Cocarde Workshop and Field Seminar

Recent and Ancient Carbonate Mounds in Morocco

Rabat, Morocco, 24-30 October 2011

Organized by

Faculty of Sciences, Mohammed V – Agdal University, Rabat, Morocco

Renard Centre of Marine Geology, Ghent University, Belgium

Ibn Battuta Center, Cadi Ayad University Marrakech, Morocco

International University of Rabat, Morocco

The Office National des Hydrocarbures et des Mines (ONHYM), Rabat, Morocco

Under the auspices of

IOC-UNESCO and The Research Foundation Flanders (FWO, Cocarde-ICA)

The European Science Foundation (ESF, Cocarde-ERN)

Report

Edited by

Andres Rüggeberg and Jean-Pierre Henriet

With contributions of

R. Barbieri, A. Foubert, J.-P. Henriet, P. Lapointe, P. Léonide, J.J.G. Reijmer, A. Rüggeberg, E. Samankassou

1. Summary

Some 10 years after the first reporting of Recent carbonate mounds off Morocco, the 2011 Cocarde workshop in Rabat has offered an opportunity to assess achievements of past oceanographic cruises, to build bridges between studies of Recent and Ancient carbonate mound systems and to exchange views about prospective actions in the future.

In coherence with Cocarde's capacity building mission and its vision on a holistic approach of carbonate mounds through geological time as a key to fundamental and applied insights and breakthroughs, the workshop was introduced by a full-day, open-access tutorial event, conceived as a voyage through time, space and Geosphere-Biosphere coupling processes in Recent and Ancient carbonate factories in Morocco and elsewhere.

The second day had been made available for targeted strategic meetings, to discuss possibly innovative approaches in carbonate mound research in Morocco on Recent and Ancient mounds - offshore and onshore - and to review opportunities of international collaboration. In addition, the PhD and postdoctoral researchers could present their research in a concise way.

A task group of 31 Moroccan and European scientists, with a balanced mix of senior scientists and PhD and postdoctoral researchers, has visited a number of field outcrops of carbonate mounds and carbonate factories from Ordovician to Jurassic ages in the Central High Atlas and eastern Anti-Atlas. The field seminar had been carefully prepared by the redaction of a comprehensive guidebook. During the field seminar and in the wake of the workshop and field action, various tracks for further research have been explored and phrased. The potential documentation of a future "Moroccan mound reference route" for capacity building and international outreach is part of the challenge.

2. Scientific content and discussions - COCARDE Workshop and Field Seminar (Rabat, October 24-25)

2.1 Scientific content

The tutorial day of the ***Workshop*** (see Annex 1), hosted by the Faculty of Sciences of Mohamed V University in Rabat was well attended by 45 scientists from Morocco and Europe, among them 12 PhD and postdoctoral grantees of the Cocarde-ERN network (6 European, 6 Moroccan). In addition, 32 students from Mohamed V University in Rabat, 9 students from Hassan II University in Casablanca and 7 students from Kenitra University had registered for the tutorial day and could attend the presentations in variable configuration (Fig. 1) (lists of participating institutions and registered participants in Annex 2).

Figure 1. Participants of the COCARDE Workshop and Field Seminar at the Faculty of Science, Mohamed V University in Rabat, Morocco, on Monday, 24 October 2011.

The workshop was opened by Prof. Said Amzazi, Dean of the Faculty of Sciences, who highlighted the longstanding record of collaboration of Moroccan and European teams in the concerned scientific field. Dr. Alexei Suzyumov welcomed the participants on behalf of IOC-UNESCO and framed the Cocarde initiative on the background of the successful IOC-UNESCO "Training-through-research" endeavour. Prof. J.P. Henriet outlined the structure and objectives of the workshop, evoking Morocco's potential to offer to Science and Industry a reference route of exceptional outcrops and field laboratories for the study of carbonate mound systems, which one day might qualify for a UNESCO world heritage label.

In subsequent presentations, scientists reviewed the state of the art in carbonate mound studies, sweeping through geological time and zooming in on processes and methods. An outlook on technology and industrial research concluded the tutorial day. Short contents of the presentations are collected in the Programme and Abstract book (Annex 1).

The second day was introduced by a Round Table hosted by the Office National des Hydrocarbures et des Mines (ONHYM). Dr. Haddou Jabour reviewed the current plays in hydrocarbon exploration in Morocco, both onshore and offshore. The re-visiting of vast data sets and the emphasis on integrative studies, to confront field data with subsurface information, opens new opportunities for collaboration with academia, not the least in the study of non-conventional resources and frontier systems.

The afternoon sessions were hosted by the International University of Rabat at the Technopolis site, a private venture with international and industrial partners, operating under a Development Contract of the Government. As part of the team building exercise in view of the subsequent Field Seminar, the Cocarde-ERN grantees from Morocco and Europe presented some highlights of their research in "flash" presentations of some 5 minutes. This session was concluded with an exchange of views on opportunities for collaboration in ocean sciences, carbonate systems and reservoir studies, also in preparation of further prospective discussions during the Field Seminar.

The ***Field Seminar*** had been thoroughly prepared by a major effort of local research teams from Marrakech and Rabat universities and their international partners (Abdellah Ait Addi, Roberto Barbieri, Joseph Canérot, Barbara Cavalazzi, Driss Chafiki, Fulvio Franchi, Naima Hamoumi, Kamal Taj-Eddine), which resulted in a highly informative Guidebook. The initial programme of Friday 28 October (cfr. Programme and abstract book, Annex 1) was modified in common agreement to carry out an exploratory raid on a unique site of Carboniferous Waulsortian mounds, described by Wendt et al. (2001). The Ibn Batutta Mars missions test site visit planned for Saturday 29 October was skipped to maximize the observation of the Ordovician setting in Alnif. The Jurassic and Bajocian mound sites of the High Atlas, reached at dusk on Wednesday 26 October, were re-visited the morning of Sunday 30 October.

In response to this preparatory effort, a number of participating scientists (Roberto Barbieri, Anneleen Foubert, Philippe Lapointe, Philippe Léonide, John Reijmer, Andres Rüggeberg, Elias Samankassou) have been invited to express views on scientific challenges and opportunities. This brainstorming exercise, compiled during and shortly after the field seminar, adds to the information and views brought by the teams presently active on various visited sites and is summarized below, as a possible nucleation point of ideas and actions.

2.2 Discussions

The ***Workshop*** compared Recent with Ancient mounds. To allow adequate reconstructions of the paleo-environments, the use of similar tools is necessary. Isotope and element ratios determined in carbonate material have the disadvantage that they may be overprinted by diagenetic alteration or recrystallization during burial processes, especially in aragonitic material. However, the continuous progress of new tools in line with new technical and instrumental development helps to overcome the difficulties of comparing different mound settings.

Clumped-isotopes (isotopologues of CO_2) for instance were discussed in more detail as they provide a powerful tool in reconstructing temperatures of carbonate precipitated material far back in geologic time. In comparison with $\delta^{18}O$ – the best-known and established temperature proxy – the advantage of clumped-isotopes is the independency to the oxygen isotope composition of the water in which the carbonate precipitated (Gosh et al. 2006). This is important especially for the study of marine sediment records of critical time periods, when the $\delta^{18}O$ of seawater is not well constrained (Schmid 2011). However, there are limitations like the precision of 10 ppm resulting in quite a large temperature uncertainty of 2 °C, or the existing calibrations only on Recent carbonates in a temperature range between 1 and 70 °C (see Schmid 2011 and references therein).

Nevertheless, clumped-isotope studies so far reconstructed for example Arctic land surface temperatures of early Pliocene (Csank et al. 2011), seawater temperatures from belemnite guards of Early Cretaceous (Schmid 2011), from aragonitic molluscs of the Carboniferous, and from brachiopods of Early Silurian (Came et al. 2007), or formation temperature in dolomites of Triassic Latemar carbonate build-ups (Ferry et al. 2011).

At the ***Round table*** at ONHYM on Tuesday 25th October 2011, Dr. Haddou Jabour introduced the "source-to-sink" approach as an important nucleus for collaborative basin research, not the least in frontier reservoir systems.

During the ***Field Seminar*** (Fig. 2) different paleo-environmental, pure carbonate- sedimentological to diagenetic and petrophysical questions were addressed with a perspective on the nature and significance of the visited carbonate mound systems. In addition to early carbonate systems of Ordovician times, several large-scale carbonate mound settings were visited: (1) Jurassic mounds, (2) bioclastic Carboniferous mounds, (3) Devonian Kess Kess mounds and Hollard mound (mudmounds related to/altered by fluid dynamics), and (4) a seep-related Silurian mound. The mounds are part of a whole sedimentary system. Studying the whole system and the entire sedimentary environment is necessary to understand the processes of mound genesis (generic mound classification), mound build-up (internal structure) and mound alteration (diagenesis).

Figure 2. Intense discussions at Ordovician carbonate outcrops introduced by Prof. Naima Hamoumi.

(1) Jurassic mounds: carbonate mounds rich in siliceous sponge spicules preserved as calcite-cemented molds are widespread in the Phanerozoic rock record. Liassic sponge mudmound sites along the transect Midelt – Errachidia have been visited during the COCARDE Field Seminar 'Ancient Carbonate Mounds in Morocco'. The detailed stratigraphical, sedimentological and geodynamic context has been presented by Prof. Driss Chafiki and Prof. Abdellah Ait Addi (University of Marrakech). The development of those Jurassic sponge mounds seems to be biologically controlled in a specific basinal and paleo-environmental context. However, a better comprehension of the processes that stop the mound growth and preserve such geological objects (early and late diagenesis processes) is needed. Similar Jurassic fossil mudmounds are well known at global scale.

Specifically, the Moroccan mounds are perfect analogues in terms of facies, depositional setting, fauna association and diagenetic features to the Aalenian mudmounds recently described from SE France. Interestingly, these mounds are similarly rich in sponge spicules and stromatactis as their Paleozoic counterparts, but the Jurassic stromatactis mounds are silicified, a feature that makes them unique. Recent detailed diagenetic analyses (cement stratigraphy, systematic isotopic analyses on different cement phases in stromatactis, fluid inclusions in well-defined cements) have shown the importance of early diagenetic processes on the early recycling of silica within these sedimentary bodies and on the control of the mounds stabilization and preservation.

(2) Bioclastic Carboniferous mounds: the absence of vegetation and erosion has exhumed Visean carbonate mounds in the Moroccan Anti-Atlas, making of this area an ideal site for research. These carbonate mounds (Fig. 3), described by Wendt et al. (2001), were visited during the COCARDE Field Seminar. Open questions and potential topics of future research that arose during the field action and subsequent discussions include the overall tectonic and paleogeographic depositional setting, oceanic circulations (e.g. currents and trophic regimes) and the overall ecological and physical conditions that triggered mound growth. These ancient, truly bioclastic mound systems with limited diagenetic alteration, representing bioclastic frameworks intercalating with siliciclastic deposits, may be compared to the recent biogenic carbonate mound build-ups as we encounter them nowadays along the continental margin off Ireland at intermediate water depths.

Figure 3. View from eastern flank of a Visean mound to the next mound further west.

(3) Devonian Kess Kess mounds and Hollard mound: the scenery of this location allows walking on an ancient seafloor (Fig. 4). Together with the Carboniferous mounds described by Wendt et al. (2001), both are scientifically considered to be world heritage carbonate mound outcrops, truly representative to compare ancient mound systems with recent carbonate mound settings. Here we had a demonstration of how methane seepage and hydrothermal fluid circulation influence the mound development and the distribution of the taxa, which allows comparison to the mud mound and coral carbonate mound settings of the Recent Gulf of Cadiz.

(4) Seep-related Silurian mound: the Silurian methane-derived mound of the Middle Atlas represents the oldest known seep carbonate accumulation. Since a number of geological and paleobiological attributes document chemosynthetic processes fueled by fluid seepage, it represent a potential excellent geologic example for in-depth studies on very ancient seep carbonates.

Figure 4. Conical mounds of the Hamar Laghdad (Kess Kess mounds) on a gently dipping seafloor surface (view to NW).

3. Scientific Outlook

3.1 COCARDE OPERATIONS – short-term actions

In the margin of the workshop and field seminar, some task groups could discuss and refine the operational aspects related to the ongoing LIMODRILL ICDP proposal (forthcoming ICDP workshop application, technical specifications of the drilling and logging operations, budgeting, further fund raising, etc.) and the imminent proposal for a German cruise and MeBo drilling on offshore mounds in the Alboran Sea (Melilla mounds) and in the Gulf of Cadiz (Pen Duick escarpment).

3.2 COCARDE SCIENCE – mid- to long-term perspectives

Discussions in the field already identified the need of further investigation and potential carbonate mound drilling initiatives. The ***Jurassic sponge mounds*** from Morocco need detailed diagenetical and geochemical analyses. Opportunities for collaborative projects could develop for instance between the University of Provence, SE France and the University of Marrakech, Morocco, to foster a better understanding of early and late diagenetic processes affecting mound build-up and preservation.

Further investigations on the ***Carboniferous Waulsortian mounds*** should focus on (1) the basal beds, upon which the mounds grew; (2) a critical quantification of mud content, from which microbial precipitation was inferred in the initial study by Wendt et al. (2001), because skeletal components (particularly crinoids) appear very abundant and dominant in the sites visited; (3) the growth dynamics of the entire system (mound core, mound flanks, mound cover beds). Furthermore, (4) comparison to modern mound systems would help to constrain the controlling factors, as pointed out during the field action. Future investigations on the well-exposed Waulsortian mounds in Morocco may significantly improve our knowledge of these enigmatic systems, so common worldwide during the Early Carboniferous. Such investigations appear ideal for collaborative projects involving research groups in Morocco (e.g. Prof. Naima Hamoumi at the University of Rabat, who expressed interest in setting up a research project on Waulsortian mounds). Former scientists from the University of Tübingen (Wendt, Kaufmann, Belka who know well this area and the nearby mounds in Algeria) should be contacted for advice and collaboration.

The exceptional record of Moroccan Paleozoic mounds of the eastern Anti-Atlas, in particular the ***Devonian Kess-Kess mounds***, urge for a good regional geologic mapping and clarification of the chronostratigraphic framework. For future research on this subject the following lines should be developed 1) refined field analyses, in particular comparative investigations of the geometry of the bodies and their facies distribution; 2) the use of the new generations of laboratory techniques; 3) a comparative analysis with modern mounds and their geometries; 4) paleobiological in-depth analyses of invertebrate and microbiological communities. As far as the microbiota is concerned, the tools of investigations should take into account the different types of morphological evidences as well as the molecular evidences (chemo-fossils), possibly preserved in the mounds cement. Some of the above approaches have been undertaken for the conical mounds of the Hamar Laghdad (Kess-Kess mounds) for explaining their (not yet completely explored) genetic processes. They deserve, however, a more systematic approach and the collection of large data sets, with the collaboration of PhD students (from Morocco and abroad). In such ventures, a truly multidisciplinary approach will shape invaluable opportunities. The geologists of the Université Cadi Ayyad, Marrakech (ref. Prof. Kamal Taj-Eddine) and their international partners no doubt have interest for future developments of this research field.

The ***Silurian methane-derived mound*** of the Middle Atlas, presented by Bologna scientists and their partners, represents the oldest known seep carbonate accumulation. Since a number of geological and paleobiological attributes document chemosynthetic processes fueled by fluid seepage, it represent a potentially excellent geologic example for in-depth studies on very ancient seep carbonates. A favorable location (proximity to a main asphalted road) and a reduced aerial extent of this geologic body may also permit to plan drilling operations with a limited budget in order to better investigate key aspects related to the formation and development of the accumulation, which can hardly be settled because of the covering by vegetation and agricultural fields. The drilled material might also provide a complete set of unweathered rocks suitable for standard geochemical investigations (as well as for new geochemical exploration concepts).

3.3 Industry perspectives on mounds

Carbonate mounds are reported throughout the stratigraphic record from the Proterozoic to the Present. They developed on continental margins, in water depths ranging from 1000 to 10's of meters, and represent a target for hydrocarbon exploration. In the past years, there were a number of hydrocarbon discoveries in carbonate mounds, deposited in shallow to deep-water environments, some of significant size. A large part of these objectives were originally misinterpreted as reefs or other carbonates buildups. As per an industry point of view, exploration for carbonate mound targets is a challenging problem.

The main criteria for defining carbonate mounds and particularly deep mounds as valid oil industry objectives imply their identification, location, reservoir potential and petroleum system.

(1) Identification: how to identify and characterize mounds on seismic data, defining simple guidelines to avoid confusion with other carbonate objects, or worse, with volcanoes or mud volcanoes.

(2) Location: what controls their potential location, i.e. where (basin type, continental margin), when (stratigraphic zones prone for their development), and accessory conditions (structural environment, oceanic characteristics).

(3) Questions like "What is the size of the potential tank?" or "What are the general diagenetic trends for these mounds?" help to identify the reservoir potential taking the negative factors of cementing and recrystallization, as well as the positive factors such as fracturing and karst *sensu largo* into account.

(4) For the petroleum system with the potential of oil, the source rock identification (basin type and stratigraphic zones), the burial history, the timing of expulsion/migration, the reservoir creation, and the formation of associated seals need to be identified.

Some of these topics are achieved through bibliographic search or actual mounds studies, on outcrops and cores (marine and continental drilling). They can contribute to a proper basin synthesis. The study of diagenetic processes would require analyses from samples, process evaluation and assessment of the opportunities for development and modeling.

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ANNEXES

Annex 1:

Programme and Abstract Book of COCARDE Workshop, Rabat, Morocco, 24.–30.10.2011

Annex 2:

Participants list of the COCARDE Workshop and Field Seminar, Rabat, Morocco, 24.–30.10.2011

Annex 3:

Financial Report

EUROPEAN SCIENCE FOUNDATION
SETTING SCIENCE AGENDAS FOR EUROPE

COCARDE

FWO VLAANDEREN
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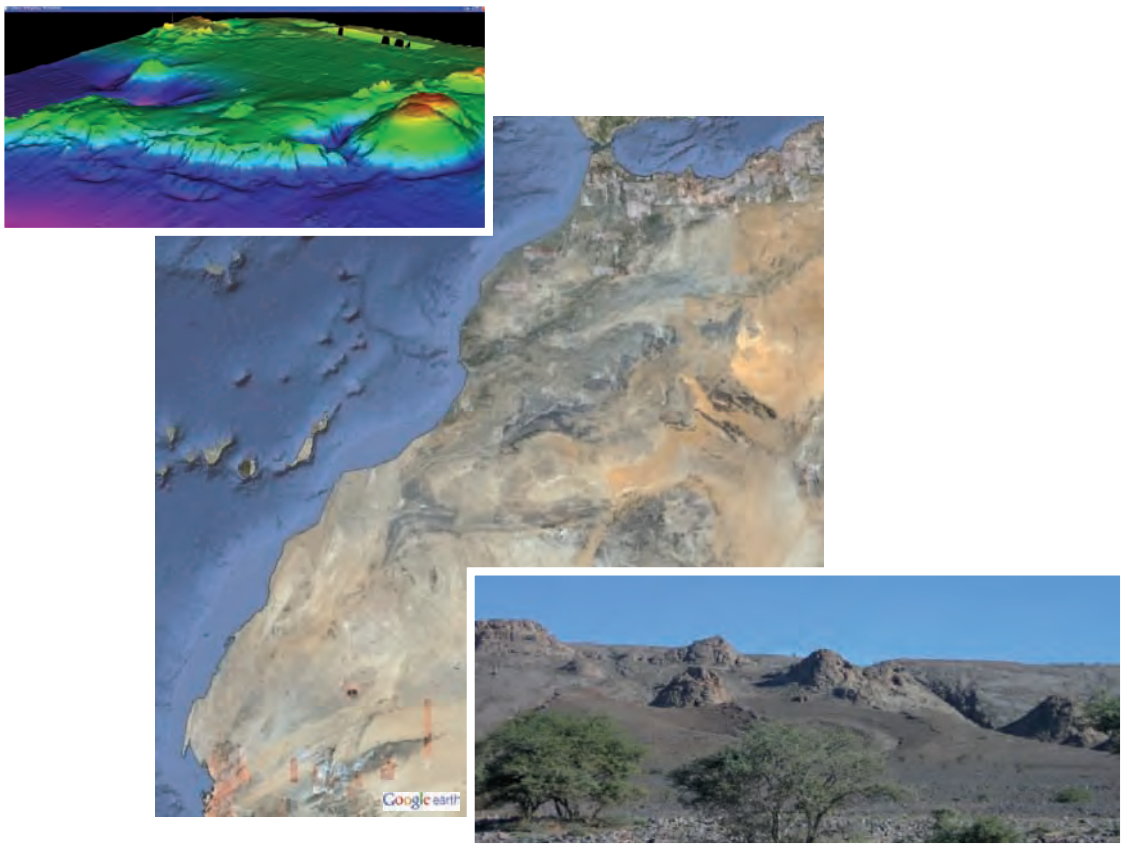
Research Foundation – Flanders

Cocarde Workshop and Field Seminar

Recent and Ancient Carbonate Mounds in Morocco

Rabat, Morocco,
24-30 October 2011



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Mohammed V - Agdal University
Faculty of Sciences Rabat
UNIVERSITEIT GENT
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ONHYM

Honorary committee

Prof. Waiil BENJELLOUN	President of Mohammed V - Agdal University, Rabat
Prof. Abdellatif MIRAOUI	President of Cadi Ayad University, Marrakech
Prof. Noureddine MOUADDIB	President of International University of Rabat
Prof. Said AMZAZI	Dean of the Faculty of Sciences, Rabat

Participating Institutions

Belgium	Ghent University
	Leuven University
France	IOC-UNESCO, Paris
	TOTAL Exploration & Production, Pau
	Université de Provence, Marseille
	Université Paul-Sabatier, Toulouse
Germany	MARUM, Bremen University
	IFM-GEOMAR, Kiel
Ireland	University College Cork
Italy	Bologna University
	Milano-Bicocca University
	Pescara University
Morocco	Cadi Ayad University, Marrakech, Faculty of Sciences Semlalia and Faculty of Sciences and Technics Gueliz
	Hassan II Mohammedia-Casablanca University, Faculty of Sciences Ben Msik
	Ibn Battuta Center, Marrakech
	Ibn Tofail University, Kenitera, Faculty of Sciences
	International University of Rabat
	Mohammed V - Agdal University, Rabat, Faculty of Sciences
	ONHYM
South Africa	Johannesburg University
Switzerland	Fribourg University
	Geneva University
The Netherlands	VU University Amsterdam
	TU Delft

Conveners of the Workshop (Rabat, October 24-25)

Dr. Amane FETTHALLAH	International University of Rabat, Head of the department of continuing education
Prof. Naima HAMOUMI	Mohammed V - Agdal University, Rabat, Chair GBCP-Morocco Consortium (IOC-UNESCO Geosphere-Biosphere Coupling Processes Programme).
hon. Prof. Jean-Pierre HENRIET	Ghent University, Belgium, Coordinator Cocarde – ICA
Dr. Idriss HILALI	International University of Rabat, Head of the department of innovation and renewable energy
Dr. Haddou JABOUR	ONHYM, Rabat
Dr. Andres RÜGGEBERG	Cocarde-ICA support officer (workshop scientific and financial management)

Objectives of the Workshop

Some 10 years after the first reporting of Recent carbonate mounds off Morocco, the 2011 Cocarde workshop in Rabat offers an opportunity to assess achievements of past oceanographic cruises and to exchange views about prospective actions in the future.

In coherence with Cocarde's capacity building and its vision on a holistic approach of carbonate mounds through geological time as a key to fundamental and applied insights and breakthroughs, the workshop is introduced by a full-day, open-access tutorial event, conceived as a voyage through time, space and Geosphere-Biosphere coupling processes in Recent and Ancient carbonate factories in Morocco.

The second day will be available for targeted strategic meetings, to discuss possibly innovative approaches in carbonate mound research in Morocco on Recent and Ancient mounds - offshore and onshore - and to review opportunities of international collaboration.

Organizers of the Field Seminar (High Atlas and Tafilalt, October 26-30)

Prof. Roberto BARBIERI	Bologna University, Italy
Prof. Driss CHAFIKI	Cadi Ayad University, Marrakech
Dr. Barbara CAVALAZZI	University of Johannesburg, South Africa
Prof. Naima HAMOUMI	Mohammed V - Agdal University, Rabat
Prof. Gian Gabriele ORI	Annunzio University, Pescara, and Ibn Battuta Center, Marrakech
Prof. Kamal TAJ-EDDINE	Cadi Ayad University, Marrakech

Objectives of the field seminar

A task group of Moroccan and European scientists, with a mix of senior scientists and PhD and postdoctoral researchers, will visit a number of field outcrops of carbonate mounds and carbonate factories from Ordovician to Jurassic ages in the Central High Atlas and eastern Anti-Atlas. An objective is the assessment of the documentation – in a collaborative effort – of a potential "Moroccan mound reference route" for capacity building and international outreach purposes.

Programme of Workshop – Monday, 24.10.2011

Mohammed V - Agdal University,
Faculté des Sciences, Avenue Ibn Batouta Agdal, Rabat

Time			
		Chair: Naima Hamoumi and Amane Fethallah	
9:00	***Opening Session***	Prof. W. Benjelloun, President of Mohammed V - Agdal University, Rabat – *Welcome*	
		Dr. Alexei Suzyumov, IOC-UNESCO – *Welcome*	
9:15		Jean-Pierre Henriet	*Recent and Ancient Carbonate Mounds in Morocco: objectives and structure of the workshop*
		Chair: Touria Hsaida and Alexei Suzyumov	
9:30	***A voyage through time***	Naima Hamoumi	*The Ordovician system of Morocco: sedimentation controls and paleogeography*
9:50		Roberto Barbieri	*Silurian seep carbonates of the Moroccan Meseta: paleobiological issues and problems of interpretation*
10:10		Fulvio Franchi	*Overview of the geology of the Devonian Kess-Kess mounds of the Anti-Atlas, Morocco*
10:30		COFFEE BREAK	
		Chair: Silvia Spezzaferri and Rachid Essamoud	
11:00	***A voyage through time***	Elias Samankassou	*Late Palaeozoic carbonate mounds: Architecture and controlling factors*
11:20		John J.G. Reijmer	*Jurassic carbonate platforms in Morocco*
11:40		Joseph Canérot	*Cretaceous mudmounds of the Pyrénées*
12:00		Dierk Hebbeln	*Recent Mounds on the Moroccan margin: distribution, forcing from glacial/interglacial to actual times*
12:20		General discussion	
12:35		LUNCH	
		Chair: Bodil Lauridsen and Kamal Taj Eddine	
14:00	***Zooming in on processes and methods***	Silvia Spezzaferri	*Foraminifera as significant components of Recent and sub-recent carbonate mounds*
14:20		Anneleen Foubert	*Paleo-environmental fingerprint and diagenetic overprint in the Plio-Pleistocene carbonate mound record*
14:40		Philippe Léonide	*Shallow burial carbonate-silica diagenesis in a Middle Jurassic stromatactis carbonate mud-mound, SE France*
15:00		Andres Rüggeberg	*Proxy studies: how to proceed from Recent to Past*
15:20		General discussion	
15:35		COFFEE BREAK	
		Chair: Anneleen Foubert and Haddou Jabour	
16:00	***Zooming out - scientific drilling, industry perspective and planetary outlook***	Tim Freudenthal	*Coring and drilling at sea and on land*
16:20		Patrice Imbert	*Carbonate mounds vs. seep carbonates: processes and petroleum implications*
16:40		Philippe Lapointe	*Hydrothermal karst process-like modeling of Palaeozoic complex mounds*
17:00		Gian Gabriele Ori	*Mud volcanoes in the geologic record of Mars - the role of methane and carbon dioxide in geological processes*
17:20		General discussion	
	Poster	Driss Chafiki	*Palaeoenvironment and geodynamic setting of the Jurassic carbonate buildups on the Midelt Errachidia section (Central High Atlas, Morocco)*

Programme of Workshop – Tuesday, 25.10.2011

Time		ONHYM	
9:00	***Round Table @ ONHYM***	***Round Table @ ONHYM*** *Salle DG Campus, ONHYM,* *3A Avenue Al Fadila, Yaakoub Al Mansour, Rabat* ***Collaborative Scientific Drilling***	
10:30			

International University of Rabat, Rocade Rabat Salé

Chair: Driss Chafiki and Patrice Imbert

14:00	***Workshop on Field Seminar***	Naima Hamoumi	*Geological overview of the High Atlas (Kamal Taj-Eddine) and eastern Anti-Atlas*
14:20		Barbara Cavalazzi	*The Hollard Mound: a very special Devonian conical mound of the Anti-Atlas, Morocco*
14:40		Flash presentations (3 slides / 5 min.) of the COCARDE Grantees:	
		Boris Dorschel	*Internal tides and cold-water coral mounds*
		Awatif Habid	*Palynological studies (dinoflagellate cysts) in the Essaouira Basin*
		Fulvio Franchi	*The Kess-Kess conical mounds and their potential as terrestrial analogues of Martian buildups*
		Abdelhafid El Ghini	*Carbonates dating by U/Th method*
		Helen Hamaekers	*In vitro bio-reactor experiments to understand early diagenesis in cold-water carbonate mounds*
		Rachid Lakbouchi	*Stages of the Triassic sedimentation basin "Benslimane, Berrechid, El Gara - BenAhmed" in the Western Meseta*
		Bodil Lauridsen	*Danian cool-water coral mounds from Faxe, Denmark – Reconstruction of the ecosystem*
		Keltoum Abazine	*Monitoring the environmental radiation*
		El Houssaine El Kabous	*The Ordovician of the SW Anti-Atlas: petrology, facies and sedimentary environments, sequence stratigraphy*
		Claudio Stalder	*Foraminifera associated to cold-water coral ecosystems*
		Mohamed El Amine Hazim	*Stratigraphy and sedimentary environment of carbonate mounds in the Gulf of Cadiz*
		Agostina Vertino	*Modern and past cold-water coral mounds from the Mediterranean: a close look at the carbonate biofacies*
15:30		COFFEE BREAK	
16:00	***Round Table @ UIR***	***Round Table @ UIR*** ***Collaborative Ocean Science and Reservoir Research***	
17:30			

Programme of the Field Seminar

Wednesday 26 October: Rabat – Errachidia, Liassic sponge mounds

Overview of the geology of the High Atlas. Jurassic carbonate mound sites along the transect Midelt -Errachidia: Liassic sponge mound Nzala (Stop 1), Foum Tillicht (Stop 2) and Tizi n'Firest (Stop 4) sections: stratigraphic, sedimentological and geodynamic context (Driss Chafiki). Bajocian buildups Assemeur n'ait Fergane (Stop 3), Tunnel de la Legion (Stop 5) sections (Abdellah Ait Addi). Call of the day.

Thursday 27 October: Errachidia – Erfoud, Ordovician stratigraphy and Devonian Kess Kess mounds

Ordovician bryozoan biostrome near Erfoud (Naima Hamoumi). Devonian Kess Kess mounds and Hollard Mound in the Hamar Laghdad, Tafilalt platform, hydrothermal activity (Roberto Barbieri, Kamal Taj-Eddine, Barbara Cavalazzi and Fulvio Franchi). Cretaceous red beds (dinosaurs site) (Gian Gabriele Ori and Kamal Taj-Eddine). Call of the day.

Friday 28 October: Maider Basin, Guelb el Maharah Kess Kess and Aferdou el Makrib reef

Maider Basin and underway stratigraphic sites (Naima Hamoumi and Kamal Taj-Eddine). Guelb el Maharah Kess Kess (Roberto Barbieri), Aferdou el Makrib Devonian reef (Kamal Taj-Eddine). Erg Chebbi at dusk. Call of the day.

Saturday 29 October: Ordovician Alnif bryozoan build-ups, Ibn Battuta Mars missions test site

Alnif Upper Ordovician bryozoans mounds in a ramp setting, controlled by glacio-eustatic variations and detritic fluxes (Naima Hamoumi). Ibn Battuta site for testing human operations on Mars (ESA, NASA, Geobiology programmes, ExoMars mission 2016) (Gian Gabriele Ori). Rissani. Call of the day.

Sunday 30 October: Erfoud – Rabat, M'rirt chemosynthetic deposits

Return to Rabat and underway visit of the oldest chemosynthetic deposits on Earth – the M'rirt chemosynthetic body (Roberto Barbieri and Gian Gabriele Ori) and Silurian stratigraphy and paleogeography of Central Morocco (Naima Hamoumi)

Participants list

Workshop contributors

Keltoum Abazine
Benbouziane Abdelmjid
Abdellah Ait Addi
Roberto Barbieri
Waiil Benjelloun
Kahlid Bouziane
Joseph Canérot
Barbara Cavalazzi
Driss Chafiki
Ida Dell'Arciprete
Boris Dorschel
Abdelhafid Elghini
Rachid Essamoud
Amane Fetthallah
Anneleen Foubert
Fulvio Franchi
Tim Freudenthal
Karima Guernouch
Awatif Habid
Helen Hamaekers
Naima Hamoumi
Dierk Hebbeln
Jean-Pierre Henriet
Idriss Hilali
Touria Hssaida
Patrice Imbert
Haddou Jabour
El Houssaine El Kabous
Rachid Lakbouchi
Philip Lapointe
Choukri Majid
Salim Lahcini
Bodil Lauridsen
Philippe Leonide
Gian-Gabriele Ori
Fatima Oumalch
John Reijmer
Andres Rüggeberg
Elias Samankassou
Silvia Spezzaferri
Claudio Stalder
Alexei Suzyumov
Kamal Taj-Eddine
Hssaida Touria
Agostina Vertino

+ Licence and Master students of the universities:
  - Hassan II Mohammedia–Casablanca
  - Ibn Tofail Kenitera
  - Mohammed V–Agdal Rabat

Field Seminar task group

Abdellah Ait Addi
Roberto Barbieri
Joseph Canérot
Barbara Cavalazzi
Driss Chafiki
Ida Dell'Arciprete
Boris Dorschel
Abdelhafid Elghini
Rachid Essamoud
Anneleen Foubert
Fulvio Franchi
Tim Freudenthal
Awatif Habid
Helen Hamaekers
Naima Hamoumi
Mohamed El Amine Hazim
Dierk Hebbeln
Jean-Pierre Henriet
Haddou Jabour
El Houssaine El Kabous
Rachid Lakbouchi
Philippe Lapointe
Bodil Lauridsen
Philippe Leonide
Gian-Gabriele Ori
John Reijmer
Andres Rüggeberg
Elias Samankassou
Claudio Stalder
Kamal Taj-Eddine
Agostina Vertino

+ *6 drivers 4WD*

Travel and accomodation

Air travel via Casablanca.

Direct rail link between Casablanca airport and Rabat Agdal station.

Recommended hotel: Hôtel Ibis Moussafir, place de la Gare de l'Agdal (next Rabat Agdal station):

Single room (BB): 653 DH – *approx. € 57,-*

Double room (BB): 725 DH – *approx. € 63,-* (1 DH = 0.08725 EUR, July 2011)

Field seminar logistics

All participants should care for their own insurance. The field party will leave early in the morning from Rabat October 26 and will be back late in the evening of October 30. Therefore an extra night will have to be booked in Rabat (return flights October 31st). Hotel accommodation is booked in Erfoud. Lunch bags will be provided and consumed in the field. All transport, both on road and off road, will happen with 4WD vehicles, hence personal luggage should be minimal (soft bags). Participants should be prepared to long transfers on paved roads and to some rough off-road driving. Some walks will be needed to visit outcrops, hence good hiking boots are necessary. Hats, sunglasses and skin protection are compulsory. Heavy showers may occur.

Contacts

Naima Hamoumi naimahamoumi@yahoo.fr

Jean-Pierre Henriet jeanpierre.henriet@ugent.be

Andres Rüggeberg andres.ruggeberg@ugent.be

Abstracts (in alphabetical order of first author)

Silurian seep carbonates of the Moroccan Meseta: paleobiological issues and problems of interpretation

Roberto Barbieri [(1)], Barbara Cavalazzi [(2)], Gian Gabriele Ori [(3)]

[(1)] Dipartimento di Scienze della Terra G.-A., University of Bologna, Bologna, Italy;
[(2)] Department of Geology, University of Johannesburg, Johannesburg, South Africa;
[(3)] IRSPS, University D'Annunzio, Pescara, Italy, and Ibn Battuta Centre, Marrakech, Morocco

In the Meseta domain of the Middle Atlas (Morocco) is preserved an anonymous carbonate mound which has been interpreted as the oldest (latest Silurian) known fossil cold-seep ecosystem. Although the isotope geochemistry, which is one important diagnostic tool in support of carbonates derived from chemosynthetic processes fueld by fluid (hydrocarbon) seepage, do not provide unequivocal evidence, a combination of geological and paleobiological attributes may support this interpretation and include: i) carbonate accumulation surrounded by siliciclastic rocks; ii) a low diversity (monospecific) and extremely dense assemblage of invertebrates (atrypid brachiopods) within faunally impoverished lithologic units; iii) microbially- and other seep-derived carbonate phases; iv) bio-induced minerals. Differently from bivalve mollusks, which have the most extensive modern and fossil (especially Cenozoic) record of all organisms inhabiting hydrocarbon seeps, brachiopod occurrences are marginal to modern chemosynthetic environments associated with hydrocarbon seeps and have a mainly Paleozoic fossil record. This combination makes brachiopods unfit for a real uniformitarian approach. It is, however, undeniable that brachiopods can represent a key component of ecosystems such as the one in the Silurian mound of the Moroccan Meseta, where they are present in rock-forming abundances with articulated shells showing a complete range of growth stages. The above attributes suggest that these Silurian assemblages must have accumulated in situ, without the interference by mechanical deposition, such as storm aggregation or landslides. Whether brachiopds represent a genuine seep taxon, the role played in hydrocarbon seep environments, and whether these environments acted as refuges for relic (Paleozoic and younger) faunas are questions that still require in-depth investigation. In carbonate mound contexts, with sufficient evidences of hydrocarbon seepage, promising fields for continued research are represented by the interplay between microbial and invertebrate-rich limestones, their field and microscale relationships, and the comparative approach with modern analogues

Brachiopod shells in rock-forming abundances

The Izeste and Arudy Lower Cretaceous mounds (Western Pyrenees, France)

Joseph Canérot [(1)]

[(1)] Laboratoire des Géosciences de l'Environnement de Toulouse (G.E.T.) 14, avenue Edouard Belin, 31400 Toulouse, France. E-mail : jcanerot@live.fr

The presented Izeste and Arudy mounds are located in the south eastern edge of the West Pyrenean Cretaceous Mauleon trough. This basin was generated through transtension movements (N-S dominant distension with synchronous sinistral E-W wrench faulting) between Europe and Iberia. In this area, the local tectonic evolution leading to the creation of the trough involves 3 main stages: 1) elaboration of a huge Gargasian, Urgonian-type platform; 2) breaking up of this platform during the Uppermost Gargasian (Clansayesian) and creation of a tilted (Arudy) block dipping strongly towards the NE; 3) burial of this structure by active flysch sedimentation during the Albian interval.

The Arudy (left) and Izeste (right) mounds observed from the Larroun complex buildup (foreground).

The buildups outcrop in the Arudy and Izeste areas where they have been actively exploited during the last century in more than fifty quarries, providing the typical "marbre d'Arudy" which can be observed nowadays in many wings, doorways and chimneypieces of the old Bearnese houses. They consist of lenticular to dome-shaped carbonate bodies up to twenty meters high, involving mainly rudist or coral-reef forms. The rudist-bearing mounds correspond to grey limestones (wackestones) rich in Toucasia, associated with red algae (archaeolithothamnium, Agardhiellopsis, Paraphyllum…). They are mainly developed within the black marls of the Clansayesian Izeste formation, overlapping the Urgo-Gargasian Lazerque formation. The coral-bearing mounds are dark grey microbialites providing flat (Microsolenidid) or reef (colonial or solitary) corals and red algae. They appear in the Arudy area, at the transition between the western Upper Clansayesian carbonates (Urgo-Clansayesian platform) and the eastern synchronous Sainte-Colome black shales (basin). A karstic surface separates these Arudy buildups from the overlying Albian "Flysch Noir".

The birth, growth and death of the described mounds are closely linked both to the local geodynamic evolution during the creation stages of the Mauleon trough and the general sea level changes at the Aptian-Albian transition period. So, The Izeste and Arudy bodies appear respectively during the transgression and regression stages (transgressive and highstand systems tracts) of the Clansayesian cycle (3rd order sequence), when the slowly subsiding Urgonian platform turns to a tilted and rimmed shelf dipping strongly towards the NE. The big size of the last mounds involving water escape structures gives evidence for an increasing subsidence rate towards the Aptian-Albian boundary. Finally, a general unconformity corresponding to a submarine erosion surface indicates

the death of the carbonate constructions and the rapid change from platform to deep marine conditions, leading to the general deposition of the Albian Flysch Noir formation.

Key-words: Gargasian, Clansayesian, Albian, mudmounds, palaeoenvironment, sea—level change, Izeste, Arudy, Western Pyrenees, France.

The Hollard Mound: a very special Devonian conical mound of the Anti-Atlas, Morocco

Barbara Cavalazzi [(1)], Fulvio Franchi [(2)], Roberto Barbieri [(2)], Gian Gabriele Ori [(3)]

[(1)] Department of Geology, University of Johannesburg, Johannesburg, South Africa;
[(2)] Dipartimento di Scienze della Terra G.-A., University of Bologna, Bologna, Italy;
[(3)] IRSPS, University D'Annunzio, Pescara, Italy, and Ibn Battuta Centre, Marrakech, Morocco

A Middle Devonian mound located in the eastern part of the Hamar Laghdad Ridge (eastern Anti-Atlas), known in the geological literature as Hollard Mound, is a partially eroded, large conical mound with a recognizable and well exposed core facies and lateral deposits consisting of different Ca-carbonate phases. Differently from the other conical mounds cropping out in the Hamar Laghdad Ridge (the Kess-Kess mounds), a combination of paleobiological, geochemical, petrographic, and geomicrobiological attributes, mostly concentrated in the core facies, support an important contribution of hydrocarbon (methane) seepage during its growth. Macro- and micro-faunal assemblages that typify the core facies of this mound include dense accumulations of articulated bivalves and the worm tubes, microbial remains and microbial fabrics. The Hollard Mound is among the oldest and better preserved known paleo-cold seep.

Monospecific bivalve assemblage from the core facies of the Hollard Mound

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Palaeoenvironment and geodynamic setting of the Jurassic carbonate buildups on the Midelt Errachidia section (Central High Atlas, Morocco)

Driss Chafiki [(1)], Abdellah Ait Addi [(1)], Joseph Canerot [(2)], Abdellatif Souhel [(3)], Ralf Löwner [(4)]

[(1)] Laboratoire de Géosciences et Environnement, Faculté des Sciences et Techniques Guéliz, BP. 549, Marrakech, Maroc. E-mail : chafiki@fstg-marrakech.ac.ma , Fax. (212) 5 24 43 31 70
[(2)] Laboratoire des Géosciences de l'Environnement de Toulouse (G.E.T.), Université Paul-Sabatier, 14 avenue Edouard Belin, 31400 Toulouse, France. E-mail : jcanerot@live.fr
[(3)] Département de Géologie, Faculté des sciences, Université Chouaïb Doukkali - B.P. 20 - El Jadida 24 000, Maroc. E-mail : abdellatif.souhel@yahoo.fr
[(4)] Technische Universität Berlin, Institut für Angewandte Geowissenschaften, FG Explorations-geologie - Sekr. ACK 1-1 Ackerstraße 76 D-13355 Berlin. E-mail : ralf.loewner@tu-berlin.de

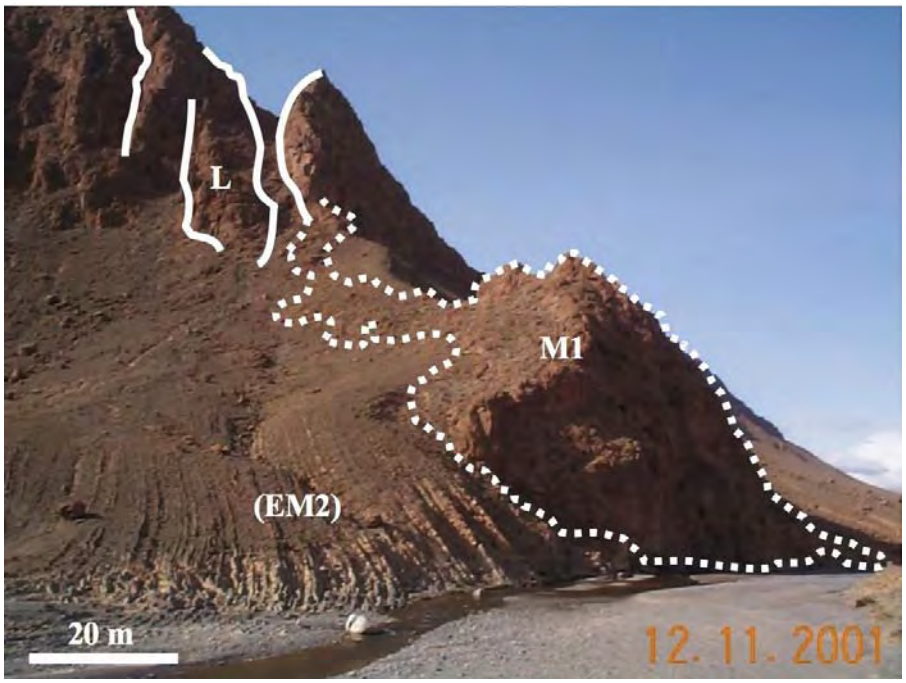
The Jurassic history of the Central High Atlas of Morocco is characterized by the strong development of carbonate mounds. Along the Midelt-Errachidia section, these buildups belong to two main stages of active carbonate sedimentation within the Lower Liassic and the Bajocian-Lowermost Bathonian periods.

The first stage is represented by carbonate mudmound-like constructions well developed towards the Lower-Upper Sinemurian boundary, between Tizi n'Firest to the south and Nzala to the north. These structures present a local evolution in the Foum Tillicht area within the Upper Sinemurian interval. The outcrops show single small-sized buildups at the base of the sequence and change to complex and high-sized forms at the top. Their sedimentologic and palaeontologic features indicate microbialite sponge-bearing bodies developed in deep, open marine, subphotic environments, at the base of the storm wave zone.

The second stage, Bajocian to Lowermost Bathonian in age, is represented mainly by reef-like constructions organized vertically into three different layers. The first one H1, located in the Aalenian to Lower Bajocian interval, observed in the Foum Zabel area, south of Tizi n'Firest, is made up of small-sized bodies involved in a reef carbonate platform. The second layer H2, developed during the Bajocian period in the Assemmeur n'Ait Fergane area, corresponds to higher sized patch reefs developed on a carbonate ramp. The third layer H3 observed close to Tazigzaout, Upper Bajocian (?)-Lowermost Bathonian in age, is represented by structures very similar to the preceding ones. The Aaleno-Bathonian buildups are mainly composed of coral-growth forms first branching and threadlike in H1 layer then massive (colonial or solitary) small-sized bodies in H2 and H3 layers where they are associated to sponges, algae, bryozoa and to a rich neritic macrofauna. The immaturity and brittleness of these buildups indicate lack of early cementation related to unfavourable ecological conditions opposed to the big development of the reef-builders.

The studied Jurassic constructions appear often at the top of the regressive half cycles (third and second orders) and can reach the base of the following transgressive half cycles. The appearance and strong development of these bodies must be related to the following main factors: 1) morphology of the sea floor controlled by tectonic processes; 2) nature and deepness of the deposits; 3) sedimentation rate. The transition from the Sinemurian mudmound-type, microbialite sponge-bearing buildups to the Aalenian-Lowermost Bathonian real coral-bearing reefs is closely related to the evolution of these factors. The final vanishing period of the mounds and coral-reef complexes respectively towards the Sinemurian-Carixian boundary and within the Lowermost Bathonian interval, indicates new subsiding conditions generating strong terrigenous flows in the Lowermost Carixian and filling up of the basin during the Bathonian stage.

Key-words: Sinemurian, Bajocian-Bathonian, carbonate buildups, morphology, palaeoenvironment, geodynamics, Midelt-Errachidia section, Central High Atlas, Morocco.



Dome shaped mound (M1) (EM2) on the right bank of Oued Nzala. The buildup is distended on its N oriented upper part (right); it contracts in its middle part, extends southward (left) and joins the last lense-shaped mounds (L) of the underlying Idikel Fm (EM1). The surrounding bedded sediments correspond to the Upper Sine-murian Aberdouz Fm. Foum Tillicht section.

Paleo-environmental fingerprint and diagenetic overprint in the Plio-Pleistocene carbonate mound record

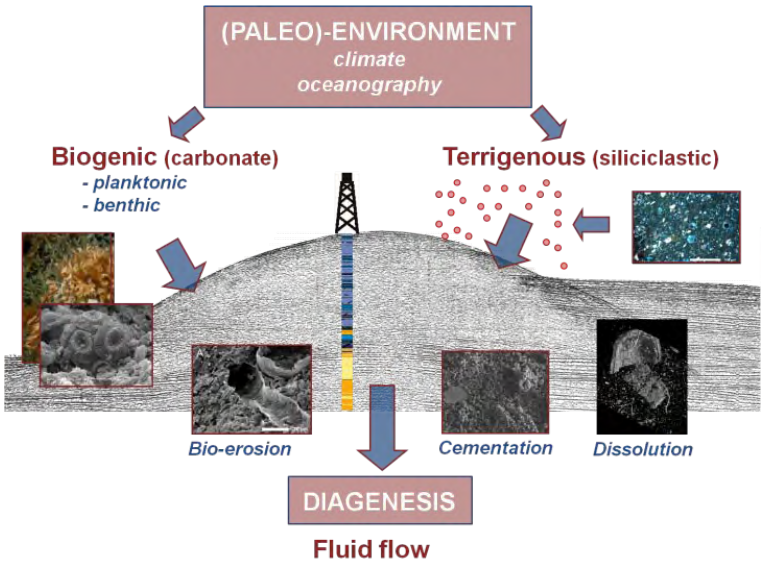
A. Foubert [(1)], A. Rüggeberg [(2)], H. Pirlet [(2)], M. Thierens [(3)], T. Frank [(4)], C. Wienberg [(5)], J.-P. Henriet [(2)]

[(1)] Department of Earth and Environmental Sciences, K.U. Leuven, Heverlee, Belgium, (anneleen.foubert@ees.kuleuven.be)
[(2)] Renard Centre of Marine Geology, Ghent University, Gent, Belgium
[(3)] Alfred-Wegener-Institute für Polar- und Meeresforschung, Bremerhaven, Belgium
[(4)] Department of Geosciences, University of Nebraska-Lincoln, Lincoln, USA
[(5)] MARUM, University Bremen, Bremen, Germany

Sub-recent carbonate mounds are important, yet often underestimated, paleo-environmental archives in mid- to deeper slope environments. Along mixed siliciclastic-carbonate-dominated continental margins they record high-resolution paleo-environmental signals which are not registered in the surrounding sediments. During IODP Expedition 307, the 150 m tall Challenger mound in Porcupine Seabight (Belgica mound province, SW of Ireland) was drilled aboard the R/V Joides Resolution, revealing the paleo-environmental history of a complete carbonate mound section. The mound is built from top to bottom of cold-water coral fragments embedded in an alternating biogenic (carbonate-rich) to terrigenous (siliciclastic) matrix (Foubert & Henriet, 2009). This creates a cyclicity which is considered to be driven by glacial-interglacial changes. Magnetostratigraphy and datings show that the mound started to grow between ~2.70 and ~2.50 Ma.

The primary paleo-environmental architecture of sub-recent carbonate mounds is well characterized. However, early diagenesis overprints often the primary environmental record (e.g.

aragonite dissolution) (Foubert & Henriet, 2009). The 155-m high Challenger mound and mounds from the Gulf of Cadiz (Moroccan margin) will be discussed in terms of (paleo)-environmental fingerprints and early diagenetic overprints. Early differential diagenesis overprints the primary environmental signals in Challenger mound, with extensive coral dissolution and the genesis of small-scaled semi-lithified layers in the Ca-rich intervals. The low cementation rates compared to the extensive dissolution patterns can be explained by an open-system diagenetic model. Along the Moroccan margins, fluid seepage and fluxes in pore water transport affect the development of mound structures, enhancing extensive cold-water coral dissolution and precipitation of diagenetic minerals such as dolomite, calcite, pyrite, etc. (Foubert et al., 2008). Recent carbonate mounds provide indeed an excellent opportunity to study early diagenetic processes in carbonate systems without the complications of burial and/or later meteoric diagenesis. Moreover, approaching the fossil carbonate mound record, through a profound study of sub-recent carbonate bodies will help to better understand processes observed in the fossil mound world (such as cementation, brecciation, fracturing, etc…).



Schematic overview illustrating paleo-environmental fingerprint and diagenetic overprint in the 150 m tall Challenger Mound (Belgica Mound Province, Porcupine Seabight, SW of Ireland (modified after Foubert & Henriet, 2009).

References

Foubert, A., & Henriet, J.P. (2009) Nature and Significance of the Recent Carbonate Mound Record: The Mound Challenger Code. Lecture Notes in Earth Sciences, Vol. 126. Springer, 298 pp. ISBN: 978-3-642-00289-2.

Overview of the geology of the Devonian Kess-Kess mounds of the Anti-Atlas, Morocco

F. Franchi [(1)], B. Cavalazzi [(2)], R. Barbieri [(1)], G.G. Ori [(3)]

[(1)] Dipartimento di Scienze della Terra e Geologico Ambientali, Università di Bologna, Bologna, Italy (fulvio.franchi2@unibo.it, roberto.barbieri@unibo.it)
[(2)] Geology Department, University of Johannesburg, Auckland Park, South Africa (cavalazzib@uj.ac.za)
[(3)] IRSPS, Università "G. d'Annunzio", Pescara, Italy (ggori@irsps.unich.it) and Ibn Battuta Centre, Marrakech, Morocco

The Devonian cone-shaped carbonate mounds, informally called Kess-Kess, cropping out in the Hamar Laghdad ridge (eastern Anti-Atlas of Morocco), were the subject of many studies since the early decades of the past century.

These cone shaped mounds developed in the Tafilalt basin, which is one of the non-folded intracratonic basin formed during the closure of the western Paleo-Tethys in the Early Devonian. The Kess-Kess buildups, entirely composed by stromatactis bearing wackestone organized in decimeters thick layers, grew on the top of a 100 meters thick crinoidal limestones unit deposed during the Pragian and the early Emsian in an epicontinental sea after a punctual submarine volcanic event. Then the conical mounds were drowned during a major transgression and consequently covered by deep marine marlstones and nodular carbonates.

The origin of these mounds has long been debated. First theories range from the tectonic folding, the hydrodynamic accumulation and the biogenic origin comparing the Hamar Laghdad conical mounds to modern atolls of the South Pacific. More recently was postulated that the muddy sediments were locally derived (authigenic carbonate) and lithified at an early stage by hydrothermal activity. Furthermore in the last years divers studies reported the presence of methane rich fluids during the formation of the neptunian dikes along the whole thickness of the crinoidal limestones.

All the discussions about the Kess-Kess genesis must account for several key considerations: the limestones unit were deposed above a volcanoclastic morphological high and late magmatic fluids circulated in the whole succession influencing mineral composition, geochemical signatures and paleo-guilds. Further it must be taken into account the presence of anomalous mineral associations within the crinoidal limestone as Fe-rich mineral aggregations, pisolitic crusts and idiomorphic dolomite crystals which derived from the fluids circulation.

Coring and drilling at sea and on land

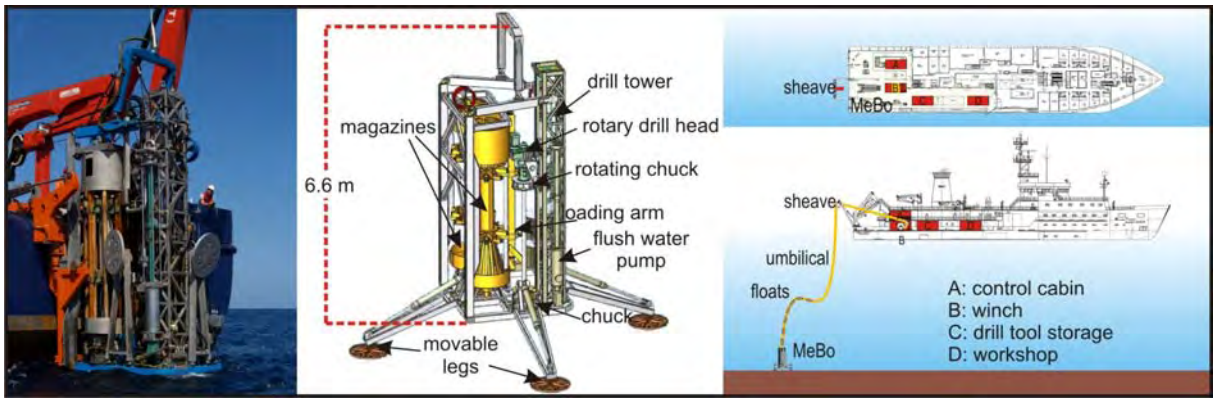
T. Freudenthal

Marum Center for Marine Environmental Sciences, University of Bremen, Germany (freuden@marum.de / +49-421-21865602)

Rotary core drilling is a standard method for sampling sedimentary and crystalline rocks. Both conventional drilling and wire line drilling are widely used methods. In both cases it is the advancing of the drill string with a drill bit at the lower end by rotary action (and washing) that causes a core to be extracted inside the drill string. This core is collected by the inner core barrel. Conventional drilling requires repeated recovery of the entire drill string each time the end of stroke is reached.

The recovery of a drilled core is much faster using the wire line method where the inner core barrel is hooked up inside the drill string using a latching system connected to a wire No casing is needed for wire-line drilling since the drill string stays in the drilled hole during the entire drilling process. The disadvantage of wire-line drilling is that the drill bit requires a bigger kerf which results in a reduction of drill speed. Water is used in most cases with additives influencing the viscosity for cooling the drill bit and flushing away the drill cuttings. Especially in desert areas the need for flush water may be the major challenge for the drilling project.

Lack of water is not an issue when drilling at the sea floor. Usually a drill ship is used for hard rock drilling at the sea floor. A drill string is built up from the drill tower on the vessel through the water column in order to sample the sea floor. For shallow drillings robotic drill rigs that are deployed on the sea floor and controlled from the vessel are a cost effective alternative. Since the sea bed drill rig is not effected by ship movements due to currents or waves, optimal control on drill bit pressure required for excellent core quality can be assured by this type of drill rigs.



The sea floor drill rig MeBo was developed at the Marum Center for Marine Environmental Sciences at the University of Bremen. Up to 70 m long cores can be drilled both in soft sediments and hard rocks.

The Ordovician system of Morocco: sedimentation controls and paleogeography

Naima Hamoumi

Laboratory "Oceanology and Geodynamics of Sedimentary basin" Mohammed V-Agdal University, Rabat, Morocco

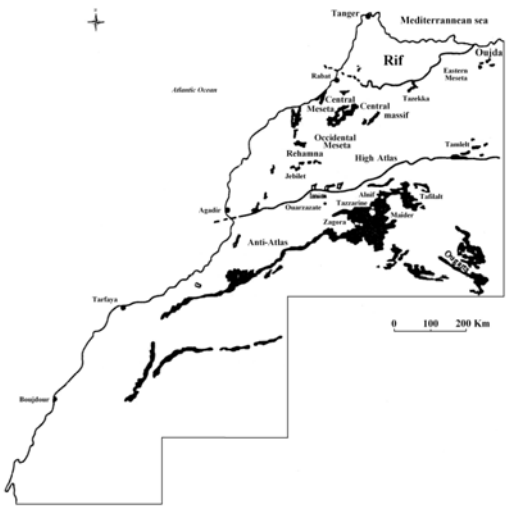
The Ordovician series are widely exposed in all structural domains of Morocco, especially in the Anti-Atlas where, there are some remarkable successions in both extent and quality of outcrop and where, here is a continuous succession from the Tremadoc to the Ashgill. The first synthesis based essentially on paleontological and stratigraphic data in the framework of mapping and mining exploration and regional monographs, allow to establish the detailed lithostratigraphy and to recognize the record of upper Ordovician glaciation, especially in the Anti Atlas. They also conclude that the Ordovician series are characterized by the same monotonous facies and belong to a wide shallow platform. Detailed sedimentological studies undertaken since 1982 leads to several conclusions concerning the sedimentary environments, the palaeography and the sedimentary basin dynamic and controls

The Ordovician sedimentation occurred in north gondwanan Moroccan margin, in two sedimentary basins: the "Mesetian basin" of north-east/south west direction in the western part of Morocco including the Moroccan Meseta, the western High Atlas and the north western Anti-Atlas domains

and the “atlasic basin” of east-north-east/west-south-west direction in the southern part of Morocco including the south western Anti-Atlas, the central and eastern Anti-Atlas and the central and eastern High Atlas domains.

These two basins were initiated by peripheral intracratonic rifting of the Gondwana during early Infra-Cambrian (possibly late Precambrian). During the lower and middle Ordovician period, they acted, both of them as epeiric shelves that were dominated by shifting of the subsidence centres (reactivation stage), block faulting associated some times with basic volcanic flows and eustasy. The sediments are mostly siliclastic with minor intercalations of carbonate lenses, glauconitic sand, oolitic ironstones and localised volcanic and pyroclastic rocks in the eastern Anti-Atlas (Jbel Siguenit) and coastal Meseta. The sedimentation took place in tide and /or waves and storms dominated nearshore and shelf environments and tides and/or storm dominated deltas.

During the Upper Ordovician, the paleogeography of the two epeiric shelves was widely modified under the interplay of the glacial climate and a major extensional event. The glacial climate induced eustatic sea level fluctuations and new transport mechanisms (cold wind and glaciers). The tectonic event created a NE-SW through in the “mesetian basin” and two NW-SE through and a mosaic of carbonate platform in the “atlasic basin”. The sediments are mostly siliciclastic deposits (mainly coarse sand derived from the Saharan ice sheet) and carbonate from bryozoan mounds and banks. The paleogeography was widely modified by these two events and a various environments occurred: glacial fjords, marine outwash fjords, mesotidal to macrotidal estuary, tidal flat, high energy waves and/or storms dominated beach, waves and storms dominated front delta, prodelta, cold (frost dominated) peritidal mixed siliciclastic/ carbonate high energy beach, carbonate platform, storms dominated continental shelf ice distal (muddy shelf, offshore transition zone, shoreface), tides and storms dominated temperate shelf (prograding sand ridge, tidal banks), mixed waves and tides temperate nearshore (ebb tidal delta), storms dominated temperate shelf (shoreface), delta slope, deep sea fan.



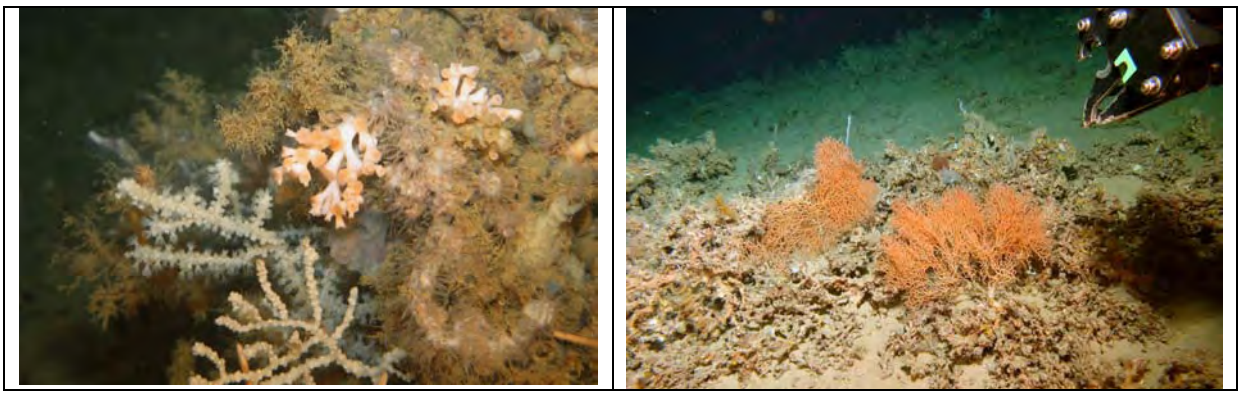
Recent Mounds on the Moroccan margin: distribution, forcing from glacial/interglacial to actual times

Dierk Hebbeln

MARUM, University of Bremen, Germany, dhebbeln@marum.de

Over the past decade numerous (sub-)recent coral carbonate mounds have been discovered along the Moroccan margin. Following early discoveries along the Moroccan Atlantic margin, such mounds also have bee detected along the Moroccan Mediterranean margin. Compared to the famous giant coral carbonate mounds of Ireland, which can be as high as reaching 350 m above the sea floor, the Moroccan mounds are generally much smaller with heights rarely exceeding a few tens of meters. Sea floor sampling as well as detailed ROV (remotely operated vehicle) observations revealed that indeed also the Moroccan mounds have been built up by cold-water corals. In 2002 a cluster of up to 60 m high coral carbonate mounds has been discovered on top of the Pen Duick Escarpment off

Larache at the northern Moroccan Atlantic coast. The location of these Pen Duick Mounds, located in 500 m to 600 m water depth, appears to be linked to the escarpment setting. However, such pronounced topography is not essential as becomes obvious from the extended fields of small-sized coral carbonate mounds slightly deeper between 800 m and 1000 m water depth. Considering only the small parts of the Moroccan margin that have been surveyed in detail so far, the number of these small mounds will be in the hundreds, at least. In 2006 a cluster of mound structures was discovered in the Western Mediterranean just off the Moroccan coast near to the Spanish enclave Melilla. First detailed investigations of the so-called Melilla Mound Field by ROV revealed a variety of cold-water coral settings related to the different structures ranging from mounds to elongated ridges occurring in water depths of 200 m to 400 m water depth. Interestingly, when comparing the cold-water corals building-up these mound structures on both sides of the Strait of Gibraltar, a marked difference became obvious: along the Moroccan Mediterranean margin, coral growth commenced after a long break approx. 14 kyr ago resulting in presently vital cold-water coral communities. In contrast, along the Moroccan Atlantic margin coral growth, and, thus, mound growth, was restricted to the last glacial period ending approximately 10 kyrs ago. Consequently, despite intense investigations, hardly any living cold-water coral has been observed along the Moroccan Atlantic margin. Thus, the coral carbonate mounds in this region are almost entirely composed of fossil coral framework, leading to the term “coral graveyards” in describing these settings. The basic driver behind these opposing patterns on both sides of the Strait of Gibraltar appears to be ocean productivity. Contrasting changes in ocean productivity controlled the food supply to the cold-water corals and, thus, finally their vitality. Presently, food availability along the Moroccan Atlantic margin appears to be insufficient to support large cold-water coral ecosystems. However, present well-suited conditions along the Moroccan Mediterranean margin support vital cold-water coral ecosystems, in which the cold-water corals serve as ecosystem engineers, providing on the short-term ecological niches for a highly diverse community and creating on the long-term impressive sea floor structures.



Sea floor images revealing the contrasting settings along the Moroccan Mediterranean and Atlantic margins, with active cold-water coral growth in the Melilla Mound Field (left) and dominating “coral graveyards” in the Atlantic (right).

Recent and Ancient Carbonate Mounds in Morocco: objectives and structure of the workshop

Jean-Pierre Henriet [(1)], Naima Hamoumi [(2)], Andres Rüggeberg [(1)]

[(1)] Renard Centre of Marine Geology, Ghent University, Belgium
[(2)] Faculty of Sciences, Mohamed V – Agdal University, Rabat Morocco

Some 10 years after the first reporting of Recent carbonate mounds off Morocco, the 2011 Cocarde workshop in Rabat offers an opportunity to assess achievements of past oceanographic cruises, and to exchange views about prospective actions in the future.

In coherence with Cocarde's capacity building and its vision on a holistic approach of carbonate mounds through geological time as a key to fundamental and applied insights and breakthroughs, the workshop is introduced by a full-day, open-access tutorial event, conceived as a voyage through time, space and Geosphere-Biosphere coupling processes in Recent and Ancient carbonate factories in Morocco.

The second day will be available for targeted strategic meetings, to discuss possibly innovative approaches in carbonate mound research in Morocco on Recent and Ancient mounds - offshore and onshore - and to review opportunities of international collaboration.

A task group of Moroccan and European scientists, with a balanced mix of senior scientists and PhD and postdoctoral researchers, will next visit a number of field outcrops of carbonate mounds and carbonate factories from Ordovician to Jurassic ages in the Central High Atlas and eastern Anti-Atlas. The potential documentation of a "Moroccan Mound Reference Route" for academic and industrial research and capacity building may be assessed.

Through the variety and quality of the outcrops of fossil carbonate mounds – some of them truly exhumed seascapes – and the offshore natural laboratories readily available for mound processes research, Morocco might once qualify for a "UNESCO Carbonate Mound World Heritage Site", meeting the criteria of *outstanding examples representing major stages of Earth's history, including the record of Life, significant on-going geological pro-cesses in the development of landforms, and significant geomorphic and physiographic features*.

Carbonate mounds vs. seep carbonates: processes and petroleum implications

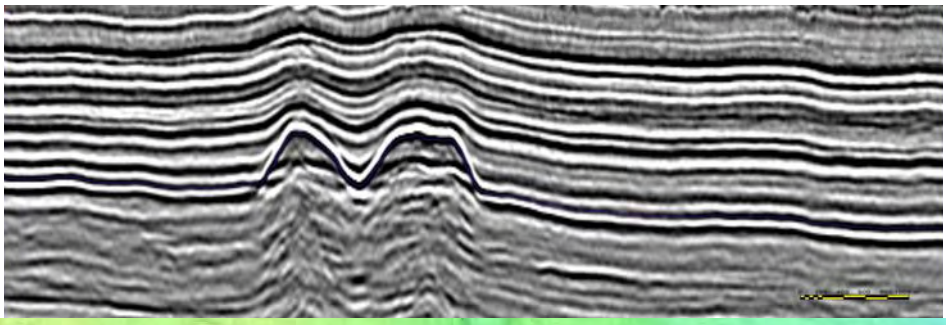
P. Imbert, TOTAL

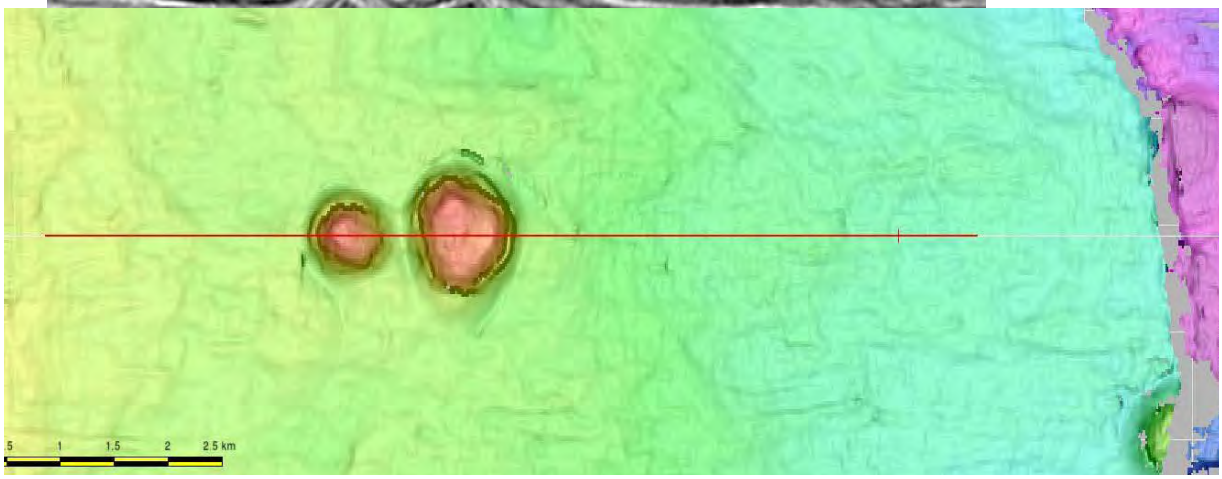
The reservoir potential of carbonate mounds gives them an obvious interest for oil and gas exploration. On a more subtle scale, the oil industry also has an interest in the potential of isolated, out-of-context carbonate bodies as indicators of (past) hydrocarbon seeps. Small subcircular carbonate patches are commonly interpreted as seep carbonates, especially when they are associated with pockmarks or similar features. Big mounds are rather thought of as potential reservoirs. But are these assumptions justified?

According to the "hydraulic theory" (Hovland and Risk, 2003), most carbonate mounds / deep-water coral reefs bear evidence to subsurface fluid (hydrocarbons preferred) circulation, which is clearly appealing to oil and gas explorationists. This theory has been challenged in recent years, and the debate is still open.

It is proposed here to depart from this "yes or no" picture, and could be summarized as follow: are there any indications from the morphology or context of the mounds (shape, size, alignment, presence or absence of a "root", relationship with structural features, time of occurrence) that could help define a "potential as a hydrocarbon indicator"?

Several examples from known petroleum basins will illustrate the topic and highlight the need for an integrated approach based on a combination of ancient and modern analogues, in various contexts, not neglecting relatively small things that are now within the reach of seismic resolution.





Hydrothermal karst process-like modeling of Palaeozoic complex mound

Philippe A. Lapointe, TOTAL E&P

Carbonate mounds are reported throughout the stratigraphic scale from the Proterozoic to the Present. They developed on continental margins or intra-platform environments, in water depths ranging from 10 to 1000 m and represent targets for hydrocarbon exploration. In Kazakhstan, the recent discoveries of giant hydrocarbon accumulations have generated renewed interest in these distinctive carbonate deposits. An understanding of ancient and recent carbonate mounds systems in particular those drilled by leg IODP 307 provides a tool to appraise potential hydrocarbon-bearing subsurface mound carbonates as well as provide a complement to classic outcrops studies.

The comparative analysis of mound evolution – focusing on early to late diagenetic processes, products and patterns – in the recent and ancient deposits provides new insights into reservoir porosity and permeability. In these carbonate reservoirs heterogeneity is primarily driven by diagenetic patterns and karst processes are one of the most critical diagenetic phases for carbonate reservoir development.

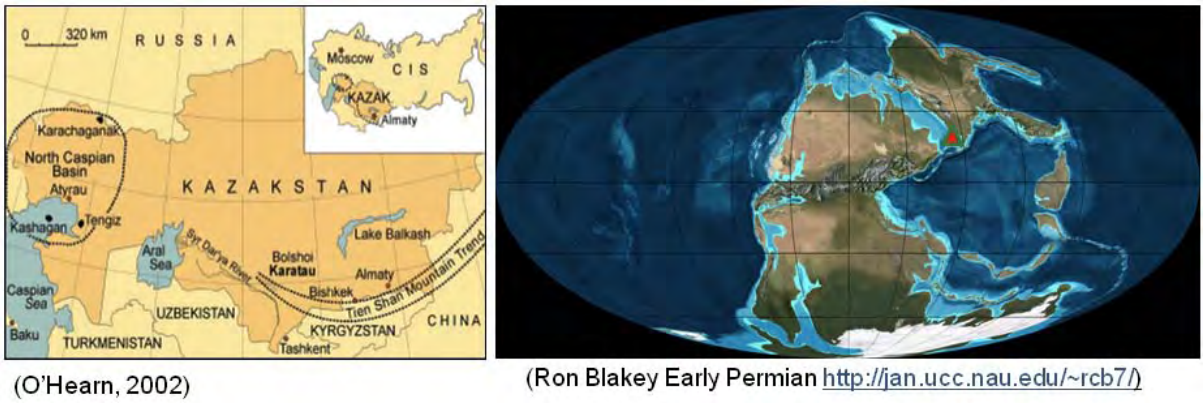


Figure 1. Geographic and time location of the Permian mound presented

Static and dynamic reservoir models are used to assess their potential; these models are populated by integrating data from core, log and analogue. Sedimentological interpretations, including the distribution of the depositional facies elements (massive, bedded cap and off-mound facies), are validated through core integration with outcrop analogue data. Coeval outcrop analogs providing geometries are rare; modern counterparts allow a better evaluation due to their undisturbed state and relative abundance as they develop large mound provinces. They allow populating the single mound elements in the mound complex structure devised through the seismic interpretation, leading to a primary 3D distribution of depositional facies, later modified by the diagenetic overprint. The main reservoir enhancement is related to hydrothermal overprint that follows the faults and syn-sedimentary fracture corridors providing a rather strong vertical control. Mapping of the actual reservoir remains critical for predicting the best distribution of porosity and permeability and the prognosis of future production well locations, particularly for horizontal or highly deviated wells. The geological modeling of the structure is based on Jacta, toolbox allowing the quantification of subsurface uncertainties. Based on nested stochastic simulations, it integrates all uncertainties from structural to reservoir properties and quantifies their impact on final volumes. The Jacta Karst module (TOTAL in house developed software) is dedicated to integrate complex karstic features in the reservoir model. Based on sedimentological knowledge and stochastic algorithms, it allows the construction of karst conduits or chambers from various origins, meteoric, mixing or hydrothermal. The overall result is a geologically constrained model.

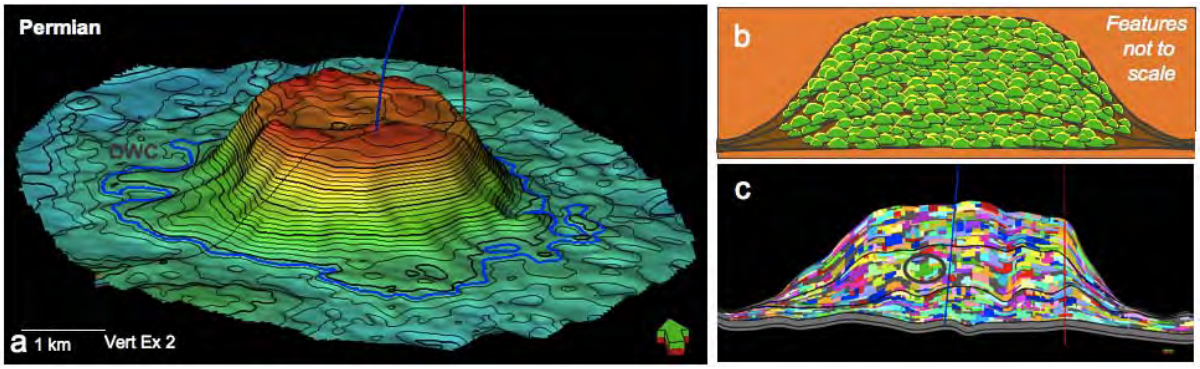


Figure 2. a) 3D overview of the deep water mound complex, b) interpreted structure made of different smaller scale mounds, c) slice of the geological model interpreting the individual mound units concept

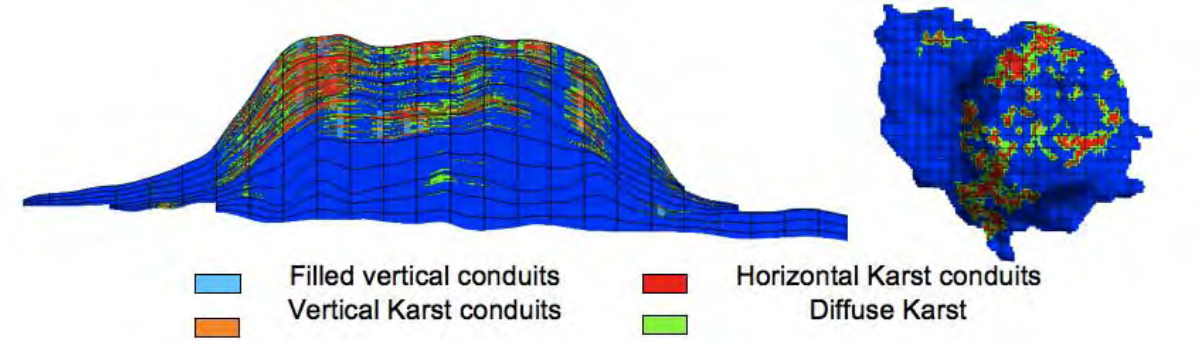


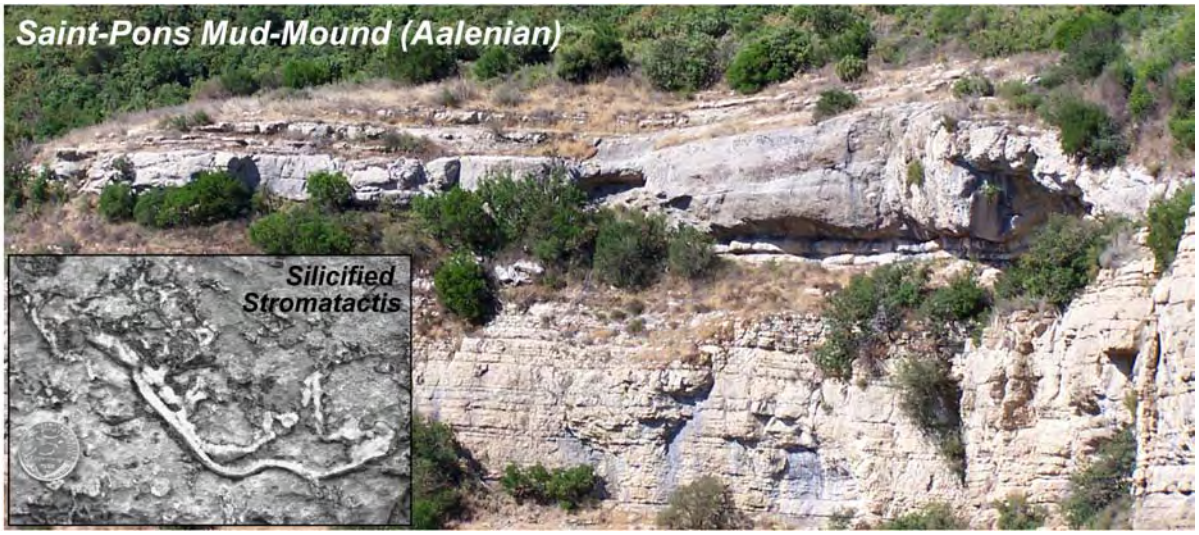
Figure 3. Cross section and planar view of the final karst model showing the vertical and horizontal conduits as well as the diffuse karst

Shallow burial carbonate-silica diagenesis in a middle Jurassic stromatactis carbonate mud-mound, SE France

Philippe Leonide, Marc Floquet, Fritz Neuweiler

Stromatactis carbonate mounds exposed in the Sainte-Baume Massif (Basse Provence, France) developed in an outer shelf environment during the late Aalenian concavum ammonite zone (Middle Jurassic). They form part of a cherty succession that is punctuated by hardgrounds and stratigraphic condensation.

These mounds are included in the upper part of the Cherty Reddish Limestone Formation of Carixian to earliest Bajocian age. The mound presented herein is of late Aalenian age, belonging to the concavum ammonite Zone, concavum and formosum ammonite subzones.



Various lithofacies shaped by siliceous sponges characterize the Southern Provence sub-Basin. Four lithofacies are distinguished: 1) sponge biostromes dominated by lithistid sponges; 2) stromatactis mud-mounds 10s to 100s of meters across and composed of hexactinellids and some lithistid sponges; 3) well-bedded limestone that contains platy hexactinellids, and 4) sponge mud-mounds (small, <10 m) dominated by lithistid sponges and devoid of stromatactis. The distribution of these lithologies follows the overall tectonic structure of the Southern Provence sub-Basin. Stromatactis mud-mounds are typically present on the outer edge of tilted blocks.

These mounds are similarly rich in sponge spicules and stromatactis as their Paleozoic counterparts but the Aalenian stromatactis mounds are silicified, a feature that makes them unique. Petrography, fabric, as well as carbon and oxygen stable isotope values indicate that four generations of carbonate polymud fabric of the mound formed in the marine diagenetic environment. Because the Aalenian mounds retained their silica in solution until shallow burial acidification occurred, stagnant conditions (low diffusion, low advection) are required. Numerical simulation of silica flux supports the fundamental control played by fluid barriers and stratigraphic condensation. There is good evidence that non-silicified Paleozoic stromatactis mounds were buried more rapidly and more continuously, being part of lower parts of shallowing-upward trends. By contrast, this unique case of early silicification of a stromatactis mud-mound appears to be linked to deepening events and tied condensed sections that combine fluid barriers (hardgrounds, marls) with protracted shallow burial conditions.

Jurassic carbonate platforms in Morocco

John J.G. Reijmer

VU University Amsterdam and TU Delft

The basin evolution of the Jurassic basins and associated carbonate platform development can be tied to two main tectonically induced sedimentary phases associated with the Mesozoic break-up of Pangea and the opening of the Proto-Atlantic. Two carbonate platform development phases can be distinguished in the Jurassic carbonate succession outcropping in the High Atlas, a Lower and an Upper Jurassic phase. The sediments deposited during these phases unconformably rest on the Hercynian basement.

The Lower Jurassic carbonate platform development phase ended in the Toarcian when the Lower Jurassic carbonate platforms drowned. This drowning probably resulted from processes related to a rapid sea-level rise, which also may be associated with renewed crustal extension characterized by rapid subsidence, and ecological changes related to the Early Toarcian oceanic anoxic event. This drowning was succeeded by period in which deep-water Toarcian hemipelagic marls were deposited. The Jbel Bou Dahar carbonate platform (Fig. 1) shows aforementioned development in great detail.

The second phase of platform development occurred during the Middle Jurassic. During this period shallow-water carbonate ramps prograded into the basin in an eastward direction. A decrease in overall accommodation space development enabled this process.

Tectonic instability (Late Lias-Early Dogger), associated with a relative high sediment supply, resulted in a change of platform geometries, from a rimmed platform to a ramp type of platform, during the Aalenian-Bajocian. The Amellago outcrop transect (High Atlas, Morocco), is a good representative of this type of carbonate platform development.

Jurassic carbonate platforms in Morocco thus show a large variety of sedimentation styles within different types of carbonate sedimentary environments. Both aforementioned field laboratories show these aspects in full detail.

Jbel Bou Dahar (High Atlas, Morocco). A well-preserved Lower Jurassic carbonate platform that drowned at the beginning of the Toarcian. Note the upper edge of the platform (present-day mountain edge) and the steep present-day mountain slopes, which that agree with the morphology of the original carbonate platform slopes.

Proxy studies: how to proceed from Recent to Past

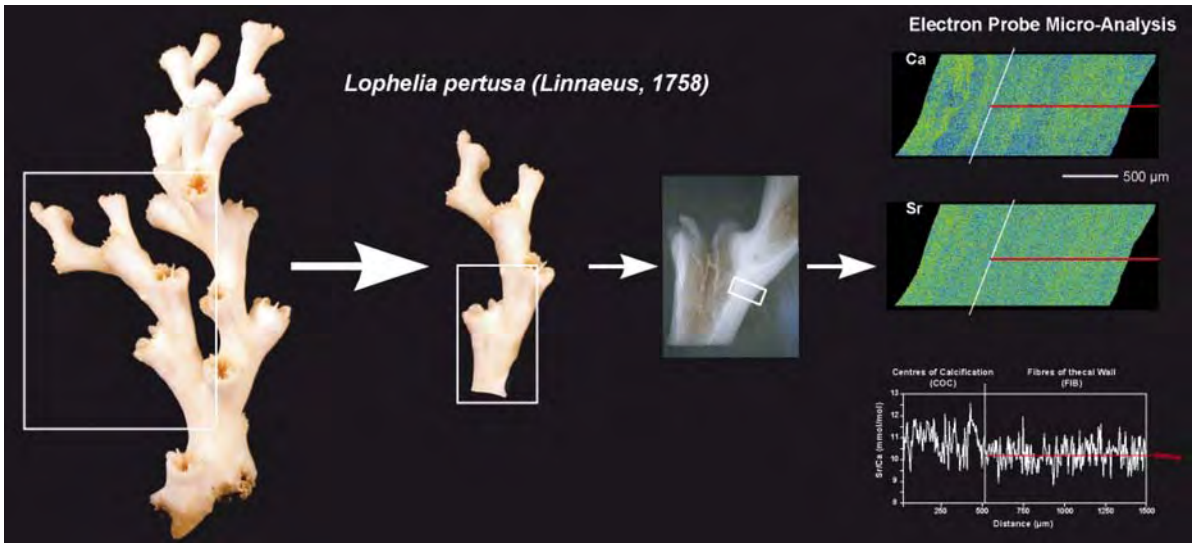
Andres Rüggeberg [(1)], Jacek Raddatz [(2)], Wolf-Christian Dullo [(2)]

(1) Renard Centre of Marine Geology, Ghent University, Krijgslaan 281, S8, B-9000 Gent, Belgium (andres.ruggeberg@ugent.be)
(2) Leibniz-Institute for Marine Sciences, IFM-GEOMAR, Wischhofstr. 1-3, D-24148 Kiel, Germany

In the past ten years paleoenvironmental reconstructions have given us new insight into our understanding of the functioning and the development of recent carbonate mounds. Based on these studies we can link occurrence and development of coral carbonate mounds off Ireland with certain environmental and climatic parameters that support and allow the coral reefs to flourish, to baffle sediments and to re-colonize elevated substrates.

However, limitations occur in the use of proxies such as stable isotopes, element ratios, faunal assemblages, grain-size parameters, to reconstruct the palaeoenvironment of ancient carbonate mounds. Limiting factors are be related to compaction of sediments, including early to late diagenetic overprint (temperature and pressure increase, influencing fluids and brines), as well as evolutionary faunal changes.

In this presentation some proxies and their use to reconstruct the palaeoenvironment of carbonate mounds and their potential for reconstruction in deep time will be presented and discussed. Paleoceanographic and -environmental reconstructions are important to understand carbonate mound systems and their settings but both methods and tools may substantially change when addressing old geological settings. A critical evaluation of both methods and tools is a pre-requisite for any research aimed to compare modern carbonate mound systems with ancient possible analogues.



Cold-water coral *Lophelia pertusa* as paleoenvironmental archive. High-resolution analysis of calcium (Ca) and strontium (Sr) on electron probe indicate annual growth pattern, but also differences in incorporation of Sr/Ca between the early calcification phase of the young coral (COC) and the later coral growth (FIB).

Late Palaeozoic carbonate mounds in Northern Spain: Architecture and controlling factors

Elias Samankassou

University of Geneva, Section of Earth and Environmental Sciences, CH-1205 Geneva, Switzerland (Elias.Samankassou@unige.ch)

Carbonate platforms and mounds are widespread and well exposed in marine Pennsylvanian deposits of the Cantabrian Mountains, Northern Spain. The presentation focuses on case studies originating from two localities in the northern of León. The first highlights the composition and growth dynamics of two large mound complexes outcropping near the village of Puebla de Lillo and evaluates the impact of siliciclastic input on mound growth. The second, based on a preliminary study, presents a mound that developed upon a carbonate platform near the village of Valdorria.
The first case study reveals that mound complex nucleated and grew on preexisting paleoreliefs, keeping consistently growing at these specific settings. Paleoreliefs and siliciclastic input are the principal factors that controlled the shape, size and growth evolution. Furthermore, the identified internal architecture as mosaic of juxtaposed small bodies composing the complexes represents an important finding for mounds modeling and for better constraining reservoir heterogeneity, particularly for Upper Paleozoic deposits where reservoirs are widespread.
The second case reveals that the carbonate mound studied shows an aggradational architecture (Fig. 1) with low export to the adjacent basin. The early lithification of the buildup flanks is identified as the main factor promoting this growth mode.

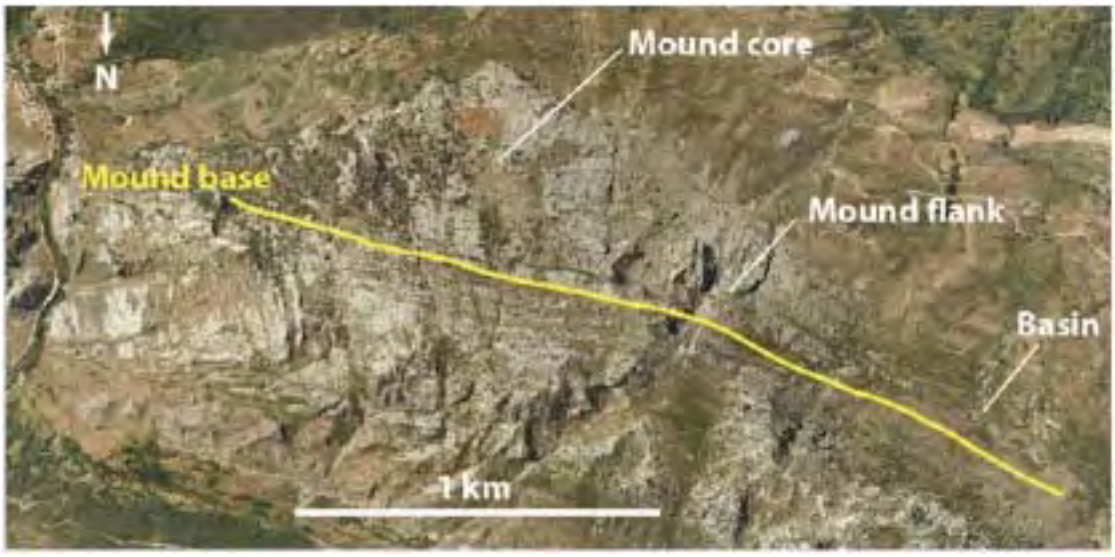


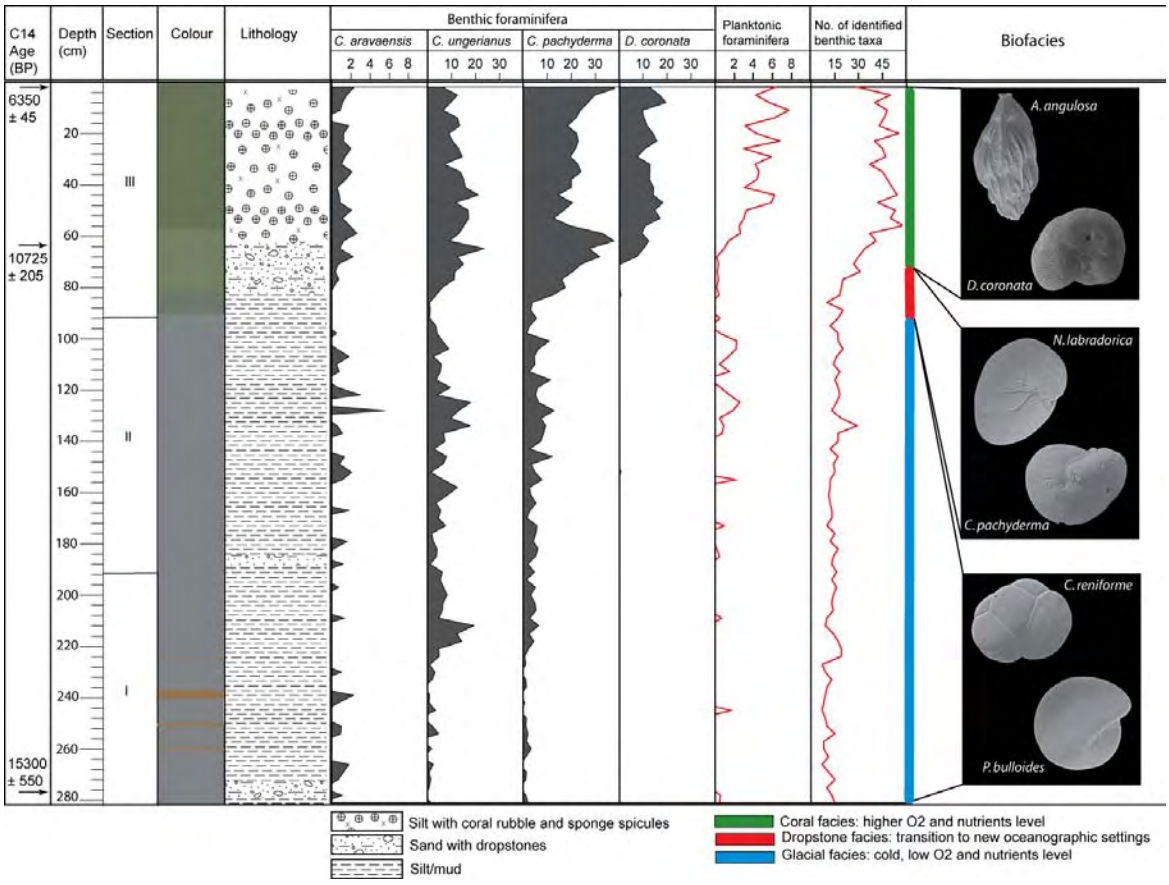
Fig. 1: Core and flank of the aggradational Valdorria carbonate mound, along with the adjacent basinal deposits, exposed near the village of of Nocedo (upper left).

Foraminifera as significant components of Recent and subrecent carbonate mounds.

Silvia Spezzaferi [(1)], Claudio Stalder [(1)], Claudius Pirkenseer [(1)], Andres Rüggeberg [(2)]

[(1)] Department of Géosciences, University of Fribourg, Chemin du Musée 6, 1700 CH-1700 Fribourg, Switzerland; silvia.spezzaferi@unifr.ch; Claudio.stalder@unifr.ch
[(2)] Renard Centre of Marine Geology (RCMG), Dept. of Geology and Soil Science, Ghent University, Krijgslaan 281 S8, B-9000 Gent BELGIUM; Andres.Ruggeberg@UGent.be

Nearly two decades of research on Cold-Water Carbonate mounds have illustrated a dominant oceanographic control in the life cycle of these mounds (Dorschel et al., 2005; Mienis et al., 2007; Huvenne et al., 2009; Thierens et al., 2010). Life, growth and demise of scleractinian coral reef is climatically controlled by a variability of physical, chemical and biological parameters (temperature, salinity, density, pressure, oxygen availability and currents, (Roberts et al., 2006); nutrient supply and availability of fresh labile organic matter (Davies et al., 2009) and density range of 27.35 to 27.65 kg m^{-3} (Dullo et al., 2008). These ecosystems are "hot-spots" for marine life and host a very diverse fauna composed of e.g., scleractinian corals, octocorals, sponges, foraminifera, hydrozoans, mollusks, bryozoans, echinoderms, polychaetes, crustaceans, and fishes with a biodiversity comparable to that of their warm water analogues.



Lithologic log of the gravity core POS391 559/3 from a cold-water coral reef off Lopphavet, Northern Norway, plotted versus the calibrated radiocarbon ages (AMS 14C, in years BP), abundances of epibenthic foraminifera (*C. aravaensis, C. ungerianus, C. pachyderma, D. coronata*) and planktonic foraminifera and total benthic foraminiferal taxa in the 250µm and 125µm size fractions. Sampling resolution is 3 cm.

In this presentation we show how benthic foraminiferal assemblages can be used to characterize the modern environment of carbonate mounds and discuss their potential for reconstruction in deeper time. Our research focus on quantitative analyses of benthic and planktonic foraminifera collected in the Porcupine-Rockall region (off Ireland, Lopphavet (Northern Norway) Alboran Sea (Mediterranean), in the age framework provided by AMS ^{14}C dating. These regions were and/or are sites of cold-water coral ecosystem settlement.

Recent assemblages from modern environments are compared with fossil assemblages spanning the intervals from 2230 ± 59 years BP and 15583 ± 185 years BP and around 7613 ± 38 years BP in the Alboran Sea, and from 2020 ± 150 years and 15300 ± 550 years BP along the Lopphavet margin. Our results indicate that benthic foraminifera assemblages associated to cold-water coral ecosystems in the three regions and in the investigated time intervals are remarkably similar with respect to the adjacent environments.

The living coral facies is always characterized by high abundances of epifaunal species *Discanomalina coronata*, *Cibicides* and *Cibicidoides* spp., whereas pelagic sediments barren of coral fragments are dominated by uvigerinids.

Although the importance of *D. coronata* as bioindicator for these environments is still in debate (Schönfeld at al., 2011) we can demonstrate that also in the sub-fossil record, this species is strictly associated to cold-water coral ecosystems, whereas, the remaining epifaunal species are more widely distributed in surrounding sediments.

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COCARDE Grantees (in alphabetical order)

Monitoring the environmental radiation

Keltoum Abazine

National Center for Energy, Science and Nuclear Techniques (CNESTEN), Kenitra, Morocco

The main goal of my future intership is to participate in a campaign of radiological monitoring program of the environment that the National Center for Energy, Science and Nuclear Techniques (CNESTEN) established.
The first phase of this program is to establish the baseline radiological of the site. For this, a methodology was adopted to determinate the points and nature of the taking of samples, as well as measurement's techniques to be implemented.
Analyses will be performed by the technique of gamma spectrometry, which allows giving qualitative and quantitative informations of all radionuclides gamma's radiation emitters present in the sample, on the one hand, these measures are used to determinate the existence of radionuclides initially present, on the other hand, after starting the system, to evaluate the impact and monitor the evolution and the contribution of the system in radioactivity in the environment.

Internal tides and cold-water coral mounds

Boris Dorschel

University College Cork, Ireland

The focus of my research is on marine geology with special emphasis on seabed and habitat mapping, cold-water coral mounds, sedimentary process on the continental margin and oceanography-continental margin interactions. Recent advances in marine remote sensing technologies (sidescan sonar, multibeam echosounder) have made it possible to map large areas of seabed revealing complex underwater morphologies in astonishing detail. These data sets allow for high resolution studies on habitats and sedimentary processes on the seabed. Cold-water coral mounds are biological hotspots on the continental margins. In order to understand these intriguing bio-geological structures, coral carbonate mound research addresses the complex interactions of biological, sedimentological and hydrographical processes leading to their formation. Towards a better understanding of the distribution of recent cold-water coral mounds, my recent research investigates the distribution of these mounds in relation to areas of enhanced energetic environments as a result of internal tides and continental margin interactions.

Carbonates dating by Th /U method

A. Elghini, O.K. Hakam, A. Choukri

Faculté des Sciences de Kénitra, Université Ibn Tofail Equipe de Physique et Techniques Nucléaires (LPRE)

The dating of the events of the late Quaternary, on an interval of time 0–350,000 years is made possible by the fact that in each of the two families of Uranium, the radioactive desintegration gives

rise to different elements. This method involves measuring the ratio $^{230}Th/^{234}U$ by physicochemical methods to deduce the date of crystallization. The materials involved are: marine carbonates such as Corals, Shells, phosphorites, marine ... Oolite; continental carbonates such as stalactites, stalagmites, draperies ...
My final project master studies concerns the determination of concentrations of Uranium and Thorium in the matrix of carbonates the subject of analysis. This analysis requires a chemical separation process led to separate isotopes of uranium and thorium from those to remove impurities in order to obtain pure deposits. The counting is made by using alpha spectrometry. These counts allow as determine the ages of the samples and bring the corrections that we need in case of open systems.

The Kess-Kess conical mounds and their potential as terrestrial analogues of Martian buildups

Fulvio Franchi

Dipartimento di Scienze della Terra e Geologico Ambientali, Università di Bologna, Bologna, Italy (fulvio.franchi2@unibo.it)

My PhD project concerns the study of the Devonian conical mound informally called Kess-Kess. My research was aimed by the recent discovery of hydrothermal mounds on the Mars surface and the detection of methane in Mars atmosphere which increased the interest for certain terrestrial geological bodies and their astrobiological potential. With this respect the Kess-Kess seem to be reliably interpreted as terrestrial analogues of some of the martian mounds for their supposed hydrothermal/methane seep related origin. A significant part of my PhD project is devoted on the reconstruction of the genetic agents and the definition of the astrobiological potential of these mounds. I'm also studying the ELDs formation and the related mounds in the southern Arabia Terra on Mars with particular attention for the peculiar formations of the Crommelin crater and Firsoff crater.

Palynological studies (dinoflagellate cysts) in the Essaouira Basin

Awatif Habid

Department of Geology, Faculty of Science Ben M'Sik, Casablanca, Morocco

The Essaouira Basin represents a segment of the Moroccan Atlantic margin, emerged from the Cenozoic in response to the Alpine orogeny in North Africa. Dinoflagellate cysts have always produced accurate stratigraphic results especially for the Jurassic-Cretaceous.
Thanks to their reliability, ONHYM (Office National des Hydrocarbures et des Mines), proposed us a revision of the old dating drills which are conducted in the Essaouira Basin. The present work reports the recent palynological investigations, using dinoflagellate cysts carried out on cores and drill cuttings from two hydrocarbon exploration wells, ESS-1 and GTE-1, from the Essaouira basin, provided by ONHYM (Office National des Hydrocarbures et des Mines).
The ESS-1 (Essaouira-1) well is located close to the coast and to the town of Essaouira (Mogador). Drilled by the SCP (Société Chérifienne des Pétroles) in 1968, it has penetrated some 700 m of Cretaceous sediments (Berriasian to Albian) and more than 2300 m of Jurassic sequences and ended in the Triassic claystones and salt, at a depth of 3087 m.

The GTE-1 (Guettata East) Well) is located in the Guettata structure, on the North- East of the Tidsi salt diapir. It was drilled by the SCP and has penetrated more than 1000 m of Cretaceous sequences (Berriasian to Albian) and about 1250 m of Jurassic units and ended also in the Triassic salt and claystones, at a depth of 2341.50 m.
Prior to our study, the two analyzed well sections, were established by SCP as Lias - Dogger, based on microfacies analyses and correlations.
These sections consist of several hundred-meter thick carbonate, shale and sandstone successions, interfingering with anhydrite and siltstone horizons. Their predominantly shallow shelf to marginal marine facies, have yielded to the SCP, some scarce Foraminifera, calcareous algae and macrofauna fragments, allowing only ill-defined age assignments.
The significant dinoflagellates cysts assemblages recovered from these two sections, have allowed us to precisely date the Pliensbachian - Toarcian, the Aalenian, the Bajocian, the Bathonian and the Callovian. Over 50 dinocysts species, belonging to 32 genera, have been recognized among the diverse organic-walled microfossils.
More studies are still needed to complete the present work but our findings are yet encouraging and the discovery for the first time of Liassic dinocyst taxa in the Essaouira basin is of major importance.

In vitro bio-reactor experiments to understand early diagenesis in cold-water carbonate mounds

Helen Hamaekers [(1)], Anneleen Foubert [(1)], Nico Boon [(2)], Rudy Swennen [(1)]

[(1)] Department of Earth and Environmental Sciences, K.U. Leuven, Leuven, Belgium
[(2)] Laboratory of Microbial Ecology and Technology, Ghent University, Gent, Belgium

During cruise 64PE284 of RV Pelagia, gravity cores have been taken through carbonate mounds in the Carbonate Mound Provinces (CMP) SE of Yuma mud volcano and N of Meknes mud volcano along the Moroccon margin. The geochemical characteristics of the sediments have been investigated with Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) and X-Ray Diffraction (XRD) to determine the influence of early diagenetic processes registered in these mounds. The presence of barite, pyrite, dolomite and gypsum as diagenetic minerals in the investigated cores has been proven and can be linked to Anaerobic Oxidation of Methane (AOM) coupled to bacterial sulphate reduction and a Sulphate-Methane Transition Zone (SMTZ) (Hamaekers et al., 2010). Also other studies highlight the importance of early diagenetic processes in such carbonate mound bodies (Foubert and Henriet, 2009).
To investigate these processes more in detail, experiments with a high-pressure bio-reactor will be performed. Precipitation of dolomite has already been detected during preliminary in vitro bio-reactor experiments. In a second phase, carbonate mound sediments will be put into the bio-reactor to understand early microbial induced diagenesis (carbonate precipitation and dissolution) through time.

References:

Foubert, A. & Henriet, J.P., 2009. Nature and significance of the Recent Carbonate Mound Record, The Mound Challenger Code. Springer, Berlin, 298 p.

Hamaekers, H., Foubert, A., Wienberg, C., Hebbeln, D. & Swennen, R., 2010. Geochemical characteristics and early diagenesis of recent carbonate mound sediments in the Gulf of Cadiz. Geophysical Research Abstracts, 12, EGU2010-11312-1.

Stratigraphy and sedimentary environment of carbonate mounds in the Gulf of Cadiz

Mohamed El Amine Hazim

Laboratoire Océanologie et Géodynamique des bassins sédimentaires Fac. Sc., Univ. Md. V-Agdal, Rabat, Morocco

Following the discovery of mud volcanoes related to hydrocarbon-rich fluid venting in the Moroccan margin of the Gulf of Cadiz during the TTR9 cruise onboard of the RV Professor Logatchev, this area has been subjected to many studies that were conducted during the cruises (to TTR10 TTR 17, CADIPOR I CADIPOR II, MD 140 PRIVILEGE, Pelagia MICROSYSTEMS Biodiversity and ESF 08). These studies have identified several other provinces of mud volcanoes and occurrences of carbonate mounds and cold water corals (CADIPOR 2002) In addition to its scientific interest for understanding the geodynamics of the Africa-Europe plate boundary, the Gulf of Cadiz is a natural laboratory for understanding the mode of genesis of mud volcanoes and cold water corals and the relations existing between them. The Gulf of Cadiz has also an undeniable interest for oil exploration in Morocco.
The objectives of the thesis are:

- Reconstruction of the Stratigraphy and sedimentary environments of the carbonate mounds
- To precise the nature and the origin of sediments associated with carbonates mounds and mud volcanoes and the rock in depth that generates gas hydrates.
- Understand the relationship between mud volcanoes, the development of cold water corals and the geodynamic events of the Gulf of Cadiz.

The Ordovician of the SW Anti-Atlas: petrology, facies and sedimentary environments, sequence stratigraphy

El Houssaine El Kabous

Laboratoire Océanologie et Géodynamique des bassins sédimentaires Fac. Sc., Univ. Md. V-Agdal, Rabat, Morocco

The Ordovician sequences (Lower Arenig – Ashgill) of the folded Bani (SW Anti-Atlas), essentially composed of siliciclastic deposits with intercalated carbonate-rich sandstones and oolithic/glauconitic ironstones, form part of the North Gondwana platform which developed in a period of global extensional tectonics at the rim of the Saharan craton. Late Ordovician times featured ice age conditions in this region. Remarkably, these sequences comprise carbonate mounds in the upper Llanvirn-Llandeilo sequence of Taghjijt and in the Caradoc of Targamait.
Earlier studies in the SW Anti-Atlas in the framework of mapping programmes have focused on palaeontology and stratigraphy. It was hence interesting to undertake a sedimentological study. For this purpose, a detailed sedimentological analysis was carried out in 7 representative sequences of the Ordovician (Lower Arenig – Ashgill) of the folded Bani in the regions of Assa, Fask and Taghjijt (sedimentary facies, sedimentary petrography and sequence stratigraphy).

The objectives of the present study are:

- to seek to understand the origin and mode of emplacement of the carbonate mounds outcropping in the Upper Llanvirn - Llandeilo of the section of Taghjijt and in the Caradoc of the sequence of Targamait,

- to reconstruct the palaeogeography of the Ordovician in the SW Anti Atlas,
- to unravel the stages of infill of the SW Anti-Atlas basin in Ordovician times and to
- analyse its geodynamic, climatic and eustatic evolution,
- to draft correlations with the Ordovician sequences in other Moroccan domains, in particular to analyse to what extent the Ordovician deposits of the SW Anti-Atlas developed in a distinct basin, or possibly linked with one of the two basins reported by Hamoumi (1995): the NE-SW striking «Mesetian» basin which comprises the Ordovician deposits of the W Moroccan Meseta and the W High Atlas, and the ENE- WSW striking « Atlas » basin which holds the Ordovician deposits of the Central and Eastern High Atlas and the Central and Eastern Anti-Atlas.

The applied methodology can be summarized as follows:

- to reconstruct the facies and depositional environments and to follow their evolution in space and time,
- to identify the mineralogical stocks and their sources,
- to propose a stratigraphic sequential pattern and an interpretation of the different orders of sequences,
- to propose a timing of the geodynamic, climatic and eustatic events,
- to precise the architecture and the geometry of the sedimentary basins.

Stages of the Triassic sedimentation basin "Benslimane, Berrechid, El Gara – Ben Ahmed" in the Western Meseta

Rachid Lakbouchi, Rachid Essamoud

University Hassan II Mohammedia – Casablanca, Faculty of science Ben M'Sik, Département of Géologiy

In most of the basins of the area Atlas, the Triassic is a time when the conditions of sedimentation and geodynamic history have been extensively studied for years and which, therefore, seem somewhat better known today. In contrast, it seems that the Triassic deposits in the area Mesetien, particularily in Benslimane, Berrechid, El Gara – Ben Ahmed, are still rather vague.
This study primarily aims to the first step, to make a sedimentological study of the region deep below the top, based on the analysis of genetic stratigraphy. The study of Triassic deposits made in our future work, was to:

(1) specify the conditions of sedimentation in the Triassic deposits,
(2) to establish the genetic logic local and regional correlations suggest,
(3) to specify, through a division into sequences of deposits, the boundary between the Triassic and Liassic carbonate deposits in the regions of Benslimane, Berrechid, El Gara - Ben Ahmed, the Meseta in the West,
(4) to study of clay mineralogy: the determination of pre-diagenetic clay phases generally allows to trace the sources of supply of sediment and the deposition conditions including climate.

Danian cool-water coral mounds from Faxe, Denmark – Reconstruction of the ecosystem

Bodil Lauridsen

Department of Geography and Geology University of Copenhagen, Denmark

Fossil cool-water coral mounds are relatively rare in contrast to the modern ones. However, in mid-Danien time, shortly after the mass extinction at the Cretaceous–Tertiary boundary and during a relative rise in sea level, the azooxanthellate scleractinian genus *Dendrophyllia* evolved and formed coral mound complexes in the epicontinental sea of the Danish Basin in northwest Europe. Deep-shelf mounded bryozoan limestones are intercalated with the cool-water mounds at several places. In Faxe quarry, at the easternmost part of the Ringkøbing-Fyn High, an extremely well preserved cool-water coral mound complex is exposed. The accentuated reliefs on the seafloor made extensive colonisation of corals possible due to intensified bottom currents rich in nutrients. The degree of preservation of the fossils in the coral limestone varies markedly. In this study a unique deposit consisting of an unconsolidated coral limestone is presented displaying a rare taphonomic window of an extremely well preserved aragonitic fauna of around 240 species.

Foraminifera associated to cold-water coral ecosystems

Claudio Stalder, Silvia Spezzaferri

Department of Géosciences, University of Fribourg, Chemin du Musée 6, 1700 CH-1700 Fribourg, Switzerland; claudio.stalder@unifr.ch, silvia.spezzaferri@unifr.ch

The distribution of cold-water corals (CWC) is global, ranging in water depth from 39m down to 3383m. It is mainly controlled by environmental parameters such as salinity, temperature and nutrients availability (Fossa et al., 2002; Freiwald et al., 2004).
My ongoing research focuses on the micropaleontological study of a 282cm core recovered from a CWC reef off Lopphavet (Northern-Norway) with the aim of identifying and quantifying benthic foraminifera to reconstruct the paleoceanographical settings during the last 15'000 years.
My research concentrates on the ESF_EuroDiversity-MiCROSYSTEM cores MD08-3227 and MD08-3216G recovered on the Pen-Duick Escarpment (Gulf of Cadiz) and on gravity cores from CWC ecosystems in the Alboran Sea. Benthic and planktonic foraminifera will help revealing the history of the CWC ecosystem development in the last 150'000 years and the relation to ecological, oceanographical and climatic changes.

References:
Føssa, J. H. et al. 2002. In: Freiwald, A. et al. Cold-water corals and ecosystems, pp. 359-391.
Freiwald, A. et al. 2004. Cold-water coral reefs, UNEP-WCMC.

Modern and past cold-water coral mounds from the Mediterranean: a close look at the carbonate biofacies

Agostina Vertino

Università Degli Studi Di Milano – Bicocca, Dipartimento di Scienze Geologiche e Geotecnologie, Piazza della Scienza, 4 – 20126 Milano, Italy

Live cold-water corals (CWC) seem to be common on subvertical and overhanging rocky outcrops of Mediterranean bathyal environments. An exception is represented by the Santa Maria di Leuca (SML) Coral Province where frame-building corals colonise the upper part of mound-like structures. Six main carbonate biofacies (associations of skeletonised organisms) characterize the surface of the SML mounds as well as the first 2 m of their sediment successions. Similar facies have been recognised in Lower Pleistocene deposits cropping out in southern Italy and interpreted as CWC mound deposits. However, the Pleistocene biofacies are more diversified and show stronger Atlantic affinity than the modern ones, implying more favourable conditions for the coral development.
These results point out the need for a comparative study of modern and Pleistocene faunistic associations from Mediterranean and NE Atlantic CWC mounds for a better understanding of the processes which (1) regulate the biofacies variations through space and time and (2) trigger the formation of CWC mounds.

ANNEX 2

List of COCARDE Workshop and Field Seminar participants, 24.-30.10.2011, Rabat, Morocco.

Name	First Name	Institute	Country	Email	Work-shop	Field Seminar
Abazine	Keltoum	Ibn Tofail University of Kenitra	Morocco	keltoum_zine@hotmail.com	X	
Abdelmjid	Benbouziane		Morocco		X	
Ait Addi	Abdellah	Chadi Ayyad University, Marrakesch	Morocco	aitaddia@yahoo.fr	X	X
Barbieri	Roberto	University of Bologna	Italy	roberto.barbieri@unibo.it	X	X
Benjelloun	Waiil	Mohammed V - Agdal University, Rabat	Morocco		X	
Bouziane	Khalid		Morocco		X	
Canérot	Joseph	University of Toulouse	France	jcanerot@live.fr	X	X
Cavalazzi	Barbara	University of Johannesburg	South Africa	cavalazzib@uj.ac.za	X	X
Chafiki	Driss	Chadi Ayyad University, Marrakesch	Morocco	drisschafiki@gmail.com	X	X
Dell'Arciprete	Ida	University of Annunzio	Italy	ida@irsps.unich.it		X
Dorschel	Boris	University College Cork	Ireland	b.dorschel@ucc.ie	X	X
Elghini	Abdelhafid	Ibn Tofail University of Kenitra	Morocco	elghinia@yahoo.fr	X	X
Essamoud	Rachid	Hassan II University, Casablanca	Morocco	r.essamoud@gmail.com	X	X
Fetthallah	Amane	International University of Rabat	Morocco	amane.fethallah@uir.ma	X	
Foubert	Anneleen	K.U. Leuven	Belgium	anneleen.foubert@ees.kuleuven.be	X	X
Franchi	Fulvio	University of Bologna	Italy	fulvio.franchi2@unibo.it	X	X
Freudenthal	Tim	MARUM, Bremen University	Germany	freuden@marum.de	X	X
Guernouch	Karima		Morocco		X	
Habid	Awatif	Casablanca	Morocco	awatif_habid@yahoo.fr	X	X
Hamaekers	Helen	K.U. Leuven	Belgium	helenhamaekers@mac.com	X	X
Hamoumi	Naima	Mohammed V - Agdal University, Rabat	Morocco	naimahamoumi@yahoo.fr	X	X
Hazim	Mohamed El Amine	Mohammed V - Agdal University, Rabat	Morocco	hazimamine@yahoo.fr		X
Hebbeln	Dierk	MARUM, Bremen University	Germany	dhebbeln@marum.de	X	X
Henriet	Jean-Pierre	RCMG, Ghent University	Belgium	jeanpierre.henriet@ugent.be	X	X
Hilali	Idriss	International University of Rabat	Morocco		X	
Hssaida	Touria		Morocco	thssaida@yahoo.fr	X	
Imbert	Patrice	TOTAL, Pau	France	patrice.imbert@total.com	X	
Jabour	Haddou	ONHYM, Rabat	Morocco	JABOUR@onhym.com	X	X
Kabous	El Houssaine El	Rabat	Morocco	h.elkabous@mem.gov.ma	X	X
Lahcini	Salim		Morocco		X	
Lakbouchi	Rachid	Hassan II University, Casablanca	Morocco	lakbouchi@gmail.com	X	X
Lapointe	Philip	TOTAL, Pau	France	Philippe.LAPOINTE@total.com	X	X

List of workshop participants (continued)

Name	First Name	Institute	Country	Email	Work-shop	Field Seminar
Lauridsen	Bodil	University of Copenhagen	Denmark	Bodill@geo.ku.dk	X	X
Leonide	Philippe	University of Provence, Marseille	France	p.s.leonide@vu.nl	X	X
Maijd	Choukri		Morocco		X	
Ori	Gian-Gabriele	University of Annunzio	Italy	ggori@irsps.unich.it		X
Oumalch	Fatima		Morocco		X	
Reijmer	John	Free University of Amsterdam	Netherlands	John.Reijmer@falw.vu.nl	X	X
Rüggeberg	Andres	RCMG, Ghent University	Belgium	andres.ruggeberg@ugent.be	X	X
Samankassou	Elias	University of Geneva	Switzerland	elias.samankassou@unifr.ch		X
Spezzaferri	Silvia	University of Fribourg	Switzerland	silvia.spezzaferri@unifr.ch	X	
Stalder	Claudio	University of Fribourg	Switzerland	claudio.stalder@unifr.ch	X	X
Suzyumov	Alexei	IOC-UNESCO, Paris	France	suzyumov@gmail.com	X	
Taj-Eddine	Kamal	Chadi Ayyad University, Marrakesch	Morocco	taj-eddine@ucam.ac.ma		X
Vertino	Agostina	University of Milan-Bicocca	Italy	agostina.vertino@unimib.it	X	X

List of student participants of COCARDE Workshop, 24.10.2011

Name	First Name	University
Afenzar	Abdelkarim	Hassan II Mohammedia Casa
Azzoui	Ali	Hassan II Mohammedia Casa
Darhnani	Mouhcine	Hassan II Mohammedia Casa
Hddine	Abdellatif	Hassan II Mohammedia Casa
Hejja	Younes	Hassan II Mohammedia Casa
Lamine	Mohamed	Hassan II Mohammedia Casa
Mejjad	Nezha	Hassan II Mohammedia Casa
Moustarhfer	Kaoutar	Hassan II Mohammedia Casa
Omalek	Myriem	Hassan II Mohammedia Casa
Bel Fakir	Makrame	Ibn Tofail Kenitra
Bougarn	Issam	Ibn Tofail Kenitra
Echchaykhi	Youssef	Ibn Tofail Kenitra
Hajjaji	Maryem	Ibn Tofail Kenitra
Laghouazi	Taha	Ibn Tofail Kenitra
Marzouk	Rachid	Ibn Tofail Kenitra
Miniya	Mohamed	Ibn Tofail Kenitra
Ahmedat	Chaima	Mohammed V-Agdal, Rabat
Anefnaf	Ikram	Mohammed V-Agdal, Rabat
Assali	Ouidad	Mohammed V-Agdal, Rabat
Assoumou N'Guessan	Andrée Ines	Mohammed V-Agdal, Rabat
Azelmad	Rajae	Mohammed V-Agdal, Rabat
Benyas	Kawtar	Mohammed V-Agdal, Rabat
Berja	Bouchra	Mohammed V-Agdal, Rabat
Berred	Sanae	Mohammed V-Agdal, Rabat
Borougui	Ayoub	Mohammed V-Agdal, Rabat
Chekar	Mouna	Mohammed V-Agdal, Rabat
El Ajhar	Laila	Mohammed V-Agdal, Rabat
El Amrani	Abdessamad	Mohammed V-Agdal, Rabat
El Asery	Fatima Zahra	Mohammed V-Agdal, Rabat
El Hajjioui	Ouafae	Mohammed V-Agdal, Rabat
El Kaissi	Sara	Mohammed V-Agdal, Rabat
El Khachine	Douae	Mohammed V-Agdal, Rabat
El Khmer	Fatima Zahra	Mohammed V-Agdal, Rabat
El Mahrad	Badr	Mohammed V-Agdal, Rabat
El Qarni	Sfia	Mohammed V-Agdal, Rabat
Essalhi	Wissal	Mohammed V-Agdal, Rabat
Hamidi	Adil	Mohammed V-Agdal, Rabat
Hassouni	Hanane	Mohammed V-Agdal, Rabat
Hout	Redouane	Mohammed V-Agdal, Rabat
Jemily	Linda	Mohammed V-Agdal, Rabat
Khaffou	Issam	Mohammed V-Agdal, Rabat
Masbahi	Reda	Mohammed V-Agdal, Rabat
Meskine	Mohamed Amine	Mohammed V-Agdal, Rabat
Micha Obiang	Eyang Juan	Mohammed V-Agdal, Rabat
Mohsine	Ismail	Mohammed V-Agdal, Rabat
Mojtahid	Sara	Mohammed V-Agdal, Rabat
Raki	Amine	Mohammed V-Agdal, Rabat
Sbihi	Fatima Zahra	Mohammed V-Agdal, Rabat

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Vakgroep **Geologie-Bodemkunde**
Onderzoekseenheid **Renard Centre of Marine Geology**

Financial Report of COCARDE Workshop and Field Seminar, Rabat 23.-30.10.2011

In coherence with the agreement to seek to equally split the cost between ESF and FWO, the cost for the European Science Foundation of the joint ESF and FWO COCARDE Workshop and Field Seminar in Rabat, Morocco from 24th to 30th October 2011 are collected in table 1. The cost cover car rental for the field seminar (4x4 jeeps) and a part of the travel costs of senior and junior scientist amounting to € 12,338.43. A similar amount (€ 11,900.00) was covered by COCARDE-International Coordination Action, funded by the FWO, Flanders Scientific Research Foundation.

Table 1. Costs of COCARDE Workshop and Fieldseminar in Rabat, Morocco, 24.-30.10.2011 covered by the European Science Foundation.

Name	First Name	Flight	Travel	Meals	Hotels in Rabat	Total
Barbieri	Roberto	384.04	0	0	238.55	**622.59**
Canérot	Joseph	296.37	6.22	0	35.52	**338.11**
Foubert	Anneleen			84	128.91	**212.91**
Freudenthal	Tim	472.32	30.00	105	232.12	**839.44**
Hebbeln	Dierk	519.32	0	42	232.12	**793.44**
Reijmer	John	354.34	71.12	84	221.60	**731.06**
Rüggeberg	Andres			84	128.91	**212.91**
Samankassou	Elias	308.24	122.86	0	125.54	**556.64**
4x4 jeeps	Field Seminar					**3843.00**
Dorschel	Boris	522.88	50.00	42	211.94	**826.82**
Franchi	Fulvio	376.23	6.00	42	117.63	**541.86**
Hamaekers	Helen	384.88	0	42	120.29	**547.17**
Lauridsen	Bodil	599.61	94.32	42	211.94	**947.87**
Stalder	Claudio	650.37	44.30	42	117.63	**854.30**
Vertino	Agostina	224.86	62.16	63	120.29	**470.31**
						12338.43

All original documents (tavel claim forms of participants, 4x4 car rental) have been transmitted to the European Science Foundation.

Contact:

Prof. Dr. Jean-Pierre Henriet
RCMG, Ghent University
Krijgslaan 281, S8
B-9000 Gent
Belgium

Jeanpierre.Henriet@UGent.be
Tel.: +32-9-264-4585

Dr. Andres Rüggeberg
RCMG, Ghent University
Krijgslaan 281, S8
B-9000 Gent
Belgium

Andres.Ruggeberg@UGent.be
Tel.: +32-9-264-4589