RV BELGICA CRUISE 2023/13 – CRUISE REPORT

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Geology research campaign: 25/06/2023 - 12/07/2023

1. CRUISE DETAILS

1.	Cruise number	2023/13
2.	Date/time Reykjavik TD Reykjavik TA	26/06/2023 at 10h00 11/07/2023 at 11h00
3.	Chief Scientist Participating institutes	Sebastiaan van de Velde Kate Hendry (2nd Chief Scientist) Royal Belgian Institute of Natural Sciences (Brussels, Belgium) Université Libre de Bruxelles (Brussels, Belgium) British Antarctic Survey (Cambridge, United Kingdom) Universiteit Antwerpen (Wilrijk, Belgium) University of Gothenburg (Gothenburg, Sweden) University of Southern Denmark (Odense, Denmark) Ghent University (Ghent, Belgium) University of Bonn (Bonn, Germany) University of Iceland (Reykjavik, Iceland)
4.	Area of interest	Iceland continental shelf, Hvalfjördur, Reydarfjördur

2. LIST OF PARTICIPANTS

Institute	NAME	Gender	25/06/2023-12/07/2023
RBINS-ODNature	Sebastiaan van de Velde	M	X
	Cathrin Wittig	F	X
	Kelle Moreau	M	X
	Saheed Puthan Puratil	M	X
BAS	Kate Hendry	F	X
UA	Cedric Goossens	M	X
	Silvia Hidalgo-Martinez	F	X
	Philip Ley	M	X
	Astrid Hylén	F	X
ULB	Sandra Arndt	F	X
	Bui Winter	F	X
	Felipe Sales de Freitas	M	X
	Lei Chou	F	X
UGOT	Per Hall	M	X
	Mikhail Kononets	M	X
UBonn	Christian März	M	X
	Katrin Wagner	F	X
SDU	John Paul Balmonte	M	X
	Jake Reardon	M	X
	Rebecca James	F	X
UGent	Lotte Verweirder	F	X
	Piet Reyniers	M	X
		Total participants:	22

3. SCIENTIFIC OBJECTIVES

DEHEAT - Natural analogues and system-scale modeling of marine enhanced silicate weathering

Global climate change is one of the biggest global challenges of the 21st century and urgently requires ambitious, transformative, and collective action to limit global warming. This can be achieved either by preventing emissions of carbon dioxide (CO2) and other greenhouse gases to the atmosphere (“conventional mitigation”) or by actively removing CO2 from the atmosphere (“negative emissions”). However, to reach the Paris climate goal and limit global warming below 2°C, we will need to rely on negative emission technologies (NETs, also called Carbon Dioxide Removal technologies, CDR). A promising NET approach is Enhanced Silicate Weathering (ESW). ESW makes use of the natural weathering reaction, whereby silicate dissolution consumes atmospheric CO2. The core idea of ESW is to distribute silicate minerals in environments that are characterized by high weathering rates, thus enhancing the uptake of atmospheric CO2 by increasing the alkalinity of the ocean. Here, we aim at examining, for the first time, the feasibility of ESW under marine conditions, taking advantage of the coastal ocean as a large-scale, natural biogeochemical reactor. One important research question pertains to the efficiency of marine ESW in stimulating oceanic CO2 uptake by increasing alkalinity in the coastal ocean. A second critical issue concerns the potential side-effects (both positive and negative) on marine ecosystems, including the enhanced availability of silicate and the potential release of iron and trace elements. To address these critical knowledge gaps, we will organize dedicated RV Belgica field campaigns to quantify the sediment geochemistry and mineralogy at a site that serves as natural analogues for ESW; the Iceland continental shelf, which is rich in basalt.

BARF - Benthic fauna as drivers of ice-to-ocean iron transport in ARctic Fjords

The ocean is critical for regulating Earth’s climate, as it represents the largest sink of atmospheric carbon dioxide. Marine primary productivity is a key driver of this essential carbon dioxide sink, and is limited by iron availability in large parts of the ocean. Because of its low residence time in seawater, oceanic iron concentrations are strongly controlled by the iron sources to the ocean. Run-off from areas of intense weathering in Arctic regions are considered important sources of iron to the ocean. However, much of the run-off from Arctic land areas first transits through fjords, and the efficiency of iron land-to-ocean transport through these dynamic transitional systems has been the subject of much debate. Because iron is highly insoluble, rapidly oxidized and removed from the water column by settling to the seafloor, benthic iron recycling is a critical, yet poorly understood, part of land-to-ocean iron transport. Sediment reworking by benthic fauna (“bioturbation”) is thought to stimulate benthic iron recycling, however, the link between benthic fauna composition, faunal activity and iron (re)cycling is largely unquantified. This knowledge gap hampers our ability to confidently predict the evolution of ice-to-ocean iron transport efficiency, and thus changes in marine primary productivity and the global carbon cycle. This RV Belgica campaign aims to describe benthic Fe cycling and fluxes in sediments from Hvalfjördur.

RBINS-OD Nature-KP (ICOS)

The AUMS (Autonomous Underway Measurement System) system is inspired by the success of similar systems deployed on various ships of opportunity in the framework of the European Union FerryBox project (www.ferrybox.org). The instrumentation will greatly enhance the continuous oceanographic measurements made by RV Belgica by taking advantage of the significant technological improvements since the design of the existing (salinity, temperature, fluorescence) systems (cfr. ICOS Standards). In particular, many new parameters can now be measured continuously including important ecosystem parameters such as nitrate, ammonia, silicate, dissolved oxygen and CO2, turbidity, alkalinity and phytoplankton pigments. In addition, the new equipment allows automatic acquisition and preservation of water samples, rendering RV Belgica operations significantly more efficient by reducing onboard human resources. Data will be available in near real-time via RBINS-OD Nature’s public website (http://odnature.naturalsciences.be/belgica/en/odas) and following quality control, from the Belgian Marine Data Centre. Since 2015, the AUMS data are also delivered to the EC ESFRI project ICOS.

4. OPERATIONAL COURSE

All times are given in local time. All coordinates in WGS84.

176day 25/06/2023

16h00-17h00	Embarkation of instruments and personnel
17h15-17h30	Safety briefing
17h30-18h00	Coordination meeting

177day 26/06/2023

9h00	Abandon ship
10h00	Transit to station HF3
12h20	CTD @ HF3
12h59	Van Veen @ HF3
13h21	Boxcorer @ HF3
17h35	Deploy lander @ HF3
18h20	GMAX gravity coring @ HF3
20h00-22h00	Transect multibeam and SBP

178day 27/06/2023

8h00	CTD @ HF2
8h27	Van Veen @ HF2
8h42	Boxcorer @ HF2
10h39	Transit to HF3
11h40	Test 3m gravity corer @ HF3
14h41	Boxcorer @ HF3
16h15	GMAX gravity coring @ HF3
17h00	Retrieve lander @ HF3
18h30-20h30	Transect multibeam and SBP

179day 28/06/2023

8h10	CTD @ HF1
9h06	Van Veen @ HF1
9h13	Boxcorer @ HF1
10h00	GEMAX gravity coring @ HF1
13h08-14h00	Transect multibeam and SBP, transit to HF2
14h00	Deploy lander @ HF2
14h30	GEMAX gravity coring @ HF2
15h10	3m gravity coring @ HF2
17h10	6m gravity coring @ HF2
18h00-22h00	Transect multibeam and SBP

180day 29/06/2023

8h05	CTD @ HF4
8h20	Van Veen @ HF4
8h40	Boxcorer @ HF4
12h10	Transect multibeam and SBP, transit to HF2
14h00	6m gravity coring @ HF2
15h30	Transit to HF1
16h30	CTD @ HF1
16h50	6m gravity coring @ HF1
17h20	Transit to HF2
18h10	CTD @ HF2
18h30 – 22h00	Transect multibeam and SBP

181day 30/06/2023

8h00	Boxcorer @ HF2
8h30	Transit to HF1
9h20	Boxcorer @ HF1
10h00	Transit to HF2

11h00	Retrieve lander @ HF2
11h10	Transit to HF3
11h55	CTD @ HF3
12h15	Boxcorer @ HF3
12h50	Transit to CS 1-1
17h00	Briefing Deheat

182day 01/07/2023

8h00	CTD @ CS1-1
8h45	Van Veen @ CS1-1
9h05	Boxcorer @ CS1-1
10h17	GEMAX gravity coring @ CS1-1
11h05	Boxcoring @ CS1-1
14h00	3m gravity coring @ CS1-1
15h00	6m gravity coring @ CS1-1
17h53	Van Veen @ CS1_sand1
19h10	Van Veen @ CS1_sand2
20h00	Transit to CS 2-2

183day 02/07/2023

7h00	Multibeam and SBP @ CS2-2
8h42	Boxcorer @ CS2-2
9h43	GEMAX gravity coring @ CS2-2
14h00	Deploy lander @ CS2-2
14h45	3m gravity coring @ CS2-2
16h15	6m gravity coring @ CS2-2
16h50	Multibeam and SBP

184day 03/07/2023

8h00	CTD @ CS2-1
8h30	Van Veen @ CS2-1
9h55	Boxcorer @ CS2-1
10h41	GEMAX gravity coring @ CS2-1
11h35	Boxcorer @ CS2-1
14h00	3m gravity coring @ CS2-1
17h15	Multibeam and SBP

185day 04/07/2023

8h00	CTD @ CS2-4deep
9h17	Boxcorer @ CS2-4deep
12h10	GEMAX gravity coring @ CS2-4deep
12h30	transit to CS2-4shallow
13h50	CTD @ CS2-4shallow
14h23	GEMAX gravity coring @ CS2-4shallow
15h30	Boxcorer @ CS2-4shallow
16h15	Multibeam and SBP

186day 05/07/2023

8h00	CTD @ CS2-0
8h20	Boxcorer @ CS2-0
9h00	transit to CS2-2
12h30	Van Veen @ CS2-2
13h00	Retrieve lander @ CS2-2
15h00	Transit to Reydarfjördur

187day 06/07/2023

8h00	CTD @ RF1
8h30	Boxcorer @ RF1

9h57	GEMAX gravity coring @ RF1
12h00	MBES and SBP
14h00	6m gravity coring @ RF1
17h20	Lander deployment @ RF1
17h30	MBES and SBP

188day 07/07/2023

8h20	CTD @ RF3
8h35	Logistics replenishment with FRB
8h48	GEMAX gravity coring @ RF3
09h30	Boxcorer @ RF3
10h30	MBES and SBP
14h00	Van Veen @ RF2
14h29	6m gravity corer @ RF2
15h40	CTD @ RFK
16h00	MBES and SBP

189day 08/07/2023

8h15	CTD @ RF2
8h55	Boxcorer @ RF2
10h00	GEMAX gravity coring @ RF2
14h00	Lander retrieval @ RF1
15h00	MBES and SBP

190day 09/07/2023

8h55	CTD @ RF4
9h25	Boxcorer @ RF4
12h00	MBES and SBP
16h00	Transit to Reykjavik

191day 10/07/2023

Transit to Reykjavik

192day 11/07/2023

11h00	Arrival in Reykjavik

- End of campaign 2023/13 -

5. TRACK PLOT

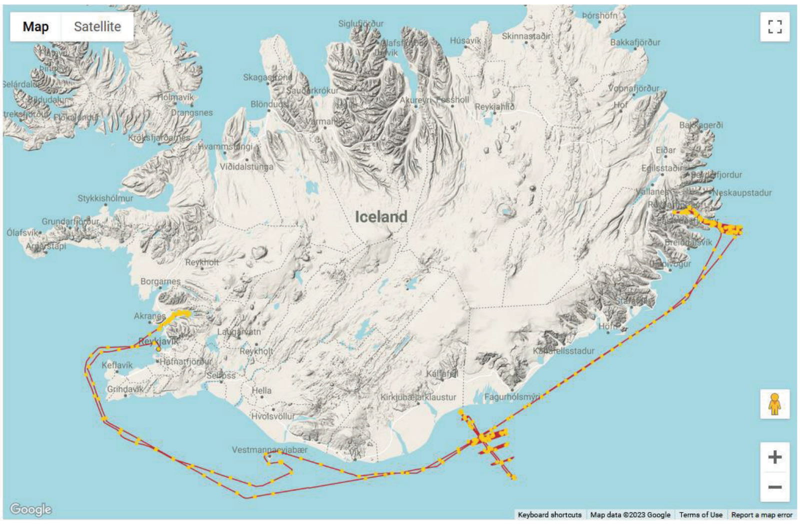

Figure 1: Track plot of campaign 2023/13

6. MEASUREMENTS AND SAMPLING

During transit and outside of sampling times, the seafloor was mapped using the multibeam echosounder (Kongsberg EM2040 and EM304) and parametric subbottom profiler (Kongsberg TOPAS PS18). Tracks are given in Fig. 2.

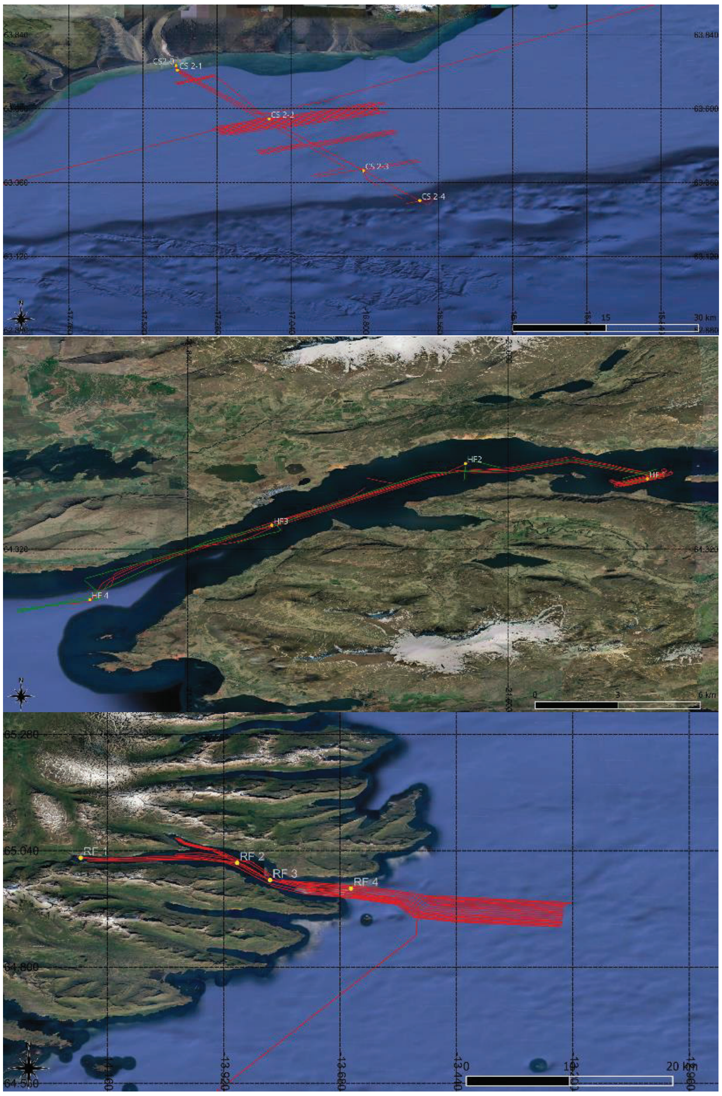

Figure 2: MBES tracks in the shelf area (top), Hvalfjördur (middle) and Reydarfjördur (bottom). Green lines indicate TOPAS subbottom profiler, red lines multibeam echosounder.

At each station, water samples from 4-6 discrete depths were collected with CTD and Niskin bottles. Water was filtered (0.42 µm) in the CTD hangar and samples were collected for dissolved inorganic carbon (DIC), total alkalinity (TA), nitrogen species (NH4 and NO3) and silicates.

Afterwards, sediment type was assessed using the Van Veen grabcorer. Sediment was collected in a container and stored in the fridge. If the sediment type allowed boxcoring, sediment was collected with the boxcorer for subsequent whole-core incubations. Cores were incubated in closed-off containers and injected with a uranine tracer dye to assess bio-irrigation rates. Samples for DIC, ^{13}C-DIC, nutrients, Si, alkalinity and metals were collected at discrete time intervals to estimate sediment-water fluxes.
Undisturbed cylindrical sediment cores were also collected with the GEMAX gravity corer (if the sediment was fine-grained). Four cores were profiled for oxygen, dissolved sulfide and pH using micro-electrodes. The microprofiled cores and additionally collected cores were subsequently sectioned with a resolution of 0.5 cm for the depth range from 0 to 2 cm, 1 cm for the depth range from 2 to 6 centimeters, and 2 cm for the depth range from 6 to 20 cm.

Duplicate microprofiled cores were sectioning in anoxic environment and porewater was extracted using rhizons for analysis of dissolved metals and sulphur species. The remaining sediment was stored anoxically and frozen for later determination of iron mineralogy and reactivity. The second duplicate set of microprofiled cores was sliced for collected for analysis of the microbial community. One core was sliced for determination of porosity and ^{210}Pb activity to determine sedimentation rates. Duplicate cores were sliced and frozen at -80°C for eDNA analysis and of the remaining material, sediment samples were taken from the top layer (0-5cm) and deeper layer (>15cm) for incubation experiments. In addition, porewater was extracted from slices of duplicated cores using centrifugation, and subsequently analyzed for DIC and TA. Leftover sediment was stored frozen for particulate organic and inorganic carbon analysis. On another set of duplicate cores, 1 ml sediment samples were taken for pigment analysis and stored at -80°C, porewater was extracted from sediment slices using rhizon samplers for analysis of dissolved Si and Si-isotopes, and sediment was stored frozen for subsequent granulometry and mineralogy. Porewater collected with rhizon samplers from another set of duplicate cores was stored for analysis of H2S and magnesium and strontium isotopes. Duplicate cores were injected with ^{35}S radiotracer for determination of sulfate reduction rates.
If the sediment was coarse grained, sediment was collected with the Van Veen and incubated in flow-through reactors to assess fluxes of TA and dissolved Si. Sediment was returned to the home laboratory for further experiments.

At selected sites, the long gravity corer (3-6m) was deployed. Upon retrieval the long gravity core was cut into 1m sections and moved to the 4°C cold room. Porewater was extracted using rhizons at 10cm intervals for measurement of H2S, TA, DIC and dissolved metals and sulfur. At the same resolution, sediment samples were collected with 15 mL syringes and stored frozen at -20°C. At selected sites and depths, additional sediment samples were taken for analysis of microbial communities.

At selected sites, the benthic chamber lander was deployed for 24h-48h. 60mL samples were collected at 9 discrete time intervals. These samples were subsampled for DIC, ^{13}C-DIC, total alkalinity, nutrients, dissolved metals and Si isotope analysis.

Table 1: List of Sampled stations

Station Name	**Latitude (°N)**	**Longitude (°W)**	**Water depth (m)**	**CTD and Niskin**	**Van Veen**	**Boxcore**	**GEMAX gravity core**	**Long gravity core**	**Benthic lander**
HF1	64° 22.362’	21° 29.731'	18	X	X	X	X	X	
HF2	64° 22.699’	21° 37.940'	28	X	X	X	X	X	X
HF3	64° 20.290’	21° 46.613'	66	X	X	X	X		X
HF4	64° 16.949'	21° 54.871'	33	X	X	X			
CS1-1	63° 24.200	20° 6.598'	134	X	X	X	X	X	
CS1_sand1	63° 25.662'	20° 20.691'	61		X				
CS1_sand2	62° 28.445'	20° 10.427'	50		X				
CS2-0	63° 44.431’	17° 24.768'	43	X	X	X			
CS2-1	63° 43.786'	17° 24.643'	79	X	X	X			
CS2-2	63° 34.040’	17° 6.646'	192	X	X	X	X	X	X
CS2-4shallow	63° 18.097'	16° 37.289'	299	X	X	X	X		
CS2-4deep	63° 18.097'	16° 37.2871	600	X		X	X		
RF1	65° 1.526'	14° 12.851'	55	X	X	X	X		
RF2	65° 0.902’	13° 53.527’	150	X	X	X	X	X	
RF3	64° 58.798'	13° 49.415'	167	X	X	X	X	X	X
RF4	64° 57.741'	13° 39.389'	136	X	X	X			
RFK	65° 3.987'	14° 1.110'	30	X					

7. REMARKS

Meteorological conditions were good for most of the campaign. It was decided that because of a predicted worsening of meteorological conditions from 6 July 2023 onward, sampling would proceed at alternative sampling location in the more sheltered Reydarfjördur, rather than originally planned stations along a second transect on the shelf.

A technical issue with the Boxcorer equipment, specifically a broken screw that secures the weights in place, delayed box coring operations for 24 hours.

EARS was unavailable during the last three days of the campaign.

8. DATA STORAGE

All sampling events have been logged using the logging system EARS. Location and time of the actions are also logged on a shared drive between all scientists.

All processed data (samples described above) generated via lab analysis will be stored in Excel and in .Rdata format. The data files will contain the location (in coordinates as well as depth in the water column and/or sediment column) and relevant metadata such as temperature and salinity for each datapoint. These data will be stored on a shared folder between all scientists, and provided to RBINS-BMDC.
The raw multibeam and TOPAS data will be stored on a shared drive at Ghent University. The processed products will be stored on a shared folder accessible by all scientists.

Contact person is Sebastiaan van de Velde (sebastiaan.vandevelde@uantwerpen.be)