Vorráðstefna
Jarðfræðafélags Íslands

Ágrip erinda

Askja, Náttúrufræðahús Háskóla Íslands
14. mars 2025

Vorráðstefna Jarðfræðafélags Íslands

Ágrip erinda

Umsjón

Þorsteinn Sæmundsson, Halldór Geirsson, Bjarni Gautason & Lúðvík E. Gústafsson

Dagskrá Vorráðstefnu JFÍ, 14. mars 2025

07:50	Skráning opnar. Veggspjöld hengd upp.
Fundarstjóri	**Bjarni Gautason. Stofa 132**
08:20 – 08:30	Setning *Halldór Geirsson*
08:30 – 08:45	Carbon isotope fractionation during the 2022-2023 Fagradalsfjall eruption tracks magma degassing *Céline Mandon*
08:45 – 09:00	How much heavy metal is released by a crystalizing lava field? *Nicolas Levillayer*
09:00 – 09:15	Volcanic Gas Compositions Track Dynamic Magma Supply and Storage at Sundhnúksgígar, Iceland *Samuel Warren Scott*
09:15 – 09:30	The contribution of tectonic stress as a driving mechanism for dike emplacement in an oblique rift setting: The February-March 2021 Fagradalsfjall dike *Sonja Heidi Maria Greiner*
09:30 – 09:45	InSAR Observations of Fracture Movements on the Reykjanes Peninsula *Nathaniel Paul Wire*
09:45 – 10:00	Rapid detection of faults and fractures using magnetometry: Insights from the Grindavík hazard zone *Elisa Johanna Piispa*
10:00 – 10:15	Jarðkönnun Grindavíkur *Ögmundur Erlendsson*
10:15 – 10:45	**Kaffi – Veggspjaldasýning**
Fundarstjóri	**Sonja Heidi Maria Greiner. Stofa 132**
10:45 – 11:00	Hraunflæði niður í opnar gjár og gjávellur *Páll Einarsson*
11:00 – 11:15	The first Icelandic DAS Deployment for Real-Time Earthquake and Volcano Monitoring/ Fyrsti íslenski Ljósleiðaravakinn *Kristín Jónsdóttir*
11:15 – 11:30	Ljósleiðaravaki varar við eldgosum *Vala Hjörleifsdóttir*
11:30 – 11:45	Hermun jarðskjálftabylgna sem mældar eru á IRIS neðansjávarstrengnum milli Íslands og Írlands *Arnar Ingi Gunnarsson*
11:45 – 12:00	DeepICE: Monitoring Oceanographic processes using Operational Subsea Cables around Iceland *Angel Ruiz Angulo*
12:00 – 12:15	Non-double-couple earthquakes in Krafla 2020-2024 *Egill Árni Guðnason*
12:15 – 12:30	Tölfræðilegt mat á jarðskjálftum á Íslandi 1904–2022 *Ingi Þorleifur Bjarnason*

12:30 – 13:30 Matur – Veggspjaldasýning

Fundarstjóri Lúðvík E. Gústafsson. Stofa 132

13:30 – 13:45	Explosive phases of the 937-40CE Eldgjá flood lava eruption, Iceland and the variability in magma composition *Þorvaldur Þórðarsson*
13:45 – 14:00	Refining the age of Iceland´s Saksunarvatn Ash: new constraints on the G10ka Series *Wesley Farnsworth*
14:00 – 14:15	Origin and age of the near-rift Fjallgarðar Volcanic Ridge revealed by noble gas geochemisty and geochronology *Noemi Löw*
14:15 – 14:30	Recent and ongoing research projects in Southeast Iceland *Steffi Burchardt*
14:30 – 14:45	S.E.C.R.E.T. Eldfjöll á Suðausturlandi: Jarðfræðileg kortlagning afhjúpar kísilrík eldfjöll sem hýsa granítberghleifinn í Slaufrudal *Rob Askew*

14:45 – 15:15 Kaffi & Veggspjaldasýning

Fundarstjóri Rosemarie Philippa Cole. Stofa 132

15:15 – 15:30	Hvað tefur Heklu? *Olgeir Sigmarsson*
15:30 – 15:45	Hratt ris Bárðarbunguöskjunnar í kjölfar öskjusigsins 2014-2015 *Magnús Tumi Guðmundsson*
15:45 – 16:00	Ris Bárðarbunguöskjunnar 2015–2024 samkvæmt endurteknum íssjármælingum *Eyjólfur Magnússon*
16:00 – 16:15	Dreifing vetrarsnævar á Sátujökli mæld með snjósjá *Þorsteinn Þorsteinsson*
16:15 – 16:30	Saga jökulhörfunar á Mið-Norðurlandi *Hreggviður Norðdahl*
16:30 – 16:45	Patterns of Uplift around Greenland’s Periphery during the Early Holocene *Clinton Phillips Conrad*
16:45 – 17:00	The impact of historical land-use changes on Icelandic lake ecosystems reconstructed from Chironomidae head capsules *Emily Koenders*
17:00 – 17:15	Tilvísun til jarðfræðifyrirbæra í Landnámu og fleiri fornritum *Ólafur Flovenz*

Fundarstjóri	**Halldór Geirsson. Stofa 131**
15:15 – 15:30	Brimnes: Nýtt lághitakerfi á höfuðborgarsvæðinu staðfest með borunum *Þráinn Friðriksson*
15:30 – 15:45	Top-down cooling: a heat transport model for the Laugarnes geothermal field *Adolph Jr. Manadao Bravo*
15:45 – 16:00	Production Fields of Hellisheiði and Nesjavellir Power Plants: Past, Present, and Future *Sigurður Ragnarsson*
16:00 – 16:15	Heat released by steaming to the atmosphere by boiling of groundwater in effusive fissure eruptions during the 1975-1984 Krafla fires, Iceland *Patricia Fehrentz*
16:15 – 16:30	Um möguleg áhrif leirríkra millilaga á vatnsbúskap í tertíera jarðlagastaflanum *Bjarni Gautason*
16:30 – 16:45	Silica Transport and Deposition in Superhot Geothermal Systems *Andri Stefánsson*
16:45 – 17:00	Efnafræði jarðhitavatns við Skoresbysund *Finnborgi Óskarsson*
17:15 – 17:15	Jarðhiti á Grænlandi og rannsóknir við Skoresbysund *Árni Hjartarsson*
17:15 –	**Hressing og veggspjaldasýning!**

Veggspjöld

Glacial Isostatic Adjustment Modelling of Iceland: Entering the 2020's

Greta Bellagamba, Peter Schmidt, Halldór Geirsson, Thomas Taylor Givens Michelle Parks, Eyjólfur Magnússon, Joaquín Muñoz-Cobo Belart, Freysteinn Sigmundsson Benedikt Gunnar Ófeigsson, Vincent Drouin & Holger Steffen

Subglacial Formations in Iceland's Western Volcanic Zone. Geochemical and Structural Analysis of Hvalfell

Birta Blöndal

Algae Remains from Hreðavatn as Reason for Turbidity in the Grábrókarhraun Drinking-Water Utility (Borgarbyggð, Iceland)

Telma Jeanne Bonthonneau, Steffen Mischke & Sigrún Tómasdóttir

The nature of crustal xenoliths brought to the surface by the 2021 Fagradalsfjall eruption.

Bryndís Ýr Gísladóttir, Edward W. Marshall, William C. Wenrich, Enikő Bali, John Maclennan, Sæmundur Ari Halldórsson & Halldór Geirsson

Nýtt jarðfræðikort af svæðinu Goðaland-Fimmvörðuháls í vinnslu

Making a new geological map of the Goðaland-Fimmvörðuháls area, south Iceland

Rosie P. Cole, Birgir V. Óskarsson, Catherine R. Gallagher, Elisa J. Piispa, Magnús T. Guðmundsson & Ana Eggleston

The mobility of trace metals upon CCS. An experimental study of CO2 injection at ambient temperature using freshwater and seawater

Daniel Duque, Iwona Galeczka & Andri Stefánsson

The pre-injection characterization of the Coda Terminal CO2 storage site, Iceland

Iwona Galeczka, Martin Voigt, Thomas Ratouis, Kjartan Marteinsson, Sandra Ósk Snæbjörnsdóttir & Bergur Sigfússon

"Is the Western Volcanic Zone still spreading? A geodetic model of plate motion in South Iceland",

Guðbjartur Helgi Kristinsson & Halldór Geirsson

Basísk sprengigos á jökulþakta hluta Bárðarbungukerfis og gjóskustabbinn á Vikrakambi

Guðrún Larsen, Bergrún A. Óladóttir, Magnús T. Guðmundsson, Catherine R. Gallagher & Sveinbjörn Steinþórsson

Controls of ice-surface structures during the 1991 surge of Skeiðarárjökull, Iceland, on the post-surge glacial landsystem

Chelsea J. Hill, Ívar Örn Benediktsson & Wesley R. Farnsworth

EPOS Iceland - Open Access to Geoscience Data

Kristín S. Vogfjörð, Ríkey Júlíusdóttir, Magnús T. Guðmundsson, Helga M. Guðmundsdóttir & Þorbjörg Ágústsdóttir

Post glacial relative sea level changes in west Iceland

Ka Yan (Hilary) Kwok, Ívar Örn Benediktsson & Wesley R. Farnsworth

Transient ground deformation observed by GNSS and InSAR during and following the 2021 Fagradalsfjall eruption, Iceland

Chiara Lanzi, Halldór Geirsson, Michelle Maree Parks, Vincent Drouin & Freysteinn Sigmundsson

Potassium and rubidium isotopic composition of Icelandic basalts: Implications for moderately volatile elements in the primitive mantle

Heini Merrill, Sæmundur A. Halldórsson, Simon Matthews, Eniko Bali, Baoliang Wang, Wei Dai & Frederic Moynier

Remote Sensing based detection of changes in Surface Thermal Anomalies from 2014 to 2023 and in relation to periods of tectono-volcanic unrest at Reykjanes Peninsula, SW-Iceland

Muanza P., Jónsdóttir I., Einarsson G., Kristinsson S. & Thordarson,T.

Preliminary investigations of cryptotephra in South Greenland

Corentin Perron, Wesley R. Farnsworth & Nicolaj Krog Larsen

FLUID INCLUSION ANALYSES IN GRANITE CUTTINGS FROM BOREHOLES AT HOFFELL/MIÐFELL AREA IN GEITAFELL CENTRAL VOLCANO

Byron Pilicita & Enikő Bali

Efnisyfirlit

Ágrip

Silica Transport and Deposition in Superhot Geothermal Systems

Andri Stefánsson, Samuel W. Scott, Anna B. Bjarkadóttir, Adolph Jr. Manadao Bravo, Sigríður M. Aðalsteinsdóttir & Erlend Straume

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Superhot geothermal resources, characterized by fluid temperatures exceeding the critical point of water (>374°C) at depths of ~2–5 km near magmatic intrusions, represent a promising frontier for geothermal energy production. These high-enthalpy fluids offer significant potential for power generation. Key initiatives targeting superhot fluids include the Iceland Deep Drilling Project (IDDP), boreholes in Krafla and Reykjanes, the planned drilling at Hengill, and the Krafla Magma Testbed (KMT).

The formation of superhot fluids is controlled by various factors including heat transfer from magmatic bodies, crustal permeability, and the brittle-ductile transition. These fluids exhibit diverse compositions, ranging from nearly pure water to saline brines and volatile-rich mixtures, with fluid chemistry influenced by surrounding lithology and magmatic inputs. However, utilizing such fluids poses significant challenges, including extreme temperatures, wellbore integrity issues, and complex fluid-rock interactions.

Silica transport and deposition play a critical role in the geochemistry of superhot geothermal systems. Recent experiments demonstrate that quartz solubility varies over several orders of magnitude, from ~10^{-5} mol/kg in superheated vapor at low pressures to ~0.1 mol/kg in supercritical water at 1 kbar, with even higher solubilities at greater pressures. In conventional geothermal systems with subcritical fluids, quartz solubility is highly temperature-dependent, with cooling and decompression induced boiling leading to silica precipitation and with such silica scales being one of the major operational challenges in geothermal power stations. In contrast, superhot geothermal environments experience rapid pressure and temperature changes that can drastically reduce quartz solubility, leading to severe silica scaling. This phenomenon has been observed in boreholes such as IDDP-1, where decompression of superhot hydrothermal fluids caused massive silica precipitation within the well.

The transition from magmatic to hydrothermal conditions may also significantly influence silica transport, though this process remains poorly understood. Initially confined at near-lithostatic pressures, these fluids depressurize as they migrate into the geothermal system, triggering quartz precipitation. The interplay between temperature, pressure, and fluid composition dictates silica transport and deposition, with temperature exerting a stronger influence in liquid-dominated systems and pressure changes playing a more critical role in superhot systems.

Silica transport and deposition are critical factors influencing superhot geothermal reservoirs. Pressure and temperature changes can drastically reduce silica solubility, for example leading to severe silica scaling, as observed in IDDP-1. Also, silica deposition can occur around superhot reservoirs where ascending fluids cool and depressurize, potentially affecting permeability and reservoir evolution. A deeper understanding of the magmatic-to-hydrothermal transition and the interplay of fluid composition, temperature, and pressure is essential for mitigating deposistion challenges and optimizing the utilization of superhot geothermal resources.

Hermun jarðskjálftabylgna sem mældar eru á IRIS neðansjávarstrengnum milli Íslands og Írlands

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Þessi rannsókn kannar möguleika á notkun neðansjávar-fjarskiptastrengja til jarðskjálftamælinga. Við hermum jarðskjálftabylgjur sem mældar eru á 17 köflum á fjarskiptastrengnum milli Íslands og Írlands, með aðferðarfræði sem byggir á vinnu Fichtner o.fl., 2022. Til að framkvæma hermunina notum við opinn hugbúnað (SPECFEM3D GLOBE) til að herma bylgjuframrás með spectral-element aðferðinni og líkjum þar eftir streituhraða á þéttu punktaneti meðfram strengnum.

Hermunin tekur tillit til raunverulegra eðlisfræðilegra aðstæðna, þar á meðal áhrifa landslags, þyngdarafls, jarðskorpubyggingar, sjávarálags og legu strengsins. Útreikningarnir fara fram á Elju - ofurtölvukerfi Háskóla Íslands með notkun 150 örgjörva.

Í þróun er kerfi skrifað í Python til að vinna úr og greina hermd streitugögn, sem gerir okkur kleift að bera saman niðurstöður við raunverulegar mælingar. Þetta kerfi leggur grunn að hugbúnaðarsafni fyrir greiningu á jarðskjálftagögnum frá neðansjávarstrengjum.

Fyrstu niðurstöður gefa til kynna að hermanir séu í samræmi við raunmælingar, en frekari betrumbætur eru í vinnslu til að leiðrétta frávik sem mögulega orsakast af umhverfishávaða og óvissu í mælingum. Með því að líkja eftir mældu viðbragði strengsins við jarðskjálftum, verður mögulegt að nýta þessi gögn í hefðbundnar jarðskjálftagreiningar. Það mun hafa í för með sér aðgang að umfangsmeiri mælingum og stuðla að betri skilningi á jarðskjálftafræði á svæðum sem ekki eru aðgengileg hefðbundnum jarðskjálftamæla-netum.

Hraðvirk greining sprungna með segulmælingum: Innsýn frá hættusvæði Grindavíkur

Rapid detection of faults and fractures using magnetometry: Insights from the Grindavík hazard zone

Robert Alexander Askew[1,2], Daniel Ben-Yehoshua[4], Sindri Bernholt[1], Rosemary Philippa Cole[1], Gregory Paul De Pascale[1], Gunnlaugur Magnús Einarsson[2], Ögmundur Erlendsson[2], Catherine Rachel Gallagher[1], Alexandra Kristín Hafsteinsdóttir[2], Irma Gná Jóngeirsdóttir[2], Katrín Ásta Karlsdóttir[2], Birgir Vilhelm Óskarsson[3], Elisa Johanna Piispa[1] & Hannah Iona Reynolds[1]

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The renewed tectonic and volcanic activity in the Reykjanes Peninsula led to significant faulting, fracturing, and graben formation in the town of Grindavík. Two main graben forming events took place in November 2023 and January 2024. During the latter event an eruptive fissure also opened just north of the town. All of this posed severe risks to infrastructure and public safety, particularly through the formation of sinkholes, subsidence, fractures and surface instability. Effective mitigation required rapid and accurate mapping of the structures, both at the surface and in the subsurface.

Magnetometry, both drone-based and ground-based, proved to be a powerful tool for detecting and characterizing subsurface fractures, sinkholes, and graben boundary faults. The method efficiently mapped hazardous areas by detecting magnetic anomalies arising from contrasts between magnetized ground and nonmagnetic features such as voids and fractures, even in a challenging urban environment. Drone magnetometry, in particular, enabled rapid data collection over large areas, which would have taken much longer using ground-based methods. Additionally, it allowed access to hazardous or otherwise inaccessible areas, minimizing risk to surveyors. Our results demonstrate how magnetometry delineated fault networks, identified potential sinkhole locations, and provided insights into the subsurface extent of deformation features.

However, the magnetometry method has certain limitations. Environmental interference from urban infrastructure can obscure magnetic anomalies. The method's resolution limits its ability to detect very small fractures, though it appears to remain effective for identifying larger, hazardous features. Detection also depends on sufficient magnetic contrast, and cavities filled with similar materials to the surrounding rock may go undetected. Additionally, environmental factors such as high winds and cold temperatures impacted data quality and equipment performance or altogether prevented surveying, requiring careful planning and flexibility.

To overcome the limitations of individual methods, we combined multiple different, complementary techniques, including remote sensing (InSAR, DEM), geophysical surveys (ERT, GPR), and surface mapping. The integration of all these datasets helped reduce uncertainties and allowed for a comprehensive evaluation and ranking of hazard zones, ensuring

that each area was assessed thoroughly. The results demonstrate the usefulness of magnetometry as part of a multi-method approach for rapid hazard assessment, decision making, and risk mitigation in tectonically active regions.

S.E.C.R.E.T. Volcanoes in Southeast Iceland: Geological Mapping Reveals Silicic Volcanoes Hosting the Slaufrudalur Granite Pluton

S.E.C.R.E.T. Eldfjöll á Suðausturlandi: Jarðfræðileg kortlagning afhjúpar kísilrík eldfjöll sem hýsa granítberghleifinn í Slaufrudal

Robert Alexander Askew*[1,3]; Steffi Burchardt[2]; Sæmundur Ari Halldórsson[3]; Catherine Gallagher[3]; Orlando Quintela[2]; Kristján Jónasson[1]; Olivier Bachmann[4] & Razvan Gabriel-Popa[4]

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The generation of large volumes of silicic magma in basalt-dominated crust remains a topic of ongoing debate. Previous models (e.g. Assimilation Fractional Crystallisation vs. crustal melting) focus on the chemical processes and may underestimate the mechanics of silicic magma production and injection. To better understand the interplay between these processes, we study the Slaufrudalur pluton (Cargill et al., 1928), the largest silicic pluton in Iceland (~8–10 km³), and its surroundings in the mountains west of Papafjörður, Austur-Skatafellssýsla. Despite previous studies investigating the pluton composition (Carmody, 1991; Carley et al., 2020) and emplacement (Burchardt et al., 2010, 2012), its existence within Iceland's basalt-dominated crust remains an enigma.

Figure 1: Þorgeirsstaðadalur. Slaufrudalur granite pluton in the background, the light-coloured rocks in the main valley and the gil to the left form part of the Þorgeirsstaðadalur Caldera Formation.

The "SECRET: Structurally Enhanced Crustal Recycling explains exTensive silicic magma production" project, a collaborative effort between the University of Iceland, The Icelandic Institute of Natural Science, Uppsala University and ETH Zurich, is focussed on unravelling the temporal, structural, and chemical relationship between the pluton and its host rocks. The discovery of caldera-confined volcanic rocks during a separate study led to further mapping by Gupta (2023, Unpublished MSc Thesis) and the defining of caldera formations bounding the pluton. During summer 2024 fieldwork we mapped and sampled the rocks of these two newly discovered central volcanoes in Kapaldalur – the Kapaldalur Caldera Formation and Þorgeirsstaðadalur (Fig 1) – the Þorgeirsstaðadalur Caldera Formation. In addition, silicic pyroclastic and volcaniclastic rocks were identified and mapped for the first time in Kvosir, here described as the Kvosir Caldera Formation, and further pyroclastic and plutonic rocks on Hvammsheiði, north of Gjádalur. These formations are distinguished by the presence of silicic volcanic rocks that are typically spatially confined and delineated by fault structures, which separate them from the adjacent plateau basalt lava formations. The spatial arrangement of these caldera formations suggests that pluton emplacement into the shallow crust was strongly controlled by structures within these formations.

Furthermore, new zircon ages from these silicic volcanics are the same, or younger than, zircons ages within the pluton. This could potentially indicate zircon recycling and suggests that the generation of the pluton's silicic magma may have been partly driven by the recycling of older silicic material from buried central volcanoes, or that the emplacement of the magma was controlled by these pre-existing formations. We are currently in the process of systematically analysing and dating the samples from the 2024 campaign.

We present an updated high resolution geological map of the area and describe the formations surrounding the pluton to support our hypothesis on the structural control of the emplacement of the largest granitic pluton in Iceland.

References

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Jarðhiti á Grænlandi og rannsóknir við Skoresbysund

Árni Hjartarson[1], Grímur Björnsson[2] & Finnbogi Óskarsson[3]

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Jarðhiti á yfirborði er ekki víða kunnur á Grænlandi. Laugar og volgrur eru þó þekktar sitt hvoru megin við Skoresbysund og á Diskóeyju. Einnig er vel þekktur stakur jarðhitastaður og heilsubað á eynni Unartoq í hinum fornu Íslendingabyggðum á Suður-Grænlandi. Annar staður er í Ikasagtivaq við suðausturströndina nálægt Tasiilaq. Litlar rannsóknir hafa verið gerðar á möguleikum til jarðhitanýtingar, engar jarðhitaboranir, mjög fáar hitastigulsmælingar og mjög takmarkaðar jarðeðlisfræðilegar mælingar, enda eru flestir jarðhitastaðirnir fjarri mannabyggð. ÍSOR hefur þó gert frumathuganir á nýtingarmöguleikum á Diskó við vesturströnd Grænlands, rannsóknarholur voru áætlaðar með það að markmiði að staðsetja vinnsluholu. Yfirvöld sýndu þessu þó ekki áhuga svo ekki varð neitt úr neinu. Sumarið 2022 fórum við undirritaðir í rannsóknarferð til Ittoqqortoormiit við Skoresbysund á austurströnd Grænlands til að kanna fýsileika jarðhitavinnslu þar í grennd. Þetta er lítið 300 manna þorp, vinabær Dalvíkur, og ein afskekktasta byggð Grænlands.

Jarðhitastaðir við Skoresbysund

Nafn	*N*	*W*	*masl*	*°C max.*	*L/s*
Unarteq við (Tóbínhöfða)	70°24’54.4‘‘	21°57’02.4‘‘	8-10	60,1	1
Unarterajik	70°25’23.9‘‘	21°54’07.1‘‘	0	45,0	1,6
Kape Hope	70°27’34.9‘‘	22°21’06.5‘‘	31	12,3	0.5
Kape Hope, Mosekilden	70°27’34.3‘‘	22°20’58.7‘‘	28	15,3	0.7

Heitasta laug Grænlands, Unarteq, er við mynni Skoresbysunds 7 km austur af Ittoqqortoormiit og um 1 km austur af gömlu veðurathugunarstöðinni á Tóbínhöfða. Þorpið sem þar var er nú komið í eyði. Laugin er um 300 m frá upp frá ströndinni og í 8-10 m y.s. Landið er þakið stórgrýti, möl og sandi en grunnt er á fast berg. Enginn hágróður er á staðnum en grænþörungar þrífast í afrennslinu. Berggrunnurinn er gneiss. Jarðhitavökvinn kemur út í tveimur augum, aðeins 7 m eru á milli þeirra. Auk þess sést lítilsháttar leki í stórgrýtinu þar skammt frá. Hitinn í stærra auganu mældist víðast á bilinu 58-60°C með hámark 60,1°C. Þetta er aðeins lægra en uppgefið hámark (61,8°C) á staðnum. Gasbólur koma upp með vatninu. Afrennsli, mælt nákvæmlega með plaströri og fötu, var 0,8 l/s. Í minna augnu, 7 m norðar, er hámarkshiti 40,6°C, rennslið var áætlað 0,2-0,3 l/s. Heildarafrennslið er því rúmlega 1 l/s. Vökvinn er saltur. Brennisteinslykt er í loftinu og þunn gufa sést yfir lauginni. Hvítar áberandi útfellingar eru á steinunum. Misgengi og sprungur eru erfitt að sjá við laugina sjálfa en í grennd eru áberandi misgengi sem stefna í N147° misvísandi. Jarðhitasvæðið hefur litla efnahagslegt þýðingu í dag og fáir heimsækja staðinn. Heita vatnið hefur verið notað til að sjóða og hreinsa höfuðkúpur af moskusuxum og ísbjörnum sem seldar eru ferðamönnum.

Unarterajik jarðhitasvæðið er 3 km ENE af Tóbínhöfða og og 7,5 km frá Ittoqqortoormiit. Fjarlægðin að Unarteq lauginni er 2 km. Aðallaugin er við ströndina rétt fyrir ofan stórstraumsmörk. Hámarkshiti þar mældist 33,2°C. Þetta er nálægt því sem fyrri mælingar hafa gefið. Erfitt er að áætla rennsli en það virðist vera nálægt 1 L/s. Bólustreymi er áberandi. Vatnið rennur til sjávar í mörgum litlum seyrum á gneiss klöppum í fjörunnni. Litlu norðvestar uppgötvuðum við litlar laugar í fjöruborðinu. Þar mældum við allt að 45°C hita en rennslið var einungis 0,1 L/s. Þetta er 12 °C hærri hiti en mælst hefur áður á svæðinu. Þar hjá er volgra, 18°C heit með 0,5 L/s rennsli. Alls gefur því svæðið 1,6 L/s. Misgengi og sprungur eru áberandi. Aðalsprungukerfið hefur sömu stefnu og strandlengjan, N355° misvísandi. Heimamenn segja að stór vök sé jafnan í lagnaðarísnum við ströndina sem helst opin yfir vetrartímann en það bendir til jarðhitauppstreymis neðansjávar. Farið var með bát á staðinn og sjávarhitinn mældur fram og til baka við ströndina í von um að finna uppstreymi jarðhitans en án árangurs. Umrædd vök kemur raunar vel fram á Google Map vetrarmyndum. Þar sést að hún er 70 m löng meðfram ströndinni og 20 m breið og þekur 1200 m^2. Útreikningar á því hve mikinn jarðhita þarf til að halda slíkri vök opinni í vetrarfrostinu sýna að til þess þarf að lágmarki 1,2 L/s af 60°C heitu vatni. Þetta þýðir jafnframt að Unarterajik svæðið er öflugra en Unarteq laugarnar.

Jarðhitastaðirnir á austurströnd Grænlands, sitt hvoru megin við Skoresbysund, teygja sig yfir 500-600 km langt og mjótt svæði meðfram ströndinni. Trúlega er jarðhitinn bundinn við siggengi sem mynduðust þegar Jan Mayen skorpuflekinn rifnaði frá Grænlandi fyrir 24 milljónum ára samfara myndun Kolbeinseyjarhryggjar. Hér virðist um talsvert stóra auðlind að ræða. Hún gæti jöfnum höndum nýst í hitaveitur, til rafmagnsframleiðslu með tvívökva vélum, baðlón í ferðamennsku og í vinnslu á helíum, sem er aukaafurð geislavirknar klofnunar í gamla meginlandsberginu. Eins er athyglisvert að seltan í jarðhitanum við Tóbínhöfða samsvarar 20-25% íblöndunar sjávar. Jarðhitakerfin í brotunum eru því tæplega yfirþrýst eins og mætti ætla út frá jökulþakta hálendinu allt um kring. Þá kom á óvart að talsverðar ferksvatnslindir er að finna vestan við Ittoqqortoormiit, með ísótópamerki um hálent innstreymi. Aðgangur að heitu og köldu vatni úr berggrunninum árið um kring virðist því tryggur. Hljóta það að teljast góðar fréttir fyrir samfélagið í Ittoqqortoormiit og vonandi víðar á Grænlandi.

Glacial Isostatic Adjustment Modelling of Iceland: Entering the 2020's

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Iceland offers an opportunity to study Glacial Isostatic Adjustment (GIA) in real-time. The ongoing deglaciation drives the present-day elastic response, which, in addition to the viscoelastic response from the lower crust and mantle, leads to a current uplift rate of up to 35 mm/yr. A GIA model is useful for quantifying and removing this time-dependent signal when analysing magma movements and tectonic deformation. Additionally, it is useful in computing GIA-induced stress changes, which influence magma production, storage stability, and the likelihood of intrusion versus eruption. Although previous studies have examined the present-day GIA process in Iceland, new glacial unloading models and new deformation data warrant re-examination of the GIA modelling.

We employ a 3D Finite Element model developed in COMSOL Multiphysics, incorporating a flat, incompressible Earth in the governing equations while allowing for material compressibility in the rheology and neglecting self-gravitation. The model consists of an elastic plate that overlies a linear viscoelastic halfspace, with rheological parameters that only vary with depth.

The ice-load history spans 1890–2023, with bigger uncertainty on glacial load changes going back in time. For Vatnajökull, we integrate two datasets: 1890–2010, based on mass balance reconstructions with temporal resolution ranging from a few years to several decades; 2010–2023, incorporating observational data with annual resolution and lateral variations. For Hofsjökull and Langjökull, the complete history of mass balance is used between 1890 and 2023, calculated as spatially integrated values. In addition, we account for the mass balance of Mýrdalsjökull and 9 other smaller glaciers from 1945 and on.

The surface displacements in Iceland, observed via GNSS and InSAR since 1993, are well reproduced by our GIA model with a mantle viscosity of $2 - 4 \times 10^{18}$ Pa s and an elastic thickness of 35 km. With this model, we predict, from the late nineties, up to three time the production of magma we expect through the plate spreading alone, due to GIA-induced decompression melting in the Earth mantle. Future work includes incorporating the 3D Earth structure and refining the glacier load model. Currently, we are benchmarking GIA-induced horizontal displacements using an axisymmetric model implemented in the software Iceage (Kaufmann, 2004).

Subglacial Formations in Iceland's Western Volcanic Zone. Geochemical and Structural Analysis of Hvalfell

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Hvalfell, located in the Western Volcanic Zone (WVZ) of Iceland, formed during the Weichselian glaciation. This study examines its eruptive history, magma evolution, and volatile content to better understand interactions between volcanic and glacial processes. Samples from Hvalfell and nearby formations (Ármannsfell, Mosfell, Sandfell í Kjós) (Map 1) were analysed using electron microprobe analysis (EMPA) for major element compositions and Fourier transform infrared (FTIR) spectroscopy for volatile content. Field mapping and remote sensing techniques helped assess structural relationships and eruption environments. EMPA results indicate two distinct magma compositions at Hvalfell. The lower pillow lava unit has higher MgO (9.0 wt%) and lower K_2O/TiO_2, suggesting a primitive melt, while the upper unit has lower MgO (7.75 wt%) and higher K_2O/TiO_2, reflecting a more evolved composition (Figure 1). FTIR analysis shows volatile contents consistent with degassed, water-transported pillow lavas, indicating interaction with meltwater during emplacement. The sampled layer is not from the base of the mountain, so its formation conditions may differ from the initial subglacial stage. While Hvalfell likely formed under ice cover, the analysed layer has undergone significant degassing and meltwater transport. The geochemical patterns align with trends seen in other subglacial volcanic formations in Iceland. This study contributes to understanding magma evolution in glaciovolcanic environments and the role of glacial retreat in shaping eruption dynamics.

Um möguleg áhrif leirríkra millilaga á vatnsbúskap í tertíera jarðlagastaflanum

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Sprungu má skilgreina sem svæði þar sem efni hefur tapað viðloðun. Í stökka hluta skorpunnar sem byggð er upp af kristölluðu bergi, hraunlögum og innskotum, er lítil von til að bergið/efnið nái aftur viðloðun og loki sprungum nema að til komi útfellingar úr vatni sem fylla sprungurnar. En fleira getur komið til sem hefur áhrif á lekt jarðlagastaflans. Í tertíera (míosen) staflanum eru sums staðar all-þykk leirrík setlög. Þessi lög eru oft til vandræða í borholum, hvort sem er í borverkinu sjálfu, eða við rekstur dælubúnaðar eftir að borverki er lokið. Þessi leirríku lög vilja síga inn í borholur og stífla þær, grugga vatnið og eyðileggja dælur. Það blasir því við að leir í slíkum lögum getur auðveldlega náð aftur viðloðun og lokað sprungum. Verði hreyfing um sprungu (misgengi) glatast viðloðun tímabundið. Leirrík millilög geta þannig skipt tertíera staflanum í hólf sem eru lítt tengd hvert öðru.

Berggangar sem skera staflann rjúfa þessi lög og ef lekt er tengd þeim (prímer eða sekúnder) ná hólfin „talsambandi“ staðbundið. Sama gildir um sprungur og misgengisbreksíur. Þannig mætti líta á þessi leirríku millilög sem eins konar regnhlífar í staflanum sem eru þó götttóttar og ráða ekki við að einangra hólfin alveg.

Horfum til Eyjafjarðar og þeirra hugmyndalíkana sem sett hafa verið fram varðandi uppruna linda og vatnsbúskap grunnt í skorpunni. Í skýrslu um Hesjuvallarlindir og Glerárdalslindir [1] var sýnt fram á að lindirnar ættu uppruna sinn að mestu eða öllu leyti í berggrunninum. Talið var að þær kæmu fram í vatnsbólabasaltinu, sem er neðst í tiltölulega lekum stafla, vegna þess að undir því lagi væri staflinn þéttur vegna ummyndunar og útfellinga, Svipað líkan var sett fram um Hallands- og Varðgjárlindir í Vaðlaheiði í aðdraganda gangagerðar þar [2]. Í greinargerð um vatnsbúskap Hríseyjar [3] var sú hugmynd sett fram að setlag sem kemur fyrir í borholum á um 100 m dýpi væri vatnsleiðandi (*aquifer*) og eftir því seytlaði vatn, að uppruna úrkoma í fjalllendinu í kringum Eyjafjörð. Vatnið kemur svo upp í lind í eyjunni.

Í þessu hugmyndalíkani er það leirríkt set sem liggur undir vatnsbólabasaltinu sem stíflar sprungur og veitir vatni fram í lindum bæði í Hlíðarfjalli (Hesjuvalla- og Gerárdalslindir) og Vaðlaheiði (Halllands-, og Varðgjárlindir). Af skýrslum má ráða að setlagið á 100 m dýpi í Hrísey sé leirríkt, enda olli leirdrulla frá því miklum vandræðum við rekstur dælu í holu HR-05. Þetta setlag er stemmir (*aquitard*) í þessu líkani ekki leiðari (*aquifer*). Það stíflar sprungur í bergrunninum og veitir vatni í áfram undan þrýstingi frá hærri grunnvatnstöðu í fjalllendinu í kringum Eyjafjörð.

Ein afleiðing af þessu hugmyndalíkani er sú að endurskoða þarf jarðhitaleit með grunnum borholum. Því þar sem leirrík millilög eru á t.d. 150 – 250 m dýpi er tilgangslítið að leita að jarðhita með 50 – 100 m holum því þær munu í mörgum (flestum) tilfellum aðeins sjá kalt vatn sem „flýtur“ ofan á setinu. Því er æskilegt að byrja jarðhitaleit, á tilteknu svæði, með borun 400 – 500 m djúprar holu sem leyfir nákvæma kortlagning á efsta hluta jarðlagastaflans.

Jarðfræðikortlagning á Eyjafjarðarsvæðinu hefur verið þokað áfram í nokkrum áföngum fyrir tilstuðlan Norðurorku [4], Vegagerðarinnar [5], í tengslum við Vaðlaheiðargöng, og síðar í átaksverkefni Umhverfis og auðlindaráðuneytisins í jarðfræðikortlagningu [6]. Vísbendingar eru um að rekja megi ofangreind setlög til suðurs, og niður í jarðlagastaflann, og að þau komi fyrir í borholum á vinnslusvæðum Norðurorku rúmlega 10 km sunnan við Akureyri. Þar hafa þessi jarðlög einnig verið til vandræða við borframkvæmdir í einhverjum tilfellum. En hvaða áhrif hafa þessi lög djúpt í staflanum?

Heimildir:

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Algae Remains from Hreðavatn as Reason for Turbidity in the Grábrókarhraun Drinking-Water Utility (Borgarbyggð, Iceland)

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The Grábrókarhraun drinking-water utility is located in West Iceland near the town of Bifröst. The utility is located in Grábrókarhraun, a late Holocene lava flow, and the groundwater within it derives mainly from Hreðavatn, a neighbouring lake. Although the utility generally produces good quality water, it has faced issues regarding turbidity since its commissioning. The turbidity in the water increases with high production rates, seismic activity and during extreme weather conditions. In this study the turbidity sediment from the Grábrókarhraun utility was analysed under high magnification and compared to lake-bottom sediments from Hreðavatn, as potential source material.

A comparative analysis of the samples was carried out, with samples taken from two locations in the utility and samples taken from Hreðavatn (Figure 1). There were 3 cores collected from Hreðavatn (Figure 2). The samples from within the utility were supplied by Orkuveitan, from well GB-15 in Grábrókarhraun and from the distribution tank in Stóru-Skógar. The samples were analyzed in an optical microscope where approximate percentages of diatoms, detrital grains and plant fragments were determined. Additionally, the samples were analyzed in a scanning electron microscope (SEM). The SEM images were then used to identify the taxonomy of the diatoms at the genus level.

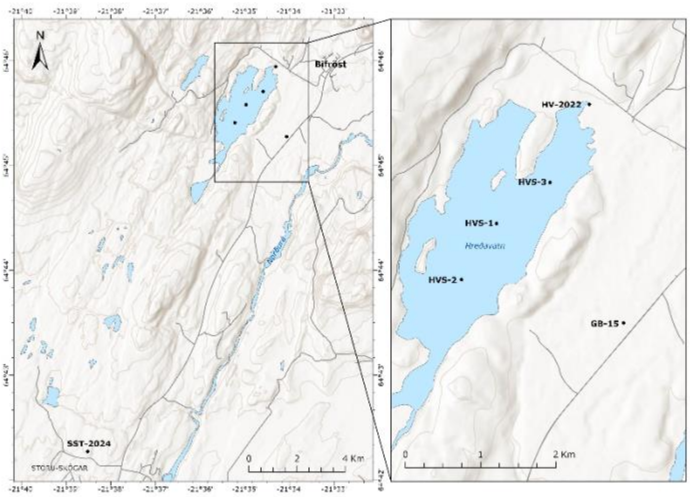

Figure 1 Locations of samples from Hreðavatn, the Grábrókarhraun utility and the distribution tank in Stóru-Skógar

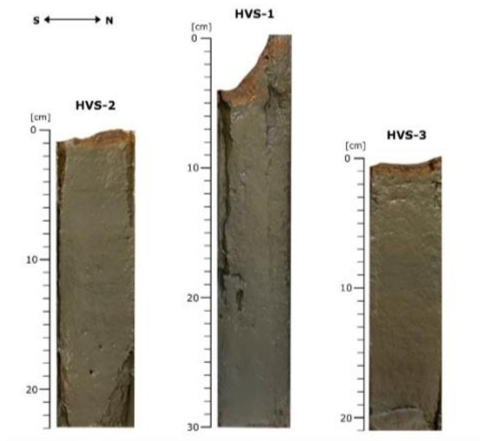

Figure 2 Sediment cores collected from Hreðavatn

The analysis revealed that both the turbidity sediment and the sediment from Hreðavatn are predominantly composed of diatoms, which are small unicellular algae with siliceous skeletons (Table 1, Figure 3). The key difference in the sediments from the lake and the utility is the preservation of the diatoms and the overall grain size of the clastic particles. The turbidity sediment is finer grained and has a higher proportion of poorly-preserved diatoms compared to the lake sediments from Hreðavatn.

Table 1 Approximate percentage of diatoms, detrital grains and plant fragments in most relevant samples

Sample	Diatoms	Detrital grains	Plant fragments
HVS-3	50%	40%	10%
GB-15	70%	30%	*
SST-2024 ***Below Detection limit**	60%	40%	*

The diatom remains from Hreðavatn are therefore considered to be the major source of the turbidity sediment in the Grábrókarhraun utility. Further knowledge about the nature of groundwater flow and nutrient levels in the water could improve our understanding of the turbidity issue. The intermittent turbidity is deeply rooted in the hydrological and geological context of the utility and it will, therefore, be challenging to mitigate the temporary occurrence of turbidity peaks.

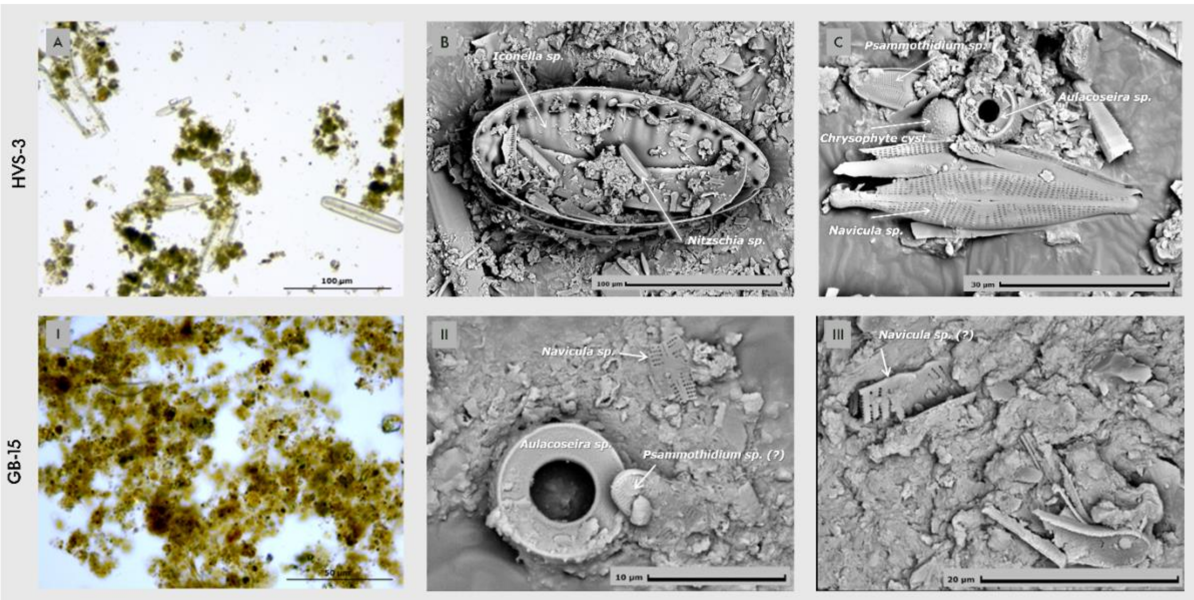

Figure 2. Images of samples HVS-3 (A, B, C) and GB-15 (I, II, III) from an optical microscope (A, I) and from a Scanning Electron Microscope (B, C, II, III). Similar species are found in both samples.

The nature of crustal xenoliths brought to the surface by the 2021 Fagradalsfjall eruption.

Bryndís Ýr Gísladóttir[1], Edward W. Marshall[1,2], William C. Wenrich[1,3], Enikő Bali[1], John Maclennan[4], Sæmundur Ari Halldórsson[1] & Halldór Geirsson[1].

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Petrographic and chemical analyses of xenoliths brought to the surface by the 2021 eruption in Fagradalsfjall provide insight into the structure and composition of the crust beneath the Reykjanes Peninsula. Wenrich (2023)[1] described 9 xenoliths collected from lava flows erupted between mid- April and mid-May. In this poster we add analysis of 14 xenoliths (total 23 xenoliths) that were collected from lava flows erupted between mid-April and mid-September.

Based on modal composition we distinguish: gabbro, olivine-gabbro, leuco-gabbro and anorthosite (Fig. 1). Plagioclase is the most abundant mineral in every xenolith. In all xenoliths, plagioclase presents bimodal size distribution, with smaller (~100 µm) grains and larger (up to 2 cm) subhedral grains (Fig. 2). Complex zonation patterns (Fig. 2) and normal zoning are common in all samples. Olivines, if present, are generally smaller than plagioclase or pyroxenes, and are mostly subhedral. Spinels are seen as inclusions in olivines and plagioclases. Clinopyroxenes are sub- to anhedral and found interstitial among plagioclase±olivine (Fig.2). On a thin section scale (4.5x2.5 cm), the extinction of clinopyroxenes through crossed polarized light in microscopic view confirms that there are 1-3 large clinopyroxene crystals in each thin section, although, in reality these pyroxenes might be larger than a few cm. The gabbros have ophitic and poikilitic texture and are holocrystalline where no glass is seen in between grains. Impingement textures are observed that formed by random juxtaposition of plagioclases where the space is mostly filled with the interstitial clinopyroxenes±olivine (Fig.2.). This textural feature suggests that clinopyroxene±olivine represent a melt which occupied the free space in a plagioclase-rich crystal mush. In the anorthosites, the plagioclase is mainly anhedral to subhedral with poikiloblastic texture and sometimes with bent albite twinning. Their grain boundaries are irregular, which could indicate dynamic recrystallization in a solid state.

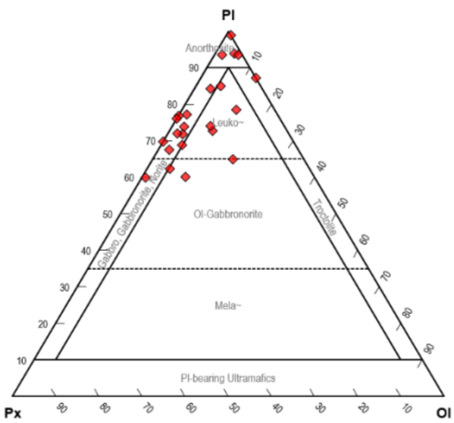

Figure 3: Classification diagram of gabbros. Pl-plagioclase, Px-pyroxene, Ol-olivine.

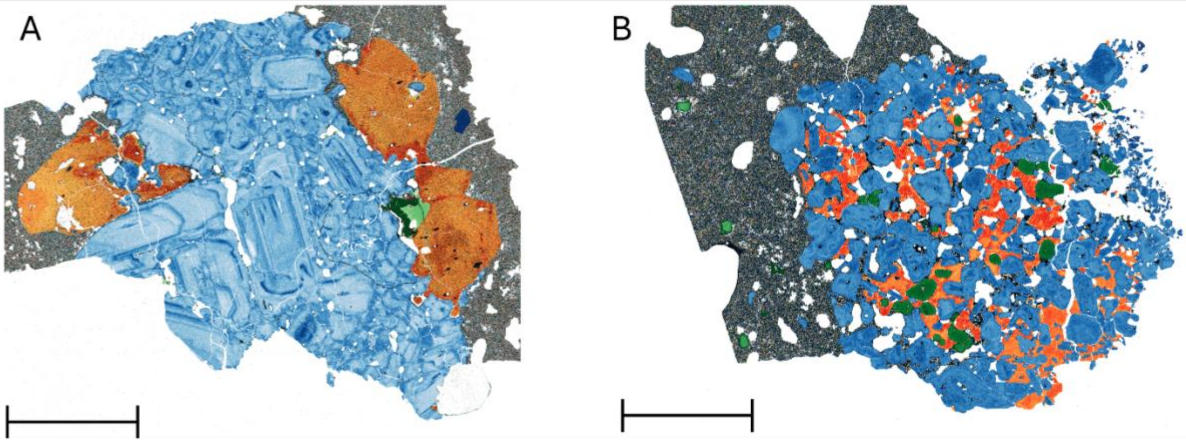

Figure 4. Representative Qemscan images of of A) Anorthosite and B) Olivine gabbro. Blue color represents Plagioclase, orange/red represents clinopyroxene and green represents olivine. Black color is the groundmass/basalt and white are vesicles. Scale bars are approximately 5mm.

Plagioclases in all xenoliths are Anorthite(An)-rich with An66 to An92. In the gabbros they have a narrower compositional range from An75 to An90. Plagioclases in gabbros tend to have lower K_2O compared to those in the anorthosites. Olivine in gabbros have a forsterite content of 82-95 and NiO from 0.15 to 0.30 wt%. Mg# and Cr_2O_3 in clinopyroxene ranges from 82-88 and 0.2-1.46 wt%, respectively. The composition of clinopyroxenes is similar to clinopyroxene macrocryst compositions from the 2021 Fagradalsfjall eruption[2]. The composition of plagioclases and olivines in the studied xenoliths overlap with the macrocryst compositions, but plagioclases have a wider range of compositions, and the olivines extend to slightly higher Fo contents compared the Fagradalsfjall 2021 macrocrysts [2].

Pressure and temperature of crystallization were calculated by clinopyroxene-melt thermobarometry and plagioclase-melt thermometry[3,4], using the thermobar software[5]. We matched glass and melt inclusion compositions to these minerals as potential equilibrium liquids from the 2021 Fargradalsfjall eruption[2,6]. Median calculated temperature from clinopyroxene melt thermobarometry is 1208±4.1 °C (SEE of 27°). The median calculated pressure is 3.36±0.32 kbars (SEE of 1.4 kbar). This pressure corresponds to crystallization depth of 10.08±4.2 km (assuming the crustal density is 3.0 g/cm^3) for gabbros. Plagioclase melt thermometry did not show differences between anorthosites and gabbros, showing median temperature of 1232±8.1 °C (SEE of 36°C) for both rock types. Textural features of plagioclase in gabbros indicate that plagioclase crystallized before the pyroxene, which fits with plagioclases showing distinctively higher temperatures than the clinopyroxenes. These results suggest that these xenoliths are sourced from the lower crust and perhaps even the moho-transition zone (e.g. refs[7-9]). While gabbros represent a crystal rich mush material, anorthosites likely represent solid rock, which suffered recrystallization in a solid state at high temperature.

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Recent and ongoing research projects in Southeast Iceland

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Southeast Iceland, here defined as the Miocene and Plio-Pleistocene successions between Àlftafjörður in the NE and Skeiđarársandur in the SW, is a geologically complex and understudied area. At the same time, it is unique compared to other areas in Iceland: Its geology is characterised by closely-spaced remnants of central volcanoes and dyke swarms, numerous exposed shallow-crustal plutons (e.g. Torfason, 1979), and the deepest erosional levels in Iceland (down to ca. 2 km; Walker, 1974). Geophysical studies indicate an extensive crustal thickness beneath the area (ca. 40 km; Kumar et al., 2007), which led some researchers to propose the presence of continental crust (Foulger, 2006; Torsvik et al., 2015). Petrologists and geochemists, on the other hand, have used the area to study the formation of continental crust, focusing on the petrogenesis of large amounts of granitic magma in the plutons (Carley et al., 2014; Law et al., 2024).

Geochronological studies of some of the plutons and central volcanoes in the 20th century indicated an age distribution deviating from the concept that the rocks should be getting older with distance from the plate boundary. This led Helgason (1983) to propose small-scale rift jumps, both towards the E and the W. More recent and reliable age dating (Martin et al., 2011, Padilla, 2015) disagrees with the earlier patter, but contains too few dates from the area to be conclusive (see also below).

On an even smaller scale, detailed studies of some of the central volcanoes have highlighted that they serve as impressive analogues to the currently active volcanoes (e.g. Fridleifsson, 1983). In parallel, the plutons have been studied as analogues for shallow crustal magma chambers beneath active volcanoes, based on petrography, geochemistry and emplacement mechanisms (e.g. Weidendorfer et al., 2014; Burchardt et al., 2012).

Hence, Southeast Iceland is a treasure chest of geological wonders and still holds the potential for many new discoveries. However, we are currently lacking the foundation for answering some of the outstanding fundamental questions about the area: systematic geological mapping and geochronology.

In recent years, two PhD projects (Rhodes, 2022 and Quintela, finishing autumn 2025.) have studied the Reyðarártindur and Slaufrudalur plutons, respectively. Rhodes et al. (2021, 2024) reported on the emplacement, petrology, and eruption of the Reyðarártindur pluton, which is a unique example of the roots of a silicic eruption. Quintela et al. (2025, this conference) studies the internal structure and deformation related to the incremental emplacement of the Slaufrudalur pluton. Work on both these plutons highlighted that essentially nothing was known about the rocks surrounding the plutons. Preliminary geological mapping revealed that the plutons intruded remnants of multiple collapse calderas and central volcanoes not shown on existing maps.

These discoveries spiked new research questions: What is the nature and geodynamic setting of the host rocks? What is their age and structural relationship with the plutons? How quickly were the central volcanoes buried and to what depth before the plutons intruded them? What role did the central volcanoes play in generating the pluton magma? Why are plutons stacked onto pre-existing central volcanoes in a pattern that does not show an age trend related to the distance from the plate boundary? When and at what rate were the plutons exhumed to their current elevation? Why are there no plutons exposed further North? What is the role of the plutons for crustal thickening and exhumation?

Two new research projects address some of these questions: The project "SECRET – Structurally Enhanced Crustal Recycling explains exTensive silicic magma production" (Askew et al., 2025, this conference) was funded by Rannís for 2024-2026. The project studies the age, geochemical, and structural relationship between the Slaufrudalur pluton and surrounding rocks. The project "MIGHTy – Magma-Induced deformation Generates exHumation in exTensional settings" was funded by the Swedish Research Council for 2025-2025-2028. MIGHTy studies the large-scale structure of the area North of Höfn to Àlftafjörður and uses paleomagnetism, structural mapping, and thermochronometry. Both projects benefit from close collaboration with Náttúrufræðistofnun and their concurrent geological mapping of Southeast Iceland in addition to laboratories and expertise at the University of Iceland.

Together, these efforts will hopefully unravel some of the open questions about the geology of Southeast Iceland. Surely, many new and interesting research questions will emerge along the way, and we welcome discussions and contributions.

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Top-down cooling: a heat transport model for the Laugarnes geothermal field

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The Laugarnes field is a low-temperature geothermal resource used for space heating in Reykjavik since the 1930s. Despite production averaging approximately 160 L s^{-1} over the past five decades, reservoir water levels and production temperatures have remained remarkably stable. A detailed review of historical static temperature surveys from wells in the field reveals "top-down" cooling in the upper few hundred meters of the system, which we interpret as evidence of cold recharge from near-surface formations percolating into the deeper, more productive sections of the reservoir. Energy balance calculations incorporating this temperature decline suggest that top-down cooling could account for the field's historical heat output. We further evaluate this process using 3D numerical simulations, successfully replicating both the natural state and production history. Finally, we incorporate this mechanism into a revised conceptual model of the field. These findings indicate that shallow recharge and the associated top-down heat extraction mechanism sustain production in Laugarnes, while also suggesting the presence of a downward-propagating thermal front with potential implications for the field's long-term sustainability. Additionally, these results offer an alternative framework for understanding reservoir processes in Laugarnes and other low-temperature geothermal systems.

Nýtt jarðfræðikort af svæðinu Goðaland-Fimmvörðuháls í vinnslu

Making a new geological map of the Goðaland-Fimmvörðuháls area, south Iceland

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We present the current draft of a new geological map of the Goðaland-Fimmvörðuháls area at 1:10,000 scale. The map is being drawn over the period 2021-2026 as part of EU H2020- and Rannís-funded projects to better understand pre-Holocene mountain building and evolution of Katla and Eyjafjallajökull volcanoes throughout environmental change. The mapping area encompasses several deep canyons that dissect the flank where the two volcanoes converge, revealing a sequence of edifice formation. We combine traditional field mapping with photogrammetry using drone images of the more remote areas and steeper terrain. We have identified key stratigraphic markers, the Þórsmörk ignimbrite and Vedde-composition pumices, within the sequence, which provide important age brackets. In addition, we use $^{40}Ar/^{39}Ar$ and paleomagnetic dating of lavas across the area to build a chronology of volcanic eruptions and landscape evolution.

The mapped sequence represents > 50 kyr of volcanic and glacial history, including the last glacial-interglacial transition. A wide variety of volcanic products preserved in the mapping area reflect eruptions occurring beneath a fluctuating ice sheet with changing hydrological conditions. Extensive hyaloclastite-lava sheets are found at the base of the sequence, indicating subglacial emplacement. Above them is the Þórsmörk ignimbrite. Recent studies of the Þórsmörk ignimbrite have determined an age of ~ 38 ka and deposition in locally ice-free conditions following supraglacial transport from Torfajökull. Various volcaniclastic and glacio-fluvial sediments intercalating the Þórsmörk ignimbrite are indicators of environmental change. Útigönguhöfði and Morinsheiði are two distinctive topographic features in the mapping area and are situated stratigraphically above these lower units. Útigönguhöfði, a prominent peak, is a tuff-dominated mountain intruded by an irregular and fluidal network of columnar-jointed intrusions formed ~ 18 ka. We interpret this formation was emplaced within an ice sheet with a minimum surface elevation of 800 m a.s.l. Morinsheiði is a flat-topped lava delta comprised of pillow lavas that transition laterally to steeply dipping pillow breccia. The lava delta prograded from the west flank of Katla into an englacial lake that was partially confined by Útigönguhöfði and with a minimum surface level ~ 800 m a.s.l. Morinsheiði is capped by ice-confined-to-subaerial lava flows and was formed between 14 and 11 ka. A 250 m-deep, narrow canyon now separates Morinsheiði from the west flank of Katla. Comparable stratigraphy and geochemistry on either side indicate the canyon was formed by very rapid incision since the youngest subaerial Morinsheiði lavas were emplaced, probably facilitated by glacial outburst floods during eruptions in a destabilising ice sheet. A thick sequence of thinly bedded tuff mingled with pillow lava comprises the slope to the Fimmvörðuháls ridge. Field relationships indicate this was emplaced before Morinsheiði, and during a subaqueous eruption. The 2010 Fimmvörðuháls lava caps the sequence and cascades into the dissecting canyons.

Our new mapping and dating are leading to better differentiation of the geology in the northern Fimmvörðuháls area, revealing the great diversity in volcanic product types that comprise the flanks of Katla and Eyjafjallajökull. We show how detailed mapping of polygenetic volcanoes can contribute to paleoenvironmental reconstructions over millennial timescales.

View of the mapping area from the Fimmvörðuháls track. Útigönguhöfði in centre and Morinsheiði to the right. Þórsmörk and Tindfjallajökull in far distance.

Patterns of Uplift around Greenland's Periphery during the Early Holocene

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Around the periphery of the Greenland ice sheet, Global Navigation Satellite System (GNSS) stations have recently recorded ground uplift nearly everywhere, with rates that can exceed 10 mm/yr in some locations. This uplift largely reflects Earth's response to mass unloading due to deglaciation, which has accelerated in recent decades. Uplift rates are fastest uplift along Greenland's southeast coast. It is noteworthy that this region of Greenland passed over the Iceland plume more than 40 Myr ago. If the plume heated the sub-lithospheric rocks here, then the observed rapid uplift may be explained as glacial isostatic adjustment (GIA) that has been accelerated by unusually low viscosity of the nearby upper mantle.

Deglaciation of Greenland at the start of the Holocene also drove coastal uplift of Greenland, and was recorded by various geologic indicators of sea level. Examination of this sea level data can tell us about past uplift rates, which we can also relate to the geological and volcanic history of different parts of Greenland. To measure uplift rates in a systematic way, we fit simple curves to Holocene sea level data from a recently-published compilation, for locations around Greenland. From these curves we placed constraints on uplift rates, which found to be several times faster than modern uplift rates. Circum-Greenland patterns of uplift rates reveal some similarities to patterns of modern uplift rates, but also some differences. The differences may reflect different patterns of early Holocene deglaciation, compared to recent deglaciation induced by modern climate change. The Holocene rates may also help us to infer near-future GIA uplift rates for a deglaciating Greenland.

The mobility of trace metals upon CCS. An experimental study of CO_2 injection at ambient temperature using freshwater and seawater

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Climate change is a global concern. Since the 19th century, the atmospheric CO_2 levels have been increasing, leading to environmental problems such as ice cap melt, ocean warming, and extreme weather events. According to the Intergovernmental Panel on Climate Change (IPCC), it is estimated that to mitigate the impact of the CO_2 emissions and limit global warming to 1.5°C by 2100, 100-1000 Gt of CO_2 needs to be removed from the atmosphere (Rogelj et al., 2018). In 2024, only 49 Mt of CO_2 were removed using carbon capture and storage (CCS) compared to 41 Gt of anthropogenic CO_2 emissions. Therefore, the development and scaling up of CCS is necessary to avoid irreversible consequences of climate change. One of the ways to store emissions underground is to dissolve CO_2 in water and pump it into basaltic subsurface where CO_2 precipitates as carbonate minerals mimicking the chemical weathering process. This methodology was successfully implemented by Carbfix in various geological sites in Iceland (e.g., Matter et al., 2011). Because this technology requires a lot of water to dissolve the CO_2, seawater as an alternative CO_2 solvent has been tested in the laboratory and in the field (e.g., Voigt et al., 2021). In this study, we aim to investigate the trace metal behaviour during the dissolution of basaltic rock in freshwater and seawater under controlled temperature and pH conditions. Different parameters like relative mobility and leaching rates allow to identify the behaviour of trace elements during the fluid-rock interaction. This understanding is important for the environmental assessment of CO_2 injection into the subsurface. The rock powders used in the experiment were collected from the drill cuttings of the potential injection well CSI-01, located in Straumsvík area, southwest of Hafnarfjörður. The area is the proposed storage site for the Carbfix's Coda Terminal project where CO_2 from Europe will be received and injected into the bedrock. The terminal is projected to gradually increase the injection of CO_2 over the years, reaching 3Mt annually in 2032. Here, both freshwater and seawater will be used for the CO_2 dissolution.

Three flow through Teflon reactors were used for dissolution of rocks in fresh and seawater. These rocks represented three lithologies in Straumsvík: 1) glass basalt, 2) fine grain basalts and 3) sediment. The experiments ran for approximately 5 weeks at a constant pH of 3 at ambient temperature. The process tried to mimic the water rock interaction occurring at depth upon CO_2 injection. The mineralogical composition of the samples from the CSI-01 well consisted of clinopyroxene, Ca-plagioclase, olivine, glass fragments, ilmenite, magnetite and zeolites. Throughout the experiment, most of the elements decreased in their concentrations in the sampled water during the first 16 days, followed by a steady decrease. After approximately 21 days, the rock powder attained steady-state of the elemental leaching rates (Figure 1). The steady-state values were higher for the fine grain basalt and glass basalt compared to sediment, although they followed the same trend. From the trace elements Mn, B, Ti, Ni, Cr, Cu, Zn and Sr showed slightly higher leaching rate compared to the other trace elements. Only Al, Fe, Mn and Cu exceeded the environmental limits guidelines for drinking-water as defined by The World Health Organization (WHO) and the Icelandic Ministry of Environment limits for metals in surface water category III. Concentrations of the other trace metals were below the guideline values during the experimental duration. The outcome of this study shows that the potential risk associated with the mobilization of the metals in freshwater during the CO_2 injection into basalts is relatively low. Further study will reveal if the same applies to the seawater as the reactive solution.

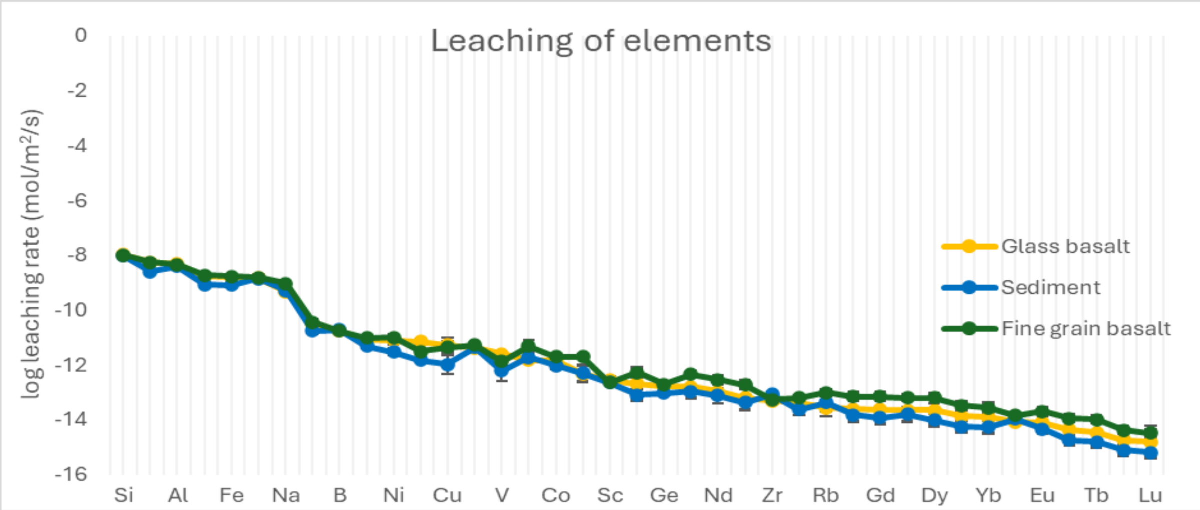

Figure 5. Leaching rates of elements for the three different lithologies. Glass basalt, fine grain basalt and sediment. Both basaltic rocks display higher leaching rates than the sediment and follow a similar release trend, being the major elements with higher leaching values, followed by trace elements and REE's with the lower leaching rate

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Non-double-couple earthquakes in Krafla 2020-2024

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The Krafla central volcano is one of five active volcanic centers of the Northern Volcanic Zone (NVZ) in NE Iceland. It is approximately 20 km in diameter, with a 90 km long, NNE-SSW trending, rifting fissure swarm extending through it. The central volcano has developed an eroded and partly filled caldera, and within the caldera structure is a NW-SE elongated high-temperature geothermal area, closely associated with a magma domain delineated at ~3-7 km depth by an S-wave shadow during the Krafla Fires in 1975-1984. This magma domain is interpreted to represent a network of basaltic sills and intrusions, further evidenced by the drilling of wells KJ-39 and IDDP-1 in Krafla, which both encountered rhyolitic magma.

Seismicity within the NVZ is mostly confined to the central volcanoes, often spatially coinciding with the known high-temperature geothermal areas. In Krafla, seismic monitoring dates to the early seventies. In 2006, Iceland GeoSurvey (ÍSOR) installed the first seismic stations of a permanent network, operated for Landsvirkjun, that today consists of 12 seismic stations within the caldera, both surface and borehole sensors. Seismic monitoring by Landsvirkjun and ÍSOR has provided a large and consistent catalogue of earthquakes in Krafla, which enables us to analyse long term changes in seismicity.

The seismic characteristics of Krafla are defined by a rather constant rate of micro-earthquakes with majority of events of $M_L < 1.0$. Seismicity occurs within four spatially separated clusters, separated by areas of little or no seismicity. Three of the clusters originate within the fissure swarm transecting Leirhnjúkur, aligning with the path of dike intrusions during the Krafla Fires, while the largest and most seismically active cluster is confined to the geothermal well field, slightly east of the fissure swarm. Seismicity is almost non-existent within other parts of the caldera, except during rifting episodes. Earthquake depth distribution suggests that the brittle-ductile transition (BDT) in Krafla is very shallow, at around 2 km b.s.l., compared to other areas in Iceland.

Focal mechanisms in Krafla are indicative of the local stress field, and the majority of calculated mechanisms display radiation patterns consistent with a double-couple source model, i.e., events that are caused by shear slip along a planar fault surface. While normal, thrust and strike-slip shear events are intermixed, most mechanisms exhibit normal to oblique normal faulting characteristics.

Some earthquakes, however, are caused by a volumetric change, instead of shear slip, and are referred to as non-double-couple in the literature. Such events are rare observations but have nonetheless been reported from a few volcanic and geothermal areas in Iceland for the last decades, such as Krafla. Here, we present over 100 pure, non-double-couple earthquakes observed in Krafla from 2020 to 2024. These non-shear faulting events involve either positive (explosive) or negative (implosive) volume change. Interestingly, all non-double-couple events in Krafla occur at the deeper end of the depth range, i.e., close to or at the BDT, or the expected melt-rock interface, which suggests that geothermal fluids play an important role in their source processes.

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Mörg af eldfjöllum Íslands eru að verulegu leyti hulin jökli. Þetta flækir mjög beinar mælingar jarðskorpuhreyfingum þessara eldfjalla þar sem þær oft einskorðast við fjallsrætur eða stöku jökulsker sem sýna ekki endilega hreyfingu áhugaverðustu svæðanna. Þannig er því varið fyrir Bárðarbungu. Beinar mælingar á hreyfingu hennar út frá gervihnattamyndum (bylgju-víxlmyndum) ná bara yfir neðra hluta fjallshlíðanna að norðvestanverðu og í sömu hlíðum eins ofarlega og hægt er rekur Veðurstofan GNSS-stöð á Kistu. Ekki er hægt að gera slíkar mælingar á föstu landi, á öskjubrúnunum eða innan öskjunnar. Í Holuhraunsgosinu 2014–2015 seig gólf Bárðarbunguöskjunnar um röska 60 m þar sem mest var undir ~800 m þykkum ís. Á meðan á öskjusiginu stóð var rekin GNSS-stöð (BARC) á jökulyfirborðinu í miðri öskjunni, enda voru aðstæður að því leiti einstakar að hreyfingar jarðskorpunnar undir jöklinum voru mun hraðari en hreyfingar jökulsins af öðrum sökum. Eftir að siginu lauk var rekstri stöðvarinnar hætt enda kostnaðarsamt og auk þess talið ómögulegt að greina hreyfingar skorpunnar frá öðrum hreyfingum jökulsins því þær væru aftur orðnar mun stærri en jarðskorpuhreyfingarnar. Upplýsingar um það hvort eða hversu mikið öskjugólfið hefur hreyfst í tengslum við verulega og vaxandi jarðskjálftavirkni í Bárðarbunga eftir Holuhraunsgosið hefur því verið byggð á óbeinum mælingum á hreyfingunni fengnum með endurteknum þyngdarmælingum. Þessar mælingar sem Magnús T. Guðmundsson og Þórdís Högnadóttir hafa gert, gefa til kynna verulegt ris öskjugólfsins af stræðargráðunni metrar á ári. Vorið 2015, eftir Holuhraunsgosið, voru gerðar umtalsverðar íssjármælingar yfir Bárðarbunguöskjunni. Til að ná beinni mælingu á hæðarbreytingum öskjugólfssins síðan þá var ákveðið vorið 2024 að endurmæla þau íssjársnið. Að auki var ákveðið að reka að nýju sumarlangt GNSS-stöðina BARC á sama stað áður. Í erindinu verður sagt frá niðurstöðum þessara nýju mælinga. Endurteknu íssjármælingarnar staðfesta túlkun þyngdarmælinga um verulegt ris öskjugólfsins. Þar sem það er mest, á svipuðum slóðum og mesta sígið í Holuhraunsgosinu, gefa ísjármælingarnar til kynna 1–2 m ris á ári að jafnaði frá 2015. Færslur sem mældust í GNSS-stöðinni BARC gefa til kynna að nokkur hluti þessa riss sé tengt stærstu skjálftunum í Bárðarbungu, en stöðin lyftist um 16 cm og hreyfðist lárétt um 14,5 cm til SV í jarðaskjálfta af stærðinni 5,0 M þann 3. september 2024.

Refining the age of Iceland´s Saksunarvatn Ash: new constraints on the G10ka Series

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The Saksunarvatn Ash, originating from the Grímsvötn volcanic system in Iceland, is a prominent and widespread tephra layer in the North Atlantic. However, due to the Grímsvötn system's frequent Early Holocene eruptions with consistent geochemical composition, both the number of the contributing eruptions and the age of the Saksunarvatn Ash has been debated. Recently, the characteristically thick and dark colored basaltic ash layer has been suggested to reflect 13 phases of eruption, spanning 1,000 years, between 10,400 and 9,400 cal. yr BP. We review and quality assess previously published age constraints on the Saksunarvatn Ash derived from marine, lacustrine and soil archives from the North Atlantic. Furthermore, we introduce eight new, well dated proximal locations (distributed around Iceland). Age constraints are added to the lower and upper bounds of the distinct tephra with radiocarbon dated macrofossils collected precisely ($\leq$3 cm) from the boundaries. We further constrain the age of the distinct Early Holocene tephra with two robust lake record age depth models (located East and West of Grímsvötn) as well as two independently dated silicic Early Holocene tephra marker layers, Askja S and Reitsvík 8 (approximately 10.8 and 10.0 cal. ka BP, respectively). We place these age constraints in hand with ice core data and ultimately suggest a refined age for the marker layer. We find no evidence of a Grímsvötn tephra being deposited between Askja S and *c.* 10.2 cal. ka BP. Furthermore, the Reitsvík tephra overlays the Saksunarvatn ash both in the east and west of Iceland suggesting the G10ka eruption(s) from the Grímsvötn system had ended prior to 10.0 cal. ka BP.

Heat released by steaming to the atmosphere by boiling of groundwater in effusive fissure eruptions during the 1975-1984 Krafla fires, Iceland

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The heat transfer dynamics in volcanic geothermal areas determine the options for geothermal energy exploration. Intrusive and eruptive events provide thermal energy into the geothermal system, as cooling and solidification of the magma heats the surrounding host rock and water in the porous matrix. The associated evaporation of the water leads to convection and an advective rise of steam in the fissures. Steam rises further and diffuses into the atmosphere depending on wind conditions. The heat lost by steam released to the atmosphere is in many cases one of the significant parameters that determine the heat budget of a geothermal system. In this study, we analyzed the size of steam clouds in a series of air photos taken during the Krafla fires to determine heat released by steaming. This was compared to the total heat input of the part of the composite dyke that was formed within the Krafla geothermal system. The geometrical parameters of the dyke were estimated by previous seismic and geodetics studies.

The Krafla fires describe a period of volcanic activity at the Krafla volcano in North-East Iceland from 1975 to 1984 with nine volcanic eruptions and several more intrusive events. They were associated with approximately 10 m widening the plate boundary within the Krafla caldera, where a high-temperature geothermal system is located. The rifting resulted in the formation of a composite dyke with an estimated volume within the geothermal reservoir of 0.18-0.41 km^3, releasing thermal energy of $0.6\text{-}1.4 \times 10^{18}$ J. The method of Hochstein and Bromley (2001) for assessing heat loss to the atmosphere by steaming, was tested in 2024 at selected locations in the Krafla area where steam flow could be measured directly. The results verified the applicability of the method at Krafla, where effects of e.g. variations in air humidity for the range of values observed are minor. Analyses of vertical air photos obtained at Krafla several times in the period 1976-1985, notably during and after the eruptive events, show that steaming was mainly prevalent in the vicinity of the eruptive fissures. The heat loss to the atmosphere within the geothermal area was ~0.9 MW/m during eruptions, declining to a more long-term value (~0.05 MW/m) in 50-100 days. This enhanced steaming after the dyke injection/ eruption is considered to be caused by the interaction of the groundwater/shallow geothermal fluid with the uppermost 100-300 m of the dyke and appears to account for about one-third of the total heat lost in this way to the atmosphere. The remaining two-thirds were lost gradually throughout the Krafla fires. The total heat lost to the atmosphere (5-10% of the total energy) was an order of magnitude smaller than the thermal energy added to the geothermal reservoir by the dyke (similar to 90-95% of the total energy).

Efnafræði jarðhitavatns við Skoresbysund

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Jarðhita á yfirborði er ekki víða að finna á Grænlandi. Heitar laugar og volgrur finnast þó, einkum á basaltsvæðum Grænlands, við Skoresbysund á austurströndinni og á Diskóeyju á vesturströndinni. Litlar rannsóknir hafa verið gerðar á möguleikum til jarðhitanýtingar á Grænlandi. Árið 2005 gerði ÍSOR frumathuganir á nýtingarmöguleikum jarðhita á Diskóeyju við vesturströnd Grænlands, en ekki varð framhald á þeim rannsóknum, né heldur leiddu þær til jarðhitaborana eða nýtingar. Í ágúst 2022 fóru höfundar þessa erindis í rannsóknarferð til Ittoqqortoormiit á Austur-Grænlandi til að kanna jarðhita þar í grennd. Þorpið Ittoqqortoormiit, sem áður hét Skoresbysund, stendur við botn lítillar víkur á norðurströnd Skoresbysunds (Kangertittivaq). Í þorpinu, sem er ein afskekktasta byggð Grænlands, búa rúmlega 300 manns.

Skammt frá Ittoqqortoormiit, á Tóbínhöfða, er heitasta þekkta laug Grænlands, Uunarteq, um 60°C heit með afrennsli rúmlega 1 L/s. Um 2 km í ANA, handan við litla vík, er önnur laug, Uunarterajik, sem er um 33°C heit með afrennsli um 1 L/s en þar í kring vætlar talsvert heitt og volgt vatn til sjávar, heitast um 45°C. Að auki eru jafnan vakir í lagnaðarís undan Uunarterajik að sögn heimamanna, sem bendir til þess að heitt vatn komi einnig upp undan ströndinni. Hinu megin við þorpið í Ittoqqortoormiit er yfirgefin byggð á Vonarhöfð (Itterajivit) og þar í nágrenninu eru einnig nokkrar volgrur, með hitastig allt að 16°C og heildarafrennsli um 1-1,5 L/s. Skammt undan fannst vatnsmikil lind með hitastig 6°C og metið afrennsli 20-25 L/s. Þótt það geti ekki talist heitt vatn, er þó greinileg velgja í vatninu enda grunnvatnshiti á svæðinu aðeins um 3°C. Í leiðangrinum 2022 var alls sjö sýnum safnað úr öllum ofangreindum laugum og volgrum, og auk þess bæði af köldu lindarvatni og yfirborðsvatni til samanburðar.

Vatnið í laugunum á Tóbínhöfða er salt; sýnið úr heitustu lauginni (Uunarteq) hefur klóríðstyrk um 5400 mg/L en kaldari laugarnar (Uunarterajik) hafa klóríðstyrk um 4000 mg/L. Kísilstyrkur er tæplega 70 mg/L í heitustu lauginni en tæplega 60 mg/L í þeim kaldari. Vottur af brennisteinsvetni greinist í vatninu og radonvirkni mælist 13-67 Bq/L – og lækkar með hækkandi hitastigi. Vatnið úr heitustu lauginni er snauðara að tvívetni en kalt yfirborðsvatn á svæðinu ($\delta D \approx -122‰$ samanborið við -105‰). Þar eð sjór hefur $\delta D \approx 0‰$ er ósennilegt að seltan í laugarvatninu sé að teljandi hluta tilkomin vegna blöndunar við sjó. Útreikningar á steindajafnvægi gefa einnig til kynna að ekki sé um að ræða blandað vatn heldur þroskað jarðhitavatn. Djúphiti vatnsins reiknast á bilinu 85-90°C (miðað við jafnvægi við kalsedón). Hins vegar benda bæði efnastyrkur og samsætuhlutföll til þess að vatnið úr kaldari laugunum geti verið blanda af vatni úr heitustu lauginni og fersku yfirborðsvatni/úrkomu. Djúphiti reiknast um 80°C. Vatnið hentar til hitaveitu með varmaskiptum.

Í volgrum og lindum við Vonarhöfða (Ittaajimmiit) er hins vegar ósalt vatn, með klóríðstyrk á bilinu 2-14 mg/L, sýrustig hærra en 9 og kísilstyrk 20 mg/L eða lægri. Það er léttara en vatnið á Tóbínhöfða, með $\delta D \approx -130‰$, og radonvirkni er nærri 5 Bq/L. Þótt á vatninu séu fremur skýr jarðhitamerki gefa efnahitamælar ekki væntingar um mikið hærra hitastig þótt leitað væri dýpra. Vatnið í heitustu volgrunni reiknast nærri jafnvægi við steindir á borð við kalsít og kalsedón. Segja má að volga vatnið við Vonarhöfða sé líkara volga vatninu á Diskóeyju hinu megin á Grænlandi en laugunum á Tóbínhöfða sem eru aðeins 15 km austar. Kalda vatnið er efnasnautt og virðist ágætt neysluvatn.

The pre-injection characterization of the Coda Terminal CO_2 storage site, Iceland

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The underground CO_2 storage using the Carbfix technology relies on neutralization of the injected acidic CO_2-charged water through its interaction with basalt. The CO_2 solubility and alkalinity trapping and subsequent carbonate mineral precipitation has been confirmed in projects that utilized this technology (e.g., Matter et al., 2016; Clark et al., 2020). Unfortunately, CO_2 storage through carbon mineralization has only marginal contribution into the CCS activities. The current global operating CO_2 capture capacity is 51 Mt/y with 80% of the captured CO_2 used for enhanced oil recovery (Global CCS Institute, 2024; Zhang et al., 2024). To increase the role of carbon mineralization, a substantial expansion in the number of projects is necessary. One example is the Coda Terminal project, located in Straumsvík, within the Hafnarfjörður municipality in southwest Iceland. Preparations for the project began in 2021 on the frontend engineering design, licensing processes and reservoir characterization. Full-scale injection of 3 $MtCO_2$ is planned to be reached in 2032.

The bedrock of the storage reservoir in Straumsvík consists of five lithological units: Holocene basaltic lava flows, basaltic lavas, glassy basalts, hyaloclastites and sediments. These layers exhibit similar mineralogical and petrological characteristics. To date, seven wells have been drilled in the injection area intersecting all but the hyaloclastites. The deep wells include the injection well CSI-01 with a vertical depth of 982 m, and two monitoring wells CSM-01 and CSM-02 with depths of 618 and 700 m, respectively. The main minerals identified in the collected drill cuttings are plagioclase, pyroxene, olivine, zeolites (analcime, chabazite, clinoptilolite) and quartz. The average oxide content of divalent cations for CaO, MgO, and Fe_2O_3 is 11, 9, and 12 wt%, respectively and it is similar to the composition of the host rock in storage sites currently operated by Carbfix.

Major feed zones in the wells were identified below 300 m depth based on well logging data and step rate injection tests. The water discharged from CSI-01 is saline with a conductivity of approximately 40,000 µS/cm. In contrast, water from the main feed zones in CSM-01 and CSM-02 ranges from fresh to brackish with a conductivity of 600-1000 µS/cm. Samples collected at various depths in CSM-01 and CSM-02 using a deep sampler show chemical composition different from the composite water discharged from the wells. The dissolved elemental ratios in the water indicate a substantial depletion of B and Na relative to Cl in brackish to saline samples compared to seawater. In contrast, an enrichment in B and Na relative to Cl is observed in fresh samples. Enrichment in Ca relative to Cl is seen in both fresh and saline samples.

The results of the reaction path models carried out to assess the potential of CO_2 mineralization in the Coda storage reservoir show that the predicted water chemical compositions and secondary minerals are similar to what has previously been observed during basalt weathering and its low temperature alteration. Mixing of the CO_2 injection water and the chemically variable reservoir water does not affect the overall chemical and mineralogical trends and mineralization efficiencies. The results of the simulations confirm high CO_2 mineralization potential with up to 100% of the injected CO_2 mineralized as calcite. However, the spatial and temporal evolution of this modelled process is unknown.

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The contribution of tectonic stress as a driving mechanism for dike emplacement in an oblique rift setting: The February-March 2021 Fagradalsfjall dike

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Repeated dike-intrusions often occur in zones where extensional stress has accumulated. In such situations, surface-deformation models can be employed to infer the dimension and orientation of the forming intrusion. However, although this provides information about the possible location and geometry of a dike, the models typically do not provide direct information on the processes driving magma emplacement, e.g. if a dike is driven largely by magmatic overpressure or tectonic stress.

We explore here the contribution of tectonic stress as a driving mechanism for dike opening in a three-dimensional viscoelastic Finite-Element deformation model. We use the February-March 2021 dike at Fagradalsfjall on the Reykjanes Peninsula, SW Iceland, as a case study due to detailed observations of pre- and co-diking surface deformation. In our model, tectonic stress first accumulates due to oblique plate motion over a time period of 800 years and is then partially released by the opening of a two-segmented dike. We find that the model can largely reproduce observed surface deformation without requiring magmatic overpressure if the dike releases approximately 60% of the previously accumulated stress through a mixture of opening and shearing of the dike plane. Partial release of tectonic stress is consistent with the emplacement of three subsequent dikes between 2021-2023. Furthermore, a large contribution of tectonic stress compared to magmatic overpressure is consistent with low initial eruptive flow rates, widespread triggered seismicity and distributed shallow fault movements. Our model helps to better understand volcanotectonic interaction in the onset of a magmatic rifting episode.

"Is the Western Volcanic Zone still spreading? A geodetic model of plate motion in South Iceland",

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The Western Volcanic Zone (WVZ) is one of the volcanic zones in Iceland and has been active since approximately 7–9 Ma, when the spreading ridge jumped from the Snæfellsnes Volcanic Zone (SVZ), forming the WVZ and the Reykjanes Peninsula Rift (RPR). Over the past 1.5–3 Ma, volcanic activity and deformation in the WVZ has dwindled as the Eastern Volcanic Zone (EVZ) developed. Various estimates of spreading rate have been put forth in recent decades, based on geodetic data, ranging from 2.5 to 7.1 mm/yr. Up to 35 documented post-glacial eruptions have occurred throughout the WVZ, including in its northernmost part where the spreading rate is very low. The most recent eruption occurred around 782– 860 AD, when Hallmundarhraun erupted in the northern section of the WVZ. In this study, we investigate whether spreading is still occurring over the WVZ and at what rate. We use GNSS and InSAR data together with the elastic block model TDEFNODE to run inversion models solving for spreading rate and locking depth in the WVZ. The GNSS data, which span 1992 to 2025, are processed using the GIPSY-OASIS II software. A major problem for assessing the spreading rate across the WVZ is deformation from various additional sources, such as earthquakes, magma movements, anthropogenic subsidence due to geothermal power plants, as well as glacial isostatic adjustment (GIA) due to retreating ice caps, all of which can lead to some bias in the results. To avoid co-seismic and co-eruptive displacements associated with the current tectonic event in the Reykjanes Peninsula, the GNSS sites located in and around this region were truncated at 2020.0. The InSAR data for Reykjanes Peninsula was also excluded for the same reason. We also correct for transient deformation signals recorded between 1992 and 2020, such as the 2000 eruption in Hekla and subsequent inflation, both the 2000 and 2008 South Iceland Seismic Zone earthquakes, the March 2010 eruption at Eyjafjallajökull, and the 2014–15 Holuhraun eruption. Preliminary results using only uncorrected GNSS velocity fields suggest that spreading across the WVZ is less than 4 mm/yr. Inversion models using the corrected GNSS velocity field and InSAR data will provide a more accurate estimate of the spreading rate across the WVZ. A strain map for western Iceland will be made to delineate the most likely plate boundary for WVZ. Most magmatic and tectonic activity occurs in the southern part of the WVZ. This includes the eruption at Nesjahraun and the Sandey cinder cone in Þingvallavatn around ~70 AD, as well as possible rifting episodes in 1339 and 1789. Seismic activity continues within the WVZ, particularly in the Hengill volcanic system, which saw intense seismic activity between 1993 and 1998, and more recently due to the reinjection of geothermal fluids from nearby geothermal power plants. Interestingly, the SVZ experienced renewed volcanic activity around 2 Ma, despite tectonic activity ceasing 7–9 Ma. This suggests that volcanic activity in the WVZ could persist long after plate spreading there nears zero.

Basísk sprengigos á jökulþakta hluta Bárðarbungukerfis og gjóskustabbinn á Vikrakambi

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Bárðarbungukerfið er er stærsta eldstöðvakerfi landsins, um 190 km langt og allt að 25 km breitt (1). Það skiptist í megineldstöðina Bárðarbungu og tvær sprungureinar, Veiðivatnarein til SV og Dyngjuhálsrein til NA. Um 70 km af eldstöðvakerfinu, megineldstöðin og hluti sprungureinanna beggja vegna (frá syðstu Holuhraunsgígum að Kerlingum í Tungnaárjökli), eru undir norðvestanverðum Vatnajökli. Bárðarbunga rís um 2000 m y.s. og í henni er ísfyllt 65 km^2 askja (2).

Eldgosasaga Bárðarbungukerfis er nokkuð vel þekkt vegna kortlagninga á hraunum og gjóskulögum. Eldgos á jökulþekta hluta Bárðarbungukerfis eru sprengigos sem skilja eftir gjóskulög í jarðvegi, setlögum og jökulís. Færa má rök fyrir að yfir 400 slík sprengigos hafi orðið undir jökli á síðustu 11.000 árum (3-5).

Efnafræðileg einkenni Bárðarbungukviku eru þekkt og því er hægt að tengja gosefnin við Bárðarbungukerfið með efnagreiningum (6). Þetta er mikilvægt fyrir sprengigosin og gjóskulögin því gosstöðvarnar eru huldar jökli og varðveisluskilyrði fyrir gjósku innan 50 km frá Bárðarbungu (miðri) eru nánast hvergi nema í Nýjadal – í um 30 km fjarlægð.

Sprengigos á jökulþakta hluta Bárðarbungukerfis – örstutt gossaga

Á sögulegum tíma eru þekkt um 25 basísk sprengigos á jökulþakta hluta Bárðarbungukerfis (gjóskulagarannsóknir og heimildir (7)). Mörg gjóskulaganna hafa aðeins fundist í ísnum í Vatnajökli, aðeins stærstu gjóskulögin bárust út fyrir jökulinn og ógróin eða uppblásin svæði umhverfis hann. Gjóskulög sem koma fram á leysingasvæðum Vatnajökuls, í 400 m löngum borkjarna á Bárðarbungu og jarðvegssniðum hafa verið efnagreind, alls 23 lög en tvö gos eru aðeins þekkt af heimildum. Fimm sprungugos á Bárðarbungukerfi utan Vatnajökuls urðu a sögulegum tíma, tvö þeirra voru sprengigos vegna hárrar vatnsstöðu (877, 1477) og þrjú flæðigos (á 13. öld, 1862-4, 2014-15).

Flest gos á jökulþakta hluta Bárðarbungukerfis síðustu 11 aldir virðast hafa verið fremur lítil. Til þess bendir hátt hlutfall Bárðarbungugjóskulaga sem eingöngu finnast í ís í Vatnajökli og fátæklegar frásagnir annála/gamalla heimilda benda til hins sama. Þrjú af hverjum fjórum gjóskulögum frá sögulegum tíma finnast eingöngu í ísnum í Vatnajökli. Gjóskulögin segja þó aðeins hve stór hluti gosefna náði upp úr jöklinum. Gostíðnin á jökulþakta hlutanum er 1-4 gos á öld nema á 18. öld þegar gosin eru a.m.k. 12 talsins.

Stærstu gjóskulög úr sprengigosum á jökulþakta hluta Bárðarbungukerfis eru úr gosum um 950 og 1717. Með samanburði við þykktardreifingu Grímsvatnagjósku frá 2011 má álykta að nýfallin gjóska í gosinu 1717 hafi verið 0,6-0,8 km^3. Gosin geta staðið með hléum í nokkrar vikur eða mánuði.

Þykkt (~3 m) og gróft gjóskulag liggur á hæðarkambi milli Bálkajökuls og Bárðarjökuls VNV í Bárðarbungu (7). Gjóskan hefur efnasamsetningu Bárðarbungukerfis og grófleiki bendir til nálægra gosstöðva. Útlit og varðveisla bendir til fremur ungs aldurs og því var kannað hvort þetta gjóskulag tengdist hugsanlega tímasettum gosum og/eða hlaupum. Sérstaklega var athugað hvort gjóskulagið tengdist gosi á Bárðarbungukerfi 1766, en það sumar voru vatnavextir í Þjórsá taldir stafa af hlaupum í Tungnaá (8). Einnig hvort gjóskulagið gæti tengst gosi á Bárðarbungukerfi 1716, en þá barst gjóska til NV. Ekki tókst að sýna fram á tengsl við gos á sögulegum tíma með tiltækum gögnum. Líklegast er að það tengist um 1300 ára gömlu gjóskulagi í Nýjadal.

Gjóskustabbinn á kambinum sem við viljum kalla Vikrakamb. Horft til vesturs yfir Vonarskarð.

Á forsögulegum tíma eru gjóskulög varðveitt í jarðvegi og setlögum en upplýsingarnar verða slitróttari með hækkandi aldri (3-5). Alls hafa fundist um 100 gjóskulög með einkenni Bárðarbungukerfis, þau elstu um 11.000 ára. Sé notað sama hlutfall og gilti um gos á sögulegum tíma gætu gos á jökulþöktum hluta Bárðarbungukerfis hafa verið um 400 á 10.000 árum eða 4 gos á öld að jafnaði. Hér þarf að hafa í huga að jökulþakti hlutinn hefur verið breytilegur að stærð og í upphafi Nútíma var mikil jökulþekja. Stærstu forsögulegu gjóskulögin voru af svipaðri stærð eða ívið stærri en G-2011 (9) miðað við þykktardreifingu í 50-100 km fjarlægð.

Nákvæm lega gosstöðva á jökulþakta hluta Bárðarbungukerfis er ekki þekkt í neinu gosi á sögulegum tíma þótt til séu mið á gosmökk og leiðir jökulhlaupa vegna gosa séu þekktar í nokkrum tilfellum. Sama gildir um gos á forsögulegum tíma. Upptök þykka og grófa gjóskulagsins við jökuljaðarinn norðvestan í Bárðarbungu eru í fárra kílómetra fjarlægð og gætu tengst „gígaröð“ sem er að koma í ljós í norðvesturhlíð hennar. Gígleifar, sem flust hafa með ísskriði að jaðri Dyngjujökuls við Urðarháls, mynda þar mikla gjóskumúga. Afstaða þeirra til þekktra gjóskulaga bendir til goss á 16. öld.

Jökulhlaup geta gefið vísbendingar um gosstöðvar. Með örfáum undantekningum hafa öll þekkt jökulhlaup vegna eldvirkni á Bárðarbungukerfi komið í Jökulsá á Fjöllum, eitt kom líka í Skjálfandafljót og eitt olli vatnavöxtum í Þjórsá (8). Það þýðir að sprengigos sem valda hlaupum verða flest austantil á jökulþakta hluta kerfisins eða tengjast öskju Bárðarbungu. Forsöguleg hlaup í Jökulsá á Fjöllum sem tengjast eldvirkni á Bárðarbungukerfi eru þekkt frá tímabili fyrir ~7000 árum þar til fyrir um 2000 árum – hér er átt við hlaup sem báru fram glerríkt set með einkennum Bárðarbungukerfis, en glerið í setinu hefur sömu einkenni og gjóskulög frá sama tímabili (10-11). Ummerki eftir 20 hlaup eru þekkt, 18 eru frá tímabilinu 7100-4100. Mat á hámarksrennsli er á bilinu 30-100 þúsund m^3/s. Flest forsögulegu hlaupin eru frá tímabili þegar jöklar voru í lágmarki, litlir eða engir nema e.t.v. á hæstu fjöllum. Basísk sprengigos þurfa vatn eða ís. Það bendir sterklega til að gosin sem ollu hlaupunum hafi verið í megineldstöðinni Bárðarbungu, annað hvort í hlíðum hennar eða í öskjunni sjálfri.

1) Haukur Jóhannesson og Kristján Sæmundsson 1998. 2) Magnús T. Guðmundsson o.fl. 2016. 3) Bergrún A. Óladóttir o.fl. 2011. 4) Esther R. Guðmundsdóttir o.fl. 2016. 5) M. Wastl 2000. 6) Sveinn P. Jakobsson 1979. 7) Guðrún Larsen o.fl. handr. 8) Sigurður Þórarinsson 1974. 9) Magnús T. Guðmundsson o.fl. 2012. 10) R.B.Waitt 2002. 11) Guðrún Larsen o.fl. inns.

Hvað tefur Heklu?

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Sprengigos Heklu stafa af uppsöfnuðu gasi í kviku fyrir gos og mynda gjósku. Færa má rök fyrir að minnkandi rúmmál gjósku síðustu fimm gosa Heklu stafi af minnkandi samsöfnun gass fyrir hvert gos. Ekki er hægt að safna og efnagreina gas í sprengigosum. Þess í stað má mæla uppsöfnun á samsætunni ^{210}Pb í gosefnum Heklu sem endurspeglar uppstreymi, samsöfnun og geislavirkt niðurbrot eðalgassins radons (^{222}Rn). Radon-222 myndast við klofnun ^{226}Ra í ^{238}U-keðjunni og klofnar síðan sjálft og myndar 210Pb, m.ö.o. (^{238}U) ->… (^{226}Ra) -> (^{222}Rn) -> … (^{210}Pb). Geislavirkni hverrar samsætu (táknað með sviga utan um samsætuna) er ein og hin sama þegar keðjan er í jafnvægi og því hlutfallið samsæta, t.d. (^{210}Pb/^{226}Ra), jafnt og 1. Ef radon tapast með öðrum eldfjallagösum úr kviku verður (^{210}Pb/^{226}Ra) < 1 í afgasaðri kvikunni og > 1 í gasinu. Ef ^{222}Rn nær aftur á móti að safnast saman og rísa með gasblöðrum upp í efstu lög kvikunnar þá mun það brotna niður (helmingunartíminn er aðeins 3,8 dagar) og mynda ^{210}Pb. Hlutfallið (^{210}Pb/^{226}Ra) yrði því > 1 gasríkri kvikunni.

Til að sannreyna þá vinnukenningu að Heklugos hefjist vegna uppsöfnunar á eldfjallagasi hafa hraun og gjóska úr Heklugosum frá 1947 verið tekin til mælinga á skammlífum samsætum ^{238}U-keðjunnar. Öll hraunin eru í geislavirku jafnvægi og sama á við um gjósku úr gosum frá og með 1980. Aftur á móti hefur fyrsta gjóska gosanna 1947 og 1970 hlutfallið (^{210}Pb/^{226}Ra) > 1, sem bendir til uppsöfnunar á gasi fyrir gos. Hvers vegna gjóska yngri gosa hefur ekki mælanlegt geislavirkt ójafnvægi er líklega vegna stutts goshlés, sem væri of stutt fyrir nægjanlega radon uppsöfnun.

Vitað er að vegna skamms helmingunartíma eru fá radon atom í kvikunni og að því nær radon ekki að mynda eigin gasblöðrur. Því er talið að blöðrur fylltar CO_2 flytji radon af einum stað til annars í kvikunni. Hraunin öll hafa hlutfallið (^{210}Pb/^{226}Ra) = 1 og því hefur ^{222}Rn hvorki tapast úr né bæst við kvikuna sem rann sem hraun. Líklegast verður því að telja að uppsafnaða gasið komi enn dýpra að eða frá basaltmóðurkviku þeirrar ísúru sem Hekla gýs. Einfalt líkan á myndun (^{210}Pb) > (^{226}Ra) í gjósku Heklu bendir til minnkandi uppstreymis radons (og þar með CO_2) sem fall af tíma, sem kann að skýra samtímis minnkandi rúmmál gjósku. Jafnframt má leiða líkur að því að endurnýja þyrfti gasforða djúpstæða basaltsins fyrir næsta Heklugos.

Controls of ice-surface structures during the 1991 surge of Skeiðarárjökull, Iceland, on the post-surge glacial landsystem

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Investigations of surge-type glaciers are important for understanding glacier dynamics and providing analogues to modern and palaeo-ice streams. However, the link between surge-related surface structures to a post-surge glacier landsystem is poorly understood. This study investigates the influence of ice surface structures during the 1991 surge of Skeiðarárjökull on the post-surge glacial landsystem, using accessible imagery and data from 1991 and 2012. The research is focused on the western limits of Skeiðarárjökull and its forefield, where surge-suggested landforms are well preserved. Common features in the forefield of Skeiðarárjökull include an end moraine, hummocky moraine, flutings, drumlins, eskers, and crevasse-squeeze ridges. The structural architecture of the western frontal margins reveals a complex network of crevasses, grouped into distinct domains based on orientation, where longitudinal crevassing is the dominant feature on the ice surface. A lateral shear margin is proposed at the interface between the surge lobe and passive ice, causing the observed counterclockwise rotation in longitudinal crevasses. Additionally, thrust and normal faults are identified and discussed in context of surge dynamics. A correlation is observed between the proximity of thrust faults during the surge to hummocky moraine in the post-surge landsystem. Based on these findings, a conceptual model is proposed, where the surge-driven thrusting is a control on the formation and development of the hummocky moraine in the forefield of Skeiðarárjökull.

Saga jökulhörfunar á Mið-Norðurlandi

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Fyrir um 23 000 árum (cal. ka BP) gekk meginjökull Íslands vestur yfir Rosmhvalanes við Faxaflóa í átt að ystu brún hans á síðasta jökulskeiði (LGM). Ummerki um mestu stærð hans er að finna á landgrunnsbrúninni umhverfis landiðog styðja líkanreikningar einnig þessa stærð hans. Ekki er vitað hve lengi jökullinn hélt þessari miklu stærð sinni, en fyrir um 18 000 árum hafði brún hans hörfað inn í Djúpál og fyrir um 16 000 árum var hlýsjór úti fyrir Norðurlandi. Þetta tvennt bendir til þess að á þessum tíma hafi hlýir sjávarstraumar á ný náð ströndum landsins. Fyrir um 15 000 árum hörfaði jökullinn úr Jökuldjúpi og skömmu seinna var brún hans komin inn fyrir núverandi strönd landsins á Vesturlandi. Þar mætti sjárvarborð landi og efstu og elstu fjörumörk á Vesturlandi mynduðust fyrir um 14 700 árum. Fjörumörk af svipuðum aldri finnast víða um Vestur-, Norðvestur- og Norðurland, ofan við fjörumörk af yngri Dryas og Preboreal aldri.

Á Mið-Norðurlandi lá brún jökulsins ýmist innan núverandi strandar eða skammt undan landi, nema þá helst í Eyjafirði. Þar í nágrenninu – í Fnjóskadal, eru vísbendingar um að nyrsti hluti dalsins hafi snemma orðið jökullaus og í honum myndast 6 jökullón með affalli til norðurs yfir Flateyjardalsheiði. Ummerki fjögurra elstu lónanna eru eingöngu varðveitt í setlögum Fnjóskadals. En ummerki þeirra tveggja lóna sem skildu eftir sig strandlínur í hlíðum dalsins eru líka varðveitt í setlögum Fnjóskadals. Jarðlagafræðilegar rannsóknir hafa leitt í ljós að þessi lón urðu til hvert á fætur öðru þannig að eitt lón tæmdist og það næsta varð til. Til þess að þetta gæti orðið þá varð jökulstífla í Dalsmynni að veikjast það mikið að vatn gæti fundið sér leið úr lóninu og til Eyjafjarðar og eflast svo á ný þannig að nýtt lón með affalli um Flateyjardalsheiði varð til í Fnjóskadal.

Í Út-Fnjóskadal, þ.e. nyrst í dalnum safnaðist gífurlegt magn sets fyrir og í þeim eru ummerki um fjögur elstu lónin. Sum þessara setlaga hafa aflagast þegar jökull í Fnjóskadal gekk ítrekað norður yfir þau. Greinilegar strandlínur urðu til við strendur tveggja næstu jökullóna og við þær safnaðist set sem mynduðu óseyrar. Áætlaður aldur þessara tveggja lóna og strandlína þeirra er á bilinu 15 000 til 13 000 ár. Þessu næst hörfuðu jöklar landsins inn til miðhálendisins og á þeim tíma varð stór hluti landsins jökullaus og afstætt sjávarborð varð hvað lægst. Á þessum tíma runnu á Norðausturlandi hraun sem síðar fóru undir jökul þegar jöklar stækkuðu á yngri Dryas.

Á yngri Dryas gekk jökull í Eyjafirðir út yfir Hrísey og lokaði Dalsmynni. Á sama tíma gekk jökull út Bárðardal, lokaði Ljósavatnsskarði og náði út í Skjálfandaflóa. Þá myndaðist lón í endilöngum Fnjóskadal og út í það barst mikið magn af gjósku, sem kennd hefur verið við Skóga og er sú sama og svonefnd Vedde gjóska, um 12 100 ára gömul. Þetta lón tæmdist og annað lón, og jafnframt það yngsta, myndaðist fyrir um 11 700 árum. Síðan hörfuðu jöklar talsvert og náði brún jökulsins tímabundið í sjó við Espihól í Eyjafirði sem og í mynni Hörgárdals og Svarfaðardals. Áætlaður aldur þessarar stöðu jöklanna er um 11 200 ár. Ný og yngri staða frambrúna þessara jökla var svo fyrir um 10 900 árum, en þá mynduðust Melgerðismelar framan við Eyjafjarðarjökulinn.

Nokkuð er vitað um aldur samsetts berghlaups (Leyningshóla) syðst í Eyjafirði, en elsti hluti þess féll á og barst þvert yfir hlutfallslega þunna jökultungu og að fjallshlíðinni austan dalsins. Jökultungan náði norður fyrir Hólavatn, en vatnsstæði þess varð til þegar jökullinn hörfaði frá umfangsmiklum jökulgörðum norðan vatnsins. Aldur berghlaupsins er að minnsta kosti 10 200 ár, sem er aldur svartrar gjósku (Saksunarvatn) sem fundist hefur ofan á hlaupinu.

Tölfræðilegt mat á jarðskjálftum á Íslandi 1904–2022.

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Nýlega voru gefnir út tveir listar yfir jarðskjálfta frá árinu 1904 og fram á okkar daga. Annars vegar er alþjóðlegur listi frá International Seismological Center (skammstafaður ISC GEM). Hann nær yfir alla jarðskjálfta yfir vissa stærð, sem orðið hafa á jörðinni á tímabilinu 1904–2022. Hinn listinn er frá árinu 2022, sem Kristján Jónasson (1), og samstarfsmenn tóku saman og nefnist ICEL-NMAR. ICEL-NMAR listinn nær yfir tímabilið 1904–2019, en takmarkast þó við skráningu á jarðskjálftum á Íslandi og annars staðar á Norður-Atlantshafshryggnum á milli 45˚–75˚ breiddargráðu. ISC GEM listinn gefur upp stærðir samkvæmt vægisstærðarkvarðanum Mw, en ICEL-NMAR listinn er auk þessa með stærðirnar reiknaðar út frá P-bylgju (mb) og S-bylgju (MS).

Þegar skoðuð eru stöplarit með fjölda skjálfta eftir stærð, má ætla, að ISC GEM listinn sé nokkuð tæmandi fyrir íslenska jarðskjálfta eftir 1917 með vægisstærðir Mw ≥ 5,6, og ICEL-NMAR listinn álíka tæmandi fyrir stærðir Mw ≥ 5,0 frá 1904, og verður það að teljast gott. Þriðji listi er til, sem báðir ofangreindir listar sækja til. Það er alþjóðlegi Global Centroid Moment Tensor listinn (GCMT). Hann nær yfir jarðskjálfta frá tímabilið 1976–2022 og virðist ná yfir jarðskjálfta af stærðinni Mw ≥ 4,7 á Íslandi. Fjórði listinn, sem notast er við hér í þessari greiningu, er listi frá International Seismological Center yfir jarðskjálfta á árabilinu 1963–2022. Ætla má, að hann nái að skrá flesta jarðskjálfta , sem urðu þá á Íslandi af stærðinni MS≥ 3,7.

Hægt er að beita Gutenberg og Richter lögmáli (jöfnu) til þess að rannsaka tölfræðilega jarðskjálfta á Íslandi á tímabilinu 1904–2022 og spá fyrir um endurkomu stærri jarðskjálfta. Gutenberg og Richter lögmálið er veldisfall, sem lýsir því, að fyrir hvern skjálfta af ákveðinni stærð M megi búast við 10 skjálftum að meðaltali á jörðinni, sem eru á stærðarbilinu M-1 til M. Greining ofangreindra gagna bendir til, að fyrir hvern jarðskjálfta á Íslandi af stærð 7,0 megi búast við 8± 1 jarðskjálftum af stærðum á milli 6,0 og 7,0.

Nærri helmingur skjálfta frá Íslandi í ofangreindum listum (gagnagrunnum) er um skjálfta frá Bárðarbungu á árunum 2014 og 2015. Ákveðið var fyrir greiningu hér að sía út Bárðarbunguskjálfta frá upphafi mælinga. Þannig endurspegla gögnin betur hreina tektoníska skjálfta. Þegar ofangreind gögn eru skoðuð, kemur í ljós fyrir Ísland sem eitt svæði, að jarðskjálftar af stærð (Mw eða Ms) ≥ 6,5 verða að meðaltali á 25 ± 5 ára fresti (dreifing er gefin í tveimur staðalfrávikum og endurspeglar líklega lágmarks óvissu). Ef gert er ráð fyrir svipaðri endurkomu skjálfta af þessari stærð á Norður- og Suðurlandi, þá má gera ráð fyrir endurkomu þeirra á hvoru landsvæði á 50 ± 10 ára fresti. Endurkomutími skjálfta af stærðinni Mw ≥ 7.0 telst þá vera 70 ± 22 ár fyrir landið í heild, eða 140 ± 44 ár á hvoru landsvæði. Ekki var kannað hér, hvort munur væri á þessum landsvæðum, en það er verðugt næsta skref.

Áætlað er, að stærstu jarðskjálftar á Íslandi á sögulegum tíma hafi verið af stærðinni 7,1 (MS). Samkvæmt Gutenberg og Richter lögmáli ættu slíkir jarðskjálftar að verða á 220 ± 90 ára fresti hér á landi. Jarðskjálftar af stærðinni MS eða Mw = 7,0 ættu að endurtaka sig á 195 ±60 ára fresti. Líkindi þess að fá tvo jarðskjálfta af stærð MS 7,0 eins og gerst hefur á síðustu 115 árum (það eru 1910 og 1912 skjálftarnir) eru um 35%. Nú eru tæp 25 ár, síðan jarðskjálfti af stærð Mw = 6,5 reið yfir Suðurland. Miðað við reiknaðan endurkomutíma staks skjálfta Mw ≥ 6,5 gætu liðið önnur 25 ár, þangað til svipaður eða stærri jarðskjálfti endurtæki sig. Hins vegar er Suðurlandsskjálftum oft lýst sem hrinu tveggja eða fleiri aðalskjálfta. Árið 2000 voru tveir meginskjálftar af stærðinni Mw ~6,5 (17. júní skjálftinn Mw=6.5 og MS=6,7; 20. júní skjálftinn Mw=6.4 og MS=6.6). Ef gert er ráð fyrir pari af skjálftum Mw ≥ 6,5, þá má búast við þeim eftir 75 ± 20 ár.

Í það minnsta í 25 ár fyrir 2000 skjálftann í Holtum (17. júní 2000) var mesta viðverandi virkni smáskjálfta (stærðir u. þ. b. 1.5–4.0) á Suðurlandsundirlendinu einmitt þar. Var þess vegna talið, að Holtin væru líklegasta staðsetning næsta Suðurlandsskjálfta, sem reyndist rétt. Á síðustu 25 árum hefur bæði dregið úr virkni eftirskjálfta síðustu Suðurlandsskjálfta, en líka orðið aukning smáskjálfta af stærðinni 1.5–4.6 á svæðum Suðurlands, sem voru róleg fyrir 2000 skjálftana. Þetta eru annars vegar Flói og hins vegar í Landssveit og á Rangárvöllum og Vatnafjallasvæðið suður af Heklu. Með svipuðum rökum og áður má ætla, að þessi aukna virkni smáskjálfta endurspegli aukna spennu í jarðskorpunni, og þessi svæði séu líklegustu upptök næstu Suðurlandsskjálfta.

(1) *A harmonised instrumental earthquake catalogue for Iceland and the northern Mid-Atlantic Ridge*. Kristján Jónasson, Bjarni Bessason, Ásdís Helgadóttir, Páll Einarsson, Gunnar B. Guðmundsson, Bryndís Brandsdóttir, Kristín S. Vogfjörd and Kristín Jónsdóttir

https://doi.org/10.5194/nhess-21-2197-2021 - Data sets ICEL-NMAR Earthquake Catalogue Kristjan Jonasson and Bjarni Bessason https://doi.org/10.17632/7zh6xg22cv.2

The impact of historical land-use changes on Icelandic lake ecosystems reconstructed from Chironomidae head capsules

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Land use in Iceland has histrorically been shaped by pastoral farming, with sheep grazing as a dominant activity. Over the past few centuries, however, agricultural land has increasingly given way to summerhouses and recreational areas, especially near lakes. This shift has introduced new anthropogenic pressures on lake ecosystems, including erosion, changes in plant coverage and nutrient loading.

In order to investigate the influence of summerhouses on the lake ecosystems in Iceland, two lakes have been selected. The first one, Hafravatn, is located within the city limits of Reykjavík and is a well-known recreational area for locals, with many summerhouses along its shore. Data from Hafravatn will be compared with those from Grænavatn, a less accessible lake ca. 35 km south-west of Reykjavík. From each lake, short sediment cores were taken, to investigate the changes in Chironomidae head capsules composition and geochemical parameters for the last ca. 200 years.

The relative uniform chironomid species composition in the sediment core from Hafravatn suggests that the lake, due to its large size, is relatively well-buffered against most anthropogenic pressures and climate change. In contrast, Grænavatn shows large shifts in the Chironomidae composition that correspond to changes in mean temperature and precipitation. For Hafravatn, only large shifts in the sediment accumulation rate, often caused by the building of large infrastructure in the catchment, resulted in short-term shifts in the Chironomidae composition. However, smaller-scale shifts in the Chironomidae composition at Hafravatn including the decrease in oligotrophic species were probably caused by the building and presence of an increasing number of summerhouses around the lake.

The first Icelandic DAS Deployment for Real-Time Earthquake and Volcano Monitoring/ Fyrsti íslenski Ljósleiðaravakinn

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We present the first Icelandic Distributed Acoustic Sensing (DAS) deployment, operated by the Icelandic Meteorological Office, a significant advancement in real-time monitoring of volcanic and seismic activity in Iceland. DAS methodology utilizes continuous optical fibers, covering tens of kilometers, as highly sensitive arrays of seismo-acoustic sensors. This exceptional spatial and temporal resolution of DAS enables the detection and characterization of subtle volcanic and seismic signals with high accuracy, making it suitable for eruption monitoring in the Reykjanes Peninsula. Thus, to enhance monitoring of the ongoing volcanic crisis at Grindavík, we installed a real-time early warning system that utilizes the DAS data and delivers alerts to the Icelandic Meteorological Office natural hazards monitoring room. We deployed an ASN OptoDAS interrogator, a long-range and low-noise instrument with low-frequency detection capability. We simultaneously monitor two telecommunication fiber-optic cables in collaboration with Ljósleiðarinn, using a combined length of roughly 150 km, extending from Ásbrú-Keflavík to Þorlákshöfn in the south, as well as to Hafnarfjörður in the north. The high sensor density, with measurements every 10 meters and a temporal sampling frequency of 100 Hz, allows the detection of diverse signals, including volcanic processes and microseismicity. The DAS dataset, acquired over two months, demonstrates the significance of DAS in ensuring continuous volcano monitoring during periods of intense weather noise degrading traditional seismometer performance. We discuss our overall operational experience, specifically the application of the early warning system (collaborative work with Reykjavík University, University of Houston and Caltech), initial results, and quality checks performed on the dataset.

Post glacial relative sea level changes in west Iceland

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The thin, dynamic crust of Iceland is particularly sensitive to the loading and unloading of land by glaciers and ice sheets, making it a key region for studying postglacial sea-level change. Despite decades of work, relative sea level (RSL) histories remain poorly resolved due to patchy coverage, poorly constrained sea level index points, and chronological uncertainties. The objective of this master's project is to develop an open-access database of sea level index points and limiting constraints for west Iceland. Existing data (n = 174) have been compiled, quality assessed and integrated into a standardized database, providing a more robust reconstruction of RSL changes. Over half of the data correspond to the Late Pleistocene – Early Holocene transition, while Holocene radiocarbon ages are skewed toward the early Holocene. The database is supplemented with new geochronological (tephra and radiocarbon) data from submerged coastal peatlands located in west Iceland, specifically the classic site of Seltjörn, Grótta (-4.2 m beneath hightide; Þorarinsson 1956). The section is interpreted as terrestrial limiting constraint representing an Early Holocene low-stand. The strata exhibits a diatom assemblage dominated by freshwater, and the presence of the G10ka tephra has been identified. These results are compared with Þorarinsson (1956)'s original findings, providing additional insights into the deglaciation of the Icelandic Ice Sheet and the timing of the Early Holocene sea level low-stand.

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Transient ground deformation observed by GNSS and InSAR during and following the 2021 Fagradalsfjall eruption, Iceland

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Geodetic observations, coupled with modelling of the detected signals, can help discriminate between different processes contributing to measured surface deformation during a volcanic eruption, providing insight into its evolution, the associated magma transport, and processes occurring in the subsurface. We use Global Navigation Satellite System (GNSS) geodesy and Interferometric analysis of Synthetic Aperture Radar (InSAR) satellite images to map overall gradual deflation during the six-month-long 2021 eruption in Geldingadalir at Mt. Fagradalsfjall, in SW-Iceland. The co-eruptive deflation shows three temporal phases: T1, 19 March – 10 May; T2, 11 May – 31 July; T3, 1 August – 18 September, correlating with changes in the effusion rate, eruptive style, and geochemistry of the erupted basalt. Effects of lava loading are evident in the geodetic observations. We remove this signal with a Finite Element Method model and infer geodetic sources responsible for the observed ground deformation. Our observations are best explained by a deflating sill-shaped source at ~12–13 km depth with volume contraction of 21–27 Mm^3, around 4-5 times lower than the estimated bulk volume of the erupted material. Inflation was detected after the eruption and can be modelled at a similar depth as the co-eruptive source. Understanding co- and post-eruptive ground deformation patterns and their correlation with other observables at volcanoes e.g., effusion rate and geochemistry is essential to unveil the architecture of the underlying magmatic plumbing system and hazard assessment, considering also the possibility of reactivation of neighboring volcanic systems, known from earlier volcanic activity periods on the Reykjanes Peninsula.

How much heavy metal is released by a crystalizing lava field?

Nicolas Levillayer

Háskóli Íslands

Eruptions of basalt are known to emit a gas phase composed of water, carbon, sulphur, halogens and rare gases but also of toxic heavy metals. While the gas composition released during an eruption is relatively well known, the post-eruptive gas emission from a cooling lava field remains less well characterised, and its environmental impact is largely unknown. During the Fagradalsfjall eruptions (2021-2023), gas was collected from an active crater and the post-eruptive gas from actively degassing but extinct crater and from the cooling lava field. A compositional shift is observed from a sulphur dominated syn-eruptive gas phase (mass ratios S/Cl and S/F > 10) to a halogen-dominated secondary gas phase (S/Cl and S/F < 0.1) from the cooling lava. The shift in major volatile composition affects the trace element volatility, resulting in a depletion post-eruptively of elements emitted as sulphide or in their elemental form such as Te and Cd. The solidifying lava emits gas rich in chloride-forming species (Sb, Pb and Zn) whereas the gas from the extinct crater is rich in elements forming fluoride species such as Mo and Ru. Estimation of the trace metal emissions reveals significant liberation of a few toxic metals from the cooling lava, up to 100 tons of Zn. Syn- and post-eruptive heavy metal emissions are markedly different and the secondary gas emissions from basalt eruptions have local environmental impacts.

Origin and age of the near-rift Fjallgarðar Volcanic Ridge revealed by noble gas geochemisty and geochronology

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High-^{3}He domains in Iceland may originate from a deep, primordial mantle component in the Icelandic mantle plume[1]. In the neovolcanic zones, the highest ^{3}He/^{4}He values (R_C/R_A, relative to air, R_A, and corrected for air-derived He) occur near the northwestern boundary of Vatnajökull, coinciding with the inferred location of the Icelandic mantle plume. This region is characterized by ^{3}He/^{4}He well above 18 R_A, reaching values as high as 26 R_A, reflecting its proximity to the plume center. In contrast, ^{3}He/^{4}He values of 8-11 R_A typify most of the Northern Rift Zone (NRZ)[1,2].

The 200 km-long Fjallgarðar Volcanic Ridge (FVR), consisting of subglacially erupted tholeiitic basalt, was emplaced parallel and ~20-40 km to the east of the NRZ. Previous studies studies[3,4] suggest that the FVR erupted either during a temporary eastward jump or a widening of the NRZ, with magma input largely sourced from the NRZ, implying that the FVR should preserve NRZ source fingerprints. The FVR is thought to have erupted entirely during the Brunhes geomagnetic polarity chron[3] (< 780 kyr). However, absolute age constraints are limited to Ar-Ar ages from subaerial lava flows (n=4: 558 ± 85 kyr to 1340 ± 140 kyr) and subglacial formations (n =7: 153 ± 29 kyr to 453 ± 152 kyr) obtained from the Kárahnjúkar region[5] which may be linked to the construction of the FVR, and one single age in the center part of the FVR (81 ± 9 kyr)[6], highlighting the need for additional Ar-Ar dates from the entire FVR.

Here, we present new He isotope data of glassy pillow rims (n=17) and new ^{40}Ar-^{39}Ar ages on subglacial lavas (n=11), together with published major and trace element data on the same glasses and lavas from the FVR[7]. He isotope data were obtained by crushing glass chips under ultra-high vacuum, and ^{40}Ar-^{39}Ar ages by incremental heating of groundmass separates, with one to two aliquots per sample.

Undegassed FVR glasses display some of the highest He isotope values (max ^{3}He/^{4}He = 22 R_A) ever obtained from the igneous rocks north of Vatnajökull, comparable to ^{3}He/^{4}He values from the inferred center of the mantle plume. Glasses with higher ^{3}He/^{4}He values correspond to lower incompatible minor and trace element ratios (e.g., K_2O/TiO_2 = 0.07-0.17, La/Yb = 2.0-3.8), similar to basalts from central Iceland, whereas lower ^{3}He/^{4}He values (~8 R_A) are observed in samples with higher ratios (K_2O/TiO_2 >0.18, La/Yb= 5.0-5.8). This latter group is identical to basalts from Kverkfjöll, a volcano located adjacent to the southern tip of the FVR. Groundmass ^{40}Ar-^{39}Ar ages (Plateau ages) range from 97 to 702 kyr, confirming the previously inferred Brunhes age of the FVR. Notably, lavas with higher La/Yb are younger than 250 kyr, whereas the ages of lavas with La/Yb < 4 span~200 to 700 kyr.

Our new dataset suggests that, rather than being linked to mantle source(s) feeding the bulk of the NRZ, a significant portion of the FVR magmas originates from a high-$^3He/^4He$ plume component currently only evident beneath central Iceland. This observation places new constraints on lateral dispersion of plume material from central Iceland towards the north over the past ca. 0.8 Ma. Importantly, the ^{40}Ar-^{39}Ar dates suggest that the geochemically more depleted, high-$^3He/^4He$ magmas, erupted all across the entire FVR over a time period of several hundred thousand years. The injection of more enriched magmas (La/Yb > 4) with lower $^3He/^4He$ values (~8R_A), best resembled by Kverkfjöll magmas, into the FVR area seems to be a more recent (< 250 kyr) phenomenon.

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Hratt ris Bárðarbunguöskjunnar í kjölfar öskjusigsins 2014-2015

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Öskjusig eru tiltölulega sjaldgæfir atburðir og tengjast oft stórum eldgosum. Frá upphafi 20. aldar eru þekkt níu tilfelli. Þar af eru þrjú sem tengjast stærstu sprengigosum sem orðið hafa á þessu tímabili, Katmaii í Alaska 1912, Pinatubo á Filippseyjum 1991 og síðast Hunga Tonga í sunnanverðu Kyrrahafi 2022. Í þessum tilfellum voru gosefnin súr eða ísúr. Hin gosin sex hafa öll tengst basískum eldgosum. Þetta eru Fernandina á Galapagoseyjum 1968, Tobachik á Kamchatka 1976, Miyakejima í Japan 2000, Piton de la Fournaise á La Reunion í Indlandshafi 2007, Bárðarbunga 2014-2015 og Kilauea á Hawaii 2018. Bárðarbunga er ein stærsta megineldstöð landsins, þakin jökli og er annað hæsta fjall á Íslandi. Hún hefur að geyma stóra öskju, um 65 km^2 og af öskjum hér á landi eru það aðeins Torfajökulsaskjan og Kötluaskjan sem eru stærri. Askjan í Bárðarbungu er djúp og aflokuð og ísinn innan hennar víðast hvar 700-800 m þykkur. Á hálfu ári, samhliða gosinu í Holuhrauni, lækkaði botn hennar um 65 metra þar sem sigið var mest. Kvikan streymdi lárétt undan Bárðarbungu, rúmlega 40 km til norðausturs að gosstöðvunum milli Dyngjujökuls og Öskju. Öskjusigið mældist tæpir 2 rúmkílómetrar sem er álíka og samanlagt rúmmál Holuhrauns og gangsins sem myndaðist í umbrotunum. Eldgosið í Holuhrauni er það stærsta sem orðið hefur á Íslandi frá stórgosinu í Laka 1783-84. Atburðirnir 2014-15 voru fyrsta tilfellið þar sem hægt var að rekja í rauntíma lárétt flæði kviku undan megineldstöð samhliða öskjusigi. Helstu gögnin voru aflögunarmælingar (GPS, InSAR), jarðskjálftamælingar og mat á stærð og rúmmáli öskjunnar og hraunsins sem myndaðist, einkum með endurteknum mælingum úr flugvél Ísavia. Gögnin sýna að kvikan sem kom upp í Holuhrauni var frá Bárðarbungu. Alls urðu 77 jarðskjálftar stærri en M 5 (stærsti M 5.8) og samhliða sumum þessara skjálfta féll askjan um 20-40 cm. Gosið og sigið fjaraði út í febrúar 2015. Fljótlega eftir það byrjaði jarðskjálftavirkni aftur í Bárðarbungu og hefur haldist töluverð. Hún hefur reyndar færst nokkuð í aukana undanfarin 1-2 ár. Til að fylgjast með þróuninni í kjölfar öskjusigsins, hafa verið gerðar endurteknar þyngdarmælingar í 25-55 punktum, sem samanlagt ná yfir alla Bárðarbungu og nágrenni hennar. Samanburður milli ára, þar sem leiðrétt hefur verið að fullu fyrir áhrifum breytinga í lögun jökulsins milli mælinga, sýna að jákvætt þyngdarfrávik hefur myndast og vaxið nokkuð stöðugt með tíma. Endurspeglar lögun þess vel öskjusigið sem varð 2014-2015. Þessar mælingar eiga sér aðeins eina mögulega skýringu: Að botn Bárðarbungu sé að rísa og að umtalsverður hluti þess sigs sem varð hafi þegar gengið til baka á aðeins átta árum. Vísbendingar um þetta hraða landris koma einnig fram í endurteknum íssjármælingum. Þessi hegðun Bárðarbungu skýrist með hröðu innflæði kviku að neðan inn í kvikuhólfið sem liggur undir öskjunni. Þetta innflæði virðist hafa byrjað nánast strax eftir að gosinu í Holuhrauni lauk. Niðurstöðurnar sýna að basískar öskjur í mjög virkum eldstöðvum geti átt það til að rísa hratt, og mun hraðar en hingað til hefur verið talið. Þetta setur eldvirkni í mjög virkum megineldstöðum/eldstöðvakerfum í nýtt samhengi – að basískar öskjur geti átt það til að ýtast upp og síga á víxl á tímaskala sem er mun styttri en hingað til hefur verið þekktur. Þetta kann einnig að skýra að stór eldgos hafa endurtekið átt sér stað á sprungusveimum Bárðarbungukerfisins á síðustu 1200 árum.

Carbon isotope fractionation during the 2022-2023 Fagradalsjfall eruption tracks magma degassing

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Carbon dioxide (CO_2) is the first major volatile to exsolve from magmas as they rise towards the surface. This progressive degassing not only affects the volatile content of the magma, but also its stable isotopic composition. Carbon dioxide loss induces isotopic fractionation of carbon in the CO_2 with $\delta^{13}C$ progressively becoming lighter, therefore providing an opportunity to track magma degassing.

This talk presents carbon isotope results from the 2022 and 2023 Fagradalsfjall eruptions. Samples collected during the 2023 eruption from the volcanic plume show $\delta^{13}C$ values similar to that of the Icelandic mantle (-5 and - 9‰). Samples collected after the end of the 2022 and 2023 eruptions from vents and lava field display light $\delta^{13}C$ values (~ -16‰). These results show that the source of eruptive CO_2 during Litli Hrútur eruption was from fresh, relatively undegassed magma and distinct from that of the extensively degassed magma left after the end of the eruptions. These observations show that samples that are collected prior to, during, and following an eruption like the ones that have occurred in 2022 and 2023 on the Reykjanes peninsula and are rapidly analyzed for $\delta^{13}C$ values, give insights into eruption dynamics, magma supply, and potentially timing of eruption cessation.

Potassium and rubidium isotopic composition of Icelandic basalts: Implications for moderately volatile elements in the primitive mantle

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Potassium (K) and rubidium (Rb) have similar physical and chemical properties. They are moderately volatile, lithophile elements and highly incompatible in magmatic processes and therefore enriched in the crust relative to the mantle. In low temperature crustal environments, they are easily mobilised by fluids. Stable isotopes of K and Rb are increasingly applied to studies of geologic material and processes, such as mantle heterogeneity and crustal recycling processes, low-T hydrothermal processes as well as the evolution of the Solar System. Previous studies show that K and Rb isotopes can fractionate in low-T processes but are subject to limited fractionation during igneous processes and magmatic evolution1,2. Thus, they may be suitable for tracing the presence of recycled crustal material in mantle sources, and any resolvable variability in K and Rb isotopic composition (expressed as d41K and d87Rb) suggests heterogeneity in source3,4.

To identify possible mantle heterogeneity, this study presents d41K and d87Rb composition ofIcelandic basalts (n=31) measured with MC-ICP-MS equipped with a collision cell (Sapphire by Nu Instruments). We test large-scale d41K and d87Rb heterogeneity in the Icelandic mantle by analysing well-characterised and largely primitive basalts from all active rift-zones and two off-rift alkalic volcanic zones. We also test small-scale, local d41K and d87Rb mantle heterogeneity by analysing lavas from the Fagradalsfjall 2021-2023 eruptions, where a clear mantle control has been identified for generating compositionally heterogenous lavas5,6.

The measured values fall mostly within the estimated mantle average for both isotope systems, d41K = –0.42 ±0.08‰ (2SD)1 and d87Rb = –0.12 ±0.08‰ (2SD)2. Two samples, however, from the Reykjanes Peninsula/Western Rift Zone have positive d87Rb values (+0.02‰) and are therefore enriched in 87Rb compared to the estimated mantle value. Within the sample set of this study, these two samples are the most incompatible element depleted and have radiogenic isotope ratios that signify minimal modification by crustal recycling. Furthermore, a primitive sample from Vestmannaeyjar has d41K‰ higher than the estimated mantle value (–0.42 ±0.08‰). All these samples have 3He/4He above that of a typical MORB value (~8 Ra) which suggests they contain a component originating from an ancient, relatively undisturbed and primitive mantle.

These elevated d41K and d87Rb values are similar to d41K and d87Rb values measured in CV chondrites7,8,9. The d41K and d87Rb could be representative of a primitive mantle component sampled by the Icelandic mantle plume, with limited influence from recycled or MORB mantle material. These observations may thus have implications for understanding the inventory of moderately volatile elements in the primitive mantle.

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Remote Sensing based detection of changes in Surface Thermal Anomalies from 2014 to 2023 and in relation to periods of tectono-volcanic unrest at Reykjanes Peninsula, SW- Iceland

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This study investigates surface temperature anomalies (STAs) on Reykjanes Peninsula, SW Iceland using thermal infrared (TIR) remote sensing data from the Landsat, ASTER MODIS satellites images obtained between 2014 and 2023. The objective is to assess the relationship between land surface temperature (LST) and volcanic unrest and thus enhancing our understanding of the geothermal and magmatic processes shaping this dynamic region.

Focusing on the geothermal fields of Reykjanes, Svartsengi, Krýsuvík, and Hengill, we analyzed temporal variations in surface temperature and classified thermal anomalies based on their intensity and characteristics. Our findings reveal a correlation between thermal anomalies and volcanic activity during unrest periods from 2019 to 2023 in some of the investigated geothermal fields. These fluctuations suggest the presence of a magmatic heat source beneath these geothermal fields, was, at least in parts, recharged during this period, highlighting their sensitivity to subsurface activity.

This research underscores the value of remote sensing in geothermal monitoring by integrating satellite data with ground-based observations to improve the accuracy and reliability of geothermal assessments. Through systematic observations of thermal anomalies in this active volcanic region, this study provides insights into potential developments of early warning systems as well as sustainable management of geothermal energy in SW-Iceland.

Tilvísun til jarðfræðifyrirbæra í Landnámu og fleiri fornritum

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Landnámabók er talin rituð um 1120-1130. Hún segir frá landnámi Íslands í smáatriðum á 9. og 10. öld og atburðum í tengslum við það. Talið er að ritöld hefjist á Íslandi upp úr Kristnitökunni árið 1000 þannig að Landnáma greinir frá atburðum sem gerðust 100-250 árum fyrir ritunartímann. Frásögn Landnámu byggist því að mestu leyti á munnlegri sagnageymd en trúlega einhverjum ritheimildum frá því upp úr árinu 1000. Menn hafa lengi deilt um heimildargildi Landnámu. Elsta gerð hennar er Sturlubók1 frá því upp úr 1250 og síðan Hauksbók2 frá því upp úr 1300. Aðrar heillegar gerðir hennar eru mun yngri en gætu þó byggst á eldri en týndum handritum. Í Landnámu segir nær ekkert frá jarðfræðilegum fyrirbærum nema rétt í framhjáhlaupi til skýringa á frásögnum af fólki. Með því að kanna hvort þessar örfáu frásagnir af jarðfræði-fyrirbærum sem eru í bókinni geti staðist samkvæmt jarðfræðirannsóknum nútímans mætti fá vísbendingar um áreiðanleika ritsins. Í grófum dráttum má skipta þessum jarðfræðifyrirbærum í þrennt; eldgos, skriðuföll og loks fljót, firði og furðufyrirbæri.

Í Landnámu eru sagnir sem talið hefur verið að segi frá þremur eldsuppkomum, í Hnappadal, Eldgjá og Heimaey.

Eldgjárgosið gerðist sannanlega á landnámsöld og Haukur Jóhannesson3 færði sannfærandi rök fyrir því að sögnin í Landnámu ætti við Rauðhálsahraun sem hefði runnið á 10. öld. Til viðbótar rökum Hauks má nefna að bærinn Landbrot stendur undir jaðri hraunsins sem bendir sterklega til þess að hraunrennsli hafi brotið þarna land eftir landnám enda eiga nær öll landbrotsörnefni í Íslandi annað hvort við um land sem menn hafa séð hraun eða vötn brjóta.

Ályktun sem áður var dregin um að Helgafellshraun á Heimaey hefði runnið eftir landnám byggist á eftirfarandi texta í Hauksbók2: „Herjólfr, sonr Bárðar Bárekssonar, bróðir Hallgríms sviðbálka, byggði fyrst Vestmannaeyjar ok bjó í Herjólfsdal fyrir innan Ægisdyr þar sem nú er hraun brunnit. Hans sonr var Ormr auðgi, er bjó á Ormsstöðum við Hamar niðri, þar sem nú er blásit allt, ok átti einn allar eyjarnar“. Hér þarf að hafa hugfast að í texta hinnar eldri Sturlubókar er ekkert nefnt um „hraun brunnit“ né „blásið allt“. Rannsóknir Trausta Einarssonar4 og Guðmundar Kjartanssonar5 bentu sterklega til þess að Helgafellshraunið væri um 5000 ára gamalt. Hugsanlegt er þó að í Hauksbók sé átt við að gróður hafi verið horfinn af hrauninu á ritunartíma hennar vegna uppblásturs og eftir standi aðeins brunahraunið bert þannig að sú túlkun texta Hauksbókar að Helgafellshraun hafi runnið eftir landnám sé röng.

Auk eldgosalýsinganna í Landnámu má benda á að lýsingar á Kristnitökuhrauninu í Kristnisögu og Hallmundarhrauni í Hallmundarkviðu Bergbúaþáttar6 séu líklega réttar.

Í Landnámu eru fjögur dæmi um skriðuföll, í Haukadal, Vatnsdal, Skriðdal og Loðmundarfirði. Í öllum tilvikum er þjóðsagnakenndur blær á frásögnunum eins og draumfarir manna, að þrælar hafi fellt skriðu á bæ (Haukadalur) eða skriða hafi verið felld með fjölkynngi (Vatnsdalur). Í öllum þessum tilvikum hafa skriður fallið á umræddum stöðum en óvist er um aldur þeirra. Árni Hjartarson7,8 fjallaði um skriðurnar í Loðmundarfirði og á Skriðdal og komst að þeirri niðurstöðu að skriðan í Skriðdal hefði fallið fyrir árið 1362 en eftir öskulagið H3 fyrir 2900 árum. Eins telur hann að Loðmundarskriður séu 1000-2000 ára gamlar og gæti sögnin í Landnámu því verið sönn.

Í þriðja flokknum hef ég skoðað fimm tilvik þar sem jarðfræðifyrirbærum er lýst. Þar eru horfin vötn í Álftaveri og horfinn fjörður vestan við Hjörleifshöfða sem standast jarðfræðiskoðun, færsla Hvítár við Hraunshöfða sem er ólíkleg en ekki útilokuð og vatnadeilur Þrasa í Skógum og Loðmundar á Sólheimum sem Sigurður Þórarinsson taldi geta verið endurómum frá hlaupum suður úr Mýrdalsjökli. Fimmta sögnin er um illan ilm úr jörðu í Dufansdal við Arnarfjörð.

Í Landnámu1 segir að Án rauðfeldr, „herjaði á Írland ok fekk Grélaðar, dóttur Bjartmars jarls. Þau fóru til Íslands og kómu í Arnarfjörð vetri síðar en Örn. Án var inn fyrsta vetr í Dufansdal. Þar þótti Grélöðu illa ilmat úr jörðu“ Af þessum sökum segir Landnáma að þau hafi flutt úr Dufansdal og gert bú að Eyri milli Langaness og Stapa. „Þar þótti Grélöðu hunangsilmur ór grasi“. Þótt þessi frásögn sé með ólíkindablæ getur hún vel staðist. Þannig háttar í Dufansdal að volgar laugar eru í dalnum sem aðeins seytlar úr. Upp með Laugará, í um 2 km fjarlægð frá bænum, er hitinn um 45°C. Þar er geysimikið kísilhrúður og finnst þar áberandi brennisteinslykt í lofti9. Efnagreiningar á sýnum úr þessum laugum sýna óvenju háan styrk brennisteinsvetnis eða um 0,5 mg/L. Samkvæmt sögunni dvöldu Án og Grélöð einn vetur í Dufansdal en það er einmitt í froststillum að vetri til sem líklegast er að mest verði vart við lyktina í dalnum. Brennisteinsvetnið er þung lofttegund og skríður með jörðinni. Uppkoma jarðhitans og þar með lyktarinnar er í Laugargili í um 200m hæð þannig að búast má við að leið hveraloftsins sé greið að bænum við rétt veðurskilyrði.

Af 12 jarðfræðifyrirbærum sem ég hef séð lýst Landnámu má segja að 4 tilvik standist, 3 tilvik eru líkleg, 3 eru hugsanleg en eitt tilvik, Helgafellshraun, stenst ekki en gæti verið mistúlkun á texta Hauksbókar. Ekkert tilvik er þannig að það geti ekki staðist. Ef höfundar Landnámu hefðu notað jarðfræðifyrirbæri sem þeir þekktu, til þess að búa til sögur í kringum, verður að telja afar ólíklegt að þeir hefðu hvergi lent í því að spinna sögur um mun eldri jarðfræðifyrirbæri en frá landnámstíma. Því má álykta að Landnáma sé býsna góð sagnfræðiheimild.

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Hraunflæði niður í opnar gjár og gjávellur

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Í nokkrum af gosunum í Kröflueldum 1975-1984 varð fólk vitni að því að hraun rann niður í opnar gjár. Fyrsti atburðurinn af þessu tagi sem tekið var eftir varð í gosinu í Gjástykki í júlí 1980. Þá rann hraunstraumur frá gosstöðvunum við Éthóla um tveggja kílómetra leið norður eftir Gjástykki og hvarf þar í breiðum fossi niður í eitt af jaðarmisgengjum sigdalsins vestan Hrútafjalla (1. mynd). Þetta stóð í 18 klukkustundir. Stór hluti hraunsins sem upp kom í gosinu rann þarna niður í jarðskorpuna aftur. Sprungan sem tók við hrauninu gliðnaði mikið og náði gliðnunin talsvert norður eftir Gjástykkinu. Þarna varð til berggangur sem fékk efni sitt ofan frá og breiddist úr bæði lárétt og niður á við. Svipuð atburðarás sást í síðari eldgosum í Gjástykki, sérstaklega í janúar-febrúar 1981 og september 1984. Þá sást einnig hvar hraun, sem runnið hafði niður í gjá kom upp úr henni aftur og gaus þannig í annað sinn. Stungið hefur verið upp á nýyrðinu „gjávella“ fyrir slík hraun. Stundum náði hraunið ekki að losna við allt gasið áður en það rann niður í gjá. Myndaðist þá haugur af gjalli umhverfis staðinn þar sem hraunið streymdi niður í gjána. Einnig mátti sjá hvar uppistaða hálfstorknaðs hrauns tæmdist þegar gjá undir því gliðnaði og tæmdi fljótandi hluta hraunsins neðan frá. Eftir því sem best er vitað eru þessar athuganir frá Kröfluumbrotunum þær fyrstu sinnar tegundar í heiminum. Svipaðar athuganir hafa síðan verið gerðar á Hawaii, í sambandi við gos í Kilauea 2014 (Orr et al., 2024). Reynslan frá Kröflu hefur verð notuð nokkrum sinnum við túlkun á jarðlögum í gosbeltum Íslands. Tvö hraun í Kelduhverfi stinga í stúf við umhverfi sitt og bera bergfræðileg einkenni Kröflueldstöðvarinnar. Færð eru rök fyrir því að hið yngra, Skinnstakkahraun, sé upprunnið í svokölluðum Hverfjallseldum fyrir u.þ.b. 2600 árum, hafi runnið niður í gjár skammt norðan Kröflu og komið upp aftur í Kerlingarhól eftir meira en 15 km ferðalag eftir sprungusveim Kröflukerfisins. Eldra hraunið, Hraungarðahraun, ber einkenni Kröfluhrauna frá Kröfluhálsi sem talin eru 8-11 þúsund ára gömul. Fjarlægð milli gosstöðvanna og uppkomustaðar Hraungarðahrauns er um 30 km. Borin hafa verið kennsl á að minnsta kosti þrjá staði til viðbótar þar sem hraun hafa runnið í sprungur. Í Seljahjallagili í Mývatnssveit rann hraun frá syðsta gíg Þrengslaborga ofan í nærliggjandi sprungu í svelg. Á Hellisheiði, austan við Stórameitil, má sjá hvar hraunuppistaða hefur tæmst við rennsli niður í sprungu. Á Reykjanesskaga er að finna ummerki um svipaða atburðarás í Stóra-Hamradal. Einnig eru vísbendingar um slíkt í gosinu á syðri hluta Sundhnúkagossprungunnar í janúar 2024. Nauðsynlegt er að hafa hraunrennsli í og eftir sprungum í huga þegar hönnuð eru varnarvirki til að verja innviði gegn hraunrennsli.

Heimild:

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Preliminary investigations of cryptotephra in South Greenland

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Investigations of cryptotephra (i.e., non-visible) horizons, outside the extent of visible fallout, has further extended the potential of tephrochronology as an application for dating and correlation. The widespread spatial potential and temporal precision allows for the investigation of synchronicity or lag-response to climate forcing across different sedimentary archives (terrestrial, lacustrine, marine and ice cores).

Iceland is the largest source of volcanic ash within the North Atlantic. The eastward transport of Icelandic tephra to European stratigraphic archives is relatively well documented however, fewer investigations have studied the distal dispersal westward. Important tephrochronological investigations have been made on Greenland's Ice cores with increasing studies focusing on the low concentration, non-visible tephra. However, no continuous cryptotephra investigation has focused on the full Holocene. While tephrochronological investigations have been conducted on the SE Greenlandic shelf, no study has yet detailed cryptotephra from a high-resolution lake sediment archive.

Here we investigate the presence of tephra (at cm scale resolution) in a full Holocene lake record (~2.2 m composite) from S. Greenland. The lacustrine record was collected from a five-meter-deep unnamed lake basin (Griso24013x14) located *c.* 49 m a.s.l., within a catchment approximately 0.32 km^2. Tephra influenced by west-ward atmospheric transport, from Iceland's explosive eruptions presumable will be encountered within the lake archive. Furthermore, given the setting, there is the potential to identify tephra from explosive eruptions from North America and other more distal volcanic provinces. This study initiates the development of a tephrochronostratigraphic framework for S. Greenland and the Western-North Atlantic. Furthermore, this region has the potential to be a key "cross-roads" connecting the North American and Northern European tephrochronological frameworks. Such correlations would provide a valuable foundation for conducting Holocene palaeoclimate studies on a broader, intercontinental scale.

FLUID INCLUSION ANALYSES IN GRANITE CUTTINGS FROM BOREHOLES AT HOFFELL/MIÐFELL AREA IN GEITAFELL CENTRAL VOLCANO

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Geitafell is a fossil central volcano located in southeastern Iceland, formed within a rift zone in central Iceland and recognized as a low-temperature geothermal system. From 2012, five deep exploration and production wells have been drilled in Hoffell, along with several gradient wells. The drilling cuttings indicate the presence of a thick granite layer from 1,000 to approximately 1,590 meters, encased by a series of basaltic lavas and mafic intrusions. Although lithology characterization and reservoir evaluation have been conducted for this system, the fluid processes related to the felsic intrusions, such as the composition and origin of fluids resulting from fluid-rock interaction or magmatic fluid influx, have not been fully understood.

Granite cuttings are composed of plagioclase, K-feldspars, and quartz (≈ 1 mm in length) with disseminated magnetite. Subhedral and colourless quartz grains contain different clusters of fluid inclusion assemblages (FIA). Based on petrographic observations, several types of inclusions have been identified. Early inclusions are located at the growth zone border of the quartz crystal and consist of spherical to elongated vapor-rich (V1) inclusions, as well as negative to irregularly shaped brine inclusions with more than one solid phase (B1), along with holocrystalline decrepitated melt inclusions. The late inclusions are mainly located in crystal fractures and can be categorized as follows: Late inclusions (1) include irregularly shaped brine inclusions with a single solid phase (B2) and irregular elongated liquid-rich (L-rich) inclusions (L1). Late inclusions (2) include sub-spherical to highly irregularly shaped liquid-rich inclusions (L2), as well as isolated, regularly shaped liquid-rich (L3) inclusions. Late inclusions (3) consist of highly irregularly shaped liquid-only (L-only) inclusions (L4).

Microthermometry analysis of a significant number of individual fluid inclusions reveals two primary ranges of homogenization temperatures (Th). The first range includes Th values greater than 580°C for V1, B1, and certain B2 inclusions. The second range spans from 220 to 300°C, corresponding to the Th values of various types of L-rich inclusions. Microthermometry and Raman spectrometry measurements also indicate two ranges of fluid salinity: from 33 to 71 wt% $NaCl_{equiv}$ (peak at >71 wt% $NaCl_{equiv}$) and from 0 to approximately 21 wt% $NaCl_{equiv}$ (peak from 0 to 5 wt%$NaCl_{equiv}$), corresponding respectively to the Th ranges.

Liquid-vapor/brine element ratios based on Laser-ablation ICP-MS analysis indicate that brine inclusions (B1-B2) exhibit higher concentrations of most elements due to their high salinity compared to the L-rich (L1-L2-L3) and V-rich (V1) inclusions. Nevertheless, the element/Na vs. Cs/Na plots indicate similar element concentrations for the most FIAs, except for the B2 inclusions, which show an enrichment in Cs/Na ratios. Normalized data expressed as molar proportions of the most abundant cations (Fe-K-Na) reveal that the majority of the FIAs are restricted to the Fe_{0-24}, K_{0-52}, and Na_{31-100} compositions.

These observations suggest the presence of two distinct fluids in the system: 1) one characterized by high Th, salinity, and elevated element concentrations (e.g., the average concentrations of Pb and Zn in the B1 inclusions are 3,900 and 56,000 ppm, respectively), potentially of magmatic origin, and 2) another with intermediate Th, low salinity, and lower element abundances, probably related to meteoric sources. Additionally, there is evidence of a mixing and re-equilibration process, as indicated by the necking down effect observed in Th within some Late FIAs.

The petrographic features and microthermometry results suggest, that the high temperature brine inclusions were trapped at vapour and salt saturation. This allows us to calculate the pressure at the time of fluid inclusion entrapment using the model of Driesner and Heinric (2007) and Bakker, (2018). The estimated pressure is approximately 0.38 kbars, which corresponds to a depth of ≈4 km depth. Late inclusions exhibit temperatures similar to those that produced the pervasive alteration of Geitafell, forming the epidote and chlorite zones reported by Friðleifsson (1983). These temperatures are also comparable to those associated with hydrothermal activity stablished by the interaction of meteoric water with the 5-6 Ma intrusive gabbro at 1.5 km, as reported by Liotta et al. (2020). Therefore, this suggests that the granite intrusion is at least coeval with or older than the Geitafell gabbro and may indicate an active geothermal system at the time of the granite intrusion.

Tracing deformation, hydrothermal alteration and mineralization around the Slaufrudalur pluton, Southeast Iceland

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Magma emplacement in the shallow crust often causes host rock deformation by means of fracturing and faulting. Host rock deformation around magma bodies such as plutons is manifested within a zone referred to as structural aureole with implications for heat and fluid transport. Analysis of structural aureoles is thus important to understand the permeability and alteration processes in hydrothermal ore deposits and geothermal systems. Here, we focus on a granite pluton in Southeast Iceland, the Slaufrudalur pluton, in order to quantify and describe host rock deformation surrounding the pluton. The pluton has a NE-SW long axis and a NW-SE short axis in map view. In sectional view, the pluton shows a sharp transition between steep walls and flat-lying roof, above which the basaltic host rocks are intensely fractured. We employ photogrammetry techniques and 3D virtual outcrop mapping in order to analyze the orientation of layering in the host rocks, fracture sets, as well as silicic and basaltic sheets. We further investigate the distribution of hydrothermal alteration and mineralization within and around the pluton. The layering is dominantly flat-lying to gently-dipping with subtle variations near the contacts to the pluton. Fractures cluster in sets that strike (1) NE-SW, (2) NW-SE, as well as (3) N-S. Silicic sheets above the pluton roof are often parallel to the fractures. Basaltic sheets in turn show variable strikes and dips, while a prominent NE-SW-striking set is most likely associated with the regional stress field. Our results suggest that the structural aureole is limited to conjugate fracturing at the pluton contacts. Hydrothermal alteration and mineralization are mostly associated with fault and fracture surfaces. Our results show the interplay between magma emplacement and is of significance for understanding the formation of ore deposits such as porphyry and epithermal systems above granite plutons, as well as fracture-controlled geothermal systems.

DeepICE: Monitoring Oceanographic processes using Operational Subsea Cables around Iceland

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There are about 500 Subsea Cables around the world and at least four of them are connected to Iceland (Figure 1). Historically, subsea cables have been explored as potential environmental sensors. In the early 1900s, resistance-based measurements from communication cables were used to estimate average bottom temperatures (Hansen et al., 1994; A. Flosadóttir 1997). Today, advances in fiber-optic technology have expanded their potential far beyond temperature measurements. This global fiber-optic-based network has been calling out for alternative functions other than transmitting data.

Recent developments in Distributed Acoustic Sensing (DAS) have been successfully used to translate changes in the propagation time of light along an optical fiber into elastic deformations and even temperature variations. The source of the elastic deformations on the cable that result in a disturbance on the light's travel time can be attributed to environmental processes. Particularly, oceanographic processes spanning ocean currents, eddies, internal waves, surface waves, and even extratropical storms are responsible for generating perturbations that modulate the light path resulting in signals that could be then associated to those processes. Several of those processes have been characterized using standard DAS systems; however, those measurements are limited in length, i.e., they could monitor only 60-80 km of the total length of the cable. Novel and currently under-development technologies built by Nokia Bell Labs allow multi-span laser interferometry to be used over the entire length of the cable.

Our team is working across disciplines to interpret these signals, with the goal of expanding research to other subsea cables (Mazur et al., 2024). To illustrate the capabilities of this technology, we present recent data from the cable connecting Iceland and Ireland (IRIS). We include the recent Storm Éowyn, which hit Ireland on the 21st of January 2025. The storm built a swell and ocean wave field visible in the closest section of the cable near Ireland. Once the core of the storm passes, the cable appears to detect residual wave energy, suggesting wave trapping on the continental shelf.

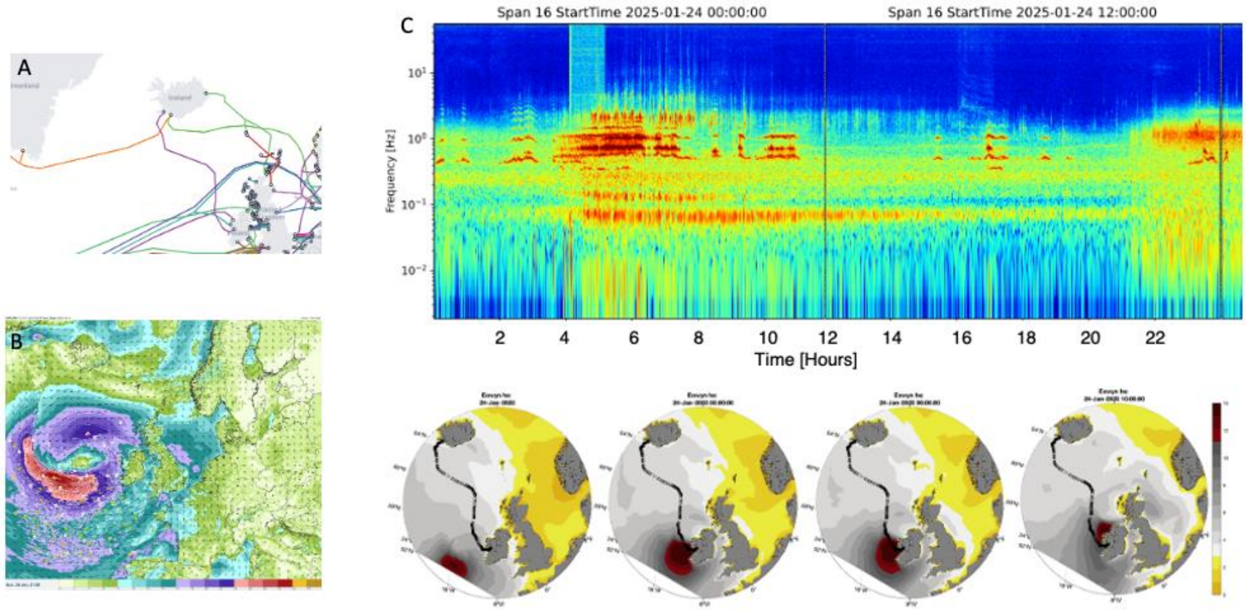

Figure 1. (A) Subsea Cables connecting Iceland (https://www.submarinecablemap.com); (B) Storm Éowyn wind speeds (https://vedur.is/); (C) Spectrogram during the storm Éowyn and significant wave height (HS) snapshots showing the storm core location over the span 16 of the IRIS cable (Copernicus Marine Service).

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Volcanic Gas Compositions Track Dynamic Magma Supply and Storage at Sundhnúksgígar, Iceland

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The chemistry of volcanic gas emissions fluctuates in response to magma recharge and storage, yet their relationship with eruption dynamics remains poorly constrained. Understanding how magma degassing influences eruptive behavior is particularly important at persistently active and reawakening volcanic systems, where magmatic gas input or loss at depth can precede and modulate eruption dynamics. The 2023–2024 Sundhnúksgígar eruptions on the Reykjanes Peninsula provided a unique opportunity to link volcanic gas emissions to magma transport and storage processes.

Our open-path Fourier Transform Infrared Spectroscopy (FTIR) measurements show that early-erupted gas during the initial eruptive event in December 2023 was depleted in CO_2 and SO_2, suggestive of magma that had undergone prolonged storage and outgassing at upper-crustal depths. As the eruptive sequence progressed, gas compositions became increasingly CO_2-rich, likely reflecting continued influx of fresher, less degassed magma. More recent gas measurements from the November 2024 eruption show a decline in CO_2 content, suggesting a waning magma supply.

Extensive pre-eruptive CO_2 outgassing appears to correlate with lower eruption volumes, potentially reflecting that deeply exsolved CO_2 that remains within the magma rather than outgassing at depth contributes to the buoyancy needed to bring magma to the surface. These results underscore the value of gas measurements for forecasting eruption dynamics and emphasize the key role of subsurface magmatic CO_2 degassing in controlling volcanic behavior.

GEOLOGY OF SIKIDANG AREA, DIENG GEOTHERMAL FIELD, INDONESIA: SUBSURFACE GEOLOGY AND FLUID GEOCHEMISTRY CHARACTERIZATION

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Sikidang area is located at the southern part of Dieng geothermal field. Exploration has been done since 1977, and the drilling campaign was completed in 1995. Since then, there are 27 wells in the area that are currently non-productive. This is due to acidic condition that has been found in several of the wells. This study aims to investigate in greater detail the subsurface geology of selected wells in Sikidang to determine the extent of acid fluids and characterize hydrothermal alteration processes in the subsurface. Cuttings from five wells (Fig. 1) and a silica scale sample from one well was analyzed in this study. Methods used include petrography analysis to describe in detail the lithology and alteration minerals at depth; ICP-OES to determine the whole rock composition and the element mobility; microthermometry analyses of fluid inclusions from silica scale, quartz and calcite samples, to determine temperature by homogenization of the inclusions (Th) and fluid salinity in $NaCl_{equiv}$ concentrations by freezing and melting. The salinity was calculated assuming NaCl as the only solute (Bodnar and Vityk, 1994).

Petrographic analysis shows that native sulfur was present continuously in the cuttings. Alunite, an acid-sulfate alteration mineral, was identified in the shallower part in well JS-1, which was drilled towards the Pangonan crater (Fig. 1). The ICP-OES result of well JS-1 reflects the changes in rock composition due to hydrothermal alteration in the form of pyritization and Fe-oxide enrichment at greater depth near the total depth of well from 1550-1759 mMD (meter measured depth), and several events of silicification, illitization, calcitization and Ca-enrichment at both the shallower and deeper part of the well (Fig. 2).

Microthermometry analysis of fluid inclusions from a scale sample at a depth of 1087 mMD in well JS-5 revealed homogenization temperatures (Th) with a median temperature of 179.9 ± 14 (1σ stddev) °C. This temperature is very close to that measured at 1100 mMD in the borehole (180.9°C). Salinity ranged between 1.64 and 6.17 wt% $NaCl_{equiv}$.

Fluid inclusions from well JS-2 at a depth of 638–641 mMD exhibited Th with a median value of 234 ± 40 (1σ stddev) °C. At a slightly larger depth of 659–662 mMD, the median Th is 178 ± 32 (1σ stddev) °C. In this well the measured temperature at 650 mMD is 221.9°C, differs by only 12°C from the median Th of fluid inclusions slightly shallower, but the Th values from slightly deeper sample show a larger difference of 43.9°C. Salinity varied between 0.53 and 7 wt% $NaCl_{equiv}$. When we compare salinities between the two depths, lower salinity values were more frequent in the shallower sample, with 0.5–1 wt% $NaCl_{equiv}$ occurring more often. In contrast, in the deeper sample, salinity values in the range of 1.5–2.5 wt% $NaCl_{equiv}$ were more prevalent. Despite this variation, both depths exhibit relatively low salinities.

Based on fluid inclusion analyses, we can conclude that although median temperatures derived from fluid inclusion homogenization reproduce reasonably well the measured borehole temperatures, the variation of Th and salinities suggest some T and compositional fluctuations in both studied boreholes.

Our next step will be to combine fluid inclusion data with fluid and gas samples collected at the well head of the five wells to estimate aquifer fluid composition. These data will be further utilized to calculate the saturation indices of acid alteration minerals using the geochemical speciation programs WATCH and PHREEQC.

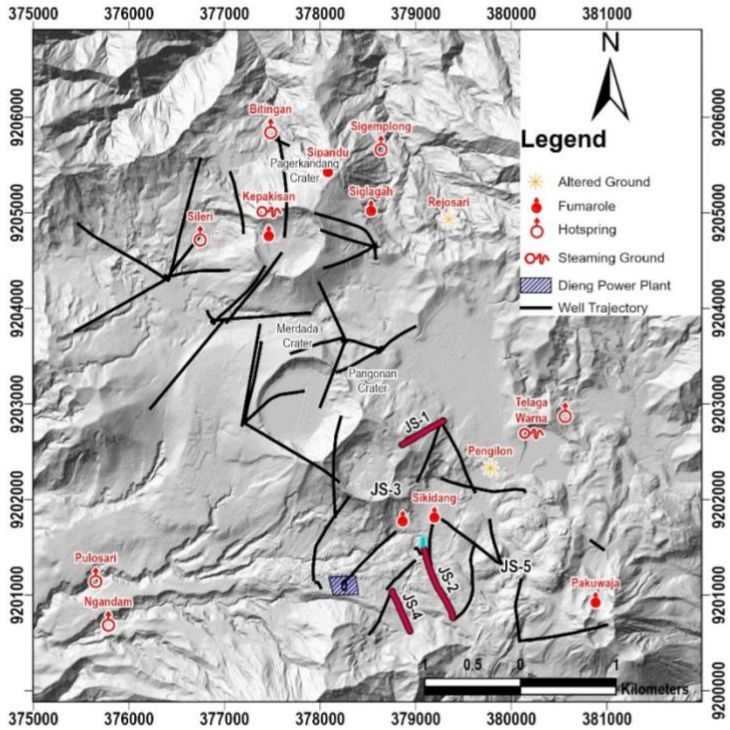

Figure 1. Dieng Geothermal Field Map. The trajectories of the selected wells are highlighted in red. Wells JS-3 and JS-5 are vertical, and their locations are marked by their well names.

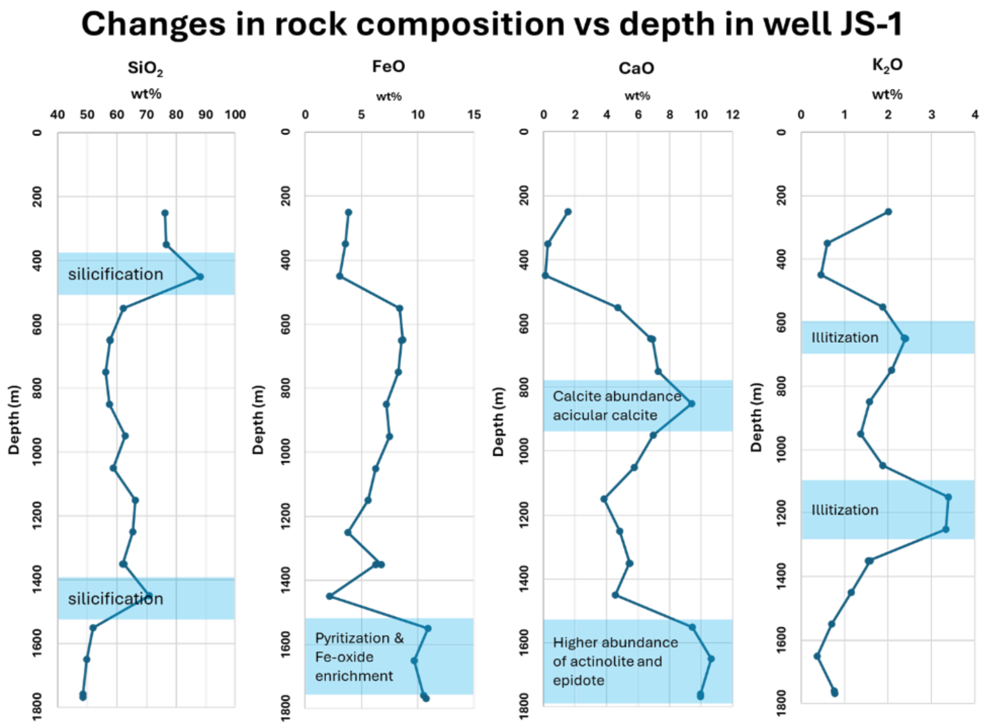

Figure 2. Log of the composition changes versus depth in well JS-1 indication several events of silicification, pyritization, calcitization, and illitization.

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Vinnslusvæði Hellisheiðar- og Nesjavallavirkjunar, saga, nústaða og framtíð

Production Fields of Hellisheiði and Nesjavellir Power Plants: Past, Present, and Future"

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Orkuveitan

Orka Náttúrunnar, dótturfyrirtæki Orkuveitunnar, rekur tvær jarðhitavirkjanir á Hengilssvæðinu. Nesjavallavirkjun með uppsett afl upp á 120 MW_e og 340 MW_{th} og Hellisheiðarvirkjun með uppsett afl upp á 303 MW_e og 200 MW_{th}. Framleiðsla hófst í Nesjavallavirkjun árið 1990 og í Hellisheiðarvirkjun árið 2006. Framleiðslan og áhrif hennar á jarðhitageymana hefur verið vöktuð á vinnslusvæðum beggja virkjana frá upphafi, sem hefur skilað verðmætum gögnum um eðli og þróun auðlindana, gögn sem meðal annars eru nýtt í forðaspágerðir og ákvarðanatökur í auðlindastýringu. Árið 2024 nam massavinnsla tæpum 37,6 milljónum tonna á Hellisheiði og um 18,9 milljónum tonna á Nesjavöllum, um 70% af unnum massa fór til niðurdælingar á báðum vinnslusvæðum. Í erindinu verður gerð nánar grein fyrir vinnslusögu úr jarðhitageymunum, vinnsluþéttleika, þróun niðurdráttar, massavinnslu og orkuinnihalds unnins massa, magni gastegunda í jarðhitavökvanum og niðurdælingu á koltvísýringi og brennisteinsvetni. Auk þess sem tæpt verður á þeim orkuöflunarverkefnum sem fyrirhuguð eru á vegum Orku Náttúrunnar og Orkuveitunnar á Hengilssvæðinu á næstu árum.

ON Power, a subsidiary of Reykjavík Energy, operates two combined heat and power (CHP), geothermal power plants located on each side of the Hengill Central Volcano. Nesjavellir Power Plant has a current capacity of 120 MW_e and 340 MW_{th}, while Hellisheiði Power Plant has a capacity of 303 MW_e and 200 MW_{th}. Production began at Nesjavellir in 1990 and at Hellisheiði in 2006. Production and its impact on the geothermal reservoirs have been monitored at both well fields since the start, providing valuable data for production forecasting and resource management decisions. In 2024, mass extraction amounted to approximately 37.6 million metric tons at Hellisheiði and about 18.9 million metric tons at Nesjavellir, with around 70% of the extracted mass being reinjected at both production fields. The presentation will provide a detailed overview of the production history of the geothermal reservoirs supplying the two power plants, production density, drawdown trends, mass extraction, and energy content of the extracted fluid, as well as the quantity of gases in the geothermal fluid and the reinjection of carbon dioxide and hydrogen sulfide. Additionally, the presentation will provide a brief overview of planned energy development projects by ON Power and Reykjavík Energy in the Hengill area over the coming years.

Crater Rims or Graben Faults? Ground-Penetrating Radar Insights into the Eldgjá Canyon Formation

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Comprehensive models of volcanic deposit distribution can be built by correlating ground-penetrating radar (GPR) data with geological and stratigraphic observations. GPR has many applications in geophysical and geological research. However, its use for studying volcanic deposits remains underdeveloped. The unique nature of volcanic materials poses challenges in interpreting radar profiles, and therefore, the development of a standardised method for applying GPR methodology to volcanic materials is preferable. The Eldgjá eruption, part of Iceland's Katla volcanic system, stands out as one of the most notable explosive basaltic eruptions in historical times, occurring between 937-940 CE. The Eldgjá fissure is one of the largest in Iceland, located in the southern Icelandic highlands. However, the proximal vent deposits are unclear about the vents, particularly within the Eldgjá eruptive units. Are the canyon walls crater rims or graben faults, as suggested by some previous researchers? To achieve this, traditional geological fieldwork observations and GPR surveys were conducted during the summer of 2024. The GPR successfully mapped various volcanic units in key locations such as the Eldgjá Canyon and Skælingar, ranging from proximal tephra fall to fire fountain deposits, with the latter varying from spatter and lapilli to rheomorphic lava layers. Field calibration of the GPR indicates proximal fire fountain deposits that thin rapidly 60-70 metres from the cliff edges in the northern section of the Eldgjá Canyon. Accordingly, we propose that these cliffs are not graben faults but rather crater rims of the Eldgjá 934 eruption. The findings enhance comprehension of volcanic stratigraphy and evaluate the applicability of GPR methodologies in similar geological contexts.

Data processing workflow for UAV magnetometry with applications in rapid hazard assessment of tectonically disrupted areas

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Recent volcano-tectonic unrest in and around the town of Grindavík, Iceland has resulted in many hazardous faults and fractures, requiring rapid hazard assessment. Among the methods used to survey these formations were magnetic surveys carried out using an unmanned aerial vehicle (UAV). Here, we used a MagArrow magnetometer bird produced by Geometrics inc. attached to a frame built around the landing legs of a DJI M600 Pro hexacopter with the leg springs removed. UAV magnetic surveys are a fast, efficient, and low-cost alternative to traditional ground surveys, especially useful in areas deemed unsafe for walking and where fast execution of surveys is paramount.

Due to the inherent similarities in their methods, UAV magnetometry is subject to all of the same sources of error as ground magnetometry: (1) Diurnal magnetic field variations due to magneto- and ionospheric effects; (2) Unwanted detection of the magnetic anomalies of utilities, buildings and other anthropogenic sources, potentially masking fainter geological signals; (3) Ambiguity in interpretation of magnetic anomalies, due to the inherent non-uniqueness of magnetic sources and their anomalies. However, we also encountered some unique challenges with UAV magnetic surveys, the most significant ones among them being: (4) Occasional inaccuracy in the recorded GPS position of the MagArrow bird, with the largest errors up to 20 m; (5) Magnetic interference from the UAV body itself.

Here we present a Python-based data processing program tailored for UAV magnetic surveys that corrects for, filters out, or otherwise minimizes as much as is possible, the aforementioned sources of error. The default graphical user interface (GUI) for the data processing is a Jupyter Notebook, a free Python software, with custom interfaces for each data processing step. The Python processing functions work independently of the user interface, maximizing the potential for user customization. Processed datasets have improved quality in both the magnetic data and positioning data. The program handles a wide range of data formats, due to its in-program configuration of the data formatting settings with options for saving the settings and sharing them with team members. Due to its versatility and customizability, this program can be used to process UAV magnetometry data for a wide range of applications.

Development of the Eyjafjallajökull ice cap (Iceland) after the 2010 summit eruption

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Although research on glaciovolcanism has increased significantly in recent years, studies usually focus on eruption processes and their direct hazard implications, while long-term effects, e.g., on the overlying glacier cover, receive little attention. For example, numerous studies exist on the 2010 Eyjafjallajökull eruption itself, but few follow-up studies have been published on how the glacier cover has evolved and how the vent areas have changed since then. During the eruption, three different areas of the Eyjafjallajökull ice cap were affected: (i) the summit caldera with the volcanic vents active for six weeks; (ii) the short-lived eruption fissure on the south flank; and (iii) the Gígjökull outlet glacier north of the caldera, which was affected by a subglacial lava flow. We provide a comprehensive overview of how these areas have changed with time and illustrate differences in their recovery. While signs of the eruption on the southern flank have completely vanished, the glacier within the caldera has not fully recovered. Observations from October 2024 also indicate the formation of a new minor cauldron near the northern rim. Gígjökull showed great fluctuations since 2010 with the glacier terminus alternating between advance and retreat, although overall the Eyjafjallajökull ice cap is retreating. Our results are primarily based on aerial photographs from overflights, visits of the investigation area, and different types of remote sensing data. Our studies are critical for understanding how single events can impact long-term glacier developments and their recovery in times of global warming.

Magnetic monitoring station at Sýlingarfell: Setup and preliminary results

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Háskóli Íslands

Monitoring active volcanoes is critical for minimising risks and hazards associated with eruptions. Effective monitoring relies on various techniques to detect and analyse changes in volcanic behaviour. The use of magnetic monitoring stations is a possible new tool for detecting volcanic unrest and monitoring the volcanic here in Iceland.

Changes within volcanic systems can alter the local magnetic field through several mechanisms. This can be detected with simple magnetic monitoring equipment and previous studies have demonstrated the possibility of using magnetic monitoring to detect changes within volcanic systems. There are three main mechanisms that contribute to detectable changes within the magnetic field surrounding a volcanic system. Magma above the Curie temperature is essentially non-magnetic and subsurface movements of magma can affect the magnetic field measured at the surface by "replacing" magnetic rocks[1,2]. Changes within the geothermal systems such as temperature changes, can also generate a detectable magnetic change through the electrokinetic effect[3,4]. Finally, stress changes, such as those associated with the propagation of a dyke can generate a change in the magnetic field through the piezomagnetic effect[5]. Measurements of the time varying magnetic field surrounding a volcanic system could thus potentially serve as an early warning tool by identifying changes indicative of magmatic movement and provide valuable insights into subsurface volcanic processes.

In late 2023 volcanic activity began on Sundahnúkagígaröðin. In May 2024, a magnetic monitoring station was installed near Sýlingarfell, consisting of various magnetometers, GPS, solar panels and batteries. Instruments at the station continuously monitored the Earth‘s magnetic field. The instruments installed were: one GSM 19 Overhauser total field magnetometer, one Geomag 3-axis fluxgate, two small digital EZIE-Mag magnetometers measuring 3-axis components of the field, and one small digital Conejo magnetometer. Additionally, three other Conejos were installed within the area: one half-way up the Þorbjörn hill, one in between Þorbjörn and Svartsengi powerplant down below and one on the small hill right east of Sundahnúkagígaröð. Here we present the station setup and preliminary magnetic data from the May 2024 eruption. Future steps of the project will also be discussed.

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Light volatile isotopic constraints on the origin of thermal fluids along the Albertine Rift, SW Uganda

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The East African Rift System (EARS) is Earth's largest active continental rift system. Seismic tomography investigations and noble gas volatiles studies have identified the African Superplume, a continental-scale, thermochemical mantle plume originating at the core-mantle boundary, as the primary driver of topographic uplift, magmatic heat and volatiles throughout the EARS, including its Western Branch. To date, there are limited noble gas and volatile isotope studies of either rocks or geothermal fluids to substantiate these findings for this part of the rift. The Albertine Rift in SW Uganda hosts several geothermal areas and active volcanoes with mafic igneous rocks and, thus, facilitates assessments of deep vs. shallow volatile inputs into a region undergoing continental extension.

We report He-CO_2-N_2-SO_2 isotope and relative abundances in thermal fluids from 16 localities from the Albertine Rift. The localities include the three major geothermal areas of this region, Katwe-Kikorongo, Buranga and Kibiro, that have been extensively explored but lack comprehensive and combined volatile isotopes studies. We supplement the fluid data with He isotope data from olivine crystals separated from mafic lavas.

Fluids show a large range in $^3He/^4He$ (R_C/R_A) but many samples are characterized by highly radiogenic values ($\geq 0.02R_A$). The highest $^3He/^4He$ is from a thermal spring from the Buranga region ($3.2R_A$). In contrast, olivine crystals show consistently higher and remarkably uniform $^3He/^4He$ ($7.67\pm0.44R_A$; n= 12, 1σ). $CO_2/^3He$ span about six orders of magnitude while $\delta^{13}C$-CO_2 values show two distinct populations whereby samples with $^3He/^4He > 1R_A$ cluster at –5‰ and samples with more radiogenic values ($<1R_A$) extend towards highly negative $\delta^{13}C$-CO_2 values (≥ –17.9‰). Only one locality has highly negative $\delta^{15}N$-N_2 values and irrespective of $^3He/^4He$, all other localities show uniform values (mean value of +1.5±2.2‰; n= 17, 1σ). A large range is evident in both $\delta^{34}S$ and $\Delta^{33}S$ values of SO_4 and $\delta^{34}S$ shows a negative correlation with $^3He/^4He$. In this case, highly radiogenic values extend to positive $\delta^{34}S$ values (≤ +18.75‰). In contrast to studies from the northern EARS (e.g., Ethiopia), extensive modifications of mantle-derived fluids that appear to largely reflect upper mantle volatile domains is thus evident in this part of the EARS.

Ljósleiðaravaki varar við eldgosum

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Frá nóv 2023-nóv 2024 var ljósleiðaravaki (DAS Interrogator) við mælingar á ljósleiðara fjarskiptafyrirtækisins *Ljósleiðarinn* á milli Keflavíkur og Þorlákshafnar. Segja má að vakinn breyti ljósleiðaranum í þétta röð skynjara sem mæli hvort sé að teygjast á ljósleiðaranum eða hann að þjappast saman. Fyrri rannsóknir hafa sýnt að með ljósleiðaravökum megi greina mismunandi upptök hreyfinga í jörðinni, svo sem jarðskjálfta, skriðuföll, snjóflóð, bíla og gangandi fólk. Í feb 2024 tókum við eftir því að skýrt merki birtist á ljósleiðaranum meira en 30 mínútum áður en eldgos hófst og var fljótlega hafist handa við að þróa aðferðafræði sem nýtir þetta merki til þess að vara við yfirvofandi eldgosi.

Aðferðin er afar einföld og felst í því að merkið er lághleypisíað við 100 sekúndur, meðaltal tekið yfir síaða merkið á 500 metra kafla á ljósleiðaranum þar sem hann liggur austan Grindavíkur og svo að lokum hlaupandi meðaltal yfir fimm mínútna glugga. Með þessari aðgerð fæst einfaldað merki sem hægt er að fylgjast með útslaginu á í nær rauntíma. Þegar einfaldaða merkið fer yfir 1 nanostrain/sec er gefin út viðvörun. Með því að keyra þessa aðgerð aftur í tíma fæst að hún nær að vara við öllum eldgosunum, en einnig gefur hún bara eina falska viðvörun; þegar gangainnskot varð sem náði ekki til yfirborðs. Í síðasta gosi sem mælingar ná yfir, í ágúst 2024, náði kerfið að senda út viðvörun 26 mínútum áður en gos hófst. Í þessu erindi verður aðferðinni lýst og hún borin saman við aðrar aðferðir til eldgosaviðvarana.

InSAR Observations of Fracture Movements on the Reykjanes Peninsula

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Widespread fracture movements have been observed on the Reykjanes Peninsula since volcano-tectonic unrest began in 2020. TerraSAR-X data were processed to create 57 interferograms spanning September 2021 to July 2024 from which fractures were mapped manually. While many of these movements can be explained by favorable stress changes associated with diking and coseismic deformation, the observed fracture distributions, particularly those associated with the 10-11 November 2023 Grindavík dike intrusion, extend well beyond the regions of positive Coulomb stress change where fracture movements are expected, assuming normal faulting. A pair of unwrapped ascending and descending interferograms spanning the Grindavík dike intrusion were decomposed into near-vertical and near-east displacement maps and high-pass filtered to reveal the displacement patterns along fractures. Systemic variations in the sense of motion along fractures striking approximately N40°E are observed: a) In regions of positive co-diking normal stress change, or unclamping, near-east displacements show opening and a significant component of vertical displacement along fractures, as observed in the town of Grindavík. b) In regions of negative normal stress change, or clamping, near-east displacements show closing and a small component of subsidence along fractures. The former a) is consistent with triggered slip along normal faults, while the latter b) is consistent with shallow closing dislocations. The fracture movements in regions of clamping are therefore interpreted as strain localization along zones of weakness at depths of <100 m. As diking puts portions of adjacent fissure swarms under compression, the resulting deformation is concentrated along weak zones at the surface: open tensional fractures and normal faults. The densest region of fracture movements within the Reykjanes fissure swarm has a characteristic spacing of approximately 200 m, and decomposed line-of-sight (LOS) displacements indicate that the amplitude of closure along fractures in this area is no more than 10 mm, corresponding to about -50 µstrain, significantly larger than the observed annual tectonic strain rates in this region.

Persistent fracture movements are also observed within the northeastern portions of the Krýsuvík and Brennisteinsfjöll fissure swarms. These do not appear to be directly related to co-diking stress changes but rather are coincident with small earthquake swarms ($M_{max} = 3.1$). Ascending and descending LOS displacement maps for these events are symmetric, indicating that deformation is primarily vertical and related to shallow normal faulting. Leveling observations across several of the active fractures within Búrfellsgjá in the Krýsuvík fissure swarm confirm centimeter-scale deformation for the 2012-2024 period. These observations suggest that fracture movements, albeit small, can occur over a much larger area than indicated by stress changes favorable for faulting.

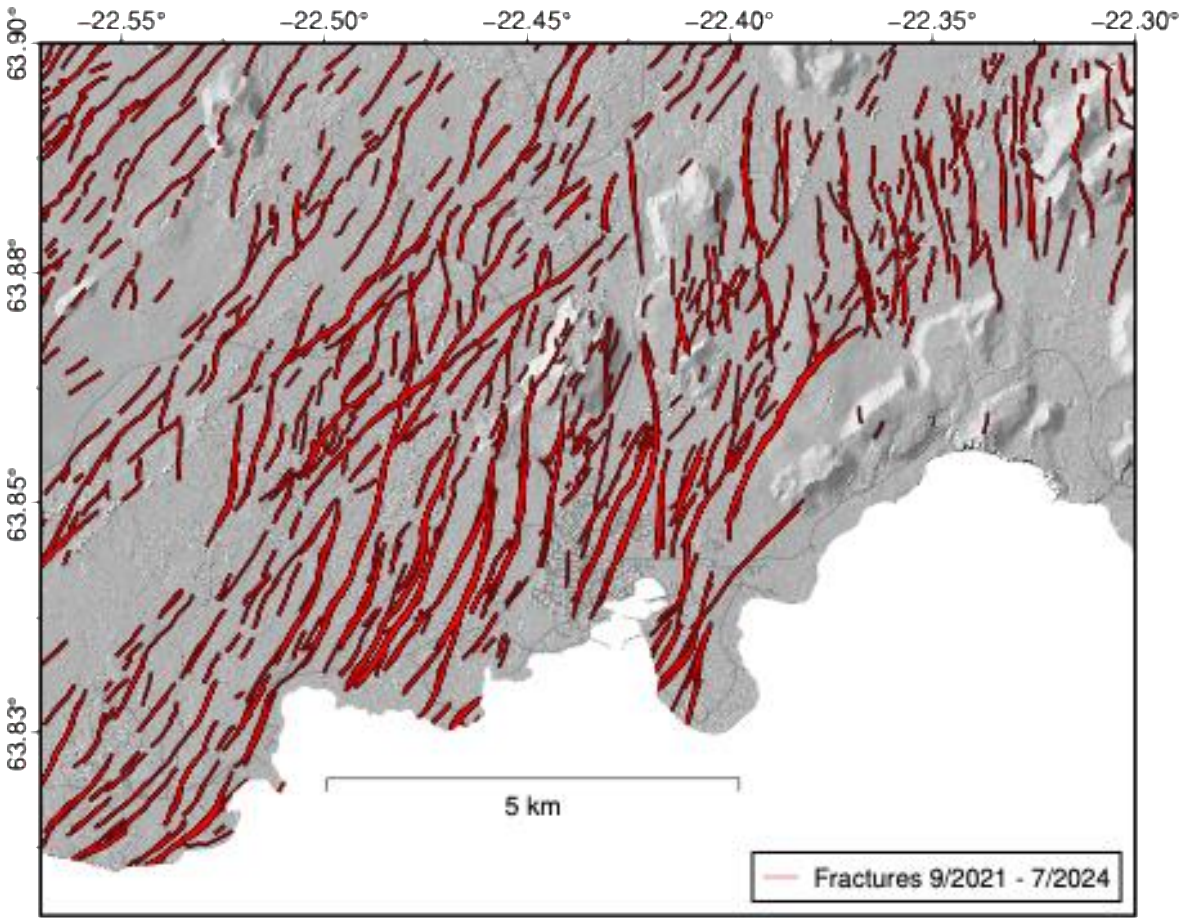

Figure 1. Active fractures mapped in the vicinity of Grindavík from September 2021 to July 2024. These consist of structures activated during diking at Fagradalsfjall in 2021, 2022, and 2023, inflation at Svartsengi in May – June 2022, and inflation and diking at Svartsengi in October 2023 - July 2024. Note prominent graben-bounding faults within Grindavík and characteristic spacing (several hundred meters) of fractures.

Dreifing vetrarsnævar á Sátujökli mæld með snjósjá

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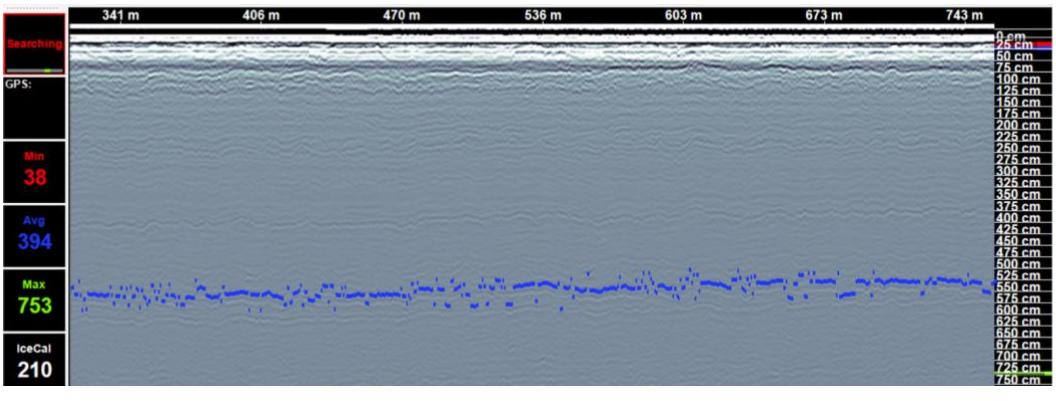
Hofsjökull er þriðji stærsti jökull á Íslandi og fer hann ört rýrnandi líkt og aðrir jöklar landsins. Við lok 19. aldar nam flatarmál hans 1038 km^2 en hefur nú minnkað í um 790 km^2.

Á norðanverðum Hofsjökli hefur verið afmarkað ísflæðisvið sem nefnt er eftir móbergsfjallinu Sátu og nær það yfir tæpan tíunda hluta af flatarmáli alls jökulsins. Mælingar á legu jökuljaðarsins ná aftur til 1950 og hefur sporðurinn hopað um 1000 m á tímabilinu 1950–2023. Ísasvið Sátujökuls nær nú yfir hæðarbilið 850–1720 m og mesta breidd þess er 7 km. Flatarmál þess hefur rýrnað úr 78 km^2 í 72 km^2 á árabilinu 1988–2023. Frá því rennur leysingarvatn til Vestari Jökulsár sem fellur niður í Skagafjörð.

Reglulegar afkomumælingar hófust á Sátujökli 1988 og síðan hefur vetrar- og sumarafkoma ísasviðsins verið mæld árlega í 8–15 punktum. Gögnin eru aðgengileg í Jöklavefsjá. Sprungur hindra för um hluta jökulsins og eru mælipunktarnir því bundnir við örugg svæði. Vetrarafkoman (B_v) er mæld með snjóborunum gegnum vetrarlagið að vori og sumarafkoman (B_s) með aflestri af leysingarstikum vor og haust. Summa B_v og B_s gefur ársafkomu, sem er neikvæð ef massatap hefur orðið. Frá upphafi mælinganna hefur ársafkoman aðeins 5 sinnum mælst jákvæð, en 32 sinnum neikvæð. Til samanburðar við punktmælingar hefur afkoma einnig verið reiknuð yfir ákveðin árabil út frá landlíkönum, sem gera kleift að meta rúmmálsrýrnun og þar með massatap. Skv. þeim niðurstöðum reynast hinar hefðbundnu punktmælingar vanmeta rýrnun Sátujökuls um 0.25 m/ári (vatnsgildi) og meðal-afkoman 1988–2023 svarar til þess að árlega hafi að jafnaði tapast um 0.8 m þykkt vatnslag af ísasviðinu öllu.

Til að skilja orsök vanmats út frá punktmælingum hafa nákvæmar mælingar á dreifingu snjóþykktar á Sátujökli farið fram síðan 2015. Notuð er snjósjá (GPR-radar) af gerðinni IceMap, sem sendir 500 MHz rafsegulbylgju niður í yfirborðslög og greinir endurköst sem stafa fyrst og fremst af snörpum breytingum á þéttleika. Tækinu er komið fyrir í sterkbyggðum plastkassa og er allt sambyggt í einni einingu: Sendir, móttakari, GPS-tæki og rafhlaða. Kassanum er komið fyrir í plastbát, sem dreginn er af vélsleða á hraðanum 20–40 km/klst. Að jafnaði næst ein þykktarmæling með 0.4 m millibili. Samanlögð lengd ekinna mælilína á Sátujökli hefur á hverju ári verið nálægt 100 km og nást því 250.000 snjóþykktarmælingar með snjósjánni á þessum hluta jökulsins í hverri vorferð.

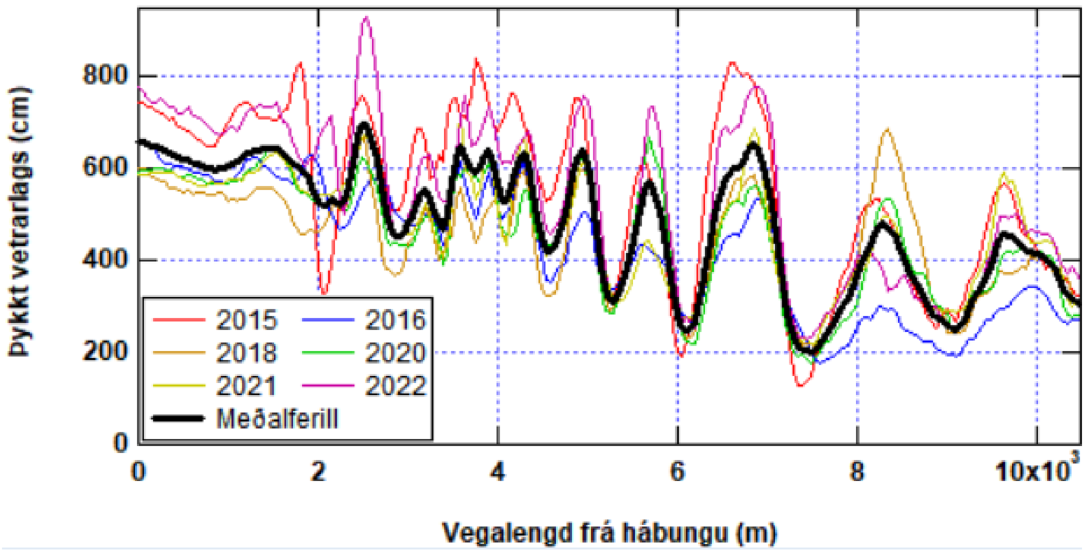


Endurkast frá hausthvörfum á um 550 cm dýpi á um 400 m löngu sniði nærri hábungu Hofsjökuls.

Snjósjáin mælir ferðatíma rafsegulbylgju milli yfirborðs og tiltekins endurkastsflatar og sé hraði bylgjunnar þekktur má reikna dýpt snævar ofan flatarins. Mælt snjódýpi niður á jökulís eða hausthvörf er notað til að ákvarða meðalhraða rafsegulbylgjunnar í vetrarlaginu á hverju vori. Hraðinn hefur reynst vera á bilinu 208–214 m/µs. Reglulega er kannað hvort endurtekin mæling á tilteknu sniði skilar sambærilegri niðurstöðu og fyrri mæling. Munur á meðal-snjóþykkt úr tveimur mælingum á sama sniði hefur reynst vera á bilinu 0.5–2.0%. Ennfremur hefur verið kannað hvernig þykktarmælingum beri saman þegar tvö mælisnið skerast og reyndist mismunur á reiknuðu dýpi í 32 slíkum skurðpunktum að meðaltali 1.2%. Af þessum samanburði er ályktað að snjósjármælingin gefi góða mynd af þykkt snjólags vetrarins. Erfiðleikar geta þó komið upp við túlkun endurkasts frá hausthvörfum innan ákomusvæðisins, því blotar snemma vetrar leiða oft til myndunar íslaga í neðsta hluta vetrarlagsins og gefa slík lög ekki minna áberandi endurköst en hausthvörfin.

Á árabilinu 2015–2024 hafa mælingar á þykkt vetrarlags farið fram á Sátujökli í öllum vorferðum (utan 2017). Í ljós kemur að snjósöfnun er með mjög áþekku móti öll árin, þótt mismikil sé. Sérstaka athygli vekja reglubundnar sveiflur í snjóþykkt á sniði sem mælt er frá hábungu Hofsjökuls (1790 m y.s.) norður að jaðri Sátujökuls. Talið er að þær orsakist af skafrenningi á jöklinum. Snjóinn skefur af hnúskum á yfirborði jökulsins og sest hann síðan til hlémegin. Hnúskarnir virðast orsakast af stallalandslagi í hlíðum öskjunnar, sem Hofsjökull hylur. Í ljós hefur komið að nokkrir mælipunktanna, sem notaðir hafa verið við afkomumælingar frá 1988, eru staðsettir í snjóþykktarhámörkum og hefur það haft áhrif á niðurstöður afkomureikninganna.

Í kynningu þessari verður lýst dreifingu snjóþykktar á Sátujökli og notkun snjósjárgagna til að meta þátt vetrarafkomu í ofangreindu vanmati á rýrnun jökulsins.



Reglubundnar sveiflur koma fram í þykkt vetrarlags mældri á S-N sniði á Sátujökli. Snjóþykktin getur allt að þrefaldast á innan við 1000 m vegalengdarbili. Staðsetning hámarka á ferlunum breytist mjög lítið milli ára. Sé stuðst eingöngu við niðurstöður borana sem (sumar hverjar) lenda í snjóþykktarhámörkum skekkir það myndina af vetrarafkomu jökulsins.

Explosive phases of the 937-40CE Eldgjá flood lava eruption, Iceland and the variability in magma composition

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The 937-40 AD Eldgjá flood lava eruption in Iceland (21 km^3) took place on a ~70-km-long vent system trending northeast from the Katla central volcano. It features four distinct vent segments: Eldgjá South, Central, Chasm, and North. The South segment is partly beneath the Mýrdalsjökull glacier, but the reminder of the vent system was subaerial. The eruption produced >16 eruption episodes each featuring phreatomagmatic or magmatic explosive activity of sub-Plinian to Plinian intensities. The tephra fall from these explosive phases covers >20,000 km^2 and has a cumulative volume of >6 km^3 (1.3 km^3 DRE). The lava volume is 19.6 km^3. The eruption started on the South segment, ~10-15 km NE of the Katla caldera and for the first ~1.5 yrs the eruption shifted between vents just outside and beneath the glacier producing stratified phreatomagmatic tephra sequence interspersed with sporadic magmatic tephra units. This part represents the Wet Phase of the eruption. In the final 1.5 yrs the activity propagated towards the northeast, away from the Katla volcano, producing magmatic tephra (and lava) representing the Dry Phase. Eldgjá magma is rather evolved (MgO: 4.9-5.7 wt.%), mildly alkalic basalt. Analyses of samples representing all eruption episodes show that the most primitive magma (MgO: 5.5-5.7 wt.%; Zr: 220-235 ppm) erupted during the initial Wet Phase. The erupted magma became more evolved (MgO: 4.9-5.5 wt.%; Zr: 240-280 ppm) during the Dry Phase, indicating extraction of magma from shallower levels within the crustal storage zone during the latter half of the eruption.

Brimnes: Nýtt lághitakerfi á höfuðborgarsvæðinu staðfest með borunum

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[1] Orkuveitan, [2] ÍSOR

Nú í vetur hafa Veitur látið bora tvær rannsóknarholur á Brimnesi, sunnanvert við Hofsvík á Kjalarnesi. Rannsóknir og mælingar á þessum holum standa enn yfir og úrvinnslu er ekki að fullu lokið. Þessar boranir hafa þó staðfest að þarna er að finna jarðhitakerfi sem er 95 til 105°C heitt. Fyrstu niðurstöður benda til þessa að efnasamsetning vökvans sé heppileg m.t.t. nýtingar, þ.e. pH virðist vera hátt, >9, og selta virðist vera lág, eða á bilinu 50 til 100 mg/kg (skv. leiðnimælingum). Fyrri rannsóknarholan, SV-08, var boruð niður á 800 m dýpi og reyndist mjög gæf. Hún hitti á lekar æðar á 250 m, 350 m og 700 m dýpi og fengust úr henni >50 l/s í blástursprófi í borlok af tæplega 90°C heitu vatni við um 60 m niðurdrátt. Seinni holan, SV-10, sem boruð var niður á 900 m dýpi var mun tregari og gaf hún rétt um 10 l/s við 120 m niðurdrátt. SV-10 virðist hins vegar örlítið heitari en SV-08. Hitastig á 600 m er um 103°C í SV-10 en um 97°C í SV-08.

Engin yfirborðsvirkni er á Brimnesi og við jarðhitaleitina var fyrst og fremst stuðst við hitastiguls-rannsóknir. Þegar yfirstandandi rannsóknarfasi hófst, árið 2022, voru einungis fimm holur á Kjalarnesi sem til voru nothæfar hitamælingar úr. Þar af voru þrjár á norðanverðu Kjalarnesi, nálægt gangnamunna Hvalfjarðarganganna og tvær á sunnanverðu nesinu. Hitastigulskort byggt á hitamælingum úr þessum holum sýndi samfellt hitafrávik með norður-suður stefnu eftir endilöngu Kjalarnesi undir vestanverðri Esju sem var tengt hitafráviki sem kom fram í Hvalfjarðargöngunum. Síðan þá hafa Veitur látið bora 29 hitastigulsholur (60 til 100 m djúpar) víðsvegar á Kjalarnesi og inn eftir Kollafirði og nú er komin fram mun skýrari mynd af hitafari í berggrunni á svæðinu. Nú hefur komið í ljós að við vestanverða Hofsvík er víðfeðmt og sterkt hitastigulsfrávik. Hæstu hitastigulsgildin, um 380°C/km, mældust yst á Brimnesi við sunnanverða Hofsvík og þar voru rannsóknarholurnar settar niður.

Stefnt er að því að gera skammtíma dælupróf á holu SV-08 í ár. Þá er gert ráð fyrir að virkja holuna með dælu og dæla úr henni í nokkrar vikur úr í sjó og fylgjast með vatnsborði, hitastigi og efnasamsetningu vökvans. Kanna þarf hvort óhætt sé að blanda vatni frá Brimnesi við annað lághitavatn í hitaveitu höfuðborgarsvæðisins m.t.t. útfellingahættu. Ef það er óhætt og skammtímaprófun leiðir ekki til kólnunar eða hækkandi seltu er stefnt að því að virkja holuna varanlega og tengja við flutningslögn Veitna á Kjalarnesi. Holan verður síðan keyrð af fullum krafti inn á dreifikerfi hitaveitu höfuðborgarsvæðisins og líta má á þá keyrslu sem annan áfanga í afkastaprófun svæðisins.

Áformað er bora fleiri holur á næstu árum á Brimnesi til að kanna umfang og vinnslugetu svæðisins. Hversu margar þær verða á endanum ræðst af niðurstöðum úr vinnsluprófunum á SV-08 og árangri af borunum en núverandi áætlanir gera ráð fyrir a.m.k. tveimur holum. Önnur verður grönn, 1200 m djúp, rannsóknarhola á norðanverðu nesinu, austan við holu SV-08 til að kanna útbreiðslu auðlindarinnar í þá átt. Þá er gert ráð fyrir einni 1500 m djúpri, stefnuboraðri holu til norðurs undir Hofsvík.

Hitastigulsboranir á Kjalarnesi voru unnar af Bergborun en Ræktunarsamband Flóa og Skeiða boraði rannsóknarholurnar tvær. Jarðfræðiráðgjöf og borholumælingar hafa verið í höndum ÍSOR. GeoEnergy og COWI hafa séð um verkefnisstjórnun rannsóknarborana fyrir hönd Veitna.

Jarðkönnun Grindavíkur

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Öflug skjálftahrina, tengd flekahreyfingum, hófst í október 2023 á svæðinu á milli Þorbjarnar og Sundhnúks, sem leiddi til myndunar sigdals og kvikuhlaups undir Grindavík þann 10. nóvember. Í kjölfarið fylgdu eldgos á Sundhnúksgosreininni, þar af nokkur sem ollu sprunguhreyfingum í Grindavík. Tveir megin sigdalir mynduðust í og við bæinn, aðgreindir af rishrygg. Við þessi umbrot opnuðust margar sprungur og skemmdir urðu á byggingum, vegum og öðrum innviðum. Landsig mældist mest um 1,5 m. Í kjölfar atburðanna fóru Almannavarnir þess á leit að ítarleg jarðkönnun færi fram á svæðinu sem nú er lokið. Jarðkönnun Grindavíkur hefur verið samstarfsverkefni ÍSOR, VERKÍS, EFLU, HÍ og Vegagerðarinnar.

Lokaskýrsla um jarðkönnun Grindavíkur ásamt fjölda minnisblaða liggur fyrir þar sem gerð er grein fyrir niðurstöðunum. Ein meginafurð verkefnisins er ítarlegt sprungukort af Grindavík. Koma þar fram sjö aðskilin sprungubelti sem hreyfst hafa í yfirstandandi umbrotum, þ.e. Stamphólsgjá, Hópssprunga, Austurhópssprunga, Víðihlíðarsprunga, Bröttuhlíðarsprunga, Stakkavíkursprunga og Strandhólssprunga (meðfylgjandi kort). Stamphólsgjá er dýpsta og breiðasta sprungan, allt að 3 m á breidd og yfir 30 m djúp. Auk þess mælist meira en 20 m dýpi á sprungum innan sprungubelta Hópssprungu og Bröttuhlíðarsprungu. Mikilvægt er að hafa í huga að Stamphólsgjá og Hópssprunga eru nokkur þúsund ára gamlar sprungur og þessi mikla gliðnun á þeim er ekki öll til komin í núverandi atburðum. Á gömlum loftmyndum sést að Stamphólsgjá var talsvert opin áður en bærinn byggðist upp. Engin ummerki eru um Austurhópssprungu, Víðihlíðarsprungu, Bröttuhlíðarsprungu og Stakkavíkursprungu á eldri loftmyndum og eru þær því taldar hafa myndast í yfirstandandi atburðum. Við Strandarhól mælist mjög mikil gliðnun á Strandhólssprungu, um 2,4 m. Þar má greina væg merki um sprunguna á eldri loftmyndum en engu að síður hefur þarna átt sér stað ein mesta gliðnunin sem hefur verið mæld í Grindavík í núverandi atburðum. Algengast er að sprungur séu um 20-60 cm breiðar og 1-5 m djúpar. Hlutfallslega fáir staðir eru með >80 cm breiðar og >8 m djúpar sprungur. Mikilvægt er að hafa í huga að víða er mikið efnishrun ofan í sprungur og oft sjást aðeins dældir og sig á yfirborði sem gefa vísbendingu um opna sprungu undir yfirborðinu. Við jarðkönnunina var ýmsum rannsóknaraðferðum beitt s.s. loftmyndatúlkun, LiDAR-hæðarmælingum, jarðsjármælingum, segulmælingum, viðnámsmælingum og sjónskoðun. Allar götur í Grindavík voru mældar með jarðsjá í því skyni að skima eftir vísbendingum um holrými undir yfirborðinu. Í framhaldinu fóru fram frekari rannsóknir á svæðunum þar sem jarðsjármælingar gáfu vísbendingar um holrými með bæði segul- og viðnámsmæli til frekari staðfestingar.

Í gryfjum sem grafnar voru í tengslum við viðgerðir á götum fékkst gott tækifæri til að skoða nokkra metra ofan í berggrunninn og sjá hvernig hann er samsettur. Þessar athuganir hafa leitt í ljós að í efstu 4-10 m berggrunnsins eru fjögur hraunlög frá eftirjökultíma aðgreind af setlögum og jarðvegi. Ekki sáust í myndanir frá ísöld, s.s. móberg eða grágrýti, sem eru þá á meira dýpi. Yngsta hraun á yfirborði er Sundhnúkahraun (~2000 ára). Gamlar þekktar gjár í Grindavík eru áberandi í eldri hraunum (>8000 ára) en sjást lítið sem ekkert í Sundhnúkahrauni.

Þó að jarðkönnun innan Grindavíkur sé lokið er mikilvægt að hafa í huga að jarðhræringar í og við Grindavík eru enn í gangi og möguleiki á frekari sprunguhreyfingum í framtíðinni. Auk þess eru sprungur á yfirborði enn að breytast og ný ummerki að koma í ljós. Ljóst er að laus jarðefni eru á hreyfingu í sprungunum og því mikilvægt að fylgjast vel með öllum breytingum.