ESF MiCROSYSTEMS – FWO COCARDE Flanders – ESF CHECREEF
Workshop and Field Seminar

CARBONATE MOUNDS IN SHALLOW AND DEEP TIME

Oviedo, Asturias, Spain: 16th – 20th September 2009

WORKSHOP AND FIELD SEMINAR REPORT INCLUDING COST STATEMENT

CONVENERS

- **Elias Samankassou**, University of Geneva, Switzerland,
  Email: elias.samankassou@unige.ch
- **Juan R. Bahamonde**, University of Oviedo, Spain
  Email: jrbaham@geol.uniovi.es
- **Jean-Pierre Henriet**, RCMG, Ghent University, Belgium
  Email: jeanpierre.henriet@ugent.be

EDITED BY

- **Andres Rüggeberg**, RCMG, Ghent University, Belgium
  Email: andres.ruggeberg@ugent.be

ESF MiCROSYSTEMS – FWO COCARDE Flanders – ESF CHECREEF
Workshop and Field Seminar

CARBONATE MOUNDS IN SHALLOW AND DEEP TIME

Oviedo, Asturias, Spain: 16th – 20th September 2009

WORKSHOP REPORT

CONVENERS

E. Samankassou, University of Geneva, Switzerland, (elias.samankassou@unige.ch)
J. R. Bahamonde, University of Oviedo, Spain (jrbaham@geol.uniovi.es)
J.-P. Henriet, RCMG, Ghent University, Belgium (jeanpierre.henriet@ugent.be)

MEETING VENUE AND PARTICIPATION

The workshop and seminar had an open and flexible structure. It offered space for addenda and new insights in cold-water carbonate mound research – of recent and ancient mound systems. The meeting is related to COCARDE (Cold Water Carbonate Reservoir Systems in Deep Environment), an international network that endeavors to build bridges between:

(1) the academic community studying subrecent carbonate mounds in midslope environments in the present ocean,
(2) the academic community which for decades has investigated the world of fossil mounds, spanning the whole Phanerozoic times,
(3) the industrial community confronted with fossil mound reservoirs facing now deep water reservoir systems of mixed carbonate and siliciclastic nature, and
(4) the youth, which moves into stimulating multidisciplinary studies and gets a perspective of exciting careers in Science and Industry.

The scientific challenges got already well defined at the ESF Magellan COCARDE Workshop in Fribourg, Switzerland, January 21-24, 2009. In March 2009, the ESF Eurodiversity Programme granted an operational support for this Workshop and Field Seminar, organized as joint venture between COCARDE, MiCROSYSTEMS (Eurodiversity) and CHECREEF (ESF EuroMARC). In April 2009, COCARDE got recognized as a new component of IOC-UNESCO's Training Through Research Programme – Geosphere-Biosphere Coupling Processes (GBCP). In June 2009, the Flanders funding agency FWO granted a coordination support 2009-2011.

The Oviedo Workshop and Field Seminar marks a next step in the progress of COCARDE. The field seminar focused on mounds from the Carboniferous platform of Asturias and Cantabria, already intensively visited by industrial and academic researchers. The Asturias-Cantabria platform system is famous for microbial carbonates: the right place for the MiCROSYSTEMS teams, studying microbial diversity and functionality in cold water coral ecosystems, associated with carbonate mounds. Juan Bahamonde (University of Oviedo) and Elias Samankassou (University of Geneva) kindly organized and guided three excursion days to visit and study ancient carbonate mound systems.

A compact workshop preceded the field seminar, highlighting ongoing research from both academic groups, the recent and ancient carbonate mound research groups, integrating the message from the industry.

PROGRAMME AND OUTCOME

Day 1 – Wednesday September 16th, 2009

Within the ***Opening Session***, Agustín Martín Izard, Head of the Department of Geology at the University of Oviedo, welcomed the participants to Oviedo and wished a successful and fruitful meeting. Following an opening statement by Alexei Suzyumov on behalf of IOC-UNESCO, Jean-Pierre Henriet (RCMG, Ghent University) reviewed the progress of COCARDE since the last meeting in Fribourg, January 2009, and summarized the goals of this workshop and field seminar.

In the first session ***Key Mound Provinces in Shallow and Deep Time***, Juan Bahamonde (University of Oviedo) and Elias Samankassou (University of Geneva) introduced the participants to the geology and ***Mound Provinces in Northern Spain***. Valentina Blinova (Moscow State University) gave an overview of 7 years of TTR investigations on Pen Duick Escarpment (2002-2008) introducing ***Mound Provinces on the North-African margins***. After lunch, Hans Pirlet (RCMG, Ghent University) presented results of the MiCROSYSTEMS cruise on Pen Duick Escarpment (MD169, 2008) and Mohamed El Amine Hazim (University Rabat) summarized preliminary results of the recently successful R/V Belgica expedition on Pen Duick Escarpment. Jean-Pierre Henriet (RCMG, Ghent University) closed this session with an update of the status of IODP proposal 673-Full – the future IODP mound drilling initiative off Morocco.

Theme 1 Palaeoenvironment

In the later afternoon of the first workshop day, the first topic ***Palaeoenvironment*** started within the overall session ***Processes, Methods and Strategies***. Theme 1 concentrated on the potentiality and reliability of proxies for palaeoenvironmental reconstruction presented by Andres Rüggeberg (RCMG, Ghent University) and Silvia Spezzaferri (University of Fribourg). Latest palaeoenvironmental reconstructions gave new insight into the understanding of the functioning and the development of recent carbonate mounds. Limitations exist in the use of proxies such as stable isotopes, element ratios, or faunal assemblages, to reconstruct the palaeoenvironment of ancient carbonate mounds. The limiting factors are mainly related to compaction of sediments, including diagenetic overprint, as well as evolutionary faunal changes.
The joint discussion following the presentations identified that the scientific community is presently engaged in finding new geological, geochemical and biological proxies in modern mounds that can be exported into the geological past. One of the key issues is to by-pass obvious differences in processes from the past to the present and that through times many geo-chemo-biological players disappeared while new ones appeared to drive the development and shaping of mounds.

What we need to consider when going back into deep time using proxies is:

- that we use a multi-proxies approach,
- to have knowledge of the proxies we use and the material on which we measure and their relevance and application through time (e.g., Tab. 1),
- of what age the material is,
- to establish new approaches (e.g., analysis of fluid inclusion containing unevaporated seawater, MRM - Microbial Resource Management (Marzorati (2007), see Theme 2).

An example for a new approache came from microbiology (Yu Zhang), with microbial community having a stable structure when its functionality is stable. The change of the environmental factors will force the change of microbial functionality, which was the consequence of the microbial community structure change. By detecting the microbial community structure, we can get a view on the environmental stability or stress. This can be used as a proxy. Ideas and approaches like this are further needed and need to be established to start comparisons between different carbonate mound systems of different geological times.

Table 1. Summary of major paleotemperature techniques (from Lea, 2003) indicating the different and limiting time scales of each technique.

	Phases	*Sensitivity* (per °C)	*Estimated SE*	*Major secondary effects*	*Time scale*[a]
Oxygen Isotopes	Foraminifera	0.18–0.27‰	0.5 °C if δ^{18}O-sw is known	Effect of δ^{18}O-sw	0–100 Ma
	Corals	~0.2‰	0.5 °C if δ^{18}O-sw is known	Kinetic effects Effect of δ^{18}O-sw	0–130 ka
	Opal			Effect of δ^{18}O-sw	0–30 ka
Mg/Ca	Foraminifera	9 ± 1%	~1 °C	Dissolution Secular Mg/Ca variations (>10 Ma)	0–40 Ma
	Ostracodes	~9%	~1 °C	Dissolution? Calibration	0–3.2 Ma
Sr/Ca	Corals	−0.4 to −1.0%	0.5 °C?	Growth effects Secular Sr/Ca changes (>5 ka)	0–130 ka
Ca isotopes	Foraminifera	0.02–0.24‰	unknown	Species effects, calcification	0–125 ka
Alkenone unsaturation index[b]	Sediment organics	0.033 (0.023–0.037) in $U_{37}^{K'd}$	~1.5 °C (global calib.)	Transport, species variation	0–3 Ma
Faunal transfer functions[c]	Foraminifera, Radiolaria, Dinoflagellates	NA	1.5 °C	Ecological shifts	0–?

[a] Timescale over which the technique has been applied. [b] Chapter 6.15. [c] (Imbrie and Kipp, 1971) [d] (Müller et al., 1998 and Pelejero and Calvo, 2003).

Day 2 – Thursday September 17th, 2009

Theme 2 Organominerals and microbial processes

The second theme of the workshop concentrates on organomineralization and microbial processes. Stéphanie Larmagnat (University of Laval, Québec) presented the ***organomineralization***, firstly defined by Trichet and Défarge (1995), and refers to «mineral formation in close association with non-living organic substrates in soils and sediments». Unlike biominerals, organomineral formation is independent of the cell's vital process. It is formed during the earliest stages of humification where degrading organic matter creates appropriate chemical conditions and also provides a substrate for mineral precipitation (induced and supported organomineralization *sensu* Trichet and Défarge, 1995). A modern example of a calcifying siliceous sponge (*Spheciospongia vesparium*, Bahamas) matches such an organomineralization process (Fig. 1). Here, freshly produced humic compounds in the form of colloids selectively sorb onto a relatively decay-resistant connective tissue (collagenous scaffold) whereas the sorbed phase serves as nuclei for calcification.

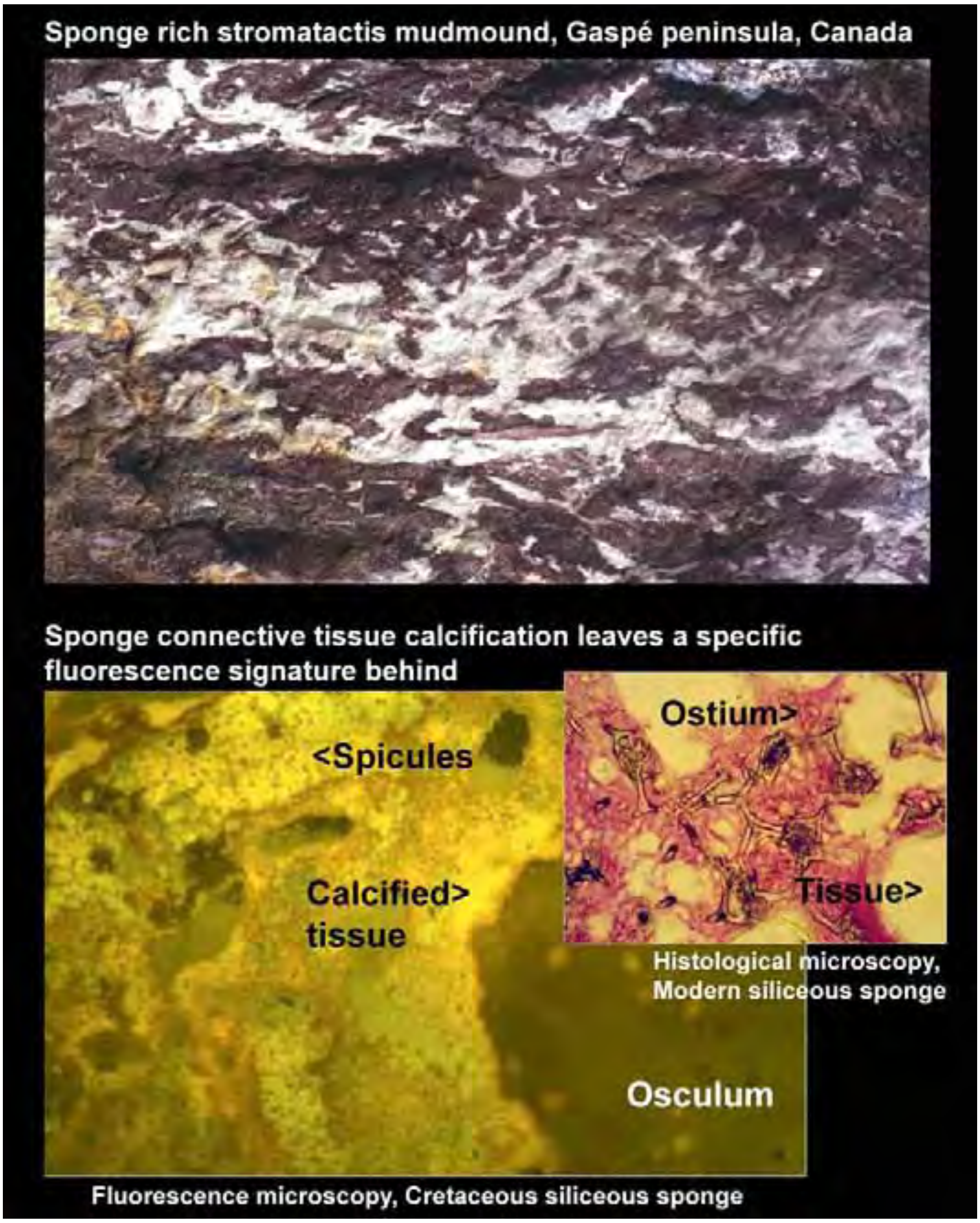

Figure 1. Top: Sponge-rich stromatactis in a mud mound, Gaspé Peninsula, Canada. Bottom: Fluorescence microscopy of a Cretaceous siliceous sponge and histological microscopy of a modern siliceous sponge showing similar structures as the fossil example (S. Larmagnat and F. Neuweiler, Laval University).

When studying ancient carbonate mounds, several proxies can be used to track organominerals:

(1) the replication of sponge tissue organisation,
(2) the local presence of secondary voids of the stromatactis type,
(3) a patchy and labyrinthine style of calcification,
(4) the local enrichment of water-soluble FDOM that leaves a specific fluorescence signature,
(5) geochemical tracers of suboxic diagenetic conditions (such as Ce/Ce*).

The follow-up discussion highlighted the importance to well separate biominerals (including microbial carbonates) from organominerals, both in shallow and deep times. Microbial carbonates represent a large amount of Paleozoic mounds. Therefore, organomineral abundance should not be underestimated when studying these ancient mud-rich carbonate mounds. We need to focus on relative rates of calcification processes. Authigenic aragonite clusters found in the modern lithifying sponge *Spheciospongia vesparium* represent only the first stages of the organomineralization process. Further steps of organomineralization processes need to be identified where such organically supported calcification takes place. The Atlantic deep-water coral mounds present appropriate environmental conditions (suboxic conditions, cryptic community within coral rubble facies) and therefore represent good candidates for further studies on organomineralic calcification.

Yu Zhang (LabMET, Ghent) presented the potential of high-pressure reactor experimentation to untangle the role of ***microbial activity in mounds*** indicating the importance of microbiology in solving geo-issues. The analysis of microbial community could help to understand the stability of the local environment and its shift. E.g., Stadsnitskaia (2007) used molecular techniques to detect the microbial community in carbonate crusts, and linked it with the isotope signature to reconstruct the microbial processes and biogeochemical conditions during the formation of the carbonate crust. The concept of Microbial Resource Management (MRM) could be used to go even deeper in time supporting the development of new tools and proxies towards exploring mound space and time.
Applications on high-pressure bioreactor at LabMET could highlight the *Shift from Exploration to Experimentation*. Microbial processes possibly drive initial carbonate precipitation. The hypothesis is that microorganisms increase the local alkalinity, which results in an ex-cellular precipitation. This initial precipitation is used as a nucleus for further fast chemical-driven carbonate precipitation. This is of special interested for the industries in the case of dolomite growth and could be tackled using high-pressure bioreactors. Additionally, studying N-cycles in deep marine ecosystems could be a “walk over stepping-stones in the implementation process”. The presence of nearly 11% of N_2 (together with 87% CH_4, 2% CO_2) was discovered in a gas seep from Mercator Mud Volcano during a TTR cruise. This nitrogen gas is deeper (possible microbiologically) generated and is the only nitrogen gas bubbling discovered so far. However, no explanation for its presence exists yet, but it is a fascinating research topic, which could be tackled by LabMET.

Theme 3 Petrophysics and diagenesis

The third topic discussed petrophysics and diagenesis with examples of IODP Exp. 307 and Devonian carbonate mounds of Belgium. Ann-Christine da Silva (Liége University) presented first the interdisciplinary IGCP-project 580, funded by the

UNESCO. This project aims is to compile published ***magnetic susceptibility*** (MS) records from Palaeozoic sedimentary rocks and to acquire new data for testing the correlation between MS and sedimentological parameters. Quantitative MS measurements have become widely used in the sedimentology of rocks from the Recent to the Paleozoic. A further goal is to investigate the cause of the MS signal in different sedimentary environments and its relationship to climate controlled environmental parameters. Finally, MS records from different globally distributed sites will be correlated for reconstructions of past climatic variations. For this purpose, all interested scientists are invited to join the project: http://www2.ulg.ac.be/geolsed/MS/.

A particular example of the use of MS followed up with the presentation of the facies and structure of Devonian mounds in Belgium. Among the various Palaeozoic carbonate mounds known throughout the world, these Frasnian carbonate mounds of Belgium are probably the earliest studied. Observed facies are showing characteristics from relatively deep, quiet, aphotic and hypoxic to very shallow restricted environments. Middle and Upper Frasnian mounds present a different facies architecture, as a consequence of different palaeoceanographic settings. MS allowed relatively good correlations between the mounds and that it is linked to different facies. Higher MS values are corresponding to the deepest facies and MS increases during transgressive phases. Therefore, the sedimentary input (through sea level and climatic changes) as well as the sedimentation rate of the carbonate mounds and the surrounding deposit are probably controlling MS signal.

Anneleen Foubert (K.U. Leuven) added MS and rock physical properties from the recent Challenger Mound, which was drilled during IODP Exp. 307. Like in the Devonian mounds, magnetic susceptibility values in Recent mounds reflect changes due to facies. A comparison between on-mound and off-mound records in recent carbonate mounds revealed also much higher susceptibility values for the off-mound facies. Therefore, magnetic susceptibility values in ancient and Recent mounds are lower in the mud mound which can be explained by different factors such as a higher carbonate production and/or less siliciclastic input in the mound. Moreover, the susceptibility pattern from the Recent mound itself cannot be recognized in the surrounding sediments. Magnetostratigraphy and absolute dating have shown that on-mound records cover not the same time-interval as off-mound records. So, recent mound systems are unique time recorders. In ancient mounds the susceptibility pattern in the mound was compared to the time lateral equivalent shallow water platform. It also appears that the record in the mound differs from the record off-mound. The clear cyclic pattern of the magnetic susceptibility curve recognized in both cases might be used as a proxy for palaeo-environmental changes. Magnetic susceptibility allowed relatively good correlations of sections within the same mound (Foubert & Henriet, 2009; da Silva et al., 2009).

Recent studies emphasize the importance of early diagenesis overprinting the primary environmental record (e.g. aragonite dissolution) in such systems (Foubert & Henriet, 2009). However, the extent of early diagenetic and biogeochemical processes shaping the petrophysical nature of mounds is until now not yet fully understood. Understanding the functioning of a carbonate mound as biogeochemical reactor triggering ***early diagenetic processes*** is necessary for the reliable prediction of potential late diagenetic processes. Early differential diagenesis overprints the primary environmental signals, with extensive coral dissolution and the genesis of small-scaled semi-lithified layers in the Ca-rich intervals in Challenger Mound. The low cementation rates compared to the extensive dissolution patterns can be explained by an open-system diagenetic model. For example 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). However, no obvious relation between cold-water coral growth and seepage is observed. Recent carbonate mounds provide an excellent opportunity to study early diagenetic processes in carbonate systems without the complications of burial and/or later meteoric diagenesis. Refining the geochemical signatures of the sediments helps to quantify the effects of early diagenetic processes, which change the geophysical and petrophysical characteristics of a carbonate mound and have an impact on the preservation of primary environmental signals.

As follow-up of this working group session, it is proposed to create a workgroup focusing on the magnetic properties in recent and ancient mound systems. This workgroup is based on an active collaboration between two projects, COCARDE and IGCP-580 (see Poster, Appendix 2).

Theme 4 Connectivity issues and compartmentalization in mixed cold water carbonate / siliciclastic systems

The last topic discussed during the workshop was presented and summarized by Jean-Pierre Henriet (RCMG, Ghent University). Today, four major carbonate mound provinces yielding a total of some 4000 mounds are known from the Porcupine Seabight, west off Ireland. They have been identified using both 3D seismic data sets and dense grids of very-high resolution 2D seismic data. Once buried, carbonate mounds should not systematically be regarded as isolated features or potential reservoir bodies. At a scale of mound province or even at basin-scale, these provinces largely root on layers of high-energy contourites with clinoform deposits, ground-truthed as siltstones (IODP Exp. 307). These layers ("sole layers") may act as migration pathways and contribute to inter-mound connectivity. Mound systems along continental slopes provide inter-mound pathways for tubiditic sediments collected downslope in plunge pools. These may not only enhance the over-all reservoir capacity of a mound province, but also contribute to connectivity and migration pathways. What we propose is to screen fossil mound settings systematically for possible mound-sole coupling. These sole layers should be penetrated over a significant depth in future oceanic and continental mound drilling campaigns.

An important aspect is the role of contourites as cap layer of the mounds. Some parts of the Belgica mounds are already covered by muddy-silty contourites, marking an abrupt boundary between (future) high/low porosity/permeability units. However, sometimes turbidites might occur and form micro-reservoirs like for Challenger mound at the basin side towards the west (Fig. 2).

However, really coarse-grained contouritic "reservoir"-like deposits are not yet found in association with the mounds. They might be an ideal (re)distributing sole layer connecting all the mounds and link them up with underlying strata connected to deep-seated reservoirs – but this has to be proven! Another reason might simply be that the Miocene sediment waves are in a way more consolidated and resistant to the RD1-moundbase erosion, hence fostering the palaeotopography on which all the mounds were rooted.

IODP Exp. 307 and investigations on Moroccan Pen Duick mounds highlight that thick lenses of coral rubble characterize cold-water coral mounds. The possible role and significance of such thick coral rubble plates in cold-water coral mound building as “mound bricks” is currently under investigation. These coral rubble plates may possibly form an early template of mound compartmentalization. To verify, to what extent past, and thus different mound-building communities might have generated similar “brick” patterns in fossil mounds, is a new challenge bringing research communities together and initiating continental carbonate mound drilling.

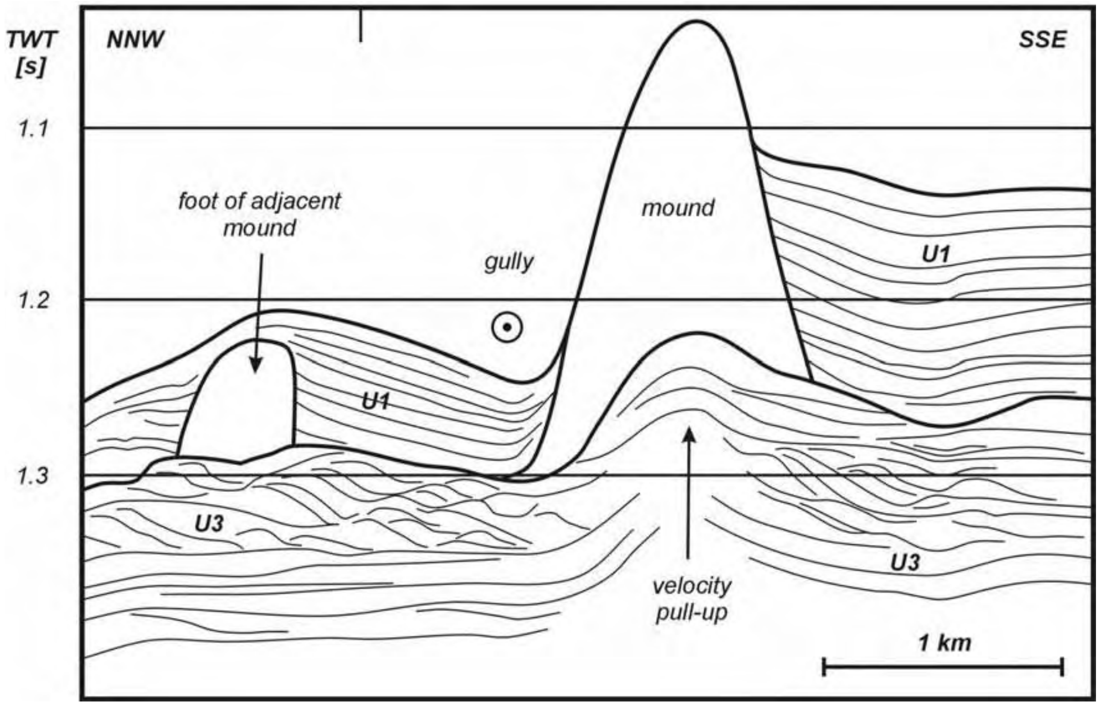

Figure 2. Challenger Mound of Belgica Mound Province (Van Rooij 2004, unpublished PhD).

Industrial Perspective

Philippe Lapointe, the industry representative from Total, ExxonMobil, and NCOC, introduced modern mounds and fossil outcrops as keys for a better understanding of Palaeozoic reservoirs. For exploration, the knowledge of the basinal settings as well as the type of sole where carbonate mounds develop and the palaeo-environmental parameters that control mound growth and their demise is important. Modern carbonate mounds allow a better evaluation of their geometries due to their freshness and relative abundance while coeval outcrop of ancient analogs are rare and scattered.
The importance of carbonate mound systems as possible hydrocarbon reservoirs passes through the understanding of the fundamental processes of mound initiation, growth and demise, and through the identification of plausible sizes, geometries, basin settings and controls. The diversity of carbonate mound systems in the sub-recent world is a key to the understanding of mound settings, morphologies and characteristics in deep time. The comparative analysis of mound evolution with a focus on early to late diagenetic processes, products and patterns in the recent and ancient worlds through integrated ventures in oceanic and continental scientific drilling fuels new insights in reservoir plumbing systems and spurs improvements in reservoir prediction.

Continental Mound Drilling

Thomas Wöhrl (Scientific Drilling ICDP, Potsdam) informed the participants of the workshop on criteria need to be fulfilled to writing a successful ICDP proposal. These criteria (e.g., global significance, international collaboration, relevance to society, collaboration with industry, clear indication of the need of drilling (necessity, from IODP to ICDP), etc.) can be viewed and guidelines for preparing proposals (preliminary proposals, workshop proposals, full proposals) can be downloaded from ICDP homepage (http://www.icdp-online.org). The first phase relevant for COCARDE will be the preparation of a preliminary proposal with deadline of 15th January 2010. Additionally, Thomas Wöhrl warmly recommends the downloadable document "Best practices in the development of scientific drilling projects"!

COCARDE Website

The workshop was closed with the introduction the new COCARDE website by Andres Rüggeberg (RCMG, Ghent University): http://www.cocarde.eu. This site serves as a platform to announce news in carbonate mound research, to present your teams and research projects on recent and ancient carbonate mounds, and will provide links to important sites and addresses for the research and industry community. Of course a platform like this homepage lives from the input of the participants, which will be regularly engaged to contribute!

SUMMARY AND CONCLUSION

The workshop has been very productive and the international group of COCARDE members will take many initiatives in the upcoming months and years. The COCARDE homepage serves as a platform to communicate these actions and to transfer ideas and projects between the different scientific and industrial communities, as well as to announce important and interesting events. The following actions got already shape during the workshop and field seminar:

- Preparation of a **White Paper on Carbonate Mound Drilling** for the IODP-INVEST Meeting held in Bremen, 22nd to 25th September 2009. "The Oviedo Declaration" was submitted to the organizing committee and can be viewed on http://www.marum.de/INVEST_Submitted_WP.html#Section31169 but is also attached (see Appendix 2). A. Foubert (K.U. Leuven) and A. Rüggeberg (RCMG, Ghent University) actively participated and supported "The Oviedo Declaration" at the INVEST meeting.
- **Preparation and submission of a proposal for the ESF Research Network Programme** (deadline was 22nd October 2009). COCARDE-ERN, the Cold-Water Carbonate Mounds in Shallow and Deep Time – The European Research Network aims to establish and strengthen the European component of the international initiative "COCARDE: An Industry-Academia Partnership for the Study of Cold-Water Carbonate Reservoir Systems in Deep Environments". The rationale of COCARDE-ERN is to bundle multidisciplinary and cross-cultural scientific efforts to explore and drill carbonate mounds through space and time. Proponents are S. Spezzaferri (University of Fribourg), A. Foubert (K.U. Leuven) and A. Rüggeberg (RCMG, Ghent University). In the middle of 2010 we will get response of the

review process and, if successful, of the evaluation of the national research foundations by the end of 2010.

- Preparation of a next workshop and field seminar of the "Oviedo-type" in spring 2010: **Moroccan Mounds Workshop and Field Seminar**.
- Preparation and submission of a preliminary proposal for **ICDP drilling** on the Pueblo de Lillo carbonate mounds (see Field Seminar Report).

Cited literature

Lea, D., 2003. Elemental and Isotopic Proxies of Past Ocean Temperatures. Treatise on Geochemistry, Vol. 6(14):365–390.

Marzorati, M., 2007. Microbial Ecology of Complex Environments. Ph.D. thesis, University of Milan.

Stadnitskaia, A., 2007. Bio- and petroleum geochemistry of mud volcanoes in the Sorokin Trough (NE Black Sea) and in the Gulf of Cadiz (NE Atlantic): from fluid sources to microbial methane oxidation and carbonate formation. Geologica Ultraiectina 271, ISBN 90-5744-133-0, (PhD thesis)

Trichet, J., Défarge, C., 1995. Non-biologically supported organomineralization. In: Allemand, D., Cuif, J.P. (Eds.), Proc. 7th Int. Symp. Biomineralization. Bulletin de l'Institut Océanographique de Monaco, n° spéc. 14, vol. 2, pp. 203-236.

Van Rooij, D., 2004. An integrated study of Quaternary sedimentary processes on the eastern slope of the Porcupine Seabight, SW of Ireland. Unpublished Ph.D. thesis, UGent. 330 pp.

ESF MiCROSYSTEMS – FWO COCARDE Flanders – ESF CHECREEF
Workshop and Field Seminar

CARBONATE MOUNDS IN SHALLOW AND DEEP TIME

Oviedo, Asturias, Spain: 16th – 20th September 2009

FIELD SEMINAR REPORT

GUIDES

E. Samankassou, University of Geneva, Switzerland (elias.samankassou@unige.ch)
J.R. Bahamonde, University of Oviedo, Spain (jrbaham@geol.uniovi.es)

FIELD SEMINAR OUTLINE

The field seminar (Sept. 18th-20th, 2009) focuses on mounds from the Carboniferous platform of Asturias and Cantabria. The Asturias-Cantabria platform system is famous for microbial carbonates, a "type locality" for studying microbial diversity and functionality in cold-water coral ecosystems, associated with carbonate mounds.

On the *first day*, Juan Bahamonde (University of Oviedo) led us to the carbonate mounds in a steep-fronted Carboniferous carbonate platform environment of the Escalada Formation in the Panga Nappe Province west of the Picos de Europa Formation (Variscan foreland basin of the Cantabrian Zone, Asturias, Fig. 1).

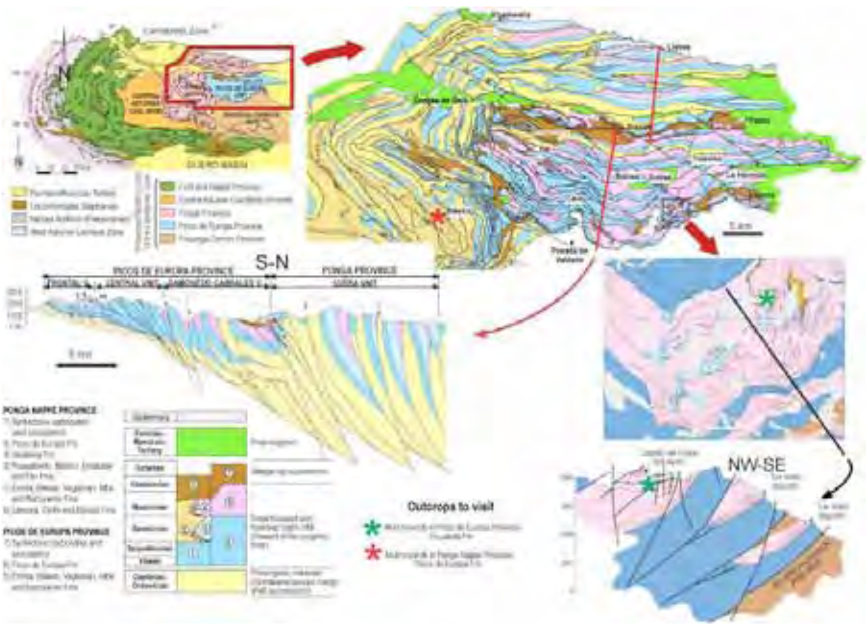

Figure 1. Geological setting of the Picos de Europa and Ponga Nappe province, Cantabrian Mountains, Asturias (from Merino-Tomé et al. (2009).

The Escalada Formation consists of Pennsylvanian icehouse carbonate platform cycles, which are dominated by algal-microbial reef mounds. These mounds were accumulated during sea level highstands in the marine foreland basin at the eastern coast of Pangaea. The Beleño (Fig. 2) and Sobrefoz sections belong to the younger Escalada Formation 2, where the carbonate platform grew in a more external tectonic units. These sections clearly show the internal arrangement of metre-scale, shallowing upward platform cyclothems consisting of 5 to 45 m thick, largely subtidal deposits with absence of peritidal carbonates and bounded by palaeokarstic surfaces. In some cases, argillaceous and marly palaeosols with coal seams occur above discontinuities.

Figure 2. Carbonate platform of the Beleño section (Escalada Formation 2) showing the internal arrangement of 5 to 45 m thick, shallowing upward platform cyclothems (Photo: A. Rüggeberg, RCMG).

These carbonate systems of microbial boundstone-dominated carbonate platform get more and more in the focus of both academic and industrial research.

The *second day* was dedicated to the Carboniferous carbonate build-ups in the Pueblo de Lillo area. Elias Samankassou (University of Geneva) guided us to the region of Castilla y León some 70 km NE of León, where the large and well exposed mounds crop out next to the village Pueblo de Lillo, alternating with clay and silt intervals (Red star in figure 1). The mounds developed on a Moscovian (~300–310 Ma) terrigenous-carbonate low-angle ramp in southeastern sector of the Central Asturian Coalfield Basin Province (Fig. 1).

The carbonate mounds, displaying internally patchy growth forms of boundstone and wackestone, started to grow on a microbial bindstone substrate. The main components of the intermound area carbonates (including the build-ups) are mud- to wackestone and clotted peloidal or donezellid boundstone alternating regularly with shales. It is noteworthy that the flanks of the mounds are very steep with depositional dips of up to 40°! Mound growth was regularly interfered by siliciclastic input, well apparent in the layers separating the intermound beds and leaving only faint traces in the mounds themselves (Fig. 3). These features are also well known from recent carbonate mounds in the Porcupine Seabight making a comparison of these two settings necessary. Additionally, a comparison of drill cores from IODP Exp. 307 (Challenger Mound) with potential ICDP drill cores from this Pueblo de Lillo mound complex is highly desirable!

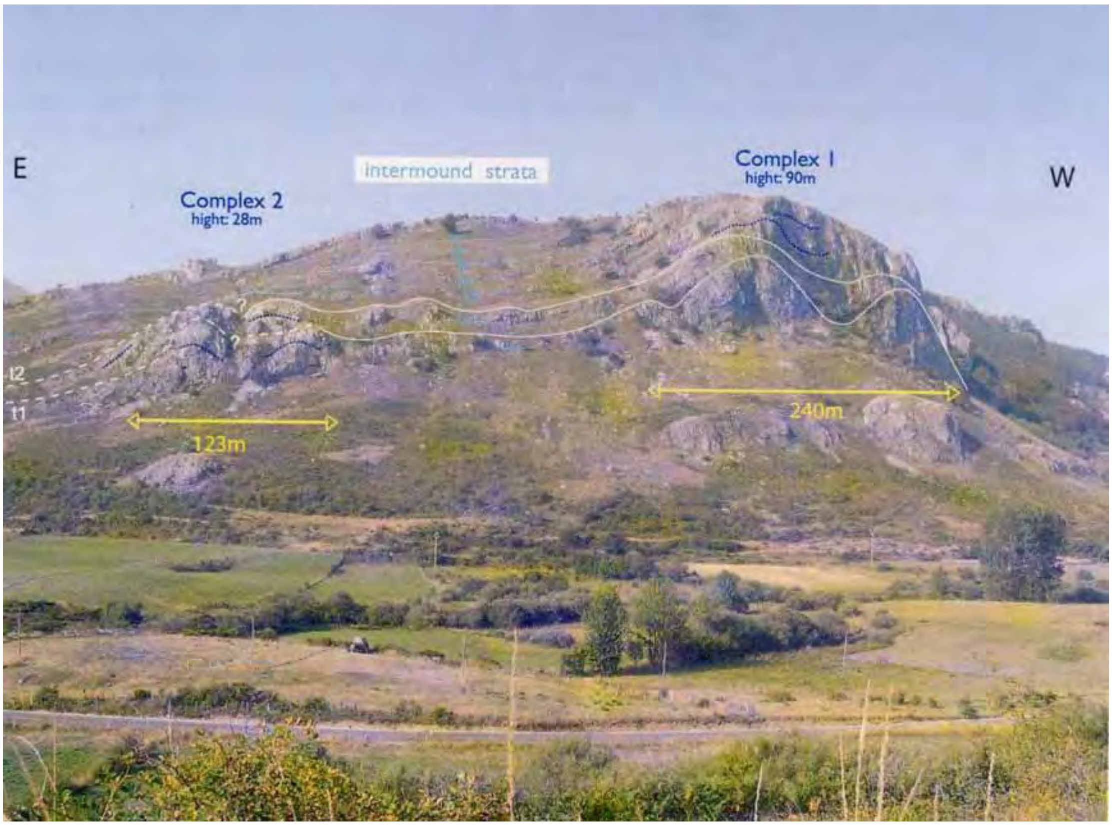

Figure 3. The intermound strata act as stratigraphic time scale between complex 1 and complex 2. The t1 strata is isochronous with the mound cores of complex 1 and the lower half of complex 2. t2 is linked with the lower-most hammocky-shaped covering mound bed of complex 1 whereas it corresponds to the capping of complex 2 (© K. von Allmen, E. Samankassou, J.R. Bahamonde 2009).

The *third field seminar day* went to the San Antolin-La Huelga section, where the Carboniferous succession at the coast of the Bay of Biscay records the northwards margin progradation of a high-relief, microbial-dominated carbonate platform. Well-bedded alternation of spiculites, calciturbidites and clast-supported calcareous breccias form the basin and toe-of-slope facies (Fig. 4). Lower slope sediments consist of massive breccia beds and micritic boundstone accumulation occurs at the upper slope of the platform. The platform top deposits form a thick and well-bedded interval with abundant and diverse marine biota and absence of early marine cements.

After this section the field seminar was closed and inspired, young and experienced scientists left Asturias with new ideas for up-coming research projects, network plans and collaborations.

Figure 4. Vertical toe-of-slope facies of Carboniferous carbonate platform of the San Antolin-La Huelga section with field guide E. Samankassou (arrow) surrounded by enthusiastic field seminar participants.