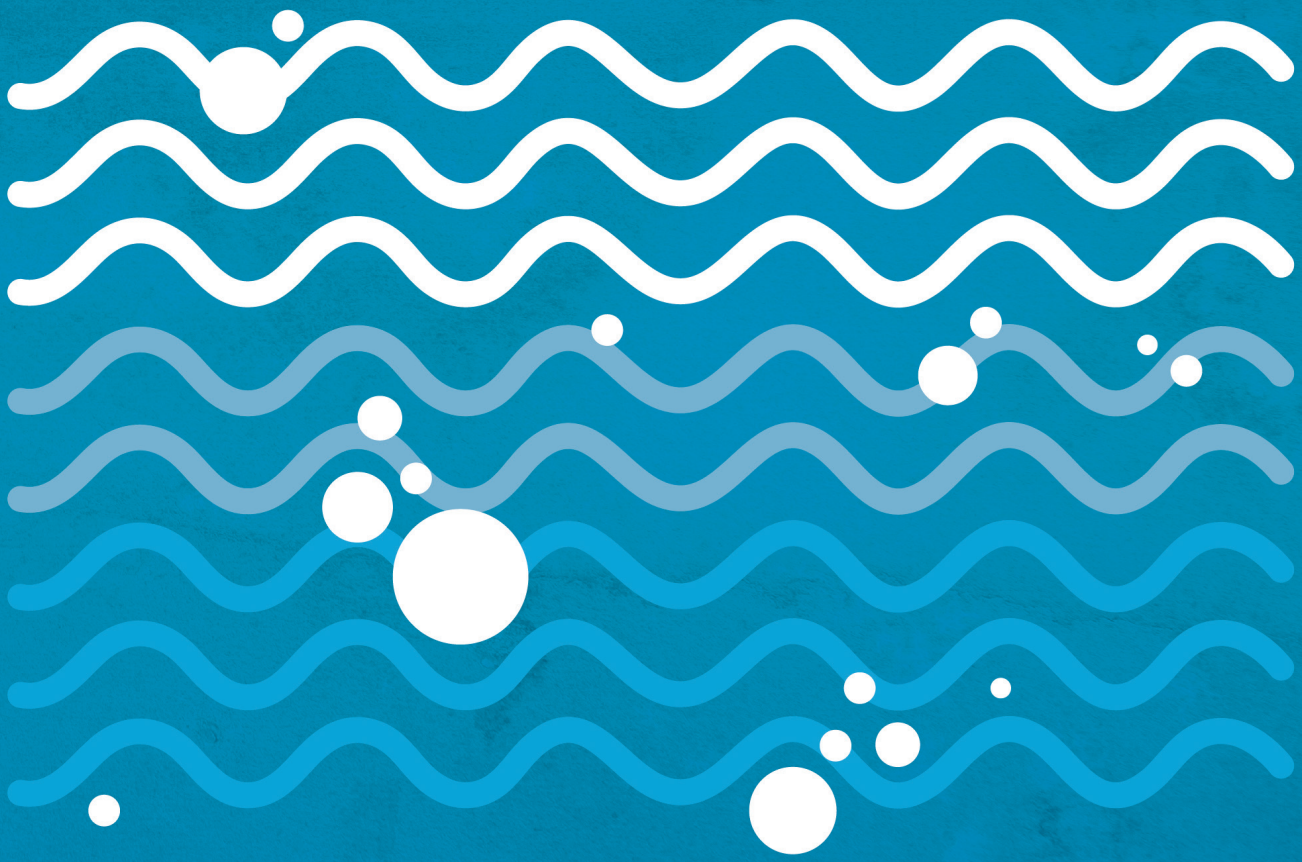
GIMS 15

23-27 OCTOBER 2023

# GAS IN MARINE SEDIMENTS CONFERENCE

CÁDIZ
Spain

# ABSTRACTS BOOK



UCA Universidad de Cádiz
cei·mar International Campus of Excellence in Marine Sciences
GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
CSIC Consejo Superior de Investigaciones Científicas
IGME Instituto Geológico y Minero de España

**Editors:**
Somoza, L., Fernández-Puga, M.C. and Santofimia, E. (Editors)

# SCIENTIFIC SESSIONS

**Thematic Session 1: The Upward Path of gas: from the Subsurface to the Atmosphere through the Ocean.**

MacDonald, I., Silva, M., O'Reilly, C. Fate of methane in the water

Zhou, X. and Katsman, R. Competitive methane bubble growth in aquatic muds

Du, Z.F., Wang, B., Luan, Z.D., Xing, L., Lian, C., Wang, L.F., Xi, S.C., Li, L.F., Cao, L., Zhang, X.A. A novel method for calculation of methane flux at cold seep area based on long-term in-situ observation data

Katsnelson, B., Uzhansky, E., Lunkov, A., Katsman, R. Estimation of gas bubble size in sediment of Lake Kinneret using bottom reflection of wideband sound signals

Katsman, R., Uzhansky, E., Lunkov, A., Katsnelson, B. Methane gas dynamics in sediments of lake Kinneret, Israel, and its limnological controls: insights from a multi-annual acoustic investigation and correlation analysis

Sánchez-Rodríguez, J., Sierra, A., Fernández-Puga, M.C., Ponce, R., Forja, J., Ortega, T. Sediment-water fluxes of $CH_4$ and $N_2O$ along the Guadalquivir Estuary (Gulf of Cádiz)

**Thematic Session 2: The Role and Diversity of Chemosynthetic Organisms at Gas Seeps.**

De la Fuente, M., Arndt, S., Marín-Moreno, H., Minshull, T.A., Vaunat, J. Examining the efficiency of the anaerobic oxidation of methane (AOM) biofilter in gassy sediments

Rincón-Tomás, B., González, F.J., Somoza, L., Medialdea, T., Lobato, A., Santofimia, E. Microbial biomineralization processes related to seabed fluid emissions: hydrocarbon cold seeps vs. volcanic-hydrothermal vents

Argentino, C., Akinselure, A., Fallati, L., Savini, A., Ferré, B., Panieri, G. Biogeochemical processes affecting the distribution of chemosynthetic communities at a cold-water coral site off the Vesterålen coast, northern Norway

**Thematic Session 3: Active Mud Volcanoes: Structure, Plumbing, Chemistry and Triggering-Mechanisms.**

Giraldo, C. Regional geology around a thermogenic gas discovery offshore Morocco (Gharb basin)

Menapace, W., Xu, S., González-Lanchas, A., Asioli, A., Urgeles, R., Perea, H., Kopf, A. Mud volcanism, fluid flow and seismicity: results from recent expeditions in the Gulf of Cádiz

Somoza, L. and Medialdea, T. Mud volcanoes along the Gibraltar Arc: episodic tectonic control of the Eurasia-Africa plates

Pierre, C., Rouchy, J.M., Blanc-Valleron, M.M. Caruso, A. Active mud volcanoes in Sicily: isotopic composition of fluids and of authigenic carbonates

Doll, M., Römer, M., Pape, T., Klügel, A., Kaul, N., Kölling, M., Bohrmann, G. Recent activity and evolutionary reconstruction of Sartori mud volcano in the Calabrian Arc, Mediterranean Sea

Argentino, C., Wittig, C., Peckmann, J., Panieri, G. Nitrogen uptake by methane-oxidizing consortia in gas hydrate-bearing sediments at Håkon Mosby mud volcano, SW Barents Sea

Menapace, W. and Kopf, A. The Mediterranean Ridge 25 years after the ODP 160 expedition: new discoveries on mud volcanism and future research trajectories

**Thematic Session 4: Active seafloor gas emissions, gas reservoirs and tectonics around the world.**

Meilijson, A., Reznik, I.J., Rosenberg, Y.O., Pape, T., Bohrmann, G. Bialik, M.O., Kanari, M., Giladi, A. Herut, B., Rubin-Blum, M., Makovsky, Y. Interaction of sub-seafloor gas reservoir drainage, the Messinian salt, and the resilience of deep-water ecosystems

Bohrmann, G., Tseng, Y., Smrzka, D., Lin, S., Berndt, C., Römer, M., Pape, T., Schröder-Ritzrau, A., Frank, N. Yam seep area at four-way closure ridge, Taiwan - a typical seep associated with an accretionary ridge

Ng-Cutipa, W.L., Ramos, A., Cerpa, L., Pieren, A., Medialdea, T., Somoza, L. Gas emission systems, BSRs and active tectonics in the NW Perú basins

Menapace, W., Perea, H., STRENGTH cruise participants. Geophysical evidence for a newly discovered mud volcano field in the northern Moroccan continental slope, south Alborán Sea

Medialdea, T., Fiorentino, A., Battaglini L., Somoza, L., Lobato, A., González, F.J. EMODnet geology: fluid emission database of the European seas

Gontharet, S., Ricard, C., Caquineau, S., Demange, J., Pierre, C., Dupré, S., Riboulot, V. Diagenetic carbonates related to hydrocarbon-rich seepage in the Romanian sector of the Black Sea (GHASS 2 oceanographic cruise)

Lobato, A., Medialdea, T., Somoza, L., González, F.J., Marino, E. Atlas of active seabed fluid emissions along the Spanish continental margin

**Thematic Session 5: The Complex Interplay of Gas Emissions in Marine Sedimentary Basins in Polar Regions, Arctic and Antarctica.**

Andreassen, K., Winsborrow, M., Patton, H., Serov, P., Mattingsdal, R. Interaction between methane and ice in an Arctic sedimentary petroleum basins

Römer, M, Rodes, N., Betlem, P., Senger, K., Noormets, R., Marcon, Y., Pape, T., Bohrmann, G. The complex gas emission systems in Svalbard fjords

Santofimia, E., Asensio-Ramos, M., Amonte, C., Rincón-Tomás, B., González, F.J., Lobato, A., Ng Cutipa, W.L., Cervel, S., Medialdea, T., Marino, E., Pérez, N.M., Somoza, L. and EXPLOSEA Team. Geochemical characterization of gas release source from a volcanic sedimentary basin (Fumarole Bay, Deception Island, Antarctica)

## Thematic Session 6: **Seafloor Gas Hydrates in the Oceans.**

Dupré, S., Agnissan, C., Akhmanov, G., Bellon, C., Brandily, C., Caquineau, S., Donval, J.P., Fandino-Torres, O., Gontharet, S., Grilli, R., Ker, S., Le Gonidec, Y., Ogor, A., Peyronnet, C., Pierre, C., Poort, J., Ricard, C., Ruffine, L., Sultan, N., Théréau, E., Thomas, Y., Riboulot, V.A. A hydrate ridge within widespread methane seeps, offshore Romania (Black Sea)

Vasilev, A., Kvamme, B., Botusharov, N., Genov, I., Pehlivanova, R., Petsinski, P. GEOHYDRATE project results and a new paradigm in gas hydrate research – scientific basis of the Bulgarian gas hydrate program

Portnov, A., Flemings, P., Meazell, K., Hudec, M., Dunlap, D. Anomalously deep gas hydrate stability zone in rapidly formed sedimentary basins

Burwicz-Galerne, E., Gupta, S., Rüpke, L. Spontaneous free methane gas migration in marine sediments at high latitudes

Firoz, B. and Virsen, G. Constraints on the authigenesis of magnetite and greigite in the cold seep sediments from the Bay of Bengal

Pape, T., Tu, T.H., Lin, S., Berndt, C., Wallmann, K., Tseng, Y., Bohrmann G. Gas hydrates and lithologies affect the composition of gases migrating through sediments drilled off SW Taiwan

Monteleone, V., Marín-Moreno, H., Bayrakci, G., Best, A, Shaon, F., Hossain, M.M., Karim, A.A., Alam, M.K. Gas hydrate deposits in the northern Bay of Bengal, offshore Bangladesh

Kumar, A., Cook, A., Portnov, A., Lawal, M., Palmes, S., Frye, M. Bottom simulating reflections and pockmark distribution in the northern Gulf of Mexico

Virsen, G. and Firoz, B. Diagenesis and authigenesis of magnetic minerals in marine gas hydrate systems from the Bay of Bengal

# THEMATIC SESSION 1

## The Upward Path of gas: from the Subsurface to the Atmosphere through the Ocean.

# FATE OF METHANE IN THE WATER COLUMN

MacDonald, I.[1], Silva, M.[1], O'Reilly, C.[1]

[1]*Dept. Earth Ocean and Atmospheric Science, Florida State University*

imacdonald@fsu.edu

## ABSTRACT

In 2004, destruction of a Gulf of Mexico oil platform by Hurricane Ivan initiated a discharge of oil and gas from a depth of 135 m, where its bundle of well conductors was broken below the seafloor near the toppled wreckage. Oil and gas bubbles formed plumes that rose to the surface, which were quantified by acoustic survey, visual inspection, and discrete collections in the water column. Continuous air sampling with a cavity ring-down spectrometer (CRDS) over the release site detected atmospheric methane concentrations as high as 11.7 ppm, ~6 times greater than an ambient baseline of 1.95 ppm. An inverse plume model, calibrated to tracer-gas release, estimated a flux to the atmosphere of 9 g $s^{-1}$ (Mason et al., 2019). Subsequent installation of a containment system allowed gas to escape into the water at 120 m depth after passing through a separator that diverted oil into storage tanks. In a follow-up investigation (Silva et al., 2022), the CRDS detected transient peaks of methane as high as 11.1 ppm while oil was being recovered to the ship from underwater storage tanks. However, concentrations returned to the ambient baseline when recovery was complete, despite the ship being stationary within surfacing plumes of gas. We conclude that methane can reach the atmosphere from depths of ~100 m when associated with oil and oil-coated bubbles, but apparently dissolves entirely into sea water when oil is removed from the flow.

**Key words:** Methane Flux, Water Column, Atmosphere, Hydrocarbon Seep

**Acknowledgments:** The 2018 survey was jointly funded by the U.S. Department of the Interior, Bureau of Safety and Environmental Enforcement, and the U.S. Department of Commerce, National Oceanic and Atmospheric Administration. The 2021 data collection was funded by the Environment and Natural Resources Division, United States Department of Justice.

**References:**

Mason, A.L., Taylor J.C., MacDonald I.R., Eds. (2019). An Integrated Assessment of Oil and Gas Release into the Marine Environment at the Former Taylor Energy MC20 Site. NOAA National Ocean Service, National Centers for Coastal Ocean Science.

Silva, M., Roa, C., Ali, N.B.H. O'Reilly, C. Abichou T., MacDonald I. R. (2022). Fate of Methane Released From a Destroyed Oil Platform in the Gulf of Mexico. Frontiers in Earth Science 10.

# COMPETITIVE METHANE BUBBLE GROWTH IN AQUATIC MUDS

Zhou, X.[1], Katsman, R.[1]

[1]*Dr. Moses Strauss Department of Marine Geosciences, University of Haifa, 199 Aba Khoushy Ave, Haifa 3498838, Israel*

xzhou@campus.haifa.ac.il

## ABSTRACT

Methane ($CH_4$) bubbles in shallow aquatic muds pose a significant environmental threat. Previous studies overlooked bubble interactions due to the opacity of muddy sediments and limited resolution for characterization. Here, we use a numerical model to simulate the growth of $CH_4$ bubble pairs with varying initial sizes in aquatic muds, considering mechanical and reaction-transport processes. Our findings reveal the dominance of mechanical and solute transport interactions at different stages of bubble growth, leading to slower growth of smaller competitive bubbles. The stress exerted by larger competitive bubbles affects their internal pressure and diffusive $CH_4$ flux to smaller bubbles, resulting in a slower initial growth rate ($t < 40$ s). Furthermore, the diversion of $CH_4$ from smaller bubbles by larger ones further inhibits their growth. These interactions contribute to the formation of more laterally oriented smaller bubbles and significant deformations of larger bubbles, particularly as the distance between the bubble pair decreases. The competitive growth of bubbles explains the observed size distribution pattern in laboratory experiments and in situ, which promotes $CH_4$ retention in muddy sediments and the formation of gas domes, which serve as precursors to pockmarks formation. Our study provides a basis for upscaling to different characteristics of effective gassy media and for transient models of gas retention evolution, while maintaining the essential features of single bubble growth. It contributes to evaluating and potentially reducing uncertainties associated with $CH_4$ fluxes from shallow aquatic sediments.

**Key words**: Methane bubble, Muddy sediments, Competitive growth, Stress field, Solute transport

**Acknowledgments**: This project was supported by the U.S.-Israel Binational Science Foundation, grant No. 2018150, and by MSc Fellowship from the University of Haifa, Israel. We thank Dr. Painuly for his help with modelling.

# A NOVEL METHOD FOR CALCULATION OF METHANE FLUX AT COLD SEEP AREA BASED ON LONG-TERM IN-SITU OBSERVATION DATA

Du, Z.F.[1], Wang, B.[1], Luan, Z.D.[1,2,4], Xing, L.[3], Lian, C.[1], Wang, L.F.[3], Xi, S.C.[1], Li, L.F.[1], Cao, L.[1], Zhang, X.[1,2,4*]

*[1]Key Laboratory of Marine Geology and Environment & Center of Deep Sea Research, Institute of Oceanology, Center for Ocean Mega-Science, Chinese Academy of Sciences, Qingdao 266071, China*

*[2]Laboratory for Marine Geology, Pilot Laboratory for Marine Science and Technology (Qingdao), Qingdao 266061, China*

*[3]Key Lab of Submarine Geosciences and Prospecting Techniques, Ministry of Education, Ocean University of China, Qingdao 266100, China*

*[4]University of Chinese Academy of Sciences, Beijing 101408, China*

xzhang@qdio.ac.cn

## ABSTRACT

The abundant multiphase methane is released from sediments to the hydrosphere in cold seep areas, and becomes an important part of the global carbon cycle. Video capture of gas bubbles and modeling analysis methods are commonly used to calculate the methane flux of the cold seep area. However, these two methods ignore the contribution of the invisible microscopic gaseous and dissolved methane to the methane flux of the cold seep area. Thus, the previously obtained methane flux may not be accurate.

Using the previously obtained in situ Raman spectra, sensor data and long-term continuous video data at cold seep area in the South China Sea, the methane flux of this cold seep area was calculated. Through the quickly formation process of natural gas hydrate observed by the "Faxian" remote operated vehicle (ROV), methane flux of a single active cold seep vent is calculated to be $2.337*10^3$-$3.526*10^3$ mol/day. Using the long-term image data, the distribution patterns of seabed substrate, and the dissolved methane concentration above the different types of seabed substrate in this cold seep area, the methane flux in the cold seep area is calculated to be $1.57*10^6$ mol/day.

The above results show that the slow methane-releasing areas such as common sediment areas and authigenic carbonate rock areas in the cold seep area contribute more to the methane flux than the active cold seep vents. It also can be seen that the flux is larger than that calculated by previous simulations, and the methane release flux needs to be re-evaluated.

**Key words:** Methane flux; cold seep area; multiphase methane; in situ detection and observation

**Acknowledgments:** This work was supported by the National Natural Science Foundation of China (52001303, 92058206), Natural Science Foundation of Shandong Province (ZR2019BD029).

**References:**

Boetius, A., Wenzhöfer, F. (2013). Seafloor oxygen consumption fuelled by methane from cold seeps. Nature Geoscience, 725-734.

Skarke, A., Ruppel, C., Kodis, M., Brothers, D., Lobecker, E. (2014). Widespread methane leakage from the sea floor on the northern US Atlantic margin. Nature Geoscience, 657-661.

Römer, M., Sahling, H., Pape, T., Bohrmann, G., SpieB, V. (2012). Quantification of gas bubble emissions from submarine hydrocarbon seeps at the Makran continental margin (offshore Pakistan). Journal of geophysical research, 117.

# ESTIMATION OF GAS BUBBLE SIZE IN SEDIMENT OF LAKE KINNERET USING BOTTOM REFLECTION OF WIDEBAND SOUND SIGNALS

Katsnelson, B.[1], Uzhansky, E.[2], Lunkov, A.[3], Katsman, R.[1]

[1]*University of Haifa, Israel*

[2]*Technion, Haifa, Israel*

[3]*General Physics Institute, Moscow, Russia*

bkatsnels@univ.haifa.ac.il

## ABSTRACT

Gas-rich sediments cause permanent concern due to their contribution to sediment destabilization and global warming. In this paper, acoustical methodology suggested by the authors is tested experimentally in Lake Kinneret using wideband acoustic signals. The experiment was carried out in the central deep part of the lake in July 2022. The recording system consisted of 7 hydrophones assembled into a 30 m long vertical line array (VLA) with 5 m spacing between the hydrophones. The highest hydrophone was located 1 m below the lake's surface. The LUBELL-9162 underwater sound speaker was located at the depth of 6 m and was attached to the VLA (i.e., zero horizontal distance between the source and the VLA). Results of experiments and the corresponding acoustic data processing are presented. Ten 5-s long wideband (0.3-15 kHz) chirp pulses were radiated by an underwater transducer deployed at the location, where the seafloor depth is 35 m. Received sound field time series consists of a sequence of pulse arrivals comprised of specular reflections from interfaces followed by reverberation codas caused by non-specular scattering from the interface roughness and volume inhomogeneity. Having studied the frequency dependence of the signal reflected from the bottom, a dip in the reflection coefficient was found at frequencies of 4-6 kHz. This suggests the existence of bubbles with an effective spherical diameter of about 3 mm, which is consistent with previous direct measurements of bubbles in the lake sediments.

**Key words:** Gassy Sediment, methane bubbles, underwater acoustics

**Acknowledgments:** Work was supported by Binational Science Foundation, grant 2018150

# METHANE GAS DYNAMICS IN SEDIMENTS OF LAKE KINNERET, ISRAEL, AND ITS LIMNOLOGICAL CONTROLS: INSIGHTS FROM A MULTI-ANNUAL ACOUSTIC INVESTIGATION AND CORRELATION ANALYSIS

Katsman, R.[1], Uzhansky, E.[1,2], Lunkov, A.[3], Katsnelson, B.[1]

*[1]Dr. Moses Strauss Department of Marine Geosciences, Leon H. Charney School of Marine Sciences, University of Haifa, Haifa, ISRAEL*

*[2]Dynamics Laboratory, Faculty of Mechanical Engineering, Technion – Israel Institute of Technology, Haifa, ISRAEL*

*[3]Prokhorov General Physics Institute of the Russian Academy of Sciences, RUSSIA; Bauman Moscow State Technical University, Moscow, RUSSIA*

rkatsman@univ.haifa.ac.il

## ABSTRACT

Methane ($CH_4$) is the simplest and most common hydrocarbon in nature. $CH_4$ gas content is accommodated in discrete bubbles in shallow aquatic sediments. Bubble dynamics there is controlled by a diversity of physical, mechanical and biogeochemical processes that vary spatially and temporally over the aquatic ecosystem. In this study, a multi-annual (2015-2021) acoustic database on gas content in sediments of lake Kinneret, Israel was compiled. Gas content was evaluated there by acoustic applications from sound speed inferred from the reflection coefficient. A multivariate linear regression was fitted, and a closed form expression of sediment gas content dependence was obtained, on the following predictors changing spatially and temporally over the lake: 1) water depth; 2) short-leaving $CH_4$ production rate peaks fueled by punctuated phytoplankton bloom crash; 3) $CH_4$ bubble dissolution rates. Our analysis indicates that short leaving $CH_4$ production peaks act as major controls on sediment gas content in the lake Kinneret, where hydrodynamic regime and slopped bottom transport the autochthonous organic matter toward the profundal lake zone. Alternatively, water depth predictor has a least significance, explained mainly by lack of ebullition from the explored medium-deep parts of the lake. The correlation enables quantification and prediction of gas content dynamics in sediments of the lake Kinneret under the changing conditions. Our modelling could be extended to other aquatic ecosystems with different limnological conditions. Predicting $CH_4$ gas content dynamics is important for accurate evaluation of $CH_4$ fluxes from the aquatic sediments, and for assessment of sediment load-bearing capabilities affected by gas presence.

**Key words**: Gas content, acoustic application, regression analysis, phytoplankton

**Acknowledgments**: The work is supported by the U.S.-Israel Binational Science Foundation (BSF) grant 2018150.

# SEDIMENT-WATER FLUXES OF $CH_4$ AND $N_2O$ ALONG THE GUADALQUIVIR ESTUARY (GULF OF CÁDIZ)

Sánchez-Rodríguez, J.[1], Sierra, A.[1], Fernández-Puga, M.C.[2], Ponce, R.[1], Forja, J.[1], Ortega, T.[1]

*[1]Dpto. Química-Física, INMAR, Universidad de Cádiz, Facultad de CC del Mar y Ambientales. Campus Universitario Puerto Real (Cádiz), Spain*

*[2]Dpto. CC de la Tierra, INMAR, Universidad de Cádiz, Facultad de CC del Mar y Ambientales. Campus Universitario Puerto Real (Cádiz), Spain*

jairo.sanchez@uca.es

## ABSTRACT

The Guadalquivir Estuary is the largest estuary in the southwest basin of the Iberian Peninsula, which is subject to strong anthropogenic influence such as the high damming or the multitude of crop fields on its margins, affecting the sediments of the system characterized by high organic matter content and low oxygen levels. We studied the benthic distribution and emissions of methane ($CH_4$) and nitrous oxide ($N_2O$) at 5 stations along the Guadalquivir Estuary in summer '21 and winter '22. Sediment samples were collected using cores to establish vertical profiles of $CH_4$ and $N_2O$, in addition, incubations per station were conducted in benthic chamber to estimate benthic fluxes. The replicates of cores profiles and the benthic fluxes obtained in the same station presented different behaviors and values, highlighting the high heterogeneity of the sediment in estuarine systems. In general, $CH_4$ profiles show maximum concentrations between 25-30 cm and more intense profiles in the inner zone of the system, while $N_2O$ shows irregular profiles with higher values in the middle zone of the estuary. The increase of $CH_4$ with depth and the $N_2O$ subsurface maximum highlight the importance of methanogenesis and nitrification/denitrification processes. Benthic $CH_4$ fluxes remain constant in winter (10 ± 6 μmol $m^{-2}$ $d^{-1}$) and increase dramatically inland in summer (from 7 μmol $m^{-2}$ $d^{-1}$ to above 9000 μmol $m^{-2}$ $d^{-1}$), while $N_2O$ benthic fluxes are relatively constant throughout the system (6 ± 4 μmol $m^{-2}$ $d^{-1}$).

**Key words**: Methane, nitrous oxide, sediments, benthic fluxes, Guadalquivir Estuary

**Acknowledgments**: This work has been funded by projects RTI2018-100865-B-C21 (Spanish CICYT) and P20_00953 (Junta de Andalucía).

# THEMATIC SESSION 2

## The Role and Diversity of Chemosynthetic Organisms at Gas Seeps.

# EXAMINING THE EFFICIENCY OF THE ANAEROBIC OXIDATION OF METHANE (AOM) BIOFILTER IN GASSY SEDIMENTS

De La Fuente, M.[1], Arndt, S.[1], Marín-Moreno, H.[2], Minshull, T.A.[2], Vaunat, J.[3]

*[1]BGeoSys, Department Geoscience, Environment & Society (DGES), Université Libre de Bruxelles,1050 Brussels, Belgium*

*[2]School of Ocean and Earth Science, University of Southampton, European Way, Southampton SO14 3ZH, UK*

*[3]Department of Civil and Environmental Engineering, Universitat Politècnica de Catalunya, 08034 Barcelona, Spain*

maria.de.la.fuente.ruiz@ulb.be

## ABSTRACT

The stability of methane hydrates in continental margins is threatened by ocean warming, potentially leading to the release of substantial, yet unconstrained, amounts of methane into the overlying water column and, eventually, the atmosphere (Rupple and Kessler, 2017). Within marine sediments, the microbially mediated process of anaerobic oxidation of methane (AOM) plays a crucial role in mitigating the benthic discharge of such methane. Nonetheless, the efficiency of the AOM biofilter can be compromised by two competing factors: (i) the potential for methane to bypass the biofilter, either via advection or migration through preferential permeable paths, and (ii) the slow growth dynamics of the AOM community (De La Fuente et al., 2022; Lenstra et al., 2023). In this study, we employed a novel 1D multiphase reactive transport model to investigate how potential methane emissions resulting from climate-induced hydrate dissociation might impact the efficiency of the sulfate-driven AOM biofilter. Particularly, we assess how multiphase transport dynamics of methane control the total methane accessible to the AOM community. Furthermore, we examine the impact of the AOM biomass dynamics on their ability to respond to transient scenarios of methane injection into the sediment column. Our preliminary findings suggest that in gassy sediments, the AOM biofilter has a notably limited capacity to mitigate benthic methane emissions. They also show that the slow growth rate of methane-oxidizing microorganisms can create significant temporal windows of opportunity for methane to escape into the ocean.

**Key words:** Anaerobic oxidation of methane, benthic methane emissions, AOM biofilter efficiency, multiphase transport of methane, AOM biomass dynamics

**Acknowledgments**: This work has been funded by the Fonds de la Recherche Scientifique de Belgique (F.R.S.-FNRS Grant No. 2.5020.11) and by the Walloon Region.

**References**:

Ruppel, C.D., Kessler, J.D. (2017). The interaction of climate change and methane hydrates, Rev. Geophys., 55, 126-168.

De La Fuente, M., Arndt, S., Marín-Moreno, H., Minshull, T.A. (2022). Assessing the Benthic Response to Climate-Driven Methane Hydrate Destabilisation: State of the Art and Future Modelling Perspectives. Energies 15, 3307.

Lenstra, W.K., van Helmond, N.A.G. M. Martins, P.D., Wallenius, A.J., Jetten, M.S.M. Slomp, C.P. (2023). Gene-Based Modeling of Methane Oxidation in Coastal Sediments: Constraints on the Efficiency of the Microbial Methane Filter. Environmental Science & Technology.

# MICROBIAL BIOMINERALIZATION PROCESSES RELATED TO SEABED FLUID EMISSIONS: HYDROCARBON COLD SEEPS VS. VOLCANIC-HYDROTHERMAL VENTS

Rincón-Tomás, B.[1], González, F.J.[1], Somoza, L.[1], Medialdea, T.[1], Lobato, A.[1], Santofimia, E.[1]

[1]*Geological Survey of Spain (IGME-CSIC), Spain*

b.rincon@igme.es

## ABSTRACT

Emission of sub-seafloor gases onto marine sediments compromises ecosystems linked to hydrocarbon seepages and volcanic-hydrothermal systems. These gases vary depending on their nature, but generally generate local reduced conditions, low oxygen, increase in temperature and seepage/venting of subseafloor fluids rich in $CH_4$, sulfur compounds (S), $CO_2$ and variable quantities of reduced metals (e.g., Fe, Mn, Cu, As, Ni, Rare Earth Elements) and silica. Microorganisms are key players in the consumption and biomineralization of these compounds, driven these metabolisms mainly in symbiosis and acting as the main primary producers. Here, we present an overview of microbial biomineralization processes in three different submarine gas-related ecosystems: (i) mud volcanoes from Gulf of Cádiz linked to hydrocarbon seepage, with characteristic formation of authigenic carbonates by symbiotic anaerobic oxidation of methane (AOM), and sulfur- and methane- oxidation driven as well in symbiosis with Bathymodiolus mussels and Siboglinidae worms (Rincón-Tomás et al., 2019; 2020); (ii) shallow-water low-temperature hydrothermal systems related to mantle $CO_2$ emission from submarine Tagoro volcano (El Hierro Island, Canary Islands) with the occurrence of thick biogenic Fe-oxyhydroxides and sulfur-oxidizing bacterial mats (González et al., 2020); and (iii) seabed fumaroles in Fumarole Bay (Deception Island volcanic island, Antarctica) rich in $CO_2$, $CH_4$ and $H_2$ gasses, where arsenic-oxidation and sulfate/sulfite reduction may play a key role in biomineralization processes at these sites. These biomineralization processes are of special interest since they participate in the reduction of emission of methane into the atmosphere, and in the bioaccumulation of toxic heavy metals like Fe, Hg and As, and compounds of industrial interest like Co, Li, Cu, Mn, Ni, and Rare Earth Elements (REE) (Santofimia et al., 2023).

**Key words**: Microbial-biomineralization, underwater gas-emission, Gulf of Cadiz, Tagoro volcano, Fumaroles Bay

**Acknowledgments**: This work was supported by the Spanish project ATLANTIS (PID2021-12455OB-I00) and the project EXPLOSEA (CTM2016- 75947) funded by the Spanish Ministry of Science and Innovation; and the European projects Horizon Europe TRIDENT (101091959), GSEU Project (101075609), and Next Generation EU-MINECRITICAL (C17.I7, MET2021-00-000).

**References**:

González, F.J., Rincón-Tomás, B., Somoza, L., Santofimia, E., Medialdea, T., Madureira, P., Reitner, J. (2020). Low-temperature, shallow-water hydrothermal vent mineralization following the recent submarine eruption of Tagoro volcano (El Hierro, Canary Islands). Marine Geology, 430, 106333.

Rincón-Tomás, B., Duda, J.P., Somoza, L., González, F.J., Schneider, D., Medialdea, T., Reitner, J. (2019). Cold-water corals and hydrocarbon-rich seepage in Pompeia Province (Gulf of Cádiz) - living on the edge. Biogeosciences, 16(7), 1607–1627.

Rincón-Tomás, B., González, F.J., Somoza, L., Sauter, K., Madureira, P., Medialdea, T., Hoppert, M. (2020). Siboglinidae tubes as an additional niche for microbial communities in the Gulf of Cádiz—A microscopical appraisal. Microorganisms, 8(3), 367.

Santofimia, E., Asensio-Ramos, M., Amonte, C., Rincón-Tomás, B., González, F.J., Lobato, A., Ng Cutipa, W.L., Cervel, S., Medialdea, T., Marino, E., Somoza, L. and EXPLOSEA Team (2023). Geochemical characterization of gas release source from a volcanic sedimentary basin (Fumarole Bay, Deception Island, Antarctica). GIMS15 Conference, Cádiz, Spain.

# BIOGEOCHEMICAL PROCESSES AFFECTING THE DISTRIBUTION OF CHEMOSYNTHETIC COMMUNITIES AT A COLD-WATER CORAL SITE OFF THE VESTERÅLEN COAST, NORTHERN NORWAY

Argentino, C.[1], Akinselure, A.[1], Fallati, L.[2], Savini, A.[2], Ferré, B.[1], Panieri, G.[1]

[1]*Department of Geosciences, UiT The Arctic University of Norway, 9037 Tromsø, Norway*

[2]*University of Milano-Bicocca, Department of Earth and Environmental Sciences, 20126 Milano, Italy*

claudio.argentino@uit.no

## ABSTRACT

Methane seepage in the Hola area off the coast of Vesterålen (N. Norway) has long been known for its peculiar association with cold water coral mounds, but only recently it was possible to explore the distribution of seafloor ecosystems using a Remotely Operated Vehicle (ROV) and to conduct targeted samplings for biogeochemical investigations.

Here, we describe the seafloor habitats and their spatial distribution using high-resolution orthomosaics obtained from the ROV photogrammetry and combine this information with sediment (carbon-nitrogen systematics) and pore fluid (sulfate, dissolved inorganic carbon, methane) geochemical datasets. Microbial mats are the dominant seep-related community and form small white patches of a few tens of cm in diameter surrounding methane-derived carbonate. The carbonates are widespread at this location and form extensive pavements controlling the seafloor distribution of methane bubbling and chemosynthetic ecosystems, thus demonstrating an efficient seal capacity. Microbial mat habitats are characterized by intense sulfate-driven anaerobic oxidation of methane (AOM) generating a shallow sulfate-methane transition located at 10 cm below the seafloor. Dissolved inorganic carbon shows isotopic values as low as −29.8 ‰ confirming high AOM rates releasing $^{13}C$-depleted carbon into the pore waters. A push core revealed the presence of a microbial biofilm at 9 cm that is associated with a sharp drop in downcore $\delta^{13}C$ of sedimentary organic matter and C/N ratios that we interpret to represent a localized accumulation of methanotrophic biomass.

**Key words**: Biogeochemistry, orthomosaics, methane seep, sediment geochemistry, Barents Sea

**Acknowledgments**: this research was supported by Eman7 project (Research Council of Norway grant No. 320100) and AKMA project (Research Council of Norway grant No. 287869) within the frame of the Centre for Arctic Gas Hydrate, Environment and Climate (CAGE) (Research Council of Norway grant No. 223259).

# THEMATIC SESSION 3

## Active Mud Volcanoes: Structure, Plumbing, Chemistry and Triggering-Mechanisms.

# REGIONAL GEOLOGY AROUND A THERMOGENIC GAS DISCOVERY OFFSHORE MOROCCO (GHARB BASIN)

Giraldo, C.[1]

[1]*U3 EXPLORE U3 EXPLORE*

cgiraldoc1958@gmail.com

## ABSTRACT

The hydrocarbon exploration campaigns in the Gharb basin, including the Gulf of Cádiz have demonstrated the existence of active petroleum systems. This talk deals with the main regional topics around a thermogenic gas discovery (Anchois -1) made in the last decade, and recently confirmed with an appraisal well (ONHYM, 2023).

The Gharb basin contains stratigraphic sequences, beginning during the syn-rift period (Triassic - Lower Jurassic) accompanied by evaporitic rocks deposition (Somoza et al., 1999). Following this, a passive margin was developed through the Mesozoic to Quaternary times. The northern edge is bounded by the Alpine Belt, associated with the collision between Eurasian and African plates. This geodynamic scenario includes an attenuated continental crust that has been stretched during the breakup of Pangea.

The two discovery wells are located along the Moroccan slope, immediately to the south of the Larache mud-volcanoes field. Miocene deepwater sands are the main reservoir targets of exploration wells. The structural deformations around this gas accumulation appear to be above an allochthonous salt nappe (salt-canopy) possibly emplaced during the early Miocene. Pliocene to Recent re-mobilization of evaporites could be responsible for the extensional deformations, as well as the associated anticlines and mini-basins located above this salt-canopy.

Several organic rich intervals, ranging from the Jurassic to Cretaceous, are considered potential source rocks for the gas trapped in the Miocene sands. Further studies are needed to establish the timing of generation and migration through Mesozoic and Tertiary sediments.

**Key words**: Thermogenic gas, salt-canopy, deep-water sands

**References**:

ONHYM (2023). https://hydrocarbons.onhym.com

Somoza, L., Lowrie and Maestro, A. (1999). Allochthonous Blocks as Hydrocarbon Traps in the Gulf of Cadiz. Proceedings of the Offshore Technology Conference, OTC-10889: 571-577. ISSN 0160-3663

# MUD VOLCANISM, FLUID FLOW AND SEISMICITY: RESULTS FROM RECENT EXPEDITIONS IN THE GULF OF CADIZ

Menapace, W.[1]; Xu, S.[2], González-Lanchas, A.[3], Asioli, A.[4], Urgeles, R.[1], Perea, H.[1], Kopf, A.[2]

*[1]Department of Marine Geosciences, Institute of Marine Sciences (ICM-CSIC), Barcelona, Spain*

*[2]Department of Marine Geotechnics, MARUM-University of Bremen, Germany*

*[3]Department of Earth Sciences, University of Oxford, United Kingdom*

*[4]Ismar-CNR, Bologna, Italy*

walter@icm.csic.es

## ABSTRACT

Mud volcanoes (MVs) are expulsion features ubiquitously present in areas of tectonic convergence both on land and on the seafloor. Eruptions are deemed crucial to understand the regional geology and fluid-sediment interactions. However, the main drivers behind these sporadic bursts in activity still remain fairly obscure. It is hypothesized that different events can trigger MVs eruptions, therefore originating a plethora of different effects with corresponding ejecta, channeled through the main conduits. Of all the MVs triggers, earthquakes (EQs) are the only ones for which a direct cause-effect relationship has been already established (e.g. Menapace et al., 2017). The Gulf of Cadiz (GoC) has arguably one of the best settings for the study of MVs and paleoseismology, due to the presence of an accretionary wedge with active fluid and solid expulsion structures (>90 MVs, at least three major transform faults, several pockmarks fields) and because of the numerous large magnitude EQs happened in the past, which are well preserved in the sedimentological record (Gracia et al., 2010). Recently, three major seagoing expeditions led by MARUM and the ICM-CSIC set out to investigate the episodicity and nature of MVism in the GoC (Menapace et al., 2021), as well as its relationship with the tectonic and seismic history of the region. We present here the main results from the aforementioned expeditions, which contributed to shed new light on the fluid and solid cycles of the SW Iberian Margin with an unprecedented level of detail, highlighting how a plethora of different processes is, in fact, fueled by and contributing to the GoC mud volcanism.

**Key words**: Mud volcanism, fluid flow, seismicity, Gulf of Cadiz

**Acknowledgments**: This study was funded by the H2020 MSCA-IF action [GA No. 101018321] and by the Austrian Science Fund (FWF) [M 3146-N] and acknowledges the 'Severo Ochoa Centre of Excellence' accreditation (CEX2019-000928-S). Data from the "ImagiNg large SeismogenIc and tsunamiGenic structures of the Gulf of Cadiz with ultra-High resolution Technologies (INSIGHT)" project were used [GA No. CTM2015-70155-R].

**References**:

Gràcia, E., Vizcaino, A., Escutia, C., Asioli, A., Rodes, A., Pallas, R., & Goldfinger, C. (2010). Holocene earthquake record offshore Portugal (SW Iberia): testing turbidite paleoseismology in a slow convergence margin. Quaternary Science Reviews, 29(9-10), 1156-1172.

Menapace W., Völker, D., Sahling, H., Zoellner, C., dos Santos Ferreira, C., Bohrmann, G., Kopf, A. (2017). Long-term in situ observations at the Athina mud volcano, Eastern Mediterranean: taking the pulse of mud volcanism. Tectonophysics, 721, 12-27.

Menapace, W., and Cruise Participants (2021). Long-term monitoring of fluid and solid emissions at the African-Eurasian tectonic boundary in the Alboran Sea and the Gulf of Cadiz, Cruise No. M167, 11.10.2020 - 05.11.2020, Emden (Germany) - Emden (Germany), ALBOCA II. METEOR-Berichte, Gutachterpanel Forschungsschiffe, Bonn, 96 pp.

# MUD VOLCANOES ALONG THE GIBRALTAR ARC: EPISODIC TECTONIC CONTROL OF THE EURASIA-AFRICA PLATE BOUNDARY

Somoza, L.[1], Medialdea, T.[1]

[1]*Geological Survey of Spain (IGME-CSIC), Spain*

l.somoza@igme.es

## ABSTRACT

An update catalogue of up to 84 mud volcanoes located in the Gulf of Cadiz and West Alborán Basin within the Gibraltar Arc has been carried out. An extensive database of multibeam bathymetry, multichannel seismic reflection profiles, ultra high-resolution sub-bottom profiles and samples allow us to carry out a new morpho-tectonic mapping and review the types, morphological characteristics and tectonic controls of MVs. The onshore-offshore mapping of allochthonous units allows us inferring the source of the fluids of the MVs as related to the distinct allochthonous units emplaced in the Gibraltar Arc. Three main types of structural controls are developed: extensional, strike-slip and compressional settings drives the migration pathways for hydrocarbon-enriched fluids acting as efficient conduits for deep-seated overpressure fluids. The correlation of the seismic structure of MVs complexes with the evolutionary stages of these systems allow inferring the onset of activity of mud volcanism since the late Tortonian to present days. Thus, after the emplacement of the allochthonous units of the Gibraltar Arc in the Gulf of Cadiz, we suggest that mud volcanism was driven by episodic compressional events during Messinian-Early Pliocene, Late-Pliocene-Quaternary (ca. 2.6 Ma) and Mid-Pleistocene period (ca. 0.9 Ma). The episodic re-activation periods of mud vulcanism related to the Gibraltar Arc suggest their tectonic-control induced by episodic increasing stress between the Africa-Eurasia plates since the Late Miocene.

**Key words**: Mud volcanoes, tectonics, Gulf of Cádiz, Alborán Sea, Gibraltar Arc

**Acknowledgments**: This work has been funded by the by the project ATLANTIS (PID2021-12455OB-I00) funded by the Spanish Ministry of Science and Innovation and TRIDENT Projects (HORIZON-CL4-2022-RESILIENCE-01).

# ACTIVE MUD VOLCANOES IN SICILY: ISOTOPIC COMPOSITION OF FLUIDS AND OF AUTHIGENIC CARBONATES

Pierre, C.[1], Rouchy, J.M.[2], Blanc-Valleron, M.M.[2], Caruso, A.[3]

*[1]LOCEAN, Sorbonne Université, 4 Place Jussieu, Paris, France*

*[2]Museum National d'Histoire Naturelle, Paris, France*

*[3]Universita degli Studi di Palermo, Italy*

catherine.pierre@locean.ipsl.fr

## ABSTRACT

Mud volcanism is active in central Sicily where it may cause important destructions during the phases of major activity. Three structures of different size were investigated in 2018 after huge muddy expulsions in Aragona and Santa Barbara. The Cianciana area comprises a single pool "Occhio de abyss" surrounded by small seeps. The venting fluids and sediments were sampled for mineralogical and isotopic analyses. The carbonate fraction of unconsolidated and cemented mud is made of calcite, associated with strontianite, ankerite and occasionally aragonite. These carbonate minerals are considered to be mostly authigenic. Pyrite is always present as a minor component. The isotopic compositions of water of the fluids from the three sites ($9.8 < \delta^{18}O$ ‰ VSMOW $< 13.9$; $-15.6 < \delta D$ ‰ VSMOW$< -6.2$) clearly indicate that these fluids are related to clay minerals dehydration. The carbon isotopic compositions of the dissolved inorganic carbon (DIC) of the fluids are much higher in Aragona ($7.3 < \delta^{13}C$ ‰ VPDB $< 24.7$) than in Cianciana ($\delta^{13}C = 1.5$ ‰ VPDB) and Santa Barbara ($\delta^{13}C = 9.6$ ‰ VPDB). The oxygen and carbon isotopic compositions of bulk carbonate of unconsolidated and cemented mud from the three sites vary also in wide ranges ($-1.8 < \delta^{18}O$ ‰ VPDB $< 12.2$; $-34.0 < \delta^{13}C$ ‰ VPDB $< 0.4$). These results complete the results of Ferrand (2007) on the gas composition of the sicilian mud volcanoes; they indicate the great variability of the fluids (water and gas components) and of the composition of the authigenic minerals.

**Key words**: Mud volcano, Sicily, isotopic composition of fluids, isotopic composition of carbonates

**Reference**:

Ferrand, J. (2007). Dynamique des systèmes de volcans de boue. Thèse doctorat de l'Université Pierre et Marie Curie, 366 pp.

# RECENT ACTIVITY AND EVOLUTIONARY RECONSTRUCTION OF SARTORI MUD VOLCANO IN THE CALABRIAN ARC, MEDITERRANEAN SEA

Doll, M.[1,2], Römer, M.[1,2], Pape, T.[1,2], Klügel, A.[2], Kaul, N.[2], Kölling, M.[1], Bohrmann, G.[1,2]

[1]*MARUM – Center for Marine Environmental Sciences, University of Bremen, Germany*

[2]*Faculty of Geosciences, University of Bremen, Germany*

mdoll@marum.de

## ABSTRACT

Mud volcanoes (MVs) are surface structures typically created by episodic discharge of overpressured fluids and solids often associated to onshore and offshore accretionary prisms along convergent plate boundaries. Marine MVs may be under-estimated regarding their activity and contribution of deep-rooted fluid fluxes erupted from the seafloor to the ocean. Detailed studies of individual MV activity and a better understanding of the temporal evolution of these highly dynamic systems can improve estimates of emitted material fluxes from submarine MVs (Loher et al., 2018). The Calabrian Arc within the Central Mediterranean Sea consists of a high abundance of proven and inferred MVs discovered using morpho-bathymetric and backscatter data (e.g. Ceramicola et al., 2014; Mascle et al., 2014). Here we present new data from three research cruises that have been conducted at the ~1 km wide and ~45 m high Sartori MV between 2016 and 2020. High-resolution AUV-derived seafloor mapping as well as multidisciplinary analysis of sediment temperatures, geochemical and sedimentological data indicate an episodical activity of the MV and fluids with a comparatively low flux were released into the bottom water in recent times. Moreover, the stratigraphic composition of sediment cores that have been age dated using tephrochronology and radiocarbon measurements, suggest an eruptive history of Sartori MV of at least 50 ka. However, sediment core analyses show that the volume of erupted mud breccia material has constantly decreased from 50 ka to present. The results contribute to a better understanding of episodically (low-) active MVs and its temporal evolution.

**Key words**: Mud volcano, mud breccia, AUV seafloor mapping, fluid flux, Calabrian Arc

**Acknowledgments**: We thank masters, crew and participants of cruise RV METEOR M112, RV POSEIDON POS499 and RV SONNE SO278. This study was financially supported by the Deutsche Forschungsgemeinschaft (DFG; grant no. BO 1049/22-1). Ship-time of expedition M112 and POS499 were funded by the DFG through the MARUM cluster of excellence EXC 309: "The Ocean in the Earth System" (grant/award no. 49926684) as individual incentive fund proposal grants. Expedition SO278 was supported by the DFG through the MARUM cluster of excellence EXC 2077: "The Ocean Floor – Earth's Uncharted Interface" (grant/award no. 390741603) and through funds related to the GPF review procedure (GPF 20-1_054, Sartori MV plus).

**References**:

Ceramicola, S., Praeg, D., Cova, A., Accettella, D., Zecchin, M. (2014). Seafloor distribution and last glacial to postglacial activity of mud volcanoes on the Calabrian accretionary prism, Ionian Sea. Geo-Marine Letters, 34(2), 111-129.

Loher, M., Ceramicola, S., Wintersteller, P., Meinecke, G., Sahling, H., Bohrmann, G. (2018). Mud volcanism in a canyon: Morphodynamic evolution of the active Venere mud volcano and its interplay with Squillace Canyon, Central Mediterranean. Geochemistry, Geophysics, Geosystems, 19(2), 356-378.

Mascle, J., Mary, F., Praeg, D., Brosolo, L., Camera, L., Ceramicola, S., Dupré, S. (2014). Distribution and geological control of mud volcanoes and other fluid/free gas seepage features in the Mediterranean Sea and nearby Gulf of Cadiz. Geo-Marine Letters, 34(2), 89-110.

# NITROGEN UPTAKE BY METHANE-OXIDIZING CONSORTIA IN GAS HYDRATE-BEARING SEDIMENTS AT HÅKON MOSBY MUD VOLCANO, SW BARENTS SEA

Argentino, C.[1], Wittig, C.[2,3], Peckmann, J.[4], Panieri, G.[1]

[1]*Department of Geosciences, UiT The Arctic University of Norway, 9037 Tromsø, Norway*

[2]*Faculty of Sciences, Marine Biology Research Group, Ghent University, Ghent, Belgium*

[3]*Operational Directorate Natural Environment, Royal Belgian Institute of Natural Sciences, Brussels, Belgium*

[4]*Center for Earth System Research and Sustainability, Institute for Geology, Universität Hamburg. Hamburg, Germany*

claudio.argentino@uit.no

## ABSTRACT

Methane-consuming microbes inhabiting marine methane seeps have recently been found to have the capacity to assimilate inorganic nitrogen, suggesting a previously unaccounted role in the global nitrogen cycle. However, despite ex-situ experimental observations, definitive evidence of this process under in-situ conditions remains elusive, hindering the complete understanding of the controlling factors and magnitude of this process. Here we report the pore water (sulfate and dissolved inorganic carbon) and sediment geochemistry (XRF core logs, organic carbon and total nitrogen systematics) of two gravity cores collected during CAGE20-3 expedition at Håkon Mosby Mud Volcano (72°N, ~1260 m water depth), SW Barents Sea. We identified a stratigraphic interval containing methane-derived carbonates directly overlying a gas hydrate layer at 67 cm below the seafloor and typified by $\delta^{13}C_{org}$ and $\delta^{15}N$ as low as –42.0‰ and 1.2‰, respectively. Concentration-weighed stable isotope mixing models indicate the occurrence of in-situ nitrogen uptake by methanotrophic consortia, contributing to up to 49.1 wt.% of the local bulk sedimentary organic matter – a finding calling for reevaluation of the role of methane seeps in the oceanic nitrogen cycle.

**Key words**: Gas hydrate, methane seep, nitrogen uptake, Barents Sea

**Acknowledgments**: this research was funded by AKMA project (RCN grant No. 287869) within the frame of the Centre for Arctic Gas Hydrate, Environment and Climate (CAGE) (RCN grant No. 223259).

# THE MEDITERRANEAN RIDGE 25 YEARS AFTER THE ODP160 EXPEDITION: NEW DISCOVERIES ON MUD VOLCANISM AND FUTURE RESEARCH TRAJECTORIES

Menapace, W.[1], Kopf, A.[2]

[1]*Department of Marine Geosciences, Institute of Marine Sciences (ICM-CSIC), Barcelona, Spain*

[2]*MARUM, Center for Marine and Environmental Sciences, University of Bremen, Germany*

walter@icm.csic.es

## ABSTRACT

Mud volcanoes (MVs) in the Mediterranean Sea have been subject of scientific research since the 1970s, contributing to the understanding of these seafloor features and their role in the subduction budgets worldwide. Since then, several decades of investigation in the region including expeditions on national and international level have left various questions unanswered, such as: what is the role of Messinian salt in the Hellenic subduction zone?; are gas hydrates present, and to which amount?; how does the stress regime in the accretionary prism influences mud volcanic activity?; What are the mechanisms behind pore water freshening on one and brines on the other hand? what is the relationship between earthquakes and MVs in the area, and could MVs being indicative of EQ precursor phenomena?; what type of microbes are colonizing the seep environments?

We present several results and new discoveries from three MARUM expeditions (Poseidon P410, P429, Sonne SO278), thereby pointing towards novel lines of investigations with focus on the following topics: i) expanding the research on salt-related structures, diapiric deformation, and brine formation in the MedRidge; ii) defining occurrence and spatial extent of gas and gas hydrates presence; iii) monitoring the MVs of the Olimpi Field for earthquakes precursors and relating the data to cascading effects in geohazards; iv) performing paleoseismological studies in the Hellenic trenches S of Crete; v) exploring the role of seep fluids in fueling microbial life. Given that the Mediterranean coastline is inhabited by >170 Million people, with a similar number joining each year as tourists, our results will also have a huge societal relevance since the future work will aim at real laboratory approaches with stakeholder involvement in Greece.

**Key words**: Mud volcanism, salt diapirism, gas hydrates, seismicity, geohazards

**Acknowledgments**: We thank the captain, crew, and scientists of expedition POS410 and expedition SO278. We acknowledge funding from the German Science Foundation (DFG) through EXC 2077: The Ocean Floor – Earth's Uncharted Interface [390741603] and from the 'Severo Ochoa Centre of Excellence' accreditation (CEX2019-000928-S). Pore water and sediment samples were provided by the GeoB Core Repository at MARUM. Walter Menapace is supported by the H2020 MSCA-IF - TURBOMUD project - GA No. 101018321.

# THEMATIC SESSION 4

## Active seafloor gas emissions, gas reservoirs and tectonics around the world.

# INTERACTION OF SUB-SEAFLOOR GAS RESERVOIR DRAINAGE, THE MESSINIAN SALT, AND THE RESILIENCE OF DEEP-WATER ECOSYSTEMS

Meilijson, A.[1], Reznik, I.J.[2], Pape, T.[3], Bohrmann, G.[3], Bialik, O.M.[1,4], Kanari, M.[5], Giladi, A.[5], Rosenberg, Y.O.[2], Herut, B.[5], Rubin-Blum, M.[5], Makovsky, Y.[1]

[1]*The Leon H. Charney School of Marine Sciences, University of Haifa Mount Carmel, Haifa, 31905*

[2]*Geological Survey of Israel, 32 Yesha'ayahu Leibowitz, Jerusalem, 9692100*

[3]*MARUM - Center for Marine Environmental Sciences and Faculty of Geosciences, University of Bremen, Bremen, 28359*

[4]*Institute of Geology and Palaeontology, University of Muenster, Correnssstr. 24, 48149 Münster, Germany*

[5]*Israel Oceanographic and Limnological Research, Haifa, 3108000*

meilijson@gmail.com

## ABSTRACT

This study aims to characterize the dynamics of seafloor gas seeps in the Levant Basin. State-of-the-art methodologies were employed for geophysical identification of seepage localities and bubble fluxes, followed by sampling for geochemical and petrophysical analysis. We address the origin and source of emerging gases, the interconnectivity of reservoirs in the Levant Basin, and their environmental impact.

We present results from a hydroacoustic autonomous-underwater-vehicle based synthetic aperture sonar (SAS) seafloor imaging, and remotely-operated-vehicle visual seafloor inspections and sampling at water depths of ~1150m in the Palmachim Disturbance, ~60km offshore Israel. SAS surveying detected and mapped gas bubbles rising from the seafloor, authigenic carbonates and pockmarks. ROV surveying confirmed the presence of unique combined gas seepage and related features including brine pools, carbonates, and chemosynthetic biology. Numerous deep-sea sharks use this habitat as a nursing ground.

To try and identify the source of the seeps, gas samples were collected from several sites, stored under in-situ hydrostatic pressure that prevented admixing with environmental gases and fluids, and subsampled on deck. The samples contain mostly $CH_4$ (> 99.8%), $C_1/C_2$ values in the range of 636-688 along with $\delta^{13}C\text{-}CH_4$ and $\delta^{2}H\text{-}CH_4$ values of -64‰ V-PDB and -190‰ SMOW, respectively, indicate a predominant microbial source of methane, with some potential admixing with secondary microbial and/or thermogenic hydrocarbons.

Here we demonstrate how availability of sub-seafloor gas stored in leaking reservoirs leaks along overlying sediment, merges with dissolved Messinian salt, and fuels the development of a unique deep marine ecology.

**Key words**: Gas seeps, leaking reservoirs, sea bottom gas sampling, geochemical analysis, Eastern Mediterranean

**Acknowledgments**: The project was funded by the State of Israel Ministry of Energy, contract no. 217-17-004, 220-17-001, 221-17-004 to YM and AM and partners; the Israel Sciences Foundation grant n° 913/19, the Ministry of Science and Technology grant n° 001126 and the Bi-National Science Foundation grant n° 20199055 to MRB; the Mediterranean Sea Research Center of Israel grant to the combined research team; and internal funding from the Charney School of Marine Sciences University of Haifa and the Israel Oceanographic and Limnological institute (IOLR) internal funds. The authors thank the captain and crew of the IOLR R/V Bat Galim vessel; University of Haifa Underwater Vehicle Lab team, and Oded Ezra, Astral Subsea, operating the Yona ROV; and all individuals who helped during the expeditions, including onboard technical and scientific personnel. We thank the Oil Commissioner's office of the State of Israel Ministry of Energy for permitting the use of the Oz seismic data; and AspenTech for sponsoring their SSE software suite to the University of Haifa.

# YAM SEEP AREA AT FOUR-WAY CLOSURE RIDGE, TAIWAN – A TYPICAL SEEP ASSOCIATED WITH AN ACCRETIONARY RIDGE

Bohrmann, G.[1], Tseng, Y[1], Smrzka, D.[1], Lin, S.[2], Berndt, C.[3], Römer, M.[1], Pape, T.[1], Schröder-Ritzrau, A.[4], Frank, N.[4]

[1]*MARUM – Center for Marine Environmental Sciences and Faculty of Geosciences, University of Bremen, Bremen, Germany*

[2]*Institute of Oceanography, National Taiwan University, Taiwan*

[3]*GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel, Germany*

[4]*Institute of Environmental Physics, University Heidelberg, Germany*

gbohrmann@marum.de

## ABSTRACT

Yam Seep at the accretionary wedge southwest of Taiwan represents an area of ~49,000 m$^2$ in ~1350 m water depth on the northern crest of the Four-Way Closure Ridge. The area is characterized by rough topography and high seafloor backscatter in AUV multibeam data. Seafloor observations and sediment sampling during R/V SONNE cruise SO266 revealed that the area is almost entirely covered by intensely fractured methane-derived carbonates, partly populated by chemosynthetic mussels, clams and tubeworms. Flares in the water column indicated the presence of several gas bubble emission sites and drilling of a 5-m-long core revealed massive authigenic carbonates and free gas below. Based on U/Th dating of various carbonate layers a 40-thousand-year record of hydrocarbon seepage of the Yam Seep area is documented. Consolidated microcrystalline aragonite representing lithified host sediments intercalated by pure aragonite present in 10–50 cm thick intervals in the core. These aragonite intervals are interpreted as having precipitated within former fractures in the host sediment which were before filled by gas hydrates. The aragonite formation as a result of AOM is not tied to a specific depth in the sediment but fluctuates in depth, which is caused by the tectonic movement within the accretionary ridge. The tectonic tensions cause multiple fractures within the carbonate plate, allowing seawater to penetrate, shifting the SMI depth and causing carbonate precipitation to occur in a significantly deeper environment. This complex formation model appears to be typical of accretionary margins and differ from seep carbonate formation on passive continental margins.

**Key words**: Seep carbonates, gas emissions, gas hydrate, formation of methane carbonates, U/Th dating, fracturing of carbonates, active margin

**References**

Tseng, Y., Römer, M., Lin, S., Pape, T., Berndt, C., Chen, T.T., Paull, C.K., Caress, D.W., Bohrmann, G. (2023). Yam Seep at Four-Way Closure Ridge: a prominent active gas seep system at the accretionary wedge SW offshore Taiwan. International Journal of Earth Sciences, 112.

Tseng, Y., Smrzka, D., Lin, S., Schröder-Ritzrau, A., Frank, N., Bohrmann, G. (2023). Authigenic carbonate precipitation at Yam Seep controlled by continuous fracturing and uplifting of Four-Way Closure Ridge offshore SW Taiwan. Geochemistry, Geophysics, Geosystems, 24(7).

# GAS EMISSION SYSTEMS, BSRs AND ACTIVE TECTONICS IN THE NW PERU BASINS

Ng-Cutipa, W.L.[1], Ramos, A.[1], Cerpa, L.[2], Pieren, A.[3], Medialdea, T.[1] and Somoza, L.[1]

[1]*Geological Survey of Spain (IGME-CSIC), Madrid, Spain*

[2]*Geological Survey of Perú (INGEMET), Lima, Perú.*

[3]*University Complutense of Madrid (UCM), Madrid, Spain*

wl.ngcutipa@igme.es

## ABSTRACT

The NW Peruvian margin shows a great variety of submarine cold seeps associated with deep hydrocarbon basins. Based on a newly acquired bathymetry data in the offshore Talara and Tumbes basin, we performed a detailed mapping of the submarine cold seeps and its associated sea-floor morphologies as pockmarks and mounds, and acoustic flares. These cold seeps have been correlated with a 2D reflection seismic survey covering the study area. Sub-seafloor hydrocarbon leakage features and Bottom Simulating Reflectors (BSRs) have been recognized associated with the submarine cold seeps. Thus, in the complex systems of the offshore Talara Basin, of the southern part of the margin, the submarine gas emissions are associated with large listric faults affecting the the Pacific subduction margin. In this area, the BSRs are related to the topography of the continental margin generating large mass transport deposits. Towards the north, in the offshore Tumbes Basin, the complex gas emissions are related to a system of active left-lateral strike-slip faults. Gas emissions take place throughout a dense network of near-vertical active faults, coinciding with the occurrence of multiple and steep BSRs. This fault system is the westernmost system of the active Guayaquil-Dolores-Caracas mega shear zone, which corresponds to the boundary between the continental Caribbean and South America plates.

**Key words**: Cold seeps, tectonics, BSRs, Peru, margin

**Acknowledgments**: Thanks to ATLANTIS project (PID2021-124553OB-I00) and TRIDENT project HORIZON-CL4-2022-RESILIENCE-01 (101091959).

# GEOPHYSICAL EVIDENCE FOR A NEWLY DISCOVERED MUD VOLCANO FIELD IN THE NORTHERN MOROCCAN CONTINENTAL SLOPE, SOUTH ALBORAN SEA

Menapace, W.[1], Perea, H.[1], STRENGTH cruise participants

[1]*Department of Marine Geosciences, Institute of Marine Sciences (ICM-CSIC), Barcelona, Spain*

walter@icm.csic.es

## ABSTRACT

On both sides of the Gibraltar Strait mud volcanoes (MVs) have been known since their discovery during the early UNESCO TTR expeditions in the 90s (Talukder et al., 2003). Up until now, the only occurrence of mud volcanism east of Gibraltar was reported in relation to the Ceuta contourite drift (Somoza et al., 2012), where several kilometers of rapidly deposited sediments created the preconditions for shale diapirism and fueled several expulsion structures (both MVs and pockmarks).

We report here for the first time, following the investigations conducted during the STRENGTH Leg 3 expedition with R/V Sarmiento de Gamboa in April 2023, of another MVs field west of Melilla, on the Moroccan continental slope. This MVs field consists of 14 features with up to 30 m height and 300 m diameter. Both bathymetric as well as side scan sonar data (DT-1 Edgetech) suggest the features can be identified as MVs (conical shape, presence of moat, mud flows irradiating from the top). The structures seem to be in a dormant stage, with heavy colonization of various types of corals, sponges and other sessile organisms, as observed during a dive with ROV Liropus.

A preliminary onboard processing and analysis of the acquired sparker data provide detailed stratigraphic information on the uppermost ~300 m below the seafloor highlighting several fluid pathways. The deep MVs' feeder channels are clearly imaged, but interestingly, the gas-related wipeouts are situated not only below the MVs edifices themselves, but also permeate the surrounding sediments horizontally, at a specific depth. Finally, we sampled the sediments of several newly discovered MVs for future geochemical and geochronological studies.

**Key words**: Mud volcano field, geophysical data, new discoveries, Alboran Sea

**Acknowledgments**: This research was supported by the grant STRENGTH (PID2019-104668RB-I00) funded by MCIN/AEI/10.13039/501100011033 and the H2020 MSCA-IF action (GA No. 101018321). This project acknowledges the 'Severo Ochoa Centre of Excellence' accreditation (CEX2019-000928-S). We also acknowledge the Captain, the officers and crew of the R/V Sarmiento de Gamboa for their professional work during cruise operations, which made possible the success of the STRENGTH cruise. We thank all the UTM-CSIC and ACSM-IEO technical teams for their professionalism, collaboration, and expertise in using their vehicles and equipment. Finally, we acknowledge the UTM-CSIC ship managers Miguel Angel Ojeda and Javier Prades for their collaboration with the cruise logistics and planning, and the director Jordi Sorribas for their constant help and support.

**References**:

Talukder, A.R., Comas, M.C., & Soto, J.I. (2003). Pliocene to Recent mud diapirism and related mud volcanoes in the Alboran Sea (Western Mediterranean). Geological Society, London, Special Publications, 216(1), 443-459.

Somoza, L., Medialdea, T., León, R., Ercilla, G., Vázquez, J.T., Hernández-Molina, J., & Fernández-Puga, M.C. (2012). Structure of mud volcano systems and pockmarks in the region of the Ceuta Contourite Depositional System (Western Alborán Sea). Marine Geology, 332, 4-26.

# EMODNET GEOLOGY: FLUID EMISSION DATABASE OF THE EUROPEAN SEAS

Medialdea, T.[1], Fiorentino, A.[2], Battaglini, L.[2], Somoza, L.[1], Lobato, A.[1] González, F.J.[1]

[1]*Instituto Geológico y Minero de España (IGME-CSIC)*

[2]*Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA)*

t.medialdea@igme.es

## ABSTRACT

EMODnet-Geology is one of the seven discipline-based projects developed within the "European Marine Observation and Data Network", a long- term initiative of the European Commission (Vallius et al., 2022). The project, in which all the maritime countries of the European Union participate, aims at providing data and data products on marine geology for the entire European seas, the Caspian Sea and soon will cover the Caribbean Sea. The EMODnet-Geology project is delivering integrated geological map products that include seabed substrates, seafloor geology, Quaternary geology, geomorphology, coastal behavior, geological events, energy resources, marine mineral and gas hydrates occurrences and submerged landscapes. All the data and products are available for consultation and use with Geographic Information Systems and are freely downloadable and accessible via map viewer through the project's web portal. (https://emodnet.ec.europa.eu/en/geology). The dataset on 'Geological events' includes maps of the distribution of different types of fluid emissions, including mud volcanoes, pockmark fields and shallow gas occurrences, accompanied by a compilation of their main characteristics, information on the source and other relevant data (Battaglini et al., 2020). Occurrences are spread from the Barents and North seas to the Gulf of Cadiz, as well as the Black Sea and the Mediterranean Sea (Medialdea et al., 2021). These maps and data gathered by EMODnet-Geology provide a useful basis for further scientific research studies and support for geohazard assessment and environmental protection of vulnerable areas, offshore installation design and marine spatial planning.

**Key words**: Mud volcanoes, pockmarks, geological mapping, EMODnet

**Acknowledgments**: This work is supported by the EMODnet-Geology project (EASME/EMFF/2020/3.1.11 - Lot 2/SI2.853812_EMODnet – Geology 5).

**References**:

Battaglini, L., D'Angelo, S. & Fiorentino, A. (2020). Mapping Geological events in submerged areas. In Moses C. (ed.) "Mapping the Geology and Topography of the European Seas (EMODnet)", Quarterly Journal of Engineering Geology and Hydrogeology (QJEGH) of the Geological Society of London, vol. 54(1).

Vallius, H.T.V., Kotilainen, A.T., Asch, K.C., Fiorentino, A., Judge, M., Stewart, H.A., Pjetursson, B. (2022). Discovering Europe's seabed geology: the EMODnet concept of uniform collection and harmonization of marine data. In: Asch, K., Kitazato, H. and Vallius, H. (eds) From Continental Shelf to Slope: Mapping the Oceanic Realm. Geol. Soc., London, Sp.Pub. 505, 7–18.

# DIAGENETIC CARBONATES RELATED TO HYDROCARBON-RICH SEEPAGE IN THE ROMANIAN SECTOR OF THE BLACK SEA (GHASS 2 OCEANOGRAPHIC CRUISE)

Gontharet, S.[1], Ricard, C.[1], Caquineau, S.[1], Demange, J.[1], Pierre, C.[1], Dupré, S.[2], Riboulot, V.[2]

*[1]LOCEAN UMR 7159, Sorbonne Université/CNRS/IRD/MNHN, Paris, France*

*[2]Ifremer, GeoOcean, Plouzané, France*

catherine.pierre@locean.ipsl.fr

## ABSTRACT

During the GHASS 2 cruise (August-October 2021), 38 sedimentary samples were recovered in three different areas of the Romanian sector of the Black Sea. They included sub-surface diagenetic carbonate crusts and sediments collected during submersible dives in the hydrate ridge and the Shelf areas that are characterized by intense methane emissions into the water column (Riboulot et al., 2017); concretions and sediments were also obtained from coring in the Flora mud volcano. Their petrographic observations and XRD analyses show that aragonite, low and high magnesium calcite are the dominant carbonate phases with minor contributions of siderite, Fe-rich and stoichiometric dolomite. The oxygen and carbon isotopic compositions of bulk carbonate from crusts, concretions and sediments exhibit large variations ($-0.7 < \delta^{18}O$ ‰ V-PDB $< +1.8$; $-49.2 < \delta^{13}C$ ‰ V-PDB $< +2.5$) related to the biogeochemical conditions in the sedimentary and diagenetic environments. The carbonate samples with $\delta^{18}O$ values around 0-1‰, were precipitated in isotopic equilibrium with present-day bottom seawater. Higher $\delta^{18}O$ values reflect the contribution of a $^{18}O$-rich water source that could be derived from gas hydrate dissociation and/or clay minerals dehydration. The very low $\delta^{13}C$ values of these carbonates indicate that bicarbonate used during their precipitation was derived from anaerobic oxidation of methane coupled with bacterial sulfate reduction. This is confirmed by the presence of pyrite in association with authigenic carbonates. Similar mineralogical and isotopic results were previously obtained in the diagenetic carbonate structures from the north-western Black Sea (Peckmann et al., 2001; Novikova et al., 2015).

**Key words**: Authigenic carbonates, mineralogy, petrography, C and O isotopic compositions, north-western Black Sea

**Acknowledgments**: This work was supported by CNRS (Tellus program) and the Ocean Institute of Sorbonne University. The authors want also to thank the support by officers and crew during the GHASS 2 cruise on board R/V Pourquoi Pas ? (2021).

**References**:

Novikova, S.A., Shnyukov, Y.F., Sokol, E.V., Kozmenko, O.A., Semenova, D.V., Kytny, V.A. (2015). A methane-derived carbonate build-up at a cold seep on the Crimean slop, north-western Black Sea. Marine Geology, 363, 160-173.

Peckmann, J., Reimer, A., Luth, U., Luth, C., Hansen, B.T., Heinicke, C., Hoefs, J., Reitner, J. (2001). Methane-derived carbonates and authigenic pyrite from the northwestern Black Sea. Marine Geology, 177, 129-150.

Riboulot, V., Cattaneo, A., Scalabrin, C., Gaillot, A., Jouet, G., Ballas, G., Marsset, T., Garziglia, S., Ker, S. (2017). Control of the geomorphology and gas hydrate extent on widerspread gas emissions offshore Romania. BSGF -Earth Sciences Bulletin, 188, 26.

# ATLAS OF ACTIVE SEABED FLUID EMISSIONS ALONG THE SPANISH CONTINENTAL MARGIN

Lobato, A.[1], Medialdea, T.[1], Somoza, L.[1], González, F.J.[1], Marino, E.[1]

[1]*Geological Survey of Spain (IGME-CSIC) Madrid, Spain*

t.medialdea@igme.es

## ABSTRACT

The "Atlas of the Spanish Continental Margin at a scale of 1:500000" is the first digital geological cartographic base of the Spanish marine. The Atlas consists of the following thematic maps prepared to be used with geographic information systems: Geological Map, Geomorphological Map, Map of Volcanic Edifices, Seabed Sediment Map, Maps of Mineral Resources and Map of Structures associated with Fluid Emissions. Online publication of these data is available also on the IGME website (https://info.igme.es/visor/?Configuracion=GeologiaMarina). This Atlas shows the distribution of seabed fluid emissions such as mud volcanoes and pockmark fields discovered along the Spanish continental margin and adjacent abyssal plains including the Mediterranean and Atlantic margins and the Canary Islands). The GIS database includes information related to the main characteristics of the structures, age, type, morphology, activity, height, depth, lithology, references and other relevant data). Mud volcanoes are concentrated in the Gulf of Cadiz and the western sector of the Alborán Sea, whereas pockmark fields are distributed along the Atlantic (Bay of Biscay, Galicia and Gulf of Cadiz) and the Mediterranean margins (Alborán Sea, Eastern margin and Balearic Islands) (Medialdea et al., 2021). The map in combination with other data provided by the Atlas is a valuable tool for consultation, support and source of information for the planning of any action aimed at the exploration and research of fluid-related structures and for the construction of marine infrastructures.

**Key words**: Mud volcanoes, pockmarks, geological mapping, continental margin, Spain

**Acknowledgments**: This work is supported by the EMODnet-Geology project (EASME/EMFF/2020/3.1.11 - Lot 2/SI2.853812_EMODnet – Geology 5).

**References**:

Medialdea, T., Somoza, L. & González, F.J. (Eds.). (2021). Atlas Geológico del Margen Continental de España, Instituto Geológico y Minero de España, Serie Geología y Geofísica, Número: 8. https://info.igme.es/visor/?Configuracion=GeologiaMarina

# THEMATIC SESSION 5

## The Complex Interplay of Gas Emissions in Marine Sedimentary Basins in Polar Regions, Arctic and Antartica.

# INTERACTION BETWEEN METHANE AND ICE IN AN ARCTIC SEDIMENTARY PETROLEUM BASIN

Andreassen, K.[1,2,3], Winsborrow, M.[1,2,3], Patton, H.[1,2,3], Serov, P.1[,3], Mattingsdal, R.[4]

*[1]UiT – The Arctic University of Norway*

*[2]iC3 – Centre for ice, Cryosphere, Carbon and Climate*

*[3]CAGE – former Centre for Arctic Gas Hydrate, Environment and Climate*

*[4]Norwegian Petroleum Directorate*

karin.andreassen@uit.no

## ABSTRACT

Results from decades of work at UiT – the Arctic University of Norway and its former centre of excellence "Centre for Arctic Gas Hydrate, Environment and Climate – CAGE" reveal a close interaction between former ice sheets, underlying hydrocarbon systems and methane emissions.
At least 40 glacial cycles of the former Polar North Atlantic Eurasian ice sheet throughout the Quaternary have caused abrupt fluctuations in temperature and pressure within the hydrocarbon systems of the Barents Sea sedimentary basins. These fluctuations, driven by the episodic advances and retreats of grounded ice sheets across the continental shelf, have led to widespread leakage of gas from the hydrocarbon reservoirs into the shallow subsurface. During glacial periods, many of these shallow gas accumulations were sequestered as subglacial gas hydrates under high-pressure, low-temperature subglacial conditions. When the ice sheets retreated and gas hydrates became unstable, methane from these shallow hydrates would be ejected into the water column. Areas of contemporary widespread, extensive leakage of methane and oil in the Barents Sea correspond to underlying geological structures which have experienced km-scale glacial erosion that has left hydrocarbon reservoirs partially uncapped since the last deglaciation. Our data also suggest that during glacial periods, subglacial gas hydrates may have acted as sticky spots, desiccating, stiffening and strengthening the subglacial sediments, and thereby contributing to regulate ice stream flow. We will present case studies documenting this complex interplay between ice sheets, subglacial hydrocarbon systems and leakage of methane and oil into the Arctic Ocean and discuss implications for climate and environment.

**Key words**: Methane, ice sheets, gas hydrate, oil, Arctic

**Acknowledgments**: This work was supported by the Research Council of Norway through its Centres of Excellence funding scheme, project no. 223259.

**References**:

Andreassen, K., Hubbard, A., Winsborrow, M, Patton, H., Vadakkepuliyambatta, S., Plaza-Faverola, A., Gudlaugsson, E., Serov, P., Deryabin, A., Mattingsdal, R., Mienert, J., Bünz, S. (2017). Massive blow-out craters formed by hydrate-controlled methane expulsion from the Arctic seafloor. Science 356, 948-953.
Winsborrow, M., Andreassen, K., Hubbard, A., Plaza-Faverola, A., Gudlaugsson, E., Patton, H. (2016). Regulation of ice stream flow through subglacial formation of gas hydrates. Nature Geoscience 9, 370-374.
Serov, P., Mattingsdal, R., Winsborrow, M., Patton, H., Andreassen, K. (2023). Widespread natural methane and oil leakage from sub-marine Arctic reservoirs. Nature Communications 14, no 1782.

# THE COMPLEX GAS EMISSION SYSTEMS IN SVALBARD FJORDS

Römer, M.[1], Rodes, N.[2], Betlem, P.[2,3], Senger, K.[2], Noormets, R.[2], Marcon, Y.[1], Pape, T.[1], Bohrmann, G.[1]

*[1]MARUM–Center for Marine Environmental, Sciences and Faculty of Geosciences, University of Bremen, Germany*

*[2]The University Centre in Svalbard, Longyearbyen, Norway*

*[3]University of Oslo, Oslo, Norway*

mroemer@marum.de

## ABSTRACT

Emissions from the seabed in the form of dissolved methane and free gas bubbles were observed not only along the margin west of Svalbard, but also within the fjord systems. During two research cruises in 2015 and 2021, an active seepage system in the main fjords of western Svalbard (primarily Isfjorden and Van Mijenfjorden) was investigated. Based on acoustic water column data, more than a thousand gas flares were identified and characterized at water depths between 13 and 278 m, which might be shallow enough for methane to reach the atmosphere. We integrated offshore 2D seismic profiles and gas geochemical data and interpret a geological control on the distribution of gas emissions, whereas the Permian to Paleogene bedrock architecture controls fluid migration from deep source rocks. Our observations of the gas seep system have been recently published by Rodes et al. (2023), presenting a first assessment of how near-shore seepage affects the carbon budget of Svalbard.

However, several questions regarding the gas system remained unresolved, such as gas associated with onshore permafrost and the presence of gas hydrates in shallow sediments. Further detailed investigations will be conducted during a 3-week long research cruise in September 2023, and the newly acquired data will contribute to the discussion on the role of the gas emissions in Arctic fjords. In particular, we aim to improve quantitative assessment of gas exchange and fluid fluxes from the seafloor to the water column and atmosphere, and provide a basis for future monitoring as environmental conditions change.

**Key words**: Methane seepage, hydroacoustic mapping, water column anomalies, hydrocarbon sources, Arctic fjord system

**Acknowledgments**: We are grateful to the master, crew and scientists of the research vessel R/V HEINCKE cruise HE449 for their support in conducting hydroacoustic water column mapping. We also acknowledge the Czech Arctic Research Station and the crew of R/V CLIONE for their assistance during the GASGEM2021 cruise. Depth data has been provided from the Mapping Authority sea division by the Norwegian Hydrographic Service (permission no. 13/G706). We want to thank Norbit Subsea for lending us an excellent multibeam system for the GASGEM2021 cruise. This work is funded through the Cluster of Excellence ›The Ocean Floor – Earth's Uncharted Interface‹.

**References**:

Rodes, N., Betlem, P., Senger, K., Römer, M., Hodson, A., Liira, M., Birchall, T., Roy, S., Noormets, R., Smyrak-Sikora, A., Olaussen, S., Bohrmann, G. (2023). Active gas seepage in western Spitsbergen fjords, Svalbard archipelago: spatial extent and geological controls. Front. Earth Sci. 11:1173477.

# GEOCHEMICAL CHARACTERIZATION OF GAS RELEASE SOURCE FROM A VOLCANIC SEDIMENTARY BASIN (FUMAROLE BAY, DECEPTION ISLAND, ANTARCTICA)

Santofimia, E.[1], Asensio-Ramos, M.[2], Amonte, C.[2,3], Rincón-Tomás, B.[1], González, F.J.[1], Lobato A.[1], Ng-Cutipa, W.L.[1], Cervel, S.[1], Medialdea, T.[1], Marino, E. [1], Pérez, N.M.[2,3], Somoza, L[1]. and EXPLOSEA Team

[1]*Instituto Geológico y Minero de España (IGME-CSIC)*

[2]*Instituto Volcanológico de Canarias (INVOLCAN)*

[3]*Instituto Tecnológico y de Energías Renovables (ITER)*

e.santofimia@igme.es

## ABSTRACT

Submarine hydrothermal fluids form an intricate system in which seawater infiltrates through fissures and fractures in seafloor sediments and rocks at varying depths. Upon interacting with magma and heated volcanic rocks, the water becomes warmer, extracting a considerable quantity of chemical elements through leaching processes. These systems support endemic chemosynthetic biological communities that produce important mineralization and have an influence on global change by emission of volcanic gases including methane.

Gas release from submarine sedimentary vents were studied in Fumarole Bay (Deception Island, South Shetland Islands, Antarctica) through hydrochemical characterization and sampling of 40 sampling stations near the coast line where active vents and bubbling were observed in the sea. Analyses based on physico-chemical parameters, dissolved elements and gases revealed differences across samples, mainly associated to the influx of hydrothermal fluids in the proximities of two identified fumaroles on land (Northern Fumarole and Southern Fumarole). The vent sites with the highest seawater temperatures (from 1.5 to 4.5 °C), located in the vicinity of the fumaroles, presented the highest values of electrical conductivity (from 29.5 to 32 mS/cm), as well as high values of dissolved elements as Li, Fe and Mn (up to 213, 319 and 49 µg/L respectively). Warmer water sampling stations (>2ºC) exhibited lower pH values of 6.5. The onshore area surrounding Southern Fumarole showed a greater gas emission anomaly compared to the zone around Northern Fumarole, detecting relatively high concentrations of dissolved gases, ranging between 9.53–26.86 ccSTP/L for $CO_2$, 7.8–11.3x10$^{-6}$ for $CH_4$ and 43.2–182 x10$^{-4}$ ccSTP/L for $H_2$. It is important to note that $CO_2$ is the predominant component among these dissolved gases. Furthermore, the analysis of the carbon isotopic signature in $CO_2$ ($\delta^{13}C$-$CO_2$) from these samples reveals they have a mantle origin, as they all plot within the Mid Ocean Ridge Basalt (MORB) reservoir.

**Key words**: Deception Island; hydrothermal emission; heavy metals; underwater gas-emission

**Acknowledgments**: The EXPLOSEA-1 cruise was funded by the by the Spanish Ministry of Science, Innovation of Spain as part of the project EXPLOSEA (CTM201675947-R, http://www.igme.es/explosea). This work was also supported by the project ATLANTIS (PID2021-12455OB-I00) funded by the Spanish Ministry of Science and Innovation; and the European projects Horizon Europe: GSEU (101075609) and TRIDENT Projects (HORIZON-CL4-2022-RESILIENCE-01), and Next Generation EU-MINECRITICAL (C17.I7, MET2021-00-000).

# THEMATIC SESSION 6

## Seafloor Gas Hydrates in the Oceans

# A HYDRATE RIDGE WITHIN WIDESPREAD METHANE SEEPS, OFFSHORE ROMANIA (BLACK SEA)

Dupré, S.[1], Agnissan, C.[1], Akhmanov, G.2, Bellon, C.[1], Brandily, C.[1], Caquineau, S.[3], Donval, J.P.[1], Fandino-Torres, O.[1], Gontharet, S.[3], Grilli, R.[4], Ker, S.[1], Le Gonidec, Y.[5], Ogor, A.[1], Peyronnet, C.[1], Pierre., C.[3], Poort, J.[6], Ricard, C.[3], Ruffine, L.[1], Sultan, N.[1], Théréau, E.[1], Thomas, Y.[1], Riboulot, V.[1]

*[1]IFREMER, Plouzané, France*
*[2]UNESCO-MSU Training and Research Centre for Marine Geology and Geophysics, Faculty of Geology, Lomonosov Moscow State University, Russia*
*[3]LOCEAN, Sorbonne Université, France*
*[4]CNRS, Université Grenoble Alpes, France*
*[5]CNRS, Geosciences Rennes, France*
*[6]ISTEP, Sorbonne Université, France*

stephanie.dupre@ifremer.fr

## ABSTRACT

The Black Sea is a well-known province for methane seepage and the presence of gas hydrates. Part of the offshore Romania was investigated during the marine expedition GHASS2 onboard the research vessel Pourquoi pas? in 2021. Acoustic water column surveys were conducted at the continental shelf area, in the upper slope area and in deeper parts of the basin. These observations provide a larger view of the spatial distribution of gas bubbles escaping from the seafloor into the water column, compared to previous surveys (Riboulot et al., 2017; Riedel et al., 2021), especially at the continental shelf area. Beyond the upper limit of the gas hydrate stability zone, which coincides with the 660 m isobath (Riboulot et al., 2017), two active seepage sites were investigated, a hydrate ridge (930-660 m water depth) and a mud volcano (Flora, 760-720 m water depth). Near-bottom surveys were carried out with the Nautile submersible, including two dives dedicated to exploration at the hydrate ridge. Seafloor observations, sediment, fluid (gas, water) and carbonate samplings, temperature and flow rate measurements were conducted; and associated preliminary results will be presented. In particular, the seafloor at the hydrate ridge exhibits a chaotic facies morphology, numerous fractures, widespread microbial mats, authigenic carbonates and sub-outcropping methane hydrates interbedded within the sediment. Low $\delta^{13}C$ values of aragonite and high Mg-calcite from the sub-surface authigenic carbonates reveal a methane source for their formation. Pore-water $\delta^{18}O$ and $\delta D$ isotopic signatures indicate that part of the water originates from gas hydrate dissociation.

**Key words**: Black Sea, methane seepage, gas hydrate, methane derived authigenic carbonates

**Acknowledgments**: The marine expedition GHASS2 (https://doi.org/10.17600/18001358) was performed in the framework of the BLAME ANR (ANR-18-CE01-0007). We thank Lukoil Overseas Atash B.V. branch in Bucharest for kindly providing location of the Flora mud volcano.

**References**:

Riboulot, V., Cattaneo, A., Scalabrin, C., Gaillot, A., Jouet, G., Ballas, G., Marsset,T., Garziglia, S., Ker, S. (2017). Control of the geomorphology and gas hydrate extent on widespread gas emissions offshore Romania. Bulletin de la Societe Geologique de France, 188(4), 26.

Riedel, M., Hähnel, L., Bialas, J., Bachmann, A.K., Gaide, S., Wintersteller, P., Klaucke, I., Bohrmann, G. (2021). Controls on gas emission distribution on the continental slope of the western Black Sea. Frontiers in Earth Science, 8(700).

# GEOHYDRATE PROJECT RESULTS AND A NEW PARADIGM IN GAS HYDRATE RESEARCH – SCIENTIFIC BASIS OF THE BULGARIAN GAS HYDRATE PROGRAM

Vasilev, A.[1], Kvamme, B.[2], Botusharov, N.[3], Genov, I.[1], Pehlivanova, R.[1], Petsinski, P.1

[1]*Institute of Oceanology "Fridtjof Nansen" – Bulgarian Academy of Sciences, Bulgaria*

[2]*Strategic Carbon LLC, 7625 Rancho Vista BLVD W, Corpus Christi, TX 78414, USA*

[3]*Faculty of Geology and Geography, Sofia University "Kliment Ohridski", Bulgaria*

gasberg@io-bas.bg

## ABSTRACT

This work presents main results of the GEOHydrate project (Bulgarian Science Fund). The aims of the project are to study the geothermal evolution of gas hydrate deposits in the Danube Fan, Black Sea and to create a draft Bulgarian Gas Hydrate Program. One of the main results is the development of a new paradigm for gas hydrate study and exploitation, production technology development, and therefore for national programs for gas hydrate R&D. The main tasks are mitigation of climate and energy crises and avoiding technology problems of renewable energetics and social problems from mass job losses changes in energy and related sectors. Our analyzes include examples from failed national programs and production tests and a thermodynamic approach as the primary method for studying gas hydrate processes. The main findings indicate the need for a new scientific basis (replacing the simplified approach based on equilibrium P-T phase curves with a consistent application of a thermodynamic approach); new primary hydrate production technology (replacement of $CH_4$ in hydrates with $CO_2$); a new first stage of exploitation (CCS); new end products ($H_2$ and/or $CH_4$ – $CH_4$ is a new product because the new paradigm creates it as the only energy source with a negative footprint on the atmosphere). The impact of a widespread application of the new paradigm does not require drastic technologies and job stresses and effectively contributes to a better climate and cheaper energy. The new paradigm drives positive changes in geopolitics, poverty, education, innovation, the environment and quality of life.

**Key words**: hydrates, CCS, $CH_4$, $CO_2$, $H_2$

**Acknowledgments**: This work was supported by:
Bulgarian Science Fund project KP-06-OPR04/7 GEOHydrate "Geothermal evolution of marine gas hydrate deposits - Danube paleodelta, Black Sea" (2018-2023);

European Union project 101000518 DOORS: Developing Optimal and Open Research Support for the Black Sea (2021-2025).

# ANOMALOUSLY DEEP GAS HYDRATE STABILITY ZONE IN RAPIDLY FORMED SEDIMENTARY BASINS

Portnov, A.[1], Flemings, P.[1], Meazell, K.[1], Hudec, M.[2], Dunlap, D.[2]

[1]*University of Texas Institute for Geophysics, Austin, Texas, USA, 78758*

[2]*Bureau of Economic Geology, The University of Texas at Austin, Austin, Texas, USA, 78758*

portnovalexey@gmail.com

## ABSTRACT

We explore the mechanisms driving overpressure and low temperature in rapidly formed sedimentary basins. We show that under rapid sedimentation, the thickness of the gas hydrate stability zone (GHSZ) can at least double relative to its equilibrium depth due to both low temperatures and elevated pressures. During rapid sedimentation (>0.5 mm $yr^{-1}$), cold sediment is rapidly buried and there is not sufficient heat flow to keep the sediment at its steady state temperature. In addition, rapid deposition marine mud results in overpressure due to the inability of the pore fluid to drain. The combined effect is that the sedimentary basin is colder and has higher pressure relative to its equilibrium steady state.

We further use seismic, well data, and salt restoration to simulate the two-dimensional evolution of pressure, temperature and GHSZ in the Terrebonne Basin, Gulf of Mexico. In the basin center, rapid burial reduces the geothermal gradient from ~30°C/km, which would be expected under equilibrium pressure and temperature, to as low as ~10°C/km; we also show that an overpressure up to 25 Mpa is developed. The GHSZ thickens towards the basin center, where it reaches ~2000 meters, which is ~3 times deeper than under the equilibrium conditions. A bottom simulating reflection also deepens basin-ward in striking agreement with the increasing sedimentation rates. In the Terrebonne and similar rapidly formed basins, an expanded cooled zone deepens and widens the thermal window for microbial methane production; in addition, microbial methane can be hydrate-trapped within a significantly wider depth interval.

**Key words**: Rapid sedimentation, basin modeling, heat transfer, pore pressure, Gulf of Mexico

**Acknowledgments**: This work is supported by U.S. Department of Energy under contract DE-FE0023919. For our seismic interpretation, we used a seismic volume provided by WesternGeco.

# SPONTANEOUS FREE METHANE GAS MIGRATION IN MARINE SEDIMENTS AT HIGH LATITUDES

Burwicz-Galerne, E.[1], Gupta, S.[2], Rüpke, L.[3]

[1]*MARUM - Center for Marine Environmental Sciences, University of Bremen, Germany*

[2]*Department of Geosciences, University of Malta, Msida, Malta*

[3]*GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany*

eburwicz-galerne@marum.de

## ABSTRACT

Marine gas hydrate deposits are natural methane reservoirs sensitive to external triggers such as bottom water warming or sea-level changes. Numerical simulations exploring this sensitivity have shown the existence of stable periodic formation and dissolution of high-saturation gas hydrate layers even in the absence of external (climate) forcing (Gupta et al., accepted; Schmidt et al., 2022). Here, we investigate the link between these periodic states, spontaneous free gas migration, and hydrate recycling processes within high-latitude marine sediments in scenarios with and without anthropogenic climate perturbations. Our results show that the future changes in environmental conditions can cause a transition of gas hydrate systems from stable into periodic and chaotic states at multiple locations in the Arctic region, thereby significantly increasing the risks of spontaneous gas migration, geomechanical failures, and gas discharge into the water column. Here we propose how to include the internal gas hydrate system dynamics into the assessment of methane resources under changing environmental conditions and provide a step forward towards complex climate-related risks analysis.

**Key words**: Gas hydrate, methane migration, numerical modelling, Arctic

**Acknowledgments**: This research is funded by the MSCA Postdoctoral ERA Fellowships 2021 action, under the Horizon Europe program, project `WarmArctic' (101090338) and by the Cluster of Excellence `The Ocean Floor – Earth's Uncharted Interface' funded by the DFG (390741603).

**References**:

Gupta, S., Burwicz-Galerne, E., Schmidt, C., Rüpke, L. (accepted). Self-Sustaining Periodic States and Their Implications in Gas Hydrate Systems. Earth and Planetary Science Letters. Preprint available at Research Square.

Schmidt, C., Gupta, S., Rüpke, L., Burwicz-Galerne, E., Hartz, E.H. (2022). Sedimentation-driven cyclic rebuilding of gas hydrates. Marine and Petroleum Geology, 140:105628.

# CONSTRAINTS ON THE AUTHIGENESIS OF MAGNETITE AND GREIGITE IN THE COLD SEEP SEDIMENTS FROM THE BAY OF BENGAL

Firoz, B.[1], Virsen, G.[1,2]

[1]*CSIR - National Institute of Oceanography, Dona Paula-403004, Goa, India*

[2]*School of Earth Ocean and Atmospheric Sciences, Goa University-403206, Goa, India*

firoz@nio.org

## ABSTRACT

A novel mechanism explaining the genesis and preservation of authigenic magnetite and greigite in marine cold seep sediments from the Bay of Bengal is unravelled in this study. Magnetomineralogical and granulometry proxies combined with electron microscopy analyses of a six-metre long sediment (gravity) core from the cold seep site in the Bay of Bengal provided evidence for the presence of nanoscale authigenic magnetite and greigite particles in the methanic sediments. Authigenic greigite occurs in large concentrations at multiple intervals in sulfidic and methanic zones. Nanoscale authigenic magnetite in the sulfide-rich intervals indicated that genesis is constrained by microbial iron-reduction process driven by rapidly changing anaerobic oxidation of methane [AOM] fronts. Selective leaching of reactive iron ($Fe^{2}$+) during reductive dissolution and diagenetic dissolution and maghemitization of detrital iron oxides coupled with iron-sulfide mineral oxidation at the paleo-AOM fronts caused enrichment of reactive secondary iron (oxyhydr) oxides. Such processes favoured the microbial iron-reduction resulting in the genesis and preservation of authigenic magnetite and greigite in methanic sediments. Multiple occurrences of authigenic carbonate provided evidence on the episodic intensification of anaerobic oxidation of methane (AOM) at the studied site. The present study provides valuable insights into the mineralogy, genesis, and state of preservation of magnetic particles in sulfidic and methanic environments at the cold seep site and thereby enhances the interpretative value of rock magnetic proxies.

**Key words**: Cold seep, rock magnetism, authigenesis, magnetic minerals, Bay of Bengal

**Acknowledgments**: We thank Ministry of Earth Sciences (MOES), Govt of India, National Gas Hydrate Program (NGHP) and CSIR-National Institute of Oceanography, India for supporting this study.

# GAS HYDRATES AND LITHOLOGIES AFFECT THE COMPOSITION OF GASES MIGRATING THROUGH SEDIMENTS DRILLED OFF SW TAIWAN

Pape, T.[1], Tu, T.H.[2,3], Lin, S.[4], Berndt, C.[5], Wallmann, K.[5], Tseng, Y.[1], Bohrmann G.[1,2]

*[1]MARUM – Center for Marine Environmental Sciences and Faculty of Geosciences, University of Bremen, Germany*

*[2]Department of Geosciences, National Taiwan University, Taipei, Taiwan, R.O.C.*

*[3]Now at: National Sun Yat-sen University, Department of Oceanography, Kaohsiung, Taiwan, R.O.C.*

*[4]Institute of Oceanography, National Taiwan University, Taipei, Taiwan, R.O.C.*

*[5]GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany*

tpape@marum.de

## ABSTRACT

Molecular and stable isotopic compositions of hydrocarbons trapped in gas hydrates provide information on their formation pathways and postgenetic modifications. In 2018, hydrate-bearing sediment cores were collected with R/V SONNE (cruise SO266) and the seafloor drill rig MARUM-MeBo200 at sites off SW Taiwan (Bohrmann et al., 2023), where geophysical surveys have demonstrated the presence of hydrates (Berndt et al., 2019). At the northern passive margin, holes were drilled to a depth of ~126 m below seafloor (mbsf) at the southern summit of Formosa Ridge (SSFR, ~1,140 m water depth). A depth of ~144 mbsf was reached at Four-Way Closure Ridge (FWCR, ~1,320 water depth) on the tectonically active convergent margin. Hydrates were not detected in cores from either site, but hydrate-related proxies documented the presence of hydrates in-situ in two intervals on SSFR (~13–39 mbsf, ~98–120 mbsf) and a single interval on FWCR (~65–120 mbsf).

The $\delta^{13}C\text{-}CH_4$- (–79 to –69 ‰) and $\delta^{2}H\text{-}CH_4$- (–197 to –187 ‰) values of methane in gas accumulating in voids in cores from each site indicate that microbial carbonate reduction is the major source of light hydrocarbons (Milkov and Etiope, 2018). $C_1/(C_2\text{-}C_3)$ hydrocarbon values < 10.000 in the hydrate-bearing sections, which contrast with values of > 10.000 in sections lacking hydrates, indicate that molecular fractionation and enrichment of ethane and propane have occurred during hydrate precipitation. The results show that the cores are excellent for studying how lithologic changes and hydrate occurrences lead to alteration of gas composition.

**Key words**: Hydrocarbons, gas hydrate, molecular fractionation South China Sea, seafloor drill rig MARUM-MeBo200

**Acknowledgments**: We are indebted to the captain and crew of R/V SONNE cruise SO266/1. We also thank the MARUM-MeBo 200 team and the shipboard scientific party for excellent support. The cruise was funded by the German Ministry of Education and Science, project TaiDrill – SO266 (Ref. #03G0288A). The project was funded by the Taiwanese Ministry of Science and Technology (MOST), project TaiGer drill (MOST107-3113-M- 002-004).

**References**:

Berndt, C., Chi, W.C., Jegen, M., Lebas, E., Crutchley, G., Muff, S., Hölz, S., Sommer, M., Lin, S., Liu, C.S., Lin, A.T., Klaeschen, D., Klaucke, I., Chen, L., Hsu, H.H., Kunath, P., Elger, J., McIntosh, K.D., Feseker, T. (2019). Tectonic controls on gas hydrate distribution off SW Taiwan. Journal of Geophysical Research: Solid Earth 124.

Bohrmann, G., Berndt, C., Lin, S., Tu, T.H., Lin, A.T., Hsu, H.H., Lai, M.L., Chi, W.C., Deusner, C., Elger, J., Wallmann, K., Freudenthal, T., Mau, S., Pape, T., Tseng, Y.T., Yu, P.S., Fan, L.F., Chen, J.N., Chen, S.C., Chen, T.T., Wei, K.Y. (2023). Geological controls on the distribution of gas hydrates in the shallow parts of the gas hydrate stability zone – constraints from seafloor drilling off Taiwan. Marine and Petroleum Geology 106253.

Milkov, A.V., Etiope, G. (2018). Revised genetic diagrams for natural gases based on a global dataset of >20,000 samples. Organic Geochemistry 125, 109-120.

# GAS HYDRATE DEPOSITS IN THE NORTHERN BAY OF BENGAL, OFFSHORE BANGLADESH

Monteleone, V.[1], Marín-Moreno, H.[2], Bayrakci, G. 1, Best, A.1, Shaon, F.3, Hossain, M.M.4, Karim, A.A.5, Alam, M.K.5

*[1]National Oceanography Centre Southampton, Waterfront Campus, European Way, Southampton SO14 3ZH, UK*

*[2]School of Ocean and Earth Science, University of Southampton, National Oceanography Centre Southampton, Waterfront Campus, European Way, Southampton SO14 3ZH, UK*

*[3]Bangladesh Oil, Gas and Mineral Corporation (Petrobangla), Dhaka, Bangladesh*

*[4]Bangladesh Petroleum Exploration and Production Company Limited (BAPEX), Dhaka, Bangladesh*

*[5]Maritime Affairs Unit, Ministry of Foreign Affairs, Dhaka-1000, Bangladesh*

vanessa.monteleone@noc.ac.uk

## ABSTRACT

The northern portion of the Bay of Bengal, offshore Bangladesh, is characterized by a thick (~20 km) sequence of shallow-marine, fluvio-deltaic and slope sediments. Within these sediments, high-amplitude reversed polarity reflections of variable continuity that mimic the seafloor and cross-cut stratigraphy are interpreted as Bottom Simulating Reflectors (BSRs). These BSRs are predominantly located in water depths of 1300–1900 m and at depths below seafloor of 250–440 m. Sediments above BSR locations generally show high seismic interval velocities reaching values of ~1920–1940 m/s, which can be explained by the presence of gas hydrate in shallow marine sediments. The BSRs lie at approximately the same depth as the theoretical base of the gas (methane) hydrate stability zone (BGHSZ), calculated assuming a 3.5% wt pore water salinity and using existing geothermal gradient and seafloor temperature data from the study region. However, in some areas the BSRs lie deeper or shallower than the modelled BGHSZ. These discrepancies occur where faults/fractures and seismic evidence linked to fluid flow from deeper reservoirs reach the GHSZ disrupting its stratigraphic continuity. At these locations, we suggest that faults/fractures act as fluid migration pathways causing localized heat-flow perturbations and/or changes in the hydrate-forming gas composition likely affecting the depth of the GHSZ. Our results provide new evidence of the gas hydrate system offshore Bangladesh and should drive future research and data acquisition aiming to understand the composition, saturation, and thickness of the gas hydrate-bearing sediments in this region.

**Key words**: Gas hydrate, offshore Bangladesh, seismic reflection data, gas migration

**Acknowledgments**: The authors are thankful to the Bangladesh Ministry of Foreign Affairs (MOFA) for sponsoring and contributing to this study, and to Petrobangla and Bangladesh Petroleum Exploration & Production Company (BAPEX) for making available the seismic reflection data. This project has been supported by the ACCORD funding scheme provided by the Natural Environment Research Council (NERC) as part of a National Capability, Official Development Assistance award (NC-ODA), NE/R000123/1.

**References**:

Monteleone, V., Marín-Moreno, H., Bayrakci, G., Best, A., Shaon, F., Hossain, M.M., Karim A.A. & Alam, M.K. (2022). Seismic characterization and modelling of the gas hydrate system in the northern Bay of Bengal, offshore Bangladesh. Marine and Petroleum Geology, 141, 105690.

# BOTTOM SIMULATING REFLECTIONS AND POCKMARK DISTRIBUTION IN THE NORTHERN GULF OF MEXICO

Kumar, A.[1], Cook, A.[1], Portnov, A.[2], Lawal, M.[1], Palmes, S.[3], Frye, M.[3]

[1]*School of Earth Sciences, Ohio State University, Columbus, Ohio, USA*

[2]*Jackson school of Geosciences Institute for Geophysics, University of Texas, Austin, USA*

[3]*Bureau of Ocean Energy Management, Sterling, Virginia, USA*

kumar. 921@osu.edu

## ABSTRACT

To understand the relationship between sub-seafloor gas hydrate systems and seafloor pockmarks, we analyze 3D seismic data covering ~50,000 km$^2$ on the northern Gulf of Mexico (GoM) slope. In seismic data, we map bottom simulating reflections (BSRs), which generally mark the base of the gas hydrate stability zone and indicate that gas hydrate is likely present. We identified sixty-four BSR zones covering 1900 km$^2$ at water depths between 700 m and 2200 m. Pockmarks, morphological depressions on the seafloor indicating over pressured fluid and gas expulsion, were manually mapped using seismically derived bathymetry. We identify a total of 2206 pockmarks over the study area. Geospatial analysis shows high spatial density of pockmarks in areas with a water depth of less than 600 m, which is the estimated updip edge of methane hydrate stability. An abrupt reduction in pockmark density is observed in water depths beyond 600 m.

We find that both BSRs and pockmarks are associated with salt flanks and ridges and are largely absent within mini basins in the northern GoM. This suggests salt diapirs and related folds and faults facilitate focused fluid migration from deeper hydrocarbon reservoirs to shallower sediments. Fifty¬five BSR zones, however, are devoid of pockmarks. The absence of pockmarks within BSR zones might be caused by hydrate reducing the permeability of fluid flow pathways. Additionally, we observe significantly fewer pockmarks in deep water regions (> 600 m) where BSRs are absent or not identified, implying alternative mechanisms may be reducing fluid flow in these regions.

**Key words**: BSRs, pockmarks, hydrate

# DIAGENESIS AND AUTHIGENESIS OF MAGNETIC MINERALS IN MARINE GAS HYDRATE SYSTEMS FROM THE BAY OF BENGAL

Virsen, G.[1], Firoz, B.[1]

[1]*CSIR - National Institute of Oceanography, Dona Paula, 403004, Goa, India*

virseng@gmail.com

## ABSTRACT

In this study, we conducted comprehensive rock magnetic analyses complemented by electron microscopy, mineralogical, and petrological methods on sediment cores from newly discovered gas hydrate sites from the Krishna-Godavari (K-G) basin, Bay of Bengal. The major aim of this study was to elucidate the control on magnetic mineral diagenesis in two marine gas hydrate systems. Bulk sediment magnetism is carried by detrital, diagenetic, and authigenic minerals. In the K-G basin, titanomagnetite is the dominant detrital magnetic mineral identified in the studied cores. Rock magnetic records clearly indicate the diagenetic dissolution and authigenic formation of magnetic minerals in sulfidic and methanic environments created by changing fluid (methane) sequences. Spatial distribution of the methane-derived authigenic carbonates manifested by a distinct drop in magnetic susceptibility throughout the core provide indications on the episodic intensification of anaerobic oxidation of methane (AOM) at these sites. We have developed a sediment magnetism-based proxy which is useful in detecting the paleo-gas hydrate zones in the shallow and deep-seated gas hydrate systems. Using this proxy, gas hydrates in marine sediments can be explored magnetically.

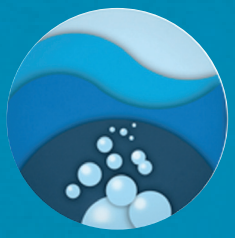
**Keywords**: Magnetic minerals, gas hydrates, authigenic magnetite, greigite, Bay of Bengal

**Acknowledgments**: We thank Secretary MOES, and National Gas Hydrate Program (NGHP) for supporting this study. We acknowledge the support of Dr. Pawan Dewangan (Chief Scientist) and participants of scientific cruise SSD-045 onboard research vessel R/V Sindhu Sadhana of CSIR-NIO, Goa.

## AKNOWLEDGMENTS

GIMS15 has been partly funded by the by the project ATLANTIS (PID2021-12455OB-I00) funded by the Spanish Ministry of Science and Innovation; and the European projects Horizon Europe: GSEU (101075609) and TRIDENT Projects (HORIZON-CL4-2022-RESILIENCE-01)

U 23



# GIMS 15

www.gims15.com

UCA
Universidad de Cádiz

cei·mar
International Campus of Excellence in Marine Sciences

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

CSIC
Consejo Superior de Investigaciones Científicas

IGME
Instituto Geológico y Minero de España