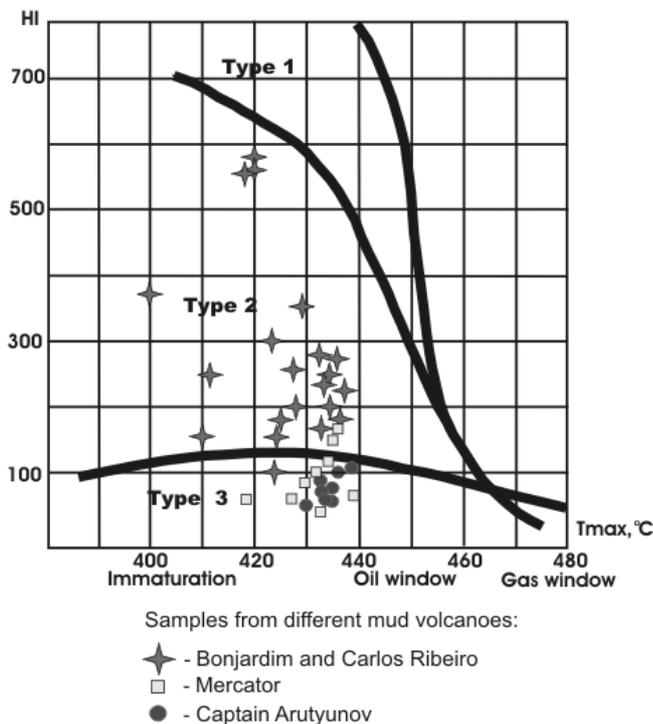


Fig. 2. Van-Krevelen diagram (HI-Tmax) showing various types of kerogen and their maturity level

The Pliocene rocks were not found in mud breccia of the Bonjardim and Carlos Ribeiro mud volcanoes. In mud volcanic deposits of other studied mud volcanoes they are represented by claystones and sandstones.

Most of the rocks in mud volcanoes are characterized by relatively low values of the TOC content (less than 0.2%), but some rocks have relatively high TOC content like the Upper Cretaceous claystones (0.5 - 6.78%) from mud breccia of the Bonjardim, Carlos Ribeiro and Captain Arutyunov mud volcano, the Eocene claystones (0.73 - 1.5%) from mud breccia of the Captain Arutyunov and Mercator mud volcanoes, the Miocene micrites (0.4 - 1.2%), the Miocene bioclastic limestones (0.78 - 3.02%) from the studied mud volcano. The Middle Miocene microcrystalline limestone found in breccia of the Mercator mud volcano is characterised by the TOC values between 0.86 - 0.94%.

According to the results of pyrolysis the organic matter in rocks from breccia of the Bonjardim and Carlos Ribeiro mud volcanoes belongs to kerogen of type II, the organic matter

in rocks from other mud volcanoes is corresponded to type III (fig. 2). The maturity of organic matter in most of the rocks corresponds to the beginning of the oil window zone ($T_{max} = 430-436^{\circ}\text{C}$), several samples are characterized by $T_{max} = 400-420^{\circ}\text{C}$.

Due to the results of gas chromatography the organic matter in rock clasts from the Bonjardim and Carlos Ribeiro mud volcanoes has the marine origin, however, the organic matter in rock clasts from the Captain Arutyunov and Mercator mud volcanoes has the marine-terrestrial origin.

According to one of the hypothesis of mud volcanoes formation in this region, fluid generation takes place in the Miocene clayey olistostrom unit. It causes mud volcanoes explosions. Thus, roots of mud volcanoes are situated there and most of rock clasts in mud breccia come from this unit. However, some facts contradict to this hypothesis.

Most of the organic matter in rock clasts from mud breccia is characterized by $T_{max} = 430-435^{\circ}\text{C}$ according to the results of pyrolysis. It means that these rocks reached the temperature of about $80-90^{\circ}\text{C}$ (Lopatin, 1987).

The depths of about 2,700-3,000 m characterized by these temperatures were estimated using an average geothermal gradient $3^{\circ}\text{C}/100\text{ m}$. According to A. Maldonado (1999), pre-olistostrom units are located at these depths.

Interesting fact is that among mud breccia clasts from the eastern mud volcanoes (Mercator, Yuma, Ginsburg, Rabat) only the Cenozoic rocks were found. Fragments of the Cretaceous rocks were found only in mud breccia from the Bonjardim, Carlos Ribeiro and Captain Arutyunov mud volcanoes that are situated in the western and central part of the Gulf of Cadiz.

Probably, the roots of mud volcanoes in the western and central parts of the Gulf of Cadiz are located in the Upper Cretaceous unit and in the eastern part - in the Paleogene unit.

The organic matter in rock clasts from the Carlos Ribeiro and Bonjardim mud volcanoes and from the Captain Arutyunov and Mercator mud volcanoes corresponds to different types that was determined using the Rock-Eval pyrolysis. The above can be explained if the rocks deposition happened in different geographical conditions. In regions located closer to the continent organic matter contains more continental admixture.

References

- Akhmanov, G.G., Ivanov, M.K., Henriot, J-P. & Sarantsev, E.S., 2003. The Al Araiche Diapiric Field and its "Exotic" Mud Volcanic Deposits Recovered During the TTT12 Cruise in the Gulf of Cadiz. - In: Marani, M. *et al.* (eds). Geological processes on European continental margins. International Conference and Eleventh Post-Cruise meeting of the Training-Through-Research Programme, Bologna, Italy, 2 - 6 February 2003, IOC Workshop Report, **187**, UNESCO, 9-10.
- Kozlova, E. V., 2003. Oil and gas potential of deep-water basins as inferred from the study of mud volcanic deposits. Ph.D. Thesis, MSU, Moscow (in Russian).
- Maldonado, A., Somoza, L. & Pallares, L., 1999. The Betic orogen and the Iberian-African boundary in the Gulf of Cadiz: geological evolution (central North Atlantic). *Marine Geology*, **155**, 9-43
- Ovsiyannikov, D., 2000. Rock clasts lithology in mud volcano breccia from the Gulf of Cadiz. - In: Comas, M. & Akhmanov, G. (eds). Geological processes on European continental margins. International Conference and Eighth Post-Cruise meeting of the Training-Through-Research Programme, Granada, Spain, 31 January - 3 February 2000, IOC Workshop Report, **168**, UNESCO, 15-16.

RELICT ICEBERG PLOUGHMARKS ON THE WESTERN GREENLAND MARGIN

A.B. Belan¹, L. Abbuehl² & A. Kuijpers³

¹ UNESCO-MSU Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevi Gory, Moscow, 119992, Russia, fu@geol.msu.ru

² Departement of Earth Science, ETH Zurich, Sonneggstrasse 5, 8092 Zurich, Switzerland luabbueh@student.ethz.ch

³ Geological Survey of Denmark and Greenland (GEUS), Øster Voldgade 10, 1350 Copenhagen K, Denmark, aku@geus.dk

Large areas of the continental shelves and uppermost slopes of the northern North Atlantic and Arctic Ocean margin have been scoured by grounded icebergs. The same applies to the Southern Ocean region. Seabed characteristics with regard to relief, sediment type and geotechnical properties are strongly varying in such areas where iceberg ploughmarks are observed. The shape and size of individual ploughmarks can strongly vary. They may be more than 25 m deep and more than 250 m wide (Lien, 1983). The size, number, and direction of the ploughmarks are mainly controlled by water depth, topography, and seabed lithology.

In deeper areas the ploughmarks are often larger and more uni-directional. In areas beyond the shelf edge iceberg ploughmarks have been found widespread down to water depths of around 500 m, as it is the case offshore Norway (Lien, 1983), on the West Shetland margin (Masson 2001), offshore East Greenland (Dowdeswell *et al.*, 1993; Syvitsky *et al.*, 2001), and around Antarctica (Beaman and Harris, 2003). In several areas grounding of deep-draft icebergs is evident at even greater water depths, i.e. between 600 and 750 m. Ploughmarks at these water depths have been observed on the Southeast Greenland margin (Kuijpers *et al.*, 2003) as well as south of the Faeroe Islands (Kuijpers *et al.*, 1998; N.H. Kenyon, unpubl. data). On the Iceland-Faeroe Ridge iceberg ploughmarks were observed at an extreme depth of 960 m (Werner, 1990; Kuijpers, 1997), which corresponds to the maximum depth of relict iceberg ploughmarks observed in the Arctic Ocean (Vogt *et al.*, 1994).

According to studies of modern iceberg drift in East Greenland waters (e.g. Syvitsky *et al.*, 2001), iceberg ploughmarks at water depth in excess of 500 m must be classified as relict, originating from (de)glacial periods when sea level was lower.

The main objective of the present contribution is to describe iceberg ploughmarks in the Davis Strait area offshore West Greenland and to determine the direction of iceberg scouring in relation to regional (paleo) circulation patterns. Oceanographically, today the area is characterised by the presence of the West Greenland Current (WGC) concentrated over the Greenland Shelf transporting at sub-surface depth relatively warm, saline water from the Irminger Sea northwards (Cuny *et al.*, 2002). Cold, low-salinity water derived from the East Greenland Current with additional meltwater input from the Greenland Inland Ice is concentrated at the surface. In the Davis Strait part of the WGC is deflected towards the west, where WGC water masses join the Baffin Current, which transports cold, low-salinity and ice-loaded Polar Water from Baffin Bay towards the south, where along the Labrador coast it further continues as the Labrador Current.

During Leg 4 of the TTR-13 Cruise with R/V *Professor Logachev* eight parallel MAK-1M side-scan sonar lines (MAK88-89, MAK92-97) were run in the Davis Strait High area (63°43' - 67°40'N, 55° 30' - 58° 20' W).

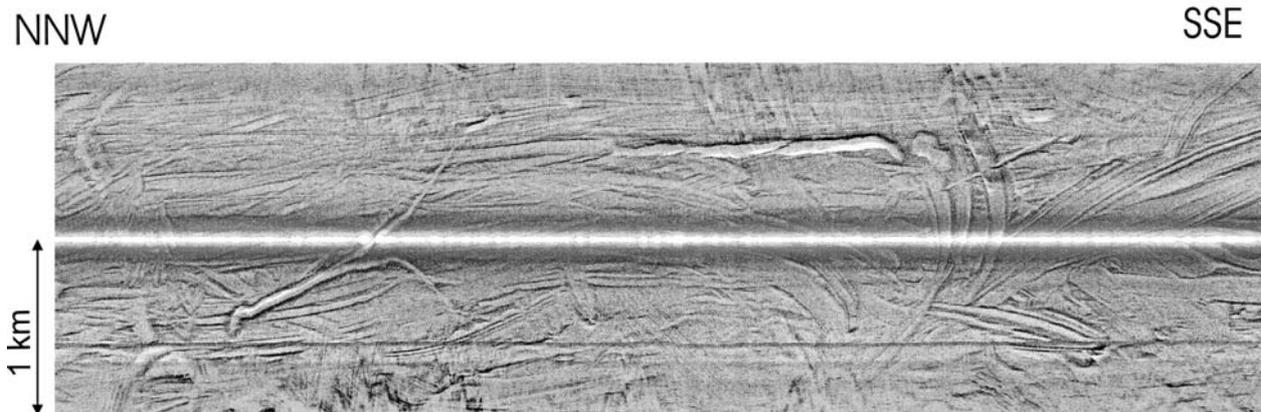


Fig. 1. Fragment of the side-scan sonar line MAKAT-92 showing iceberg ploughmarks, the Davis Strait study area

During this survey the profiling was carried out with a side-scan sonar frequency of 30 kHz, with the exception of line MAK90, which was run at 100 kHz. The water depth in the area of investigation is between about 500 and nearly 800 m. No large-scale topographic features were observed, while water depth gradually increases towards the south in direction of the Labrador Sea.

The sonographs showed a seabed intensively covered by iceberg ploughmarks (Fig. 1). Various generations of ploughmarks could be distinguished. Referring to studies of modern iceberg drift (Syvitsky *et al.*, 2001) offshore East Greenland, it may be concluded that considering the water depth (> 500 m) wide-spread iceberg grounding in our study area must have occurred in the past, and ploughmarks thus do generally not reflect modern iceberg drift. At the present, only few icebergs advected by the East Greenland Current towards coastal waters around the Kap Farvel will drift from here northwards with the WGC, but other potential areas of modern deep-draft iceberg discharge should be taken into consideration as well. On the West Greenland coast the most productive, and simultaneously the fastest moving tidally controlled glacier on the global scale (Clarke and Echelmeyer, 1996), is Jakobshavn Isbræ. This glacier produces icebergs moving northward from the Disko Bay, where the glacier is located, along the coast of Greenland into the Baffin Bay, where they move westward and later, off the Canadian coast, become entrained in the southward flowing Baffin Current. Water depth in the Disko Bay near the Jakobshavn Isbræ calving front is 300-400 m, which is thus the maximum keel depth of the icebergs produced here. It cannot be excluded, however, that due to collapse and turnover of large icebergs at a later stage some of them could increase their draft.

Measurements of depths, widths, lengths and azimuths of the iceberg ploughmarks were made on the *Logachev*. Maximum width was found to be 170 m, which is close to the maximum width (c. 160 m) of deep-draft iceberg ploughmarks observed at the Southeast Greenland margin (Kuijpers *et al.*, 2003). Based on sub-bottom profiler cross-sections of individual ploughmarks, a maximum depth of about 10 m was found.

Scour direction can be determined from various observations of the scour mark. It must be noted, however, that an interpretation may be difficult due to the complex scour morphology and form ("multi-keeled arcuate", "multi-keeled sinuous", "single-keeled linear", etc.), changes of the orientation, and cross-cutting relationships of the scours. The termination mark generally indicates the ending of the ploughing event and may reveal the direction of the iceberg drift. These features are associated with surrounding berm material. According to the termination marks, iceberg scouring prevailed in a NW to NNW (315-350°) direction (Fig. 2).

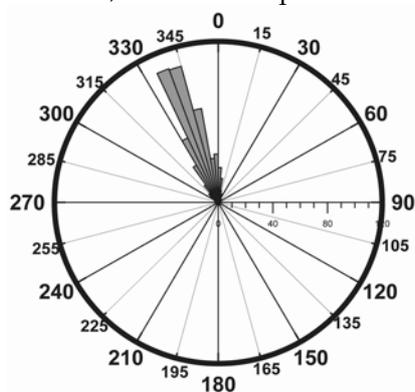


Fig. 2. Rose-diagram showing orientation of the iceberg ploughmarks

It is known that the direction of drift of icebergs mainly depends on the prevailing main current. In addition, tidal currents may cause periodic deviations from the main current direction. Measurements of the orientation of the relict ploughmarks show that the iceberg drift can be related to a (paleo)circulation pattern corresponding to the actual WGC. At least 2 generations of ploughmarks appear to exist, but the difference in orientation between the

older and younger generation, i.e. between 330-350° and 315-345 °, respectively, is not significant. Sediment cores from the ploughmark area show clear evidence of a major iceberg drift (IRD) event presumably close to the Pleistocene-Holocene boundary, but results of AMS ¹⁴C dating measurements are presently not yet available.

Marine geological investigations at the Southeast Greenland margin (Kuijpers *et al.*, 2003) demonstrate the existence of a pre-Holocene East Greenland Current reaching far into the Irminger Basin and transporting numerous icebergs from East Greenland glaciers towards the south. We may conclude that, in contrast to present-day conditions, many of these icebergs reached the area around the Kap Farvel. Furthermore, in analogue to the actual circulation pattern, this early East Greenland Current system is likely to have had a well-developed WGC extension towards the Davis Strait, which is thus thought to have been responsible for transporting deep-draft icebergs to the area of investigation. Within this context, we should note that the sea level at that time probably was at least 100 m lower than at the present. During the same, late glacial period the Laurentide Ice Sheet collapsed, and iceberg discharge from the Hudson Strait was considerable (e.g. Andrews *et al.*, 1995). Although the general surface circulation may have favored iceberg transport from the Hudson Strait mainly south(east)wards towards the region off Newfoundland, the general cyclonic surface circulation pattern of the Labrador - Irminger Sea region could have caused part of the ice-loaded water masses from the Southern Labrador Sea later to deflect northwards into the north-eastern Labrador Sea, joining there the WGC iceberg drift.

References

- Andrews, J.T., Maclean, B., Kerwin, M., Manley, W., Jennings, A.E. & Hall, F., 1995. Final stages in the collapse of the Laurentide Ice Sheet, Hudson Strait, Canada: ¹⁴C AMS dates, seismic stratigraphy, and magnetic susceptibility logs. *Quaternary Science Reviews*, **14**, 983-1004.
- Beaman, R.J. & Harris, P.T., 2003. Seafloor morphology and acoustic facies of the George V Land shelf. *Deep-Sea Research II*, **60**, 1343-1355
- Clarke, T.S. & Echelmeyer, K., 1996. Seismic reflection evidence for a deep subglacial trough beneath Jakobshavn Isbrae, West Greenland. *Journal of Glaciology*, **141** (42), 219-232.
- Cuny, J., Rhines, P.B., Niiler, P.P. & Bacon, S., 2002. Labrador Sea boundary currents and the fate of the Irminger Sea Water. *Journal of Physical Oceanography*, **32**, 627-647.
- Dowdeswell, J.A., Villinger, H., Whittington, R.J. & Marienfeld, P., 1993. Iceberg scouring in Scoresby Sund and on the East Greenland continental shelf. *Marine Geology*, **111**, 37-53.
- Kuijpers, A. & Shipboard Scientific Party, 1997. Deep-tow side scan sonar study of Norwegian Sea Overflow pathways off the Faeroe Islands. DANA 97/9 Cruise Report SNF Project No. 9601628, Geological Survey of Denmark and Greenland, Copenhagen, 14 pp.
- Kuijpers, A., Andersen, M.S., Kenyon, N.H., Kunzendorf, H. & Van Weering, T.C.E., 1998. Quaternary sedimentation and Norwegian Sea overflow pathways around Bill Bailey Bank, northeastern Atlantic. *Marine Geology*, **152**, 101-127.
- Kuijpers, A., Troelstra, S.R., Prins, M.A., Linthout, K., Akhmetzhanov, A., Bouryak, S., Bachmann, M.F., Lassen, S., Rasmussen, S. & Jensen, J.B., 2003. Late Quaternary sedimentary processes and ocean circulation changes at the Southeast Greenland margin. *Marine Geology*, **195**, 109-129.
- Lien, R.L., 1983. Iceberg scouring on the Norwegian continental shelf. Continental Shelf Institute (IKU), Trondheim, Publication no. 109, 147 pp.
- Masson, D.C., 2001. Sedimentary processes shaping the eastern slope of the Faeroe-Shetland Channel. *Continental Shelf Research*, **21**, 825-857.
- Syvitsky, J.P.M., Stein, A.B. & Andrews, J.T., 2001. Icebergs and the sea floor of the East Greenland (Kangerlussuaq) Continental Margin. *Arctic, Antarctic, and Alpine Research*, **33**, 55-61.
- Vogt, P.R., Crane, K. & Sundvor, E., 1994. Deep Pleistocene iceberg ploughmarks on the Yermak Plateau: sidescan and 3.5 kHz evidence for thick calving ice fronts and a possible marine ice sheet in the Arctic Ocean. *Geology*, **22**, 403-406.
- Werner, F., 1990. Untersuchungen zur Sedimentverteilung und -Dynamik am Island-Färöer Rücken. Cruise Report R/V *Poseidon* Cruise 158, Geologisch-Paläontologisches Institut, Universität Kiel, Report 38 (II), 17 pp.

CARBONATE CRUSTS OF THE NORTH PORCUPINE BANK: MINERALOGICAL COMPOSITION AND ISOTOPIC MEASUREMENTS

E. Bileva¹, A. Mazzini² & X. Monteys³

¹ UNESCO-MSU Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevi Gory, Moscow 119899, Russia, fu@geol.msu.ru

² Department of Geology and Petroleum Geology, University of Aberdeen, Meston Building, King's College, Aberdeen AB24 3UE, Scotland, UK, a.mazzini@abdn.ac.uk

³ GSI Seabed Survey, 7 Dundrum, Business Park, Windy Arbour, Dublin 14, Ireland, xavier.monteys@dcmnr.gov.ie

Carbonate mounds represent the main structures on the northern part of the Porcupine Bank. The main objective of Leg 5 of the TTR-13 Cruise, supported by the Geological Survey of Ireland, was multi-disciplinary study of modern processes and depositional environments in an area of the mounds occurrence. Geological and geophysical studies were performed there, included side-scan sonar survey, underwater TV and bottom sampling.

During these investigations special attention was paid to autigenic carbonate mineralization in the area. The carbonate crusts were sampled on a steep escarpment at the eastern part of the studied area (sampling stations AT498D, AT499D, AT500D). Besides, the similar crusts were observed in dredges AT501D and AT509D from the carbonate mounds. Fragments of crusts were also noticed in the lower part of the core AT494G taken from a canyon in the western part of the Porcupine Bank. Recovered carbonate crusts are predominantly tabular with rough, porous and usually oxidized surface.

Sampled crusts were studied with thin section description, X-ray diffraction (XRD) analysis and analysis of stable isotopes: ¹³C and ¹⁸O in order to determine their composition and origin.

After the interpretation of XRD data and thin section descriptions these crusts were divided into 5 types according to their mineralogical composition:

1. aragonite crust with insignificant content of other carbonate minerals and quartz;
2. crust composed predominantly of calcite with the presence of clayey minerals, microcline, plagioclase and quartz;
3. carbonate crust composed predominantly of calcite and Mg-calcite;
4. crusts predominantly composed of fluorapatite and Mg-calcite;
5. pure dolomite with insignificant content of quartz and calcite.

The measurements of stable isotopes of C and O were performed for 9 samples of different types of crusts. The value of $\delta^{13}\text{C}$ varies from $\pm 1 - 2.0$ ‰ PDB and $\delta^{18}\text{O}$ - from 25.1 - 34.2 ‰ SMOW suggesting that the carbonate precipitated from the sea water.

The formation of these crusts was probably affected by the presence of the Mediterranean water masses in the interval from 750 - 950 m. (Hargreaves, 1984). This water is characterised by high salinity and low oxygen content. The crusts in the Porcupine Bank can be formed as carbonate ooze subjected to early diagenesis controlled by ionic diffusion from the sea to interstitial waters. Similar processes are known on the Mediterranean continental slope (J. Alloué, 1990). Strong bottom currents in the studied area can result to enhancing diffusion through the uppermost part of the sediment. Diversity of the crusts can be explained by different composition of deposited carbonate ooze.

Therefore the formation of carbonate crusts on the Porcupine Bank is probably related to early diagenetic processes and controlled by the presence of the Mediterranean water masses and bottom currents.

References

- Hargreaves, P.M., 1984. The distribution of Decapoda (Crustacea) in the open ocean and near-bottom over an adjacent slope in the North-East Atlantic ocean during autumn 1979. *Journal of the Marine Biological Association of the United Kingdom*, **64**, 829 - 857.
- Alloué, J., 1990. Quaternary crusts on slopes of the Mediterranean Sea: A tentative explanation for their genesis. *Marine Geology*, **94**, 205 - 238.

ORIGIN AND COMPOSITION OF CARBONATE CHIMNEYS FROM THE IBERICO MUD MOUND (GULF OF CADIZ)

V. Blinova¹, I. Belenkaya¹, A. Eisenhauer², M. Ivanov¹ & L. Pinheiro³

¹ UNESCO-MSU Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevi Gori, Moscow 119899, Russia, vblinova@uni-bremen.de, vblinova@mail.ru

² GEOMAR Forschungszentrum für marine, Geowissenschaften an der Christian Albrechts universität zu Kiel, Wischhofstrasse 1-3, 24148 Kiel, Germany

³ Departamento de Geociências, Universidade de Aveiro, Campus de Santiago, 3810-193-Aveiro, Portugal, lmp@geo.ua.pt

A number of hydrocarbon-derived carbonate chimneys and slabs were sampled during the TTR-11 cruise in the Gulf of Cadiz. A large variety of carbonate chimneys was recovered from the Iberico mound. Observations with an underwater camera revealed a spectacular high density of pipe-like chimneys. Some of them are longer than 2 m and up to 0.5 m in diameter, lying over the sea floor, and some protruding from muddy sediment. The most of them are located on the top and terraces of the structure at depth from 800 to 1100 m.

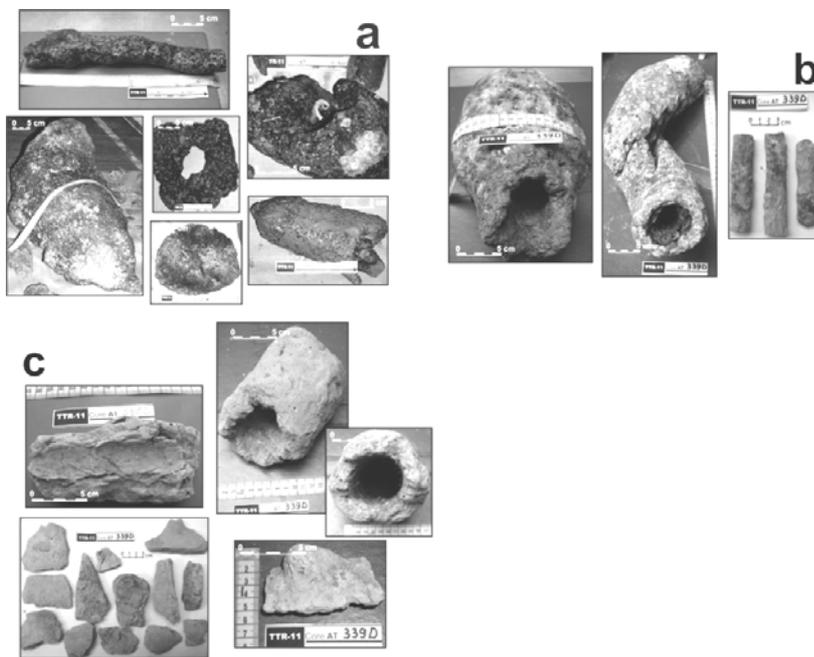


Fig. 1. Three groups of chimneys (a, b, c), Gulf of Cadiz (TTR-11 cruise)

Dark brown edifices with very porous surface and numerous cemented burrows represent the 1st group (Fig. 1, a). Chimneys belonging to the 2nd group (b) are just “touched” by oxidation. The 3rd group (c) includes light gray chimneys with smooth surface and full-cemented or open canals.

The chimneys are mainly composed of authigenic carbonates (dolomite and calcite) with iron oxides admixture. $\delta^{18}\text{O}$ isotopic values vary from 0.8 to 6.3‰ whereas $\delta^{13}\text{C}$ values indicate that chimney carbonates are moderately depleted in ^{13}C ranging from -31.7 to -47.2‰.

According to the U/Th dating, the chimneys were formed in the Early Pleistocene during different low sea level stages, i.e. glacial periods.

More than 120 specimens of chimneys, crusts and their fragments were taken from the Iberico mud mound. The collected chimneys show a wide range of morphological types (spiral, cylindrical, conical, etc.). Most of them vary from 10 to 50 cm in length and up to 30 cm in diameter. Longitudinal canals varied in size from 1 to 7 cm in diameter. In most cases these canals were free of cohesive sediments, but full-cemented chimneys were also observed. Besides, some chimneys with solid “internal cylinders” (about 10 cm in length, 1-1.5 cm in diameter) were found. Based on color and surface morphology these chimneys were divided into 3 groups (Fig. 1).

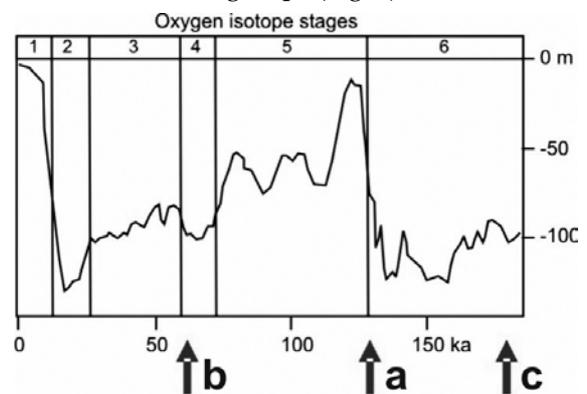


Fig. 2. Timing (arrows) of formation of different types of chimneys (a, b, c on Fig.1), based on the U/Th dating. The sea-level curve is from Martinson et al. (1987) and oxygen isotope stages from Chappe & Shackleton (1986)

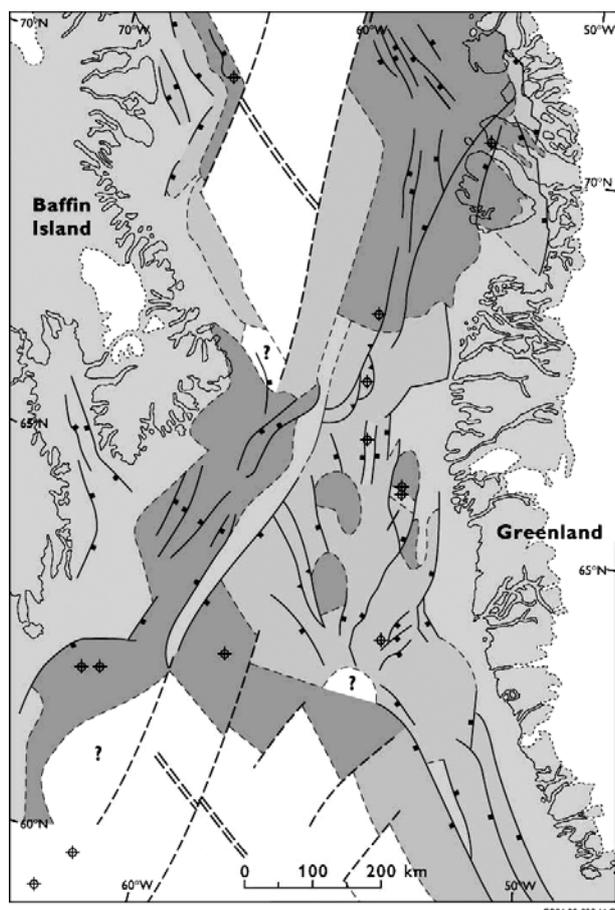
References

- Chappell, J. & Shackleton, N.J., 1986. Oxygen isotopes and sea level. *Nature*, **324**, 137-140.
Martinson, D. G., Pisias, N.G., Hays, J.D., Imbrie, J., Moore, T.C. & Shackleton, N.J., 1987. Age dating and the orbital theory of the ice ages: development of a high resolution 0 to 300,000 year chronostratigraphy, *Quat. Res.*, **27**, 1-29.

REGIONAL GEOLOGY, CENTRAL AND SOUTHERN WEST GREENLAND

J.A. Chalmers

Geological Survey of Denmark and Greenland, Øster Voldgade 10, DK1350 Copenhagen K, Denmark, jac@geus.dk



Geological map of the northern Labrador Sea/Davis Strait/southern Baffin Bay

Most of West Greenland onshore consists of high-grade metamorphic rocks of Archaean and Proterozoic age. Offshore, sedimentary basins are present along the whole of western Greenland and onshore in central West Greenland. The early development of these basins is not understood and the oldest sediments within them, visible on seismic data, have never been sampled.

A period of extensional tectonism, probably in the Early to mid-Cretaceous, formed large rotated fault blocks. The basins subsided thermally

during the Late Cretaceous and a second episode of tectonism took place during the latest Cretaceous and early Paleocene, prior to the onset of sea-floor spreading in the Labrador Sea and Baffin Bay in the mid-Paleocene.

Around the northern Labrador Sea, Davis Strait and in southern Baffin Bay, voluminous picrites and basalts were erupted at and shortly after the commencement of sea-floor spreading. Volcanism occurred again in the early Eocene at the same time as sea-floor spreading commenced in the northern North Atlantic.

Further south-east, oceanic crust is separated from continental crust by a highly stretched but non-magmatic transition zone that developed prior to sea-floor spreading. A complex transform zone, which developed during sea-floor spreading in the late Palaeocene and early Eocene, separates continental and oceanic crust along the Baffin Island margin.

- Oceanic crust
- Transitional crust
- Mesozoic Basin
- Paleogene volcanics
- Shallow/ exposed continental basement
- Unknown crust

Thick deltaic sediments, derived from central West Greenland, were deposited during the Palaeogene, but the basins were sediment-starved during the Neogene until the onset of glaciation in the Pliocene-Pleistocene when large prograding shelf-margin wedges formed.

MEGAFAUNA FROM A CANYON BORDERING THE FYLLA STRUCTURAL COMPLEX (SOUTHWESTERN MARGIN OF GREENLAND). RESULTS OF THE TTR-13 CRUISE (LEG 4)

M.R. Cunha¹ & V. Blinova²

¹ Departamento de Biologia, Universidade de Aveiro, 3810-193 Aveiro, Portugal, E-mail: mcunha@bio.ua.pt

² UNESCO-MSU Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevi Gory, Moscow 119899, Russia, fu@geol.msu.ru

Canyons are deep incisions in the continental margins, often connected to major river outflow systems. They channel and concentrate large quantities of organic matter, which leads to the occurrence of high faunal biomass and biodiversity (Rogers *et al.*, 2003). Canyons are complex hydrographic and sedimentary systems with unique environmental conditions that determine the faunal diversity and ecology in each individual system (Vetter & Dayton, 1998).

The megafaunal assemblages of a canyon located between the Fylla structural complex and the Nuuk basin (west of Greenland, approx. 55°27'W) were studied during the TTR-13 cruise using video imagery (deep-towed TV). The observations were made along two transects crossing the steep flanks and the channel of the canyon at approximately 63°18'N (northern profile) and 63°14'N (southern profile).

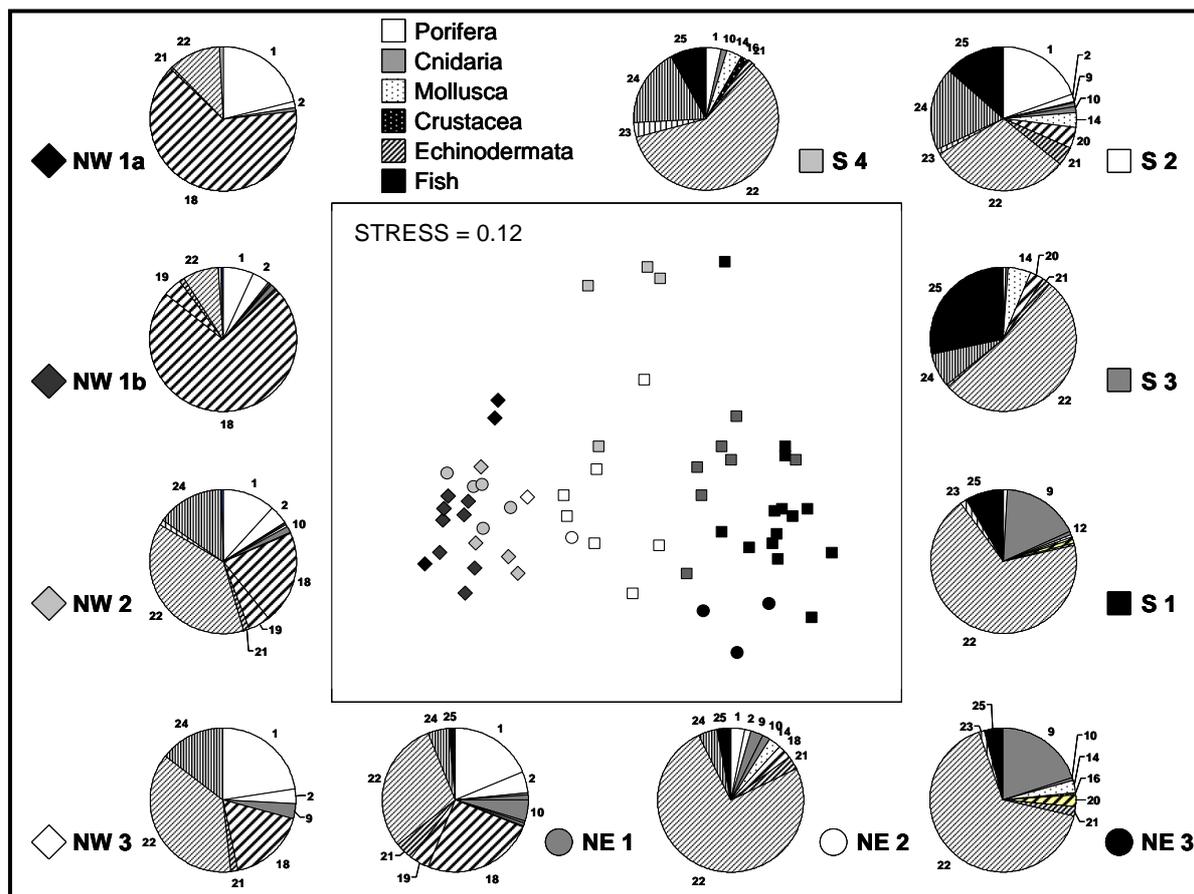


Fig. 1: MDS plot of the canyon megafaunal assemblages (off West Greenland).

The pie charts show the variation in the structure of the assemblage for the different areas in the two profiles.

S: south profile; NW: west flank of the northern profile; NE: east flank of the northern profile.

1-2: Porifera (two different morphological forms); 9: Cerianthidae; 10: Actinaria; 14: Gastropoda; 16: Decapoda; 18-19: Crinoidea (two different species of stalked crinoids); 20: Crinoidea (sessile); 21: Asteroidea; 22: Ophiuroidea; 23: Echinoidea; 24: Holothuroidea; 25: Fish.

During real-time watching of the footage, notes on the occurrence of different taxa were taken and referred to the time of observation. The abundances of each taxa per 5 minutes of observation were estimated and the analysis of the data was performed using the statistical package PRIMER 5. UPGMA classification and non-metric MDS (multi-dimensional scaling) were performed using the Bray-Curtis similarity measure after fourth root transformation of the data (Fig.1).

The results show a gradual change in the composition of the assemblage down the flanks and towards the channel as well as important differences in the structure of the assemblages in the northern and southern profiles. Both areas are dominated by echinoderms but ophiuroids characterize the southern area (30-69% of the total observations) while the northern area is more diverse and typified by the presence of stalked crinoids. These organisms are especially abundant (75% of the total observations) in the upper part of the flank and gradually decrease their abundance (fig. 1 NW1 to NW3) towards the channel where they are absent. Near the channel (fig. 1 NE3) the assemblage is more similar to the one in the southern area (fig. 1 S1 and S3) and the sandy bottom is favourable to the occurrence of cerianthids.

The interpretation of the MDS results identified depth-related factors and sediment type as the main drivers for megafaunal colonisation. The variation in the structure of the assemblages in the flanks and channel of the canyon is related mainly to physical conditions such as topographic features (e.g., steepness of the slope), water circulation (current velocity) and type of substrate (hard vs soft substrate).

Dredge and TV-assisted grab samples were also collected in the area but are not yet completely processed. The analysis of these samples will provide a more detailed characterization of the faunal assemblages and some information on the relation between the type of substrate and the distribution of the organisms. Preliminary results appear to indicate that, besides the physical factors mentioned above, macrofaunal colonisation depends also on the lithology of the substrate. There is a peculiar fauna associated with mudstones: most of these rocks were heavily bioturbated by the sipunculid *Golfingia cf vulgaris* but other animals are also able to excavate borrows in this soft consolidated material increasing the colonisable area and heterogeneity of the substrate. Some of the mudstones collected were heavily colonised by cryptic and sessile macroinvertebrates. This is apparently an interesting and poorly studied fauna. Two specimens of the genus *Heteromesus* (Crustacea: Isopoda: Asellota) collected in one of the samples (AT-457-GR) were already identified as belonging to a new species that is now being described (Cunha and Wilson, in prep.).

References

- Rogers, A. *et al.*, 2003. Life at the edge: achieving prediction from environmental variability and biological variety. - In: Wefer, G. *et al.* (eds). Ocean Margin Systems, Springer Verlag, 387-404.
- Vetter, E.W. & Dayton, P.K., 1998. Macrofaunal communities within and adjacent to a detritus-rich submarine canyon system. *Deep-Sea Research II*, **45**, 25-54.

SOUTHERN WEST GREENLAND - SEABED SAMPLING PROJECT 2003. TTR-13 CRUISE LEG 4 AND PART OF LEG 3

F. Dalhoff, A. Kuijpers, T. Nielsen, N. E. Poulsen & Shipboard Scientific Party

Geological Survey of Denmark and Greenland, Øster Voldgade 10, DK1350 Copenhagen K, Denmark, fd@geus.dk

Reworked palynomorphs encountered in the Qulleq-1 well and many other examples of reworked palynomorphs and microfossils from on- and offshore West Greenland (Nøhr-Hansen 1998; Nøhr-Hansen *et al.* 2000) as well as the finalising of a comprehensive multidisciplinary project combining seismic interpretation with a new interpretation of well data from offshore southern West Greenland (Dalhoff *et al.* 2002; Dalhoff *et al.* 2003; Nøhr-Hansen 2003; Rasmussen & Sheldon 2003; Sheldon 2003) initiated a preliminary seabed sampling programme in 2002. The preliminary programme was carried out in the canyon bordering the Fylla Structural Complex to the west (Fig. 1). Samples collected by gravity core on the deeper slope of the canyon revealed palynomorphs and spores assemblages suggesting the presence of Middle-Upper Jurassic and Lower Cretaceous strata.

These results and the possibility of joining the Training-Through-Research Programme in 2003 led the Bureau of Minerals and Petroleum to fund a major seabed sampling programme. This was carried out by

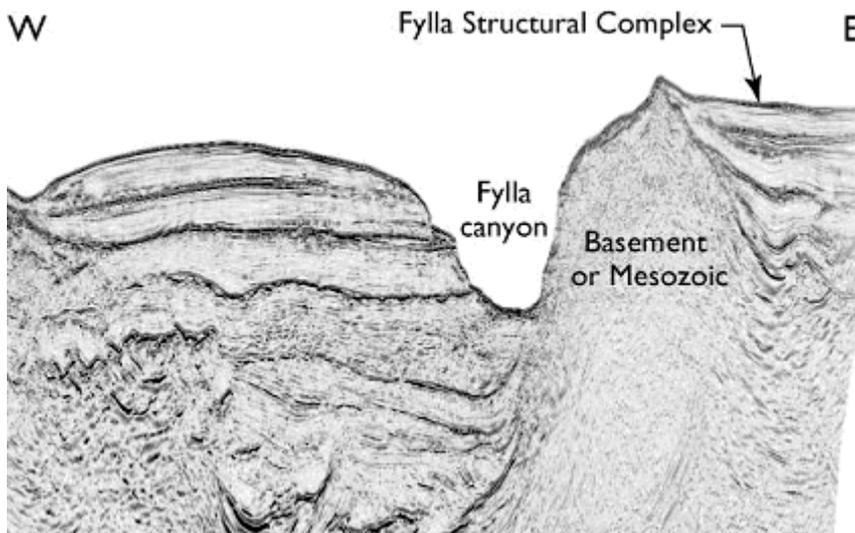


Fig. 1. Part of conventional seismic line crossing Canyon margin A bordering the Fylla Structural Complex to the east. The 2002 sample locality was on the upper eastern slope and the 2003 sampling has been grab samples, dredging and gravity coring from the bottom and up the eastern and western slopes

the Davis Strait High and canyon systems nearby and to investigate some prominent seamounts.

During 15 days of operation of Leg 4, four areas with different seabed features were investigated. The first area of investigation was Seamount B (Fig. 2) in the Lady Franklin Basin. This feature was observed on a conventional seismic line rising c. 1000 m above the sea bottom. Various geophysical data acquired during the cruise revealed a complex outline of the seamount area that comprises several individual cone-like features. Two dredges were collected containing basalts of which one sample consists of altered alkali basalt with a vein filled by biogenic carbonate containing Miocene fossils and traces of oil. However, dating of the alkali basalt has not been possible due to the sample size and alteration of the sample. Other samples from the seamount area have revealed preliminary biostratigraphical ages of E.-M. Miocene to recent.

Conventional seismic and new single-channel seismic data acquired on the TTR cruise in the Davis Strait High area (Fig. 2) confirmed dipping units of unknown age, most probably pre-Cretaceous, to be exposed or sub-cropping at sea bed below a veneer of Quaternary sediments. Relict iceberg ploughmarks were found to be a widespread phenomenon in the area. Samples were acquired by vibro-corer, gravity corer and dredge sampling and consisted of gneiss, basalts and sedimentary rocks. Palynological results from the samples indicate reworked Cretaceous palynomorphs and Eocene ages of the samples.

Seep area C and D (Fig. 2) were investigated for possible hydrocarbon seep structures ("pock-marks"). Both areas were scanned by deep-towed side-scan sonar; however, no direct evidence for seeping was found and a number of gravity cores were collected from locations selected on conventional seismic lines.

The sampling included two types of sample treatment. The conventional way normally used on TTR cruises implied the core being split up into half for sedimentological and biostratigraphic

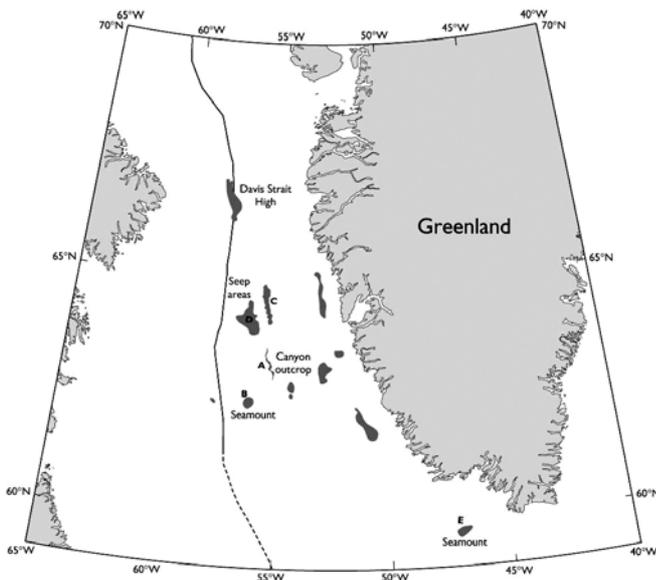


Fig. 2. Sample localities of the seabed sampling programme on TTR-13 cruise Leg 3-4

GEUS during three weeks in August 2003 with additional sponsorship by NUNAOIL. The seabed sampling project offshore south and southern West Greenland became part of Leg 3 and the entire Leg 4 of the TTR-13 cruise. Focus areas and the main targets were mainly selected based on results of a desk top study of all the conventional seismic lines offshore West Greenland outlying some interesting seabed features (Fig. 2) (Nielsen *et al.* 2001). The aim of the project was to investigate and sample possible seabed exposures of potential hydrocarbon seep structures ("pock-marks"), inverted Palaeozoic and Mesozoic basins on

investigations. In addition, applying another technique, the liner was cut into 1 meter length and sealed off after samples were collected for head space gas analysis and analysis by the Gore-Sorber method. Reworked palynomorphs of U. Jurassic? – L. Cretaceous and U. Cretaceous along with Paleocene, L.–M. Eocene and Miocene forms are found in both areas.

Canyon outcrop A (Figs. 1 & 2) is a deep canyon with water depths from 1700–2400 m deepening to the south and bordering the western margin of the Fylla Structural Complex (Bate *et al.* 1995). The canyon was investigated by geophysical methods and by variously ways of sampling and by underwater video inspection. The dredge and grab samples recovered a wide range of rocks from weathered Precambrian gneiss to sub-recent marly mudstone. One grab sample from the bottom part of the canyon contained a very promising carbonate source rock with a HI > 400 of Upper Ordovician – Lower Silurian age. Preliminary biostratigraphic results revealed reworked Upper Cretaceous palynomorphs and samples of Paleocene and Eocene ages.

One of the objectives on Leg 3 was the study of Seamount E (Fig. 2), a structure seen on a 2D seismic line, rising c. 700 m above the seabed from below Cenozoic sediments. This structure was thought to be a faulted basement block, outcropping Mesozoic sediments or Paleogene basalt. Approximately 120 km of single channel seismic was acquired along with OKEAN side scan sonar and the hull mounted sub-bottom profiler. The seamount can be seen on the side scan sonar mosaic for about 25 km, but its full extent is unknown at present. The seismic lines and the side scan sonar image imply that the structure could be a long faulted block. One dredge sample was collected part way up on the seamounts western wall in the depth interval around 2500–2100 m revealing mostly gneiss, quartzite and basalts.

In summary, throughout part of the 3rd and the complete 4th leg, the seabed in four different areas were scanned by a large amount of side scan sonar and single channel seismic lines, and a total of thirty-seven bottom samples were collected by dredging, gravity coring, vibro-coring and TV-controlled grab combined with video transects of selected sample sites. More detailed studies of some of these data can be found in several other papers of the present volume (Belan *et al.* 2004; Cunha & Blinova 2004; Korost *et al.* 2004; Ovsyannikov & Nielsen 2004; Poludetkina *et al.* 2004; Sarantsev 2004).

References

- Bate, K.J., Whittaker, R.C., Chalmers, J.A. & Dahl-Jensen, T., 1995. The Fylla structural complex: possible very large gas reserves offshore southern West Greenland. *Rapport Grønlands Geologiske Undersøgelse*, **165**, 22-27.
- Belan, A.B., Abbuehl, L. & Kuijpers, A., 2004. Relict iceberg ploughmarks on the western Greenland margin. - In: Poulsen N.E. & Suzyumov, A. E. (eds). North Atlantic and Labrador Sea margin architecture and sedimentary processes. International conference and thirteen post-cruise meeting of the Training-Through-Research programme, Copenhagen, Denmark, 29–31 January 2004. IOC Workshop Report, **191**, UNESCO, 9-11.
- Cunha, M.R. & Blinova, V., 2004. Megafauna from a canyon bordering the Fylla structural complex (southwestern margin of Greenland). Results of the TTR-13 cruise (Leg 4). - In: Poulsen N.E. & Suzyumov, A. E. (eds). North Atlantic and Labrador Sea margin architecture and sedimentary processes. International conference and thirteen post-cruise meeting of the Training-Through-Research programme, Copenhagen, Denmark, 29–31 January 2004. IOC Workshop Report, **191**, UNESCO, 15-16.
- Dalhoff, F., Chalmers, J.A., Gregersen, U., Nøhr-Hansen, H., Rasmussen, J.A. & Sheldon, E., 2003. Mapping and facies analysis of Paleocene–Mid-Eocene seismic sequences, offshore southern West Greenland. *Marine and Petroleum Geology*, **20**, 935-986.
- Dalhoff, F., Chalmers, J.A., Nøhr-Hansen, H., Rasmussen, J.A., Sheldon, E. & Gregersen, U., 2002. A multi-disciplinary study of the Palaeogene succession offshore West Greenland. *Geology of Greenland Survey Bulletin*, **191**, 90-96.
- Korost, D., Ovsyannikov, A. & Blinova, V., 2004. Principle results of hard rock sampling on the Greenland margin and way of interpretation of these data. - In: Poulsen N.E. & Suzyumov, A. E. (eds). North Atlantic and Labrador Sea margin architecture and sedimentary processes. International conference and thirteen post-cruise meeting of the Training-Through-Research programme, Copenhagen, Denmark, 29–31 January 2004. IOC Workshop Report, **191**, UNESCO, 24.

- Nielsen, T., Andersen, C., Jensen, J.B., Kuijpers, A., Marcussen, C., Piasecki, S., Sønderholm, M. & Rasmussen, R., 2001. Geohazard 2001 study offshore West Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2001/127**, 64 pp.
- Nøhr-Hansen, H., 1998. Dinoflagellate cyst stratigraphy of the Upper Cretaceous to Paleogene strata from the Hellefisk-1, Ikermiut-1, Kangâmiut-1 and Nukik-1 wells, offshore central West Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport **54**, 58 pp.
- Nøhr-Hansen, H., 2003. Dinoflagellate cyst stratigraphy of the Palaeogene strata from the wells Hellefisk-1, Ikermiut-1, Kangâmiut-1, Nukik-1, Nukik-2 and Qulleq-1, offshore West Greenland. *Marine and Petroleum Geology*, **20**, 987-1016.
- Nøhr-Hansen, H., Piasecki, S., Rasmussen, J.A. & Sheldon, E., 2000. Bistatigraphy of well 6354/4-1 (Qulleq-1), West Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2000/101**, 81 pp.
- Ovsyannikov, A. & Nielsen, T., 2004. Geological evidence of volcanic origin of the seabed hills on the western and south-western Greenland margin. - In: Poulsen N.E. & Suzyumov, A. E. (eds). North Atlantic and Labrador Sea margin architecture and sedimentary processes. International conference and thirteen post-cruise meeting of the Training-Through-Research programme, Copenhagen, Denmark, 29-31 January 2004. IOC Workshop Report, **191**, UNESCO, 39-40.
- Poludetkina, E., Korost, D., Ivanov, M. & Nielsen, T., 2004. Geochemical investigation of organic matter in the rocks from outcrops (western Greenland margin). - In: Poulsen N.E. & Suzyumov, A. E. (eds). North Atlantic and Labrador Sea margin architecture and sedimentary processes. International conference and thirteen post-cruise meeting of the Training-Through-Research programme, Copenhagen, Denmark, 29-31 January 2004. IOC Workshop Report, **191**, UNESCO, 41-42.
- Rasmussen, J.A. & Sheldon, E., 2003. Microfossil biostratigraphy of the Palaeogene succession in the Davis Strait, offshore West Greenland. *Marine and Petroleum Geology*, **20**, 1017-1030.
- Sarantsev, E.S., 2004. Depositional environment of the northern part of the Davis Strait High area revealed from lithology of two cores collected during the TTR-13 cruise. - In: Poulsen N.E. & Suzyumov, A. E. (eds). North Atlantic and Labrador Sea margin architecture and sedimentary processes. International conference and thirteen post-cruise meeting of the Training-Through-Research programme, Copenhagen, Denmark, 29-31 January 2004. IOC Workshop Report, **191**, UNESCO, 43-44.
- Sheldon, E., 2003. Palaeogene nannofossil biostratigraphy of the Kangâmiut-1 and Nukik-2 wells, offshore West Greenland. *Marine and Petroleum Geology*, **20**, 1031-1041.

TURBIDITY CURRENTS AND AGGRADATIONAL CANYON FILL: THE CASE OF THE STROMBOLI CANYON BEND

F. Gamberi & M. Marani

Istituto di Scienze Marine - Sezione Geologia Marina Bologna, Via Gobetti 101, 40129 Bologna, fabiano.gamberi@bo.ismar.cnr.it, michael.marani@bo.ismar.cnr.it

Introduction

The Stromboli Canyon is a main submarine morphologic element that runs with SW-NE direction in the Gioia Basin and after turning to an E-W path north of Stromboli Island, fed the Marsili deep-sea fan. In 1994 during the TTR-4 cruise, two MAK deep towed side-scan sonar lines were acquired over the structurally forced Stromboli Canyon bend north of Stromboli Island. Although a first interpretation of these data was presented by Kidd *et al.* (1998), the lack of accurate bathymetric control on the observed seafloor features did not allow the Authors to describe the details of the sedimentary processes occurring in the area. In 1996, a multibeam bathymetric map of the area was acquired by the Institute for Marine Geology of Bologna. In this paper we describe the sedimentary processes within the Stromboli canyon bend as deduced from the integrated interpretation of its main architectural elements and of its smaller scale seafloor features.

Main architectural elements

Upslope of the bend, the Stromboli Canyon is V-shaped, 400 m deep and 4 km large; approaching the bend, on the contrary, the canyon enlarges to 10 km and becomes flat bottomed. The canyon widening is

mainly realised through widespread failures of the outer canyon bank where higher shear stress and larger scale erosion must be concentrated.

Beside the canyon enlargement, the bend area is characterised by the development of a multithalweg system at variance with the single thalweg that runs along the canyon axis upslope of the bend. Three thalwegs run in the upper bend area and connect downslope in a single collector thalweg located in the lower bend along the outer canyon margin; longitudinal bars flank the thalwegs. The thalwegs are in the order of 500–1000 m wide and up to 20 m deep while the bars have a relief of up to 50 m. In addition, a flat area, interpreted as a marginal terrace, develops at the base of the Stromboli edifice slope and marks the inner bend limit of the present-day canyon axis. Longitudinal bars in the floor of multithalweg submarine canyons, channels and valleys, are either interpreted as less-eroded elevated seafloor sectors or as positive depositional features (Clarck & Pickering, 1996). In the Stromboli Canyon, the longitudinal bars appear either to be eroded along or to be accreting laterally over the adjacent thalwegs. Therefore we interpret the architecture of the Stromboli canyon floor as resulting from the combination of the lateral migration of small-scale thalwegs and of the vertical and lateral growth of depositional longitudinal bars. This process causes a net aggradation of the canyon floor through time as also evidenced by seismic lines. The resulting architecture is very similar to a braided subaerial river where longitudinal bars develop separated by chutes. Braided segments of present-day submarine channels have been interpreted as being the result of additional bedload entering the channel via tributaries or from channel enlargement (Hesse *et al.*, 2001). In the study area, the Angitola canyon enters the Stromboli one 15 km up slope of the bend but the only effect of this junction, is of deflecting the canyon thalweg. We can therefore interpret the development of a multithalweg canyon as resulting from canyon widening, due to the progressive erosion of the outer bend. Canyon enlargement can cause the expansion of turbidity currents leading to the formation of secondary flow cells that in turn are responsible for localised erosion and deposition in preferred seafloor sites.

Smaller architectural elements

Within turbidite systems, the depositional and seafloor features generated in areas where flow expansion occurs are assumed to be representative of the channel-lobe transition zone (Mutti & Normark, 1991; Piper & Normark 1991; Wynn *et al.*, 2002). Here, the turbidity currents are thought to undergo a hydraulic jump that results in increased internal turbulence and enhanced seafloor erosion and flow enlargement and dilution (Mutti & Normark, 1987). Both ancient and recent examples of turbidite system sectors generated under this flow regime, show that the change in flow conditions cause the extensive development of erosional and tractive features at the seafloor (Mutti & Normark, 1987; Wynn *et al.*, 2002).

The seafloor features of the different architectural elements of the Stromboli canyon bend, consisting of a large variety, both in shape and in scale, of erosional elements and of bedforms due to traction show that seafloor features similar to those of channel-lobe transition zone can occur elsewhere in turbidite systems provided that the conditions for flow expansion are met.

In order to account for the different grain-size and for the occurrence of specific erosional features and tractive bedforms in the single main architectural elements, however, highly variable current regimes must develop within the expanding flows. Flow stratification in submarine channels has been interpreted to result in the confinement of the higher-density, coarser-grained basal part of flows in the more depressed channel areas, while the upper parts of the flows spread in more uniform suspension over the entire channel (Hickson & Lowe, 2002; Camacho *et al.*, 2002). We therefore suggest that the coarser-grained seafloor and the different seafloor features that characterise the thalwegs as compared to the adjacent longitudinal bars are the evidence that the vertical structure of turbidity currents has a major impact on the sedimentary processes within submarine canyon and channels.

The upper more dilute part of the turbidity currents spreads over the whole Stromboli canyon and can also overbank and deposit fines in the canyon terrace; in addition, it is responsible for trains of megaflutes preferentially located on the bar margins and of traction over the central bar that is characterised by an almost continuous field of sediment waves. The upper flow portion is also responsible for the formation of a widespread, stepped erosion surface with a few metres of erosive relief in the western part of the inner bend bar adjacent to the overbank terrace. Similar, widespread erosion surfaces have been described in the Upper Carboniferous Ross Formation (Elliott, 2000; Lien *et al.*, 2003). As in the Stromboli canyon inner bend bar, they are ornamented by megaflutes and laterally flank shallow turbidity channels (Elliott, 2000). Elliott (2000) concluded that both the megaflute surfaces and the flanking channels were produced by the erosional

action of single turbidity currents. However, in the case of the Stromboli canyon, the widespread erosion surface is flanked by a megaflute train and cannot be traced laterally into the adjacent thalweg floors. Interestingly, linear erosional features are observed in the western margin of the thalweg that flanks the inner bend bar; they could represent the remnants of former widespread erosion surfaces partially obscured by successive erosive flows during thalweg excavation.

If this is the case, we can envisage that small scale thalwegs within canyons and channels are not the result of single flows but rather represent the result of a gradual focusing of erosion from initial widespread low-relief erosion surfaces through trains of megaflutes to narrow thalwegs. The stepped profile observed in many ancient examples of turbidity channels with dimensions comparable to those of the Stromboli canyon thalwegs (Hickson & Lowe, 2002; Lien *et al.*, 2003), could be the result of this evolution.

The confinement of the lower, high-density portion of turbidity currents within the floor of the thalwegs can explain their coarser-grained seafloor. Traction features, in the form of coarse-grained sediment waves, often reworked in longitudinal ribbons, and smaller scale streaks of alternating coarser- and finer-grained sediments are also widespread in the thalweg floor.

However, particularly in the proximal part of some of the thalwegs, patches of homogeneous coarse-grained sediments that do not show any evidence of traction are present. They can indicate that at least the initial deposition from the basal, high-density part of the flows occurs under high rate of suspended load fall-out capable of suppressing bedform development. The bedforms developed in the distal thalweg portions, on the contrary, could be the result of reworking due to the more hindward part of the flows related to the longitudinal flow structure as proposed by Mutti *et al.* (1999) and Kneller & McCaffrey (in press). In the flank of the collector thalweg close to the outer flank of the canyon bend, small-scale bedforms that can be interpreted as megaripples are almost perpendicular to larger scale sediment waves. These megaripples could be the evidence of the reflection of the upper part of the flows against the opposing confining canyon margin.

Conclusions

The observed architectural elements and seafloor features on the Stromboli Canyon furnish an insight on the processes that concur in the active aggradational infill of submarine canyons. In addition, they provide a present-day example stressing the importance of the vertical and longitudinal structure of turbidity currents on their resulting deposits.

References

- Camacho, H., Busby, C.J. & Kneller, B., 2002. A new depositional model for the classical turbidite locality at San Clemente State beach, California. *Am. Ass. Petr. Geol. Bull.*, **86**, 1543–1560.
- Clarck, J.D. & Pickering, K.T., 1996. Submarine channels: processes and architecture. Vallis Press, London.
- Elliott, T., 2000. Megaflute erosion surfaces and the initiation of turbidite channels. *Geology*, **28**, 119–122.
- Hickson, T.A. & Lowe, D.R., 2002. Facies architecture of a submarine fan channel-levee complex: the Juniper Ridge Conglomerate, Coalinga, California. *Sedimentology*, **49**, 335–362.
- Hesse, R., Klauke, I., Khodabakhsh, S., Piper, D.J.W. & Ryan, B.F., 2001. Sandy submarine braid plains: potential deep-water reservoirs. *Am. Ass. Petr. Geol. Bull.*, **85**, 1499–1521.
- Kidd, R.B., Lucchi, R.G., Gee, M. & Woodside, J.M., 1998. Sedimentary processes in the Stromboli Canyon and Marsili Basin, SE Tyrrhenian Sea: results from side-scan sonar surveys. *Geo-Mar. Lett.*, **18**, 146–154.
- Kneller, B. & McCaffrey, W., (in press). The interpretation of vertical sequences in turbidite beds: the influence of longitudinal flow structure. *Journ. Sed. Res.*
- Lien, T., Walker, R.G. & Martinsen, O.J., 2003. Turbidites in the Upper Carboniferous Ross Formation, western Ireland: reconstruction of a channel and spillover system. *Sedimentology*, **50**, 113–148.
- Mutti, E., Tinterri, R., Remacha, E., Mavilla, N., Angella, S. & Fava, L., 1999. An introduction to the analysis of ancient turbidite basins from an outcrop perspective. *Am. Ass. Petr. Geol.*, Continuing Education Course Note Series #39.
- Mutti, E. & Normark, W.R., 1987. Comparing examples of modern and ancient turbidite systems: problems and Concepts. - In: Leggett, J.K. & Zuffa, G.G. (eds). *Marine clastic sedimentology: Concepts and case studies*. Graham & Trotman, London.

- Mutti, E. & Normark, W.R., 1991. An Integrated approach to the study of turbidite systems. - In: Weimer P. & Link H. (eds). Seismic facies and sedimentary processes of submarine fans and turbidite systems. Springer-Verlag, New York, 75–106.
- Normark, W.R. & Piper, D.J.W., 1991. Initiation processes and flow evolution of turbidity currents: implications for the depositional record. - In: Osborne, R.H. (ed.). From shoreline to abyss: SEPM Spec. Publ., **46**, 1143–1115.
- Wynn, R.B., Kenyon, N.H., Masson, D.G., Stow, D.A.V. & Weaver, P.P.E., 2002. Characterisation and recognition of deep-water channel-lobe transition zones. *Am. Ass. Petr. Geol. Bull.*, **86**, 1441–1462.

SEARCH FOR A HIGH RESOLUTION HOLOCENE RECORD ON THE EIRIK DRIFT, SOUTHERN GREENLAND

N.H. Kenyon¹, A. Akhmetzhanov¹, S. Hunter¹, A. Kuijpers², E. Rohling¹, S. Bacon¹ & D.A.V. Stow¹

¹ Southampton Oceanography Centre, Southampton SO14 3ZH, UK

² Geological Survey of Denmark and Greenland (GEUS), Copenhagen NV, Denmark, aku@geus.dk

Changes in the Thermohaline Circulation are implicated as the immediate cause of rapid climate changes that are known from, for instance, ice-core records. The Eirik Drift was chosen as a critical site for the study of palaeoceanographic data that should record the history of the deep western boundary current. A geophysical survey using a hull mounted profiler and an air gun profiler showed that the drift crest has migrated northwards through time and that there is little sedimentation on the southern flank. This sedimentation pattern will be related to planned hydrographic measurements in order to link drift development to bottom-current regime. Mud waves are common in the early history of the drift but are not found in the uppermost 500 m of sedimentation. Sediment slides are common down the steeper southern side, making this a particularly failure prone drift. Corrections have been made to the GEBCO bathymetry.

Two deep towed profiles were run in order to find a core site suitable for a high resolution Holocene record. A regular pattern, presumably a bedform due to the action of the current on the drift surface, was seen on the sonographs. A superficial lens of sediment, with a maximum thickness of 25 m, was located on the north side of the crest. Core TTR13-AT451G, from the centre of this lens, appears to have less bioturbation than has been reported in cores from the Drift. It will be put through the multisensor loggers at SOC prior to micropalaeontological and grain size analysis.

MINERALOGICAL AND GRAIN SIZE ANALYSES OF A RECENT TURBIDITE IN THE LOFOTEN BASIN, NORWEGIAN SEA

R. Khamidullin¹ & J. S. Laberg²

¹ UNESCO-MSU Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevi Gory, Moscow, 119992, Russia, fu@geol.msu.ru

² Department of Geology, University of Tromsø, N-9037 Tromsø, Norway, jan.laberg@ig.uit.no

The Lofoten Basin is situated to the west of the northern Norwegian continental margin and it reaches a water depth of more than 3000 m. Part of the basin was investigated during Leg 1 of the TTR-13 Cruise of R/V *Professor Logachev*. Five cores were taken in this area (AT-437V, AT-438K, AT-440V, AT-441K and AT-442K). Locations of the sites were chosen according to interpretation of MAK-1 side-scan sonar and sub-bottom profiling data (TTR-13 Cruise) and on the base of the GLORIA and TOBI side-scan sonar mosaic, which were obtained during the R/V *James Clark Ross* surveys in 1994 and 2000 (Dowdeswell *et al.*, 2002; Taylor *et al.*, 2002).

Station AT-440V sampled a patchy area observed on the side-scan sonar profile MAKAT-81. This station aimed to sample the channel mouth sand lobe using a vibro-corer. This device retrieved about 94 cm of sediment. A sandy unit was observed in the interval of 0 – 87 cm covered by a few millimeter thick veneer

of brownish marl. Fine and very well sorted sand was water saturated in the upper part on this unit. The water content gradually decreased towards the bottom, where the sediment was more consolidated. The sand includes sponge spicules and other organic fragments (e.g. plants fragments). The lowermost unit (87 – 94 cm) consists of stiff structureless grey clay with foraminifera. After visual description, the samples from

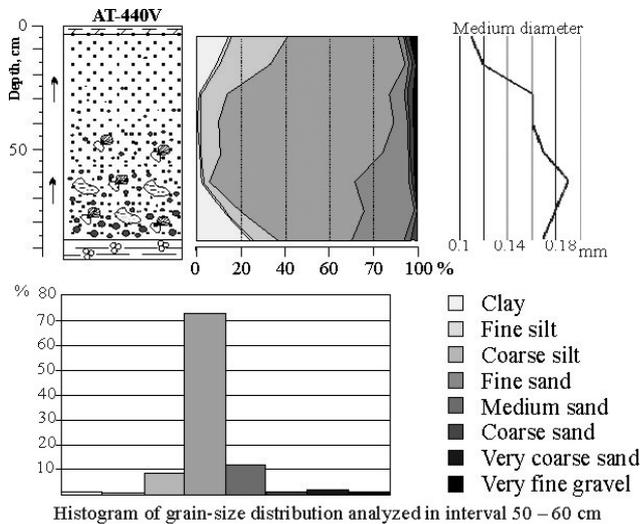


Fig. 1. Distribution of the grain size fractions for the core AT-440V showing typical positive gradation for the turbiditic layer

According to mineralogical analysis, the studied layer comprises quartz (about 80%), mica, feldspar, rock fragments and heavy minerals. The most common heavy minerals are garnet and amphiboles (Fig. 2). Pyroxenes, epidote, sphene, apatite and iron minerals were also observed. Among the iron minerals there are limonite, pyrite and hematite. According to the heavy mineral assemblages the source rocks of this turbidity layer belongs to a high-metamorphic provenance (Pettijohn, 1975).

each 10 cm were taken for the following studies: thin-section description, grain-size analysis and separation of heavy and light minerals in bromoform (heavy liquid; its specific gravity is 2.9 g/cm³).

According to the grain size analysis, the interval of 0 – 87 cm showed positive gradation (Fig. 1). The lower part (80 – 87 cm) is represented by medium-grained sand with semi consolidated clayey fragments while the central part (30 – 80 cm) consists of fine and very fine sand. Towards the top the size of the particles decreases and the interval of 10 – 30 cm is represented by clayey sand. The uppermost part of the cycle is represented by sandy silt. Sediments with these characteristics can be interpreted as turbidites (Pickering *et al.*, 1989).

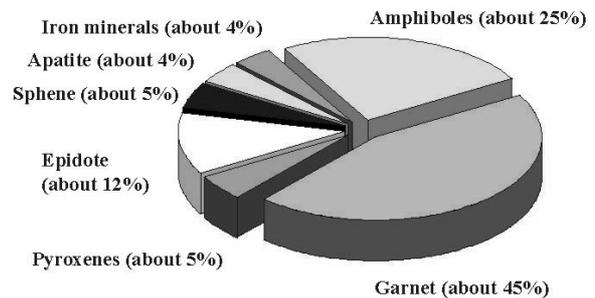


Fig. 2. Average heavy minerals composition of the core AT-440V sediments

References

- Dowdeswell, J.A., Ó Cofaigh, C., Taylor, J., Kenyon, N.H., Mienert, J. & Wilken, M., 2002. On the architecture of high-latitude continental margins: the influence of ice-sheet and sea-ice processes in the Polar North Atlantic. - In: Dowdeswell, J.A. & Ó Cofaigh, C. (eds): Glacier-influenced sedimentation on high-latitude continental margins. *Geological Society, London, Special Publications*, **203**, 33-54.
- Taylor, J., Dowdeswell, J.A. & Siegert, M.J., 2002. Late Weichselian depositional processes, fluxes and sediments volumes on the margins of the Norwegian Sea (62-75° N). *Marine Geology*, **188**, 61-77.
- Vorren, T.O., Laberg, J.S., Blaume, F., Dowdeswell, J.A., Kenyon, N., Mienert, J., Rumohr, J. & Werner, F., 1998. The Norwegian-Greenland Sea continental margins: Morphology and Late Quaternary sedimentary processes and environment. *Quaternary Science Reviews*, **17**, 273-302.
- Pettijohn, F.J., 1975. *Sedimentary rocks*, 3rd edition.

PRINCIPLE RESULTS OF HARD ROCK SAMPLING ON THE GREENLAND MARGIN

D. Korost, A. Ovsyannikov & V. Blinova

UNESCO-MSU Center for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevy Gory, Moscow 119899, Russia, E-mail: fu@geol.msu.ru

One of important objectives of Legs 3 and 4 of the TTR-13 cruise was sampling of pre-Cretaceous rocks based on the interpretation of multichannel seismic data provided by GEUS. Different areas at the Southern and Western Greenland margins, which characterised by seabed structures with possible outcrops, were surveyed with single channel seismic, side-scan sonars (MAK and OKEAN), underwater TV and sampling. Studied targets were seabed hills, steep walls of the canyon between the structure complex Fylla and the Nuuk basin and places that are not covered by sediments in ploughmarks in the Davis Strait High. Based on data from the onboard profiler (5 kHz) and TV-data areas with outcrops on the steep slopes were identified. Main complication for interpretation of nature of hard rock samples in this region is a wide distribution of ice-rafted material on the sea bottom. Also some places that look like outcrops are in fact covered by thick layers of Quaternary sediments.

A few outcrops were sampled by dredging and TV-guided grab during the cruise. The collected samples from each single site (up to 0.5 t) consist of bedrocks, but also of dropstones. Among the collected rocks there are magmatic, metamorphic and sedimentary ones. To reveal the origin of the collected hard rocks it is necessary to take into account several specific features of this region.

Usually, the distribution of dropstones in one specific area depends on a relatively uniform melting of icebergs and has similar pattern. Based on the underwater TV-lines TVAT-43 and TVAT-44 in the canyon area irregularity in distribution of rock fragments on the seafloor were observed. On the flat bottom only a few or no rock fragments were observed. In contrast, a large number of clasts and big rock blocks were located on steep slopes in the canyon and beneath the outcropping layers and were very well recognised on a TV record. So we suggest that most of rock fragments situated under the steep slopes are represented by rock clasts from the outcrops.

Large amount of samples from a seabed hills area (AT-453D, AT-454D) are angular-subangular and sub-rounded. Partial roundness of rocks is possibly related to chemical and biological weathering *in situ*, physical distraction due to local transportation downslope and influence of bottom currents. Based on interpretation of lithological and petrologic study of rocks from these dredges, most of angular-subangular-sub-rounded clasts (about 30–40%) have similar composition and represented by volcanic and contact-metamorphic rocks due to volcanic nature of these structures.

In all samples from dredges and TV-grabs taken during Legs 3 and 4 of the TTR-13 cruise the same types of rocks were found, such as granites, gneisses, red sandstones and others. This allows us to conclude on the ice-rafted origin of these rocks. Most of the volcanic, metamorphic and sedimentary rocks can be interpreted as bedrocks due to their local distribution and repetition in sampling sites at close distances.

COMPOSITION AND MATURITY OF ORGANIC MATTER IN THE ROCK CLASTS OF MUD VOLCANIC BRECCIA

E. Kozlova¹, M. Ivanov¹, F. Baudin², C. Largeau³ & S. Derenne³

¹ UNESCO-MSU Centre for Marine Geology and Geophysics, Geological Faculty, Moscow State University, Russia, fu@geol.msu.ru

² Département de Géologie Sédimentaire, CNRS-FRE 2400, Université P. et M. Curie, Paris-VI, France

³ Laboratoire de Chimie Bioorganique et Organique Physique, ENSCP, France

During several TTR cruises investigations were focused on hydrocarbon seep areas characterised by widespread underwater mud volcanism. More than 1500 samples of rock clasts from mud breccia of different mud volcanoes from the Black Sea, the Eastern Mediterranean, the Alboran Sea and the Gulf of Cadiz were studied. More than 500 samples were analysed with a big set of different organic geochemical

methods such as fluorescent analysis, Rock-Eval pyrolysis, chemical extraction, gas-chromatography, gas-chromatography-mass-spectrometry and others.

Mud breccia usually appears as pluricentimetric subrounded to angular clasts embedded in dark to light grey silty clayey matrix. The clasts from mud volcanoes of the Black Sea mud volcanic fields consist mostly of claystones and sandstones. Fragments of rocks from different fields in the Mediterranean Sea and the Gulf of Cadiz are represented by large variety of lithotypes: bioclastic or micritic limestones, marlstones, claystones and sandstones. The clasts from the mud volcanoes derived from different sedimentary rocks ranging in age from Cretaceous to Pleistocene; Miocene rocks are being most important in volume (Sadekov *et al.*, 2000; Akhmanov, 1996; Fadeeva *et al.*, 2001).

Information on thermal evolution and origin of organic matter (OM) can be achieved by pyrolytic measurements (Espitalie *et al.*, 1977). About half of the studied clasts are virtually free of OM, with the total organic carbon (TOC) contents lower than 0.05%. The other part shows the TOC content ranging from 0.06 – 10%. Organic-rich samples (> 1% TOC) correspond to claystones and micritic limestones, while sandstones and bioclastic limestones display lower OM contents. Practically no relationship is noted between TOC content and age of the clasts. The organic carbon content of mud matrix shows a narrower range in TOC (0.06 – 0.5%), and an average of 0.2% TOC.

According to a wide range of the hydrogen index HI-values (21 to 654 mg HC/g TOC), estimated by Rock-Eval instruments and results of elemental analysis (H/C), OM of the studied samples could be attributed to Types II, III (Tissot and Welte, 1984). Type II is usually related to a marine phytoplankton material while Type III is derived from terrestrial higher plants debris. Mud matrix has the same mean HI-value around 200 mg HC/g TOC and shows a narrower range of this parameter.

The maximum of hydrocarbon production (Tmax) values of all studied samples are relatively low (<438°C with the mean value around 423°C) indicating that the organic matter of both clasts and matrix has not experienced strong thermal maturation. However, the clasts present a wider range of Tmax (402–438°C) compared to the matrix, in which Tmax ranges between 414 and 432°C. A low maturity of OM is also confirmed by the distribution of biomarkers.

Generally, OM of the rock clasts belongs to immature and low mature kerogen of Types II and III Types. Organic carbon content is different in the different mud volcanoes and depends on environmental conditions during sedimentation. The level of maturity and significant range (from poor to excellent) of oil/gas potential of the samples suggest that OM of the studied rocks can produce mostly gas from the upper gas window zone, and quantity of this gas strongly depends on TOC and a type of kerogen.

References

- Akhmanov, G., 1996. Lithology of mud breccia clasts from the Mediterranean Ridge. *Mar. Geol.*, **132**, 151–164
- Espitalie, J., Laporte, J., Madec, M. *et al.*, 1977. Méthode rapide de caractérisation des roches-mères, de leur potentiel pétrolier et de leur degré d'évolution. *Rev. Inst. Fr. Petrole*, **32**, 23–42.
- Fadeeva, N., Kozlova, E. & Ponomareva, E., 2001. Organic matter of the maykopian rocks of the Sorokin trough. Proceedings of the 5th conference "Petroleum Geology in the XXIth Century", MSU, 463–465, in Russian.
- Sadekov, A. & Ovsyannikov, D., 2000. Age of rock clasts from the Yuma mud volcano breccia on the basis of foraminifera study (Gulf of Cadiz, NE Atlantic). Geological processes on European continental margins. - In: Comas, M. & Akhmanov, G. (eds). Geological processes on European continental margins. International conference and eighth post-cruise Meeting of the Training-through-Research programme, Granada, Spain, 31 January- 3 February 2002, IOC Workshop Report, **168**, UNESCO, 19.
- Tissot, B. & Welte, D., 1984. Petroleum formation and occurrence. New York, Springer-Verlag, 699 pp.

ASPECTS OF DEEP-WATER BOTTOM CURRENTS IN THE BILL BAILEY BANK AREA, OFFSHORE SW FAEROES

M. Kruse & L.O. Boldreel

Copenhagen University, Øster Voldgade 10, 1350 Copenhagen K, Denmark, km220775@geo.geol.ku.dk

Abstract

A study of the flow of recent deep-water bottom currents in the Bill Bailey Bank area are based on five (5) reflection seismic surveys acquired in the period 1975-1997 (*North Atlantic 1975, Magnus Heinason 1990, Pelagia 1993, Of 1995 and TTR7 1997*). The area is characterised by a highly variable sea floor topography (Fig. 1). At the central parts of the banks basalt is exposed at the seafloor otherwise the surface of the basalt is covered with a variable amount of sediments. Analysing the data on workstation using Geographix software®, reveal a number of synclines at the seafloor and these structures have been interpreted as channels. Contourites created by bottom currents have been recognized and are described. On the TTR-7 (1997) profiles a seismic pattern that may represent carbonate mounds are identified and discussed. Processing of the TTR-7 cruise data proved necessary prior to any interpretation and the processing carried out is outlined in the last chapter of the present paper.

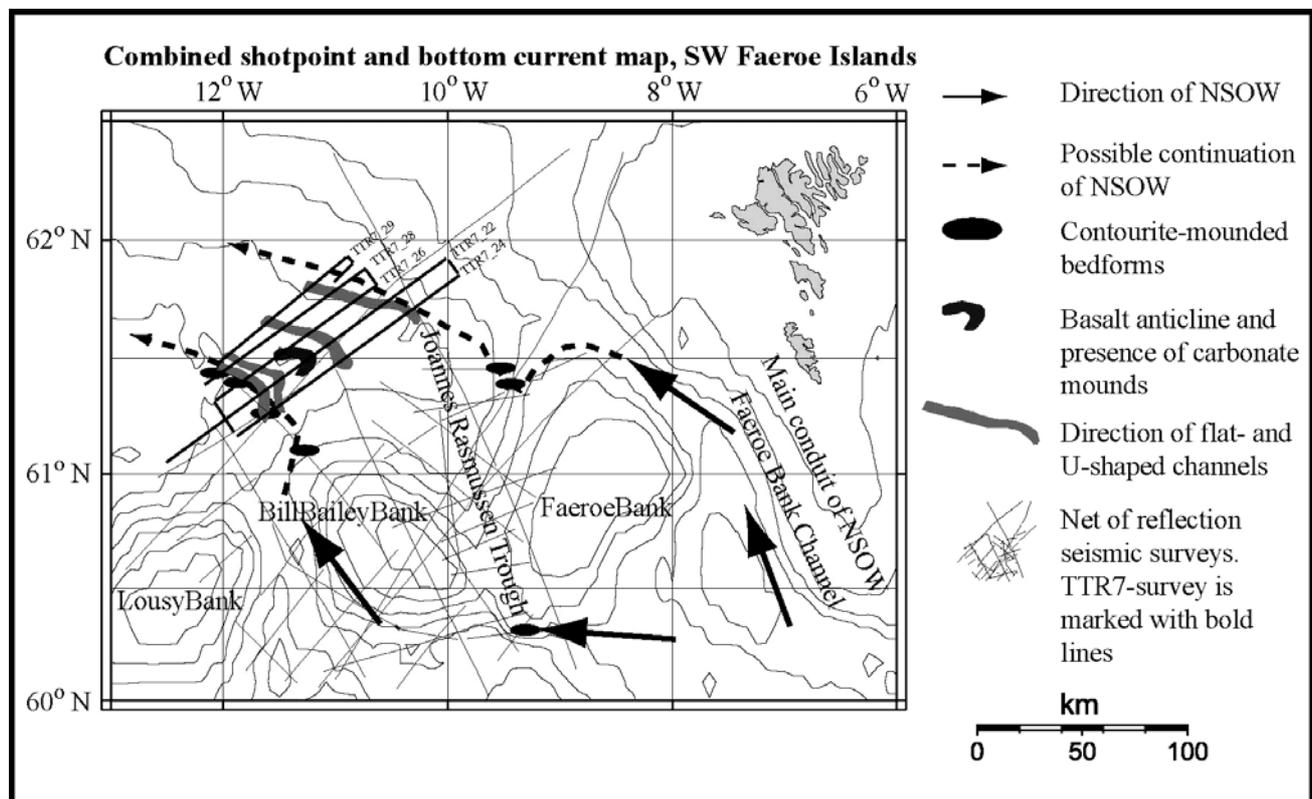


Fig.1. Shotpoint map; the TTR- 7 (1997) survey is marked with bold lines. The map also shows the flow of the NSOW (Kuijpers et al., 1998) and a suggested continuation north of the Bill Bailey Bank and the Lousy Bank based on the presence of channels of flat- and U-shaped bottoms and contourite-mounded bedforms

Introduction

In the centre of the area covered by the TTR-7 (1997) survey a minor basalt anticline not directly connected to the Bill Bailey Bank is seen (Fig. 2 C, D). The anticline separates the northeastern part of the TTR-7 survey from the southwestern part and two different sedimentation systems are present as a result of the anticline. On the northeastern side a depression in the basalt gradually disappearing to the north is

observed (Fig. 2 C, D, E). Based on interpretation of the seismic profiles in the Joannes Rasmussen Trough it seems as the depression observed northeast of the basalt anticline is the northern continuation of the Trough. The sedimentation system to the southwest comprises parallel-bedded sediments resting on a gently south-westerly dipping surface of the basalt. This system is interpreted to consist of contourites connected to the current system located between the Bill Bailey Bank and the Lousy Bank.

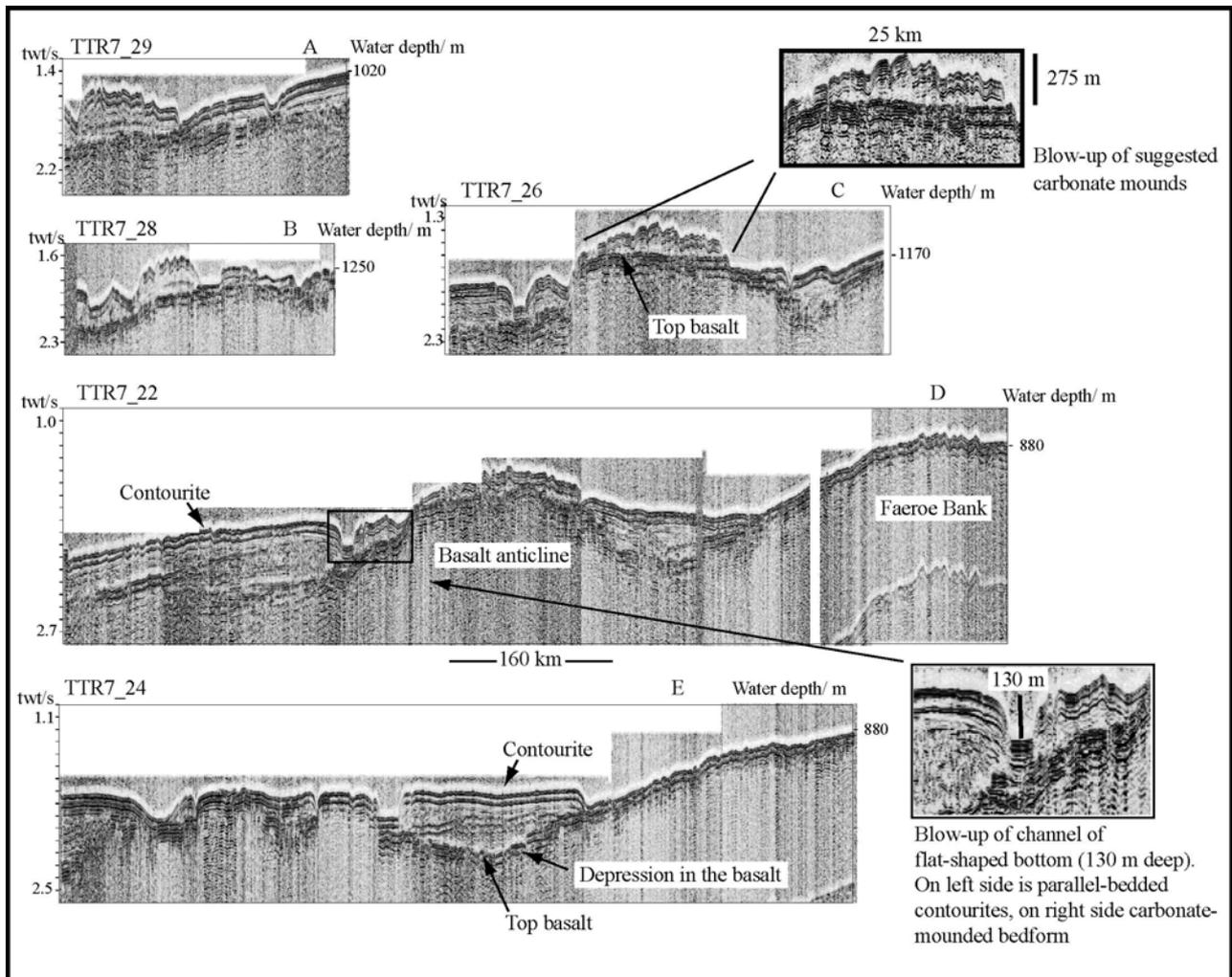


Fig. 2 A-E: The five main seismic lines of the TTR-7 (1997) survey. For location see Fig. 1. Water depth is indicated for reference.

Deep-water bottom currents

A number of asymmetric channels of flat- and U-shaped bottoms appear on both sides of the basalt anticline (Fig. 2). The asymmetry of the channels may be ascribed to the oblique cut, tectonics or to the Coriolis effect, which causes the flow to turn right and to deposit to the left (Faugères *et al.*, 1999). These deposits are interpreted as contourites. The layering of the contourites demonstrates a gradual build-up as the current passes. Mapping the channels (Fig. 1), the direction of the bottom flows that creates the channels seems to be orientated southeast northwest. The Norwegian Sea Overflow Water (NSOW) flows from the Norwegian Sea to the Icelandic Sea passing through the Bill Bailey Bank area and the main conduit of the NSOW is the western outlet of the Faeroe Bank Channel (Kuijpers *et al.*, 1998). It is speculated that the main conduit is connected to the contourite-mounded bedforms northwest of the Faeroe Bank, indicated by the dashed line in Fig. 1. Contourite-mounded bedforms south of the Bill Bailey Bank are ascribed to intermittent NSOW overflow of the Wyville-Thomson Ridge passing between the Bill Bailey Bank and the

Lousy Bank (e.g. Kuijpers *et al.*, 1998; Boldreel *et al.*, 1998). The present study suggests that those two bottom currents are represented in the TTR-7 survey (Fig. 1). We propose that the anticline separates two different bottom current systems, supported by the different sedimentation patterns. However, a mixing of the main current from the Faeroe Bank and the overflow of the Wyville-Thomson Ridge is an option due to the free passageway between the Bill Bailey Bank and the anticline.

Carbonate mounds

In a water-depth of 1000-1300 m a hummocky seismic section is seen on the crest of the basalt anticline (Fig. 2 A-D). The hummocky section is about 275 m high and 25 km wide and rests on a surface of basalt that seems to be horizontal. The reflection free lower part of the hummocky section and the lack of hummocky structures in the vicinity of the anticline suggest the possibility of a stacking of several carbonate mounds on top of the basalt anticline (Nielsen *et al.*, 2003). As several bottom currents join up in this area interaction between the currents and topographic elevation create an environment of increased flow velocities, which appears to be a major control on the growth of carbonate mounds (Masson *et al.*, 2002). Steep-sided topography of the hummocky section implies the occurrence of bottom currents in the channels and on top of the anticline. Other factors like accurate salinity and temperature are also important but are not known for this area.

Processing

The eight reflection seismic profiles of the TTR-7 survey was deconvoluted and bandpas-filtered after acquisition. The following process has been performed before the digital data can be used on the workstation:

- (i) Dipscan filtering: *Max. and Min. of dip limits: 6 ms/trace;*
- (ii) Shot trace summation: *Diminution from 6 to 1;*
- (iii) Delay correction;
- (iv) Trace editing.
- (v) Bandpas filtering:
 - 0-800 ms: 10-15 Hz lowcut filter, 70-100 Hz highcut filter*
 - 1000-1300 ms: 8-14 Hz lowcut filter, 60-80 Hz highcut filter*
 - 1600-2000 ms: 6-12Hz lowcut filter, 50-65 Hz highcut filter*
- (vi) AGC scaling: *a window of 150 ms robust type with a coefficient of 6.*

References

- Boldreel, L.O & Andersen, M.S., 1998. Neogene seismic facies and deep-water gateways in the Faeroe Bank area, NE Atlantic. *Marine Geology*, **152**, 129-140.
- Faugères, J.-C. *et al.*, 1999. Seismic features diagnostic of contourite drifts. *Marine Geology*, **162**, 1-38.
- Kuijpers, A. *et al.*, 1998. Quaternary sedimentation and Norwegian Sea overflow pathways around Bill Bailey Bank, northeastern Atlantic. *Marine Geology*, **152**, 101-127.
- Masson, D.G. *et al.*, 2003. The origin of deep-water, coral-topped mounds in the northern Rockall Trough, Northeast Atlantic. *Marine Geology*, **194**, 159-180.
- Nielsen, L. *et al.*, 2003. GPR and marine seismic imaging of carbonate mound structures in Denmark and SW Sweden; a case study of imaging structures at different scales. - In: Ground penetrating radar in unconsolidated and unconsolidated sediments. *The Leading Edge* (Tulsa, Ok), **22** (9), 872-875.

ARCHITECTURAL ELEMENTS OF A MODERN DEEP-SEA CHANNEL AND SANDY LOBE, NORWEGIAN SEA

J.S. Laberg¹, T.O. Vorren¹, N.H. Kenyon², M. Ivanov³ & E.S. Andersen⁴

¹ Department of Geology, University of Tromsø, N-9037 Tromsø, Norway, jan.laberg@ig.uit.no

² Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH, UK

³ UNESCO Centre for Marine Geology and Geophysics, Moscow State University, Moscow 119899, Russia

⁴ Norsk Hydro ASA, N-0246 Oslo, Norway

A modern deep-sea channel, the Lofoten Basin Channel, extends about 200 km beyond the base of the continental slope to the abyssal plain of the Lofoten Basin at about 3200 m water depth (Dowdeswell *et al.*, 1996; Vorren *et al.*, 1998; Taylor *et al.*, 2002) (Fig. 1). This part of the slope is the steepest on the Norwegian margin and has suffered sediment starvation throughout the Cenozoic. Based on high-resolution side-scan sonar data together with subbottom profiles and cores (gravity cores and vibro-cores) we have studied the channel-lobe transitional area in the Lofoten Basin.

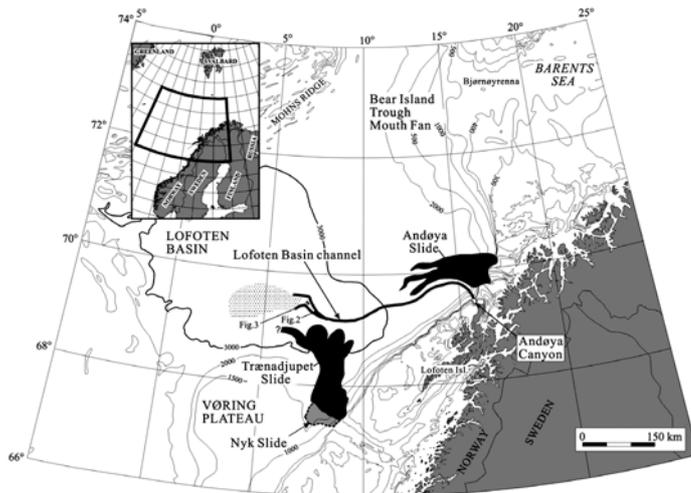


Fig. 1. Bathymetric map covering the north-eastern Norwegian-Greenland Sea. The Lofoten Basin channel, the Andøya canyon, the Bear Island Trough Mouth Fan and large submarine slides (the Andøya, Trænadjupet and Nyk slides) are shown. Figs. 2 and 3 are indicated.

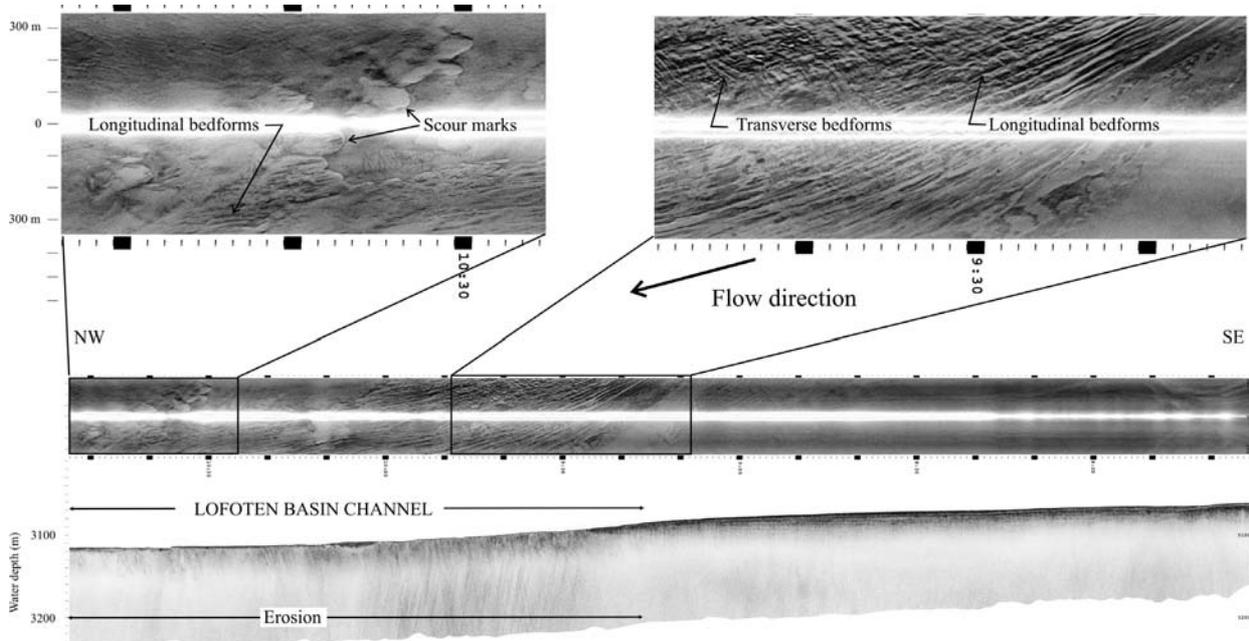


Fig.2. Part of MÅK side-scan line MAKAT-81 (100 kHz) and corresponding sea-bottom profile (5 kHz) showing longitudinal and transverse bedforms and incisions (scour marks) in the Lofoten Basin channel. These features are inferred to be caused by turbidity current erosion. See Fig. 1 for location.

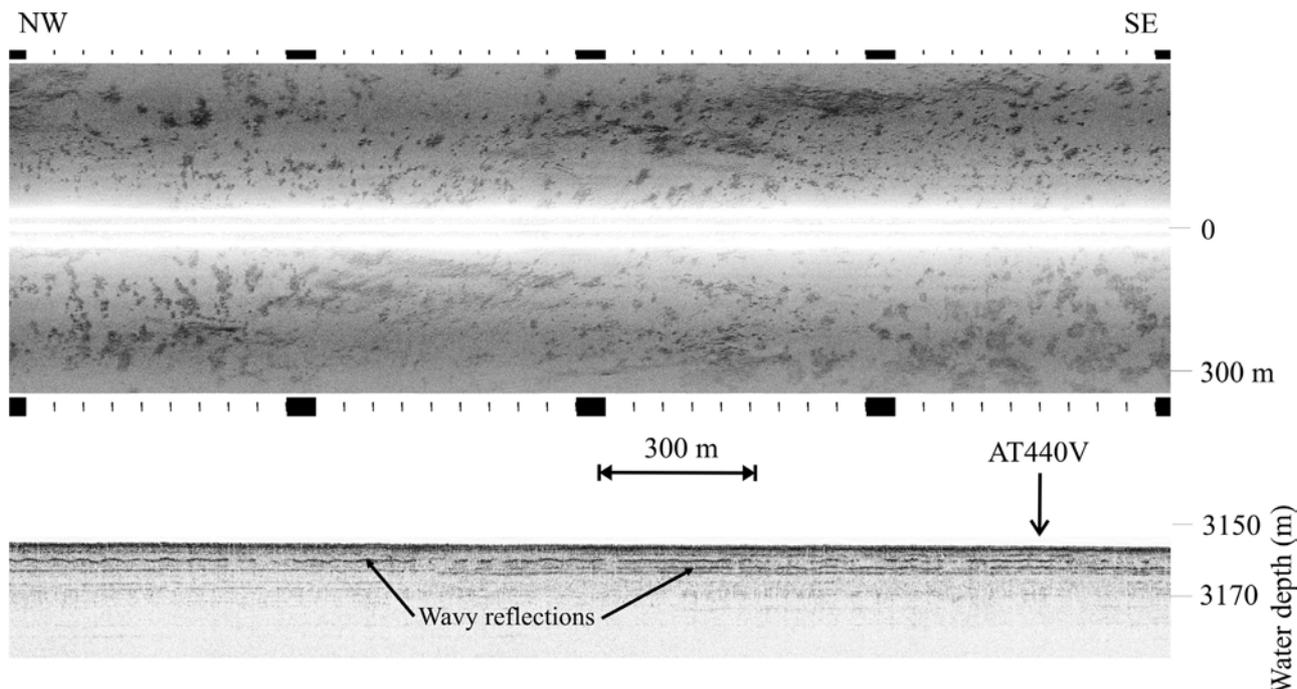


Fig.3. Part of MAK side-scan line MAKAT-81 (100 kHz) and corresponding sea-bottom profile from the depositional area in front of the channel showing seismic units up to 2 m thick. The youngest comprise fine sand. See Fig. 1 for location.

R/V Professor Logachev TTR-13		CORE AT-440V				
Location: Lofoten Basin Channel mouth sand lobe						
Latitude: 69°25,321' N	Date: 22.07.2003					
Longitude: 6°56,795' W	Recovery: 94 cm	AGE: LP - Late Pleistocene EP - Early Pleistocene H - Holocene				
Water Depth: 3205 m		SUBSAMPLING CODES: 1- Express analysis 3- Geochemistry 5- Other 2- Sedimentology 4- Palaeontology				
Depth, cm	LITHOLOGY	Age	Colour	Section	Samples	Magnetic susceptibility, SI
0	MARL: 0 - 0.2 cm. Brownish, very thin disturbed layer	5Y 5/2				
50	SAND: 0.2 - 37 cm. Grey, fine, well sorted, composed of quartz, feldspar, sponge spicules and organic fragments, water saturated. At the bottom (15-37 cm) varying in grain size to fine - medium, very well sorted and less water saturated. Between 37 - 86 cm appears as medium well sorted, less water saturated, more shell fragments. Between 59 - 86 cm non consolidated clasts of mixed sandy admixture and clayey brownish matrix are visible (2-3 cm in size), sharp lower boundary, where the sand is coarse.	5Y 4/1		1		
		5Y 4/1		2		
	CLAY: 86 - 94 cm. olive grey, stiff, with foraminifera and structureless.	5GY				

Fig. 4. Core AT-440V core log. For location, see Fig. 3.

The channel is up to 2 km wide and 20 m deep, lacking prominent levee deposits. Within the channel, an irregular relief comprising longitudinal and transverse bedforms and incisions (scour marks) indicate profound erosion by turbidity currents (Fig. 2). The location, orientation and dimensions of the erosional features suggest that they were formed by turbidity currents of varying size, smaller confined to part of the channel, larger occupied the whole channel. Further into

the basin, several subsurface reflections, most of them parallel or subparallel with the sea-floor and some wavy reflections occur. These reflections separate units up to about 2 m thick (Fig. 3). Coring and camera surveys showed that the youngest of these units comprise fine sand (Fig. 4) overlain by 20 - 30 cm of yellow-brown hemipelagic mud. A sandy system is also indicated by the lack of prominent levee deposits. This shows that sandy turbidites occur on glaciated margins. In the Lofoten Basin the upper part of the succession probably comprise stacked units of sandy turbidites separated by muddy intervals. Further ground-truthing must be undertaken in order to verify this.

Acknowledgement

We gratefully acknowledge financial support from the EUROSTRATAFORM project (EC Contract No. EVK3-CT-2002-00079) and SEABED (NHT-B44-VK09546-00) and we recognize the great help provided by the R/V *Professor Logachev* master, crew and technicians during Leg 1 of TTR-13.

References

- Dowdeswell, J.A., Kenyon, N.H., Elverhøi, A., Laberg, J.S., Hollender, F.-J., Mienert, J. & Siegert, M.J., 1996. Large-scale sedimentation on the glacier-influenced Polar North Atlantic margins: long-range side-scan sonar evidence. *Geophys. Res. Lett.*, **23**, 3535-3538.
- Taylor, J., Dowdeswell, J.A. & Siegert, M.J., 2002. Late Weichselian depositional processes, fluxes, and sediment volumes on the margins of the Norwegian Sea (62-75°N). *Marine Geology*, **188**, 61-77.
- Vorren, T.O., Laberg, J.S., Blaume, F., Dowdeswell, J.A., Kenyon, N.H., Mienert, J., Rumohr, J. & Werner, F., 1998. The Norwegian-Greenland Sea continental margins: morphology and late Quaternary sedimentary processes and environment. *Quater. Sci. Rev.*, **17**, 273-302.

SEDIMENTARY FEATURES OF THE DISTAL ANDØYA SLIDE

J.S. Laberg¹, T.O. Vorren¹, N.H. Kenyon², M. Ivanov³ & E.S. Andersen⁴

¹ Department of Geology, University of Tromsø, N-9037 Tromsø, Norway, jan.laberg@ig.uit.no

² Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH, UK

³ UNESCO Centre for Marine Geology and Geophysics, Moscow State University, Moscow 119899, Russia

⁴ Norsk Hydro ASA, N-0246 Oslo, Norway

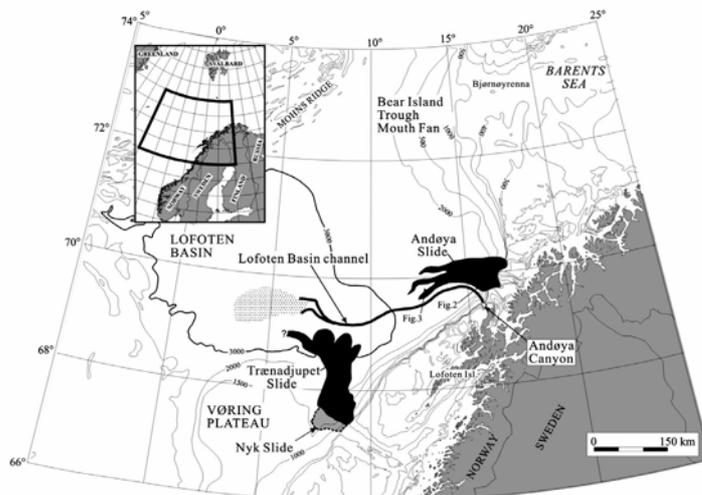


Fig.1. Bathymetric map covering the north-eastern Norwegian-Greenland Sea. The Andøya, Trænadjupet and Nyk submarine slides, the Andøya Canyon, the Lofoten Basin channel and the Bear Island Trough Mouth Fan are shown. Figs. 2 and 3 are indicated.

At the base of the continental slope the sea floor is irregular and dominated by blocks of consolidated sediments (Fig. 2). The blocks may have been transported downslope by large debris flows or rock fall. Further into the basin the slide deposits include three large debris flows, the largest up to 15 m thick and 30 km across. Small-scale surface irregularities correspond to blocks of consolidated sediments (Fig. 3). Individual blocks are up to 50 m across and raise some meters above the surrounding sea floor. Their presence witness incomplete remoulding and sediment disintegration even in the most distal part of the debris flow. Truncation of an underlying unit with parallel reflections indicates basal erosion. The age of the debris flows is not known, but the mud drape seem to be of similar thickness on the three debris flow de-

Several large submarine landslides have been identified on the continental slope of Norway (Kenyon 1987; Vorren *et al.*, 1998; Dowdeswell *et al.*, 2002).

The Andøya Slide was studied during the TTR-13 (2003) cruise of R/V *Professor Logachev*. This slide covers an area of about 9,700 km² and its run-out distance has been estimated to about 190 km (Laberg *et al.*, 2000) (Fig. 1). Using deep-towed high-resolution side-scan sonar (30 and 100 kHz) together with sub-bottom profiling and coring we focused on the distal sediments of the slide at 2200 - 2700 m water depth.

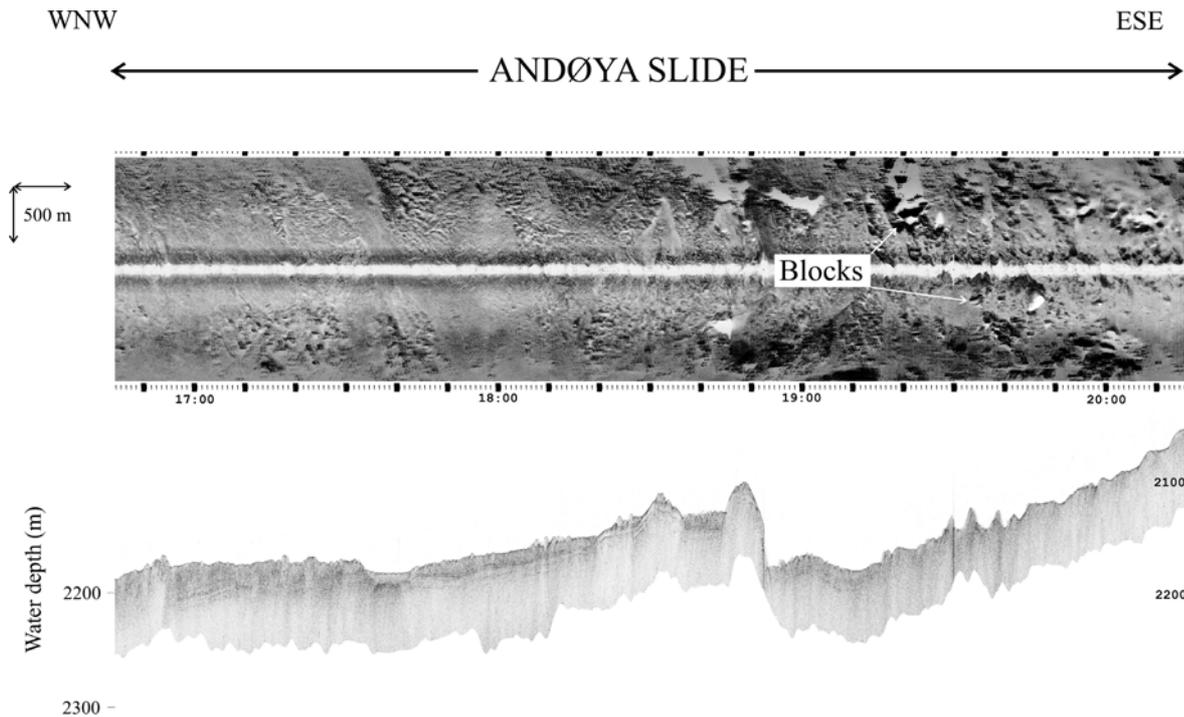


Fig.2. Part of MAK side-scan line MAKAT-84 (30 kHz) and corresponding sea-bottom profile (5 kHz) showing the blocky sea floor characterising the Andøya Slide deposits at the base of the continental slope. See Fig. 1 for location.

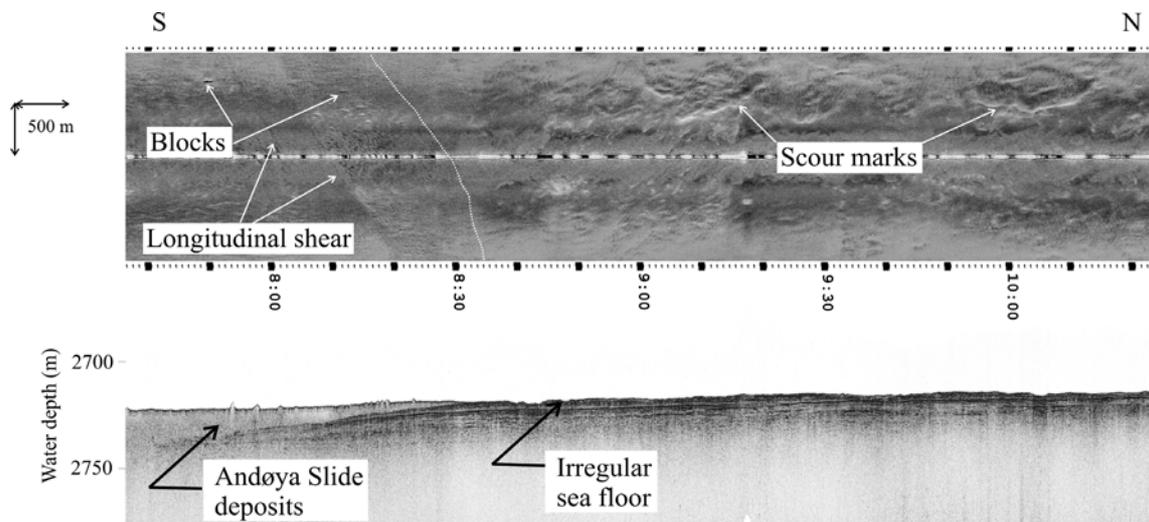


Fig.3. Part of MAK side-scan line MAKAT-82 (30 kHz) and corresponding sea-bottom profile from the most distal slide deposits. Here small-scale surface irregularities of the slide deposits correspond to blocks of consolidated sediments. In the area north of the deposits, an irregular surface relief is due to the presence of scour marks caused by turbidity current erosion. See Fig. 1 for location.

posits, about 30 – 40 cm, indicating a late glacial or early Holocene age.

In the areas between the debris flows, an irregular surface relief and underlying irregular sub-surface reflections, indicates several episodes of erosion. The youngest erosional features include scour marks (Fig. 3). The largest, about 1 km across and some meters deep are of the largest reported from the modern ocean. Erosion by turbidity currents is the most likely explanation. The relationship between the debris flows and turbidity currents is so far not established. As indicated by the sub-bottom profiles, the area have probably been affected by several episodes of turbidity current erosion showing that this process has been an

important sediment transport agent into the deep sea. This implies that sediments released from the Andøya Slide scar may have been transported far beyond the distal debris lobes.

Acknowledgement

We gratefully acknowledge financial support from the EUROSTRATAFORM project (EC Contract No. EVK3-CT-2002-00079) and SEABED (NHT-B44-VK09546-00) and we recognize the great help provided by the R/V *Professor Logachev* master, crew and technicians during Leg 1 of TTR-13.

References

- Dowdeswell, J.A., Ó Cofaigh, C., Taylor, J., Kenyon, N.H., Mienert, J. & Wilken, M., 2002. On the architecture of high-latitude continental margins: the influence of ice-sheet and sea-ice processes in the Polar North Atlantic. - In: Dowdeswell, J.A. & Ó Cofaigh, C. (eds). *Glacier-influenced sedimentation on high-latitude continental margins*. Geological Society, London, Special Publications, **203**, 33-54.
- Kenyon, N., 1987. Mass-wasting features on the continental slope of northwest Europe. *Mar. Geol.*, **74**, 57-77.
- Laberg, J.S., Vorren, T.O., Dowdeswell, J.A., Kenyon, N.H. & Taylor, J., 2000. The Andøya Slide and the Andøya Canyon, north-eastern Norwegian-Greenland Sea. *Marine Geology*, **162**, 259-275.
- Vorren, T.O., Laberg, J.S., Blaume, F., Dowdeswell, J.A., Kenyon, N., Mienert, J., Rumohr, J. & Werner, F., 1998. The Norwegian-Greenland Sea continental margins: morphology and late Quaternary sedimentary processes and environment. *Quater. Sci. Rev.*, **17**, 273-302.

THE UNIQUE CHARACTER OF SUBMARINE VOLCANISM: MARSILI AND PALINURO SEAMOUNTS, TYRRHENIAN SEA

M.P. Marani, F. Gamberi, D. Penitenti & TTR-12 Cruise participants

Istituto di Scienze Marine - Sezione Geologia Marina Bologna, Via Gobetti 101, 40129 Bologna, michael.marani@bo.ismar.cnr.it

Submarine basaltic volcanic landforms have been shown to result, in part, from processes that are those commonly observed in similar terrestrial volcanic settings. All land-based lava flow morphologies have been recognised in the marine environment while the products of the range of pyroclastic eruption styles have been documented; even from the deep ocean (>3000 metres water depth).

However, submarine conditions dictate the development of unique basalt lava flow morphologies and landforms that are absent from terrestrial counterparts. In essence, these are represented by ubiquitous pillow or tube lavas forming hummocks or ridges, and observations in practically all submarine geological settings of very low aspect ratio flat top volcanic seamounts. These differences are in part explained by the faster cooling rates and greater pressure ranges of the marine ambient, considering all other parameters, particularly general magma composition, unchanged.

In the TTR-12 cruise (August 2002), the distinguishing characteristics of submarine volcanism were targeted in the southern Tyrrhenian on the Marsili seamount with very high-resolution surveys. The objectives were to identify the most volcanically and tectonically active portions of the 3000-m high, 65-km long volcano in order to understand the mechanisms that have governed the growth of the edifice. Nine SSS lines were acquired over the elongated volcano, obtaining a continuous sonar image mosaic of the south-eastern and northern portions of the seamount. The mosaic revealed the generally low backscatter sedimented nature of the south-eastern portion, site of volcanoclastic sediment mobility in the form of gravity-driven sediment flows and landslides. This contrasts with the northern part of Marsili seamount, where volcanism and tectonics, in the form of lava terraces, small seamounts and fault scarps, govern the present-day makeup of the volcano. In the summit area, the detailed SSS images of fissure-controlled elongated cone ridges show them characterised by single central eruptive centres; the volcanic cones and lava terraces on the northern flank of the volcano, on the other hand, have circular bases and flat tops, some with craters and others displaying a summit dome. TV-runs were performed in the summit area at ~500/700 metres water depth and on a flat topped volcano at ~2600 metres water depth.

An outstanding discovery during the camera run in the summit portion of Marsili volcano was an extensive field of hydrothermal chimneys. Two styles of chimney generation seem to indicate a waning of fluid temperatures. This is represented by tall (1–2 metres), consolidated extinct structures, in all probability generated by high temperature base metal sulphide precipitation, interspersed by smaller, active and soft low-temperature Fe-oxyhydroxide constructs.

High temperature sediment-hosted hydrothermal deposits consisting of Cu, Zn and Pb sulphides were known to occur also in the western portion of Palinuro volcano; in particular one of the domes that surround a depressed area corresponding to a collapse caldera.

A SSS line was run over the dome in order to gain outcrop information and to plan a TV-run across the feature. The SSS data show the dome having two high backscatter ~ 700m deep summit areas separated by a smaller depression. High backscatter characterises the outcropping lava flanks of the dome. The TV-run identified numerous areas of hydrothermal precipitates in the form of chimneys and fractures and extensive outcrops of pillow lavas. The location of hydrothermal activity is situated on and seems to be controlled by the presence of similarly oriented small scarps. As observed on Marsili volcano, the chimneys have two distinct characters: numerous are robust, high-standing (and fallen) structures which seem to be extinct, others are lower chimneys or patches of actively forming Fe-oxyhydroxide and, in only the Palinuro case, Mn precipitates.

An additional find was that the population density of benthic biota in the muddy seafloor dramatically increased in certain areas which, when cored, were characterised by a thin cover of recent muddy sediment overlying a clayey, extensively altered substratum, probably related to the diffuse flow of low temperature hydrothermal fluids.

FEATURES RELATED TO MUD DIAPIRISM IN THE NORWEGIAN SEA

I. Mardanian¹, M. Ivanov¹, T. Nielsen², A. Kuijpers², T. van Weering³, T. Richter³ & N. E. Poulsen²

¹ UNESCO-MSU Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevi Gori, Moscow 119899, Russia, imard@nm.ru

² Geological Survey of Denmark and Greenland, Øster Voldgade 10, DK1350 Copenhagen K, Denmark

³ Netherlands Institute for Sea Researches, Den Burg, Texel, the Netherlands

Positive structures related to mud diapir fields in the different parts of the Norwegian Sea (the Vøring Plateau, the Bear Island fan and the continuation of the Fugloy Ridge) were studied during the TTR-8, TTR-12, TTR-13 cruises using a set of geophysical and geological methods.

Single-channel seismic lines on the Fugloy Ridge area showed acoustic basement formed by dome-like structure. This structure, built up of basalts, is overlaid by five seismic units presenting sediments of the Eocene-Holocene age. Diapiric structures characterized by chaotic internal reflections were observed within a sedimentary succession, some of them are exposed on the sea floor (Nielsen *et al.*, 2002). Side-scan sonograms show piercing diapirs as isometric patches with high and medium backscatter. Two gravity cores and a dredge obtained during the TTR-12 cruise revealed mud diapirs formed by the Miocene diatom ooze. Piston core STRAT01-06 obtained in 2001 onboard the R/V *Pelagia* showed the 4.8-m interval of the diatom ooze overlaying by the 2.5-m hemipelagic succession.

Diapirs on the Vøring Plateau within the Vema, the Vivian and the Vigrid diapir fields were reported by several researches (Hjelstuen *et al.*, 1997, Hovland *et al.*, 1998). Diapir ridges, isometric groups of diapirs and individual structures were observed above the Vema Dome according to seismic, side-scan sonar and subbottom profiler data obtained during the TTR-8 cruise. Single-channel seismic line carried out within the Vigrid field in 2003 showed a group of mounds with strong reflector beneath at the depth of 150 meters. Seismic survey within the Vivian diapir field revealed seabed high with gentle slopes. Buried positive structure was observed under the north-eastern flank of the high.

During the TTR-8 cruise several diapir structures were observed on the southern part of the Vøring Plateau, one of the cones formed by stiff silty clays showed presence of gas (Kozlova, 1998). Diapirs within the Bear Island fan slide valley were reported by Vogt (1999). Geophysical and geological survey of the area

was carried out in 1998 during the TTR-8 cruise. Bottom sampling of two diapiric structures using gravity corer recovered 40 cm of consolidated mud with abundant sand and gravel.

Different types of diapirs in the Norwegian basin were observed. The first one is presented by diapirs from the Norwegian and Faroe margins, structures reach 150 m high and are formed by biosiliceous material. The most probable cause for such diapir development was plastic water-saturated ooze accumulations covered by more dense sediments. The second type of diapirs was observed in the Bear Island fan area, where individual structures are formed of protruded consolidated mud. A diapir located in the southern part of the Vøring Plateau showing presence of gas in the silty clayey sediments could be referred to the third type of the studied structures.

References

- Hjelstuen, B.O., Eldholm, O. & Skogseid J., 1997. Vøring Plateau diapir fields and their structural and depositional settings. *Marine Geology*, **144** (1–3), 33–57.
- Hovland, M., Nygaard, E. & Thorbjørnsen S., 1998. Piercement shale diapirism in the deep-water Vema Dome area, Vøring basin, offshore Norway. *Marine and Petroleum Geology*, **15** (3), 191–201.
- Kozlova, E., Stadnitskaya, A. & Egorov, A., 1999. Distribution and composition of hydrocarbon gas in the gas-saturated seabed sediments of the Vøring Plateau and Bear Island (North-East Atlantic). North-East Atlantic slope processes: Multi-disciplinary approaches incorporating TTR-8 post-cruise conference, 4th ENAM II workshop, IGCP workshop 432. 24-27 January 1999, Southampton Oceanography Centre, UK, Programme and Abstracts, 49.
- Nielsen, T., Kuijpers, A. & Ivanov, M., 2002. Mapping and sampling diapirs and mass flows on the eastern Faeroe margin. Results from cruise TTR12, Leg 1. Geological Survey of Denmark and Greenland. Report 2002/75, 1-23.
- Vogt, P.R., Crane, K., Sundvor, E., Hjelstuen, B.O., Gardner, J., Bowles, F. & Cherkashev, G., 1999. Ground-Truthing 11- to 12-kHz side-scan sonar imagery in the Norwegian-Greenland Sea: Part II: Probable diapirs on the Bear Island fan slide valley margins and the Vøring Plateau. *Geo-Marine Letters*, **19**, 1/2 (8), 111–130.

CARBONATE MOUNDS AND CARBONATE-PHOSPHATE DEPOSITS IN THE PORCUPINE BANK

A. Mazzini¹, E. Bileva², M. Ivanov², X. Monteys³, J. Parnell¹ & B. T. Cronin¹

¹ Department of Geology and Petroleum Geology, University of Aberdeen, Meston Building, King's College, Aberdeen AB24 3UE, Scotland, UK, a.mazzini@abdn.ac.uk

² UNESCO-MSU Center for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevy Gory, 119899 Moscow, Russia, fu@geol.msu.ru

³ GSI Seabed Survey, 7 Dundrum, Business Park, Windy Arbour, Dublin 14, Ireland, xavier.monteys@dcmnr.gov.ie

A head of a large canyon system developing on the western Porcupine Bank (west of Ireland) was investigated with acoustic and sampling techniques during the TTR-13 marine expedition. A large cluster of seabed carbonate mounds discovered here earlier during the national multibeam survey conducted by GSI (Ireland) was the main target of the study. Side-scan sonar records and bottom sampling revealed details of these mounds, where biogenic rubble, coral colonies and carbonate deposits were recovered.

Different types of carbonate deposits were retrieved from the escarpment on the eastern part of the study area and from carbonate mound features. All the crusts were colonised on their external surface by sponges and worms. Macroscopic and microscopic observations show three distinct types of carbonate deposits with different degrees of lithification and mineralogical composition.

The *first* type, retrieved from the escarpment area and from carbonate mounds, consists of irregularly shaped blocks of cemented foraminiferal ooze showing a porous and burrowed texture. This carbonate can be well cemented (with high content of Mg calcite) or semilithified containing cemented biodegraded coral debris. The texture can be biologically related, or associated with phases of aragonite dissolution of the corals. Among the samples retrieved, this type is likely to be the most recent carbonate deposit that forms in

the region where foraminiferal ooze and coral branches are cemented directly on the sea floor using seawater- and bioclast-derived carbon.

The *second* type consists of irregularly shaped blocks of dolomite collected from the escarpment area. Thin section petrography shows the presence of microfossil ghost features, suggesting possible recementation of ancient carbonate deposits now exposed on the seafloor.

The *third* type, collected from the escarpment area, form extensive slabs of well cemented hemipelagic sediment and bioclasts. Mineralogically it contains mostly calcite and a high content of apatite and glauconite crystals. The texture, the petrography and the characteristics of this type of carbonate suggest the presence of hard ground deposit consisting of rounded nodules of micritic and apatitic cement mixed with clays. The cross-cutting relationships between the different nodules indicate that they formed directly on the sea floor or that localised reworking occurred prior to new cementation. Well preserved microfossils suggest that cementation occurred close to the surface, whilst nodules that show evidence of local transportation include more fragmented fossils. It is likely that this deposit formed under a low sedimentation rate in order to be glauconitized and phosphoritized. Strong currents flushing the escarpment area are likely to cause the erosion of the hemipelagic capping sediment, exposing the described hard ground to the sea floor.

Samples retrieved showed that these carbonate deposits, and in particular the *first* type described, act as a hard substratum for the growth of coral colonies where drop stones or outcropping rocks are not present. The *third* carbonate type described could be a potential hard substratum for the growth of new coral colonies in the escarpment area, but this has not yet been observed.

Stable isotope data show no evidence of methane-derived carbon in the carbonates and in the lithified sediments analysed. Therefore the suggested association of coral reef, carbonate deposits and methane seepages remains unproven in this case.

GIANT CARBONATE MOUNDS ON THE WEST PORCUPINE BANK, IRISH MARGIN, NE ATLANTIC: MORPHOLOGY AND DISTRIBUTION

X. Monteys

Irish National Seabed Survey, Geological Survey of Ireland, Beggars Bush, Haddington Road, Dublin 4, xavier.monteys@gsi.ie

During the TTR 13 cruise on board the R/V *Professor Logachev* several side-scan sonar lines (MAK II - 30 kHz) were obtained on the west Porcupine Bank, at the continental shelf break. This is an area dominated by a cluster of giant carbonate mounds limited eastwards by a N/S fault scarp and to the west by the steep edge of the canyon. The large carbonate mounds occur between 700-1100 m water depth. They are up to 150 m high, 800 m wide and 2 km long. The influence of hydrodynamic processes particular to banks and seamounts seem to have an important role in carbonate mound growth and distribution. Abundance evidence was found of strong bottom current regime in the study area.

This study presents preliminary results from side-scan sonar backscatter, combined with high resolution multibeam data acquired in 2000 during the Irish National Seabed Survey.

The cores collected by the *Logachev* cruise were acquired in an area that is relatively sheltered from bottom current action, and no evidence of sediment reworking is recorded. These cores therefore represent an excellent stratigraphic record for biostratigraphic and climatic analyses. A preliminary study suggests that this sedimentary record can be correlated across the canyon to the smooth section of the slope. This correlation provides a useful aid in placing the deposits north of the canyon into a climatic framework. This together with high-resolution bathymetry can improve the understanding of how the bottom current circulation varied with time and space.

THE FAEROE MARGIN: PLIOCENE-QUATERNARY SLOPE INSTABILITY ON THE WESTERN FLANK OF THE FAEROE-SHETLAND CHANNEL*

T. Nielsen¹, A. Kuijpers¹, A. Mathiesen¹, S. J. Lassen¹, STRATAGEM WP2 Partners &
TTR Shipboard Scientific Parties (TTR8, 9, 12)

¹ Geological Survey of Denmark and Greenland, Øster Voldgade 10, DK1350 Copenhagen K, Denmark, tni@geus.dk, aku@geus.dk, anm@geus.dk, sl@geus.dk

Recent studies have provided evidence for slope instability and mass flow processes having contributed to shape the western slope of the Faeroe-Shetland Channel throughout Pliocene-Quaternary times. This conclusion is based on the results from the EU-funded STRATAGEM project and supplied with data from commercially-supported (Faeroes offshore consortium GEM/FOIB) work that was carried out within the framework of the international TTR programme.

The mass flow deposits can be subdivided in buried deposits of late Pliocene to early Pleistocene age, and surficial deposits with an age from early Pleistocene to early Holocene.

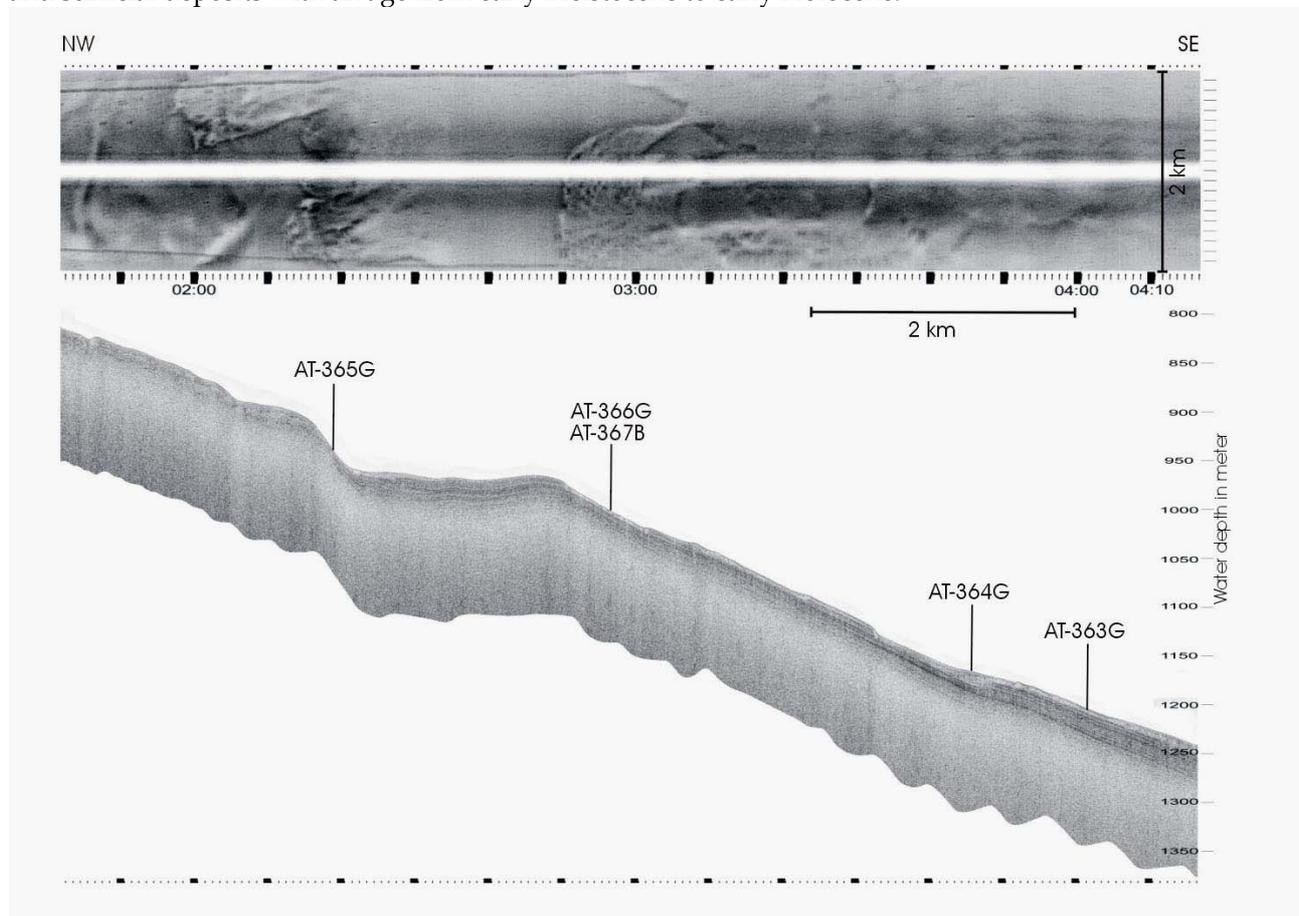


Fig.1. Part of deep-towed side-scan profile MAK-AT49 crossing the GEM Raft at the eastern Faroese slope. Also shown are the sampling sites AT-363 to AT-367 (TTR-12 cruise, 2002)

Conclusions

- The known mass-wasting deposits in the Faeroe-Shetland Channel area are found within the seismic FSN-1 megasequence, and thus yield evidence of recurrent slope instability since late Pliocene time.
- The mass-wasting deposits can be subdivided in buried deposits of late Pliocene to early Pleistocene age, and surficial deposits with an age ranging from the later part of the early Pleistocene to the Holocene.

* Presented first time at the Ocean Margin Research Conference, Paris, September 15th-17th, 2003

- A 'dividing line', which part the Faeroe-Shetland Channel into a southern and northern region, is found to mark a difference in the type and style of mass-wasting features observed within the two areas:
 - South of the dividing line mass-wasting occurred as debris flow processes, and the bathymetric setting is characterised by shallower channel depth, shallower depth of shelf break and less steep slopes.
 - North of the dividing line mass-wasting occurred as sliding and slumping processes (see Fig.1), and the channel deepens and broadens, the depth of shelf break increases and the slope, especially on the east Faeroe margin, steepens considerably.
- The mass failures on the slopes of the Faeroe-Shetland Channel are not caused by one forcing mechanism in isolation, but are a combination of:
 - Differential subsidence, causing sliding and slumping in the area north of the dividing line
 - Different sedimentary setting, with glacial debris flows to develop south of the dividing line and instability of contourite deposits north of the line.
 - Neo-tectonic activity like growth of anticlinal features and re-activation of deeper-lying transfer zones might play an important role in the slope instability north of the dividing line.
 - Changes in sea level and ocean circulation patterns during glacial/interglacial climate change resulted in Late Quaternary slope instability on the Faeroe margins.
- No evidence was found for any major mass-wasting activity having occurred after ending of the fast, early Holocene sea level rise, i.e. during the past c. 7000 years the Faeroe margin appears to have generally been stable.

GEOLOGICAL EVIDENCE OF VOLCANIC ORIGIN OF THE SEAMOUNTS ON THE WESTERN AND SOUTH-WESTERN GREENLAND MARGIN

A. Ovsyannikov¹ & T. Nielsen²

¹ UNESCO-MSU Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevi Gori, Moscow 119899, Russia, fu@geol.msu.ru

² Geological Survey of Denmark and Greenland, Thoravej 8, DK2400, Copenhagen NV, Denmark, tri@geus.dk

One of the aims of investigations on the Western and Southwestern Greenland margin during Legs 3 and 4 of the TTR-13 cruise was to study seamounts that were first discovered based on bathymetric and seismic data held at GEUS. The seamounts, which are raising up to 500 m above the surrounding seafloor, are found along the margin of the Labrador Sea. Several hypothesis of the nature of the seamounts were suggested: diapiric origin (clay or serpentinite), volcanic origin (basalts) or rising of basement blocks.

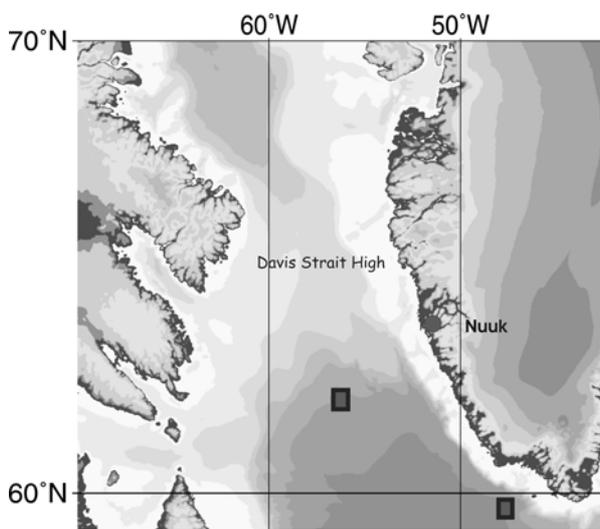


Fig.1 Location map of seamounts, the Labrador Sea

Two of the seamounts were chosen for detailed studies, both situated at the foot of the slope at the central northern and western Labrador Sea margins, respectively (fig. 1). A set of instruments, including single channel seismic, long-range and deep-towed side-scan sonars, acoustic profilers, digital underwater TV and dredging were applied for this investigations. According to the obtained seismic and side-scan sonar data the seamounts have a complex structure and consist of a plateau with up-sticking cones on the top. As a result of the bottom sampling, approximately 150 fragments of rocks were retrieved. Each fragment was classified and the roundness and the size were described (Korost *et al.*, this volume). Volcanic rocks proved to represent the main part of the samples and, moreover, they were characterized by the worse roundness.

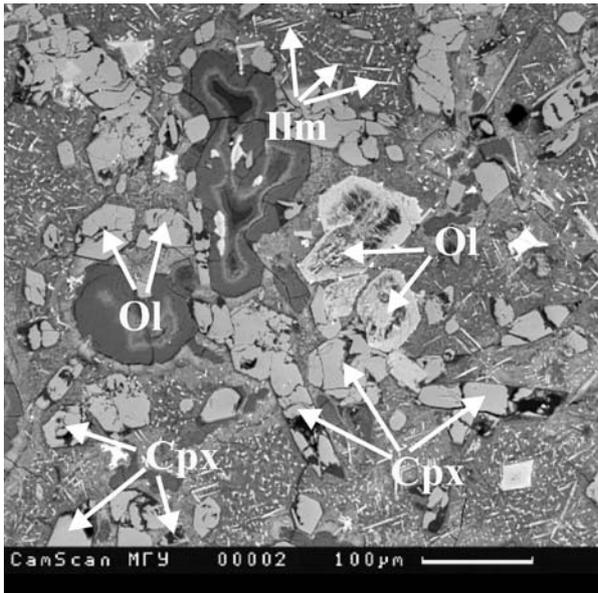


Fig. 2. Example of back-scattered electron image

Post-cruise laboratory studies of the rock fragments comprised microscopical description, microprobe and geochemical analyses. Thin sections from selected samples were prepared at Moscow State University. Thin sections showed that all fragments of volcanic rocks have the same mineralogical composition and structure. They consist mostly of pyroxene (Cpx) and olivine (Ol) in the highly altered volcanic glass. A detailed study of minerals showed, that pyroxene is represented by titanite. A large amount of ilmenite (Ilm) was also observed in the groundmass (fig. 2). Microprobe data showed that studied rocks in the ground-mass also contain feldspar. According to geochemical analyses, content of SiO₂ in the rocks is less than 40%, TiO₂ is about 3%, Na₂O and K₂O are approximately 1,5%.

Geochemical analyses showed that the rocks are high-alkaline.

The results of the analyses suggest that all investigated fragments of volcanic rocks are represented by picrites (high-alkaline rocks). Picrites are known on the Western Greenland margin. Dam & Nøhr-Hansen (2001) divided volcanic activity of this region into two phases. The first phase was dominated by extrusion of olivine-rich basalts and picrites. The picrites volcanism is related to the mantle plume that took place in the area in the Late Maastrichtian-Early Paleocene (Nielsen *et al.*, 2002). It can be supposed, that the studied seamounts on the Western and South-western Greenland margin are the result of the first phase of volcanic activity of the mantle plume.

References

- Dam, G. & Nøhr-Hansen, H., 2001. Mantle plume and sequence stratigraphy; Late Maastrichtian-Early Paleocene of West Greenland. *Bulletin of the Geological Society of Denmark*, **48**, 189-207.
- Korost, D.V. *et al.*, 2004. Principle results of hard rock sampling on the Greenland margin and way of interpretation of these data. This volume, p. 24.
- Nielsen, T.K., Larsen, H. C. & Hopper, R. J., 2002. Contrasting rifted margin styles south of Greenland: implication for mantle plume dynamics. Danish lithosphere centre. Elsevier Science B.V., 271-286.

EFFECT OF MUD VOLCANO ACTIVITY ON BIODIVERSITY AT SHALLOW TO DEEP WATER MUD VOLCANOES AT THE MOROCCAN ATLANTIC SLOPE AND IN THE GULF OF CADIZ

A. Pannemans¹, M. Cunha², P. van Rensbergen¹, E. Bileva³, J.-P. Henriët¹, M. Ivanov³,
L. Pinheiro⁴ & S. van Gaever⁵

¹ Renard Centre of Marine Geology, University of Ghent, Belgium, pieter_vanrensbergen@yahoo.com

² Departamento de Biologia, Universidade de Aveiro, 3810-193 Aveiro, Portugal, mcunha@bio.ua.pt

³ UNESCO-MSU Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevi Gori, Moscow 119899, Russia, fu@geol.msu.ru

⁴ Departamento de Geociências, Universidade de Aveiro, Campus de Santiago, 3810-193-Aveiro, Portugal, Imp@geo.ua.pt

⁵ Biology department, University of Ghent, Belgium

The Al Arraiche mud volcano field at the Moroccan Atlantic slope (200 m – 700 m water depth), and a deep water mud volcano field (1000 m – 1200 m water depth) in the Portuguese sector of the Gulf of Cadiz, have been investigated using side-scan sonar, multibeam, video imagery, TV-guided grab, dredge and coring. At five mud volcanoes (Al Idrissi, Mercator, Gemini, Aveiro, and Captain Arutnyov) biodiversity was studied in relation to environmental factors.

This study illustrated that the occurrence of mud volcanoes on the continental slope creates new habitats and add to biodiversity. The study yielded the following results:

- The thickness of hemipelagic drape overlying mud breccias showed that all mud volcanoes have been active in the last 1600 years.
- Video imagery observations indicate an eastbound current over the Al Arraiche mud volcano field. At greater water depths this current becomes more variable.
- Faunal assemblages change with the sedimentary facies of the sea floor at each mud volcano.
- Currents influence the distribution of trophic groups over the mud volcanoes. Populations of filter feeders are more dense on the upcurrent slope. On the downcurrent slope they are replaced by deposit feeders and scavengers.
- Faunal diversity and bioturbation increases at seep sites.
- Abundances of megafauna decreases with increasing water depth.

The disturbance of the fauna by mud eruptions is small as periods inactivity are much larger than the time needed for recolonization. Seepage of fluids has a longer-lasting influence, resulting in a decrease of sessile filter feeders and burrows towards the summit of most mud volcanoes.

The data were acquired during two consecutive surveys by the R/V *Belgica* (CADIPOR cruise) and the R/V *Prof. Logachev* (TTR-12 cruise).

GEOCHEMICAL INVESTIGATION OF ORGANIC MATTER IN THE ROCKS FROM OUTCROPS (WESTERN GREENLAND MARGIN)

E. Poludetkina¹, D. Korost¹, M. Ivanov¹ & T. Nielsen²

¹ UNESCO-MSU Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevy Gory, Moscow 119899, Russia, fu@geol.msu.ru

² Geological Survey of Denmark and Greenland, Øster Voldgade 10, DK1350 Copenhagen K, Denmark, tni@geus.dk

Discovery of extensive oil seepages onshore the Nuussuaq Basin has been an important progress in documentation of West Greenland as an oil-prone area (Christiansen, 1992). Offshore West Greenland satellite investigations have been held and oil films on the water surface, considered as indices of oil seepages offshore, have been determined. Thus, one of the tasks of investigations during the 4th Leg of the TTR-13 cruise of the R/V *Professor Logachev* was concerned to searching of possible indications of hydrocarbon fluids unloading to the sea bottom and also possible investigation of source-rock formations. Unfortunately, no indications of fluid seepages have been found. During research works to the south of the

study area (western slope of the canyon dividing the Fylla structural complex and the Nuuk basin), a collection of rocks (both sedimentary and igneous) from (presumably) outcrops was gathered (TV-grab 488GR) and investigated. Geochemical investigations of sedimentary rocks embraced a set of analyses, including fluorescent analyses, bitumen extraction on Sokslet apparatus, determination of TOC content, bitumen chromatography, pyrolysis Rock-Eval and mass-spectrometry of several samples. In order to verify possible migration of oils through the igneous rocks, fluorescent analysis was done for basaltic rocks. As a result, in one of the studied basalts allochthonous bitumoid was determined.

Sedimentary samples are represented mainly by grey to dark grey high maturity limestones with different content of clayey and silty admixture, and by carbonate clays, siltstones and sandstones. The TOC content is changing in different samples from 0,1% to 7%. The richest in OM are clayey limestones and carbonate clays and silts. All the rocks contain residual syngenetic bitumoid that has mostly given its migratory part (level of OM bituminization $\beta = \text{Bitumoid A, \%} \cdot 100\% / \text{TOC, \%} < 2\%$). By the Rock-Eval data, generation potential (S_1+S_2) varies from 0.29 - 0.41 kg/t_{rock}, PI = 0.31 - 0.38 that states that rocks are practically out of the oil window and oil potential is practically used. One black clayey limestone was got in the grab. It has PI = 0.1, $S_1+S_2 = 14$ kg/t_{rock} that attest to a lower maturation (beginning of the oil window) of bitumoid. Analyses of the basalt sample AT-488GR-12 revealed its bitumoid to be allochthonous ($\beta \rightarrow 100\%$), probably migrated from the underlying sedimentary sequence.

Bitumen from limestones AT-488GR-4 (typical for the canyon deposits), AT-488GR-18 (black limestone) and a piece of basalt from AT-488GR-12 have been examined by bitumen chromatography and mass-spectrometry. Pr/n-C₁₇ and Ph/n-C₁₈ diagram shows that the studied samples occur in the field of mixed type of OM precipitated with the influence of demolition of terrigenous material from the continent.

Chromatographic analysis of the fractions showed that bitumen of basalt and grey limestone samples have many similarities: n-alkanes are present in the range between n-C₁₃ (n-C₁₆) and n-C₃₆, the amount of naphthenes is low. The Pr/Ph ratio is respectively 0,8 and 0,5, proving marine reducing conditions of sedimentation. The samples display mono-modal distribution of n-alkanes with maxim at C₂₆ (C₂₉) as well as the presence of a small hump in the high molecular weight region. Based on mass-spectrometry indexes (C₂₉ $\beta\beta\alpha$ is 0,61 and 0,65 respectively; C₂₉S/R is 1,05 and 0,99; C₂₉ $\beta\beta/\alpha$ is 1,57 and 1,82) we can propose that these samples have high level of maturity (the central part of the oil window).

Bitumoid of the black limestone is characterised by biodegradation activity (partially biodegraded). N-alkanes are present in the range between n-C₁₆ and n-C₃₅; the sample displays mono-modal distribution of n-alkanes with maxim at C₂₉ as well as the presence of a small hump in a high molecular weight region. The Pr/Ph ratio is 0,6; Ki=1,93. Mass-spectrometry indexes (C₂₉ $\beta\beta\alpha$ is 0,66, C₂₉S/R - 1,21; C₂₉ $\beta\beta/\alpha$ - 1,94) prove that the sample has a high level of maturity (the central part of the oil window) in influence of biodegradation.

As a result of geochemical investigations we can assume that the studied clayey limestones could have been good source rocks in the region offshore West Greenland. Their oil generating potential is mostly realised by present days that is proved by presence of residual bitumen in the source rocks. Thus, in the region where these deposits are overlain by the sedimentary sequence we can suppose a presence of hydrocarbon fields. Therefore, the studied region can be considered as an oil-potential basin.

References

- Christiansen, F. G., Dam, G. *et al.*, 1992. Renewed petroleum geological studies onshore West Greenland: Rapport Grønlands Geologiske Undersøgelse, **155**, 31-35
- Chalmers, J.A., Christiansen, F.G., Bojesen-Koefoed *et al.*, 2001. Offshore West Greenland: Basin geology, petroleum potential and exploration activity. Abstracts of St. John's meeting, Newfoundland.
- Skaarup, N., Chalmers, J. A. & White, D., 2000. An AVO study of a possible new hydrocarbon play, offshore Central West Greenland. *AAPG Bulletin*, **84**, 174-182

DEPOSITIONAL ENVIRONMENT OF THE NORTHERN PART OF THE DAVIS STRAIT HIGH AREA REVEALED FROM LITHOLOGY OF TWO CORES COLLECTED DURING THE TTR-13 CRUISE

E.S. Sarantsev

UNESCO-MSU Centre for Marine Geology and Geophysics, Faculty of Geology, Moscow State University, Vorobjevi Gori, Moscow 119899, Russia, fu@geol.msu.ru

An important objective of Leg 4 of the TTR-13 cruise was to study depositional environment and processes within the Davis Strait High area.

The Davis Strait (maximum depths - 800 m) is located between the Labrador Sea and the Baffin Bay and connected to the Arctic Ocean through the Smith, Jones and Lancaster sounds.

Quaternary sediments in the Davis Strait are believed to be originated from the Baffin, Devon, Ellesmere and other adjacent Canadian islands, and from the Western Greenland. Transport and sedimentation mechanisms for the sediments include turbidity and contour currents, sedimentation from suspensions, and meltout from icebergs. The surface sediments in this area consist predominantly of hemipelagic deposits mixed with varying proportions of ice-rafted debris (IRD). The sub-surface deposits largely include ice-rafted sediments, debrites, and turbidites, indicating a strong influence by glacial erosion from the nearby ice-sheets, glaciomarine transportation, and outwash deposition (Srivastava S.P. *et al.*, 1989).

Two cores were retrieved in the northern part of the Davis Strait High area during Leg 4 of the TTR-13 cruise. Visual description showed that core TTR13-AT462G recovered in the western part of the area consisted dominantly of hemipelagic sediments with IRD units. A core recovered in the eastern part of the area (site TTR13-AT464V) almost entirely consisted of a well-sorted succession of sand and pebbles, characterised by grading. In a comparison to core TTR13-AT462G considered as typical for the area, the core TTR13-AT464V looked very unusual showing characteristics of a proximal turbidite, which hardly can be explained at such a distance from a source on land.

Main characteristics of the sediments of both cores were determined and compared to understand the origin of this unusual units recovered in the core TTR13-AT464V. Detailed visual descriptions, magnetic susceptibility measurements, granulometric investigation and thin section study were applied.

Each core was sub-sampled at a 10-cm interval for further studies. As a result, curves for grain-size distribution, median diameter, magnetic susceptibility and lithoclast distribution were plotted and analysed. It allowed to distinguish several units with particular set of characteristics for the cores.

The core TTR13-AT462G was found to consist of five main intervals with interbedded hemipelagic and ice-rafted material. Units of mainly clayey hemipelagic sediments are characterised by the absence of pebble constituent on the grain-size distribution curve and low values of median diameter. Uncommon dropstones are represented mostly by basalts and granites with very rare fragments of limestones. Units enriched in IRD are marked by pebble constituent increase on the grain-size distribution curve and higher values of median diameter. Among abundant dropstones of basalts and granites, clasts of limestones are of rather significant value.

In the core TTR13-AT464V three intervals were determined. Lower and middle intervals are characterised by high values of median diameter. Grain-size distribution curve showed an extreme increasing of pebble constituent in the middle unit and rather high values in the lower one. Both units are characterised by a pick of amount of limestones on the curve of the lithoclast distribution. Similarity of measured characteristics of these intervals to the ice-rafted material units of the core TTR13-AT462G allowed an interpretation of their origin as strongly affected by ice-rafting.

The uppermost interval was marked by monotone coarsening down from fine sand to gravel and the lack of limestone fragments among dropstones. It looks rather similar to coarse-grained turbidite deposits ("Lowe sequence") characteristic for upper parts of a slope (Shanmugam, 2000). A distance from continental slope does not allow to apply such interpretation to the sediments described in the studied core. Other tentative hypothesis of their origin was proposed. The author believes that the graded sequence of the core was initially deposited on a surface of a vast ice-sheet covering Greenland during Late Pleistocene (Escher *et al.*, 1976). Later, in a post-glacial period (Early Holocene) during intensive ice-sheet melting the whole sequence was "exposed" to the recent seafloor.

References

- Escher, A. & Watts, W.S., 1976. Geology of Greenland. Geol. Surv. of Greenland, Copenhagen.
- Srivastava, S.P., Arthur, M., Clement, B. *et al.*, 1989. Texture and microstructure of Neogene-Quaternary sediments, ODP sites 645 and 646, Baffin Bay and Labrador Sea. Proceedings of the Ocean Drilling Program, Scientific Results, **105**, 7–20.
- Shanmugam, G., 2000. 50 years of the turbidite paradigm (1950s–1990s): deep water processes and facies models – a critical perspective. *Marine and Petroleum Geology*, **17**, 285–342.

DISTRIBUTION AND STABLE CARBON ISOTOPIC COMPOSITION OF BIOMARKERS IN METHANE-RELATED CARBONATES AND MUD VOLCANO SEDIMENTS, THE SOROKIN TROUGH, NE BLACK SEA

A. Stadnitskaia^{1,2}, M. Baas¹, V. Blinova², T.C.E. van Weering¹, M. Ivanov² & J. Sinninghe Damsté¹

¹ Royal Netherlands Institute for Sea Research, P.O.Box 59, 1790 AB Den Burg, Texel, the Netherlands, alina@nioz.nl

² UNESCO-MSU Center for Marine Geosciences, Moscow State University, Faculty of Geology, Vorobijevi Gory, 119899 Moscow, Russia, fu@geol.msu.ru

Among various fluid flow indicators, mud volcanoes are the most spectacular ones, serving as direct evidence for upward fluid and hydrocarbon gas migration from the deep subsurface. A considerable number of mud volcanoes were discovered in the euxinic waters of the Sorokin Trough (NE Black Sea). Three of them were chosen for detailed geochemical investigations. In general, these gas-venting structures reveal rather contrasting fluid discharge features (mound morphology, presence of gas hydrates, molecular and isotopic composition of hydrocarbon gas, etc.) and expressions of the microbial life at these cold-seeps (microbial mats, methane-related carbonates). We determined the $\delta^{13}\text{C}$ of methane, molecular and stable carbon isotopic compositions of specific archaeal and bacterial lipids in four authigenic carbonates and mud volcanic deposits (mud breccia) to study the anaerobic oxidation of methane in these settings. Although the strongly ^{13}C -depleted lipids of archaea and sulphate-reducing bacteria directly indicate an incorporation of methane-derived carbon into their biomass, the lipids found in the carbonates are characterised by more depleted $\delta^{13}\text{C}$ values compared to those in the mud breccia. This isotopic difference could be explained by a different origin for the methane. This hypothesis has been confirmed by the carbon isotopic measurements of methane, which display substantial differences between the various mud volcanoes. In general, the combined data show good correlation between carbon isotopic composition of specific archaeal and bacterial lipids and $\delta^{13}\text{C}$ of methane. Implications for the methane fluxes to the water column of the Black Sea will be discussed.

FLOW TRANSFORMATION IN A CHANNELISED DEBRIS FLOW LOCATED ON THE NORTH-EASTERN ROCKALL TROUGH MARGIN

J.D. Stanford, A. Akhmetzhanov, N.H. Kenyon & D.A.V. Stow

Southampton Oceanography Centre, Southampton, SO14 3ZH, United Kingdom, jds100@soton.ac.uk

Geophysical exploration, including 3.5 kHz hull mounted profiler data, 10 kHz OKEAN imagery and 100 kHz OREtech profiles, over an area of approximately 1680 km², south of the Donegal fan, on the northeastern Rockall Trough Margin, was collected during the TTR-10 cruise in the year 2000. Interpretation of the data indicates that the predominant down-slope processes include debris flows and turbidity currents, with minor amounts of slumping. It can be postulated that “ripple fields”, observed on the side-scan sonographs, with crests parallel to the contours, are coarse-grained sediment waves, resulting from turbidity current reworking.

Gravity cores from the upper rise penetrated up to 3.14 m of a partly channelised debrite, which is shown by the geophysical data to have a maximum thickness of 8 m, and an approximate volume of

1.45 km³. The cores indicate that the main sedimentation within the area was hemipelagic, disrupted by infrequent fine-grained turbidity currents, contour currents and debris flows. The debrite is observed directly underlying Holocene hemipelagite, and comprises predominantly fine-grained mud and silts, interspersed with <25 mm clasts of micritic limestone and dolerite. The clasts most likely originate from north-west Ireland via a cross-shelf glacial trough. The terrigenous nature of the sediments suggests the debrite was a glacial event, with a date no later than 74 ka, based on nannofossil evidence from the adjacent hemipelagites. The presence of relatively undeformed mud clasts and sand nodules (held together by halos of pyrite) within the main body of the debrite suggests subordinate amounts of internal agitation of the sediments, and a cohesive debris flow regime. Grain size analysis indicates a fine-grained top and base to the flow, indicative of surface transformation and basal shear respectively. A core transecting the margin of the debrite shows little evidence of basal shear, but is underlain by a 4 cm thick, inversely graded gravel layer. It is postulated that this represents a traction carpet, formed by radial dispersive pressures. Contour currents are indicated by the winnowing of the top of the debrite, which is directly overlain by a 10 cm thick, foraminifera-rich, fine to medium grained contouritic sand. Contour currents may have been generated after the glacial to non-glacial climate transition.

It can be postulated from the geophysical data that the dynamics of the debris flow changes between the lower slope and the upper rise based upon the evidence that the flow begins to spread laterally, thins at the margins, and becomes erosive. This may be due to the interaction between the sediment waves and the base of the flow.

RECENT DEPOSITS AND DEPOSITIONAL ENVIRONMENT ON THE WEST PORCUPINE BANK, IRISH MARGIN, NE ATLANTIC

L.K. Øvrebø¹ & X. Monteys²

¹Department of Geology, University College Dublin, Belfield, Dublin 4, lana.ovrebo@ucd.ie

²Irish National Seabed Survey, Geological Survey of Ireland, Beggars Bush, Haddington Road, Dublin 4, Ireland, xavier.monteys@gsi.ie

During the TTR-13 cruise on board the R/V *Professor Logachev* several gravity cores were taken on the west Porcupine Bank, south of the Porcupine Bank Canyon, at the continental shelf break. This is an area dominated by a cluster of giant carbonate mounds limited eastwards by a N/S fault scarp and to the west by the steep edge of the canyon. The large carbonate mounds occur between 700–1100 m water depth. They are up to 150 m high, 800 m wide and 2 km long. The *Logachev* cores targeted intermound areas on a coral populated seabed. The earlier *Challenger* cruise in 1998 acquired a number of cores along both margins of the Rockall Trough. The *Challenger* cores studied by the authors are from a section of smooth slope just north of the Porcupine Bank Canyon. The recorded stratigraphy reveals that the main depositional processes on this part of the slope are bottom current deposition and winnowing.

The cores collected by the *Logachev* cruise were acquired in an area that is relatively sheltered from bottom current action, and no evidence of sediment reworking is recorded. These cores therefore represent an excellent stratigraphic record for biostratigraphic and climatic analyses. A preliminary study suggests that this sedimentary record can be correlated across the canyon to the smooth section of the slope. This correlation provides a useful aid in placing the deposits north of the canyon into a climatic framework. This together with high-resolution bathymetry can improve the understanding of how the bottom current circulation varied with time and space.

Acknowledgements

This Project, including data and survey results acquired for the purpose, has been undertaken on behalf of the Rockall Studies Group (RSG) and the Offshore Support Group (OSG) of the Irish Petroleum Infrastructure Programme Group 2.

ANNEX I

PROGRAMME

Thursday, January 29

09:00 Registration of participants

Opening Session

09:30 Welcoming addresses by Kai Sørensen, Vice Director, GEUS
Welcoming address by A. Suzyumov, UNESCO-IOC

Plenary Session

Chair: Niels E. Poulsen

09:40 M.K. Ivanov *et al.* TTR-13 cruise to the North Atlantic: review of the results
10:00 J.S. Laberg, T.O. Vorren, N.H. Kenyon, M. Ivanov & E.S. Andersen. Architectural elements of a modern deep-sea channel and sandy lobe, Norwegian Sea

Scientific Session 1

Chair: Tove Nielsen

11:10 N.H. Kenyon, A. Akhmetzhanov, S. Hunter, A. Kuijpers, E. Rohling, S. Bacon & D.A.V. Stow.
Search for a high resolution Holocene record on the Eirik Drift, Southern Greenland
11:35 J. Chalmers. Regional Geology, central and southern West Greenland

Scientific Session 2

Chair: Michael Ivanov

13:00 J.D. Stanford, A. Akhmetzhanov, N.H. Kenyon & D.A.V. Stow. Flow transformation in a channelised debris flow located on the North-eastern Rockall trough margin
13:25 J.S. Laberg, T.O. Vorren, N.H. Kenyon, M. Ivanov & E.S. Andersen. Sedimentary features of the distal Andøya slide
13:50 A. Akhmetzhanov, X. Monteys, N.H. Kenyon, V. Huvenne & M.K. Ivanov. Survival guide for a giant carbonate mound
14:15 F. Dalhoff, A. Kuijpers, T. Nielsen & N.E. Poulsen. Southern West Greenland – sea-bed sampling project
14:40 A.B. Belan & L. Abbueh. Relict iceberg ploughmarks on the Western Greenland margin

Scientific Session 3

Chair: Neil Kenyon

15:45 V. Blinova, I. Belenkaya, A. Eisenhauer, M. Ivanov & L. Pinheiro. Origin and composition of carbonate chimneys from the Iberico mud mound (the Gulf of Cadiz)
16:10 E.S. Sarantsev. Depositional environment of the northern part of the Davis Strait High area revealed from lithology of two cores collected during the TTR-13 cruise
16:35 O. Barvalina¹ & E. Sarantsev. Sedimentary succession inferred from studying of rock clasts from mud volcanic deposits (Central part of the Gulf of Cadiz)

Friday, January 30

Scientific Session 4

Chair: Jan Sverre Laberg

09:00 F. Gamberi & M. Marani. Turbidity currents and aggradational canyon fill: the case of the Stromboli Canyon Bend
09:25 A. Stadnitskaia, M. Baas, V. Blinova, T.C.E. van Weering, M. Ivanov & J. Sinninghe Damsté. Distribution and stable carbon isotopic composition of biomarkers in methane-related carbonates and mud volcano sediments, the Sorokin Trough, NE Black Sea
09:50 X. Monteys. Giant carbonate mounds on the west porcupine bank, Irish margin, NE Atlantic morphology and distribution

Scientific Session 5

Chair: Andrey Akhmetzhanov

- 11:10 E. Poludetkina, D. Korost, M. Ivanov & T. Nielsen. Geochemical investigation of organic matter in the rocks from outcrops (Western Greenland margin)
- 11:35 L.K. Øvrebø & X. Monteys. Recent deposits and depositional environment on the West Porcupine Bank, Irish Margin, NE Atlantic

Scientific Session 6

Chair: Xavier Monteys

- 13:00 M.R. Cunha & V. Blinova. Megafauna from a canyon located west of Greenland. Results of TTR-13 cruise in the area of the Labrador sea and Davis Strait (Leg 4)
- 13:25 E. Bileva, A. Mazzini & X. Monteys. Carbonate crusts of the North Porcupine Bank: mineralogical composition and isotopic measurements
- 13:50 A. Mazzini, E. Bileva, M. Ivanov, X. Monteys, J. Parnell & B.T. Cronin. Carbonate mounds and carbonate-phosphate deposits in the Porcupine Bank
- 14:15 E. Kozlova, M. Ivanov, F. Baudin, C. Largeau & S. Derenne. Composition and maturity of organic matter in the rock clasts of mud volcanic breccia
- 14:40 A. Ovsyannikov & T. Nielsen. Geological evidence of volcanic origin of the seamounts on the Western and South-western Greenland margin

Scientific Session 7

Chair: Jean-Pierre Henriët

- 15:35 M.P. Marani, F. Gamberi, D. Penitenti & TTR-12 Cruise participants. The unique character of submarine volcanism: Marsili and Palinuro Seamounts, Tyrrhenian Sea
- 16:00 D. Korost, A. Ovsyannikov & V. Blinova. Principle results of hard rock sampling on the Greenland margin and way of interpretation of these data
- 16:25 I. Mardanian, M. Ivanov, T. Nielsen, A. Kuijpers, T. van Weering, T. Richter & N. E. Poulsen. Features related to mud diapirism in the Norwegian Sea
- 16:50 R. Khamidullin & J. V. Laberg. Mineralogical and grain size analyses of a recent turbidite in the Lofoten Basin, Norwegian Sea

17:00 **Open meeting of the TTR Executive Committee**

Closing session

- T. Nielsen. Closing remarks on behalf of GEUS
- N. Kenyon. Closing statement on behalf of the TTR programme
- M. Marani. Delivery of Conference prizes for the best students' presentations
- M. Ivanov. Closing remarks on behalf of the TTR-13 participants and the MSU group
- E. Poludetkina. Expression of gratitude to GEUS and the TTR executives of behalf of students

Thursday – Friday, January 29–30

Poster Session

- M. Kruse & L.O. Boldree. Aspects of compressional uplift and the deep water bottom currents of the Bill Bailey Bank Area, Offshore SW Faeroes
- B. Pannemans, M. Cunha, P. van Rensbergen, E. Bileva, J.-P. Henriët, M. Ivanov, L. Pinheiro & S. van Gaever. The effect of mud volcano activity on biodiversity at shallow to deep water mud volcanoes at the Moroccan Atlantic slope and in the Gulf of Cadiz
- T. Nielsen, A. Kuijpers, A. Mathiesen, S. J. Lassen, STRATAGEM WP2 Partners & TTR Shipboard Scientific Parties (TTR 8, 9, 12). Pliocene-Quaternary slope instability on the western flank of the Faroe-Shetland Channel

Saturday, January 31, 2004

Field excursion

ANNEX II

LIST OF PARTICIPANTS

Belgium

Henriet, Jean-Pierre
Renard Centre of Marine Geology,
University of Ghent,
Krijgslaan 281, S8
B-9000 Ghent,
jeanpierre.henriet@ugent.be

Denmark

Anthony, Dennis
The Royal Danish Administration of Navigation
Overgaden oven Vandet 62 B
Postboks 1919, DK-1023 Copenhagen K
dea@frv.dk

Bidstrup, Torben
Geological Survey of Denmark and Greenland,
Øster Voldgade 10,
DK-1350 Copenhagen K,
tb@geus.dk

Bojesen-Kofoed, Jørgen
Geological Survey of Denmark and Greenland,
Øster Voldgade 10,
DK-1350 Copenhagen K,
jbk@geus.dk

Chalmers, Jim
Geological Survey of Denmark and Greenland,
Øster Voldgade 10,
DK-1350 Copenhagen K,
jac@geus.dk

Dalhoff, Finn
Geological Survey of Denmark and Greenland,
Øster Voldgade 10,
DK-1350 Copenhagen K,
fd@geus.dk

Ghisler, Martin
Geological Survey of Denmark and Greenland,
Øster Voldgade 10,
DK-1350 Copenhagen K,
mg@geus.dk

Gregersen, Ulrik
Bureau of Minerals and Petroleum (BMP)
Government of Greenland
P.O. Box 930, DK-3900 Nuuk, Greenland
ugr@gh.gl

Hviid, Simon
Geological Institute,
University of Copenhagen,
Øster Voldgade 10,
DK-1350 Copenhagen K
simon@stud.ku.dk

Knutz, Paul C.
Geological Institute,
University of Copenhagen,
Øster Voldgade 10,
DK-1350 Copenhagen K
knutz@geologicalku.dk

Kruse, Mette
Geological Institute,
University of Copenhagen,
Øster Voldgade 10,
DK-1350 Copenhagen K
km220775@geo.geologicalku.dk

Kuijpers, Antoon
Geological Survey of Denmark and Greenland,
Øster Voldgade 10,
DK-1350 Copenhagen K,
aku@geus.dk

Køser, Claus
Geological Institute
University of Aarhus
C.F. Møllers Allé
DK-8000 Aarhus C
claus.koeser@geo.au.dk

Laier, Troels
Geological Survey of Denmark and Greenland,
Øster Voldgade 10,
DK1350 Copenhagen K,
tl@geus.dk

Larsen, Michael
Geological Survey of Denmark and Greenland,
Øster Voldgade 10,
DK1350 Copenhagen K,
mil@geus.dk

Lauridsen, Arne
Geological Institute
University of Aarhus
C.F. Møllers Allé
DK-8000 Aarhus C
arne.lauridsen@geo.au.dk

Møller, Henrik S.
Geographical Institute,
University of Copenhagen,
Øster Voldgade 10,
DK-1350 Copenhagen K
hsm@geogr.ku.dk

Nielsen, Tove
Geological Survey of Denmark and Greenland,
Øster Voldgade 10,
DK1350 Copenhagen K,
tni@geus.dk

Nøhr-Hansen, Henrik
Geological Survey of Denmark and Greenland,
Øster Voldgade 10,
DK1350 Copenhagen K,
hnh@geus.dk

Piasecki, Stefan
Geological Survey of Denmark and Greenland,
Øster Voldgade 10,
DK1350 Copenhagen K,
sp@geus.dk

Poulsen, Niels Erik
Geological Survey of Denmark and Greenland,
Øster Voldgade 10,
DK1350 Copenhagen K,
nep@geus.dk

Sørensen, Aage Bach
Geological Survey of Denmark and Greenland,
Øster Voldgade 10,
DK1350 Copenhagen K,
abs@geus.dk

Sørensen, Kai
Geological Survey of Denmark and Greenland,
Øster Voldgade 10,
DK1350 Copenhagen K,
ks@geus.dk

Germany

Spiess, Volkhard
Fachbereich 5 - Geowissenschaften
University of Bremen
Postfach 330 440
28334 Bremen
vspiess@uni-bremen.de

Ireland

Monteys, Xavier
Geological Survey of Ireland,
Seabed Survey,

7 Dundrum, Business Park, Windy Arbour,
Dublin 14,
xavier.monteys@dcmnr.gov.ie

Italy

Gamberi, Fabiano
Istituto di Scienze Marine
Sezione Geologia Marina Bologna,
Via Gobetti 101,
40129 Bologna,
fabiano.gamberi@bo.ismar.cnr.it

Marani, Michael
Istituto di Scienze Marine
Sezione Geologia Marina Bologna,
Via Gobetti 101, 40129 Bologna,
michael.marani@bo.ismar.cnr.it

The Netherland

Stadnitskaia, Alina
Royal Netherlands Institute
for Sea Research,
P.O.Box 59, 1790 AB Den Burg, Texel,
alina@nioz.nl

Norway

Laberg, Jan Sverre
University of Tromsø
Department of Geology,
University of Tromsø,
N-9037 Tromsø,
jansl@ig.uit.no

Portugal

Cunha, Marina
Departamento de Biologia,
Universidade de Aveiro,
3810-193 Aveiro,
mcunha@bio.ua.pt

Russian Federation

Barvalina, Olga
UNESCO-MSU Centre for Marine Geosciences,
Geology Faculty, Moscow State University,
Vorobjevy Gory, 119899 Moscow,
ivolga2001@hotmail.ru, fu@geol.msu.ru

Belan, Anna
UNESCO-MSU Centre for Marine Geosciences,
Geology Faculty, Moscow State University,
Vorobjevy Gory, 119899 Moscow,
annabelan@mail.ru, fu@geol.msu.ru

Bileva, Evgenia
UNESCO-MSU Centre for Marine Geosciences,
Geology Faculty, Moscow State University,
Vorobjevy Gory, 119899 Moscow,
fu@geol.msu.ru

Blinova, Valentina
UNESCO-MSU Centre for Marine Geosciences,
Geology Faculty, Moscow State University,
Vorobjevy Gory, 119899 Moscow,
fu@geol.msu.ru, vblinova@uni-bremen.de

Ivanov, Mikhail
UNESCO-MSU Centre for Marine Geosciences,
Geology Faculty, Moscow State University,
Vorobjevy Gory, 119899 Moscow,
fu@geol.msu.ru

Khamidullin, Ruslan
UNESCO-MSU Centre for Marine Geosciences,
Geology Faculty, Moscow State University,
Vorobjevy Gory, 119899 Moscow,
fu@geol.msu.ru

Korost, Dmitry
UNESCO-MSU Centre for Marine Geosciences,
Geology Faculty, Moscow State University,
Vorobjevy Gory, 119899 Moscow,
fu@geol.msu.ru

Kozlova, Elena
UNESCO-MSU Centre for Marine Geosciences,
Geology Faculty, Moscow State University,
Vorobjevy Gory, 119899 Moscow,
fu@geol.msu.ru

Mardanian, Inna
UNESCO-MSU Centre for Marine Geosciences,
Geology Faculty, Moscow State University,
Vorobjevy Gory, 119899 Moscow,
imard@nm.ru, fu@geol.msu.ru

Ovsyannikov, Andrey
UNESCO-MSU Centre for Marine Geosciences,
Geology Faculty, Moscow State University,
Vorobjevy Gory, 119899 Moscow,
fu@geol.msu.ru

Poludetkina, Elena
UNESCO-MSU Centre for Marine Geosciences,
Geology Faculty, Moscow State University,
Vorobjevy Gory, 119899 Moscow,
fu@geol.msu.ru

Sarantsev, Evgeny
UNESCO-MSU Centre for Marine Geosciences,
Geology Faculty, Moscow State University,
Vorobjevy Gory, 119899 Moscow,
fu@geol.msu.ru
Switzerland

Abbuehl, Luca
Department of Earth Science,
ETH Zurich,
Sonneggstrasse 5, 8092 Zurich,
Luabbuehl@student.ethz.ch

United Kingdom

Akhmetzhanov, Andrey
Challenger Division,
Southampton Oceanography Centre,
Empress Dock, Southampton, SO14 3ZH,
Andrey.Akhmetzhanov@soc.soton.ac.uk

Kenyon, Neil
Southampton Oceanography Centre,
Empress Dock, Southampton, SO14 3ZH,
nhk@soc.soton.ac.uk

Mazzini, Adriano
Department of Geology and Petroleum Geology,
University of Aberdeen,
Meston Building, King's College,
Aberdeen AB24 3UE,
a.mazzini@abdn.ac.uk

Stanford, Jennifer
Southampton Oceanography Centre,
Southampton, SO14 3ZH,
jds100@soton.ac.uk

UNESCO

Suzyumov, Alexei E.
Science Sector
1, rue Miollis 75015 Paris
a.suzyumov@unesco.org

IOC Workshop Reports

The Scientific Workshops of the Intergovernmental Oceanographic Commission are sometimes jointly sponsored with other intergovernmental or non-governmental bodies. In most cases, IOC assures responsibility for printing, and copies may be requested from:

Intergovernmental Oceanographic Commission – UNESCO
1, rue Miollis, 75732 Paris Cedex 15, France

No.	Title	Languages	No.	Title	Languages	No.	Title	Languages
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).	E (out of stock)		5-9 June 1978 (UNESCO reports in marine sciences, No. 5, published by the Division of Marine Sciences, UNESCO).		40	24-29 September 1985. IOC Workshop on the Technical Aspects of Tsunami Analysis, Prediction and Communications; Sidney, B.C., Canada, 29-31 July 1985.	E
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)	20	Second CCOP-IOC Workshop on IDOE Studies of East Asia Tectonics and Resources; Bandung, Indonesia, 17-21 October 1978	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
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)	21	Second IDOE Symposium on Turbulence in the Ocean; Liège, Belgium, 7-18 May 1979.	E, F, S, R	41	First Workshop of Participants in the Joint	E
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)	22	Third IOC/WMO Workshop on Marine Pollution Monitoring; New Delhi, 11-15 February 1980.	E, F, S, R		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
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	23	WESTPAC Workshop on the Marine Geology and Geophysics of the North-West Pacific; Tokyo, 27-31 March 1980.	E, R	43	IOC Workshop on the Results of MEDALPEX and Future Oceanographic Programmes in the Western Mediterranean; Venice, Italy, 23-25 October 1985.	E
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	24	Workshop on the Inter-calibration of Sampling Procedures of the IOC/WMO UNEP Pilot Project on Monitoring Background Levels of Selected Pollutants in Open-Ocean Waters; Bermuda, 11-26 January 1980.	E (out of stock)	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
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	25	IOC Workshop on Coastal Area Management in the Caribbean Region; Mexico City, 24 September- 5 October 1979.	E, 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
8	Joint IOC/FAO (IPFC)/UNEP International Workshop on Marine Pollution in East Asian Waters; Penang, 7-13 April 1976	E (out of stock)	26	CCOP/SOPAC-IOC Second International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific; Noumea, New Caledonia, 9-15 October 1980.	E	45	IOCARIBE Workshop on Physical Oceanography and Climate; Cartagena, Colombia, 19-22 August 1986.	E
9	IOC/CMG/SCOR Second International Workshop on Marine Geoscience; Mauritius 9-13 August 1976.	E, F, S, R	27	FAO/IOC Workshop on the effects of environmental variation on the survival of larval pelagic fishes. Lima, 20 April-5 May 1980.	E	46	Reunión de Trabajo para Desarrollo del Programa 'Ciencia Oceánica en Relación a los Recursos No Vivos en la Región del Atlántico Sud-occidental'; Porto Alegre, Brasil, 7-11 de abril de 1986.	S
10	IOC/WMO Second Workshop on Marine Pollution (Petroleum) Monitoring; Monaco, 14-18 June 1976	E, F E (out of stock)	28	WESTPAC Workshop on Marine Biological Methodology; Tokyo, 9-14 February 1981.	E	47	IOC Symposium on Marine Science in the Western Pacific: The Indo-Pacific Convergence; Townsville, 1-6 December 1966	E
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)	29	International Workshop on Marine Pollution in the South-West Atlantic; Montevideo, 10-14 November 1980.	E (out of stock) S	48	IOCARIBE Mini-Symposium for the Regional Development of the IOC-UN (OETB) Programme on 'Ocean Science in Relation to Non-Living Resources (OSNLR)'; Havana, Cuba, 4-7 December 1986.	E, S
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	30	Third International Workshop on Marine Geoscience; Heidelberg, 19-24 July 1982.	E, F, S	49	AGU-IOC-WMO-CPPS Chapman Conference: An International Symposium on 'El Niño'; Guayaquil, Ecuador, 27-31 October 1986.	E
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	31	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	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
13	Report of the IOCARIBE Workshop on Environmental Geology of the Caribbean Coastal Area; Port of Spain, Trinidad, 16-18 January 1978.	E, 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	51	CCOP/SOPAC-IOC Workshop on Coastal Processes in the South Pacific Island Nations; Lae, Papua-New Guinea, 1-8 October 1987.	E
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	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	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
15	CPSP/FAO/IOC/UNEP International Workshop on Marine Pollution in the South-East Pacific; Santiago de Chile, 6-10 November 1978.	E (out of stock)	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	53	IOC Workshop on the Biological Effects of Pollutants; Oslo, 11-29 August 1986.	E
16	Workshop on the Western Pacific, Tokyo, 19-20 February 1979.	E, F, R	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	54	Workshop on Sea-Level Measurements in Hostile Conditions; Bidston, UK, 28-31 March 1988.	E
17	Joint IOC/WMO Workshop on Oceanographic Products and the IGOSS Data Processing and Services System (IDPSS); Moscow, 9-11 April 1979.	E	36	IOC/FAO Workshop on the Improved Uses of Research Vessels; Lisbon, Portugal, 28 May-2 June 1984.	E	55	IBCCA Workshop on Data Sources and Compilation, Boulder, Colorado, 18-19 July 1988.	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	36 Suppl.	Papers submitted to the IOC/FAO Workshop on the Improved Uses of Research Vessels; Lisbon, 28 May-2 June 1984	E	56	IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Cleveland, Australia, 24-30 July 1988.	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	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	57	IOC Workshop on International Co-operation in the Study of Red Tides and Ocean Blooms; Takamatsu, Japan, 16-17 November 1987.	E
19	IOC Workshop on Marine Science Syllabus for Secondary Schools; Llantwit Major, Wales, U.K.,	E (out of stock), S, R, Ar	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	58	International Workshop on the Technical Aspects of the Tsunami Warning System; Novosibirsk, USSR, 4-5 August 1989.	E
			39	CCOP (SOPAC)-IOC-IFREMER-ORSTOM Workshop on the Uses of Submersibles and Remotely Operated Vehicles in the South Pacific; Suva, Fiji,	E	58 Suppl.	Second International Workshop on the Technical Aspects of Tsunami Warning Systems, Tsunami Analysis, Preparedness,	E

No.	Title	Languages	No.	Title	Languages	No.	Title	Languages
59	Observation and Instrumentation. Submitted Papers; Novosibirsk, USSR, 4-5 August 1989. 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	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	103	Liège, Belgium, 5-9 May 1994. IOC Workshop on GIS Applications in the Coastal Zone Management of Small Island Developing States; Barbados, 20-22 April 1994.	E
60	IOC Workshop to Define IOCARIBE-TRODERP proposals; Caracas, Venezuela, 12-16 September 1989.	E	84	Workshop on Atlantic Ocean Climate Variability; Moscow, Russian Federation, 13-17 July 1992	E	104	Workshop on Integrated Coastal Management; Dartmouth, Canada, 19-20 September 1994.	E
61	Second IOC Workshop on the Biological Effects of Pollutants; Bermuda, 10 September-2 October 1988.	E	85	IOC Workshop on Coastal Oceanography in Relation to Integrated Coastal Zone Management; Kona, Hawaii, 1-5 June 1992.	E	105	BORDOMER 95: Conference on Coastal Change; Bordeaux, France, 6-10 February 1995.	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	86	International Workshop on the Black Sea; Varna, Bulgaria, 30 September - 4 October 1991	E	105 Suppl.	Conference on Coastal Change: Proceedings; Bordeaux, France, 6-10 February 1995	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	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)	106	IOC/WESTPAC Workshop on the Paleographic Map; Bali, Indonesia, 20-21 October 1994.	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	88	IOC-CEC-ICSU-ICES Regional Workshop for Member States of Eastern and Northern Europe (GODAR Project); Obninsk, Russia, 17-20 May 1993.	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
65	Second IOC Workshop on Sardine/Anchovy Recruitment Project (SARP) in the Southwest Atlantic; Montevideo, Uruguay, 21-23 August 1989.	E	89	IOC-ICSEM Workshop on Ocean Sciences in Non-Living Resources; Perpignan, France, 15-20 October 1990.	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
66	IOC ad hoc Expert Consultation on Sardine/Anchovy Recruitment Programme; La Jolla, California, U.S.A., 1989	E	90	IOC Seminar on Integrated Coastal Management; New Orleans, U.S.A., 17-18 July 1993.	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
67	Interdisciplinary Seminar on Research Problems in the IOCARIBE Region; Caracas, Venezuela, 28 November-1 December 1989.	E (out of stock)	91	Hydroblack'91 CTD Intercalibration Workshop; Woods Hole, U.S.A., 1-10 December 1991.	E	109	First IOC-UNEP CEPOL Symposium; San José, Costa Rica, 14-15 April 1993.	E
68	International Workshop on Marine Acoustics; Beijing, China, 26-30 March 1990.	E	92	Réunion de travail IOCEA-OSNLR sur le Projet « Budgets sédimentaires le long de la côte occidentale d'Afrique » Abidjan, Côte d'Ivoire, 26-28 juin 1991.	E	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
69	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Leningrad, USSR, 28-31 May 1990.	E	93	IOC-UNEP Workshop on Impacts of Sea-Level Rise due to Global Warming. Dhaka, Bangladesh, 16-19 November 1992.	E	111	Chapman Conference on the Circulation of the Intra-Americas Sea; La Parguera, Puerto Rico, 22-26 January 1995.	E
69 Suppl.	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Submitted Papers; Leningrad, USSR, 28-31 May 1990.	E	94	BMTIC-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	112	IOC-IAEA-UNEP Group of Experts on Standards and Reference Materials (GESREM) Workshop; Miami, U.S.A., 7-8 December 1993.	E
70	IOC-SAREC-UNEP-FAO-IAEA-WHO Workshop on Regional Aspects of Marine Pollution; Mauritius, 29 October - 9 November 1990.	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	113	IOC Regional Workshop on Marine Debris and Waste Management in the Gulf of Guinea; Lagos, Nigeria, 14-16 December 1994.	E
71	IOC-FAO Workshop on the Identification of Penaeid Prawn Larvae and Postlarvae; Cleveland, Australia, 23-28 September 1990.	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	114	International Workshop on Integrated Coastal Zone Management (ICZM) Karachi, Pakistan; 10-14 October 1994.	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	96 Suppl.	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Submitted Papers 1. Coastal Erosion; Zanzibar, United Republic of Tanzania 17-21 January 1994.	E	115	IOC/GLOSS-IAPSO Workshop on Sea Level Variability and Southern Ocean Dynamics; Bordeaux, France, 31 January 1995	E
73	Expert Consultation for the IOC Programme on Coastal Ocean Advanced Science and Technology Study; Liège, Belgium, 11-13 May 1991.	E	96 Suppl.	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Submitted Papers 2. Sea Level; Zanzibar, United Republic of Tanzania 17-21 January 1994.	E	116	IOC/WESTPAC International Scientific Symposium on Sustainability of Marine Environment: Review of the WESTPAC Programme, with Particular Reference to ICAM, Bali, Indonesia, 22-26 November 1994.	E
74	IOC-UNEP Review Meeting on Oceanographic Processes of Transport and Distribution of Pollutants in the Sea; Zagreb, Yugoslavia, 15-18 May 1989.	E	97	IOC Workshop on Small Island Oceanography in Relation to Sustainable Economic Development and Coastal Area Management of Small Island Developing States; Fort-de-France, Martinique, 8-10 November, 1993.	E	117	Joint IOC-CIDA-Sida (SAREC) Workshop on the Benefits of Improved Relationships between International Development Agencies, the IOC and other Multilateral Inter-governmental Organizations in the Delivery of Ocean, Marine Affairs and Fisheries Programmes; Sidney B.C., Canada, 26-28 September 1995.	E
75	IOC-SCOR Workshop on Global Ocean Ecosystem Dynamics; Solomons, Maryland, U.S.A., 29 April-2 May 1991.	E	98	CoMSBlack '92A Physical and Chemical Intercalibration Workshop; Erdemli, Turkey, 15-29 January 1993.	E	118	IOC-UNEP-NOAA-Sea Grant Fourth Caribbean Marine Debris Workshop; La Romana, Santo Domingo, 21-24 August 1995.	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	99	IOC-SAREC Field Study Exercise on Nutrients in Tropical Marine Waters; Mombasa, Kenya, 5-15 April 1994.	E	119	IOC Workshop on Ocean Colour Data Requirements and Utilization; Sydney B.C., Canada, 21-22 September 1995.	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	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	120	International Training Workshop on Integrated Coastal Management; Tampa, Florida, U.S.A., 15-17 July 1995.	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	101	IOC Regional Science Planning Workshop on Harmful Algal Blooms; Montevideo, Uruguay, 15-17 June 1994.	E	121	Atelier régional IOC-CERESCOR sur la gestion intégrée des zones littorales (ICAM), Conakry, Guinée, 18-22 décembre 1995	F
79	IOC/WESTPAC Workshop on River Inputs of Nutrients to the Marine Environment in the WESTPAC Region; Penang, Malaysia, 26-29 November 1991.	E	102	First IOC Workshop on Coastal Ocean Advanced Science and Technology Study (COASTS);	E	122	IOC-EU-BSH-NOAA-(WDC-A) International Workshop on Oceanographic Biological and Chemical Data Management. Hamburg, Germany, 20-23 May 1996	E
80	IOC-SCOR Workshop on Programme Development for Harmful Algae Blooms; Newport, U.S.A., 2-3 November 1991.	E			E, S	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
81	Joint IAPSO-IOC Workshop on Sea Level Measurements and Quality Control; Paris, France, 12-13 October 1992.	E			E	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
82	BORDOMER 92: International Convention on Rational Use of Coastal Zones. A Preparatory	E			E	125	Atelier sous-régional de la COI sur les ressources marines vivantes du Golfe de Guinée; Cotonou, Bénin, 1-4 juillet 1996.	E

No.	Title	Languages	No.	Title	Languages	No.	Title	Languages
126	IOC-UNEP-PERSGA-ACOPS-IUCN Workshop on Oceanographic Input to Integrated Coastal Zone Management in the Red Sea and Gulf of Aden, Jeddah, Saudi Arabia, 8 October 1995.	E	155	project) Capetown, South Africa, 30 November-11 December 1998. Science of the Mediterranean Sea and its applications UNESCO, Paris 29-31 July 1997	E	189	Workshop for the Formulation of a Draft Project on Integrated Coastal Management (ICM) in Latin America and the Caribbean (LAC), Cartagena, Colombia, 23-25 October 2003	E F <i>(electronic copy only)</i>
127	IOC Regional Workshop for Member States of the Caribbean and South America GODAR-V (Global Oceanographic Data Archeology and Rescue Project); Cartagena de Indias, Colombia, 8-11 October 1996.	E	156	IOC-LUC-KMFR Workshop on ECOSCIX-WIO in the Year 2000 and Beyond, Mombasa, Kenya, 12-16 April 1999	E		Taller de Formulación de un Anteproyecto de Manejo Costero Integrado (MCI) en América Latina y el Caribe (ALC), Cartagena, Colombia, 23-25 de Octubre de 2003	
128	Atelier IOC-Banque Mondiale-Sida/SAREC-ONE sur la Gestion Intégrée des Zones Côtières ; Nosy Bé, Madagascar, 14-18 octobre 1996.	E	157	'98 IOC-KMI International Workshop on Integrated Coastal Management (ICM), Seoul, Republic of Korea 16-18 April 1998	E	190	First ODINCARSA Planning Workshop for Caribbean Islands, Christchurch, Barbados, 15-18 December 2003	E <i>(electronic copy only)</i>
129	Gas and Fluids in Marine Sediments, Amsterdam, the Netherlands; 27-29 January 1997.	E	158	The IOCARIBE Users and the Global Ocean Observing System (GOOS) Capacity Building Workshop, San José, Costa Rica, 22-24 April 1999	E	191	North Atlantic and Labrador Sea Margin Architecture and Sedimentary Processes — International Conference and Twelfth Post-cruise Meeting of the Training-through-research Programme, Copenhagen, Denmark, 29-31 January 2004	E
130	Atelier régional de la COI sur l'océanographie côtière et la gestion de la zone côtière ;Moroni, RFI des Comores, 16-19 décembre 1996.	E	159	Oceanic Fronts and Related Phenomena (Konstantin Federov Memorial Symposium) — Proceedings, Pushkin, Russian Federation, 18-22 May 1998	E			
131	GOOS Coastal Module Planning Workshop; Miami, USA, 24-28 February 1997	E	160	Under preparation				
132	Third IOC-FANSA Workshop; Punta-Arenas, Chile, 28-30 July 1997	S/E	161	Under preparation				
133	Joint IOC-CIESM Training Workshop on Sea-level Observations and Analysis for the Countries of the Mediterranean and Black Seas; Birkenhead, U.K., 16-27 June 1997.	E	162	Workshop report on the Transports and Linkages of the Intra-americas Sea (IAS), Cozumel, Mexico, 1-5 November 1997	E			
134	IOC/WESTPAC-CCOP Workshop on Paleogeographic Mapping (Holocene Optimum); Shanghai, China, 27-29 May 1997.	E	163	Under preparation				
135	Regional Workshop on Integrated Coastal Zone Management; Chabahar, Iran; February 1996.	E	164	IOC-Sida-Flanders-MCM Third Workshop on Ocean Data Management in the IOCINCWIO Region (ODINEA Project), Cape Town, South Africa, 29 November – 11 December 1999	E			
136	IOC Regional Workshop for Member States of Western Africa (GODAR-VI); Accra, Ghana, 22-25 April 1997.	E	165	An African Conference on Sustainable Integrated Management; Proceedings of the Workshops, An Integrated Approach, (PACSICOM), Maputo, Mozambique, 18 –25 July 1998	E, F			
137	GOOS Planning Workshop for Living Marine Resources, Dartmouth, USA; 1-5 March 1996.	E	166	IOC-SOA International Workshop on Coastal Megacities: Challenges of Growing Urbanization of the World's Coastal Areas; Hangzhou, P.R. China, 27 –30 September 1999	E			
138	Gestión de Sistemas Oceanográficos del Pacífico Oriental; Concepción, Chile, 9-16 de abril de 1996.	S	167	IOC-Flanders First ODINAFRICA-II Planning Workshop, Dakar, Senegal, 2-4 May 2000	E			
139	Sistemas Oceanográficos del Atlántico Sudoccidental, Taller, TEMA;Furg, Rio Grande, Brasil, 3-11 de noviembre de 1997	S	168	Geological Processes on European Continental Margins; International Conference and Eight Post-cruise Meeting of the Training-Through-Research Programme, Granada, Spain, 31 January – 3 February 2000	E			
140	IOC Workshop on GOOS Capacity Building for the Mediterranean Region; Valletta, Malta, 26-29 November 1997.	E	169	International Conference on the International Oceanographic Data & Information Exchange in the Western Pacific (IODE-WESTPAC) 1999, ICWIP '99, Langkawi, Malaysia, 1-4 November 1999	<i>under preparation</i>			
141	IOC/WESTPAC Workshop on Co-operative Study in the Gulf of Thailand: A Science Plan; Bangkok, Thailand, 25-28 February 1997.	E	170	IOCARIBE-GODAR-I Cartagena, Colombia, February 2000	<i>under preparation</i>			
142	Pelagic Biogeography ICoPB II. Proceedings of the 2nd International Conference. Final Report of SCOR/IOC Working Group 93; Noordwijkerhout, The Netherlands, 9-14 July 1995.	E	171	Ocean Circulation Science derived from the Atlantic, Indian and Arctic Sea Level Networks, Toulouse, France, 10-11 May 1999	E			
143	Geosphere-biosphere coupling: Carbonate Mud Mounds and Cold Water Reefs; Gent, Belgium, 7-11 February 1998.	E	172	<i>(Under preparation)</i>				
144	IOC-SOPAC Workshop Report on Pacific Regional Global Ocean Observing Systems; Suva, Fiji, 13-17 February 1998.	E	173	The Benefits of the Implementation of the GOOS in the Mediterranean Region, Rabat, Morocco, 1-3 November 1999	E, F			
145	IOC-Black Sea Regional Committee Workshop: 'Black Sea Fluxes' Istanbul, Turkey, 10-12 June 1997.	E	174	IOC-SOPAC Regional Workshop on Coastal Global Ocean Observing System (GOOS) for the Pacific Region, Apia, Samoa, 16-17 August 2000	E			
146	Living Marine Resources Panel Meeting, Paris, France, 23-25 March 1998.	E	175	Geological Processes on Deep-water European Margins, Moscow-Mozhenka, 28 Jan.-2 Feb. 2001	E			
147	IOC-SOA International Training Workshop on the Intregation of Marine Sciences into the Process of Integrated Coastal Management, Dalian, China, 19-24 May 1997.	E	176	MedGLOSS Workshop and Coordination Meeting for the Pilot Monitoring Network System of Systematic Sea Level Measurements in the Mediterranean and Black Seas, Haifa, Israel, 15-17 May 2000	E			
148	IOC/WESTPAC International Scientific Symposium – Role of Ocean Sciences for Sustainable Development Okinawa, Japan, 2-7 February 1998.	E	177	<i>(Under preparation)</i>				
149	Workshops on Marine Debris & Waste Management in the Gulf of Guinea, 1995-97.	E	178	<i>(Under preparation)</i>				
150	First IOCARIBE-ANCA Workshop Havana, Cuba, 29 June-1 July 1998.	E	179	<i>(Under preparation)</i>				
151	Taller Pluridisciplinario TEMA sobre Redes del Gran Caribe en Gestión Integrada de Areas Costeras Cartagena de Indias, Colombia, 7-12 de septiembre de 1998.	S	180	Abstracts of Presentations at Workshops during the 7 th session of the IOC Group of Experts on the Global Sea Level Observing System (GLOSS), Honolulu, USA, 23-27 April 2001	E			
152	Workshop on Data for Sustainable Integrated Coastal Management (SICOM) Maputo, Mozambique, 18-22 July 1998	E	181	<i>(Under preparation)</i>				
153	IOC/WESTPAC-Sida (SAREC) Workshop on Atmospheric Inputs of Pollutants to the Marine Environment Qingdao, China, 24-26 June 1998	E	182	<i>(Under preparation)</i>				
154	IOC-Sida-Flanders-SFRI Workshop on Ocean Data Management in the IOCINCWIO Region, ODINEA	E	183	Geosphere/Biosphere/Hydrosphere Coupling Process, Fluid Escape Structures and Tectonics at Continental Margins and Ocean Ridges, International Conference & Tenth Post-cruise Meeting of the Training-through-Research Programme, Aveiro, Portugal, 30 January-2 February 2002	E			
			184	<i>(Under preparation)</i>				
			185	<i>(Under preparation)</i>				
			186	<i>(Under preparation)</i>				
			187	Geological and Biological Processes at deep-sea European Margins and Oceanic Basins, Bologna, Italy, 2-6 February 2003	E			
			188	Proceedings of 'The Ocean Colour Data' Symposium, Brussels, Belgium, 25-27 November 2002	E			