Check for updates

DATA NOTE

Sampling deeply sourced seeps around the icelandic hotspot, Iceland: ISL23 expedition report

[version 1; peer review: 1 approved with reservations]

Francesco Montemagno[1], Martina Cascone[1], Feliciana Oliva[1], Annarita Ricciardelli[1], William J. Lowe[1,2], Angelina Cordone[1], Antonino Pollio[1], Jacopo Pasotti[1], Namitha Kumar[3], Peter H. Barry[3], Carlos Ramirez[4], Roy E. Price[5], Snædís Björnsdóttir[6], Ingi Agnarsson[7-9], Andri Stefánsson[7], Sæmundur Ari Halldórsson[7], J. Maarten de Moor[10,11], Donato Giovannelli[1,3,12-14]

[1]Department of Biology, University of Naples Federico II, Naples, Italy, 80126, Italy
[2]Department of Chemistry, Howard University, Washington, District of Columbia, USA
[3]Department of Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, USA
[4]Servicio Geologico Ambiental, Heredia, Costa Rica
[5]School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, New York, USA
[6]NordVulk, Institute of Earth Sciences, University of iceland, Reykjavık, Iceland
[7]Faculty of Life and Environmental Sciences, University of Iceland, Reykjavik, Europe, Iceland
[8]Department of Entomology, National Museum of Natural History, Smithsonian Institution, Washington, D.C., USA
[9]Centre for Behavioural Ecology and Evolution, College of Life Sciences, Hubei University, Wuhan, China
[10]Observatorio Volcanológico y Sismológico de Costa Rica (OVSICORI), Universidad Nacional, Heredia, Costa Rica
[11]Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico, USA
[12]Italian National Research Council, CNR-IRBIM, Institute for Marine Biological Resources and Biotechnologies,, Ancona, Italy, Italy
[13]Earth-Life Science Institute, ELSI, Tokyo Institute of Technology, Meguro-ku, Tokyo, Japan
[14]Department of Marine and Coastal Science, Rutgers University, New Brunswick, New Jersey, USA

v1 **First published:** 13 Jun 2026, **6**:199
https://doi.org/10.12688/openreseurope.21785.1
Latest published: 13 Jun 2026, **6**:199
https://doi.org/10.12688/openreseurope.21785.1

Abstract

The ISL23 expedition, conducted in Iceland during 2023, aimed to investigate microbial diversity and biogeochemical processes in Icelandic geothermal systems. These environments, characterized by extreme physicochemical gradients, provide unique insights into microbial life under extreme conditions. During this expedition we sampled 30 localities in geothermal systems located within neovolcanic zones and older segments of the Icelandic crust, in geothermal systems located within neovolcanic zones and older segments of the Icelandic crust,, including a variety of geothermal features like shallow-sea chimneys, and terrestrial hot springs. We collected fluids, sediments, and gases, alongside environmental data such as temperature, pH, and conductivity, to better understand the

Open Peer Review

Approval Status ?

	1
version 1 13 Jun 2026	? view

1. **Pushp Lata**, University of Delhi Faculty of Science (Ringgold ID: 124707), New Delhi, India

Any reports and responses or comments on the article can be found at the end of the article.

interactions between geology, geochemistry, and microbial communities. The samples will contribute to our understanding of microbial life in extreme environments, and offer potential insight into biogeochemical cycling, astrobiology, and biotechnological applications. Ultimately, this expedition aims at expanding our comprehension of how geological activity shapes microbial ecosystems, providing a foundation for future research in Earth's extreme environments and their potential analogs on other planetary bodies.

Plain Language summary

During the ISL23 expedition in 2023, we sampled geothermal environments across Iceland to document their environmental diversity and support future microbiological and geochemical studies. We visited 30 sites, including terrestrial hot springs and shallow-water hydrothermal areas, and collected water, sediments, and gas samples. At each site we recorded key field measurements such as temperature, pH, and conductivity. The resulting site metadata and sampling information provide a standardized reference for follow-up analyses and for researchers planning new sampling campaigns. The expedition site information is openly available through the CoEvolve Database and an archived record with a DOI.

Keywords

Expedition report, Iceland, Hot springs, Geomicrobiology, Biogeochemistry

This article is included in the European Research Council (ERC) gateway.

This article is included in the Horizon 2020 gateway.

Corresponding author: Donato Giovannelli (donato.giovannelli@unina.it)

Author roles: Montemagno F: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Supervision, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Cascone M**: Data Curation, Investigation, Methodology, Writing – Original Draft Preparation; **Oliva F**: Investigation, Methodology, Writing – Review & Editing; **Ricciardelli A**: Investigation, Methodology, Writing – Review & Editing; **J. Lowe W**: Investigation, Writing – Original Draft Preparation, Writing – Review & Editing; **Cordone A**: Project Administration, Supervision, Writing – Original Draft Preparation, Writing – Review & Editing; **Pollio A**: Methodology, Supervision, Writing – Original Draft Preparation, Writing – Review & Editing; **Pasotti J**: Investigation, Writing – Original Draft Preparation, Writing – Review & Editing; **Kumar N**: Investigation, Methodology, Writing – Review & Editing; **H. Barry P**: Funding Acquisition, Methodology, Project Administration, Supervision, Writing – Original Draft Preparation, Writing – Review & Editing; **Ramirez C**: Investigation, Methodology, Writing – Original Draft Preparation, Writing – Review & Editing; **Price RE**: Funding Acquisition, Investigation, Methodology, Supervision, Writing – Review & Editing; **Björnsdóttir S**: Investigation, Methodology, Writing – Review & Editing; **Agnarsson I**: Investigation, Methodology, Writing – Review & Editing; **Stefánsson A**: Investigation, Methodology, Supervision, Writing – Review & Editing; **Ari Halldórsson S**: Investigation, Methodology, Supervision, Writing – Review & Editing; **de Moor JM**: Funding Acquisition, Investigation, Methodology, Project Administration, Supervision, Writing – Review & Editing; **Giovannelli D**: Conceptualization, Data Curation, Funding Acquisition, Investigation, Methodology, Project Administration, Resources, Supervision, Writing – Original Draft Preparation, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 948972 (Coevolution of Life and Planet: role of trace metal availability in the evolution of biogeochemically relevant redox metalloenzymes [COEVOLVE]). This work was partially supported by NSF award 2121637 to PHB and JMdM. We also acknowledge NSF awards 2152551 and 2151120 to PHB. This work was partially supported by NASA Habitable Worlds grant 80NSSC24K0076 to REP.
The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Copyright: © 2026 Montemagno F *et al*. This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

How to cite this article: Montemagno F, Cascone M, Oliva F *et al.* **Sampling deeply sourced seeps around the icelandic hotspot, Iceland: ISL23 expedition report [version 1; peer review: 1 approved with reservations]** Open Research Europe 2026, **6**:199 https://doi.org/10.12688/openreseurope.21785.1

First published: 13 Jun 2026, **6**:199 https://doi.org/10.12688/openreseurope.21785.1

Introduction

Iceland straddles the divergent boundary between the North American and Eurasian plates, where the plate boundary overlies an upwelling mantle plume (Einarsson, 2008; Hjartarson et al., 2017; Jakobsson and Gudmundsson, 2008). Its unique setting gives rise to a big diversity of hydrothermal systems, ranging from terrestrial high-temperature springs and fumaroles, to underwater shallow-water hydrothermal vents such as the Strýtan vent (Gutiérrez-Ariza et al., 2024; Marteinsson et al., 2001; Price and Giovannelli, 2019; Stefánsson et al., 2021). The interaction between active volcanism and groundwater circulation supports diverse microbial ecosystems, providing a large range of physicochemical gradients (Friðleifsson et al., 2017; Twing et al., 2022). In Iceland, hydrothermal systems span a broad range of pH and temperature conditions, from acidic solfataras to alkaline carbonate chimneys, and are enriched in dissolved gasses (*e.g.*, CO_2, H_2, CH_4), and trace metals (*e.g.*, Fe, Mn, Cu) (Geptner et al., 2002; Stefánsson et al., 2021; Szponar et al., 2013). Such gradients cause strong redox disequilibria that fuel chemolithotrophic microbial metabolisms, including hydrogen oxidation, methanogenesis, and sulfur cycling (Dahle et al., 2015; Torsvik et al., 2015). As a result, Icelandic hydrothermal sites represent rare natural laboratories for studying microbes–mineral interactions, biogeochemical cycles, and the limits of life in extreme environments (Früh-Green et al., 2003; Fullerton et al., 2021; Martin and Russell, 2006).

Beyond their ecological importance, Icelandic environments have been proposed as analogues for early Earth conditions and for potential habitable niches on other planetary bodies (Sojo et al., 2016). Studying the microbial communities that these places host across multiple geothermal sites bridging large geological scales allows one to capture a more comprehensive view of how environmental heterogeneity influences and shapes microbial diversity, community structure, and metabolic potential (Giovannelli et al., 2022).

The ISL23 expedition was designed to investigate the Icelandic microbial diversity and its interactions with the geology by sampling a wide range of hydrothermal systems, including shallow-sea chimneys, hot springs, and fumarolic fields. This report describes the methods and the sites sampled during the ISL23 expedition, which is part of a project that, by combining geochemical analyses with microbial community profiling, aims to improve our understanding of the complex interplay between geological activity and microbial life.

Expedition team and logistics

The project team is composed of interdisciplinary scientists spanning the fields of microbiology, biogeochemistry, microbial ecology, gas geochemistry and science communication. The expedition logistics was facilitated by the University of Iceland. Access to the cabins and direct contact with land owners was provided through the University of Iceland. The Field Science Party was responsible for sample collection and the field measurements. The remote location of some springs and the lack of roads and paths on the island, required extensive planning with reasarchers of the University of Iceland for the logistics, preparation of the expedition and to understand the best way to reach the sites, in particular the ones in the center of Iceland. To reach these sites it was necessary to use 4x4 vehicles with high clearance and equipped with winter-rated all-season tires. Access to site SC_230907 requires a boat and diving equipment for cold water conditions. The dive is technical and we were supported by the Strýtan Dive Center.

Field Science Party composition: Francesco Montemagno, Annarita Ricciardelli, Feliciana Oliva, Martina Cascone, Namitha Kumar, Maarten de Moor, Jacopo Pasotti, Carlos José Ramírez Umaña, Roy Price, Snaedis Bjornsdottir, Ingi Agnarsson, Sæmundur Ari Halldórsson and Donato Giovannelli (Expedition Leader and PI of the project).

Support Science Party composition: Angelina Cordone, Jake Lowe, Antonino Pollio, Peter Barry and Andri Stefansson.

Geological and environmental background

Iceland sits atop the Eurasian-North American divergent plate boundary and a mantle plume (Einarsson, 2008; Eiríksson and Símonarson, 2021), resulting in the extensive volcanism and basaltic flows which characterize this unique geological setting. Relative motions between the two features lead to oblique faulting, fissuring, and a general eastward shift of volcanic zones over time volcanic activity is more intensive where these phenomena cut across the plate boundary (Stefánsson et al., 2017).

Basaltic volcanism transports mantle volatiles to the surface, including carbon, sulfur, noble gases, and halogen species (Ranta et al., 2023). Typically, seawater at mid-ocean ridges dominates other possible sources of volatiles (Stefánsson et al., 2017); the subaerial setting of Iceland's divergent plate boundary means volcanic hydrothermal systems can be used to investigate alternative volatile sources, and to gauge the contribution of degassing intrusions to volatile release (Ranta et al., 2023; Stefánsson et al., 2017).

Each neovolcanic rift zone has its own distinct He isotope signature (West Rift Zone: 12–17 Ra, the ratio of $^3He/^4He$ is reported relative to the ratio of air (Ra); North Rift Zone: 8–11 Ra; East Rift Zone: 18–21 Ra), suggested to mark the

location of past and present plume activity (Harðardóttir et al., 2018). Such high ratios have been associated with un-degassed and primordial mantle sources (Füri et al., 2010; Harðardóttir et al., 2018), and together with estimates for pre-eruptive carbon isotope signatures ($\delta^{13}C$ values from neovolcanic zone basalts) suggest close resemblance to primary mantle composition (Barry et al., 2014). However, a large range of $\delta^{13}C$ values measured across fluid samples across Iceland suggests that hydrothermal processes extensively modify the original source composition through degassing and/or crustal assimilation (Barry et al., 2014). The extent to which microbial processes might further contribute to altering the mass balance of volatiles recycled through the crust as demonstrated in other locations globally (e.g. Costa Rica and South America (Barry et al., 2025, 2022; Fullerton et al., 2021)).

Geothermal activity in Iceland is classified by high- and low-temperature systems, the former are typically associated with volcanism within its neovolcanic zones, such as the EVZ and NVZ, and the latter with active fractures and faults which are widespread across Quaternary and Tertiary formations (Stefánsson et al., 2017) (Figure 1). Geothermal fluids are characterized by a wide range in carbon isotope ratios $CO_2/^3He$ values. Extreme geothermal values suggest that original source compositions have been extensively modified by hydrothermal processes such as degassing and/or calcite precipitation. Relatively low $\delta^{13}C$ and $CO_2/^3He$ values in low-temperature zones are consistent with calcite precipitation as a dominant process in older portions of the Icelandic crust (Barry et al., 2014). High-temperature regions demonstrate maximum $\delta^{13}C$ and $CO_2/^3He$ values, with orders of magnitude higher for fluids, relative to gas-phase samples suggesting that hydrothermal phase separation processes may be prevalent in these zones (Barry et al., 2014).

Sampling methods

Sample selection

Fluids, sediments and gases were collected from 30 locations identified based on the literature and the knowledge of the researcher of the University of Iceland. Several of the springs show characteristics compatible with the definition of deeply-sourced seeps (Giovannelli et al., 2022). We identified the main seep outlet by using a combination of field observation and measurements, as pH, temperature, conductivity and the use of a thermal camera. The aim of this approach is to sample pristine gasses and fluids as they emerge from the subsurface, minimizing their interaction with the surface environment. We also sampled background soil samples in the proximity of each site, choosing a close point that did not show geothermal alterations. This type of sampling approach, described in detail in Giovannelli et al. (2022), aims to maximize the subsurface information that can be extrapolated from the data. Temperature, conductivity, pH, redox potential, total suspended solids and dissolved oxygen were measured directly in the field using a Hanna Multiparameter probe (HANNA, HI98196, accuracy: ± 0.15°C, ± 0.02 pH), regularly calibrated. Water emission rates were estimated by measuring the spring outlet dimensions and the water flow velocity using a FL-K1 stream flow metre, handheld rod with impeller and LCD readout (JDC Instruments Electronics Flowatch Flowmeter). Alkalinity, iron (II) and dissolved hydrogen sulfide were also measured in the field as described below.

Geochemistry samples acquisition

Aqueous and Sediment Geochemistry

When possible, we took sediment samples as close as possible to the water outlet point, and collected them into 50 ml metal-free conical tubes. For the characterization of the major dissolved ions, 0.22 µm filtered fluids were collected in a 50 ml conical tube (Correggia et al., 2024a). For the analysis of trace elements, a duplicate sample was collected in acid-washed tubes and acidified with nitric acid 2% final concentration to avoid the precipitation of metals (Correggia et al., 2024). Filtered fluids (0.22 µm) were also collected in a 10 ml penicillin vial air-free for dissolved inorganic carbon isotope composition.

Dissolved and free gas geochemistry

Fluids were collected both for gas composition analysis, stable isotope of the carbon pools ($\delta^{13}C$ of CO_2, dissolved inorganic carbon and organic carbon) and water ($d^{18}O$ and D) and noble gas isotope systematics. Fluid samples for noble gas analysis were first flushed through silicone tubing and into 3/8-inch copper tubes. After sample flushing (i.e., approximately 10x the volume of the tubing), stainless steel clamps were closed on each end of the copper tubes, trapping the fluid sample inside of the copper tubing between the clamps (Barry et al., 2022). Fluids to be analyzed for dissolved gas compositions were collected in pre-evacuated 250 ml Giggenbach bottles as previously described (Barry et al., 2019). At sites where a free gas phase was present, copper tubes were also used to collect free gas for noble gas isotope analysis using a funnel to collect the gases. Gases were concentrated using an inverted funnel and silicone tubing and after flushing the sampling line with gas for approximately 30 minutes, clamps were closed. Free gas for major and trace gas analysis was collected using Giggenbach bottles containing 4 M NaOH to remove CO_2 from the gas phase and allowing trace gas to accumulate (de Moor et al., 2013).

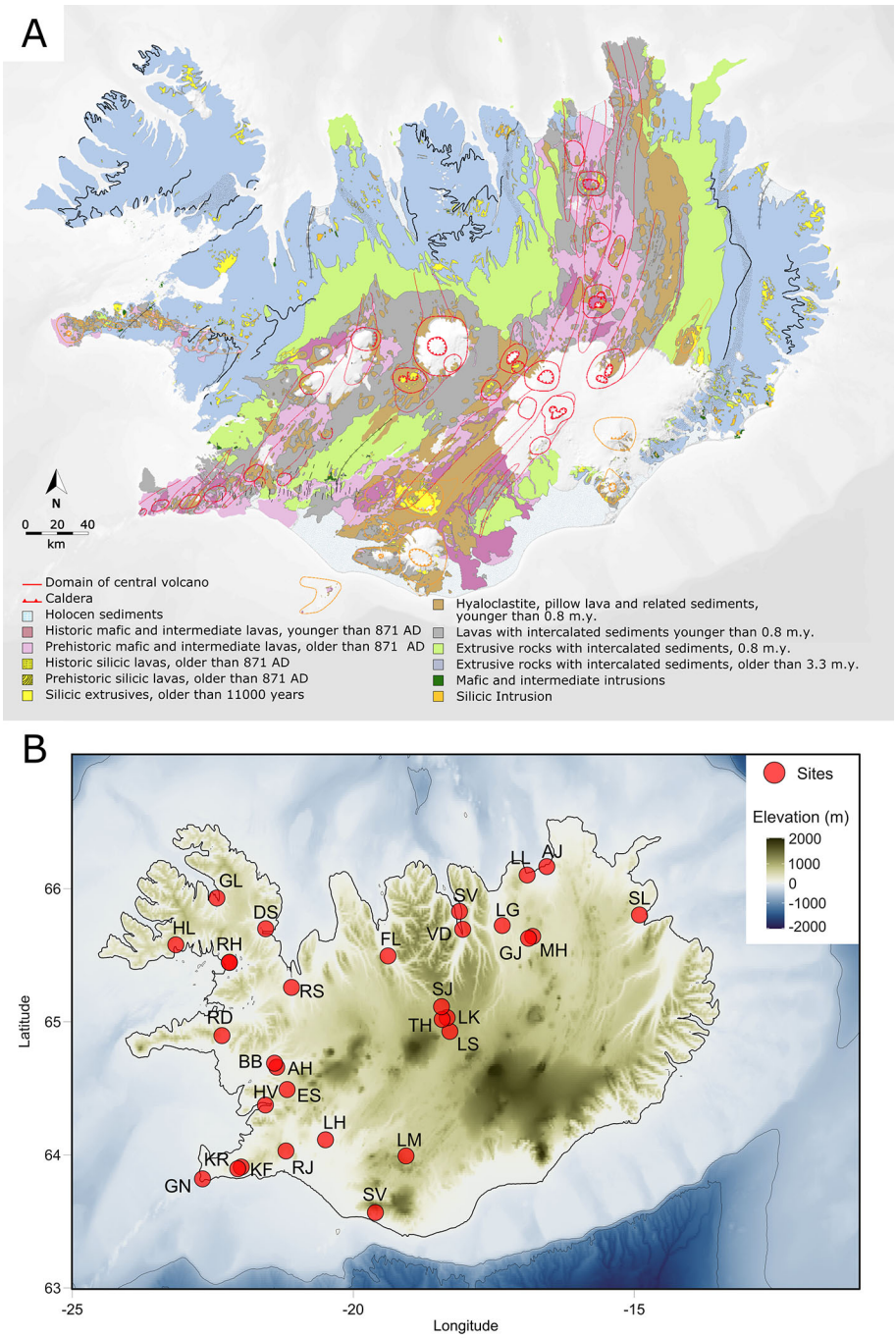

Figure 1. Geological map of the bedrock of Iceland (A) and location of the sites sampled (see Table 1) during the ISL23 expedition (B). Red circles mark the sites sampled during the expedition. The geological map was modified from the Natural Science Institute of Iceland (Jóhannesson, 2014 "Geological maps | Náttúrufræðistofnun"). The basemap shows shaded relief topography and surrounding bathymetry; colors indicate elevation (m), from −2000 (dark blue) to +2000 (tan/green).

Determination of total Alkalinity, dissolved sulfide and iron (II) in geothermal fluids

Ferrous iron (Fe^{2+}), sulfide (S^{2-}), and dissolved silica (SiO_2) concentration, as well as alkalinity, were measured immediately after sampling to minimize oxidation and precipitation processes. Fluid aliquots were filtered through 0.22 µm membranes.

Iron (Fe^{2+}) concentration was determined colorimetrically using the Hach test kit based on the ferrozine method, in which Fe^{2+} forms a complex with ferrozine, which was then measured using the Hach DR1900 portable spectrophotometer. Concentrations were calculated from a calibration curve prepared with $FeSO_4$ standards. Sulfide (S^{2-}) was quantified using the methylene blue method, also implemented in the Hach field kit. Sulfide reacts to form methylene blue, which is measured spectrophotometrically. Dissolved silica (SiO_2) was measured using the Hanna silica test kit and quantified using the Hanna field spectrophotometer. Total alkalinity was determined with the Hanna alkalinity test kit by acid titration to a colorimetric endpoint, providing results expressed as mg/L $CaCO_3$.

All measurements were performed on site immediately after filtration to ensure accuracy and to prevent the chemical alteration of the samples.

Biological samples acquisition

Sediments and fluid samples were collected aseptically for molecular analysis, with a sampling approach described in Fullerton et al. (Fullerton et al., 2021). We filtered about 4 L of seeping fluid in 3 replicated 0.22 µm polysulfonate Sterivex filter cartridges (Millipore Sigma), to collect enough biomass for DNA extraction from geothermal fluids. Filtration was achieved using a 3D-printed custom designed peristaltic pump (https://github.com/giovannellilab/Field_3D-printed_peristaltic_pump) connected to a battery powered portable drill. Sediments and background solid were collected in sterile 50 ml conical tubes. Sediments, background and filters were immediately frozen. Fluids were also collected in 2 ml cryovial preserved in 3% paraformaldehyde for cell counts. Glass vials (120 ml) were filled with biofilms and fluids for culturing and isolation purposes.

Sites and samples log

Details on the sampling locations and the measured environmental parameters are reported in Table 1 and Figure 2. The description of each sampled location follows together with pictures useful for future identification of the site.

Site 1 - Kleifarvatn, KF230826 (63.9082429 °N, −21.9950715 °E)

The first site of this expedition is located on the Reykjanes Peninsula (Figure 3), specifically in Lake Kleifarvatn located at 138 meters above sea level (masl), which is surrounded by volcanic features of both Holocene and Upper Pleistocene ages. These predominant features include hyaloclastites, pillow lavas, and other post-glacial lavas. To reach the site, one must leave the Krýsuvíkurvegur road and travel approximately two kilometres on an unpaved road. Upon reaching the destination point, it is necessary to park and walk towards the beach for a distance of 200 meters. The site of interest is submerged at a depth between 80 centimetres and 2 meters below the water surface and located 70 metres from the shoreline. The area of interest extends parallel to the beach for approximately 200 metres. Notably, the area exhibits two main underwater depressions from which a substantial amount of gas is emitted, along with numerous small emission points scattered all around. A faint sulphur smell can be detected in the air. A whitish encrusted mat is present in the area. The water at the emission points reaches a temperature of 66°C and has a pH of 5.9.

Site 2 - Krýsuvík, KR230828 (63.8954748 °N, −22.0570171 °E)

This site is located in the high-temperature geothermal area called Krýsuvik on the Reykjanes Peninsula (Figure 4). Specifically, Seltún is a small area where geothermal activity is very intense located at 170 masl. The site is dotted with pools of mud, fumaroles and hot springs with temperatures reaching boiling point, and there is a moderate risk of burns. As it is a tourist site, there are well-maintained wooden walkways around the springs providing easy access. We sampled a hot spring near the boardwalk with fine suspended sediment. The main emission point measured 78°C and had an acidic pH of 2.10.

Site 3 - Gunnuhver, GN230828 (63.8194083 °N, −22.6846433 °E)

The southernmost point we sampled on the Reykjanes Peninsula is the tourist site known as Gunnuhver (Figure 5). Here, a wooden walkway for tourists facilitates access to the area. The site was characterised by pools of mud, fumaroles and hot springs with temperatures reaching boiling point located at an altitude of 17 masl. The sites of interest are a bit far from the walkways (30–40 m). We identified several mud pools approximately 20 meters from the tourist boardwalk and chose to sample the one most suitable for our purposes, without risking the safety of our team. The temperature at the emission point measured 72°C with a pH of 2.14.

Site 4 - Reykjadalur, RJ230829 (64.0289940 °N, −21.1996159 °E)

The site RJ230829 is located at an altitude of 128 masl and is situated at approximately 1 kilometer from the Parking de Reykjadalur (Figure 6). It is situated within the Reykjadalur area, which translates to ‘Valley of Steam’ in Icelandic. Along the path to the site, there are several points of steam emission. To reach the site, one must traverse a small

Table 1. Location and principal physico-chemical characteristics of the sampled sites. NA - Fluid flux not available. No flow - no visible flow of fluids from the source visible for measurements.

Collection ID	Site name	Sampling date	Latitude (°N)	Longitude (°E)	Elevation (m)	Temp (°C)	pH	Fluid flux (L/s)	SPC (mS/cm)	ORP (mV)	DOsat (%)	DO (ppm)	TDS (ppm)	Sal (%)	TA (ppm)	Sulfide (ppb)	Fe^{2+} (ppb)
KF_230826	Kleifarvatn	2023-08-26	63.9082429	−21.9950715	138	66	5.9	NA	0.955	−44.1	21.8	1.99	480	0.05	36	NA	NA
KR_230828	Krýsuvik	2023-08-28	63.8954748	−22-0570171	170	78	2.1	no flow	12.08	6.6	22	1.11	6,000	0.66	0	11,700	2,950
GN_230828	Gunnuhver	2023-08-28	63.8194083	−22.6846433	17	72	2.14	no flow	13.98	34	10.7	0.58	6,992	0.78	0	0	4,060
RJ_230829	Reykjadalur	2023-08-29	64.028994	−21.1996159	128	69.5	6.98	0.15	0.86	2.8	52.3	2.85	430	0.04	126	6	0
LH_230829	Laugarás	2023-08-29	64.1129167	−20.4958392	59	80	9.38	17.4	0.81	−2.6	29.4	1.57	408	0.04	150	169	39
LM_230830	Landmannalaugar	2023-08-30	63.9915483	−19.0627467	597	60	6.18	406	1.09	10.5	14.9	0.73	545	0.05	255	131	1,890
SV_230831	Seljavallalaug	2023-08-31	63.5661483	−19.6079383	76	57.5	7.75	0.24	1.96	14.3	34.3	2	979	0.10	270	0	34
HS_230901	Hvammsvík	2023-09-01	63.5661483	−19.6079383	25	91.3	8.93	16.75	1.09	−22.2	7.1	0.4	544	0.05	78	1,810	42
ES_230901	Englandshverir	2023-09-01	64.4905648	−21.179099	178	78	9.17	7	0.62	−3.1	37.8	2.03	314	0.02	114	382	28
AH_230901	Árhver	2023-09-01	64.6584216	−21.3639612	29	57	9.16	NA	0.46	2.6	97.6	7.13	232	0.02	75	420	343
BB_230902	Borgarbyggð	2023-09-02	64.6883977	−21.4028918	41	99.8	9.2	18	0.80	−0.3	12	0.64	401	0.04	109	1,970	221
RD_230902	Rauðamelsölkelda	2023-09-02	64.8956115	−22.3388239	107	10.53	4.53	no flow	0.18	13.6	45.4	4.7	90	0.01	27	0	178
RS_230903	Reykjaskóli	2023-09-03	65.2577603	−21.100458	19	86.9	9.12	5	2.86	10.3	60.4	3.44	1430	0.14	36	47	930
RH_230904	Reykhóar	2023-09-04	65.4456505	−22.2064709	12	82	9.4	NA	0.53	2.1	58.8	3.51	268	0.03	96	0	117
DS_230904	Drangsnevegur	2023-09-04	65.6479000	−21.6429000	11	79.6	8.99	2.1	0.964	5.3	38.6	2.29	482	0.046	63	350	0
HL_230905	Hellalaugur	2023-09-05	65.5776628	−23.1597213	10	39.5	9.99	4.8	0.261	−3.6	54	3.55	130	0.012	73.5	0	20
GL_230905	Gamla Laugin	2023-09-05	65.9290867	−22.428785	6	84.4	8.19	NA	6.365	14.7	49.3	3.21	3182	0.34	30	9	590
FL_230906	Fosslaug	2023-09-06	65.4941967	−19.3836483	49	68.5	10	NA	0.618	−0.8	53.6	3.39	309	0.029	132	64	10
SC_230907	Strýtan vent cone	2023-09-07	65.828852	−18.111779	−23.5	72	9.5	NA	33.28	12.6	59.4	4.98	16.64	2.092	189	166	12
LG_230907	Laugar	2023-09-07	65.7225747	−17.3505889	163	53.5	10.4	0.4	0.511	21.7	96.6	5.66	256	0.024	159	0	15
LL_230908	Lón lake	2023-09-08	66.1020433	−16.9077	5	10.77	8.26	NA	0.231	8.2	126.9	13.43	116	0.011	72	19	76
MH_230908	Mývatn Námaskarð Hverir	2023-09-08	65.6415088	−16.8090939	369	85	NA	no flow	NA	NA	NA	NA	NA	NA	NA	0	NA
SL_230909	Selárdals laug	2023-09-09	65.8023317	−14.9095317	63	53	10.12	4	0.378	−5.2	0	0	189	0.017	109.5	43	0
AJ_230909	Ærlækjarsel	2023-09-09	66.1652014	−16.5584453	6	88	7.77	no flow	11.26	25	30.5	1.85	5629	0.624	42	0	23
GJ_230910	Grjótagjá	2023-09-10	65.6264991	−16.882801	302	48.7	8.2	no flow	0.831	17	1.5	0.08	415	0.039	105	21	58
VD_230911	Vaðlaheiðargöng	2023-09-11	65.6942367	−18.0543738	72	47.7	9.87	NA	0.392	−5.3	108.5	6.13	196	0.018	153	0	26
LS_230912	Laugafell South	2023-09-12	64.9271304	−18.282252	765	31	10.08	NA	0.24	−8.9	25.7	1.69	120	0.011	79.5	6	7
TH_230912	Þuríðarhver (Thuridahver)	2023-09-12	65.0302351	−18.3305599	757	43.2	10.03	NA	0.243	−11.9	26.7	1.41	121	0.011	100.5	0	0
SJ_230913	Sesseljubær	2023-09-13	65.1127117	−18.431581	648	10.3	9.65	NA	0.052	15.7	74.9	8.35	26	0.002	90	10	14
LK_230913	Laugakvísl	2023-09-13	65.024425	−18.3319267	724	40.3	9.67	NA	0.12	1.8	44	2.65	60	0.005	36	0	5

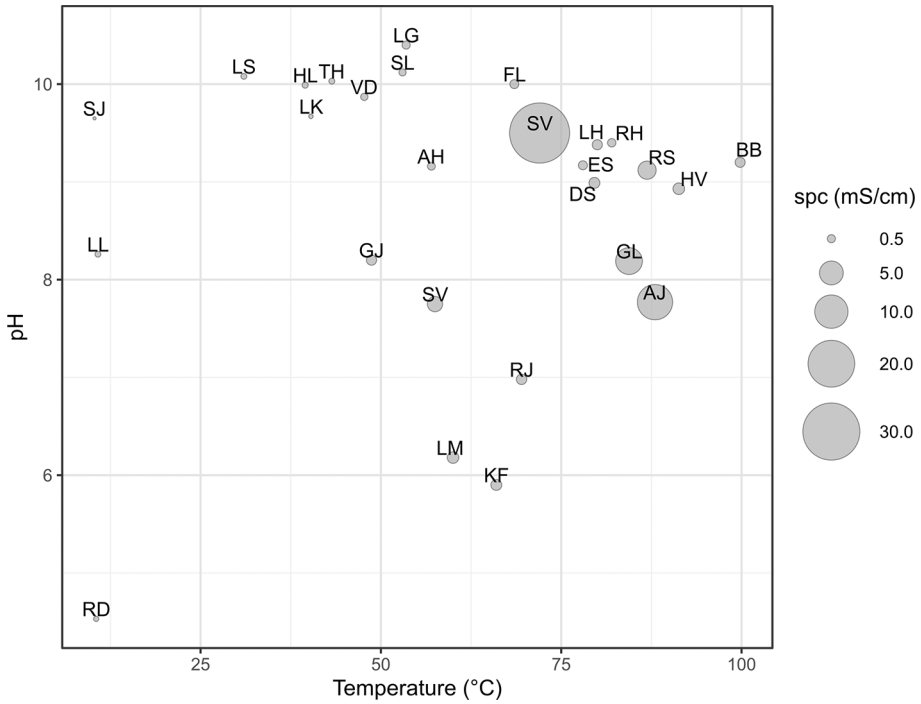

Figure 2. Graph showing the range of temperature (°C), pH, and specific conductivity (spc, mS/cm) of the sampled locations.

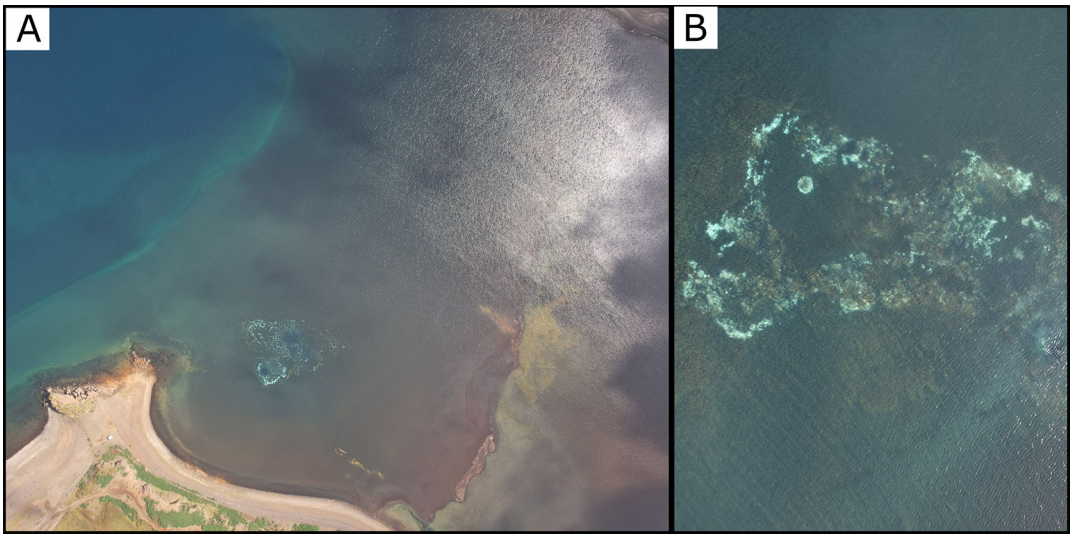

Figure 3. Aerial view (A) and close up (B) of the sampled location KF230826. Fluids, sediments and biofilms were sampled by scuba divers. Drone and underwater photograph taken by author RP for this publication.

glacially-formed valley with a small river running through it. By following the river in a northeast direction for approximately 700 meters and then moving away from the riverbed to the north, one arrives at Site 4 of this expedition. The soil in this area is rich in water content, and at the emission points, pools are formed where temperature measurements have recorded a maximum of 69.5°C with a pH of 6.98 and a flow rate of 0.15 L/s. This is evident in the substantial presence of vegetation, including a grassy covering, and microfauna such as insects and birds. Furthermore, grazing animals are allowed to pasture near the river.

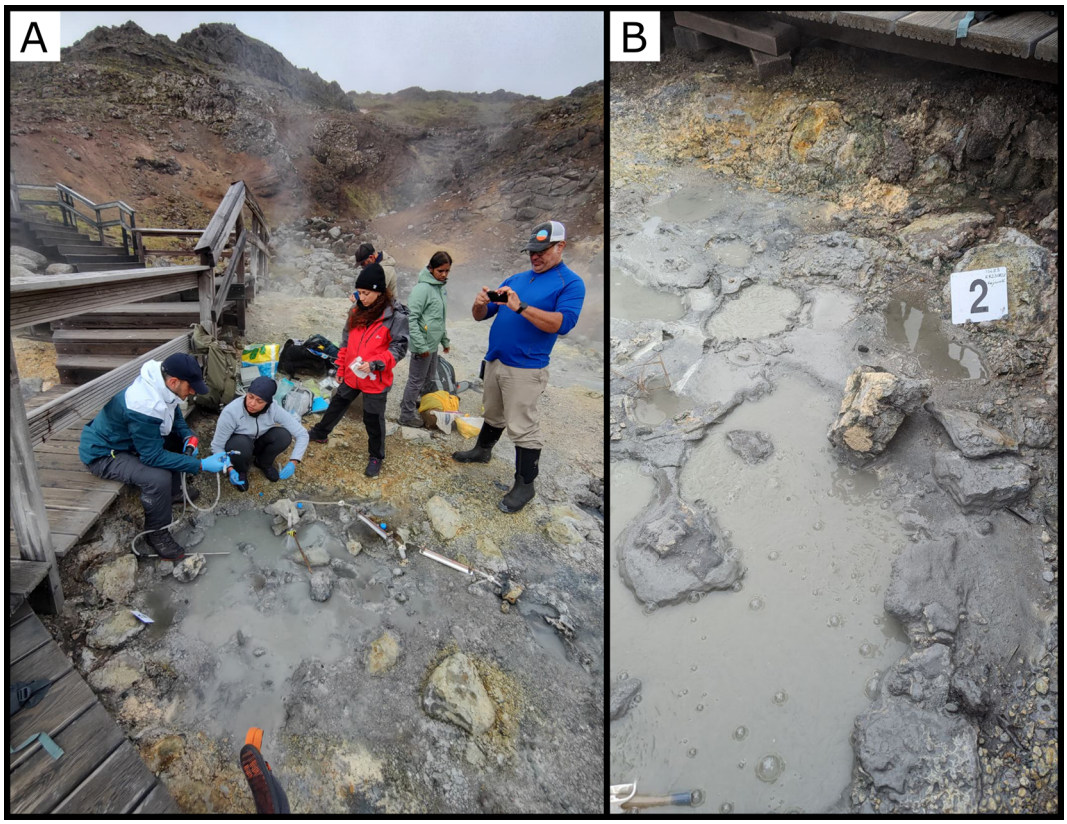

Figure 4. (A) Overview of Site 2 during sampling. (B) Ground-level view of the mud spring next to the boardwalk. Photograph taken by author FM and DG for this publication.

Site 5 Laugarás, LH230829 (64.1129167 °N, −20.4958392 °E)

The Laugarás site is easily accessible, situated near the Hvítá River (Figure 7). We departed from the main road, Skálholtsvegur, and continued for an additional 200 meters by vehicle. From there, it is only a short walk of a few minutes to reach this grass plain rich in gas emissions (Figure A) at an altitude of 59 masl. It stretches for approximately 1 kilometer in length and it is about 100 meters wide. Walking from north to south while keeping to the left for 400 meters, one arrives at an artificial pool measuring 1x1.5 meters (Figure C). From this structure, there is a hot emission with a temperature of 80°C, pH of 9.38 and a flow rate of 17.4 L/s. Surrounding this site, there are additional points of fluid and gas emissions.

Site 6 Landmannalaugar, LM230830 (63.9915483 °N, −19.0627467 °E)

The Fjallabak Nature Reserve represents the location of the sixth site (https://nat.is/fjallabak-nature-reserve/) (Figure 8). The area is not particularly hazardous, as evidenced by the presence of numerous tourists in the pools. In close proximity to the site, there are several hot springs with temperatures ranging between 40 and 60 degrees Celsius. Our emission point is at an altitude of 597 masl and located approximately 200 meters south of the bathing area frequented by tourists. The spring measured approximately 60°C and had a pH level of 6.18. A few meters away, measurements were taken for both water flow (406 L/s) and gas emissions (605 L/s). The site featured a multilayered microbial mat of various colors.

Site 7 Seljavallalaug, SV230831 (63.5661483 °N, −19.6079383 °E)

Seljavallalaug is a protected outdoor pool in southern Iceland located at an altitude of 76 masl, fed by a natural hot spring (Figure 9). We moved from the main road and traversed 4 kilometers within one of the glacial valleys that characterize the area. Inside the valley, there is a river that flows right by the pool. The main spring inlet was located right above the pool on top of a carbonate structure, which had a water flow of 0.24 L/s and a multicolored mucilaginous microbial mat. The water temperature measured 57.5°C with a pH of 7.75.

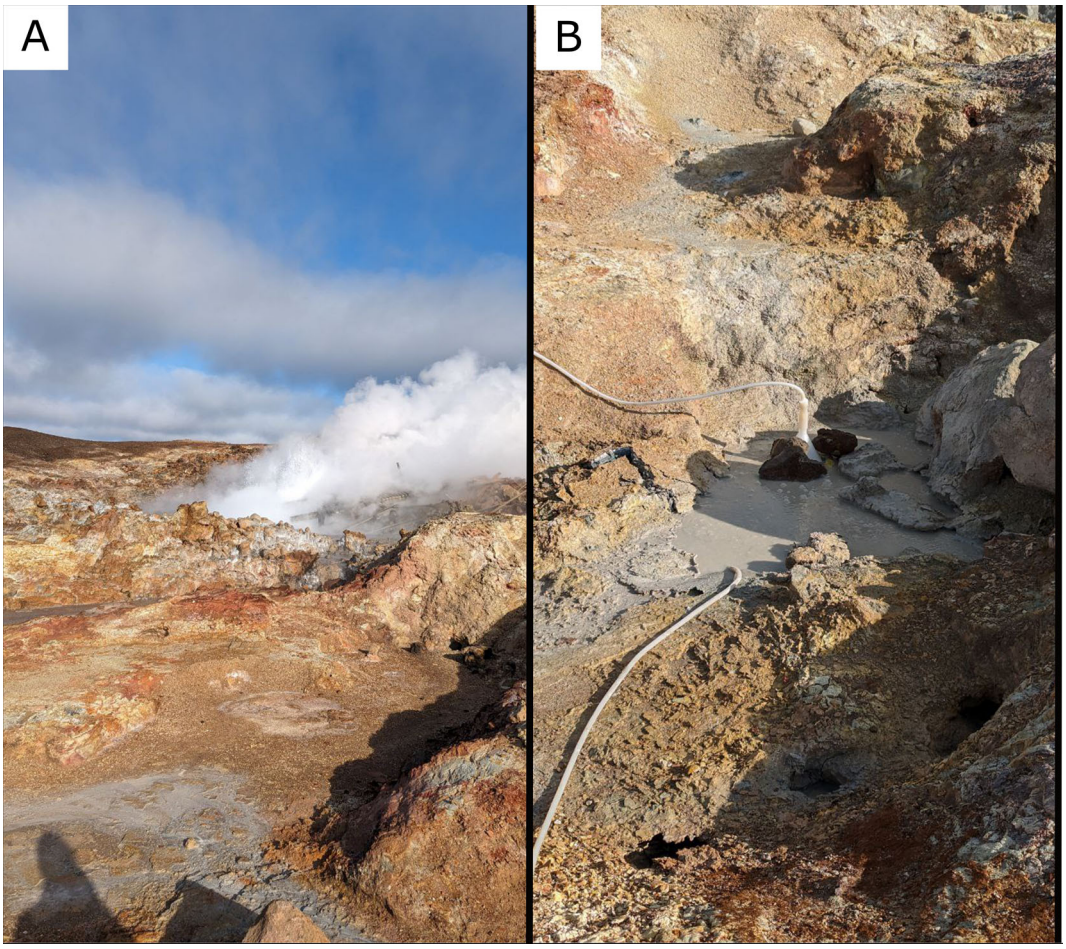

Figure 5. (A) Overview of the geothermal field with a steam plume. (B) Close-up of the selected mud pool. Photograph taken by author FM for this publication.



Figure 6. (A) Overview of Site 4 with a muddy geothermal pool during sampling. (B) Close-up of the sampled pool with silicone and titanium tube to recover the fluids. Photograph taken by author FM for this publication.

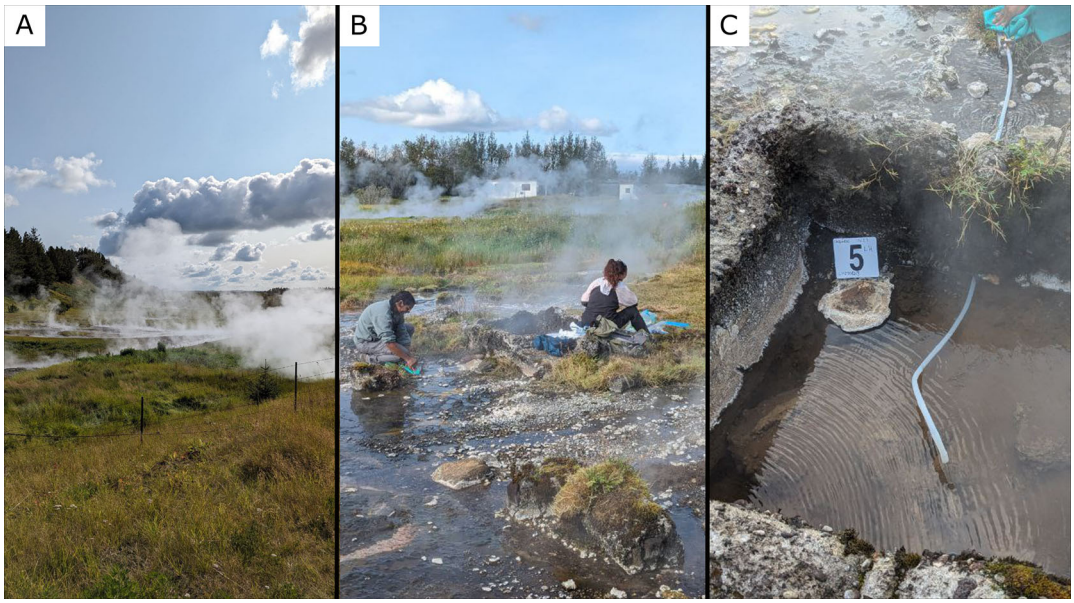

Figure 7. (**A) Large view of the area of the sampling site. (B) We sampled an artificial pool measuring 1x1.5 meters (C) Detail of the sampling location where the fluids were collected.** Photograph taken by author FM for this publication.

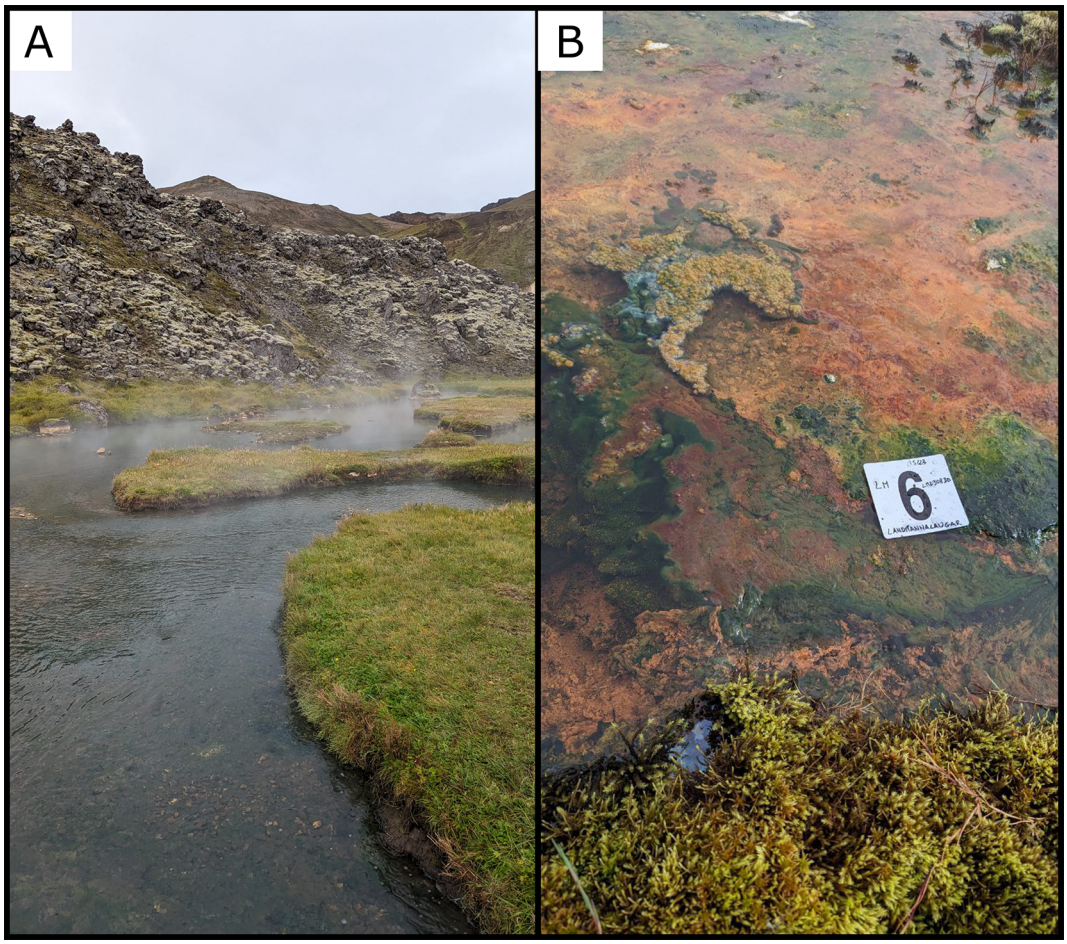

Figure 8. (A) An overview of the site (B) Microbial mats at the sampling site showing orange and green coloration. Photograph taken by author FM for this publication.

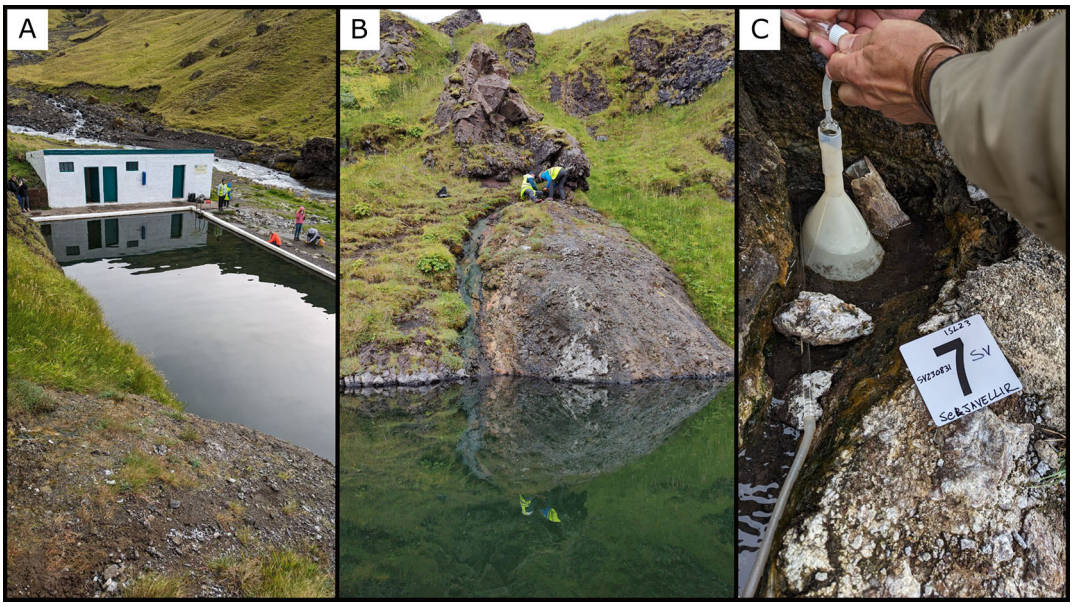

Figure 9. (A) Seljavallalaug pool is 10 meters (30 feet) in width and 25 meters (82 feet) in length. (B) The emission point that we sampled was above the pool on top of a carbonate structure. (C) Close up of the emission point.

Site 8 Hvammsvík, HS230901 (64.3742033 °N, −21.5658497 °E)

This site is an artificial well utilized for heating nearby buildings of a geothermal bathing facility (https://guidetoiceland.is/travel-iceland/drive/hvammsvik-hot-springs) (Figure 10). It is located at an altitude of 25 masl on a side of the fjord Hvalfjörður on the western side of Iceland. Along its coast, situated 200 meters from the sea there is the site HS230901. We connected our silicone tube with connectors to the well, and we collected our water sample. No sediment samples were collected for this site. The water from this well had a flow rate of 16.75 L/s, a temperature of 91.3°C, and a pH of 8.93.

Site 9 Englandshverir, ES230901 (64.4905648 °N, −21.179099 °E)

This site was located at an altitude of 178 masl and approximately 240 meters from the structure that we used as a bridge at the coordinates 64.492778 °N, −21.176364 °E, along a small river (Figure 11). We sampled one of the emission points, which had a temperature of 78°C and a pH of 9.17. The water flow of the river near the emission point was 7 L/s, and the area was rich in this reddish-orange mucilaginous microbial mat.

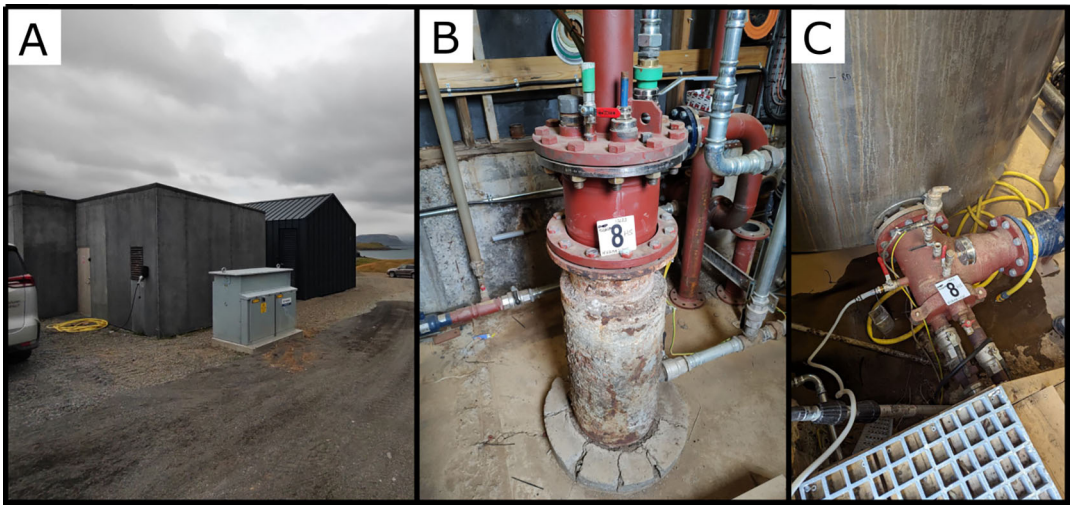

Figure 10. (A) An overview of the site (B) The artificial well used for heating nearby buildings (C) A closeup of the emission point sampled. Photograph taken by author FM and DG for this publication.

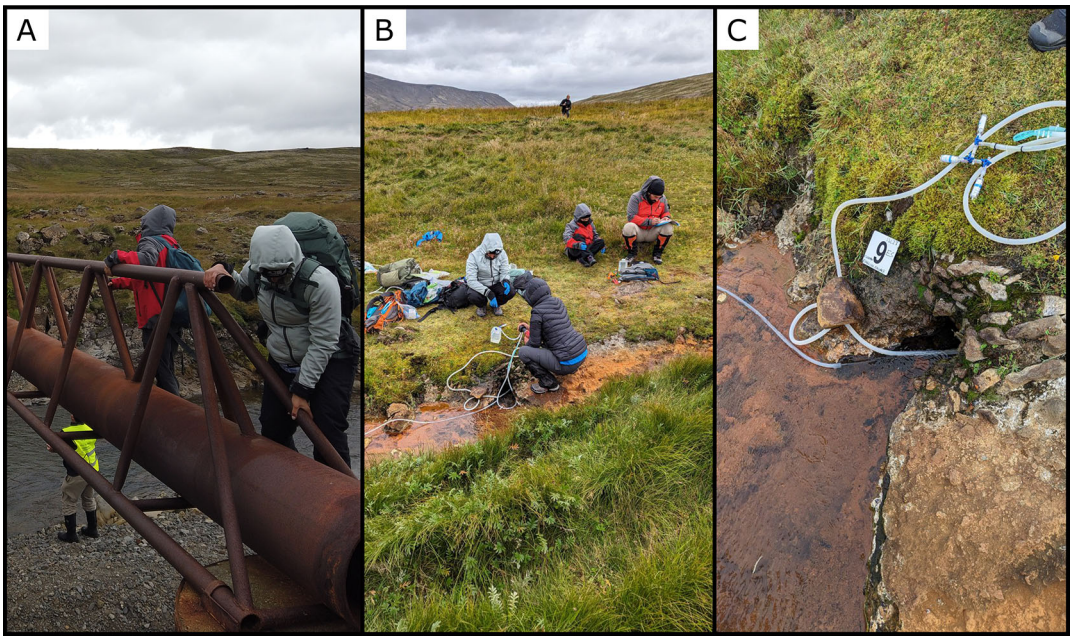

Figure 11. (A) The structure used as a bridge to cross the river (B) An overview of the site (C) A closeup of the emission point, we used a titanium tube to go how deep it was possible. Photograph taken by author FM and JP for this publication.

Site 10 Árhver, AH230901 (64.6584216 °N,-21.3639612 °E)

Árhver is a spring located in the middle of a river (a tributary of the Hvítá River) at an altitude of 29 masl (Figure 12). The car can be parked 50 meters away from the spring, and it can be reached by crossing sand bars and shallow water areas. The spring consists of a large emission point with water temperatures around 100°C and significant gas discharge. Additionally, both near the main crater and along the river, there are several smaller emission points where hot water emerges at varying temperatures. To avoid being struck by sudden jets of boiling water, we chose not to work on the main crater and instead moved a few meters away to one of the smaller emission points. The water temperature at this location was 57°C, and the pH was 9.16.

Site 11 Borgarbyggð, BB230902 (64.6883977 °N, −21.4028918 °E)

This site is located on private property at an altitude of 41 masl and 450 meters from the Hvítá River (Figure 13). A few meters from an old building (Figure A), there was an emission point of water and gas at an altitude of 41 masl. The water had a temperature of 99.8°C with a pH of 9.20. The area was water-rich, and there were multiple emission points. We selected a point with a flow rate of 18 L/s.

Site 12 Rauðamelsölkelda, RD230902 (64.8956115 °N, −22.3388239 °E)

Rauðamelsölkelda is a spring located at an altitude of 107 meters asl. After crossing a small bridge, we found the spring among the rocks in a pool approximately 1 x 2 meters in size (Figure 14). The water temperature was 10.5°C and pH 4.53, and there were gas emissions with a flow rate of 3.5 L/s.

Site 13 Reykjaskóli, RS230903 (65.2577603 °N, −21.1004580 °E)

The site RS230903 is located at an altitude of 19 masl in an area with water-rich soil, near the Barnaskólavegur towards Reykir road, close to some houses at an altitude of 19 masl (Figure 15). There is a concrete pool measuring 2 x 3 meters, with gas emissions at multiple points, and a water temperature of 86.9°C and the pH was 8.12. The water flow rate was 5 L/s. We sampled the water and the sediment at the bottom of the pool.

Site 14 Reykhólar, RH230904 (65.4456505 °N, −22.2064709 °E)

In the fjord area in the northwest of Iceland, there is a small village named Reykhólar, which is 12 meters above sea level (Figure 16). Here, we found a hot water spring on the property of a local resident. The spring consisted of a series of small outlets emerging on the side of a small creek running through the property. The sampled outlet had a fluid temperature of 82°C with a pH of 9.4 and was surrounded by bright green and orange microbial mats and precipitated calcite. Free gas was sampled a few meters away from the point where we sampled the fluids.

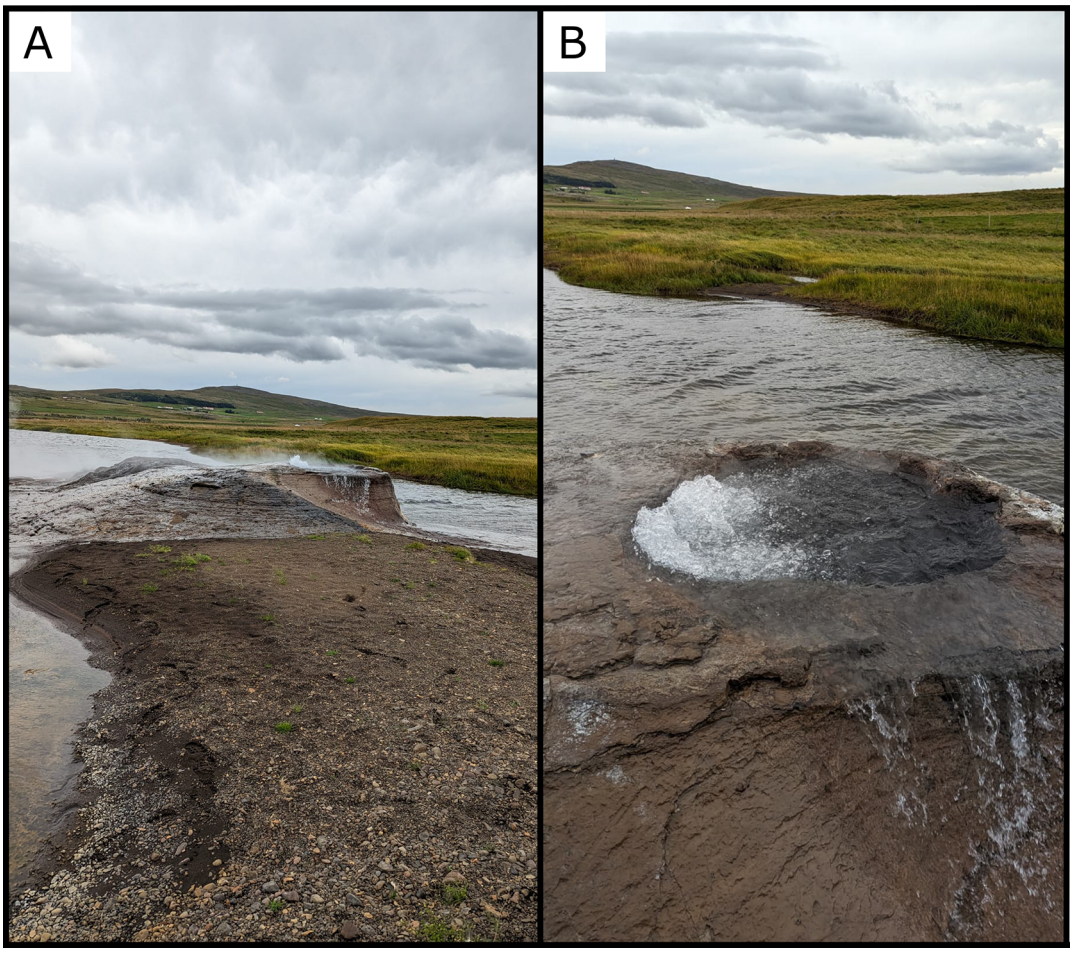

Figure 12. (A) Overview of the geothermal mound emerging from the riverbed. (B) Close-up view of the boiling vent opening. Photograph taken by author FM for this publication.

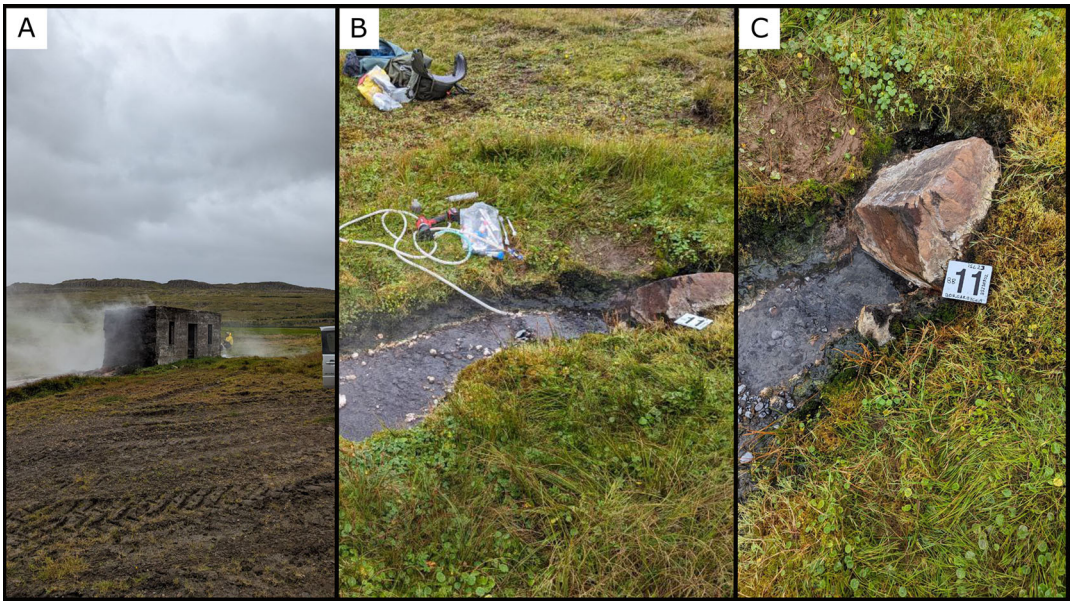

Figure 13. (A) An old building on private property close to the site. (B) An overview of the sampled site (C) A closeup of the emission point sampled. Photograph taken by author FM for this publication.



Figure 14. (A) Overview of the sampling activity at the spring of Rauðamelsölkelda. (B) Close-up view of the bubbling pool where water was collected. Photograph taken by author FM for this publication.

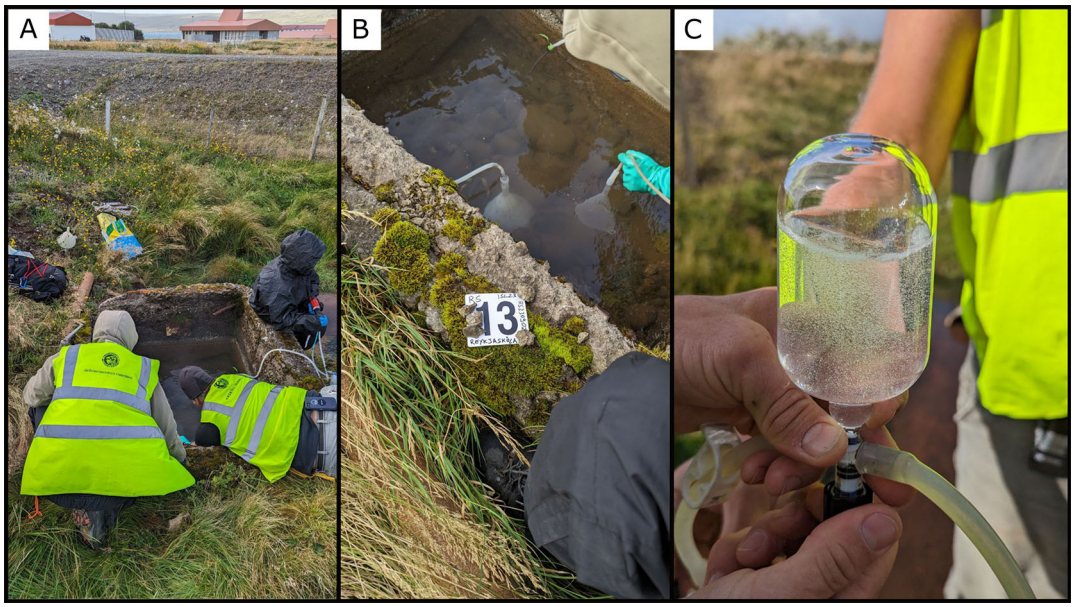

Figure 15. (A) Overview of the artificial basin used for water sampling. (B) Close-up view of the tubing system and collection setup. (C) Water sample collected in a giggenbach bottle for gas analysis. Photograph taken by author FM for this publication.

Site 15 Drangsnesvegur, DS230904 (65.698493 °N, −21.559922 °E)

At 2 meters above sea level, near Drangsnesvegur road, we sampled our fifteenth site. This location was historically utilized by humans, as evidenced by the small artificial pool (Figure A) just above the sea (Figure 17). Along the coast near the pool, there are several points where high-temperature water emerges. The point we sampled (Figure B) had a temperature of 79.6°C, a pH of 8.99, and a flow rate of 2.1 L/s. The site was characterised by very large and thick multicoloured microbial mats. Photograph taken by author FM for this publication.

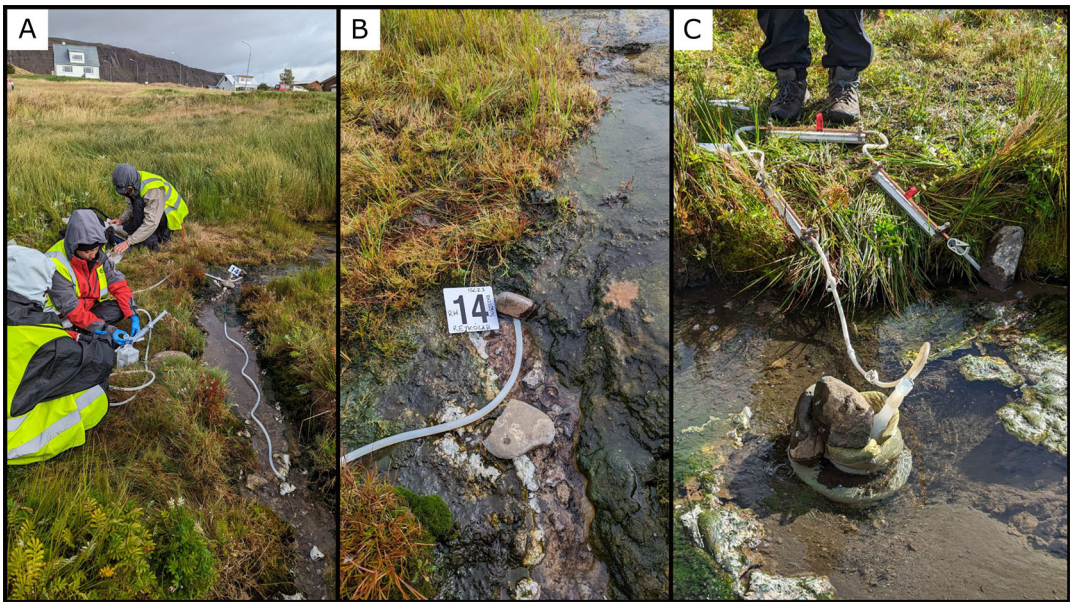

Figure 16. (A) Collecting water samples using silicon tubes, syringes, and a peristaltic pump. (B) and (C) Close-up views of the small geothermal stream and the tubing system used for water collection. Photograph taken by author FM for this publication.

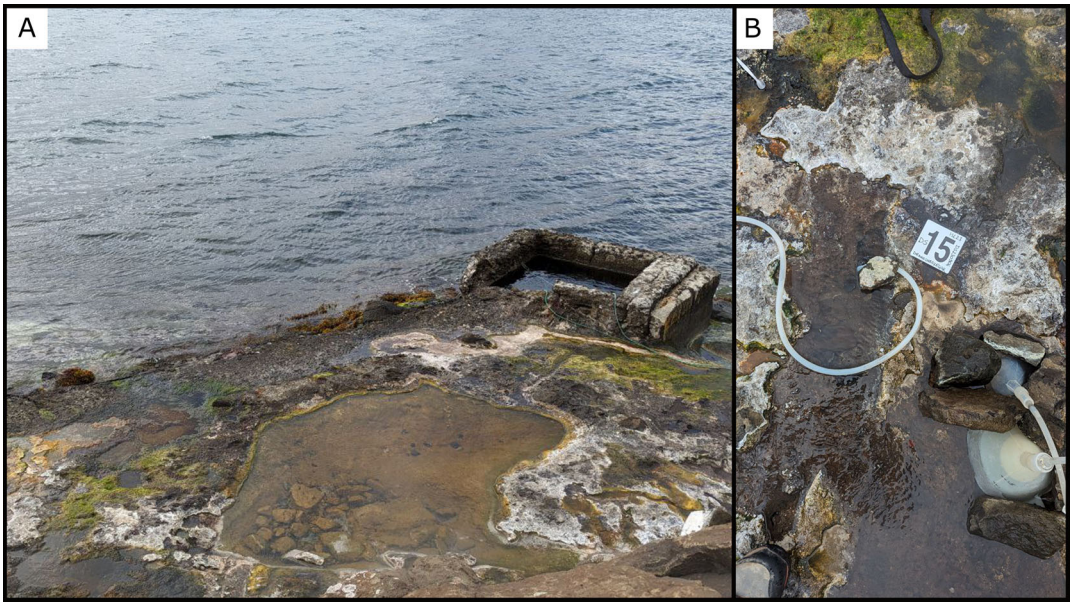

Figure 17. (A) Overview of the coastal geothermal pool adjacent to the shoreline. B) Close-up view of the sampling setup used to collect water from the outflow area.

Site 16 Hellulaug, HL230905 (65.5776628 °N, −23.1597213 °E)

Hellulaug is located in the northwest region of Iceland, a natural hot spring pool near the village of Flókalundur (Figure 18). The pool is located in one of the fjords of the area and is measuring approximately 4 x 3 meters, and about 20 to 30 inches deep. The site has an altitude of 5 masl, just a few meters from the sea. The water temperature is 39.5°C, and the pH is 9.99. At the point where the water flows from the pool to the sea, we measured a flow rate of 4.8 L/s.

Site 17 Gamla Laugin Reykjanes, GL230905 (65.9290867 °N, −22.4287850 °E)

The site GL230905 is located at an altitude of 6 masl and in the inner part of the Ísafjarðardjúp fjord in northwestern Iceland (Figure 19). Its accessibility depends on the tidal cycle. When the water recedes, it leaves exposed pools and



Figure 18. (A) Overview of the small geothermal pool where water was collected through tubing connected to the lateral outflow. Photograph taken by author FM for this publication.

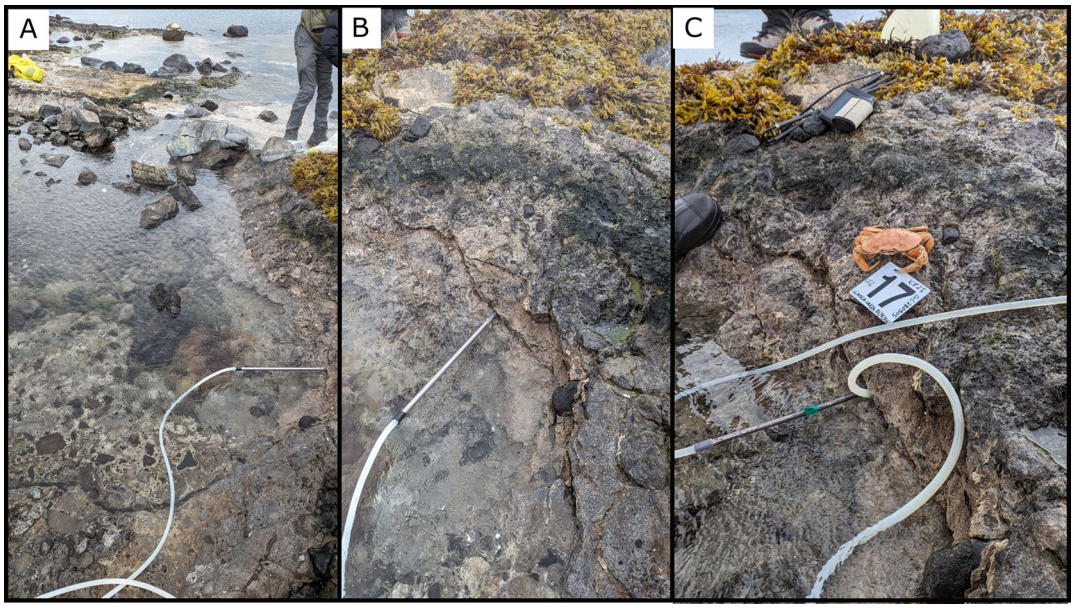

Figure 19. (A) Overview of the coastal sampling area. (B) and (C) Close-up views showing the tubing system used to collect water directly from the outflow cracks. Photograph taken by author FM for this publication.

marine vegetation, and there are several fractures from which high-temperature water emerges (Figure A). Our site is situated among the rocks just a few meters from the sea (6 meters above sea level). In our case, we sampled an emission point with a temperature of 84.4°C and a pH of 8.19.

Site 18 Fosslaug, FL230906, (65.4941967 °N, −19.3836483 °E)

This site is located in northern Iceland at an altitude of 49 masl, near the Húseyjarkvísl River (Figure 20 A) at the Reykjafoss waterfall. There is easy parking near the site. The waterfall is a tourist site, easy to access. Just before the waterfall, there is the Fosslaug spring (Figure 20 B), which flows into a pool along the river. The spring had intermittent gas emission with an average period of 2.45 minutes, fluid temperature of 68.5°C and pH 10.

Site 19 Strýtan vent, SV230907 (65.828852 °N, −18.111779 °E)

In northern Iceland, not far from the country's second-largest town, Akureyri, there is a unique dive site: Strýtan (Figure 21). Situated in the middle of Eyjafjörður at a depth of around 70 meters, this site has been venting warm water into the ocean for approximately 11,000 years. When the mineral-rich freshwater mixes with the cold seawater, the dissolved minerals precipitate, gradually forming a towering silica chimney. Over millennia, this process has built a structure that rises 55 meters from the seafloor, reaching to within 15 meters of the surface. Thanks to the Strytan Dive Center (Strytan Divecenter), we reached the site by Zodiac boat and collected data, including the water temperature from one of the vents, which was 72°C, and the pH was 9.5.

Site 20 Laugar, LG230907 (65.7225747 °N, −17.3505889 °E)

In the Laugar area of North Iceland lies site LG230907 within a private residence, surrounded by vegetation at an altitude of 163 masl, there is a well covered by a metal plate (Figure 22). It is located on a small hill, unstable and slippery due to water and vegetation. After lifting the metal plate, we measured the water temperature (53.5°C) as close as possible to the source. The pH was 10.4 and the water flow rate was 0.4 L/s.

Site 21 Lón Lake, LL230908 (66.1020433 °N, −16.9077000 °E)

In the northern part of the island at an altitude of 5 masl, 3 km from the Arctic Ocean, there is Lake Lón (Figure 23). Near a fish farm, just a few meters from one of the lake's shores, there is the site LL230908. The water temperature was low, 10.77°C and pH 8.26.

Site 22 Mývatn Námaskarð Hverir, MH230908 (65.6415088 °N, −16.8090939 °E)

The twenty-second site is located in the tourist area of Námaskarð Hverir, near Lake Mývatn at an altitude of 369 masl (Figure 24). In this area there are many mud pools, some reaching boiling temperature. There are also several gas emission



Figure 20. (A) Overview of the river system where sampling was conducted. (B) and (C) Close-up views of the field setup and tubing used for water collection. Photograph taken by author FM for this publication.

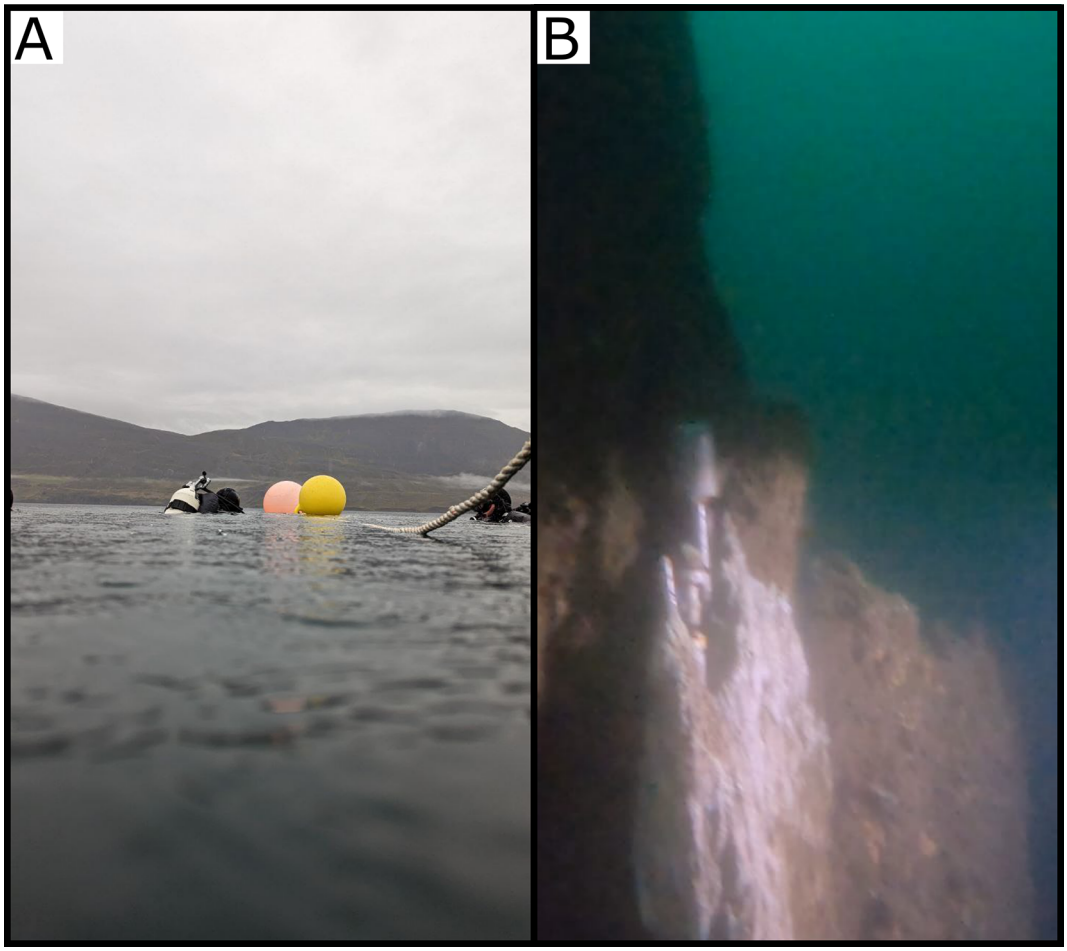

Figure 21. (A) Overview of the diving operation conducted at the hydrothermal field, showing the sampling area marked by buoys. (B) A close-up of one of the venting sites at Strýtan. Photograph taken by author FM and DG for this publication.

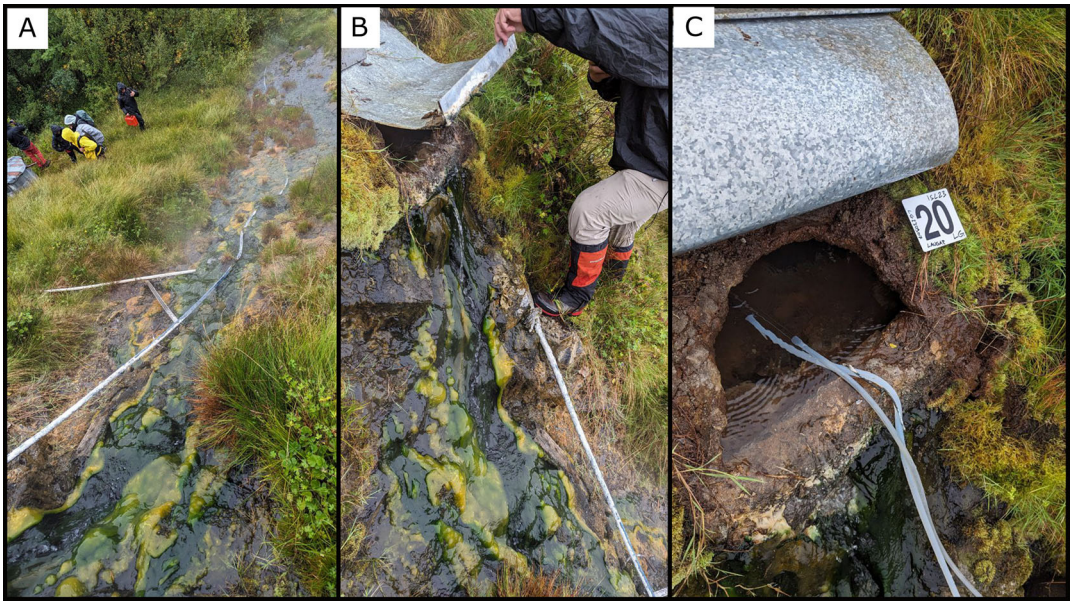

Figure 22. (A) Overview of the geothermal outflow covered by microbial mats. (B) and (C) Close-up views of the water collection setup near the outlet pipe. Photograph taken by author FM for this publication.

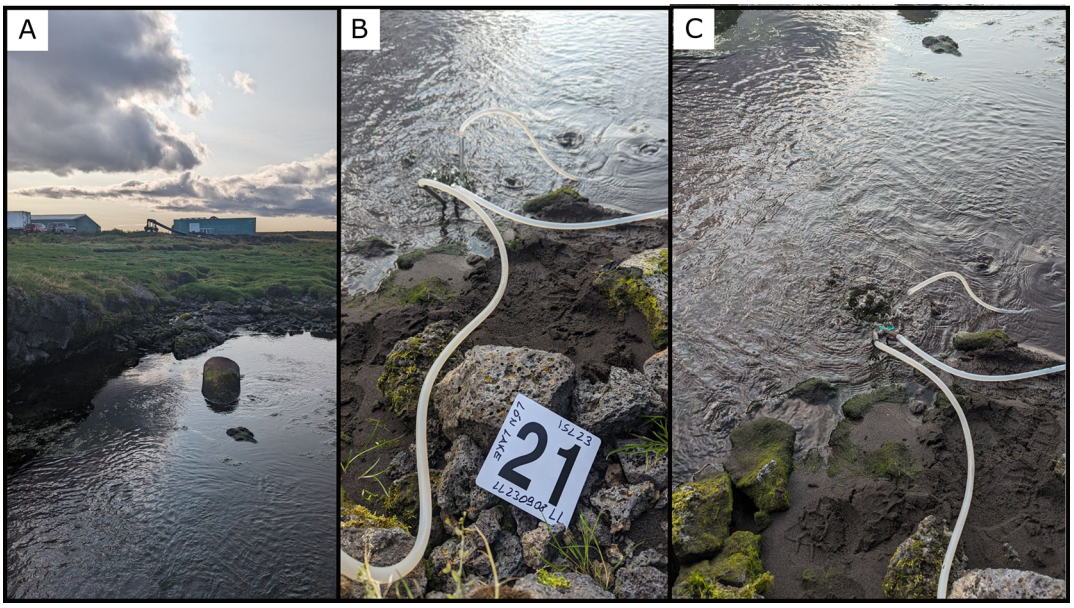

Figure 23. (A) Overview of the pond where sampling was conducted. (B) and (C) Close-up views of the tubing system used for water collection from the outflow area. Photograph taken by author FM for this publication.

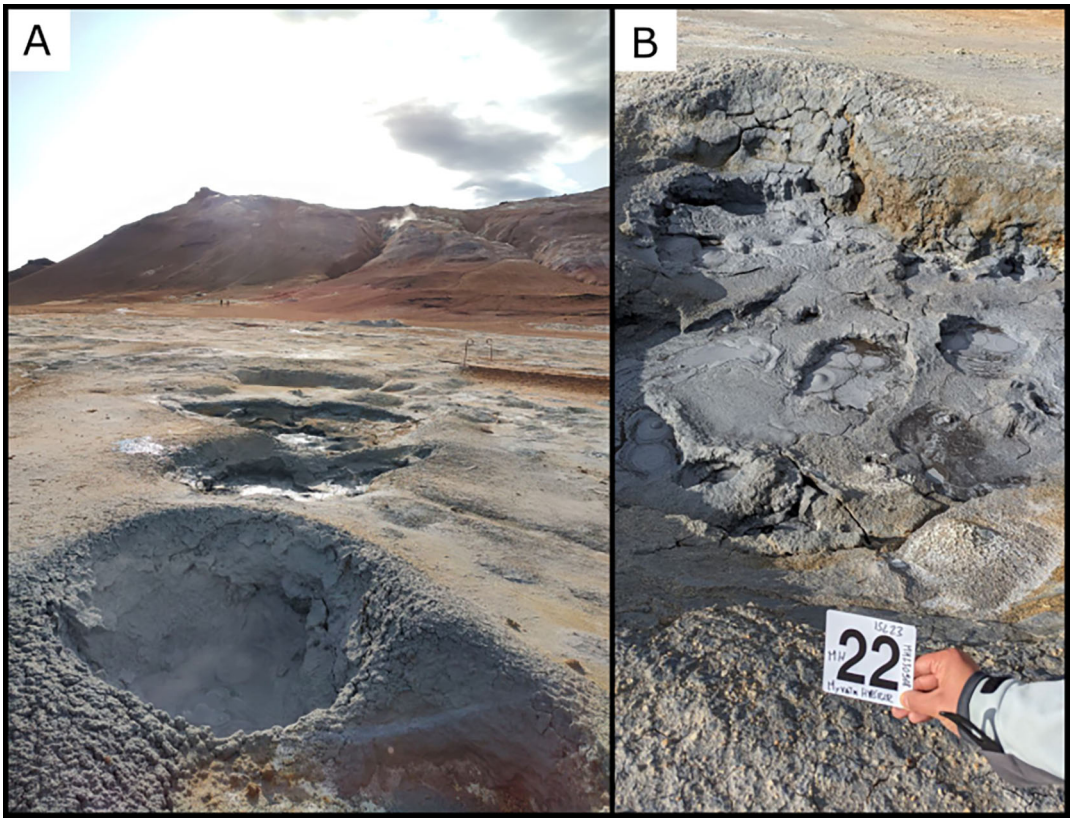

Figure 24. (A) Overview of the mud pool sampled, showing active geothermal activity and gas bubbling. Photograph taken by author FM for this publication.

points. In one of these pools, we collected samples for geochemical analysis, and the temperature was 98.4°C. We collected microbiological samples within this same pool, and at the place where we collected the samples we measured a temperature of 84°C. In the same area, we also sampled a fumarole with a temperature of 137°C.

Site 23 Selárdalslaug, SL230909 (65.8023317 °N, −14.9095317 °E)

Along the Selá River, which flows into the Arctic Ocean in eastern Iceland, there is at an altitude of 63 masl, the site SL230909 (Figure 25). This site is a well with unknown depth, utilized by a public pool called Selárdalslaug. The well is located at a higher point than the pool, and unfortunately, the well's structure only allowed us to sample water at a temperature of 53°C and pH 10.12, while we sampled sediments further downstream near a pipe discharging water close to the river. The water flow near the well was 4 L/s.

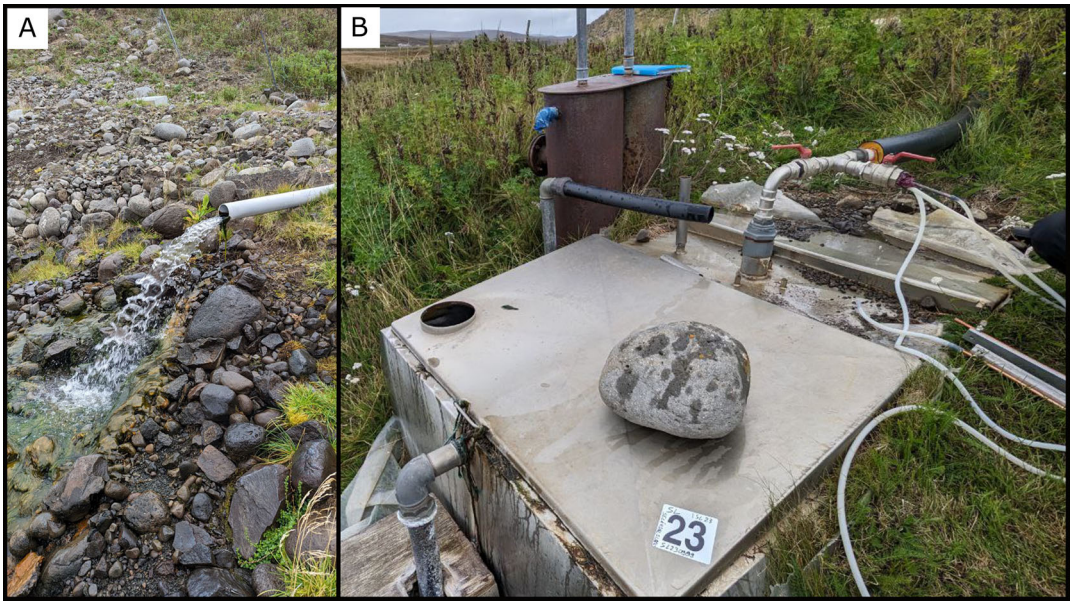

Figure 25. (A) Overview of the artificial outlet discharging geothermal water. (B) Close-up view of the sampling setup connected to the outlet tube. Photograph taken by author FM for this publication.

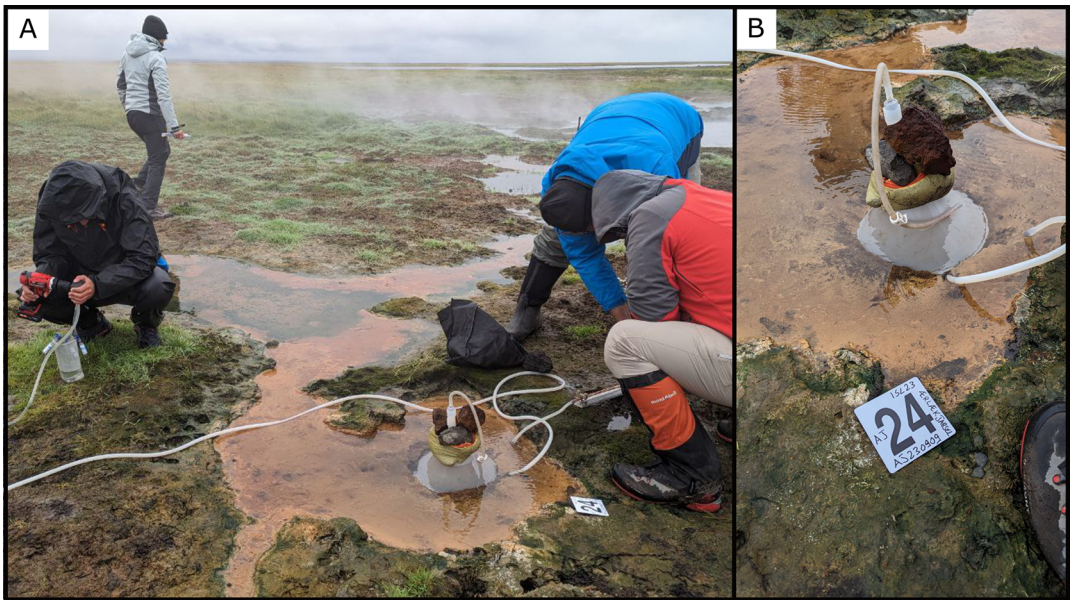

Figure 26. (A) Overview of the sampling activity, showing the geothermal outflow area. (B) Close-up view of the funnel used for sampling at the emission point. Photograph taken by author FM for this publication.

Site 24 Ærlækjarsel, AJ230909 (66.1652014 °N, −16.5584453 °E)

The site AJ230909 is located on private property in northern Iceland, at an altitude of 6 masl, 1 km from the Arctic Ocean and 2 km from the owner's residence (Figure 26). The terrain in this area was rich in water. Near a shed we found a spring at 88°C and pH 7.87 with little gas flow. Near the spring there was a thin, filamentous brown microbial mat.

Site 25 Grjótagjá, GJ230910 (65.6264991 °N, −16.8828010 °E)

Grjótagjá is a small lava cave located at an altitude of 302 masl in northern Iceland, near Lake Mývatn (Figure 27). Inside, it hides a hot spring that, for many years, was a popular natural bathing spot among Icelanders. Entering from the right entrance and keeping to the right while following the perimeter of the pool, near the surface, you can observe a flow of hot water at 48.7°C. The measured pH was 8.20.

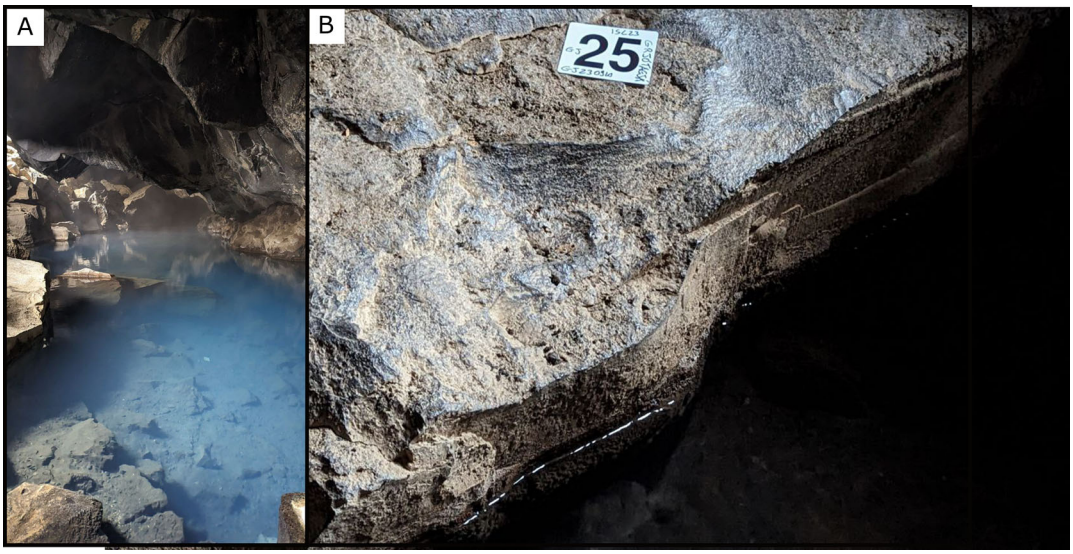

Figure 27. (A) Overview of the cave pool selected for water sampling. (B) Close-up view of the emission point. Photograph taken by author FM for this publication.

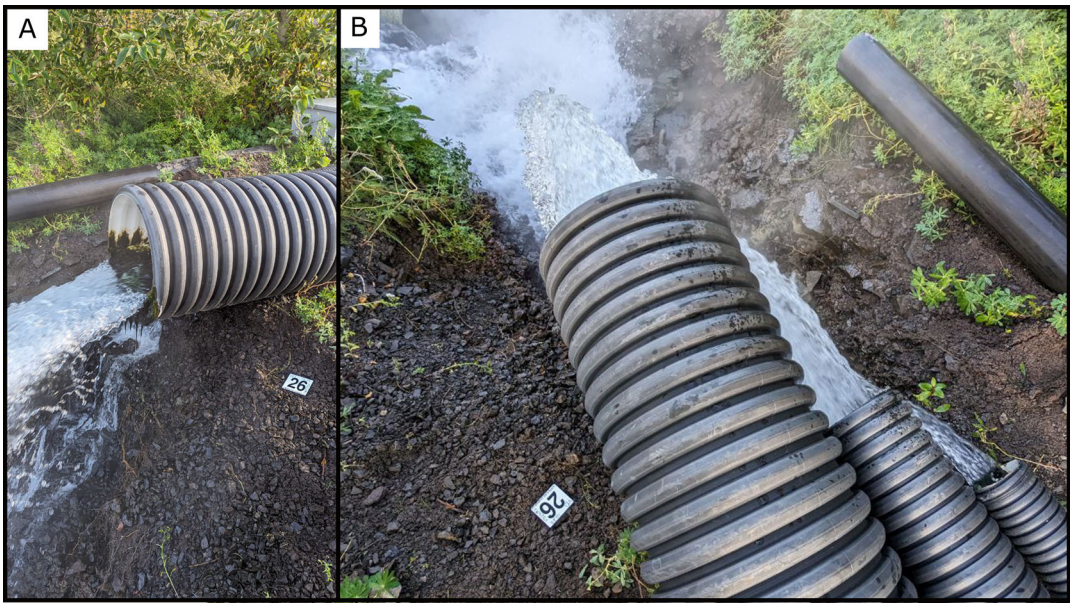

Figure 28. (A) Overview of the artificial tube selected for water sampling. (B) Close-up view of the emission point. Photograph taken by author FM for this publication.

Site 26 Vaðlaheiðargöng, VD230911 (65.6942367 °N, −18.0543738 °E)

At an altitude of 72 masl, in the Eyjafjörður fjord on the shore opposite to Akureyri, 50 meters east of the road, there are three pipes with hot water emerging from a friable soil (Figure 28). Of the three pipes, we sampled the central one with a PP bottle because the flow of the water was too strong for our tube. The water temperature was 47.7°C, and the pH was 9.87.

Site 27 Laugafell South, LS230912 (64.9271304 °N, −18.2822520 °E)

For the last four sites we move to the center of the island, specifically between two large glaciers, Hofsjökull and Vatnajökull (Figure 29). At an altitude of 765 masl, in an area that the locals call Laugafell South, is our twenty-seventh site. We sampled a spring marked by a pile of rocks, with no gas emissions. Here the water temperature was 31°C and a pH was 10.08.



Figure 29. (A) An overview of the site chosen for the sampling. (B) Close-up view of the emission point. Photograph taken by author FM for this publication.

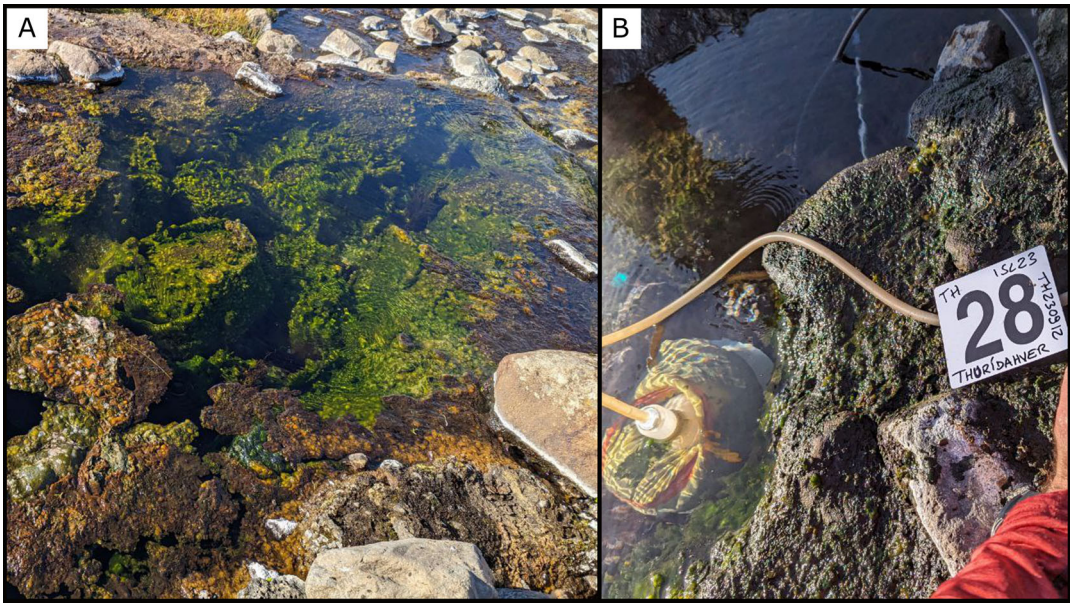

Figure 30. (A) A close-up view of the sampling location. (B) Close up of the emission point. Photograph taken by author FM for this publication.

Site 28 Þuríðarhver, Thuridahver, TH230912 (65.0302351 °N, −18.3305599 °E)

TH230912 is the twenty-eighth site of this expedition, and is located at an altitude of 757 masl and at 250 meters from Icelandic university cabins, northwest direction (Figure 30). Between two small hills there is a pool filled with algae, and with a small flux of gas that we accumulated in a flannel and then sampled. The water temperature was at 43.2°C and a pH of 10.03.

Site 29 Sesseljubær, SJ230913 (65.1127117 °N, −18.4315810 °E)

To reach the site SJ230913 from the cabins, we had to drive on poorly maintained roads and cross two rivers (Figure 31). In a small valley at an altitude of 648 masl and 11 km far from the cabins, there is a small valley with a cabin next to a river.

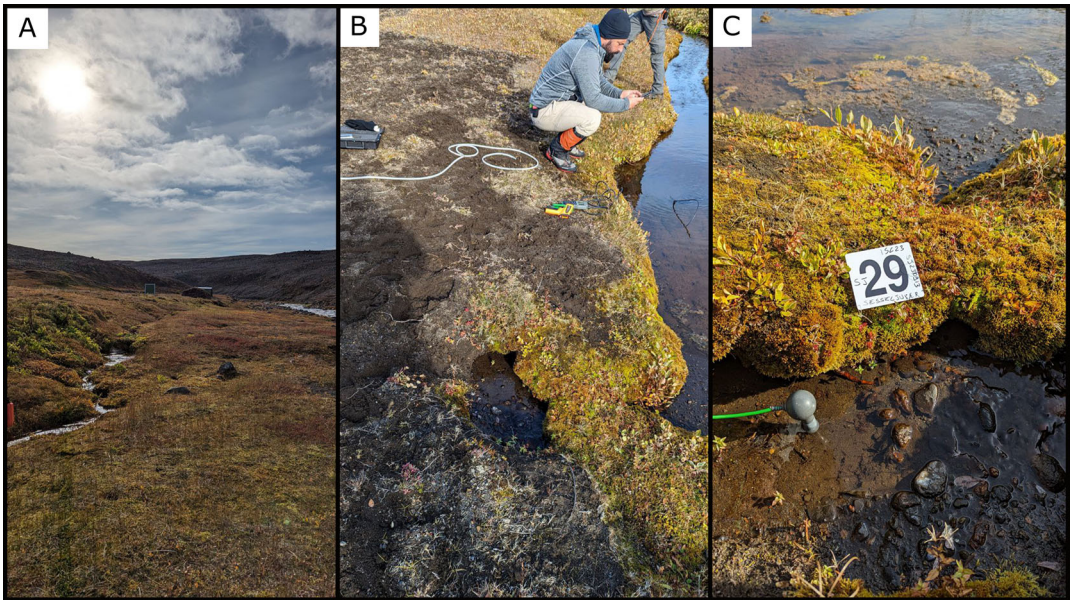

Figure 31. (A) An overview of the location chosen for the sampling. (B) Close-up view of the sampling location. (C) Close up of the emission point. Photograph taken by author FM for this publication.

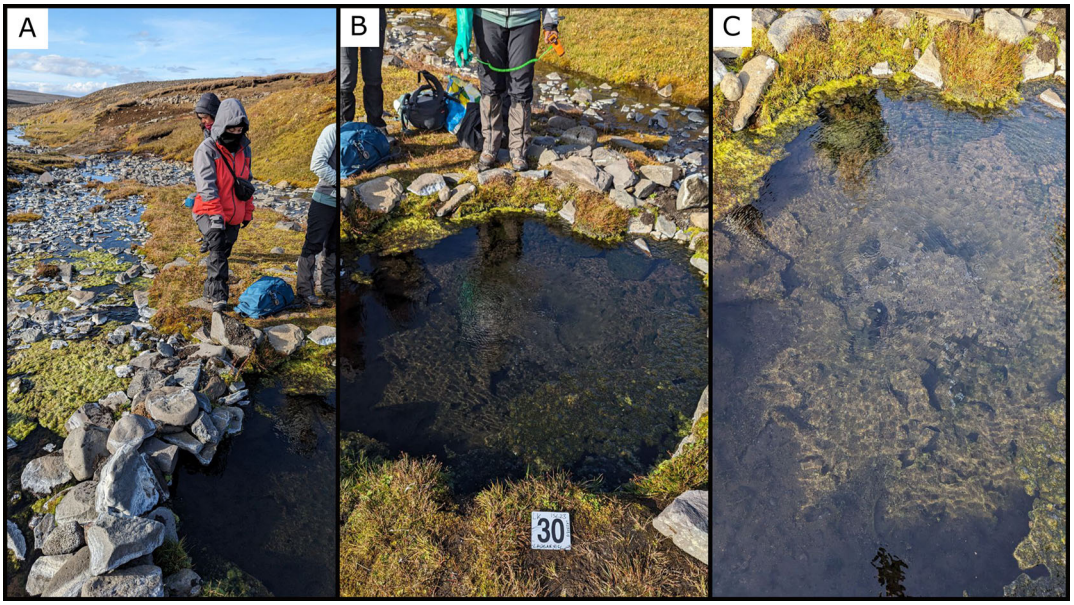

Figure 32. (A) Overview of the sampled site. (B) Close-up view of the sampling location. (C) Close up of the emission point. Photograph taken by author FM for this publication.

On the sides of the river there were a lot of small pools. In one of these we found a small flux of cold water (10.3°C) that we sampled. The pH measured there was 9.65.

Site 30 Laugakvísl, LK230913 (65.0244250 °N, −18.3319267 °E)

The twenty-ninth site is an old artificial pool to accumulate the water coming out from the ground (Figure 32). It is located at an altitude of 724 masl 300 meters from the Laugafell cabins, preceding the southeast direction. The temperature of the water was 40.3 and pH was 9.67. We sampled gas emission coming from the bottom of the pool (C).

Conclusion

The ISL23 expedition provided a comprehensive opportunity to explore the microbial diversity of Iceland's geothermal ecosystems. By sampling a wide range of features we captured a diverse array of microbial communities that live in a variety of environments, with different ranges of temperatures, pH, and chemical conditions. Our approach of minimizing the interaction between subsurface fluids and the surface environment allowed us to collect robust geochemical and biological data reflecting subsurface processes at different levels of mixing with the surface, which will contribute to our understanding of microbial adaptation to such environments.

The data collected will enable us to investigate how microbial communities respond to the dynamic and extreme conditions of these geothermal habitats. The multidisciplinary approach used in this expedition, which combines geochemical and microbiological analyses, provides a holistic understanding of how geological processes influence microbial life. The results from this expedition will also contribute to ongoing discussions on the analogs between Earth's geothermal environments and similar habitats on other planetary bodies, where subsurface hydrothermal activity could potentially host life.

Software availability

Source code available from: https://github.com/giovannellilab/ISL23_expedition

Archived software available from: https://doi.org/10.5281/zenodo.17375986

Ethics and consent

Ethical approval and consent were not required.

Data availability

Underlying data are available from: https://github.com/giovannellilab/ISL23_expedition

Archived data available from: https://doi.org/10.5281/zenodo.17375986

License: (CC-BY 4.0).

Acknowledgments

All authors contributed equally to this manuscript.

References

Barry P, de Moor J, Broadley M, *et al.*: **Carbon, nitrogen, and noble gas isotopes reveal deep volatile signatures in thermal springs in the Central Volcanic Zone (CVZ) of the Andes.** *Earth Planet. Sci. Lett.* 2025; **651**: 119169.
Publisher Full Text

Barry P, Hilton D, Füri E, *et al.*: **Carbon isotope and abundance systematics of Icelandic geothermal gases, fluids and subglacial basalts with implications for mantle plume-related CO_2 fluxes.** *Geochim. Cosmochim. Acta.* 2014; **134**: 74–99.
Publisher Full Text

Barry PH, De Moor JM, Chiodi A, *et al.*: **The Helium and Carbon Isotope Characteristics of the Andean Convergent Margin.** *Front. Earth Sci.* 2022; **10**.
Publisher Full Text

Barry PH, Nakagawa M, Giovannelli D, *et al.*: **Helium, inorganic and organic carbon isotopes of fluids and gases across the Costa Rica convergent margin.** *Sci. Data.* 2019; **6**: 284.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Correggia M, Di Iorio L, Bastianoni AB, *et al.*: **Standard Operating Procedure for the determination of trace elements in hydrothermal fluids by Inductively Coupled Plasma Mass Spectrometry (ICP-MS).** *Open Res. Eur.* 2024; **3**: 90.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Dahle H, Økland I, Thorseth IH, *et al.*: **Energy landscapes shape microbial communities in hydrothermal systems on the Arctic Mid-Ocean Ridge.** *ISME J.* 2015; **9**: 1593–1606.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

de Moor JM, Fischer TP, Sharp ZD, *et al.*: **Gas chemistry and nitrogen isotope compositions of cold mantle gases from Rungwe Volcanic Province, southern Tanzania.** *Chem. Geol., Frontiers in Gas Geochemistry.* 2013; **339**: 30–42.
Publisher Full Text

Einarsson P: **Plate boundaries, rifts and transforms in Iceland.** *Jökull.* 2008; **58**: 35–58.
Publisher Full Text

Eiríksson J, Símonarson LA: **A Brief Resumé of the Geology of Iceland.** Eiríksson J, Símonarson LA, editors. *Pacific - Atlantic Mollusc Migration : Pliocene Inter-Ocean Gateway Archives on Tjörnes, North Iceland.* Cham: Springer International Publishing; 2021; pp. 1–11.
Publisher Full Text

Friðleifsson GÓ, Elders WA, Zierenberg RA, *et al.*: **The Iceland Deep Drilling Project 4.5 km deep well, IDDP-2, in the seawater-recharged Reykjanes geothermal field in SW Iceland has successfully reached its supercritical target.** *Sci. Drill.* 2017; **23**: 1–12.
Publisher Full Text

Früh-Green GL, Kelley DS, Bernasconi SM, *et al.*: **30,000 Years of Hydrothermal Activity at the Lost City Vent Field.** *Science.* 2003; **301**: 495–498.
Publisher Full Text

Fullerton KM, Schrenk MO, Yücel M, *et al.*: **Effect of tectonic processes on biosphere–geosphere feedbacks across a convergent margin.** *Nat. Geosci.* 2021; **14**: 301–306.
Publisher Full Text

Füri E, Hilton DR, Halldórsson SA, *et al.*: **Apparent decoupling of the He and Ne isotope systematics of the Icelandic mantle: The role of He depletion, melt mixing, degassing fractionation and air interaction.** *Geochim. Cosmochim. Acta.* 2010; **74**: 3307–3332.
Publisher Full Text

Geological maps | Náttúrufræðistofnun [WWW Document], n.d. (accessed 10.5.25).
Reference Source

Geptner AR, Alekseeva TA, Pikovskii YI: **Polycyclic Aromatic Hydrocarbons in Holocene Sediments and Tephra of Iceland (Composition and Distribution Features).** *Lithol. Miner. Resour.* 2002; **37**: 148–156.
Publisher Full Text

Giovannelli D, Barry PH, de Moor JM, *et al.*: **Sampling across large-scale geological gradients to study geosphere–biosphere interactions.** *Front. Microbiol.* 2022; **13**.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Gutiérrez-Ariza C, Barge LM, Ding Y, *et al.*: **Magnesium silicate chimneys at the Strytan hydrothermal field, Iceland, as analogues for prebiotic chemistry at alkaline submarine hydrothermal vents on the early Earth.** *Prog. Earth Planet. Sci.* 2024; **11**: 11.
Publisher Full Text

Harðardóttir S, Halldórsson S, Hilton D: **Spatial distribution of helium isotopes in Icelandic geothermal fluids and volcanic materials with implications for location, upwelling and evolution of the Icelandic mantle plume.** *Chem. Geol.* 2018; **480**: 12–27.
Publisher Full Text

Hjartarson Á, Erlendsson Ö, Blischke A: **The Greenland–Iceland–Faroe Ridge Complex.** *Geol. Soc. Lond. Spec. Publ.* 2017; **447**(SP447): 127–148.
Publisher Full Text

Jakobsson S, Gudmundsson M: **Subglacial and intraglacial volcanic formations in Iceland.** *Jökull.* 2008; **58**: 179–196.
Publisher Full Text

Marteinsson VT, Kristjánsson JK, Kristmannsdóttir H, *et al.*: **Discovery and Description of Giant Submarine Smectite Cones on the Seafloor in Eyjafjordur, Northern Iceland, and a Novel Thermal Microbial Habitat.** *Appl. Environ. Microbiol.* 2001; **67**: 827–833.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Martin W, Russell MJ: **On the origin of biochemistry at an alkaline hydrothermal vent.** *Philos. Trans. R. Soc. B Biol. Sci.* 2006; **362**: 1887–1926.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Price RE, Giovannelli D: **Marine Shallow-Water Hydrothermal Vents: Geochemistry.** *Encyclopedia of Ocean Sciences.* 2019; 346–352.
Publisher Full Text

Ranta E, Halldórsson SA, Barry PH, *et al.*: **Deep magma degassing and volatile fluxes through volcanic hydrothermal systems: Insights from the Askja and Kverkfjöll volcanoes.** *Iceland. J. Volcanol. Geotherm. Res.* 2023; **436**: 107776.
Publisher Full Text

Sojo V, Herschy B, Whicher A, *et al.*: **The Origin of Life in Alkaline Hydrothermal Vents.** *Astrobiology.* 2016; **16**: 181–197.
Publisher Full Text

Stefánsson A, Stefánsdóttir G, Keller NS, *et al.*: **Major impact of volcanic gases on the chemical composition of precipitation in Iceland during the 2014–2015 Holuhraun eruption.** *J. Geophys. Res. Atmospheres.* 2017; **122**: 1971–1982.
Publisher Full Text

Stefánsson H, Peternell M, Konrad-Schmolke M, *et al.*: **Microplastics in Glaciers: First Results from the Vatnajökull Ice Cap.** *Sustainability.* 2021; **13**: 4183.
Publisher Full Text

Szponar N, Brazelton WJ, Schrenk MO, *et al.*: **Geochemistry of a continental site of serpentinization, the Tablelands Ophiolite, Gros Morne National Park: A Mars analogue.** *Icarus, Terrestrial Analogs for Mars: Mars Science Laboratory and Beyond.* 2013; **224**: 286–296.
Publisher Full Text

Torsvik TH, Amundsen HEF, Trønnes RG, *et al.*: **Continental crust beneath southeast Iceland.** *Proc. Natl. Acad. Sci.* 2015; **112**.
Publisher Full Text

Twing KI, Ward LM, Kane ZK, *et al.*: **Microbial ecology of a shallow alkaline hydrothermal vent: Strýtan Hydrothermal Field, Eyjafördur, northern Iceland.** *Front. Microbiol.* 2022; **13**.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Open Peer Review

Current Peer Review Status: ?

Version 1

Reviewer Report 13 August 2026

https://doi.org/10.21956/openreseurope.23565.r78395

© **2026 Lata P.** This is an open access peer review report distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

?

Pushp Lata
Department of Zoology, University of Delhi Faculty of Science (Ringgold ID: 124707), New Delhi, Delhi, India

The data note entitled *"Sampling deeply sourced seeps around the Icelandic hotspots, Iceland: ISL23 expedition report"* describes a sampling campaign across 30 Icelandic geothermal systems conducted in 2023. These localities were sampled for fluids, sediments, gases, and field environmental measurements (temperature, pH, specific conductivity, ORP, DO, TDS, flow, alkalinity, Fe (II), sulfide, dissolved silica). Site span acidic solfataras (pH 2.1) to strongly alkaline springs (pH 10.4), temperatures from approximately 10- 100 °C, and both terrestrial and submarine features, across volcanic and older crustal settings. The reports describe the geological context, team and logistics, the field sampling protocols, and provide per-site narratives. However, the **manuscript requires major revision before it can be indexed**. The expedition and its sampling design are scientifically sound and the dataset is valuable, but the version reviewed contains unresolved internal data inconsistencies, technical terminology errors, and missing methodological detail that a data-note article must contain.

Strengths.

- Broad, well-chosen geographic and physicochemical coverage (30 sites; pH 2.1-10.4; ~10 to 100 °C; natural and engineered features; terrestrial and submarine), a useful standardized reference for the community.
- Transparent, reproducible sampling protocols (copper-tube noble-gas sampling, Giggenbach bottles, Sterivex filtration, on-site wet chemistry).
- Adequate geological framing with appropriate citations.

Major comments (must be addressed)

A. **Text–table data conflicts**: For a dataset intended as a community reference, the following discrepancies must be resolved, and the authors must state which value is correct in each case

- Hvammsvík (HS_230901): narrative coordinates 64.3742033 N, 21.5658497 E (Hvalfjörður, western Iceland) vs. Table 1 coordinates 63.5661483, 19.6079383, which are an exact duplicate of the Seljavallalaug (SV_230831) row.
- Drangsnesvegur (DS_230904): narrative coordinates 65.698493 N, 21.559922 E and 2 m asl

vs. Table 1 coordinates 65.6479000, 21.6429000 and 11 m asl
- Reykjaskóli (RS_230903): pH 8.12 (narrative) vs. 9.12 (Table 1).
- Ærlækjarsel (AJ_230909): pH 7.87 (narrative) vs. 7.77 (Table 1).
- Hellulaug (HL_230905): 5 m asl (narrative) vs. 10 m (Table 1).
- Strýtan (SC_230907): narrative heading uses ID "SV230907" while Table 1 uses "SC_230907"; note that the "SV" prefix is already used for Seljavallalaug (SV_230831), creating duplicate/ambiguous collection IDs.
- Krýsuvik (KR_230828): Table 1 longitude "22-0570171" contains a typo (hyphen instead of decimal point).
- Mývatn Námaskarð (MH_230908): narrative reports 98.4 °C (geochemical pool), 84 °C (at the microbial sampling point), and 137 °C (fumarole); Table 1 lists 85 °C and pH = NA. Clarify which temperature is tabulated and why?
- Strýtan (SC_230907): "elevation 23.5 m" in Table 1; the site is submarine (chimney between ~15 and 70 m depth). Report depth below sea level rather than elevation.

B. **Verify or clarify anomalous field values:** Landmannalaugar (LM_230830): water flow 406 L/s and gas 605 L/s are exceptionally high for a single hot-spring outlet (cf. 17.4 L/s at Laugarás in the same table). Confirm these are spring-outlet discharges (not nearby stream/river flow), state the measurement procedure, and, if tabulated gas fluxes are to be included, define units and conditions.

C. **Missing methodological details (expected for a data note):**
- Storage and transport: "immediately frozen" at what temperature (−20 °C/−80 °C/dry ice) and what was the cold-chain procedure between field, Iceland, and the home laboratories?
- DIC isotope vials (10 mL penicillin vial "air-free"): how was air-free achieved (no headspace, crimp sealing). Please describe how the DIC samples were preserved and how biological alteration and CO_2 exchange were minimized.
- QA/QC: field blanks (trace elements, DNA), number of replicates per site/type, and total sample counts. I strongly recommend adding a sample-inventory matrix (site × sample type × replicates) to Table 1 or as a supplementary table, this is what makes an expedition report usable as a reference.
- Sterivex volume: "about 4 L of seeping fluid in 3 replicated ... Sterivex cartridges", 4 L per cartridge or 4 L split across three?
- Culturing vials (120 mL glass): anaerobic handling? storage conditions? any preliminary enrichment strategy?
- Probe QA: several sites >60 °C, up to ~100 °C, state how pH was measured in fluids above the probe's specified operating-temperature range, including whether measurements were made in situ or after cooling.
- The stated aim is to sample "pristine" subsurface fluids, but several sites are engineered (wells, pipes, artificial/concrete pools: Hvammsvík, Selárdalslaug, Laugar, Vaðlaheiðargöng, Laugakvísl, Reykjaskóli). Classify sites as natural vs. engineered (e.g., a column in Table 1) and note the implications for the "deep-sourced, minimally mixed" interpretation.
- Background soils: state how many sites yielded background samples and the criteria for "background" (distance from visible alteration).

D. **The conclusion overclaims microbial results**: no microbial community data are presented anywhere in the report. This is an expedition/data-note: its content is methods, site metadata, and physico-chemical field measurements. The manuscript contains no microbial community data whatsoever no 16S/18S rRNA amplicon or metagenomic sequences, no taxonomic inventories, no diversity metrics (e.g., OTU/ASV richness, Shannon indices), no cell counts, no microscopy results,

and no culture/enrichment isolates.

- The only microbial content is (i) descriptions of sample types collected *for future analyses* (Sterivex-filtered biomass for DNA, PFA-fixed fluids for cell counts, sediment and biofilm samples for culturing) and (ii) visual mat descriptions (e.g., "multilayered microbial mat of various colors"; "reddish-orange mucilaginous microbial mat"), morphology, not community data.
- Against that background, the conclusion's statement "By sampling a wide range of features we captured a diverse array of microbial communities that live in a variety of environments, with different ranges of temperatures, pH, and chemical conditions", overclaims: the expedition captured samples that may host diverse communities, and habitats, not demonstrated community diversity.
- Similarly, "The multidisciplinary approach... combines geochemical and microbiological analyses" should be prospective, since no microbiological analyses are reported here. The abstract and plain-language summary are already appropriately prospective ("The samples will contribute..."; "support future microbiological and geochemical studies"), the conclusion should be aligned with them.

Minor comments

- "gasses"- "gases"
- "reasarchers"- "researchers" (Expedition team and logistics).
- "microfauna such as insects and birds"- birds are not microfauna (Site 4).
- "about 20 to 30 inches deep" (Site 16)" - paper is otherwise metric; convert.
- "The area is not particularly hazardous, as evidenced by the presence of numerous tourists in the pools" (Site 6) is odd justification; also consider noting potential anthropogenic disturbance/contamination at tourist sites.
- Define EVZ/NVZ at first use (currently undefined abbreviations).

Is the rationale for creating the dataset(s) clearly described?

Yes

Are the protocols appropriate and is the work technically sound?

Yes

Are sufficient details of methods and materials provided to allow replication by others?

Yes

Are the datasets clearly presented in a useable and accessible format?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Hot spring Metagenomics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.