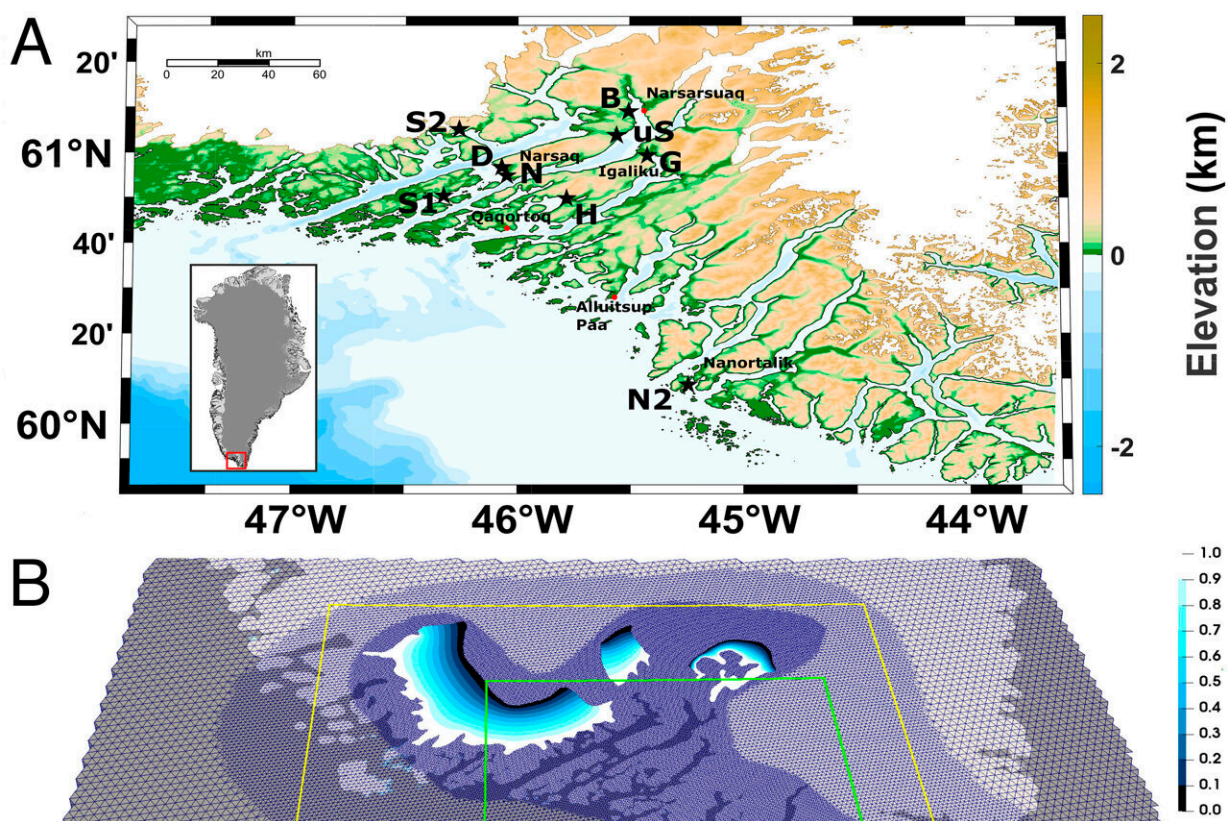


Researchers describe sea-level rise in southwest Greenland as a contributor to Viking abandonment

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Regional setting and ice history. (A) The Eastern Settlement of Southern Greenland. The inset shows the entirety of Greenland; dark gray depicts grounded ice cover at present, light gray is land, and white is ocean. Eight black stars show locations of the Viking sites considered herein and also Nanortalik, where Late Holocene relative sea-level data have been collected (11). B is Brattahlid, D is Dyrnaes, G is Gardar, H is Hvalsey, N is Narsaaq, N2 is

Nanortalik, S1 is Site 1, S2 is Site 2, and uS is Undir Solarfjollum. (B) The tetrahedral grid across Southern Greenland used in the sea-level simulation (top 72 km of Earth's interior is shown in light gray; surface shading reflects grid resolution and is discussed in Material and Methods Section 3B) with ice mask (blue to white gradient) overlain. The ice mask is estimated from ref. 12. The yellow box shows an area encompassing the Eastern Settlement and the area of ice growth (the same area is shown in Fig. 3A). The green box shows an area with several important Viking settlements, where coastal flooding is assessed (also seen in Fig. 4A). For more details, Section 3A. (C) Time-varying growth for our ice history, normalized to a maximum value of 1.0, and adapted from refs. 13–15. Credit: *Proceedings of the National Academy of Sciences* (2023). DOI: 10.1073/pnas.2209615120

Vikings occupied Greenland from roughly 985 to 1450, farming and building communities before abandoning their settlements and mysteriously vanishing. Why they disappeared has long been a puzzle, but a new paper from the Harvard University Department of Earth and Planetary Sciences (EPS) determines that one factor—rising sea level—likely played a major role.

"There are many theories as to what exactly happened," to drive the Vikings from their settlements in Greenland, said Marisa J. Borreggine, lead author of the "Sea-Level Rise in Southwest Greenland as a Contributor to Viking Abandonment," which published this week [April 17] in *Proceedings of the National Academy of Sciences (PNAS)*.

"There's been a shift in the narrative away from the idea that the Vikings completely failed to adapt to the environment and toward arguments that they were faced with a myriad of challenges, ranging from social unrest, economic turmoil, political issues, and [environmental change](#)," said Borreggine, a doctoral candidate in the Harvard Griffin GSAS in EPS.

"The changing landscape would've proven to be yet another factor that challenged the Viking way of life. Alongside these other challenges," said Borreggine, who works in the Mitrovica Group led by Frank B. Baird, Jr. Professor of Science Jerry X. Mitrovica. This likely led "to a tipping point before they abandoned the settlement."

The departure of these Viking settlers coincided with the beginning of the period known as the Little Ice Age, which had a particular impact on the North Atlantic. But while cooling and freezing might seem likely to lower sea levels, a variety of factors combined to have the opposite effect in Greenland.

With the waters of the North Atlantic "contributing to that new ice volume, intuition might suggest that sea level should go down," Borreggine noted. However, a closer look at previously published geomorphological and paleoclimate data and the researchers' modeling of ice-sheet growth suggested that the opposite occurred in Greenland, focusing on the Vikings' Eastern Settlement. "What we study in our group is [glacial isostatic adjustment](#), a process that leads to changes in the [gravitational field](#), the rotation axis, and crustal deformation as the ice grows or melts," said Borreggine.

In a first for this kind of research, Borreggine noted, "We were able to apply that analysis of non-uniform sea-level change and more accurate sea-level physics to this longstanding archeological question of 'Why exactly did Vikings abandon the Eastern Settlement?'"

What the researchers found was striking: Not only were sea levels drawn up by gravity, other factors—including the subsidence of Greenland's land mass—made the settlement more prone to flooding.

Focusing on the period of Viking habitation from 1000 to 1450, "There's already a background trend of sea-level rise upon Viking arrival in the

Eastern Settlement," they said. "It's been rising for a few thousand years." But there's also a local effect: "Crustal subsidence, or the sinking of land and the gravitational pull of water toward the growing ice sheet."

"Not only do you have the ground being pushed down, you also have the sea surface going up," Borreggine noted. "It's a double whammy."

During this period, researchers found that the settlers experienced "up to 3.3 meters of sea-level rise throughout their occupation. That's two to six times the rate of 20th-century sea-level rise. So it was pretty intense," they said.

Archaeological research into the life of the Vikings who settled in Greenland together with this novel application of sea-level science fleshed out this compelling story. Noting the partially drowned ruins of a Viking warehouse, Borreggine pointed out that one analysis done by the group found that 75% of Viking sites are within a thousand meters of an area of flooding. "This flooding was pervasive," they observed.

The impact of rising seas can also be seen in the changing diet of the Vikings; as they shifted from their own agricultural products to more marine-based foods, perhaps as their fields became saturated with salt or flooded. Such a shift, said Borreggine, reveals that "they were attempting to adapt to the [rising sea level](#)."

This paper "...shows the advantages of interdisciplinary research, bringing ideas from one field to another and contributing powerful new insights," said Mitrovica, noting that Borreggine "has shown that in addition to the various challenges the Vikings faced as the climate descended into the ice age, they also faced pervasive flooding—an insight that only someone like Marisa, with deep expertise in the sea-level physics, could have had."

If the lasting impact of [sea-level](#) rise sounds familiar in understanding current efforts to mitigate climate change, Borreggine noted the parallels—and one major difference. "The Vikings didn't really have a choice," they said. "They couldn't stop the Little Ice Age. We can do work to mitigate climate change. The Vikings were locked into it."

More information: Borreggine, Marisa, Sea-level rise in Southwest Greenland as a contributor to Viking abandonment, *Proceedings of the National Academy of Sciences* (2023). [DOI: 10.1073/pnas.2209615120](https://doi.org/10.1073/pnas.2209615120).

Provided by Harvard University

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