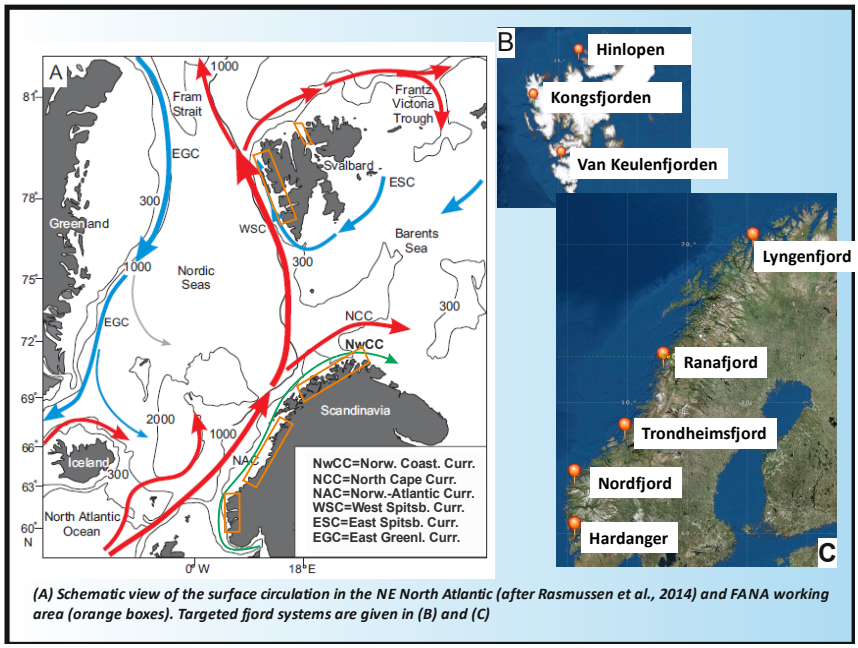
Report of MagellanPlus Workshop Series

Fjord sediment archives in the northeastern North Atlantic

7-8 April 2018, Vienna, Austria

Convenors: Jacques Giraudeau (CNRS/Univ. Bordeaux), Jochen Knies (Geol. Survey of Norway), Simon Belt (Univ. Plymouth), Matthias Forwick (UiT The Arctic Univ. of Norway), Berit Hjelstuen (Univ. Bergen), Katrine Husum (Norwegian Polar Inst.), Seung-Il Nam (Korea Polar Research Institute), James Scourse (Exeter Univ.).



(A) Schematic view of the surface circulation in the NE North Atlantic (after Rasmussen et al., 2014) and FANA working area (orange boxes). Targeted fjord systems are given in (B) and (C)

ECORD European Consortium for Ocean Research Drilling

IODP INTERNATIONAL OCEAN DISCOVERY PROGRAM

Summary:

The MagellanPlus workshop "Fjord sediment archives in the northeastern North Atlantic" aimed at refining the scientific rationale and strategies for drilling/coring in Norwegian and Svalbard fjord systems as part of the FANA – IODP 915-Pre initiative, and to stimulate the submission of a Full IODP proposal for the October 2018 deadline. The location and timing of this workshop (7-8 April, 2018, Vienna, Austria), as a pre-EGU event, were selected in order to foster the participation of key-scientists who planned to attend the General Union Meeting from April 9th. This workshop gathered a broad spectrum of scientists willing to share their expertise and develop original concepts on the identification and reconstruction of post-glacial paleoclimate changes and coastal geohazards based on fjord sediment archives. The workshop was attended by 23 scientists including 5 early-career scientists, and a representative of the ECORD Science Operator.

Kenynotes and open discussions covered a wide range of disciplines and topics related to the motivation and objectives of FANA. Break-out sessions wrre dedicated to discussing recommendations made by the IODP SEP (June 2017 meeting) and to finalize the agenda and tasks for the preparation of the Full Proposal.

Five main overarching themes were discussed:
- On the importance of bridging marine and continental climates using fjord sedimentary records.
- Lessons from initiatives in other polar/subpolar coastal and shelf settings.
- Past and present sedimentary processes in fjord systems: glacimarine vs. hemipelagic vs. mass transport deposits.
- Decrypting fjord sedimentary records: proxies and analytical developments.
- Developping the FANA Full proposal: state of site survey, methods and shore-based analyses.

The main deliverables can be summarized as follows:

* Investigating carbon burial in fjord system, its evolution over the last deglaciation and Holocene, and the relative impact of climate changes, human activities and local fjord physiography (thresholds) upon the origin and amount of carbon stored in fjord basins have to be highlighted as one of the key FANA topic.
* Fjord sedimentary records offer a unique opportunity to investigate the influence of human activities (agriculture, demography, heavy industry, coastal infrastructure, ...) on biogeochemical and sedimentary processes and sediment/carbon budgets in coastal environments. The existence of long-term (multi-decadal) instrumental records in most Norwegian and Svalbard sectors investigated as part of FANA constitutes an important added value which need to be clearly highlighted.
* The most recent works conducted on the topic of dating mass transport deposits (MTDs) and discriminating processes responsible for their triggering suggest (1) an overall synchronicity in the occurence of major MTDs in southern Norwegian fjord systems which needs to be tested in more northern setting, (2) the interest of combining physical and sedimentological parameters measured in sediment cores to discriminate types of MTDs, (3) the interest of high resolution swath bathymetry when investigating local processes which triggers MTDs.
* The development of robust chronologies is challenging in fjord settings and has to rely on the combination of ^{14}C dating and paleomagnetic data with implications on the choice of coring/driiling technologies, and on strategies for the determination of reservoir ages (coupled ^{14}C dating of marine and terrestrial material, as well as tephra chronology, when possible, have to be considered in this respect).
* Good to high quality seismic datasets are already available for most of the initially selected 8 fjord systems. Efforts should concentrate over the next two months on (1) collecting missing data for the northernmost Norwegian and Svalbard fjord sectors, (2) better advancing on identifying, in parallel to

general objectives, specific scientific questions in relation to individual drilling/coring sites or fjord systems according to heterogeneities in fjord physiography and sedimentary processes.

Given the implication and enthusiasm of all participants, and the very productive discussions which took place throughout those two days, the workshop conveners agreed on the possibility to submit a full proposal by the fall 2018 deadline and to drastically extend the list of co-proponents according to inputs provided during the meeting as well as additional interests formulated by colleagues which, unfortunately, could not attend this gathering.

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Objectives :

The purpose of this two-day workshop was to refine the scientific rationale and strategies for drilling/coring in Norwegian and Svalbard fjord systems as part of the initiative "Fjord sediment archives in the northeastern North Atlantic – FANA -" (IODP 915-Pre, https://docs.iodp.org/Proposal_Cover_Sheets/915-Pre_Giraudeau_cover.pdf), and to stimulate the submission of a high-quality Full IODP proposal for the October 2018 deadline.
The location and timing of this workshop (7-8 April 2018, Arkotel Kaiserwasser, Vienna, Austria), as a pre-EGU event, were chosen in order to foster the participation of key scientists who planned to attend the General Union Meeting from April 9th, 2018.

The workshop conveners hoped to gather a broad spectrum of scientists willing to share their expertise and develop original concepts on the identification and reconstruction of post-glacial paleoclimate changes and coastal geohazards based on fjord sediment archives.
A preliminary list of 24 scientists (11 different nationalities), whose expertise and interests in fjord-related marine geological investigations were deemed to be central for the preparation of the IODP Full "FANA" proposal, was drafted by the initial co-proponents of IODP 915-Pre during a recent FANA's Steering Committee held in Bordeaux (October 2017).
In addition, a request was forwarded to JRSO and SO managers to send representatives (2 – 3) to this workshop, according to an IODP SEP recommendation (June 2017 meeting).
Following a positive review by the MagellanPlus Steering Committee, this workshop was advertised on the MagellanPlus Workshop Series Programme web page, as well as in the EGU2018 pre-activity programme section, with the purpose of completing the list of attendees (with a limit of 30 pp).

Norwegian and Svalbard fjords communicate with the Norwegian Sea and Greenland Sea/Fram Strait, respectively, and constitute extensions of the open ocean towards land. Changes in their modern hydrology and sedimentary budget are related to changes in the volume transport and physical-chemical signature of Atlantic and Arctic-derived water masses circulating over the continental margin, to the seasonal development of sea-ice such as in coastal Svalbard, as well as to processes acting on the hinterland such as precipitation variations and the dynamics of tidewater glaciers (when present). Their estuarine circulation and adjacent ocean circulation are strongly influenced by modes of atmospheric circulation of regional to global significance (e.g. North Atlantic Oscillation -NAO- / Arctic Oscillation –AO-) which in turn modulate the amount and seasonality of precipitation over the hinterland. Finally, fjords are characterized by frequent mass-movement events whose understanding is of vital importance given their catastrophic impacts on coastal infrastructures and human lives.
Sediments of marine and terrigenous origin accumulate at very high rates in sheltered fjords, with rivers and/or tidewater glaciers as major sediment sources. Decades of marine geological and geophysical research in Norwegian and Svalbard fjords highlight differences in the rate, nature and history of sedimentation within these settings according to the fjord physiography and latitudinal position (i.e. glaciated vs. non-glaciated fjords). Sub-bottom mapping has constrained the location of post-glacial recessional grounding zone wedges during the retreat of the Scandinavian and Svalbard ice-sheets, and, together with field sampling, have been used to map the margin of the Younger Dryas ice re-advance in western Norway and Western Svalbard. Fjords are the focii of frequent mass-movement deposition induced by climatic deterioration (affecting the amount of sediment supplied by rivers and tidewater glaciers) or tectonic processes (e.g. isostatic adjustment, local earthquakes and tsunamis triggered by offshore megaslides or mass failure within fjords).

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 demise of the NW European ice-sheets has precluded any firm understanding of (1) high and low frequency behaviors, and the impact in this region of internal modes of the climate variability such as NAO and

the Atlantic Multidecadal Oscillation, (2) interactions with external climate forcing acting over short (volcanic and solar forcing) and long (orbital forcing) time-scales, (3) the coupled ocean/ cryosphere/ atmosphere dynamics and the connections between marine and continental climates, (4) the synchronicity and trigger mechanisms of past mass movements in high latitude coastal environments of Northwestern Europe.

These four themes were taken into consideration when developing the workshop program

Program:

The workshop program was developped in the form of keynotes and open discussions covering a wide range of disciplines and topics related to the motivation and objectives of "FANA". Break-out sessions were dedicated to discussing recommendations made by the IODP SEP (June 2017 meeting) and to finalize the agenda and tasks for the preparation of the Full proposal.

The workshop was attended by 23 scientists including 5 early-career scientists, 7 out of the 9 initial co-proponents of IODP 915-Pre, a representative of the ECORD Science Operator (a JRSO representative was ready to attend but had to cancel her participation at the last minute) as well as a representative of the French national IODP Office. Michele Rebesco, OGS, Trieste, Italia, attended the workshop as the MagellanPlus watchdog.
The final program was edited according to the final list of participants:

Saturday April 7th	**Session**	**Chair(s) & keynote speakers**	**Tentative presentations**
Coffee break			
10.30 - 12 am: open session	Why core NW European fjords? Bridging marine and continental climates	J. Giraudeau, H.-P. Sejrup, B. Austin	H.P. Sejrup : "why coring NW european fjords" + ongoing work on high-resolution (fjords ?) archives. B. Austin: Quaternary environmental changes from mid-latitude shelf and fjord systems (Scottish fjords? Others?).
Lunch break			
1.30 - 3.00 pm: open session	What can be learnt from initiatives in other subpolar/polar shallow and slope settings?	K. Husum, A. Pienkowski, M.S. Seidenkrantz, M. Rebesco	A. Pienkowski (Canadian Arctic): dating deglacial sequences, determining appropriate DR reservoirs for 14C calibration, selection of dateable materials. M.S. Seidenkrantz: preliminary results from a recent (September 2017) expedition to the NE Greenland shelf. M. Rebesco: post-glacial paleoclimate changes from contourite sediments (continental shelf and slope, NW Barents Sea).
Coffee break			
3.30 - 5.30 pm	IODP 915-Pre "FANA": scientific & operational strategies	J. Giraudeau, J. Knies, JRSO and ESO representatives, M. Rebesco, I. Snowball	J. Giraudeau and J. Knies: Operational strategies in view of scientific objectives. M. Rebesco: drilling with MeBO in fjord systems. I. Snowball: Influence of unnecessarily high hydraulic pressures used by the [IODP] Advanced Piston Corer on sediment fabrics and anisotropy of magnetic susceptibility - an IODP Exp. 347 case study. S. Morgan: JRSO and ESO recommendations on operational strategies (drilling vs. coring, etc...)

Sunday April 8th	**Session**	**Chair(s) & keynote speakers**	
8.30 - 10.00 am: open session	Past and present sedimentary processes in fjord systems: glacimarine vs hemipelagic vs. mass transport deposits	B.O. Hjelstuen, K. Van Landeghem, M. Forwick	B.O. Hjelstuen: sedimentary processes in southern Norwegian fjords - a summary. K. Van Landeghem: physical properties and mapping of MTDs. M. Forwick: short synthesis and/or selected results on post-glacial dynamics of climate and ocean circulation from high latitude (Svalbard) fjord systems.
Coffee break			
10.30 - 12 am: open session	Decrypting fjord sedimentary records: proxy and analytical developments	M. Forwick, J. Faust, C. Smeaton, A. Pienkowski	A. Pienkowski : Comparing reconstructions from various micropaleontological proxy groups (e.g., foraminifera vs. dinocysts vs. diatoms); proxy calibrations from modern fjord environments. J. Faust: On the use of elemental geochemistry in fjord sediments - provenance studies, etc... C. Smeaton: Carbon burial in fjord systems.
Lunch			
1.30 - 3.30 pm: break-out sessions	Developing the FANA Full proposal:		
	* Site survey	J. Knies, J. Giraudeau	State of data implementation; revisions of site location.
	* Methods & shore-based analyses	J. Scourse, S. Belt	With particular focus on organic geochemical proxies, on the development of reliable chronologies + other issues raised by SEP.
Coffee break			
4 - 5 pm: open session	Syntheses of group discussions.	Chairs of break-out sessions, FANA Pis	

Outcome and future plans:

Keynotes, group exchanges, and discussions during break-out sessions were particularly productive. Among the most import outcome of this meeting was the highlighting of additional key scientific topics to put forward in the upcoming FANA proposal :

* Blue Carbon: Investigating carbon burial in fjord system, its evolution over the last deglaciation and Holocene, and the relative impact of climate changes, human activities and local fjord physiography (thresholds) upon the origin and amount of carbon stored in fjord basins have to be highlighted as one of the key FANA topic.

* Human perspective: Fjord sedimentary records offer a unique opportunity to investigate the influence of human activities (agriculture, demography, heavy industry, coastal infrastructure, ...) on biogeochemical and sedimentary processes and sediment/carbon budgets in coastal environments. The existence of long-term (multi-decadal) instrumental records in most Norwegian and Svalbard sectors investigated as part of FANA constitutes an important added value which need to be clearly highlighted.

Recent (over the last few months) developments in the investigation of mass transport deposits (MTDs) in coastal settings suggest that discriminating processes responsible for their triggering is reachable. In this regard, the upcoming FANA proposal will insist on

* the overall synchronicity in the occurence of major MTDs in southern Norwegian fjord systems which needs to be tested in more northern setting,

* the interest of combining physical and sedimentological parameters measured in sediment cores to discriminate types of MTDs,

* the interest of high resolution swath bathymetry when investigating local processes which triggers MTDs.

The break-out sessions were the occasion of reviewing some key comments of the IODP SEP on the matters of the analytical strategy and on the current state of seismic data:

* Analytical strategy: The development of robust chronologies is challenging in fjord settings and has to rely on the combination of ^{14}C dating and paleomagnetic data with implications on the choice of coring/driiling technologies, and on methods for the determination of reservoir ages; coupled ^{14}C dating of marine and terrestrial material, as well as tephra chronology, when possible, have to be considered in this respect. Pore-water analyses were mentionned at several occasions as important methods to implement when it comes for instance to methane and sea-water chemistry.

A useful addition to the proposal would be a timeline/flowchart describing requirements during coring, post-cruise workshops, further applications, etc...

* Seismic data: Good to high quality seismic datasets are already available for most of the initially selected 8 fjord systems. Efforts should concentrate over the next two months on (1) collecting missing data for the northernmost Norwegian and Svalbard fjord sectors, (2) better advancing on identifying, in parallel to general objectives, specific scientific questions in relation to individual drilling/coring sites or fjord systems according to heterogeneities in fjord physiography and sedimentary processes.

Given the implication and enthusiasm of all participants, and the very productive discussions which took place throughout those two days, the workshop conveners agreed on the possibility **to submit a full IODP proposal by the fall 2018 deadline** and to drastically extend the list of co-proponents according to inputs provided during the meeting as well as additional interests formulated by colleagues which, unfortunately, could not attend this gathering.

List of participants (ESRs marked by an asterisk) by alphabetic order:

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