MagellanPlus Workshop

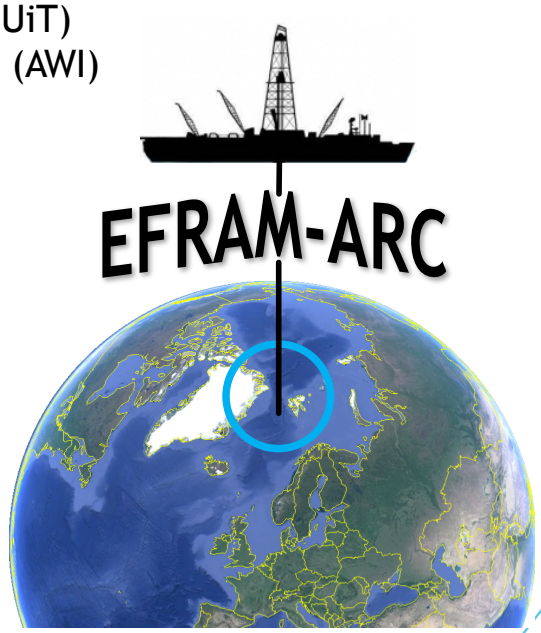
Eastern Fram Strait Paleo Archive
EFRAM-ARC
The drill of a high-resolution Early Pleistocene Arctic palaeoclimatic record

Trieste, January 21st-24th, 2020

The workshop aims bringing together scientists with different background in Arctic studies, to bridge knowledge gaps in the present understanding of the **Arctic Quaternary palaeoclimatic and palaeoceanographic record**, and to explore common scientific goals and specific drilling targets within the **EFRAM-ARC APL-954 initiative** in synergy with the other active Arctic IODP proposals.

Conveners:

Lucchi R.G. (OGS; CAGE-UiT)
Rebesco M., Geletti R. (OGS)
Laberg J.S. (UiT)
Gruetzner J. (AWI)



WORKSHOP PURPOSES AND OUTCOMES

EFRAM-ARC Magellan+ workshop was initially designed to implement and strengthen the synergies of APL-954 EFRAM-ARC, submitted on April 1st, 2019, with other IODP Full proposal submitted to study the Arctic around the Fram Strait. In particular, APL-954 was complementary and synergic with:

- Full proposal 934: Arctic Atlantic Gateway Climate (AAG-DRILL), focused on the timing of the opening of the Fram Strait having drill sited located on the western side of the Fram Strait. The results from the two proposals can be combined for a better comprehension of the mechanisms regulating the northern component of the global thermohaline circulation and the onset of glaciations.
- Full-proposal 915: Fjord sediment archives: assessing the recent (post LGM) millennial to sub-decadal scale variability of marine and continental climates in the northeastern North Atlantic (FANA), focused on the reconstruction of the recent depositional history recorded in the fjord sequences. The two proposals could collaborate to generate a comprehensive climate-related depositional model of high latitudes with major climatic changes recorded on the slope, (EFRAM-ARC proposal) and a very-high resolution record of last glacial termination and present interglacial recorded in the fjord sequences (FANA proposal).
- Full-proposal 935: Pleistocene evolution of Arctic gas hydrates and fluid flow systems (PATH), for which EFRAM-ARC drill site can provide a stratigraphic framework for core-to-core correlation through the seismic record.
- Full Proposal 708: *Central Arctic Paleoceanography (ArcOP)*, for which EFRAM-ARC drill site can represent a foothold, through the seismic record, to link stratigraphic units from the Central Arctic to a standard isotope/magnetic stratigraphic record.

Following SEP recommendations (July 2019), EFRAM-ARC Magellan+ workshop was converted in a planification meeting to discuss common, synergic objectives of the former Arctic proposals in order to develop a systematic strategy to combine research targets and related drill sites in a coherently integrated proposal. For this reason, the workshop hosted the PIs of the above IODP proposals as well as the PIs of other Arctic or sub-Arctic proposals (i.e. Full 909-CENICE, and Full 962) that participated remotely to the discussion in order to explore possible synergies for a future overall comprehension of the pan-Arctic system.

The workshop successfully identified two main synergic research lines that will be developed as Full proposals to be submitted by April 1st, 2020.

EFRAM-ARC Magellan+ workshop hosted 39 scientists (3 remotely connected) proceeding from 9 Nations (including USA and Korea), that represented 21 Research Institutes and Universities, covering a wide range of expertise. The workshop working group particularly benefitted by the presence of a consistent group of Early Career Scientists that actively participated to the scientific discussion and the definition of the new proposals working hypothesis and objectives.

WORKSHOP FINANCIAL SUPPORT AND EXPENSES

Maximum financial support available for the workshop:

ECORD: 15.000,00 euro
IODP-Italia: 3500,00 euro

Expenses subdivision:

ECORD covered participants' travel, accommodation, most of the meals (excluding lunches), and the transfers to the venue (OGS head-quartier of Borgo Grotta Gigante) and airports on the last day.

IODP-Italia covered lunches.

OGS contributed with conference room at the head-quartier of Borgo Grotta Gigante (Sgonico-Trieste) and conference material.

VOCI	TOTAL COST (Euro)
ICE-BREAKER (21 Jan, 35 people)	1050,00
DINNER (22 Jan, 21 people)	630,00
CONFERENCE DINNER (23 Jan, 30 people)	900,00
COFFEE BREAKS (36 people)	1501,50
LUNCHES (average of 30 people)	750,00
CONFERENCE ROOM	0,00
CONFERENCE MATERIAL (USB, block notes, pen, etc)	0,00
ACCOMMODATION	3093,00
TRAVEL	7052,36
Daily TRANSFER Trieste-OGS-Trieste	464,00
TRANSFER from OGS to Airport Trieste	197,00
TRANSFER from OGS to Airport Venice	71,00
	15708,86

Repartition of total expenses

ECORD: 14.958,86 euro
IODP- Italia: 750,00 euro

Details of participants' travel and accommodation expenses

PARTICIPANTS		AFILIATION	TRAVEL	ACCOMMODATION		
				DATE	Room / Nigts	Total cost
Alexandropoulou *	Nikolitsa	CAGE-UiT, The Arctic University of Norway	399,69	IN 21 OUT 24/1/20	1 DUS/ 3	171,00
Battaglia *	Francesca	University of Venice, Italy				
Buenz	Stefan	CAGE-UiT, The Arctic University of Norway	596,30	IN 21 OUT 24/1/20	1 DUS/ 3	171,00
Caburlotto	Andrea	OGS, Italy				
Camerlenghi	Angelo	OGS, Italy				
Caricchi	Chiara	INGV-Rome, Italy	165,41	IN 21 OUT 24/1/20	1 DUS/ 3	171,00
Colizza	Ester	Università di Trieste				
Colleoni	Florence	OGS, Italy				
Conte *	Rudy	University of Venice, Italy				
Cronin	Thomas	US Geological Survey, USA	**SELF PAID**			
De Vernal	Anne	Université du Québec à Montréal, Canada	705,48	IN 21 OUT 24/1/20	1 DBL/ 3	126,00
Douss *	**Nessim**	**University of Trieste, Italy**	**REMOTELY CONNECTED**			
Esteves *	Mariana	CAGE-UiT, The Arctic University of Norway	399,77	IN 21 OUT 24/1/20	1 DBL/ 3	126,00
Gamboa-Sojo *	Viviana	University of Pisa, Italy	143,85	IN 21 OUT 24/1/20	1 DBL/ 3	126,00
Gariboldi *	Karen	University of Pisa, Italy	143,85	IN 21 OUT 24/1/20	1 DBL/ 3	126,00
Geissler	Wolfram	Alfred Wegener Institute, Germany	283,35	IN 21 OUT 25/1/20	1 DUS/ 4	228,00
Geletti	Riccardo	OGS, Italy				
Gerinam *	Andrea	Università di Trieste				
Girardeau	Jacques	University of Bordeaux, France	395,73	IN 21 OUT 24/1/20	1 DUS/ 3	171,00
Gruetzner	Jens	Alfred Wegener Institute, Germany	223,23	IN 21 OUT 25/1/20	1 DUS/ 4	228,00
Grunert	Patrick	University of Colonia, Germany	320,87	IN 21 OUT 24/1/20	1 DUS/ 3	171,00
Hillaire-Marcel	Claude	Université du Québec à Montréal, Canada	229,30	IN 21 OUT 24/1/20	1 DBL/ 3	126,00
Husum	Katrine	Norwegian Polar Institute	693,00	IN 21 OUT 25/1/20	1 DUS/ 4	228,00
Knies	Jochen	Norwegian Geological Survey	710,00	IN 20 OUT 25/1/20	1 DUS/ 5	285,00
Knutz	**Paul**	**Geological Survey of Denmark (GEUS)**	**REMOTELY CONNECTED**			
Laberg	Jan Sverre	UiT, The Arctic University of Norway	351,97	IN 21 OUT 24/1/20	1 DUS/ 3	171,00
Lucchi	Renata Giulia	OGS, Italy				
Malone	Mitch	Texas A&M Univ., USA	**SELF PAID**			
Melis	Romana	Università di Trieste				
Müller	Juliane	Alfred Wegener Institute, Germany	**203,00**	Declined on the last days §		
Nam	Segun-Il	Korea Polar Research Institute	**SELF PAID**			
Olivo *	Elisabetta	OGS, Italy				
Pike	Jennifer	University of Cardiff	303,81	IN 21 OUT 24/1/20	1 DUS/ 3	171,00
Pochini *	Enrico	Università di Trieste				
Rebesco	Michele	OGS, Italy				
Sagnotti	Leonardo	INGV-Rome, Italy	**105,90**	Declined on the last days §		
Shackleton *	Calvin	CAGE-UiT, The Arctic University of Norway	424,62	IN 21 OUT 24/1/20	1 DBL/ 3	126,00
Stein	Rüdiger	Alfred Wegener Institute, Germany	253,23	IN 21 OUT 24/1/20	1 DUS/ 3	171,00
Stoner	**Joseph**	**Oregon State University, USA**	**REMOTELY CONNECTED**			
Torricella *	Fiorenza	University of Pisa, Italy				

* Early Career Scientists

§ cost of the flight ticket upon partial refund by the flying company

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* Early Career Scientists
° Remotely connected

EFRAM-ARC Magellan + Workshop

Trieste, 21st–24th January, 2020

WORKSHOP PROGRAM

TUESDAY 21st: participants arrival **18:00-20:00 Icebreaker at the *Caffè Degli Specchi* (Piazza dell'Unità di Italia, 7)**	
WEDNESDAY 22nd (*remotely connected)	
9:00 – 9:30	**Welcome, introduction and workshop goals** ***Paola Del Negro (General Director OGS), Renata Giulia Lucchi***
Session 1	**The former Arctic proposals: objectives, synergies, SEP criticisms** **Chair: J.S. Laberg**
9:30 – 9:50 9:50 – 10:10 10:10 – 10:30 **10:30 – 11:00** 11:00 – 11:20 11:20 – 11:40 11:40 – 12:00 12:00 – 13:00 **13:00 – 14:00**	***Wolfram Geissler*** (AWI, Germany): 934-Full (AAG-DRILL) ***Stefan Buenz*** (UiT, Norway): 935-Full (PATH) ***Jacques Giraudeau*** (Univ. of Bordeaux, France): 915-Full (FANA) COFFEE BREAK ***Rüdiger Stein*** (AWI, Germany): 708-Full (ArcOP), MSP scheduled ***Renata Giulia Lucchi*** (OGS, Italy): EFRAM-ARC APL-954 ****Paul Knutz*** (GEUS): 909-Full (CENICE). Discussion LUNCH
Session 2	**High-latitude sedimentary records and investigation techniques** **Chair: J. Gruetzner**
14:00 – 14:20 14:20 – 14:40 14:40 – 15:00 **15:00 – 15:30** 15:30 – 15:50 15:50 – 16:00	***Mariana Esteve*** (UiT- Norway): Deglaciation of the marine-based Barents Sea Ice Sheet: Inferring glacial dynamics from multibeam bathymetric datasets. ***Jan Sverre Laberg*** (UiT, Norway): Contourites as paleoclimatic records ***Florence Colleoni*** (OGS, Italy): Past ice-ocean interactions along the Svalbard margins. Potentialities for a new IODP proposal COFFEE BREAK ****John Jaeger*** (Uni. Florida, USA): Seismic and drilling on high latitude margins ***Mitch Malone*** (Texas A&M, USA): Coring IRD and glacigenic debris flow
Session 3	**Discussion** **Chair: R.G. Lucchi, M. Rebesco, R. Geletti**
16:00-18:00	Identification of common objectives and targets from the former IODP Full proposals and APL, for the definition of one or two main research lines to develop. Points to discuss: i) objectives/main targets, ii) key sites, iii) data availability.
19:30 Dinner at the restaurant *DRAW* (Via Torino, 26)	
THURSDAY 23rd	
Session 4	**The proxies we need** **Chair: F. Colleoni, R.G. Lucchi**
9:00 – 9:20	***Patrick Grunert*** (U. Köln, Germany): Benthic foraminifera from high-latitude contourite drifts in the North Atlantic.

9:20 – 9:40	***Jennifer Pike*** (University of Cardiff, UK): Diatom proxies for past polar oceans
9:40 – 10:00	***Claude Hillaire-Marcel*** (U. Montréal, Canada): Inherited/exchangeable radiogenic isotopes as tracers of sediment sources and water masses in Fram Strait sedimentary sequences
10:00 – 10:20	***Anne de Vernal*** (U. Montréal, Canada): Palynological tracers of ocean and climate changes at high latitudes of the Northern Hemisphere
10:20 – 10:50	COFFEE BREAK
10:50 – 11:10	***Thomas Cronin*** (US Geological Survey): Interglacial periods in the Arctic Ocean
11:10 – 11:30	***Katrine Husum*** (Norwegian Polar Institute): Reconstructions of water masses and sea ice on the western Barents Sea margin during the Holocene: a multiproxy review
11:30 – 11:50	***Chiara Caricchi*** (INGV, Italy): Paleomagnetism and constraints for cores correlation and age models
11:50 – 13:00	Discussion
13:00 – 14:00	LUNCH
Session 5	**Planning of proposal(s) for submission on April 1st, 2020** **Chair: R.G. Lucchi, M. Rebesco**
14:00 – 15:30	Proposal(s) outline, definition of contributors, working groups and leaders
15:30 – 16:00	COFFEE BREAK
Session 6	**Working group break-out**
16:00 – 18:00	Draft writing of Proposal
19:30 Conference Dinner at the restaurant *Pier The Roof* (Molo Venezia, 1)	
FRIDAY 24th	
Session 7	**Working group break-out**
9:00 – 11:00	Draft writing of Proposal
11:00 – 11:30	COFFEE BREAK
Session 8	**All together** **Chair: R.G. Lucchi, M. Rebesco**
11:30 – 13:00	Presentation of contributions and definition of deadlines for proposal submission on April 1st, 2020.
13:00 – 14:00	**LUNCH and Participants departure**

ABSTRACTS

Wednesday 22nd January, morning session

THE OPENING OF THE ARCTIC-ATLANTIC GATEWAY: TECTONIC, OCEANOGRAPHIC AND CLIMATIC DYNAMICS ("AAG-DRILL" – ARCTIC-ATLANTIC GATEWAY DRILLING CAMPAIGN"), Full-934

Wolfram Geissler, Jochen Knies, Tove Nielsen, Carmen Gaina, Christoph Vogt, Catalina Gebhardt, Jens Matthiessen, Katrine Husum, Caterina Morigi, Jan-Sverre Laberg, Renata Giulia Lucchi, Wolfram Kürschner, Aradhna Tripati, Michele Rebesco, Anders Carlson, Matthias Forwick, Seung-Il Nam, Kai Berglar, John Hopper, Stijn De Schepper

The modern polar cryosphere reflects an extreme climate state with profound temperature gradients towards high-latitudes. It developed in association with stepwise Cenozoic cooling, beginning with ephemeral glaciations and the appearance of sea ice in the late Middle Eocene. The polar ocean gateways played a pivotal role in changing the polar and global climate, along with declining greenhouse gas levels. The opening of the Drake Passage finalized the oceanographic isolation of Antarctica, some 40 Ma ago. The Arctic Ocean was an isolated basin until the early Miocene when rifting and subsequent sea-floor spreading started between Greenland and Svalbard, initiating the opening of the Fram Strait / Arctic-Atlantic Gateway (AAG). Although this gateway is known to be important in Earth's past and modern climate, little is known about its Cenozoic development. Indeed, the opening history and AAG's consecutive widening and deepening must have had a strong impact on circulation and water mass exchange between the Arctic Ocean and the North Atlantic. To study the AAG's complete history, ocean drilling at four (primary) sites located between 73°N and 78°N are proposed. These sites will provide unprecedented sedimentary records that will unveil (1) the history of shallow-water exchange between the Arctic Ocean and the North Atlantic, and (2) the development of the AAG to a deep-water connection and its influence on the global climate system.
The specific overarching goals of this proposal are to study:
- the influence of distinct tectonic events in the development of the AAG and the formation of deep water passage on the North Atlantic and Arctic paleoceanography, and
- the role of the AAG in the climate transition from the Paleogene greenhouse to the Neogene icehouse for the long-term (~50 Ma) climate history of the northern North Atlantic.
The proposed drilling addresses a number of key questions raised in the IODP Science Plan 2013-2023. It is specifically linked to the Research Theme "Climate and Ocean Change: Reading the Past, Informing the Future".

PLEISTOCENE EVOLUTION OF ARCTIC GAS HYDRATES AND FLUID FLOW SYSTEMS (PATH), Full-954

Stefan Bünz, Andreia Plaza-Faverola, Sunil Vadakkapuliyambatta, Jochen Knies, Joel Johnson, Michael Riedel, Helge Niemann, Marta Torres, Gerhard Bohrmann, Dan Condon, Aivo Lepland, Giuliana Panieri, Javier Escartin, Carolyn Ruppel

We present a drilling proposal that focuses on the Pleistocene evolution of fluid flow, gas hydrate and methane seepage systems in the Fram Strait. The Fram Strait is the major gateway between the Arctic and the North Atlantic. This peculiar setting has been well known for its importance to paleoceanography, global climate and its ultra-slow mid-ocean ridge system (Knipovich and Molloy Ridges). More recent work discovered large gas hydrate and fluid flow systems situated on

young and hot oceanic crust extending from the upper continental slope off Svalbard to the mid-ocean ridge. Seafloor and subseafloor depressions on seismic data and authigenic carbonate samples document past and ongoing seepage of hydrocarbons. Here we hypothesize that carbon has been remobilized several times in response to mid-ocean ridge tectonics, hydrothermal circulation, and ice sheet dynamics of the glacial/interglacial cycles. Carbon inventories in this Arctic fluid flow system are unique as they may not only include microbial and thermogenic hydrocarbons but also abiotic methane derived from the serpentinization of ultramafic rocks. However, the relative importance of these hydrocarbon sources is not known. Deep biosphere microbes and ecosystems in the Arctic remain largely unexplored and the possibility of co-existing hydrothermal and cold seep microbial communities may hold some very unique interaction among these populations.
Large sediment drifts, named Vestnesa and Svyatogor Ridge, situated on the continental slope and on the western flank of the Knipovich Ridge respectively, have trapped fluids, formed gas hydrate and developed active seepage systems associated with exceptional chemosynthetic communities. These ridges resemble unique archives for the evolution and interaction of crustal processes and the shallow earth system, gas hydrate and seepage dynamics, the deep biosphere and global climate change. Here, we propose to study these interactions thereby providing new insights into how these processes dynamically interplay and transfer carbon from one system to another.
Our proposed drilling program involves logging and coring at six sites in the eastern Fram Strait on a strategic transect from the continental slope off western Svalbard to the mid-ocean ridge. Four of the six sites are defined by high-resolution 3D seismic site survey data allowing very exact targeting of subseafloor features including an oceanic detachment. Recovering sediment cores from high latitudes presents one of the most important challenges for scientific ocean drilling and would fill the need for data in this underrepresented region.

FJORD SEDIMENT ARCHIVES: ASSESSING THE RECENT (POST LGM) MILLENNIAL TO SUB-DECADAL SCALE VARIABILITY OF MARINE AND CONTINENTAL CLIMATES IN THE NORTHEASTERN NORTH ATLANTIC. Full-915

Jacques Giraudeau, Jochen Knies, Katrine Husum, Seung-Il Nam, Berit Oline Hjelstuen, James David Scourse, Matthias Forwick, Jan Sverre Laberg, Simon T. Belt.

The northeastern North Atlantic is a key area for unraveling oceanographic and atmospheric processes implied into millennial to decadal-scale climate changes of the present interglacial as well as the mechanisms involved into the last dismiss of northern European ice sheets. As the seat of the northward transport of Atlantic water to the Arctic and of the formation of oceanic deep water, the eastern sector of the Nordic Seas has a direct control over the climate of northwestern Europe. The impact of the major mode of atmospheric circulation in the northern hemisphere (North Atlantic/Arctic Oscillations) is particularly strengthened in this region: NAO/AO explains much of the present strength of the poleward flow of the surface and sub-surface waters over the NW European continental margin as well as recent changes in the mass balance of the maritime Scandinavian glaciers.
The general paucity of high resolution, continuous, coupled marine and continental records of Holocene environmental changes in the northeastern North Atlantic region since the initial dismiss of the NW European ice-sheets so far precludes any firm assumption on (1) the behavior and impact in this region of internal modes of the climate system variability (alike NAO and the Atlantic Multidecadal Oscillation), (2) their interactions with external climate forcing acting over short (volcanic and solar forcing) and long time-scales (orbital forcing), (3) the coupled ocean/cryosphere/atmosphere dynamics and the connections between marine and continental climates.

Tackling these three important scientific issues is the main motivation behind the FANA initiative. A fourth incentive and co-benefit of FANA's researches derives from the occurrence of frequent mass transport events in coastal systems of Norway and Svalbard. Hence, the climate-related records obtained as part of FANA will incidentally help moving forward on the questions of (4) the synchronicity and trigger mechanisms of past mass movements in high latitude coastal environments of Northwestern Europe.
A major step towards understanding natural climate changes in the northeastern North Atlantic region during the Holocene and the last glacial Termination, as well as their relation to the occurrence and frequency of mass failures, can be achieved by applying multi-proxy approaches to paleoceanographic, paleoclimatic, and age-model reconstructions from ultra-high-resolution sedimentary records retrieved in Norwegian and Svalbard fjords. FANA targets 8 fjord systems distributed along a latitudinal gradient from Southern Norway to Svalbard spanning the spread of the western sector of the last Scandinavian and Svalbard ice sheets.

ARCTIC OCEAN PALEOCEANOGRAPHY: TOWARDS A CONTINUOUS CENOZOIC RECORD FROM A GREENHOUSE TO AN ICEHOUSE WORLD (ACEX2), Full-708

R. Stein, W. Jokat, H. Brinkhuis, L. Clarke, B. Coakley, M. Jakobsson, J. Matthiessen, M. O'Regan, C. Stickley, K. St. John, E. Weigelt.

Prior to 2004, the geological sampling in the Arctic Ocean was mainly restricted to near-surface Quaternary sediments. Thus, the long-term Pre-Quaternary geological history is still poorly known. With the successful completion of the Arctic Coring Expedition - ACEX (IODP Expedition 302) in 2004, a new era in Arctic research has begun. Employing a novel multi-vessel approach, the first Mission Specific Platform (MSP) expedition of IODP has proven that drilling in permanently ice-covered regions is possible. During ACEX, 428 meters of Quaternary, Neogene, Paleogene and Campanian sediment on Lomonosov Ridge were penetrated, providing new unique insights into the Cenozoic Arctic paleoceoceanographic and climatic history. While highly successful, the ACEX record also has three important limitations. Based on the original age model, the ACEX sequence contains a large hiatus spanning the time interval from late Eocene to middle Miocene, i.e., 44.4 to 18.2 Ma. This is a critical time interval, as it spans the time when prominent changes in global climate took place during the transition from the early Cenozoic Greenhouse world to the late Cenozoic Icehouse world. Furthermore, generally poor recovery during ACEX prevented detailed and continuous reconstruction of Cenozoic climate history. Finally, a higher-resolution reconstruction of Arctic rapid climate change during Neogene to Pleistocene times, could not be reached during ACEX in 2004. We believe, this justifies a return to the Lomonosov Ridge for a second MSP - type drilling campaign within IODP to fill these major gaps in our knowledge on Arctic Ocean paleoenvironmental history through Cenozoic times and its relationship to the global climate history.
Overall goal of the proposed drilling campaign is the recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continuous long-term Cenozoic climate history of the central Arctic Ocean. Furthermore, sedimentation rates two to four times higher than those of ACEX permit higher-resolution studies of Arctic climate change in the Pleistocene and Neogene. As demonstrated in the proposal, this goal can be achieved by careful site selection, appropriate drilling technology, and applying multi-proxy approaches to paleoceanographic, paleoclimatic, and age-model reconstructions. We propose one primary drill site with three APC/XCB/RCB holes to recover multiple sections of the sediment sequence to ensure complete recovery for construction of a composite section.

ACEX2 objectives are key elements in the IODP New Science Plan, Theme 1 Climate and Ocean Change, especially Challenges 1 and 2.

EASTERN FRAM STRAIT PALEO ARCHIVE: EFRAM-ARC, APL-954

Renata Giulia Lucchi, Michele Rebesco, Riccardo Geletti, Caterina Morigi, Jan Sverre Laberg, Juliane Müller, Katrine Husum, Jacques Giraudeau, Jennifer Pike, Anne De Vernal, Thomas Cronin, Claude Hillaire-Marcel , Leonardo Sagnotti, Jochen Knies, Stefan Büenz, Wolfram Geissler, Rüdiger Stein, Florence Colleoni.

EFRAM-ARC aims to recover a high-resolution (sub-centennial) Early Pleistocene stratigraphic sequence containing the paleoceanographic archive after the onset of shelf-edge glaciation on the western Barents Sea (c. 1.3 Ma), the Mid-Brunhes Period (0.5–0.4 Ma) and switch from 41-ka to 100-ka glacial cycles periodicity (c. 1 Ma). The target is a sedimentary depocenter (Bellsund or Isfjorden plastered sediment drifts) on the western margin of Svalbard formed under the effect of the Norwegian Sea Deep Current (deep branch of the North Atlantic Current) flowing on the eastern Fram Strait.
The primary target is the triple-hole recovery of a 340 m-thick, normally consolidated depositional sequence in 1650 m water depth, using the Advanced Piston Corer (APC) plus a full wireline logging . Extended Core Barrel (XCB) may be necessary in the lowermost part of the sequence. The expected time of operations is 6 days.
EFRAM-ARC is coherent with the IODP Science Plan 2013–2023: Climate and Ocean Change: Reading the Past, Informing the Future, and it is complementary and synergic with the active IODP proposals addressing the Arctic: 708-Full, Central Arctic Paleoceanography (ACEX2); 934-Full, Arctic Atlantic Gateway Climate (AAG-DRILL); 915-Pre, Fjord sediment archives - assessing the recent (post LGM) millennial to sub-decadal scale variability of marine and continental climates in the northeastern North Atlantic (FANA); 935-Pre, Pleistocene evolution of Arctic gas hydrates and fluid flow systems (PATH).
EFRAM-ARC Site is motivated by the need to obtain a robust high-resolution Quaternary cronostratigraphic reference section for a better understanding of the boundary conditions and forcing mechanisms in the Barents Sea ice sheet evolution, and will provide an important foothold to link stratigraphic units from the Central Arctic to standard isotope/ magnetic stratigraphic record. Svalbard can be considered as a “sentinel of climate change”. The paleo Barents Sea ice sheet is considered the best available analogue to the West Antarctic ice sheet, whose loss of stability is the major uncertainty in projecting future global sea level. Projecting models struggle in simulating the deglaciation of the Barents Sea complex (the Svalbard-Barents Sea Ice Sheet) because little is known on the mechanisms that triggered the retreat, and the overall complexity of ice sheet dynamics operating on multiple timescales in the Earth system and ice sheet response to major climate transitions, such as the Pleistocene glacial terminations, are still poorly known.
EFRAM-ARC will provide a unique marine paleo-climatic archive complementary to the Ice Memory archives and the terrestrial paleo-climatic archives.

CENOZOIC EVOLUTION OF THE NORTHERN GREENLAND ICE SHEET EXPOSED BY TRANSECT DRILLING IN NORTHEAST BAFFIN BAY (CENICE), Full-909

Paul Knutz, Calvin Campbell, Paul Bierman, Anne de Vernal, Mads Huuse, Anne Jennings, David Cox, Rob DeConto, Karsten Gohl, Kelly Hogan, John Hopper, Benjamin Keisling, Andrew Newton, Lara Perez, Janne Rebschläger, Kasia Sliwinska, Elizabeth Thomas, Eske Willerslev, Chuang Xuan, Joseph Stoner.

Understanding the long-term history of the Greenland Ice Sheet (GrIS) is key to understanding northern hemisphere glaciation, to elucidating mechanisms underlying amplification of glacial cycles since the late Pliocene and to predicting how the GrIS will respond to modern climate warming. To address current knowledge gaps in the evolution and variability of the GrIS and its role in Earth's climate system, we propose to drill along a transect across the northwest Greenland margin extending from the shelf to Baffin Bay where thick Cenozoic sedimentary successions primarily reflect the evolution of the northern GrIS (NGrIS). The mission strategy is to retrieve a composite stratigraphic succession representing the Late Cenozoic era from Oligocene/early Miocene to Holocene. The proposed drill sites will specifically target high-accumulation- rate deposits associated with contourite drifts and potential interglacial deposits within a trough-mouth-fan system including proximal shelf deposits, all densely covered by excellent quality 2-D and 3-D seismic data. We seek to test if the NGRIS underwent near-complete deglaciations in the Pleistocene and assess recent models for the change in orbital cyclicities through the Mid-Pleistocene transition. Moreover, the proposal will examine a possible linkage between the general decrease in atmospheric CO2 from the Oligocene to the early Miocene and arrival of cold and possibly glacially-dominated environments in northwest Greenland and establish the timing for tectonic margin adjustments inferred from the seismic record. Finally, records will be produced that can test hypothesis that glacial expansion of the NGrIS is linked with intensification of northern hemisphere glaciations (3.3-2.8 Ma) and unravel marine heat transport through the western North Atlantic and Baffin Bay as a potential cause for the Pliocene high Arctic warmth. The detailed information obtained from these paleoclimate archives will be of great value for predictive models addressing how the GrIS may respond to global warming in the near future. The overall aim is to investigate the full range of forcing and feedbacks - oceanic, atmospheric, orbital, tectonic - that influence the GrIS over a range of time scales, as well as conditions prevailing at the time of glacial inception and deglacial to interglacial periods. The scientific objectives of this proposal are of key significance in addressing the challenges "How do ice sheets and sea level respond to a warming climate?" and "How does Earth's climate system respond to elevated levels of atmospheric CO2?" under the Climate and Ocean Change theme of the IODP science plan.

Wednesday 22nd January, afternoon session

DEGLACIATION OF THE MARINE-BASED BARENTS SEA ICE SHEET: INFERRING GLACIAL DYNAMICS FROM MULTIBEAM BATHYMETRIC DATASETS

Mariana Esteve (CAGE, UiT- Norway).

The Barents Sea Ice Sheet (BSIS) is a good palaeo-analogue for the present day West Antarctic Ice Sheet. Both were marine-based ice sheets, vulnerable to ocean warming and sea-level rise. Understanding the BSIS ice dynamics and patterns of retreat since the Last Glacial Maximum (LGM) is useful in developing our knowledge of spatial and temporal variations during marine-based ice sheet retreat. While the western margins of the Barents Sea have been extensively studied, few studies have focused on the central regions, which hosted key ice stream tributaries and major ice domes and divides. The availability of high-resolution (5 m) bathymetric datasets, allow for extensive and comprehensive glacial geomorphological studies to be undertaken, such as the reconstruction of the Sentralbankrenna palaeo-glacial system in the central Barents Sea. Here, large numbers of grounding zone wedges, mega-scale glacial lineations and areas with tunnel valleys and palaeo-subglacial basins were observed on the seafloor. These form the basis for a six-stage reconstruction of ice stream retreat through deglaciation since the LGM.

In reconstructing the retreat of the Sentralbankrenna Ice Stream, we document the rapid but highly spatially variable pattern of retreat of a marine-based ice sheet margin. The presence of several tunnel valleys and interconnected palaeo-subglacial basin systems indicates an abundance of meltwater, likely to have been stored and released through several discharge events, significantly influencing the ice stream margin dynamics. This study provides insight into the behaviour and dynamics of ice during the late stages of the BSIS deglaciation within the central Barents Sea, increasing our understanding of grounding line processes.

CONTOURITES AS PALEOCLIMATIC RECORDS

Jan Sverre Laberg (UiT, Norway)

Muddy contourites, mainly located on the middle and lower continental slope along the Norwegian – Barents Sea – Svalbard continental margin (modern sandy deposits are found on the shelf – upper slope) are important paleoclimatic records because they represent undisturbed deposits (formed from fall-out from suspension when flow velocity drops below a certain threshold) on the continental slope often dominated by reworked glacigenic deposits. Because of this, they may provide important paleoceanographic information, information on ice sheet and sea ice distribution, and they may also provide important age constrains on the reworked part of the succession. In this review, we will briefly discuss how they are identified, where they are located, what they are recording, and what they are not recording. Other sedimentary processes which may obscure the record will also be addressed, and finally, drilling recovery to be expected will be discussed.

PAST ICE-OCEAN INTERACTIONS ALONG THE SVALBARD MARGINS: POTENTIALITIES FOR A NEW IODP PROPOSAL

Florence Colleoni, Michele Petrini, Renata G. Lucchi, Michele Rebesco

During the last glacial cycle, the Eurasian ice sheet covered out most of the Barents and Kara Seas and advanced to the continental shelf edge of the Arctic and Atlantic margins in many occasions. Similarly, Greenland ice sheet expanded over the continental shelf edge. The Laurentide ice sheet instead did not reach the Arctic continental shelf edge all along its Arctic margin. Those discrepancies have implications in terms of ice sheet dynamics and ice-ocean interactions under changing climate. During the last deglaciation, for example, different meltwater pulses occurred, with different implications at regional and inter-hemispheric level in atmosphere and ocean. Recent numerical simulations showed that the Eurasian ice sheet responded to sea level rise and intrusion of ocean warming at its grounding line along the Svalbard margins accelerating its retreated during the last deglaciation. The Laurentide ice sheet is thought to have triggered some Heinrich event with abrupt discharge of icebergs in the Labrador Sea with a large influence on ocean meridional circulation and heat transport. Arctic Ocean-ice sheet interactions remains poorly understood, and relationship between this region and the North Atlantic is essential to understand the evolution of ocean circulation and heat transport under dramatic ice sheet melting events. Synchronism between the Greenland ice sheet and the Eurasian ice sheet is also poorly investigated. Here we highlight some of the gaps related to ice sheet ocean interactions to better constrain the potentialities of a full IODP proposal along the Svalbard marginal and relationship with other existing or planned/scheduled expeditions in the Arctic regions.

JR CORING: IRD AND PROXIMAL GLACIAL MARINE SEDIMENTS

Mitch Malone (JRSO, Texas A&M University, USA)

Over the last 34 years, the JOIDES Resolution (JR) has cored a range of glacial proximal to distal environments, including a recent Southern Ocean campaign in 2018-2019. An introduction to the JOIDES Resolution coring tools will be presented. A review of successes and challenges with coring Ice Rafted Debris (IRD) and more proximal glacial marine deposits will be discussed. Examples will include past Antarctic, North Atlantic, and Pacific JR expeditions. An overview of previous drilling in the EFRAM region will also be presented. The recent additional of an X-ray imager on the JR for the 2019 South Ocean campaign was a welcome analytical development to identify IRD, although it was designed as quick temporary addition. Continued heavy use on non-polar expeditions has led to the initiation of a project to provide a standalone, improved system using a Time-Delayed Integration X-ray line scanner, which will improve distortion and core flow over the current deployment.

Thursday 23rd January, morning session

BENTHIC FORAMINIFERA FROM HIGH-LATITUDE CONTOURITE DRIFTS IN THE NORTH ATLANTIC

Patrick Grunert[1], Anna Saupe[1], Johanna Schmidt[1], Joachim Schönfeld[2]

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Benthic foraminifera occupy a wide range of habitats in the world's oceans. A distinct group of epibenthic foraminifera has developed strategies to attach themselves to elevated substrates and to exploit the nutrient load carried by persistent bottom currents. This "elevated epifauna" is particularly abundant in contourite drifts and considered a proxy for bottom current strength (Schönfeld, 1997, 2002). Studies of the elevated epifauna, however, are largely limited to the mid-latitude contourite drift system along the southern Iberian Margin. Biogeographic patterns and the applicability of the method to the fossil record beyond the Iberian Margin remain poorly understood.

In this paper, I will present new results from our ongoing faunal studies in the northern North Atlantic (project GR 5285 "Benthic foraminifera from Contourite Drift Systems" of the DFG). These studies specifically address and compare benthic foraminiferal faunas indigenous to the Gardar, Björn, and Eirik drifts. The faunal data lay the groundwork for a robust and easily applicable proxy method for the reconstruction of bottom current strength from the fossil record of contourite drifts at high latitudes.

Schönfeld, J., 1997. The impact of the Mediterranean Outflow Water (MOW) on benthic foraminiferal assemblages and surface sediments at the southern Portuguese continental margin. Marine Micropaleontology 29/3-4, 211–236.

Schönfeld, J., 2002. A new benthic foraminiferal proxy for near-bottom current velocities in the Gulf of Cadiz, northeastern Atlantic Ocean. Deep Sea Research I, 49, 1853–1875.

DIATOM PROXIES FOR PAST POLAR OCEANS

Jennifer Pike (School of Earth and Ocean Sciences, Cardiff University, Wales, UK)

Marine diatoms are well-established as quantitative and qualitative proxies for past polar ocean conditions due to their sensitive habitat preferences for the sea ice zone, marginal ice zone, or the permanently open ocean. In the contemporary northern high latitudes, different assemblages of diatoms have been observed to contribute approximately 70% of the phytoplankton biomass during the spring bloom, greater than 50% of the summer sea ice-edge surface phytoplankton bloom and can also dominate the early spring ice-edge-associated subsurface chlorophyll maximum. As ice has thinned in the Arctic Ocean and reduced in extent, annual phytoplankton productivity has increased and under-ice phytoplankton blooms can become increasingly dominated diatoms during the summer melt season. Further, the marine biological carbon pump can be strongest when diatoms dominate the phytoplankton and, thus, marine diatoms can strongly influence the flow of energy and carbon through the surface ocean ecosystem and the export of carbon into the deep ocean. As such, this strong association of diatoms with the sea ice zone, and their increasing contribution to carbon export around the shrinking margins of the Arctic sea ice, makes diatoms an ideal proxy for investigating the advance and retreat of the sea ice zone and evolution of the biological pump in the northern polar region over (multi)millennial to decadal timescales. Case studies will be presented to illustrate the potential of diatom-based reconstructions to contribute to our understanding of past polar and sub-polar sea ice and ocean circulation.

INHERITED/EXCHANGEABLE RADIOGENIC ISOTOPES AS TRACERS OF SEDIMENT SOURCES AND WATER MASSES IN FRAM STRAIT SEDIMENTARY SEQUENCES

Claude Hillaire-Marcel (Geotop-UQAM, Montréal, Canada)

Radiogenic isotopes (Sr, Nd, Pb) are frequently used to document sediment sources and water masses (cf. mode waters, currents, thermohaline circulation, AMOC…). Deciphering between these two isotopic signatures in hemipelagic muds requires extracting first a leachable fraction, seen as representative of the ambient water mass during sedimentation. The residue is then analyzed to document particulate sediment sources. These approaches will be discussed in the context of the coring of late Quaternary sedimentary sequences from Fram Strait and existing data from various authors will be presented in order to anticipate the potential outcome of such studies on cores from the eastern Fram Strait area, in particular.

PALYNOLOGICAL TRACERS OF OCEAN AND CLIMATE CHANGES AT HIGH LATITUDES OF THE NORTHERN HEMISPHERE

Anne de Vernal (Geotop-UQAM, Montréal, Canada)

Palynomorphs that are resistant organic-walled microfossils recovered after palynological preparations includes the remains of several types of organisms. Among them, the cysts of dinoflagellates (protists including phototrophic and heterotrophic taxa) are very useful as their assemblages relate to sea-surface conditions including temperature, salinity, sea-ice cover and productivity. For example, in the Fram Strait, dinoflagellate cyst assemblages of late Quaternary age permitted to reconstruct large amplitude changes related to variations in the inflow of North Atlantic water and freshwater/meltwater discharge (e.g. Falardeau et al.,

https://doi.org/10.1016/j.quascirev.2018.06.030). Palynological assemblages may also include pollen and spores that document on adjacent land vegetation and climate, in addition to freshwater taxa that relate to freshwater input. Furthermore, reworked material in palynological assemblages might help identifying sedimentary input from erosion.

INTERGLACIAL PERIODS IN THE ARCTIC OCEAN

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Arctic amplification involves changes in albedo, ocean-atmosphere heat exchange, and sea ice and exaggerated climate response in high latitudes. An amplified climate response is expected to occur due to rising greenhouse gas concentrations and paleoclimate records indicate the Arctic Ocean exhibits amplification to past climate changes notably during the early Holocene, Marine Isotope Stages (MIS) 11 and MIS 5 [the last interglacial period]. We will discuss the paleoclimatology of Quaternary interglacial periods in the Arctic Ocean with focus on records from planktic foraminifer assemblages, benthic foraminiferal oxygen isotope stratigraphy ($\partial^{18}O_b$), ostracode Mg/Ca paleothermometry and paleo-sea-ice proxies from the Northwind, Mendeleev, Alpha and Lomonosov Ridges. We will discuss the possible causes and implications for past interglacial warmth in the central Arctic Ocean and relevance of proxy records for future coring in the Arctic.

RECONSTRUCTIONS OF WATER MASSES AND SEA ICE ON THE WESTERN BARENTS SEA MARGIN DURING THE HOLOCENE: A MULTIPROXY REVIEW

Katrine Husum (Norwegian Polar Institute)

Today's rapid changes, such as warmer waters entering the Arctic Ocean, make it important to obtain information about natural variations in ocean currents and sea ice in this sensitive region. Knowing the past conditions are important for establishing natural reference values in order to better understand the causes and consequences of current changes. The aim of the study is to elucidate the limits of different water mass and sea ice conditions using a multi-proxy-based approach. The study site is situated close to the modern-day marginal ice zone and is influenced by Atlantic and Arctic waters. A gravity core from the western Barents Sea margin has been investigated using benthic and planktic foraminifera, stable isotopes ($\partial^{18}O$, $\partial^{13}C$), coccoliths and biomarkers (e.g. IP25). A depth-age model was developed using eight radiocarbon dates and showed sediment accumulation rates from ca. 3 cm/kyr – 25 cm/kyr. During the Early Holocene, the bottom and subsurface water mass temperature proxies show an overall warming of 2.5 - 3°C. Additionally, the sea ice proxies show a decrease of seasonal sea ice throughout the period. Coccolith ratios (surface water proxy) indicate a continuous influence of Atlantic Water, although distributions may also be caused by melt water and a strong stratification of the upper surface water masses during this time interval. During the Mid – Late Holocene, the temperature of bottom and subsurface water masses remains relatively stable. The benthic and planktic d18O values reflect slightly decreasing temperatures consistent with the decreasing insolation. The coccolith ratio reflects the fluctuations of the Arctic Front and the variations of Arctic and Atlantic Water in the surface water during this time interval. The relative abundance of the coccolith G. muellerae also indicates a sustained flow of Atlantic Water. Seasonal sea ice disappears, but it re-appears in intermittent intervals during the mid-Holocene. After ca. 1.100 cal. yr BP, all proxies generally fluctuate, reflecting more unstable oceanographic conditions. Seasonal sea ice occur again from 1.500 cal. yr BP towards the present. The coccolith record indicates an increased inflow of Atlantic

water in the same time period. These apparent contradicting findings after 1.500 cal. yr BP may reflect a decoupling of the water masses and/or different forcings of ocean currents and atmospheric circulation. This study illustrates well the different signatures of biological-based proxies. It also demonstrates how integrated multi-proxy studies enable a more comprehensive reconstruction of paleoceanographic and climatic evolution.

PALEOMAGNETISM AND CONSTRAINTS FOR CORES CORRELATION AND AGE MODELS

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Accurate dating is of fundamental importance to paleoclimatic studies. Without reliable estimates on the age of past events, it is impossible to assess accurately the rate of past environmental changes and their duration. Paleomagnetic analyses provide original dating methods and stratigraphic correlation tools.

Paleomagnetic record in rocks and sediments allow to reconstruct the past Earth's magnetic field variations. In sediments, during deposition, fine-grained ferromagnetic particles align with local geomagnetic field direction and are then locked with compaction and diagenesis preserving a record of the direction and intensity of the magnetic field through time. These changes, eventually supported by other chronostratigraphic constraints, can be tied to regional and global curves of paleomagnetic secular variation to accurately date sedimentary sequences of the past 10-15 kyr. Relative paleointensity variations and the identification of geomagnetic excursions can be instead used to date older sedimentary sequences spanning up to the last 2 Myr. In the last years, an integrated paleomagnetic and rock magnetic data set was collected from various sediment cores recovered from the NW Barents Sea. The data set gave the opportunity to refine the reconstruction of past geomagnetic field variation at high latitudes and to constrain the ages of palaeoclimatic events in a time range spanning from marine isotope stage 3 to the Holocene.