Research Networking Programme

Cold-Water Carbonate Mounds in Shallow and Deep Time – The European Research Network (COCARDE-ERN)

Standing Committee for Life, Earth and Environmental Sciences (LESC)

The ESF Research Networking Programme "Cold-Water Carbonate Mounds in Shallow and Deep Time – The European Research Network" (COCARDE-ERN) aims to bring together Earth scientists from the research fields of modern and ancient carbonate mound systems. For over a century, paleontologists and reef research teams have unveiled the world of carbonate mounds in the geological record. The discovery of extensive provinces of giant carbonate mounds in the modern ocean fuels the interest towards comparative studies between recent and ancient analogues and opens completely new perspectives for testing hypotheses by experimentation.

The exciting research subject of mounds as a fundamental strategy of life throughout the history of the Earth meets industry's interest for unconventional carbonate reservoirs. The acceptance of carbonate mound systems as plausible hydrocarbon reservoirs relies on the understanding of mound initiation, growth and demise, and through the tentative characterisation of sizes, geometries, basin settings and controls. Approaching these mound systems from recent and fossil perspectives will shed new light on carbonate mounds in a changing world. Furthermore, studying the diversity and variability of carbonate mound systems in the recent world is the key to understanding the diversity of mound settings, morphologies and characteristics in deeper time.

The aim of COCARDE-ERN is to foster new views and strategies in the study of modern cold-water carbonate mounds and to explore the possibility of providing new insights into the geological past. COCARDE-ERN will trigger a common European effort towards integrated and comparative scientific drilling research in sub-recent and ancient carbonate factories, on land and at sea, in warm and cold water systems, crossing intersectoral boundaries within the academic community and building bridges with industrial research. COCARDE-ERN will create a profound knowledge platform upon which young researchers can build their career by training and acquiring multidisciplinary skills in Earth sciences.

The running period of the ESF COCARDE-ERN Research Networking Programme is five years, from June 2011 to June 2016.

Scientific Context

Over the past few years, European researchers have played a significant role in the international marine drilling community and have made major contributions to important discoveries and scientific advances. The ESF Magellan Workshop Series Programme has stimulated European scientists and engineers to a large degree in the planning and realisation of marine drilling proposals and expeditions. This underlines the importance of programmes like the ESF Magellan Workshop Series in nurturing and developing successful new and innovative science projects, as well as in stimulating young researchers to take a role in steering and managing research initiatives.

COCARDE-ERN is an offspring of Magellan, yet with its own profile. The initial Magellan Workshops addressed the research objectives in the IODP's Science Plan through a focused approach: ocean coring and drilling. COCARDE-ERN takes a thematic focus – frontier carbonate systems in deep and shallow time – while broadening the approach to include both marine and continental drilling, thus deepening our understanding both in space and time. This initiative (a) fully fits into the new roadmap identified for the next phase of the "Integrated Ocean Drilling Program" (IODP) beyond 2013, now named "International Ocean Discovery Program" (IODP), (b) integrates with the International Continental Scientific Drilling Program (ICDP)'s strategy and (c) directly meets most national science funding agencies' key challenges and strategies in Europe. It also harmonises with the approach of Magellan follow-up initiatives.

COCARDE-ERN results from the successful ESF-supported (RNP Magellan) "COCARDE" Workshop in Fribourg (CH), January 2009, and the ESF-supported (EUROCORES Programmes EuroDIVERSITY and EuroMARC) Workshop and Field Seminar "Cold-Water Carbonate Mounds in Shallow and Deep Time" (MiCROSYSTEMS-COCARDE-CHECREEF) held in September 2009 in Oviedo (ES). These workshops (a) identified the urgent need to integrate common knowledge on carbonate mound systems – through time and space, and (b) traced the roadmap for achieving this goal. Under the auspices of the UNESCO Intergovernmental Oceanographic Commission (IOC) and with prime coordination support of Research Foundation – Flanders (FWO), a nucleus for an international network was launched in September 2009.

IOC/UNESCO's recognition supports not only the scientific merits of COCARDE, but also recognises its capacity-building perspective. As a milestone in carbonate mound research, IODP Expedition 307 (2005) has shaped through numerous European programmes an impressive worldwide community of young researchers. These young researchers are eager to confront their findings and test their hypotheses in the present ocean with the messages from remote times. The unrivalled resolution in studies of recent carbonate mound systems and the "live" observation of controlling mechanisms is ideally complemented by three- and four-dimensional insights gained in ancient carbonate mound systems. COCARDE-ERN provides a platform for the next generation of young scientists, which is now in a position of joining forces to address – worldwide – emerging new challenges in the fields of paleo-environment, deep biosphere and global change.

Objectives and Envisaged Achievements

"New views on old mounds" is the principal scientific objective of COCARDE-ERN. Throughout Phanerozoic times, mounds have represented a recurrent strategy of Life, and an exemplary mode of geosphere-biosphere coupling. Scrutinising parallelisms and contrasts between mound systems in the present ocean and the geological record deepens our insights in the basic drivers (Figure 1).

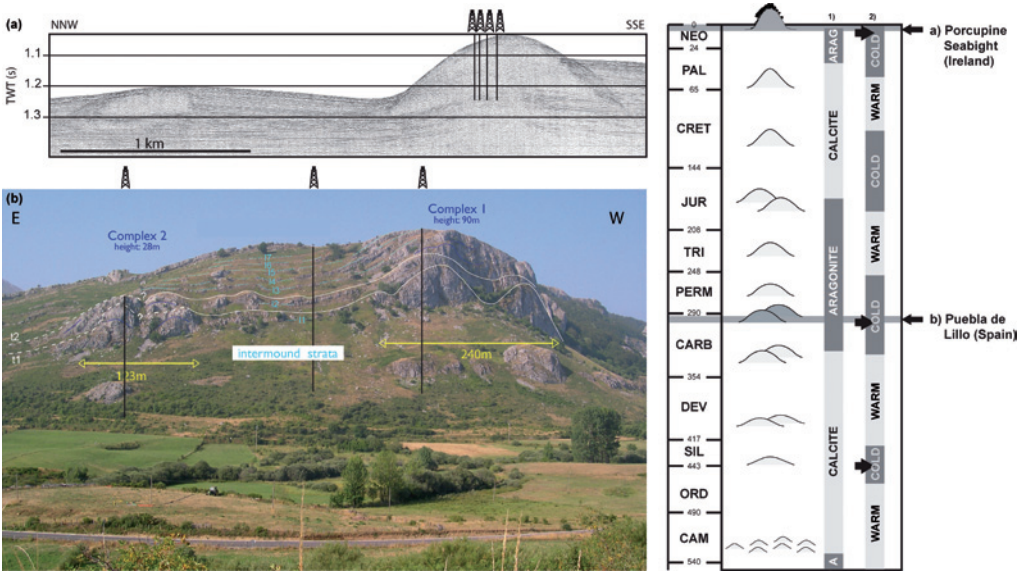
The prominent position of carbonate mound systems in both warm- and cold-water 'carbonate factories' is increasingly recognised and analysed in terms of relevance and importance in the global carbon cycle. The recurrence of prolific mound provinces at the junction between 'icehouse' and 'greenhouse' periods triggers our scientific interest in their potential significance and role in a changing environment. This new understanding on the global carbonate factory in cold and warm waters is accompanied by new views on processes, actors and products in carbonate mound formation and transformation.

The full spectrum of biosphere and geosphere actors during major oceanic turnover events in 'aragonitic' and 'calcitic seas' includes benthic, planktonic and microbial ecosystems in combination with siliciclastic input, bio- and organo-mineralisation.

The integration of recent and fossil mound research will for the first time present the opportunity to study the transformation of a mound to a geological body. Diagenesis and the prominent role of geofluids can be studied from the immediate post-depositional stage to deep burial.

With this new view on global carbonate factories, the scientific objectives and envisaged achievements of the COCARDE-ERN Programme can be summarised as follows:

- To **review** ODP/IODP data and the results of satellite projects of both academic and industrial origin addressing recent/sub-recent carbonate mound settings (expeditions 133, 182, 307; EUROCORES Projects MiCROSYSTEMS, CARBONATE and CHECREEF; TRACES; 3D datasets, etc.). A significant input results from the conclusion of the first exploitation phase of IODP Expedition 307, in 2010. The aim of COCARDE-ERN is to pool these data and re-evaluate and compare the results from different carbonate settings to *build a synthesis of our present knowledge on carbonate mound systems from recent settings*. This synthesis will be the initial stepping stone in COCARDE-ERN's vision for proceeding stepwise into the geological past.
- To **survey** relevant Cenozoic, Mesozoic and Paleozoic carbonate systems. The COCARDE-ERN sponsored workshops and field seminars will allow the screening of outstanding land sites as potential candidates for scientific drilling, for moving stepwise back in time.
- To **identify** and **develop** thematic topics of common academic and industrial interest in carbonate mound research: (I) Mound occurrence along continental margins (structural and basinal setting). (II) Mounds in frontier carbonate systems. (III) Mound province landscapes. (IV) Mound size and composition. (V) Key players in mound development: external vs. internal controls on biogeochemistry. (VI) The role of microbial communities in mound development. (VII) Possible primary templates for reservoir compartments. (VIII) Fluid migration pathways and implications for reservoir connectivity. (IX) Early diagenesis, carbonate dissolution and precipitation, dolomitisation, and hence (X) controls on reservoir porosity – primary



and secondary – permeability and compartmentalisation.

These are topics of high interest for the hydrocarbon industry, with a tremendous potential for catalysing fundamental breakthroughs. Indeed, while obvious potential topics of interest for industry may be identified in modern mound research, conversely, fundamental scientific research on carbonate mounds may dramatically benefit from interaction with the hydrocarbon industrial community. Cooperation with industry indeed may open increased access to the vast industrial database on fossil mound systems, to better confront the observations from the modern ocean with those of the geological record.

- To **address** a key issue in mound systems, that is mound diversity and variability in space and time. Drilling subsurface in fully buried mounds in a variety of settings is a key issue in the understanding of the transformation of a recent mound body, on its way to the fossil record. A new drilling proposal with

Figure 1
Left. (a) Seismic line across Challenger mound (Porcupine Seabight, SW Ireland) with indicated drill sites A, B, C, and E (from left to right) of IODP Exp. 307 (modified from Foubert and Henriet, 2009, Springer-Verlag). **(b)** Mound Complex 1 and 2 of the Puebla de Lillo mounds (Province of León, NW Spain) with proposed drilling strategy through Mound Complexes 1 and 2 and intermound strata. White lines of t1 and t2 indicate physically traceable timelines for correlation between complex 1 and 2, greenish-blue dotted lines l1 to l7 indicates timelines for correlation between Mound Complex 1 and intermound facies (modified from von Allmen, 2006, MSc thesis, University Fribourg, Switzerland).
Right. Comparison of recent cold-water coral mounds from Porcupine Seabight with Carboniferous algal mounds at Puebla de Lillo is indicated to the right. Although the mounds have different framework constructors (corals *vs.* algae) and therefore different demands on food (heterotrophic *vs.* autotrophic), the mounds were built up in comparable states of climate and seawater chemistry (= similar boundary conditions with aragonitic sea, cold climate period with strong glaciations). **(1)** Secular variation in the mineralogy of Phanerozoic non-skeletal marine carbonates (from Stanley and Hardie 1998, Paleo^3 144, 3–19). **(2)** Periods of icehouse (dark grey) and greenhouse (light grey), arrows indicate glaciations (from Frakes *et al.* 1992, Cambridge Univ. Press). Figure modified after Samankassou *et al.* (2010, ICDP Pre-proposal LIMO-Drill).

the ‘Remotely Controlled Sea-Floor Drill Rig’ “MeBo” (Meeresboden-Bohrgerät) on Moroccan mounds and the EuroFLEETS cruise “Atlantic-Mediterranean Gateway” scheduled for 2013 will initiate in-depth research in cold-water coral carbonate mounds on non-glaciated Moroccan continental margins. COCARDE-ERN will provide support to such initiatives, and will catalyse satellite projects in various settings.

- To **foster** long-term, sustainable support for global training through research in the frontier domain of modern and fossil mound science, which presents an opportunity for coaching students and young researchers during workshops and field seminars towards scientific excellence and entrepreneurship.

Figure 2. Cold-water coral reef off Norway

The research groups potentially contributing to COCARDE-ERN are spread across Europe, and their partners and associates across the world. The Programme is designed to bring together scientists representing a wide spectrum of disciplines (e.g. geophysics, sedimentology, paleobiology, paleoceanography, biogeochemistry, geomicrobiology, etc.). Short visiting grants within the Programme will help both experienced and young researchers to exchange expertise and to get access to facilities and opportunities for multidisciplinary training. Moreover, the combination of a wide range of expertise in exploring mounds in space and time will drive scientists towards the development of new tools and protocols.

The Programme will benefit from lab facilities at both large European research institutions and smaller research clusters within the academic world. Creating an international pool of lab facilities necessary for carbonate mound research will foster the mobility of young scientists and induce stimulating discussions between different institutions. Additionally, one of the tasks of the Programme is the facilitation of the organisation of scientific cruises. The Programme will stimulate the use of research vessels from different nations. The access to advanced drilling technology is one of the crucial success factors for the Programme. The University of Bremen (MARUM), where one of Europe’s most promising new tools for ocean margin exploratory drilling – the Remotely Controlled Sea-Floor Drill Rig “MeBo” – has been developed in recent years, will take the lead within the Programme to fully address the community’s technological needs. MeBo is designed to address

targets with a mid-range penetration and with technical standards which meet IODP practice. Continental drilling and logging is foreseen in collaboration with ICDP.

Through a close collaboration with industry, academic researchers will get access to unique datasets and will become familiar with exploration techniques used in industry. Moving from exploration to experimentation and modelling is a basic approach in reservoir engineering: cooperation with industry will enhance the skills of young researchers to move into predictive modelling and into modelling of the transformation of a carbonate body through time.

- Exploring mounds in shallow and deep environments (warm-water *versus* cold-water) and time (recent *versus* ancient) with a holistic approach will drive the understanding of the global carbonate factory beyond its present limits.
- Cross-fertilisation between the industrial and academic worlds will spur innovative thinking and practices in frontier carbonate systems research.
- The development of new drilling strategies (onshore *versus* offshore) for exploring mounds in multiple space and time scales will significantly contribute to the development of new tools and protocols.
- Enhancing the human and societal dimension: COCARDE-ERN can contribute to the development of a network of dynamic Masters and PhD programmes throughout Europe and beyond, to the stimulation of professional apprenticeships and temporary staff secondments between industry and academia, and to the co-funding of doctoral and postdoctoral research.

Figure 3. COCARDE field seminar (Oviedo, Spain).

Activities, Key Targets and Milestones

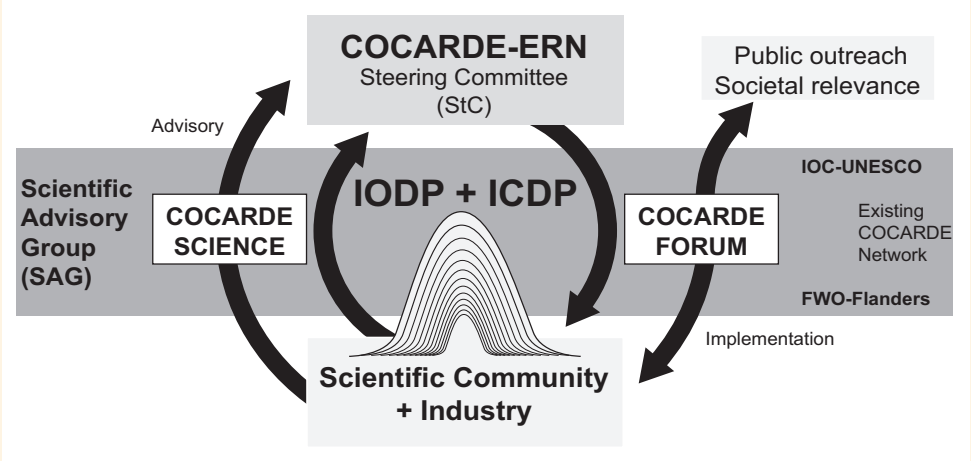
COCARDE-ERN builds upon the operational structure of the COCARDE International Coordination Action (ICA) concept, launched in 2009 under the auspices of IOC/UNESCO. As an emanation of "COCARDE Science", the COCARDE-ERN Science Advisory Group (SAG) will provide additional external expertise to the Steering Committee (SC), whenever invited (Figure 4). "COCARDE Forum" takes upon request or autonomously initiatives for mining ideas and opportunities, which are then compiled and translated into research plans. The SC will meet once a year over the duration of the Programme, discussing strategies, organising open calls for workshops and field seminars, managing visiting grant applications and assessing targets and milestones each year. SAG members may join the meetings to support the SC, upon invitation.

At the Oviedo workshop on "Cold-Water Carbonate Mounds in Shallow and Deep Time", the strategy of "Walking over Stepping Stones" in the implementation process has been elaborated. The 2011-2016 roadmap for COCARDE-ERN to achieve its scientific and operational objectives is shown in Figure 5. The key activity is a scheme of yearly open calls for organising integrated workshops and field seminars, in accordance with the adopted "Oviedo format" (two-day workshop, three-day field seminar). The start of the COCARDE-ERN Programme has been marked by the first SC meeting held on June 27th, 2011 in Fribourg (CH).

The dedicated workshops and field seminars are designed to bring the marine and continental carbonate mound research groups together to plan and discuss common actions, including:

- to review existing carbonate mound data and set up an integrated database;
- to identify ICDP targets to explore Cenozoic, Mesozoic and Paleozoic mound provinces, to sample them with protocols, comparable to ocean drilling practice, where relevant, and to support their exploitation phase;
- to actively support the preparation and exploitation phases of marine coring and drilling campaigns;
- to foster new ocean drilling initiatives and support their exploitation, where relevant.

Figure 4. The structure of COCARDE-ERN.



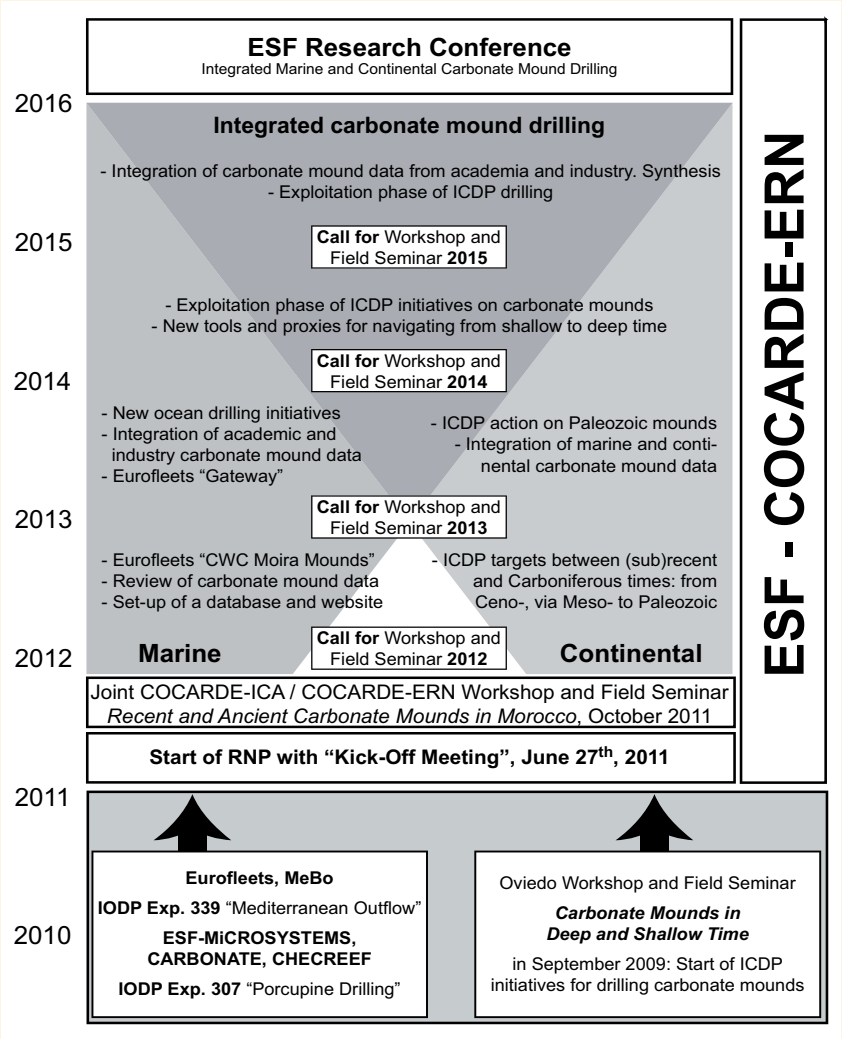


Figure 5. Roadmap of COCARDE-ERN. The Research Conference "Integrated Marine and Continental Carbonate Mound Drilling" will mark the end of the COCARDE-ERN implementation phase and provides a platform for follow-up networking and research initiatives.

A key target of the Programme for the final year will be the organisation of a large research conference to compile the scientific objectives and achievements and to formulate strategies for the future of mound science. As for the COCARDE Fribourg meeting in January 2009, a special volume in a scientific journal or an edited book dedicated to Integrated Marine and Continental Carbonate Mound Drilling may mark a landmark of the COCARDE-ERN Programme.

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For the latest information on this Research Networking Programme consult the COCARDE-ERN websites: **www.esf.org/cocarde** and **www.cocarde.eu**

Cover picture:
Kess Kess mounds, Tafilalt, Morocco.

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