Caves of Hella:
Visual and Environmental Clues for the Early Medieval Christian Settlement in Southern Iceland

Thesis Submitted in Partial Satisfaction of the Requirements for the Degree of Bachelor of Arts in Art History and Earth Science

By
Yidan Xu 徐一丹

Advisor
Laura Haynes, Elizabeth Lastra, Kirsten Menking

Vassar College Art History and Earth Science

April 2024

Abstract

This thesis explores the early medieval Christian settlement in Iceland through an interdisciplinary approach that combines Art History and Earth Science. The primary focus of the thesis is the artificial caves in Hella, Iceland. By examining literature, regional climate changes, and visual materials, the thesis argues that the construction of these caves is linked to early medieval Insular *peregrini*—Christian hermits who pursued life-long self-exile in foreign lands.

The late Holocene regional climate was reconstructed by analyzing the changes of the oxygen isotopes in the foraminifera *Neogloboquadrina pachyderma* extracted from an ocean sediment core near Iceland's south coast. An onsite survey was undertaken to examine the local landscape of Hella and the artificial caves, with specific attention given to the cave structures and cross carvings. These features were then compared with those observed in Insular caves and ecclesiastical architecture. Chapter 2 of this thesis focuses on Earth Science, Chapter 3 has contents for both subjects, and Chapter 4 is about Art History.

Medieval sources from Iceland and Britain suggest an Insular interest in exploring the North Atlantic, potentially indicating a pre-Viking Christian discovery of Iceland. The reconstructed climate data reveals a general temperature decline since the Roman Ages Warm Period (~250 BC) and a significant drop during the Little Ice Age (~ 1300 CE). Notably, the early medieval cooling phase known as the Dark Age Cold Period (400 CE - 900 CE) and the subsequent Medieval Warm Period (950 - 1250 CE) are not observed in local environmental changes, suggesting that early medieval Iceland may have been more habitable than during the Viking's Age.

Comparison between the Hella caves and Insular ecclesiastical architectures indicates that Hella caves have a stronger connection to Insular caves with cross carvings than to ecclesiastical churches. The investigation into the cross motifs shed light on suggests that the caves might have been made by the Columban *peregrini*, particularly those from southeast Scotland.

This thesis serves as a starter for a potentially long-term project on artificial caves in southern Iceland and aims to contribute to the study of Iceland's early medieval social and climatic history.

Table of Contents

Acknowledgements

I hope to first thank my family, particularly my parents, for supporting me with their unconditional love and trust.

I would like to thank all my professors at Vassar, who not only guided me to find the sweets in knowledge but also taught me how to understand this world, the social one and the natural one. Thank you to Professor Haohao Lu, Jin Xu, Brian Lukacher, Yvonne Elet, John Zayac, Kirsten Menking, Michael Walsh, and Marc Michael Epstein, for the wonderful courses and your help in and outside the classroom. Thanks to my dear Earth Science advisor Professor Jeff Walker, who has always been encouraging.

Most of all, thank you to Professor Elizabeth Lastra and Laura Haynes. Thank you for making the Iceland project possible, which, I found hard to believe till the moment we actually landed in Keflavík. Thank you for advising me on this thesis and patiently guiding me in exploring new things in the fields.

Professor Lastra, I feel like I owe you so many thanks that I don't know where to start to write. Thank you for your support and care and really everything in the past three years.

Many thanks also to my friends, who accompanied, inspired, and helped me to be a better person in this changing world. Also, thanks for bearing with me for three (yes covid does not count) or more years.

I also would like to thank the owner of the cave, Baldur Þórhallsson, who generously allowed us to conduct research on-site. I want to thank my classmates from the 2023 Fall Iceland seminar. This thesis cannot be done without you all. I would like to thank Vassar Innovative Lab for allowing me to print all the 3D models and Columbia's Lamont-Doherty Earth Observatory for giving me the sediment core and running the tests. And I want to thank Vassar's Art Department and Earth Science & Geography Department for making this project possible.

With LOVE
Yidan

Introduction

Transactis autem diebus octo viderunt insulam non longe, valde rusticam, saxosam atque scoriosam, sine arboribus etherba. (§23.1)
(After eight days had gone by, they saw an island not far away, quite uncultivated, rocky and slag-filled, without trees or grass.) [1]
—*Navigatio Sancti Brendani,* written around 780-800

Located in the middle of the northern Atlantic Ocean, Iceland is geographically separated from the rest of Europe. Due to its isolation, Iceland is one of the last places to have been settled by humans. Vikings, who arrived in Iceland in the late ninth century, have long been thought to be the first inhabitants.[2] Nevertheless, medieval documents and archaeological evidence shed light on the possibility that Christians may have settled in Iceland before the Vikings. Over the past century, the question "Were there Christian settlers in Iceland before the arrival of the Vikings?" was asked every so often. Studies regarding the pre-Viking existence of Christians—particularly Gaelic Christians—have been conducted by scholars in different fields, yet no conclusive answer has been given to the question.

Among the possible evidence for pre-Viking Christian existence, artificial caves found in southern Iceland hold significant research potential yet have received limited study. Starting in the west in Suðurland, more than 170 artificial caves excavated in sandstone and tuffs have been discovered in the south near the coastline (Fig. 1).[3] Carvings and inscriptions are present in most caves, with cross markings being one of the most prominent motifs.[4] In this thesis, I explore a particular set of caves on the south coast of Iceland, the caves of Hella. Through an

[1] The text and translation **quoted from** Nicholas Thyr, “Is Iceland Hell? Realism and Reality in the ‘Navigatio Sancti Brendani.’” *Proceedings of the Harvard Celtic Colloquium* 38 (2018): 314.

Note that Thyr argues against the theory that this text is referring to Iceland. However, it is sufficient to say that the manuscript suggests that the Irish people were aware of Iceland in the north and potentially searched for it.

[2] It is believed that the Vikings arrived in Iceland after around 871 CE; this is supported by tephra evidence: the Landnam tephra, which is found beneath Vikings’ archeological remains, were from 871±2. Steinunn Kristjansdottir, *Monastic Iceland,* 1st ed. (United Kingdom: Taylor & Francis, 2022), 31-32

[3] Árni Hjartarson, Guðmundur J. Guðmundsson, and Hallgerður Gísladóttir, *Manngerðir Hellar á ÍSlandi*, (Reykjavík: Bókaútgáfa Menningarsjóðs, 1991), 11-12

[4] Kristjan Ahronson, “One North Atlantic Cave Settlement: Preliminary Archaeological and Environmental Investigations at Seljaland, Southern Iceland,” *Northern Studies,* vol.37 (2003): 54

interdisciplinary study that combines Art History and Earth Science, I aim to investigate whether the caves are evidence of early medieval Christian settlement in Iceland. Through climate reconstruction and visual analysis, I explore the clues of an Insular origin of the Hella caves and study how people's choice of habitat and their construction of caves are influenced by both environmental conditions and their spiritual pursuits.

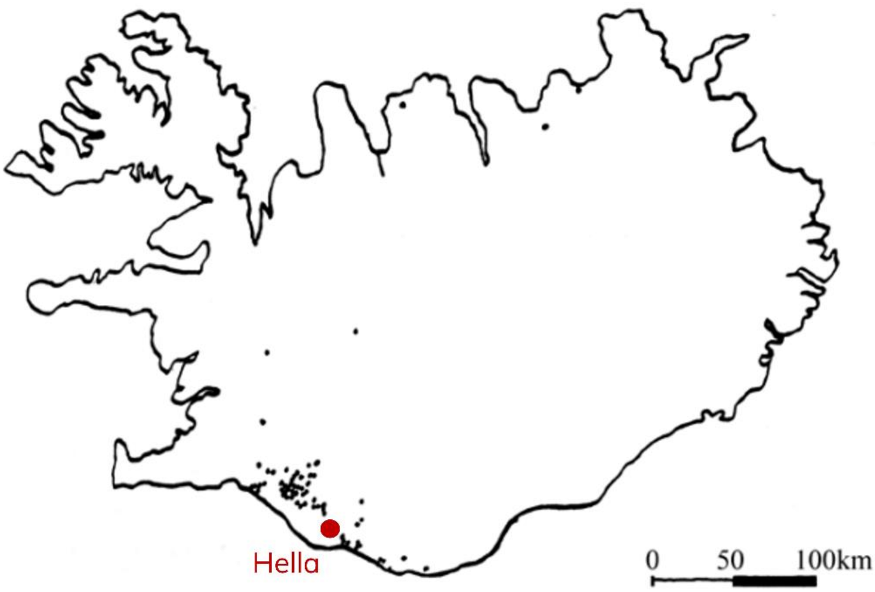


Figure 1. Map of artificial caves in southern Iceland (Modified from Ahronson, *In Into the Ocean*, 96, originally from Hjartarson et al., *Manngerðir Hellar á ÍSlandi* (1991), 12)

The Hella caves are among the most famous artificial caves in southern Iceland. They are located in the town of Ægissíða, between Iceland's capital Reykjavík and the southern village Vík. Like other human made caves, Hella caves are carved out of soft sandstone.[5] Since the early twentieth century, scholars have been attempting to relate artificial cave sites in southern Iceland to the early medieval monastic communities from Ireland and Scotland.[6] While the Hella caves were mentioned in a few nineteenth and early twentieth century reports, there is currently no specific scholarship on their origin history, for these privately owned caves were

[5] Kristján Ahronson, *Into the Ocean: Vikings, Irish, and Environmental Change in Iceland and the North*, (University of Toronto Press, 2015), 77

[6] *Ibid*., 76

only recently opened to the public in 2019. [7]

The Hella caves are known for both their quantity and size. In the late eighteenth century, a person named Þórðar Tómassonar mentions that there are 18 caves in Ægissíða.[8] Today, 12 of the 18 caves have been discovered, among which three are open to visitors. Among the three opened caves, Fjóshellir (directly translated to "Barn Cave") is the primary focus of my study. Fjóshellir is not only the largest cave in Ægissíða but also one of the largest manmade caves in Iceland.[9] It is also among the most visually interesting caves because it bears the most graffiti and cross carvings in Ægissíða.

Since the late nineteenth century, various hypotheses have been proposed to explain the enigmatic origins of the artificial caves in Iceland. The theory regarding the connection between Insular caves and Icelandic caves, in particular, has been an area of great interest. Brynjúlfur Jónsson (1838-1914) and Einar Benediktsson (1864-1940) were early promoters of a theory that Irish monks were responsible for the Icelandic caves.[10] In the 1980s, Scottish archaeologist Ewan Campell linked an "expanded terminal" cross carving in an Icelandic cave with early medieval monastic houses in northern British Isles.[11] Contemporary British archeologists, such as Richard Warner, also note potential connections between Icelandic caves and Scottish and Irish caves.[12]

In more recent decades, archeologist Kristjan Ahronson has arguably been the most prominent figure in the field. His studies on Seljalandshellar and Kverkarhellir, Seljaland caves that located east of Ægissíða, not only indicate a possible connection between Gaelic

---

[7] Hjartarson, Guðmundsson, and Gísladóttir, *Manngerðir hellar á Íslandi*, 144

[8] *Ibid*.

[9] *Ibid*., 148

[10] Ahronson, *Into the Ocean*, 76

[11] Columban monastic community is an early Christian monastic familia of St Columba, based in and around the small Scottish island of Iona.

Kristján Ahronson, "Testing the Evidence for Northernmost North Atlantic Papar: A Cave Site in Southern Iceland" In *The Papar in the North Atlantic: Environment and History: The Proceedings of a Day Conference Held on 24th February 2001*, (St. Andrews: University of St. Andrews Committee for Dark Age Studies, 2001), 107

[12] Richard Warner, "The Irish Souterrain and their Background," *Subterranean Britain*, Harriet Crawford ed., (London : John Baker, 1979), 142

monasticism and the Icelandic cave-construction but also suggest that the southern artificial caves were likely made prior to 870 CE, the time that Vikings first settled Iceland.[13] In his studies, Ahronson primarily used tephrochronology and radiocarbon dating to reconstruct Seljaland caves' construction chronology.[14] Moreover, he compared the Icelandic cave carvings with Scottish cave carvings. Ahronson's interdisciplinary approach to Icelandic caves serves as a crucial inspiration for this paper.

Different from Ahronson's focus on tephra records, however, this paper examines regional climate data. Climatic fluctuations play a crucial role in human migration and settlement. Foraminiferal stable isotope records from marine sediment cores have been widely used to reconstruct paleoceanographic climates; however, they are rarely used in medieval studies. In this paper, I examine an oceanic sediment core taken near the southern coast of Iceland. Through analysis of foraminifera contained in different strata, I reconstruct temperature changes in the early medieval period to examine whether climate change may have been a driving factor behind human settlement in Iceland.

The thesis aims to contextualize the Hella artificial caves in the settlement history of Iceland. The overarching research question is whether these caves could be related to Christian monks who might have visited Iceland before the permanent settlement of Vikings. Three crucial aspects of the research question are examined in this thesis: the habitability of the region around the time the caves were constructed, the layout and the usage of the cave, and the function and significance of the cross graffiti. In the first chapter, I examine medieval sources from both Iceland and the rest of Europe that suggest a pre-Viking discovery and occupation of Iceland. The second chapter investigates the climate conditions in early medieval Iceland by examining a sediment core that has not been studied before. In the third chapter, my focus shifts to the Hella caves and their relationship to the surrounding environment; in this section, I explore the

---

[13] Ahronson, *Into the Ocean*, 203
[14] *Ibid.*, 82

regional landscape and its relation with the caves' structures. The fourth chapter focuses exclusively on the carvings inside Fjóshellir. Investigating the visual form of the cross carvings and their position in the cave, I explore the religious significance of these caves. Finally, I relate the caves' potential religious function to the early medieval Christian cult of living in a remote and isolated space, which has long been popular among monks of the northern British Isles.

Chapter 1. Seeking a desert in the ocean – Insular literatures on early medieval expeditions in the North Atlantic

> “At that time Iceland was covered with woods between the mountains and the seashore. There were then Christians here, whom the Northmen call papar, but they later went away, because they did not wish to stay here with heathens; and they left behind them Irish books and bells and staffs. From this it could be seen that they were Irishmen.”[15]
>
> —Ari Þorgilsson the Wise, *Íslendingabók*, 1122–33

The oldest recorded history written in Icelandic, *Íslendingabók* [the Book of Icelanders] contains an intriguing passage that recounts the presence of Irish Christians upon the Vikings' initial arrival in the late ninth century. The passage not only acknowledges the presence of human beings in Iceland before the Norse but also quite specifically identifies them as a particular group of Christians, which they referred to as papar. The word papar originates from the Old Irish word "papa," which means “pope” or “anchorite.”[16] It is a term that is also used in describing the Columban monastic communities, an early medieval monastic order established by the Irish saint Columba and based mainly in western Scotland.[17] Thus, this Icelandic history book serves as prime evidence for an early connection between Iceland and the British Isles.

Written in the early twelfth century, *Íslendingabók* is perhaps the most important source that documents the Norse settlement in Iceland. However, little is known about the accuracy of the text, as it was written several centuries after the events it describes. Did the author, Ari Þorgilsson the Wise, rely on continental writings that narrated Christian explorations of Iceland?[18] How could he have been certain that the Irish books and bells predated the Viking

[15] *Ari Þorgilsson, and Siân Elizabeth Grønlie, Íslendingabók, Kristni Saga. The Book of the Icelanders, The Story of the Conversion.*, Text Series (Viking Society for Northern Research), (London: Viking Society for Northern Research, University College London, 2006), 4

[16] *Ibid*.,17

[17] Ahronson, “One North Atlantic Cave Settlement,” 58-59

[18] The possibility that Ari gets his account from Ducuil, a Carolingian monk which I will further discuss later in this chapter as argued by Helgi Gudmundsson. Jonathan M. Wooding, *The Otherworld Voyage in Early Irish Literature: An Anthology of Criticism.* (Dublin Ireland: Four Courts Press, 2014), 242

settlement? While none of these questions can be easily answered, one thing we can be sure of is that the presence of pre-Viking Christians in Iceland was a popular cultural belief in medieval times. A few decades after *Íslendingabók*, another medieval Icelandic chronicle, *Landnámabók* [the Book of Settlement] also included a similar description of papar Christians in the settlement history of Iceland. [19]

This chapter focuses on the historical context for the possible early medieval Christian settlement in Iceland. In medieval Christian cosmology, ocean water encloses the three continents and marks the liminal space between the known world and the unknown. Living at the edge of the Christian world, medieval Irish and Scottish Christians are known for their interest in sea voyages. Their exploration of the ocean as a "religious desert" serves as the cornerstone for the central hypothesis of this thesis. Exploring the early medieval monks' imagination and exploration of the North Atlantic, I posit that a medieval association between the Insular land and Iceland existed in the collective imagination. Furthermore, I argue that the settlement of Iceland was motivated by religious cult of *Peregrinatio*, a religious practice involving a life-long exile for the sake of God.[20]

Írland et mikla

Curiosity about the world beyond the boundless sea lies in every culture. British People, in particular, have exhibited a longstanding interest in the North Atlantic Ocean since the pre-Christian era. Early Irish folk tales portray a paradise-like Otherworld beyond the sea.[21] In medieval Irish literature, a fictional concept of the Otherworld, known as *Írland et mikla* [Great

---

[19] The high similarity of these two texts has made the scholars to believe that *Íslendingabók* is a source for *Landnámabók*. Aidan MacDonald, "The *papar* and some Problems; a brief Review," In *The Papar in the North Atlantic : Environment and History : The Proceedings of a Day Conference Held on 24th February 2001*, (St. Andrews: University of St. Andrews Committee for Dark Age Studies, 2001): 14

[20] Elva Johnston, "Exiles from the Edge? The Irish Contexts of Peregrinatio." *The Irish in Early Medieval Europe*, (2016): 39

[21] Eldar Heide, "Holy Islands And The Otherworld: Places Beyond Water," In *Isolated Islands*, edited by Torstein Jørgensen and Gerhard Jaritz, NED-New edition 1., (Central European University Press, 2011), 63

Ireland]—also entitled *Hvítramannaland* [the land of white men]—was believed to exist in the Atlantic Ocean.[22] From Irish literature, this otherworldly land *Írland et mikla* is also found in Old Norse and Icelandic sagas.[23] However, its location is much contested. While one cannot be certain about whether the term referred to Iceland or the Faroe Islands in the original Irish context, it is evident that when the name was incorporated into Old Norse and Icelandic sagas, *Írland et mikla* was not Iceland. For example, according to *Landnámabók*, the land mentioned is believed to correspond to "Vinland," a place believed to be in North America.[24] Nonetheless, the fictional concept *Írland et mikla* reveals the early Irish interests and awareness of the existence of lands lying within the northern seas.

Immram

In Ireland, there is a particular branch of literature called *Immram*, which describes voyages by sea.[25] When Christianity reached Ireland in the fifth century, oceanic voyages began to bear religious significance, and *Immram* started to refer to the stories of seafaring monks, who sought a life of solitude on the ocean.[26] The *Immrama* collection shows various medieval imaginings of the northern seas and islands, ranging from the promised land of saints to the gateway to hell.[27] These literature sources are important for medieval readers as they are to contemporary historians, as the sea voyages became so important that they rose to the level of religious cults.

---

[22] Else Mundal, "Hvítramannaland And Other Fictional Islands in The Sea," In *Isolated Islands*, edited by Torstein Jørgensen and Gerhard Jaritz, NED-New edition, 1., (Central European University Press, 2011), 83

[23] Heide, "Holy Islands And The Otherworld: Places Beyond Water," 58

[24] Mundal, "Hvítramannaland And Other Fictional Islands in The Sea," 81–2

[25] *Ibid*., 83

[26] *Ibid*.

[27] St. Brendan is said to have sailed in search of the promised land of saints. Many places, including the volcano Hekla, have been recognized as gateways to hell. Peter Harbison, *Pilgrimage in Ireland: The Monuments and the People*. 1st ed. Irish Studies (Syracuse, N.Y.: Syracuse University Press, 1992),39-41

Vita Columbae

One of the earliest Christian *Immram*-type literary works is *Vita Columbae* (c.680-700). Written by Adamnán, the abbot of Iona Abbey, Scotland, the hagiography contains stories of both St. Columba and his fellow Christian monks.[28] The oceanic voyages in *Vita Columbae* indicate that Irish monks were exploring the North Atlantic Ocean as early as the sixth century. Cormac Ua Liathain, a Munster saint, is one of the main protagonists of the ocean voyage episodes in the *Immram*.[29] In his third voyage into the Northern seas, Cormac is said to have traveled to the liminal boundary of the known world and to have encountered obstacles that he could not pass through:

> ... after the tenth hour of the fourteenth day, that there arose all around them almost overwhelming and very dreadful objects of terror; for they were met by loathsome and exceedingly dangerous small creatures covering the sea, such as had never been seen before that time; and these struck with terrible impact the bottom and sides, the stern and prow, with so strong a thrust that they were thought able to pierce and penetrate the skin-covering of the ship.[30]

While Cormac was unsuccessful in terms of seeking a solitary life in the ocean, his journey into the ocean shows that Irishmen were capable of traveling long distances in the sea. More importantly, the fact that this story was recorded in the late seventh century indicates that his attempts were appreciated and even promoted. It thus reveals the general interest in oceanic voyages in early medieval Ireland.

Navigatio Sancti Brendani

The most famous *Immram* in Ireland is perhaps the eighth century tale *Navigatio Sancti Brendani*, written around 780-800.[31] This *Immram* recounts the story of the sixth century Irish

[28] Wooding, *The Otherworld Voyage in Early Irish Literature*, 230-231
[29] *Ibid*., 232-3, 241
[30] Adomnan vita Columbae II 42. In *ibid*. 235 and Harbison, *Pilgrimage in Ireland*, 43
[31] Wooding, *The Otherworld Voyage in Early Irish Literature*, 229

monk Brendan, who set out across the northern seas in search of the Promised Land of the Saints.[32] Brendan and his brethren encountered many islands, and quite a few have geologic descriptions that correspond to actual islands in the North Atlantic. For example, one island in *Navigatio Sancti Brendani* is described to be full of sheep and lambs, and another neighboring island is said to be a Paradise of Birds. These islands, as Jonathan M. Wooding points out in his study of Monastic Voyaging, have been identified as the Faroe Islands.[33]

In fact—though this argument is still quite controversial among scholars—*Navigatio Sancti Brendani* may be the first book to record the Irish discovery of Iceland. It is said that after sailing past the Island of sheep and lambs, the Paradise of Birds, and a series of other islands, Brendan came to the Island of Smith and a mountainous island of fire. Brendan's descriptions of these islands suggest a highly active volcanic environment:

> *Nam ubi cecidit in mare coepit fervere, quasi ruina montis ignei fuisset ibi, et ascendebat jumus de mare sicut de olibano ignis. (§23.10)*
> And [the place] where it fell in the sea began to boil, as if the ruin of a fire-mount were there, and smoke rose from the sea as if from a fire-pot.
>
> *et simul apparuit quasi tota arsa illa insula sicut unus globus, et mare aestuabat sicut cacabus plenus carnibus aestuans quando bene ministratur ab igne (§23. 13)*
> and at once the island appeared as though utterly burnt, just like a single round mass (?), and the sea simmered like a simmering cauldron filled with meat, when it is well tended to by the fire
>
> *[Viderunt montem discoopertum a fumo et a se spumantem flammas usque ad aethera et iterum ad se easdem flammas respirantem (§24.10)*
> They saw the mountain, no longer covered by smoke, and it was spewing flames from itself up to the ether and breathing them in again back to itself[34]

Given that there is no volcano between the Faroe Islands and Iceland, the text naturally leads one to associate the descriptions with Iceland. The tale of St. Brendan is thought to have been drawn from several different sources, and the authenticity of the story is still debated.[35] For example, Thyr argued that the volcanic descriptions above all come from previous early

[32] Harbison, *Pilgrimage in Ireland*, 39-41
[33] Wooding, *The Otherworld Voyage in Early Irish Literature*, 237-238
[34] Thyr, “Is Iceland Hell?,” 310
[35] *Ibid*., 306

medieval texts.[36] It is also possible that the island is purely imaginary; as both Wooding and Thyr argue, the setting of the island and smoking mountain may mean to prompt the viewers to connect it to the gates of Hell.[37] Nonetheless, it is still possible that the descriptions in St. Brendan's tale was referring to Iceland.

De mensura orbis terrae

Another important early medieval source that recorded early Christian overseas exploration is *De mensura orbis terrae*, a book written by Irish Carolingian geographer and historian Dicuil circa 825.[38] Many islands mentioned in the *Navigatio Sancti Brendani* also appeared in *De mensura orbis terrae.*[39] In the book, Dicuil reports the presence of Irish monks on islands that are now widely believed to be the Faroes and Iceland. He is the first historian who explicitly mentioned the settlement of monks on these remote islands.

In *De mensura orbis terrae*, Dicuil argued that Irish monks had been living in the Faroe Islands for almost a hundred years.[40]

> There is another small set of islands, nearly all separated by narrow stretches of water; in these for nearly a hundred year hermits sailing from our country, Irland have lived. But just as they were always deserted from the beginning of the world, so now because of the Northman pirates they are emptied for anchorites, and filled with countless sheep and very diverse kinds of sea-birds. I have never found these islands mentioned in authorities.[41]

Recent Earth Science research on the sedimentary record from the Faroe Islands shows that sheep DNA appeared on the islands as early as 500 CE.[42] Moreover, anthropogenic ash deposits and charred barley grains that date back to 351–543 CE have been discovered on the islands.[43]

---

[36] Thyr, "Is Iceland Hell?," 306
[37] Wooding, *The Otherworld Voyage in Early Irish Literature,* 243
[38] Harbison, *Pilgrimage in Ireland*, 44
[39] Wooding, *The Otherworld Voyage in Early Irish Literature,* 237-238
[40] On the other hand, Gordon Donaldson, the Historiographer Royal of Scotland, suggested the island to be the island of Foula. Harbison, *Pilgrimage in Ireland*, 44
[41] Wooding, *The Otherworld Voyage in Early Irish Literature*, 239-240
[42] Lorelei Curtin, et al., "Sedimentary DNA and Molecular Evidence for Early Human Occupation of the Faroe Islands." *Communications Earth & Environment* 2, no. 1 (December 16, 2021): 1–7.
[43] M. J Church, et al. "The Vikings were not the first colonizers of the Faroe Islands," *Quat. Sci. Rev.* **77**, 228–232

The archeological evidence indicates that humans likely have settled on the Faroe Islands by the sixth century; it also suggests that Dicuil's writing is to an extent a reliable source for studying early medieval settlement in the North Atlantic.

In *De mensura orbis terrae,* Dicuil mentions an island called Thule, an island which many scholars have speculated to be Iceland. This island first appears in the fourth century Greek explorer Pytheas's writing.[44] It is also mentioned in several other sources, including Isidore of Seville's etymological encyclopedia *Etymologiae,* a series of books published in 625 CE.[45] In these sources, as Dicuil summaries, Thule was portrayed as an Arctic island in the northwest of Britain, with no night or day during certain times of the year.[46]

Dicuil claims that he once encountered a monk who had been to an unsettled island Thule around thirty years prior.[47] He mentions that monks lived on Thule seasonally, from February to August[48] and that they left after the arrival of the Norse people, a narrative that is obviously adopted in *Íslendingabók* and *Landnámabók:*

> It is now thirty years since clerics, who had lived on the island from the first of February to the first of August, told me that not only at the summer solstice, but in the days round about it, the sun setting in the evening hides itself as though behind a small hill in such a way that there was no darkness in that very small space of time, and a man could do whatever he wished as though the sun were there, even remove lice from his shirt, and if they had been on a mountain-top perhaps the sun would never have been hidden from them.

If Dicuil's account is real, then at the year 795 CE Irish monks would have been settled in Iceland.[49]

(2013)

[44] Gunnar Karlsson, *The History of Iceland*, (Minneapolis, Minn.: University of Minnesota Press, 2000),9. The date, not surprisingly, is debated. Wooding in his work suggests that Pytheas discovered Thule in 325 (Wooding, *The Otherworld Voyage in Early Irish Literature*, 234)

[45] Dicuil, *Liber De Mensura Orbis Terrae*, compiled by Liam Owen O'Driscoll , Beatrix Färber, (CELT: Corpus of Electronic Texts: a project of University College, Cork, 2018), 75

[46] *Ibid*.

[47] Karlsson, *The History of Iceland,* 9

[48] Wooding, *The Otherworld Voyage in Early Irish Literature,* 241

[49] Johnston, "Exiles from the Edge?," 9

Peregrinatio pro Christo

The aforementioned *Immrama* demonstrate that, during the seventh to ninth centuries, there were abundant historical writings or imaginative literature of the exploration of the North Atlantic by saints and monks living in from the fifth to eighth centuries. The appearance of literature of these kinds not only reflects that early medieval Irish people had a strong and continuous interest in ocean voyages but also shows that such interest was bound up with the religious pursuit for an ascetic lifestyle.

The flourishing of the *Immrama* of saints and monks was not unrelated to the development of Christianity in the Insular world. The Irish interest in the religious ascetic living style is thought to have been inspired by the desert fathers, Saint Paul and Anthony of Egypt.[50] The practice of oceanic exile can be traced back to as early as St. Patrick, who sailed away from Ireland and received prelamination from the Angel Victor.[51] As Elva Johnston acknowledges in her research on early medieval Irish religious exiles, such religious ideals—entitled as *Peregrinatio pro Christo*—became particularly popular among Irish ecclesiastics in the sixth to seventh centuries.[52] The act of renouncing the mundane life and leaving one's hometown forever is seen as a devotion to Christ.

The word *peregrinatio* describes the voluntary exile that monks choose to undertake in showing their determination to follow God above their worldly life.[53] It is different from, as Louis Gougaud emphasizes, pilgrimage, for their exile is thought to last for the rest of their lives.[54] *Peregrinatio* is an act that has been described in both the Old and New Testaments. In the Book of Genesis (12:lff.), the Lord said to Abraham, "Get thee out of thy country, and from

---

50 Johnston, "Exiles from the Edge?," 1
51 Benjamin T Hudson, *Studies in the Medieval Atlantic*. 1st ed. New Middle Ages (Palgrave Macmillan (Firm)). (New York: Palgrave Macmillan, 2012),7
52 *Ibid*., 2
53 Johnston, "Exiles from the Edge?," 8
54 Louis Gougaud, *Christianity in Celtic Lands; a History of the Churches of the Celts, Their Origin, Their Development, Influence, and Mutual Relations*. Translated by Maud Joynt. (London: Sheed & Ward, 1932), 130

thy kindred, and from thy father's house, unto a land that I will shew thee."[55] In the New Testament, Christ asks his believers to put aside the comfort of home and family to follow him.[56]As Johnston notes, *peregrinatio* in medieval literature is described as "both the physical journey to find paradise and the pilgrimage of the Christian through life."[57] *Peregrinatio* is motivated by the *peregrini*'s love for God, with *peregrini* being the hermits who reside in remote lands

The presence of *peregrini* are found in the early medieval *Immrama*. In *Vita Columbae*, Adomnán presents Columba as a model for monks who wish to find their hermitage in the ocean.[58] As Thomas O'Loughlin points out, there is a strong "self-conscious remoteness and belongingness" in Adomnán's narration of the life of Columba and his followers.[59] Similarly, one can surely ascribe the behavior of St. Brendan and the Irish monks that Dicuil described as pursuing a form of *peregrinatio*. St. Columbanus, a contemporary monk of St. Columba, also undertook *Peregrinatio*. In the mid-seventh century St. Columbanus's biographer Jonas of Bobbio wrote that those *peregrini* who "left his native country forever" would have practiced "the highest form of asceticism."[60] His writing reveals the hierarchy in the different kinds of *peregrinatio,* showing that monks merit overseas voyages over domestic journeys.[61] Under this standard, a religious voyage to Iceland would be considered as one of the highest forms of *peregrinatio,* presumably equivalent to the act of the saints described in *Immrama*.

As Anthony Faulkes and Alison Finlay point out in their research of *Íslendingabók*, Ari Þorgilsson's portrayal of the papar Christians appears to align with the practices of Irish monks engaging in *peregrinatio*.[62] Papar is believed to be the word that describes the monks who

[55] Harbison, *Pilgrimage in Ireland*, 34
[56] Mark 10:29–30
[57] Johnston, "Exiles from the Edge?," 8
[58] Wooding, *The Otherworld Voyage in Early Irish Literature,* 230-231
[59] Thomas O'Loughlin, *Journeys on the Edges: The Celtic Tradition*, Traditions of Christian Spirituality, (Maryknoll, N.Y.: Orbis Books, 2000),51
[60] Harbison, *Pilgrimage in Ireland*, 34
[61] Johnston, "Exiles from the Edge?," 2-3
[62] Þorgilsson and Grønlie*, Íslendingabók, Kristni Saga,* 17

follow St. Columba, who himself is a *peregrini*. The papar monks probably have a mixed Irish and Scottish origin. for St. Columba established his monastery order in Scotland. The presence of papar Christians in remote islands in Britain and possibly Iceland can also be identified in the naming pattern of certain places. There are a lot of places in both the small islands near the Large British Isle—such as the Shetlands, Orkneys, and Caithness—as well as in Iceland, that have *pap*-roots.[63] As Ahronson points out, there are even a notable number of such names recorded in the *Landnámabók.*[64] Hence, if there were ever Christian monks living in Iceland, they were likely inspired by this same religious impulse of *peregrinatio*.

There is one more question remaining: when did these papar Christians go to Iceland? This thesis speculates that the *peregrini* traveled to Iceland around the seventh to the eighth century. As Charles-Edwards and Hughes point out, *peregrinatio* reached its peak popularity in Britain in the seventh and eighth centuries.[65] The emergence of the previously discussed medieval texts and a Litany of Pilgrim saints around 800 CE is potent evidence for an increased attention in *peregrinatio* in that period. Additionally, the eighth century may mark a shifting interest from *peregrinatio* in continental Europe to that in the Atlantic Ocean. As Peter Harbison notes in his study of Irish pilgrimage, "As early as the 730s, efforts were being made on the Continent to restrict the activities of the Irish *peregrini*, and these culminated in edicts issued at various councils in 813, the year before Charlemagne's death."[66] Before *peregrinatio* fell out of favor at the end of the eighth century due to the emergence of the monastic order Céli Dé, an order that promotes a stable monastic life in the home country, Irish monks may have sought their exile in the ocean at a time when continental travel was less possible.[67] It is unlikely that the monks in Iceland appeared there after the ninth century. As Harbison concludes, "For the

[63] MacDonald, "The *papar* and some Problems," 14
[64] Ahronson, *Into the Ocean*, 78
[65] Þorgilsson and Grønlie, *Íslendingabók, Kristni Saga,* 17
[66] Harbison, *Pilgrimage in Ireland*, 35
[67] Johnston, "Exiles from the Edge?," 3

ninth century Irish, the old-style ascetic wandering peregrinatio became a thing of the past, something to be dreamed of more than to be realized."[68]

Conclusion: *Peregrini* and *Immram*

Early medieval documents show that Insular people had great religious interests in the North Atlantic Ocean. In the age where travel is difficult for ordinary people, *peregrini* explored the ocean with the aim of seeking an inaccessible place where they could pursue their promise to God.[69] Admittedly, the reliability of the medieval texts discussed above is highly debated and questioned.[70] It is very likely that these stories were composed through a combination of geographical data and mythological tales. However, these texts serve as strong evidence that early medieval Irish and Scottish people were aware of the islands in the North Atlantic and had developed a tradition of exploring them. These texts also demonstrate that Icelandic people were similarly aware of such narration of history.

The *Immrama* discussed above show that the early medieval journeys overseas were normally religiously inspired. If these caves and carvings are medieval at all; they were made by monks or *peregrini* rather than "ordinaries." With the consideration of the social context, I would like to argue that that seventh and eighth century Irish and Scottish *peregrini* are the most likely travelers to Iceland and, therefore, the strongest candidates for the creators of the Hella caves.

[68] Harbison, *Pilgrimage in Ireland*, 36
[69] Johnston, "Exiles from the Edge?," 6
[70] See for example Thyr, "Is Iceland Hell?'"; Mundal, "Hvítramannaland And Other Fictional Islands in The Sea;" Wooding *The Otherworld Voyage in Early Irish Literature: An Anthology of Criticism,* and Sveinbjarnardottir, Gudrun. "The Question of papar in Iceland." In *The Papar in the North Atlantic: Environment and History: The Proceedings of a Day Conference Held on 24th February 2001*, 97-106

Chapter 2. Reconstructing the past climate – Late Holocene Environmental Change in Southern Iceland

Could people have survived the frigid conditions of early medieval Iceland? Given the prevailing cold climate during that era, it is a question worth exploring. The second half of the first millennium CE is generally understood as the "Dark Age Cold Period" (DACP). Identifying a global cooling phase between 400 CE and 900 CE mainly using historical documents and glaciation records, the twentieth century English climatologist Hubert Lamb was one of the first scholars who introduced the DACP concept.[71] In current studies relating to the DACP, the median values of the starting and ending dates are considered to be 450 and 800 CE.[72] The cold climate conditions of the DACP have been considered a major challenge for human settlement of Iceland. In fact, it is widely believed that the arrival of the Vikings in Iceland was directly related to the ending of the DACP and the beginning of the Medieval Warm Period (MWP), which lasted from around 950 to 1250 CE.[73] In the past decade, Patterson et al. (2010) showed that Iceland was not uniformly cold in the DACP through examining $\delta^{18}O$ values of mollusks in near-shore marine cores in northwest Iceland. According to their study, northwest Iceland experienced a warm period from around 600 to 760 CE, which predated the MWP in Western Europe.[74] Patterson et al. (2010) challenges the conventional understanding of a European-wide cold early medieval period. Thus, it becomes plausible to consider the presence of humans in early medieval Iceland.

In this chapter, I use foraminiferal stable isotope records from an ocean sediment core to reconstruct regional climate conditions on the south coast of Iceland in the early medieval

[71] Lamb also notes his use of isotope records, however, he did not specify the isotopic elements. H. H. Lamb, *Climate, History and the Modern World,* 2nd ed. (London: Routledge, 1995), 165-167.

[72] Samuli Helama, Phil D Jones, and Keith R Briffa. "Dark Ages Cold Period: A Literature Review and Directions for Future Research." *The Holocene* 27, no. 10 (October 1, 2017): 1602.

[73] E.g. Don J Easterbrook, "Geologic Evidence of Recurring Climate Cycles and Their Implications for the Cause of Global Climate Changes—The Past Is the Key to the Future." In Evidence-Based Climate Science, 3–51. Elsevier, 2011.

[74] William P. Patterson et al., "Two Millennia of North Atlantic Seasonality and Implications for Norse Colonies," *Proceedings of the National Academy of Sciences of the United States of America* 107, no. 12 (March 23, 2010): 5308.

period. Planktic foraminifera are calcifying marine zooplankton that respond sensitively to changes in sea surface temperatures.[75] Climate changes can impact human settlement both directly and indirectly. A study of the regional climate, therefore, contributes to the investigation of whether Iceland indeed had an early warming period and whether the land was habitable in the early medieval period.

Context

Iceland, situated northwest of the British Isles in the North Atlantic, lies along the Mid-Atlantic Ridge, the divergent boundary between the Eurasian and North American tectonic plates. Composed predominantly of basalt, the island's geological formation is a consequence of volcanic activities stemming from mantle upwelling at the passive divergent boundary. In contemporary Iceland, the summer's average temperature is around 10°C whereas in the winter, average temperature is generally around 0°C.[76] Strong winds and frequent precipitation, however, often make one feel colder than the actual measured temperature.

As Iceland lies in a geologically active spot, its climate is subject to a number of global and regional factors, such as oceanic and atmospheric circulation, volcanic eruptions, glacial dynamics, and variations in solar radiation. Iceland is located near the boundary of the Ferrel and Polar atmospheric cells (Fig. 2) and is situated between North Atlantic and Arctic currents (Fig. 3). Its climate is particularly sensitive to North Atlantic circulation patterns, such as the Atlantic Meridional Overturning Circulation (AMOC) and the North Atlantic Oscillation (NAO), which modulate the climate at different time scales.[77]

---

[75] Sven Pallacks et al., "Planktic Foraminiferal Changes in the Western Mediterranean Anthropocene," *Global and Planetary Change* 204 (September 1, 2021): 1.

[76] Haraldur Ólafsson, Markus Furger, and Burghard Brümmer. "The Weather and Climate of Iceland." *Meteorologische Zeitschrift - METEOROL Z* 16 (February 1, 2007): 5.

[77] Patterson et al, "Two Millennia of North Atlantic Seasonality and Implications for Norse Colonies," 5306.

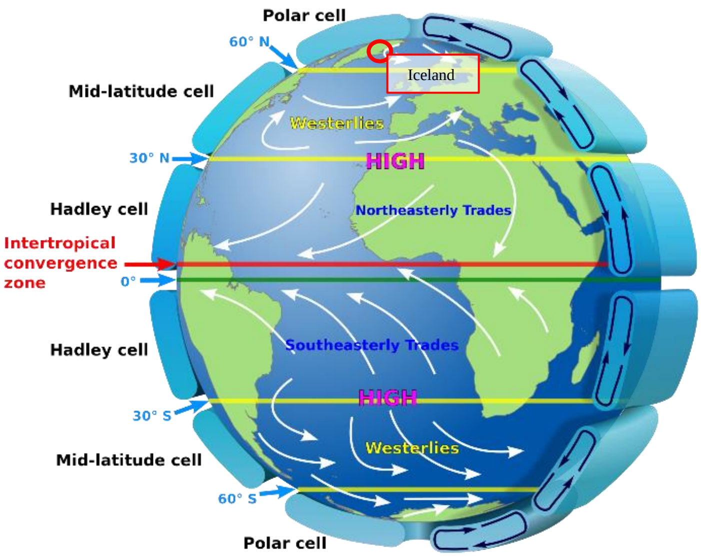


Figure 2. Global air circulation map. Adopted from Wikipedia (https://commons.wikimedia.org/wiki/File:Earth_Global_Circulation_-_en.svg)

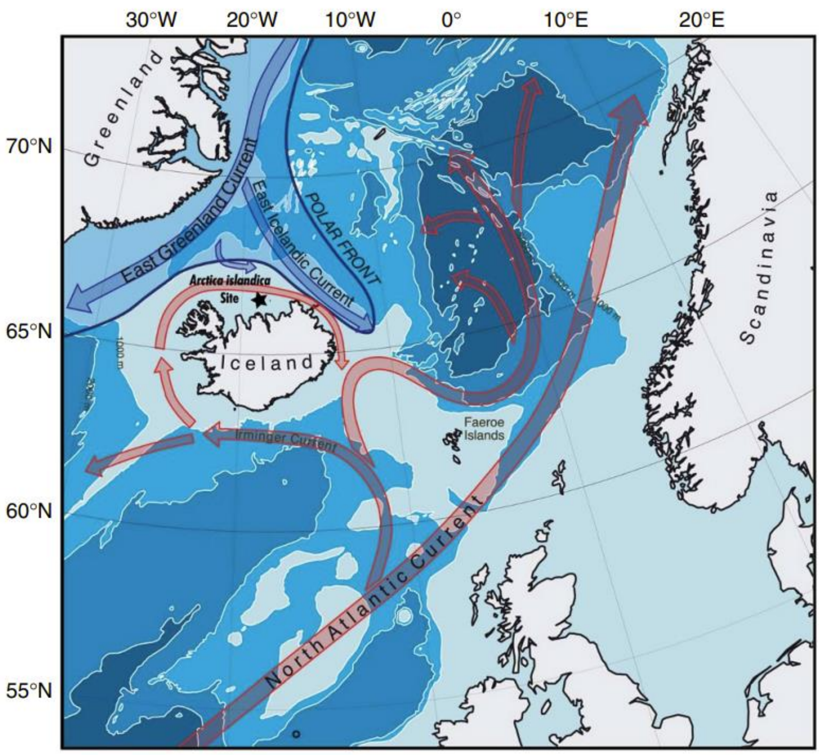


Figure 3. Location map of modern ocean surface circulation patterns in the northern North Atlantic. (Alan D. Wanamaker Jr et al., 2012)

- **The influence of Ocean Circulation on Icelandic Climate**

The North Atlantic Current (NAC) is the key modulator of northern Europe's climate conditions. The northward flow of warm surface water transports heat from the equator to the high latitude regions (Fig. 3).[78] Through convective mixing, heat carried by the NAC enters the atmosphere. The cooled surface waters then sink to the bottom of the ocean and form southward flowing deep waters in a process called the Atlantic Meridional Overturning Circulation (AMOC).[79] As a part of AMOC, Iceland–Scotland Overflow Water (ISOW) (Fig. 4) serves as a return flow that both sustains and counterbalances the north flowing warm NAC.[80] The ocean circulation and the ocean-atmosphere interaction in the Nordic Seas help to maintain a temperate climate in northwestern Europe.[81]

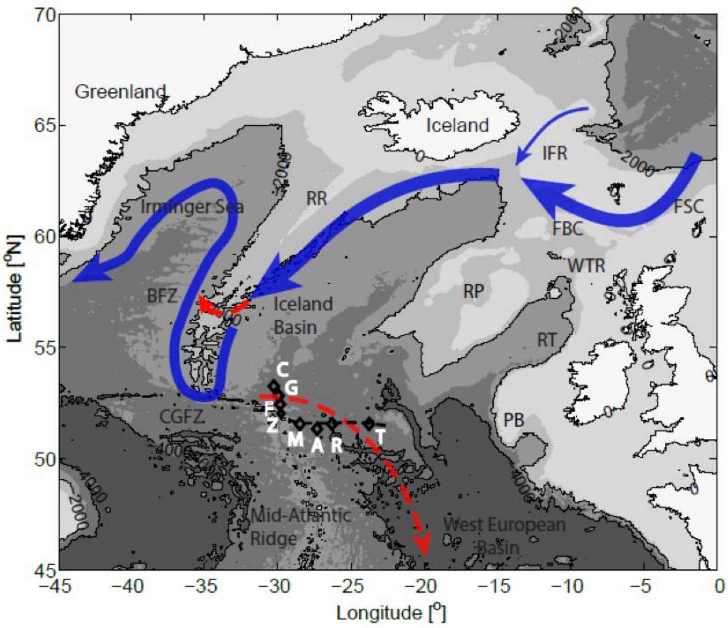


Figure 4. ISOWspreading pathways. The blue lines show the major spreading pathways of ISOW; the red dash lines are two other ISOW pathways that have been identified. (Sijia Zou, "Observed Southward Spreading of the Iceland Scotland Overflow Water along the Eastern Flank of the Mid-Atlantic Ridge | OSNAP," 2017)

The North Atlantic Current consists of several intense northeastward currents, including the Rockall Trough branch, Iceland Basin branches, and the Irminger Current (Fig. 3).[82] These

[78] David J. R. Thornalley, Harry Elderfield, and I. Nick McCave. "Intermediate and Deep Water Paleoceanography of the Northern North Atlantic over the Past 21,000 Years." *Paleoceanography* 25, no. 1 (2010): 2

[79] Paola Moffa-Sánchez, and Ian R. Hall. "North Atlantic Variability and Its Links to European Climate over the Last 3000 Years." *Nature Communications* 8, no. 1 (November 23, 2017): 2.

[80] Giancarlo G. Bianchi, and I. Nicholas McCave, "Holocene Periodicity in North Atlantic Climate and Deep-Ocean Flow South of Iceland," *Nature* 397, no. 6719 (February 1999): 515.

[81] *Ibid*.

[82] Elena Brambilla, and Lynne D. Talley, "Subpolar Mode Water in the Northeastern Atlantic: 1. Averaged Properties and Mean Circulation." *Journal of Geophysical Research: Oceans* 113, no. C4 (2008): 2

surface and near-surface water masses, which are also referred to as Subpolar Mode Waters (SPMW), have nearly uniform properties from the ocean surface to the pycnocline.[83] One of the major branches that affects Icelandic climates is the Irminger Current. Having an average temperature of 6-8°C, the Irminger Current carries warm, salty waters past the south and west of Iceland and meets the cold East Greenland Current in the Greenland-Iceland Ridge.[84]

The oceanic conditions in the north and south of Iceland are thus drastically different. Whereas in the south the ocean waters are warm and saline, in the north, the waters are colder and fresher in the Iceland Sea and the Norwegian Sea (Fig.5). In the interaction between the warm NAC waters and the cold East Greenland Current, coastal currents form and flow in a clockwise direction around Iceland (Fig.6).[85]

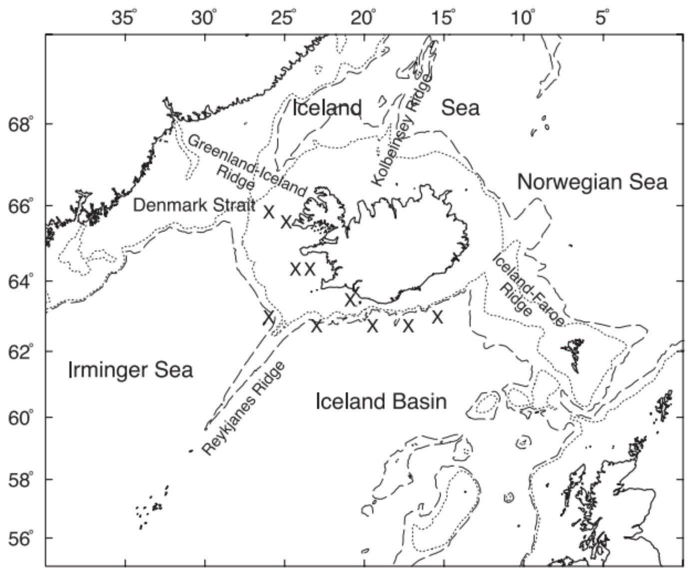


Figure 5. Bottom topography of Iceland and surrounding areas. Depth contours are 500m and 1000m. (adapted from Valdimarsson and Malmberg, "Near-Surface Circulation in Icelandic Waters Derived from Satellite Tracked Drifters")

[83] Brambilla and Talley, "Subpolar Mode Water in the Northeastern Atlantic," 1

[84] Héðinn Valdimarsson, and Svend-Aage Malmberg. "Near-Surface Circulation in Icelandic Waters Derived from Satellite Tracked Drifters," *Rit Fiskideildar 16*,(1999): 23

[85] *Ibid.*

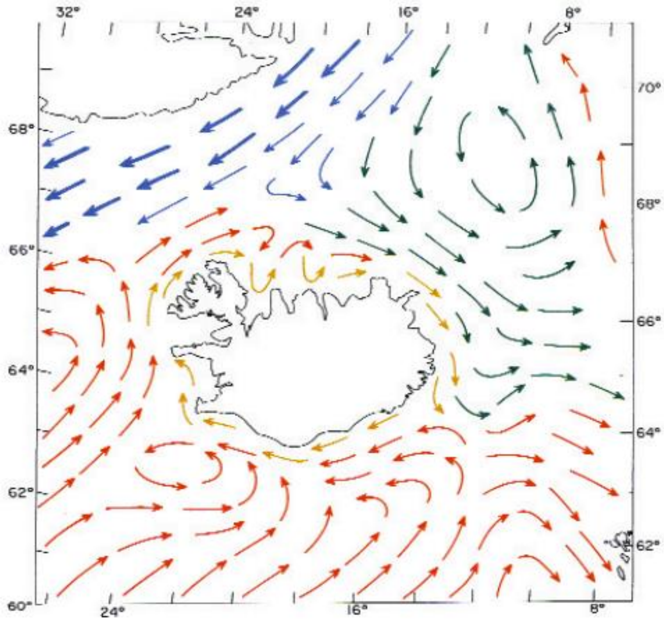


Figure 6. Ocean current around Iceland. Red: relatively warm and saline Atlantic water. Blue: Cold and low-salinity water. Green: Cold Artic water. Yellow: Icelandic coastal water.(Stefánsson, U. and J. Ólafsson 1991, "Nutrients and fertility of Icelandic waters")

Another important factor that controls Icelandic climate is the North Atlantic Oscillation (NAO). The NAO is, as Hurrell and Deser (2009) summarizes, "a redistribution of atmospheric mass between the Arctic and the subtropical Atlantic."[86] The NAO influences the Icelandic climate on both seasonal and decadal levels.[87] During a positive NAO phase, Iceland is predominantly surrounded by NAC waters, and the weather conditions are warmer and wetter; in a negative NAO phase, on the other hand, Iceland is cooler and drier because of the greater influence of Arctic waters.[88]

[86]James W. Hurrell, and Clara Deser, "North Atlantic Climate Variability: The Role of the North Atlantic Oscillation," *Journal of Marine Systems*, Impact of climate variability on marine ecosystems: A comparative approach, 79, no. 3 (February 10, 2010): 231.

[87] Edward R. Cook, Rosanne D. D'Arrigo, and Keith R. Briffa. "A Reconstruction of the North Atlantic Oscillation Using Tree-Ring Chronologies from North America and Europe." *The Holocene* 8, no. 1 (January 1, 1998): 9.

[88] Andrew N. Mackintosh, Andrew J. Dugmore, and Alun L. Hubbard, "Holocene Climatic Changes in Iceland: Evidence from Modelling Glacier Length Fluctuations at Sólheimajökull." *Quaternary International*, Late Pleistocene and Holocene Investigations in Europe. International Conference on Past Global Changes (PAGES), 91, no. 1 (May 1, 2002): 39.

Iceland late-Holocene climate

While there is rich scholarship on Iceland's late-Holocene climate changes, most of the research focuses on sites in the north and northwest. In the south, what is known is that beginning around 600-800 CE, the glacier Sólheimajökull in central southern Iceland advanced, and that advancement, which is named the Ystagil Stage, ended around 1000 CE.[89] The mollusks recovered from near-shore marine cores in northwest Iceland in Patterson et al. (2010) shows that Iceland entered a cooler temperature at around 410 CE, with maximum annual temperatures of 4.0 to 6.5°C. The same evidence also indicates that the island experienced an exceptionally warm period from 600 to 760 CE, with an average maximum annual temperature of 11 °C.[90]

Material

Planktic foraminifera are unicellular, shell-making zooplankton that are globally distributed in the ocean.[91] Regional and global temperature changes exert a direct influence on the isotopic composition of the calcium carbonate shells of foraminifera, of which is correlated with the carbonate equilibrium of the surrounding seawater and the atmosphere.[92] Therefore, a measurement of the relative abundance of oxygen and carbon isotopes—$\delta^{18}O$ and $\delta^{13}C$—as in a foram's shell can be used to reconstruct past temperatures. Due to their widespread presence in sedimentary records worldwide, foraminifera play a crucial role as recorders and sources of information regarding past environmental and climatic conditions.

The foraminifera species used in this study is *Neogloboquadrina pachyderma*, the dominant planktonic foraminifer in high-latitude regions.[93] *N. pachyderma* is a left-coiling low

[89] Hjalti J. Gudmundsson, "A Review of the Holocene Environmental History of Iceland," *Quaternary Science Reviews* 16, no. 1 (January 1, 1997): 84.
[90] Patterson et al., "Two Millennia of North Atlantic Seasonality and Implications for Norse Colonies," 5308.
[91] Ralf Schiebel, and Christoph Hemleben. *Planktic Foraminifers in the Modern Ocean*, (Berlin, Heidelberg: Springer, 2017), 3
[92] *Ibid*., 264-6
[93] Schiebel and Hemleben, *Planktic Foraminifers in the Modern Ocean*, 63

trochospiral test foram: its shell consist of 4–4.5 chambers spiraling around the central axis and it has a rather squared outline.[94] It is typically found in surface ocean waters. According to research by Johannes Simstich et al., most *N. pachyderma* in the northern region of the Nordic Sea have a calcification depth of about 20-50 m.[95] Given their relatively shallow living depth, *N. pachyderma* can provide useful proxy data for atmospheric temperature.

N. pachyderma forams have been widely used as the temperature proxy in the study of climate conditions in the Subpolar North Atlantic. Castañeda et al. (2003) used $\delta^{18}O$ data obtained from *N. pachyderma* in the northwest and central North Iceland Shelf to study the regional climate variation in the past 4500 years.[96] Moros et al. (2012) used *N. pachyderma* in cores excavated from the Reykjanes Ridge to track the late-Holocene climate changes in north Atlantic.[97] Among all investigations of north Atlantic climate and current flows, only very few focuses on southern part of Iceland. Thornalley et al. (2010) examined *N. pachyderma* from four sediment cores located on the South Iceland Rise to reconstruct the paleoceanographic changes up to the Last Glaciation Maximum (LGM).[98] Apart from Thornalley et al.'s research, which targets the broader oceanic area south of Iceland, there are currently no study addressing the late Holocene climate conditions in the coastal region of southern Iceland. Therefore, this thesis aims to provide a preliminary understanding of the late Holocene coastal climate in the central-west region of southern Iceland.

---

[94] Schiebel and Hemleben, *Planktic Foraminifers in the Modern Ocean*, 63

[95] Johannes Simstich, Michael Sarnthein, and Helmut Erlenkeuser. "Paired δ18O Signals of *Neogloboquadrina Pachyderma* (s) and *Turborotalita Quinqueloba* Show Thermal Stratification Structure in Nordic Seas," *Marine Micropaleontology* 48, no. 1 (May 1, 2003): 107.

[96] Isla S. Castañeda, L. Micaela Smith, Gréta Björk Kristjánsdóttir, and John T. Andrews. "Temporal Changes in Holocene δ18O Records from the Northwest and Central North Iceland Shelf." *Journal of Quaternary Science* 19, no. 4 (2004): 321–34.

[97] Matthias Moros et al., "Reconstruction of the Late-Holocene Changes in the Sub-Arctic Front Position at the Reykjanes Ridge, North Atlantic," *The Holocene* 22, no. 8 (August 1, 2012): 877–86.

[98] Thornalley, Elderfield, and McCave, "Intermediate and Deep Water Paleoceanography of the Northern North Atlantic over the Past 21,000 Years."

Methodology

- Core Description

Stable isotope analysis was performed on samples from sediment core VM27-104PC (coordinates 63.285, -20.6483; depth of 139 meters), collected during the Vema cruise in 1969.[99] The core was collected on the continental shelf in the southern sea of Iceland, near the volcanic island Surtsey (Fig. 7). Since the day it was obtained, the core has been stored dry at room temperature in the Lamont-Doherty Earth Observatory, Columbia University core repository.[100] The core has not been used in any research since the day it was collected. Hence, this thesis also aims to explore the stratigraphy and time-coverage of the core, laying the foundation for future works.

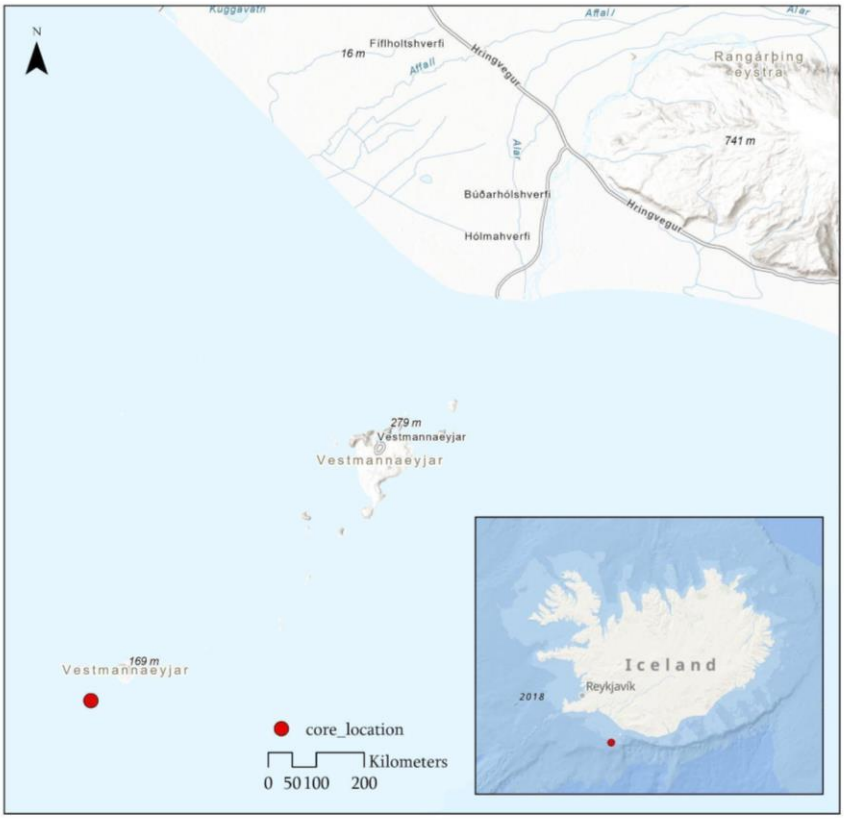


Figure 7. The location of the sediment core VM27-104PC

[99] Curators of Marine and Lacustrine Geological Samples Consortium. The Index to Marine and Lacustrine Geological Samples (IMLGS). National Geophysical Data Center, NOAA.

[100] Lamont-Doherty Core Repository (LDCR). 1977: Archive of Geosample Data and Information from the Columbia University Lamont-Doherty Earth Observatory (LDEO) Lamont-Doherty Core Repository (LDCR). NOAA National Centers for Environmental Information. https://doi.org/10.7289/V5M61H7G

The complete core is 1020 centimeters long. It contains fine sediments that mainly consist of volcanic ashes, muds, and shells remains of various sizes. The sediment is stratified, with alternating layers of light greyish-brown mud and black volcanic ash (Fig.8).

Figure 8. a partial image of the cross section of the core VM27-104PC (Lamont-Doherty Core Repository (LDCR). NOAA National Centers for Environmental Information. https://doi.org/10.7289/V5M61H7G)

For the purpose of the study, two 1 cm³ samples were taken every 20 cm of the core. This research focuses mainly on the top 200 cm of the core, which is the younger sediments on the ocean floor and is presumed to be more related to the late Holocene, the geological period that spanning from approximately 11,700 years ago to the present.[101] A total of 22 samples were taken from the core. The first 20 samples cover the core length from 1 to 200 cm (Table. 1). Three additional samples from depths of 230, 320, and 360 cm were collected to facilitate the understanding of the broader trend of climate change. Samples from depths of 230 and 320 cm consist primarily of volcanic ashes; they were collected in hope of constructing a correlation

[101] This is because the sedimentation rate at nearby sites ranges from 10 to 60 cm/kyr.

between the samples' depths and their ages using tephrochronology.

Table 1: raw sample list

no.	sample series	depth (cm)	dry sample weight (g)
1	VM27-104PC	0-1	2.4367
2	VM27-104PC	1-2	3.543
3	VM27-104PC	20-21	4.5723
4	VM27-104PC	21-22	3.2151
5	VM27-104PC	40-41	5.262
6	VM27-104PC	41-42	4.0509
7	VM27-104PC	60-61	6.5142
8	VM27-104PC	61-62	4.6274
9	VM27-104PC	80-81	5.0206
10	VM27-104PC	81-82	4.0843
11	VM27-104PC	100-101	4.3195
12	VM27-104PC	101-102	5.3924
13	VM27-104PC	120-121	5.1752
14	VM27-104PC	121-122	5.7408
15	VM27-104PC	141-142	4.9185
16	VM27-104PC	160-161	7.0166
17	VM27-104PC	161-162	5.9088
18	VM27-104PC	180-181	9.4677
19	VM27-104PC	200-201	6.5506
20	VM27-104PC	230-231	4.5231
21	VM27-104PC	320-321	8.4071
22	VM27-104PC	360-361	4.9919

- Sample Preparation

The dry sediment samples were weighed and then soaked in deionized water mixed with Calgon and sodium hydroxide.[102] They were put on a rotating wheel for 3 hours so that the sediments could disaggregate into individual pieces of forams and rock fragments. The disaggregated samples were then washed through a 63 μm sieve using deionized water after which the portion retained on the sieve was dried in an oven. Given that most forams are 100

[102] The mixture is made of 10L of deionized water, 20g Calgon, and 1 ml NaOH

μm to 1 mm in length, the >63 μm residue of each sample captured most tests.[103] Each piece of coarse fraction residue was then evenly divided between an archive jar and a working jar.

The sediments in the working jar were further separated into >250 μm, 150-250 μm, and <150 μm size fractions using sieves. *N. pachyderma* were of highest abundance in the size range 150–250 μm, which is consistent with other studies in *N. pachyderma* such as Jonkers et al. (2013).[104] For each of the 22 samples, approximately 40 specimens of *N. pachyderma* were randomly picked from the 150–250 μm fraction using an ultra-fine paint brush and a dissecting microscope. Among all 22 samples, sample VM27-104PC from 230-231 cm is the only one that did not contain any foram. The black color of this sample suggests that it is a volcanic ash layer. It is likely that the layer was formed due to a rapid deposition of volcanic sediments from one powerful volcano eruption. The fast sedimentation rate of the ashes left no time for the forams to accumulate.

From each of the other samples, 7-10 *N. pachyderma* tests with a net weight ranging from 60 to 100 mg were chosen for stable isotope analysis. These forams were weighed and cleaned through sonication. Stable isotope measurements were performed at Lamont using a Thermo Delta V+ coupled to a Kiel device.

[103] Pratul Kumar Saraswati, *Foraminiferal Micropaleontology for Understanding Earth's History*, 2021

[104] Lukas Jonkers, et al., "Seasonal Mg/Ca Variability of *N. Pachyderma* (s) and *G. Bulloides*: Implications for Seawater Temperature Reconstruction." *Earth and Planetary Science Letters* 376 (August 15, 2013): 138. **and** Lukas Jonkers, et al., "Seasonal Stratification, Shell Flux, and Oxygen Isotope Dynamics of Left-Coiling N. Pachyderma and T. Quinqueloba in the Western chunky North Atlantic." *Paleoceanography* 25, no. 2 (2010): 3.

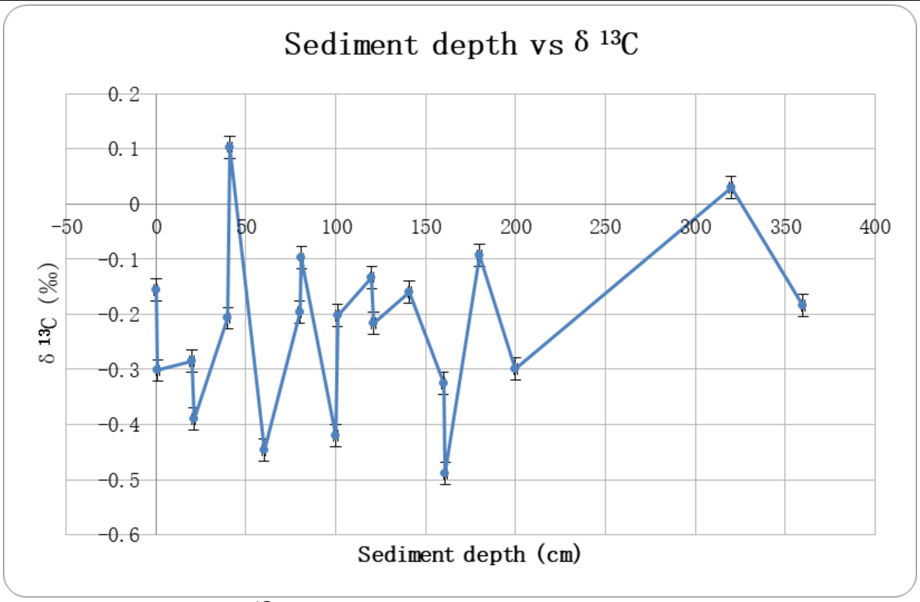
Results

For each sample, $\delta^{13}C$ and $\delta^{18}O$ values of the forams were recorded (Table 2). The analytical uncertainty for $\delta^{13}C$ is 0.02 and for $\delta^{18}O$ is 0.04. $\delta^{13}C$ values reflect biological productivity; a heavy δ13C value would indicate increased productivity in the ocean. $\delta^{18}O$ values exhibit a negative relationship with temperature; a higher value of $\delta^{18}O$ indicates a colder climate condition. This thesis primarily investigates temperature changes in the late Holocene; hence $\delta^{18}O$ will be the focus of the following research.

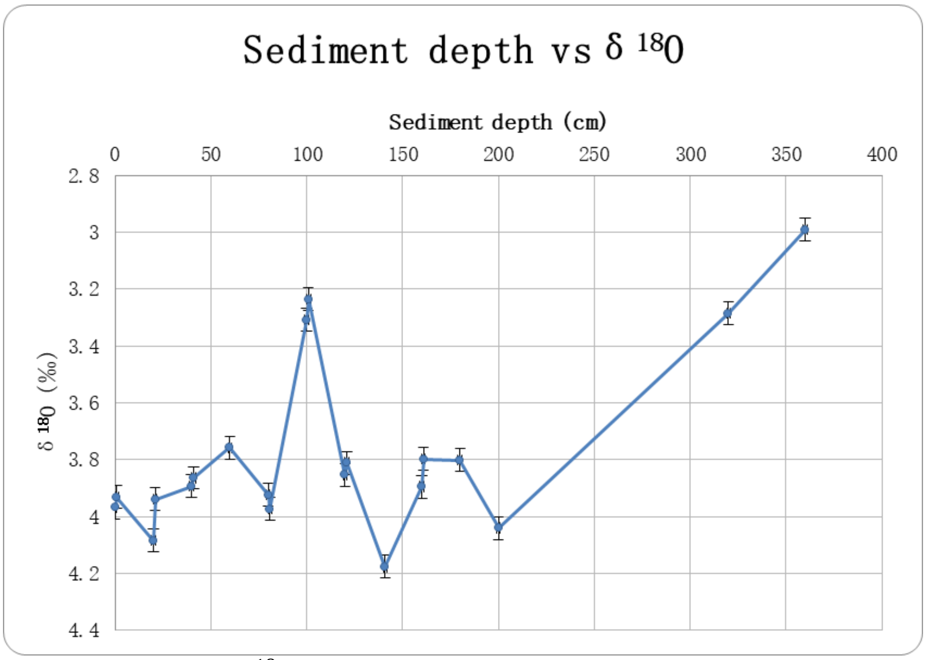
Table 2. $\delta^{13}C$ and $\delta^{18}O$ results

Sample ID	$\delta^{13}C$ (‰)	$\delta^{18}O$ (‰)
VM27-104PC-0-1	-0.156	3.968
VM27-104PC-1-2	-0.302	3.932
VM27-104PC-20-21	-0.285	4.084
VM27-104PC-21-22	-0.39	3.939
VM27-104PC-40-41	-0.207	3.893
VM27-104PC-41-42	0.103	3.864
VM27-104PC-60-61	-0.446	3.758
VM27-104PC-80-81	-0.196	3.924
VM27-104PC-81-82	-0.098	3.974
VM27-104PC-100-101	-0.42	3.308
VM27-104PC-101-102	-0.202	3.236
VM27-104PC-120-121	-0.133	3.853
VM27-104PC-121-122	-0.216	3.811
VM27-104PC-141-142	-0.16	4.177
VM27-104PC-160-161	-0.325	3.895
VM27-104PC-161-162	-0.489	3.798
VM27-104PC-180-181	-0.093	3.801
VM27-104PC-200-201	-0.299	4.04
VM27-104PC-230-231	NA	NA
VM27-104PC-320-321	0.03	3.286
VM27-104PC-360-361	-0.184	2.991

Preliminary graphs of $\delta^{13}C$ and $\delta^{18}O$ were made based on the raw data (Fig. 9). As sedimentation depth and the time of deposition are in a direct positive relation, the scatter plots show how the temperature changed over time.



a. Sedimentary depth vs $\delta^{13}C$



b. Sedimentary depth vs $\delta^{18}O$

Figure 9. Preliminary graphs showing the change of $\delta^{13}C$ and $\delta^{18}O$ overtime.

The $\delta^{18}O$ and $\delta^{13}C$ show very different trends. The $\delta^{18}O$ graph shows a significant temperature increase from 140-100 cm. The two additional layers display particular low δ18O percentages. This suggests they were formed under very warm climatic conditions. The $\delta^{13}C$ graph, meanwhile, shows more fluctuating values, suggesting that the $\delta^{13}C$ value of the seawater is more variable than the temperature.

- Calculating paleo-temperatures

The $\delta^{18}O$ values of foraminifera are related to global temperature, local water temperature, as well as the $\delta^{18}O$ of seawater.[105] Given the scope of this study, this thesis assumes the local temperature change to be the same as the global temperature. Thus, the change in $\delta^{18}O$ of the foraminifera can be expressed in the following equation:

$$\Delta\delta^{18}O_{\text{calcite shell}} = \Delta\delta^{18}O_{\text{seawater}} + \Delta\delta_{\text{temperature}} \quad (1)$$

Temperature has a much more significant influence than the $\delta^{18}O_{\text{seawater}}$ value.[106]

Epstein et al. (1953) first established the paleotemperature equation using the isotopic composition of calcite and of the surrounding waters. Shackleton and Opdyke (1973) further developed the equation, finding that temperature could be determined from the following equation:[107]

$$T=16.9 - 4.38\,(\delta^{18}O_{\text{calcite shell}}-\delta^{18}O_{\text{seawater}}) + 0.10\,(\delta^{18}O_{\text{calcite shell}}-\delta^{18}O_{\text{seawater}})^2 \quad (2)$$

The $\Delta\delta^{18}O_{\text{seawater}}$ value, which is determined by the mixture of meltwaters from glaciers and sea ice and the mean ocean water, could be obtained from its linear relationship with ocean salinity:[108]

$$\delta^{18}O_{\text{seawater}}= (S-34.75)/1.345 \quad (r^2=0.95)^{109} \quad (3)$$

with *S* representing the surface salinity of the region (Came et. al, 2007). The relationship was derived using temperature and salinity data obtained from the Global Seawater Oxygen-18 Database. Spanning 54-68°N, 18-32°W and depths of 10-50 meters, the data used in formulating the equation cover the area of the target core VM27-104PC. Hence, it is reasonable to adopt the formula in the reconstruction of the temperature at the research site.

---

[105] C. Waelbroeck et al., "Sea-Level and Deep Water Temperature Changes Derived from Benthic Foraminifera Isotopic Records," *Quaternary Science Reviews*, EPILOG, 21, no. 1 (January 1, 2002): 296.

[106] Patterson et al., "Two Millennia of North Atlantic Seasonality and Implications for Norse Colonies," 5307

[107] Guoping Wu, and Claude Hillaire-Marcel. "Oxygen Isotope Compositions of Sinistral *Neogloboquadrina Pachyderma* Tests in Surface Sediments: North Atlantic Ocean," *Geochimica et Cosmochimica Acta* 58, no. 4 (February 1, 1994): 1305.

[108] *Ibid.*, 1304

[109] R.E. Came, D.W. Oppo, J.F. McManus, "Amplitude and timing of temperature and salinity variability in the subpolar North Atlantic over the past 10 k.y.," *Geology* 35, (2007): 315–318. Data repository p5

Contemporary salinity data were obtained from the Marine and Freshwater Research Institute (MFRI) in Iceland. *N. pachyderma* survive in an environment with salinity >34.5‰.[110] MFRI records indicate that the ocean waters near the volcanic island Surtsey have a salinity of about 35~35.1‰, with occasional fluctuations that may lead the salinity to drop to 34.7‰ (Fig. 10).[111] To reconstruct the temperature, this study thus assumes that the average salinity was 35.05‰. Hence, a 0.223‰ $\delta^{18}O_{seawater}$ is obtained through equation (3).

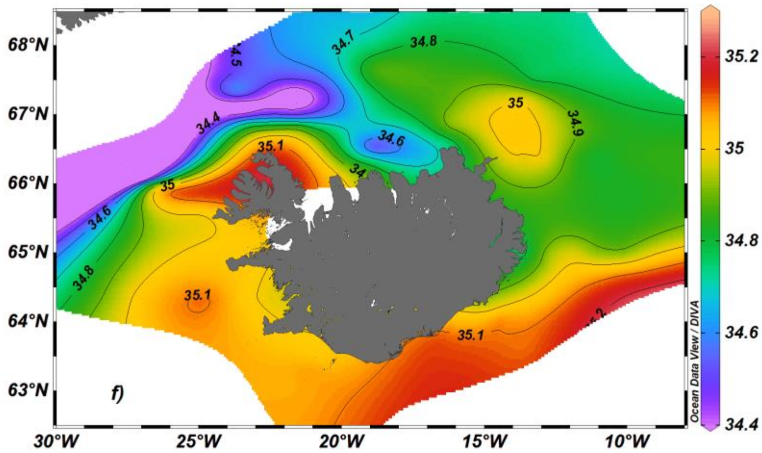


Figure 10. Ocean salinity at the depth of 50m, 2016. (Marine and Freshwater Research Institute (MFRI), https://sjora.hafro.is/reports/larettar.php?L=B13-2016&T=S)

The influence of the ice melts on the salinity is not considered. In studying a nearby site, Came et al. (2007) shows that the ice volumed corrected $\delta^{18}O_{seawater}$ value is relatively stable in the past 4000 years (Fig.11). Hence, the impact of the Ice melts is comparably insignificant for studying the period of interest.[112]

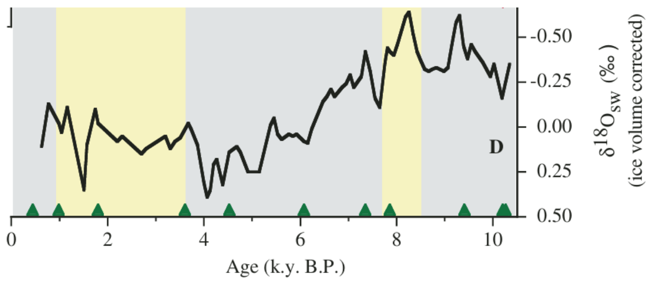


Figure 11. ice volume corrected $\delta^{18}O_{seawater}$ VS time (Came et al., 2007)

---

[110] Claude Hillaire-Marcel, and Anne de Vernal. "Stable Isotope Clue to Episodic Sea Ice Formation in the Glacial North Atlantic." *Earth and Planetary Science Letters* 268, no. 1 (April 15, 2008): 143–50.

[111] Data may be found at https://sjora.hafro.is/

[112] Came, Oppo, and McManus, "Amplitude and timing of temperature and salinity variability in the subpolar North Atlantic over the past 10 k.y.," *316*

Regional temperature can therefore be determined through the Shackleton and Opdyke (1973) equation (2) above (Table 3 and Fig. 12). The $\delta^{18}O$ values of the examined *N. pachyderma* indicate that, during the period in which the top 200 cm of the core were accumulated, the regional temperature oscillated around 2 °C. In the sediment depths of 100-101cm and 101-102 cm, there was a sharp increase in the temperature, surpassing 4 °C. The two extra samples from volcanic ash layers—VM27-104PC-230-231 and VM27-104PC-320-321—also recorded temperatures indicative of warm period climates.

Table 3. reconstructed temperature at each sampled depth of the core

Sample ID	Temperature (°C)
VM27-104PC-0-1	1.899
VM27-104PC-1-2	2.030
VM27-104PC-20-21	1.480
VM27-104PC-21-22	2.005
VM27-104PC-40-41	2.172
VM27-104PC-41-42	2.278
VM27-104PC-60-61	2.666
VM27-104PC-80-81	2.059
VM27-104PC-81-82	1.878
VM27-104PC-100-101	4.339
VM27-104PC-101-102	4.611
VM27-104PC-120-121	2.318
VM27-104PC-121-122	2.472
VM27-104PC-141-142	1.1449
VM27-104PC-160-161	2.165
VM27-104PC-161-162	2.5196
VM27-104PC-180-181	2.509
VM27-104PC-200-201	1.638
VM27-104PC-230-231	NA
VM27-104PC-320-321	4.422
VM27-104PC-360-361	5.542

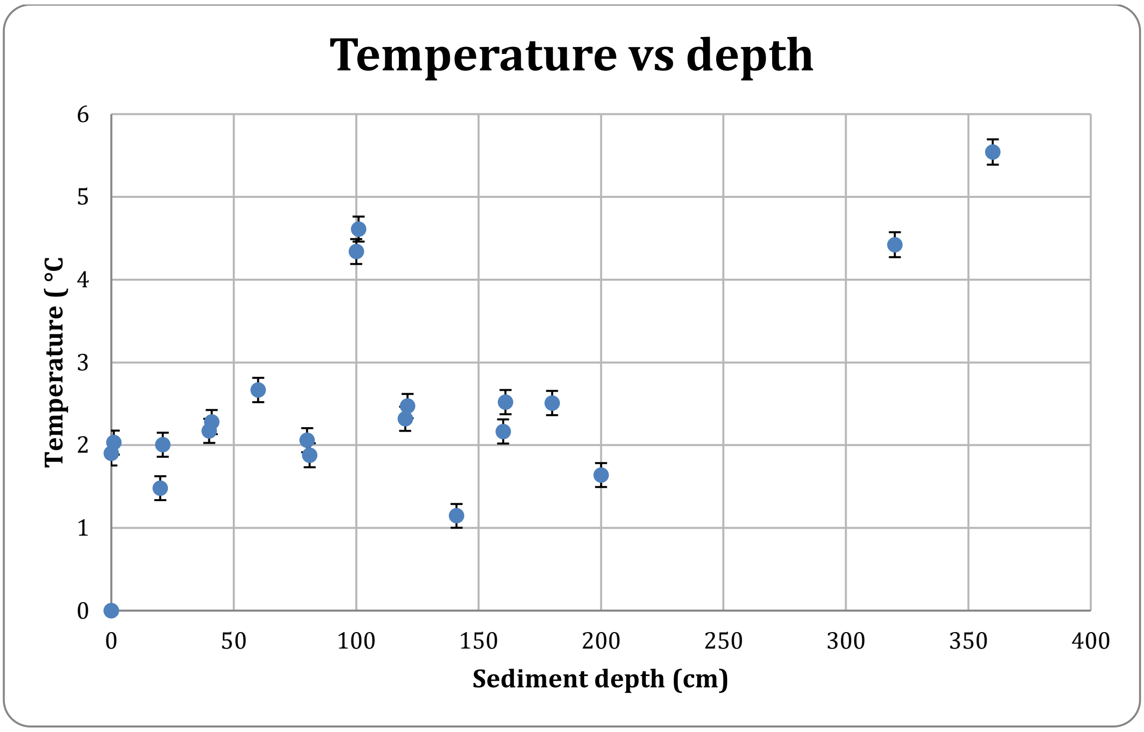


Figure 12. temperature vs sediment depth plot, based on $\delta^{18}O$

Age Model

While a prominent warming period at the sedimentation depth of 100 cm is observed in Fig. 12, I am not yet sure when this warm period occurred. Given that this core has never been studied, an age model has not yet been built.

- Sedimentary rate

The primary method to estimate the age model is through calculating the sedimentation rate. While in northern Iceland the sedimentation rate can be as fast as a few hundred centimeters per thousand years, southern Iceland has a much slower sedimentation rate, ranging from 10.88 cm/kyr (RAPiD-10-1P) to 66 cm/kyr. (RAPiD-17-5P) (Table 4).[113]

[113] Sædís Ólafsdóttir et al., "Holocene Variability of the North Atlantic Irminger Current on the South- and Northwest Shelf of Iceland." *Marine Micropaleontology* 77, no. 3 (December 1, 2010): 101–18. **And** Thornalley, Elderfield, and McCave, "Intermediate and Deep Water Paleoceanography of the Northern North Atlantic over the Past 21,000 Years."

TABLE 4. sedimentation rate in nearby sites

Core/ Site Name	Sedimentation rate (cm/kyr)	coordinate
MD99-2256	30	64°18.19’ N, 24°12.40 W
RAPiD-10-1P	10.88	62°58.53’ N, 17°35.37’ W
RAPiD-17-5P	66.33	61°28.90’ N, 19°32.16' W
RAPiD-15-4P	34.97	62°17.58' N, 17°08.04’ W
Site 984	29	61°25.5'N, 24°04.9'W

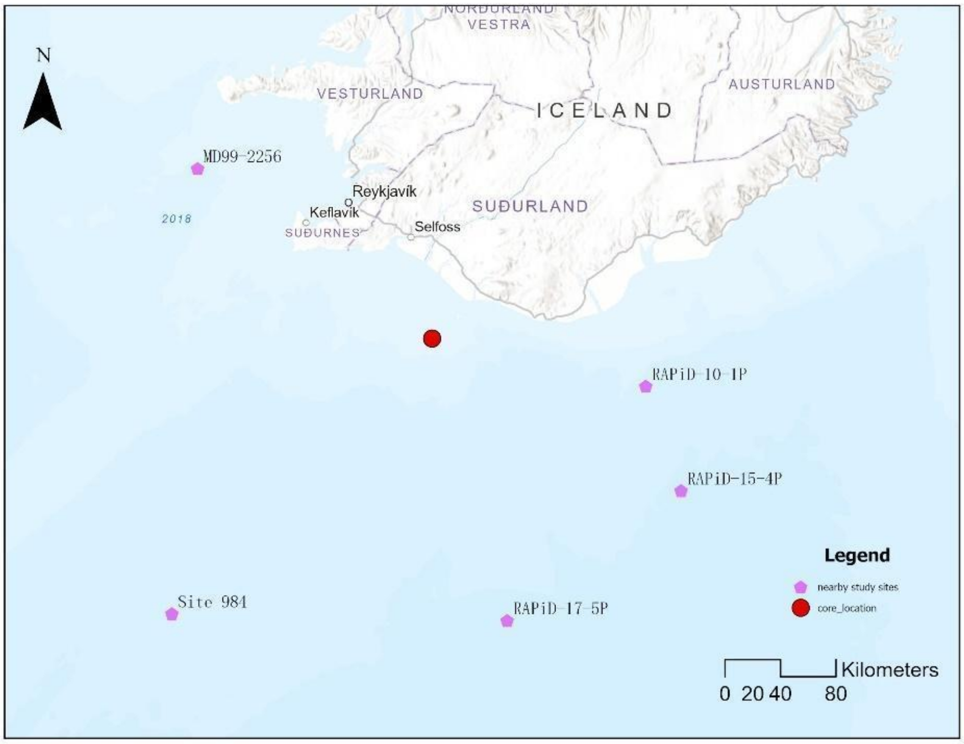


Figure 13. Map showing the spatial relationship between “VM27-104PC” and the core sites that have been previously studied.

Normally, the sedimentation rate is higher in coastal areas than in open ocean areas. However, the core RAPiD-10-1P exhibited a very slow sedimentation rate. If the sedimentation rate at core “VM27-104PC” is that slow, the sediment at 200 cm depth would have been deposited during the LGM about 20,000 years ago. However, the forams at 200 cm depth show that the ocean at that time was relatively similar in temperature to the Holocene (Fig.13). Hence, the sedimentation rate of the core "VM27-104PC" is likely faster than that. Given that three other nearby spots all have rates of around 30 cm/kyr, our preliminary assumption of the sedimentary rate of the core "VM27-104PC" is also around 30 cm/kyr.

- Tephrochronology

The accuracy of the age model is further refined using additional volcanic layers. "VM27-104PC-230-231" and "VM27-104PC-320-321," as observed in Fig. 8, are the two most prominent volcanic ash layers in the top 420cm of the sediment core. Their thickness indicates that they must correspond to two significant volcanic eruptions. The three far-travelled late Holocene tephra layers that have been identified and dated are the Suduroy tephra from a Katla eruption (~8000 years Before Present, BP), the Saksunarvatn tephra from a Grímsvötn eruption (~10300 years BP), and the Vedde tephra from a Katla eruption (~12100 years BP).[114] Thornalley et al. (2011) dated the major tephra layers found in ocean sediment cores south of Iceland, including a Saksunarvatn alike Grímsvötn at ~ 8100 years BP, basaltic eruption(s) of Katla at ∼8400 years BP that may be related to the Suduroy tephra, the Saksunarvatn tephra, the Vedde tephra, a basaltic eruption of Katla at ∼12600 years BP, a rhyolitic eruption of Katla at ∼13600 years BP, a basaltic eruption of Katla at ∼14000 years BP, and two basaltic eruptions of Grímsvötn at ∼14600 years BP and ∼15000 years BP.[115] They also acknowledge the similarity between the chemical compositions of different Katla eruptions.[116]

The chemical composition of two of the volcanic layers from the studied core—"VM27-104PC-230-231" and "VM27-104PC-320-321"—were examined under SEM (Table 5).

[114] Karl Grönvold et al., "Ash Layers from Iceland in the Greenland GRIP Ice Core Correlated with Oceanic and Land Sediments." *Earth and Planetary Science Letters* 135, no. 1 (October 1, 1995): 150–154. And David J. R. Thornalley, I. Nick McCave, and Harry Elderfield. "Tephra in deglacial ocean sediments south of Iceland: Stratigraphy, geochemistry and oceanic reservoir ages." *Journal of Quaternary Science* 26, no. 2 (2011): 190.

[115] David J. R. Thornalley, I. Nick McCave, and Harry Elderfield. "Tephra in deglacial ocean sediments south of Iceland: Stratigraphy, geochemistry and oceanic reservoir ages," *Journal of Quaternary Science* 26, no. 2 (2011): 190.

[116] Thornalley, McCave, and Elderfield, "Tephra in deglacial ocean sediments south of Iceland: Stratigraphy, geochemistry and oceanic reservoir ages," 190

Table 5. Selected chemical elements wt % for the sample layer "VM27-104PC-230-231" and "VM27-104PC-320-321"

	VM27-104PC-230-231				VM27-104PC-320-321			
	SiO_2 wt %	K_2O wt %	CaO wt %	FeO wt %	SiO_2 wt %	K_2O wt %	CaO wt %	FeO wt %
	43.505	1.492	11.267	13.414	45.53	1.109	10.452	14.481
	44	1.093	10.863	14.528	44.747	1.229	10.422	14.702
	43.671	1.439	10.636	12.852	45.754	1.099	10.354	13.823
	44.385	1.463	10.763	13.411	44.929	1.358	10.465	14.498
	44.783	1.455	9.858	13.595	46.512	1.721	9.141	13.264
	47.497	1.12	11.271	10.363	44.855	1.362	11.937	14.678
	44.734	1.223	10.937	13.451	43.893	1.854	10.766	13.462
	43.254	1.34	11.317	13.657	45.131	1.364	10.656	13.24
	44.112	1.096	11.315	13.654	45.669	1.107	10.433	13.404
	43.322	1.328	11.362	13.542	45.469	1.124	10.3	13.472
	43.967	1.342	11.333	13.676	43.807	1.636	10.818	13.441
	46.769	0.853	12.038	11.329	42.839	1.837	10.383	13.993
	45.642	1.34	8.772	10.537	47.33	1.376	10.319	13.363
	43.459	1.73	10.624	15.84	46.26	1.229	10.419	14.041
	44.626	1.348	12.957	11.259	45.827	0.997	10.716	13.447
	58.576	3.93	3.32	3.688	44.403	1.368	10.692	13.684
	53.426	1.62	4.838	0.741	42.974	1.597	10.559	14.824
	44.8	1.086	11.637	11.473	43.81	1.736	10.368	13.372
	44.212	1.214	11.003	13.748	46.039	1.252	10.765	13.509
	45.361	0.916	10.777	3.058	44.955	1.332	10.411	14.229
	37.959	0.373	2.743	24.155	42.69	1.993	10.851	14.233
	47.783	0.741	19.355	10.809	46.189	1.375	10.022	13.354
	42.086	0.741	17.061	15.028				
	44.302	1.217	10.177	13.776				
	43.684	1.206	11.765	13.135				
average	45.1966	1.30824	10.71956	12.18876	44.98	1.41	10.51	13.84
standard deviation	3.811549	0.623852	3.437168	4.50934	1.37	0.28	0.48	0.53

The chemical compositions of these two layers are very similar to the chemical composition of the Loch Ashik ash layer, the Vedde tephra found on Scottland (Fig. 14).[117] This indicates that these two layers are also Katla tephra, and that they may be a part of the Vedde tephra.

[117] C. S. Lane et al., "Was the 12.1 Ka Icelandic Vedde Ash One of a Kind?" *Quaternary Science Reviews* 33 (February 6, 2012): 89.

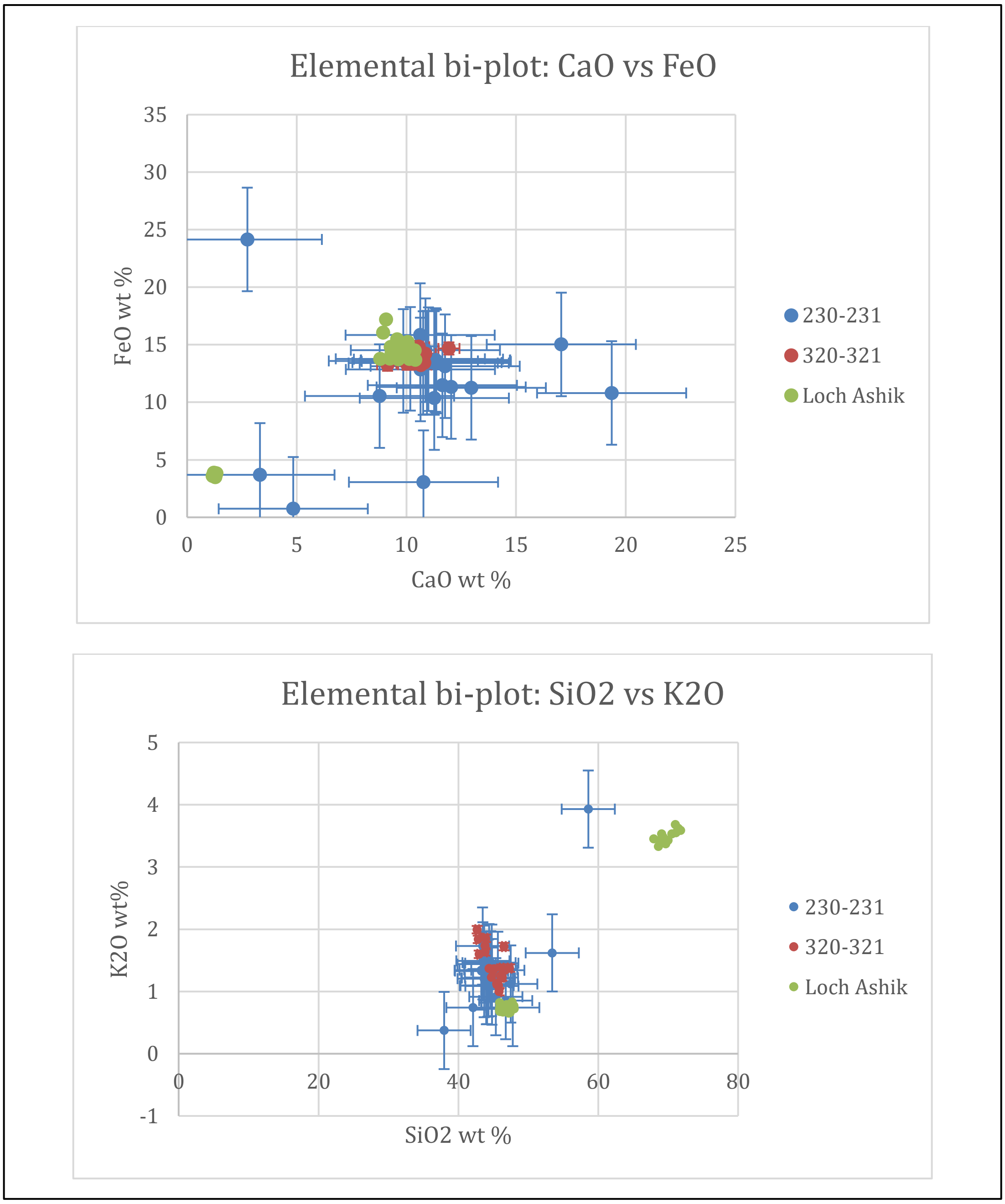


Figure 14. Selected elemental bi-plots of "VM27-104PC-230-231," "VM27-104PC-320-321," and Loch Ashik glass chemistry.

If the 230-231cm layer is the Vedde layer, an eruption that is known for its extensive sediment dispersal, then the sedimentation rate would be approximately 19 cm/kyr.[118] The 320-321 cm tephra would have come from a volcanic eruption that occurred approximately 16842 years ago. If the 320-321cm is Vedde layer, then the sedimentation rate would be approximately

[118] Karl Grönvold et al., "Ash Layers from Iceland in the Greenland GRIP Ice Core Correlated with Oceanic and Land Sediments," 153

26.45 cm/kyr. The 230-231cm tephra would have come from a volcanic eruption approximately 8695 years ago. Moreover, Fig. 8 shows another thin volcanic layer at the sediment depth of 335cm of the core. If the sedimentation rate is 26.45 cm/kyr, then the 335 cm layer would have been deposited 12665 years ago. The date coincides with the basaltic eruption of Katla at ~12600 years BP.[119] Hence, it seems that the sedimentation rate is more likely to be 26.45 cm/kyr. Based on this model, the stratigraphy of the core is represented in Table 6 and Fig. 15.

Table 6. Age Model with correlating temperature data

Sample ID	Time BP (before present)	Time (CE/BCE system)	Temperature (°C)
VM27-104PC-0-1	0	1969 CE	1.899
VM27-104PC-1-2	38	1931 CE	2.030
VM27-104PC-20-21	756	1213 CE	1.480
VM27-104PC-21-22	794	1175 CE	2.005
VM27-104PC-40-41	1512	457 CE	2.172
VM27-104PC-41-42	1550	419 CE	2.278
VM27-104PC-60-61	2268	299 BCE	2.666
VM27-104PC-80-81	3025	1056 BCE	2.059
VM27-104PC-81-82	3062	1093 BCE	1.878
VM27-104PC-100-101	3781	1812 BCE	4.339
VM27-104PC-101-102	3819	1850 BCE	4.611
VM27-104PC-120-121	4537	2568 BCE	2.318
VM27-104PC-121-122	4575	2606 BCE	2.472
VM27-104PC-141-142	5331	3362 BCE	1.1449
VM27-104PC-160-161	6049	4080 BCE	2.165
VM27-104PC-161-162	6087	4118 BCE	2.5196
VM27-104PC-180-181	6805	4836 BCE	2.509
VM27-104PC-200-201	7561	5592 BCE	1.638
VM27-104PC-230-231	8695	6726 BCE	NA
VM27-104PC-320-321	12098	10129 BCE	4.422
VM27-104PC-360-361	13611	11642 BCE	5.542

[119] David J. R. Thornalley, I. Nick McCave, and Harry Elderfield. “Tephra in deglacial ocean sediments south of Iceland: Stratigraphy, geochemistry and oceanic reservoir ages.” *Journal of Quaternary Science* 26, no. 2 (2011): 190.

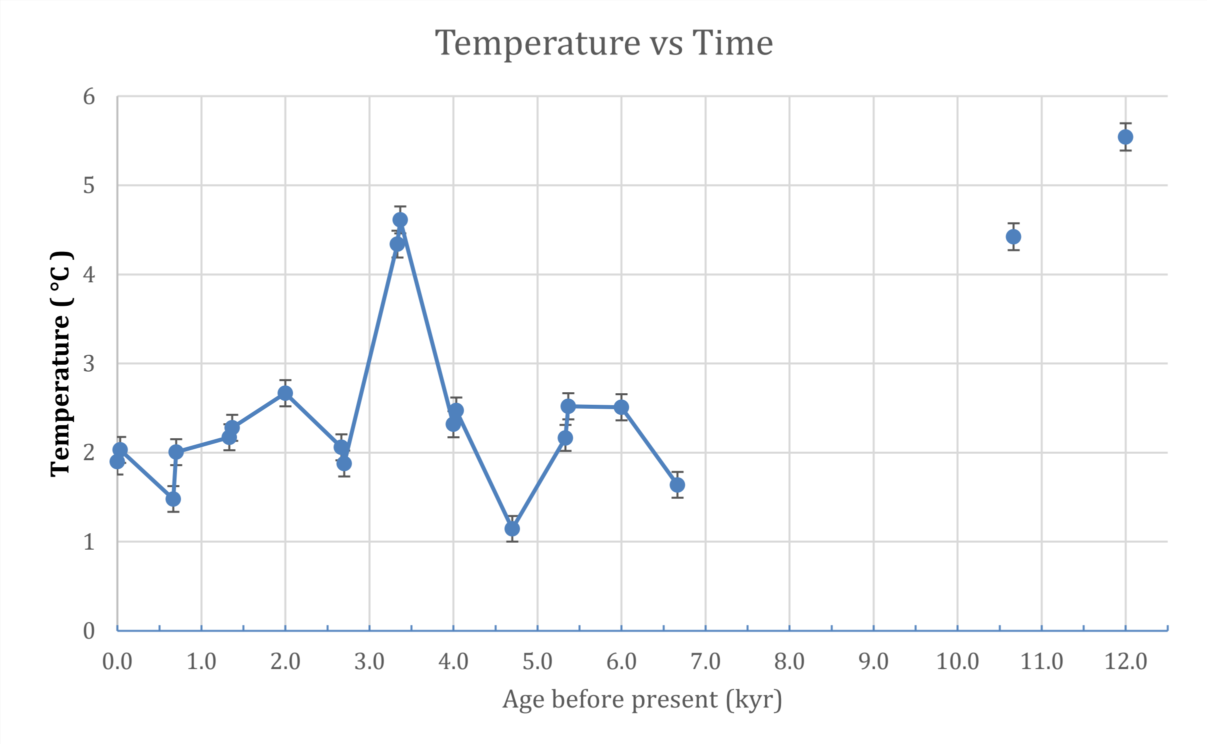


Figure 15. Temperature vs Time

Discussion

The δ^{18}O records analyzed in this research suggest a possible general trend of climate fluctuation in the period of interest. Over the past two thousand years, according to the reconstruction, the regional climate started at a relatively warm period with the oceanic temperature reaching 2.6°C, which could coincide with the Roman Ages Warm Period.[120] It then underwent a gradual cooling of 0.5°C over the course of 1300 years. Around 1300 CE, there was an abrupt drop of 0.5°C in temperature, a period that appears to correlate with the onset of the Little Ice Age. After the cooling period, the model shows that the temperature returned to the pre- "Little Ice Age" level, with the ocean surface temperature being 2°C. Due to the limited sampling of temperature data in the time period of interest, this research cannot provide more detailed information on climate fluctuations during the early medieval period. However, the core itself surely has the potential to do so.

[120] Paola Moffa-Sánchez and Ian R. Hall, "North Atlantic Variability and Its Links to European Climate over the Last 3000 Years," *Nature Communications* 8, no. 1 (November 23, 2017): 6

Despite the low resolution of the temperature model that I reconstructed, the temperature changes under this age model seem to be arguably coherent with the general regional climate fluctuation in the late Holocene. The overall trend is like the climate model Came et. al (2007) made using *N. pachyderma* forams at Site 984 (Fig. 16). While this thesis' speculative reconstruction of local temperature is not perfectly in alignment with Came et. al (2007) climate mode, both reconstructions indicate an occurrence of local temperature maximum around 3000 years ago and two other local temperature maximums that are about 1500 years before and after it. The differences may be due to the low resolution of the sample examined and due to the change of sedimentation rate at different locations. The observed differences could be caused by the variations in the sedimentation rates and the low resolution of the samples analyzed in my climate reconstruction.

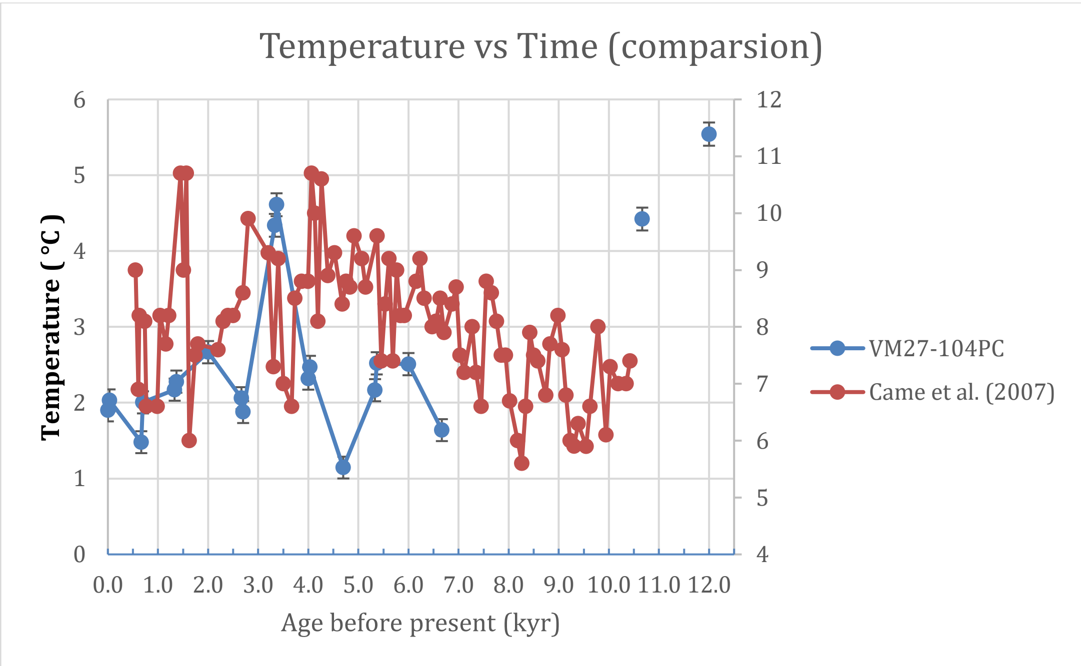


Figure 16. Temperature vs Time.
Comparison between VM27-104PC model and Came et al. (2007) model

Additionally, key climate events and transitions can also be identified within my reconstruction climate model. For instance, the local climate maximum at 2000 years BP and the following decreasing climate trend is also observed in Moffa-Sánchez and Hall's (2017) research on North Atlantic climate variability.[121]

- Interpretation on the low temperature results

What is unusual about the sediment core is the rather low average temperature obtained through the foraminifera record. The northward-flowing Irminger Current typically maintains a water temperature of 6-8°C.[122] The studied region's contemporary surface water temperature is 6-7 °C according to Reid and Mantyla (1994), which is higher than what the core indicated (2°C).[123] The temperature of the water masses passing through the site VM27-104PC is in fact closer to those of the cold East Greenland and East Icelandic Currents, which are normally around 2°C or lower.[124] It is possible that the site is more heavily influenced by ISOW return flow (Map of ISOW above), or that the encircling coastal currents that surround Iceland brought colder water from the north to the south (Fig.6).

Another possible cause of this unusual cold water may be the upwelling of cold bottom water. Site VM27-104PC is located on the edge of the continental shelf and near a submarine canyon (Fig. 17).

---

[121] Moffa-Sánchez and Hall, "North Atlantic Variability and Its Links to European Climate over the Last 3000 Years," 4

[122] Valdimarsson and Malmberg, "Near-Surface Circulation in Icelandic Waters Derived from Satellite Tracked Drifters," 23

[123] J. L. Reid, and A. W. Mantyla, *World Dataset of Temperature, Salinity, Oxygen, Nutrient Profiles*, (1994) http://dss.ucar.edu/datasets/ds543.0/data/

[124] Valdimarsson and Malmberg, "Near-Surface Circulation in Icelandic Waters Derived from Satellite Tracked Drifters," 23

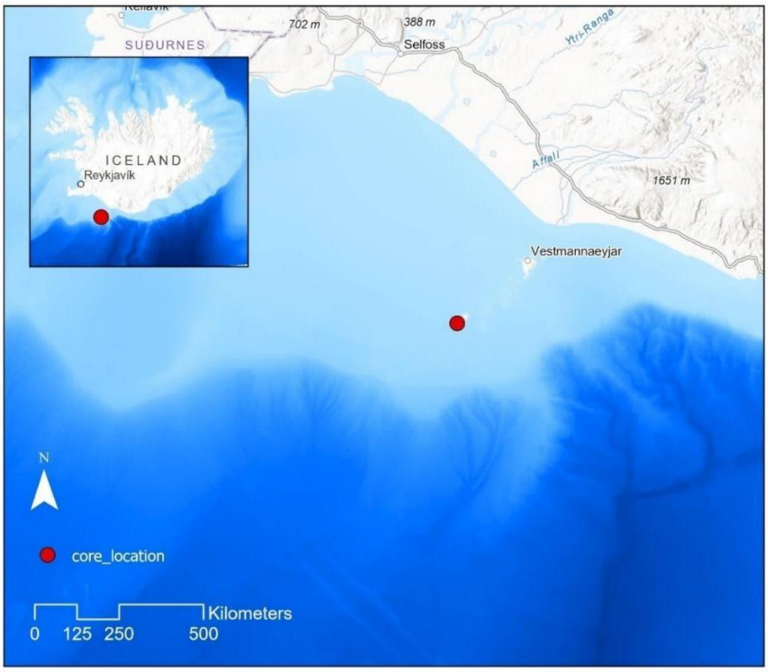


Figure 17 submarine canyon. basemap source: (https://emodnet.ec.europa.eu/geoviewer/)

Upwelling of bottom seawater is common in submarine canyons. It can occur as advection-driven flow that upwells along the canyon (Fig. 18).[125] It may also happen, due to the conservation of potential vorticity, according to Maria K. Filonczuk in her report of an unusual upwelling that happens in southeast Iceland. [126] As Filonczuk and Brink (1990) suggests, potential vorticity is conserved when quasi-geostrophic flow occurs over submarine canyons, which creates favorable conditions for upwelling to happen (Fig. 19).[127]

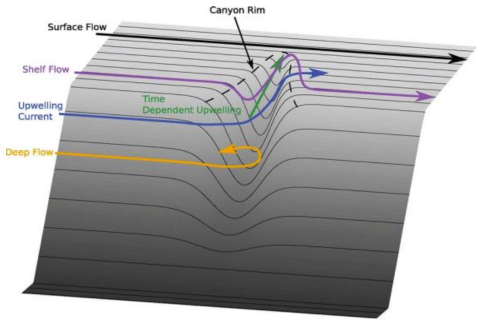


Figure 18 Schematic of the flow around a submarine canyon (Howatt and Allen, 2013)

[125] T. M. Howatt, and S. E. Allen, "Impact of the Continental Shelf Slope on Upwelling through Submarine Canyons." *Journal of Geophysical Research: Oceans* 118, no. 10 (2013): 5815

[126] Maria K Filonczuk, "Upwelling Southwest of Iceland Due to Quasi-Geostrophic Flow." *UNITED STATES NAVAL ACADEMY*, (1990),10

[127] *Ibid.*

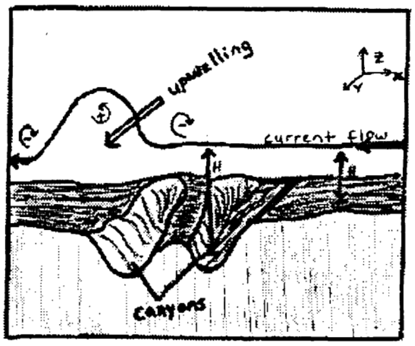


Figure 19. Conservation of potential vorticity at submarine canyon (Filonczuk 1990)

The low temperature may also be due to the encrustation that happened at the end of the forams' life cycle. The final curst, which would form in deep ocean and on the top of the crust formed in the shallow waters above the pycnocline, may takes up more than 50% of the total test.[128] The high-resolution images (Fig.20) generated by scanning electron microscope (SEM) show that *N. pachyderma* in this sediment core have irregular and granular surfaces, which indicate that the experienced some degrees of encrustation at deeper level of the ocean.[129]

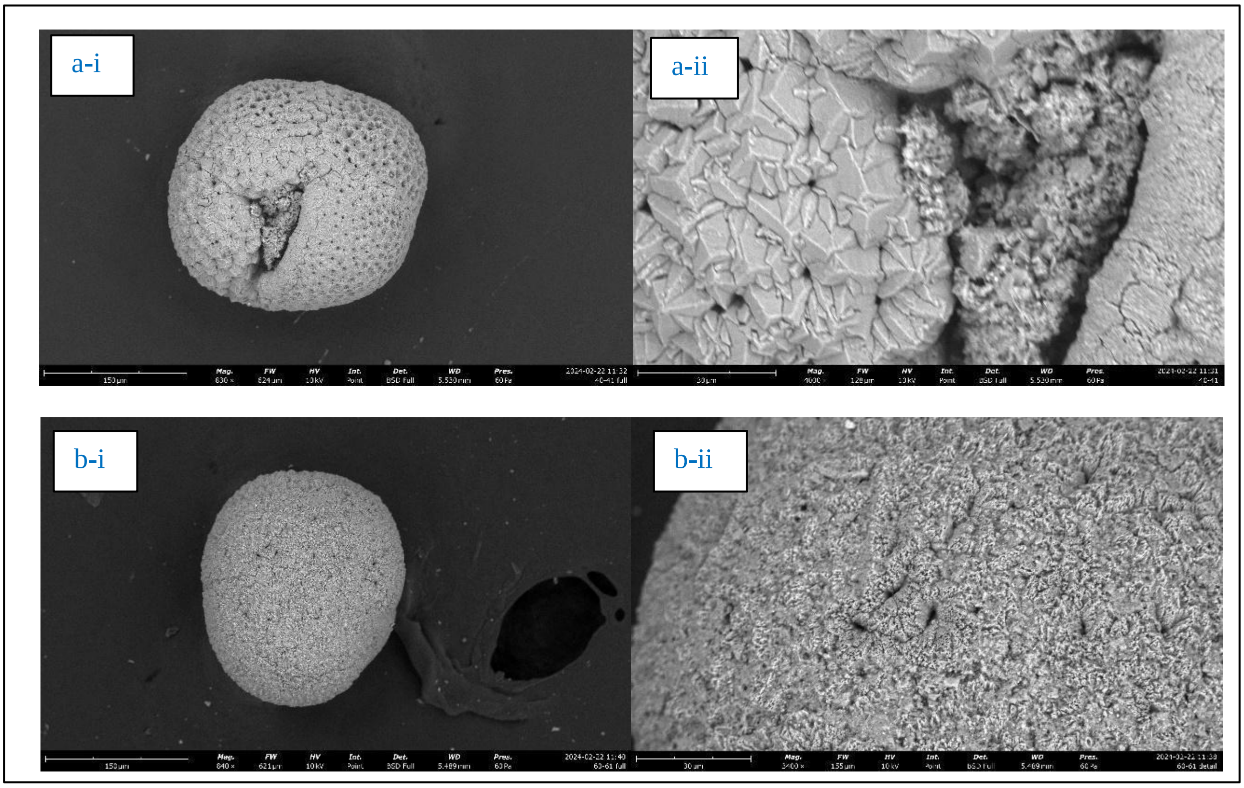


Figure 20. SEM photos of forams. (a-i) shows a foram from the sample section VM27-104PC-40-41cm; (a-ii) is the detailed image of the foram in (a-i); (b-i) shows a foram from VM27-104PC-60-61cm; (b-ii) is the detailed image of the foram in (b-i).

[128] R. Kozdon, R. et al., "Intratest Oxygen Isotope Variability in the Planktonic Foraminifer *N. Pachyderma*: Real vs. Apparent Vital Effects by Ion Microprobe." *Chemical Geology* 258, no. 3 (January 30, 2009): 328

[129] Caitlin M. Livsey, et al., "High-Resolution Mg/Ca and δ18O Patterns in Modern Neogloboquadrina Pachyderma From the Fram Strait and Irminger Sea," *Paleoceanography and Paleoclimatology* 35, no. 9 (2020): 4

R. Kozdon, R. et al. (2009) shows that, for *N. Pachyderma*, the average difference in $\delta^{18}O$ between inner crust and outer crust can be as high as 2.1‰.[130] It also indicates that the offset value can be very different in different location. *N. Pachyderma* in the sediment core top 23528-3 (North Atlantic, 63.16°N, 28.84°W) shows an offset of 1.8‰.[131] If *N. Pachyderma* in VM27-104PC have a similar offset value, then the real surface temperature will be around 9 °C, which is very similar to the temperature in Came et al. (2007) (Fig.21). However, further research is needed to acquire the exact offset value. The data presented in Fig. 21 suggest that the surface temperature of Iceland's southern sea, as recorded in core VM27-104PC, may in fact align closely with findings from other studies.

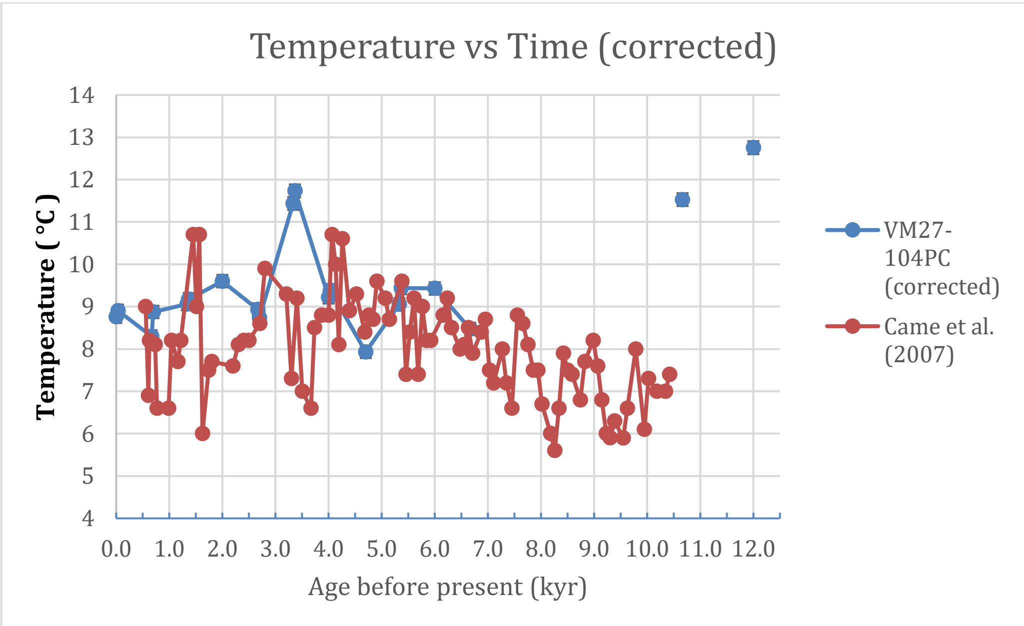


Figure 21. Temperature vs Time (With an estimation of 1.8‰ offset of $\delta^{18}O$ at the site VM27-104PC)

[130] Caitlin M. Livsey, et al., "High-Resolution Mg/Ca and δ18O Patterns in Modern Neogloboquadrina Pachyderma From the Fram Strait and Irminger Sea," 336

[131] *Ibid.*, 332

Conclusion: Early medieval climate

While the exact surface temperature requires further investigation, the climate reconstruction of *N. Pachyderma* in the core VM27-104PC shows that there is no significant climate variation between the so-called “Dark Age Cold Period” and the "Medieval Warm Period.” Additionally, the seventh century may have actually been warmer than the thirteenth century, which indicates that early medieval Iceland may have been even more habitable than Iceland in the Middle and high Middle Ages. The mollusks’ record in Patterson et al. (2010) indicates that the northern Iceland experienced a “period of exceptional warmth from ∼A.D. 600 to 760” and a “maximum warmth began ∼A.D. 800–850.”[132] While these specific climate changes were not observed in the core taken from the site VM27-104PC, both Patterson et al. (2010) and this thesis’ reconstruction suggest the early medieval Iceland may not be as cold as people would imagine. Therefore, the island is likely habitable for Insular *peregrini.*

132 Patterson et al., “Two Millennia of North Atlantic Seasonality and Implications for Norse Colonies,” 5308.

Chapter 3. structuring the cave: a survey of regional landscape and the Hella caves' layout in relation to Insular ecclesiastical "space"

In 1905, Icelandic poet Einar Benediktsson wrote an article in the local newspaper *Fjallkonan* recounting his visit to Hella caves, "I raise a small wax candle as high as I can reach under the dome in the first cave that I found with clear signs that there were Christian hermits there."[133] Acknowledging that crosses that "cut in many places on the cave vaults," and the presence of "a rather large cross-mark" at the innermost corner of the cave, Benediktsson concludes that the caves were constructed by the Christians who settled here long before the Vikings.[134] Though not extensively investigated, the caves of Hella have been among those earliest speculated to have associations with Christianity.

The various theological associations of the caves render them to be favorable locations for hermitage. Many important moments in the life of Christ happened in caves: early Christian fathers believed that Christ was born in a cave, and it is widely believed that he was also resurrected from one.[135] Under the Foundation Stone of the Dome of the Rock is the mystic Well of Souls, a partly natural, partly man-made cave. Many Early Christian Saints lived their lives in the caves in the wild. In Ireland, St Patrick experienced the visions of purgatory in the cave.[136] Hidden from plain sight and disconnected from the surrounding environment, caves are both physically and metaphorically isolated from the outside world.[137] In monastic understanding, it is therefore the place that is set apart, where God delights to dwell.[138]

The enigmatic origin of the man-made caves in southern Iceland, despite the large quantity, has always been a question that lies at the margins of the study of Icelandic history.

---

133 Google translation. Hjartarson, Guðmundsson, and Gísladóttir, *Manngerðir hellar á Íslandi*, 40.

134 Ahronson, *Into the Ocean*, 148, 153

135 Marion Dowd, "Out of the Darkness, Into the Light: The Early Medieval Period (400–AD 1169)." In *The Archaeology of Caves in Ireland*, (Oxbow Books, 2015), 174

136 Marion Dowd, "Archaeology of the Subterranean World." *Archaeology Ireland* 15, no. 1 (2001): 28.

137 J. Alexandra Nickell, "The Early Churches of Fife: A Gazetteer of Sites." Thesis, (University of St Andrews, 2003), 53

138 David Prestel, "The Kievan Caves Monastery: What Do Monks Have To Do With The World?" *Russian History* 33, no. 2/4 (2006): 202

In this chapter, I will explore the local landscape, the location choice, and the structures of Hella caves from both art history and earth science perspectives. The investigation of the relationship between the caves and the surrounding environment shows why this location was specifically selected. The study of the “architectural” structure of the Hella caves in relation to that of the early medieval Scottish and Irish caves, meanwhile, offers insights into their function and origin.

Regional Landscape

Before diving into the specific investigation on the caves in Hella, I would like to first explore the regional environment of southern Iceland and the local conditions of Hella. Today, southern Iceland has become the most developed tourist destination in Iceland. With the warm NAC traveling northward and reaching the south coast, southern Iceland is perhaps climatically the most habitable place in the entire island aside from the potential danger posed by the active volcanic systems. The geomorphic landscape of Iceland is predominantly shaped by volcanic activities and glacial dynamics. The southern coast, particularly, is sculpted by postglacial lava flows and coastal sandur plains.[139] Sandur is an Icelandic geologic term, which refers to "the classical land of the alluvial outwash plains.”[140] In other words, sandur marks the plains that are made of unconsolidated materials and the landform can be easily subject to the changes in fluvial systems. Investigating the artificial caves in Seljaland, Ahronson claims that "there are no obvious physical or cultural reasons for the extreme concentration of caves in southern Iceland.”[141] However, as seen in the geologic map (Fig. 22), the distribution of the manmade caves seems to follow a certain geologic pattern: most caves are concentrated on the elevated lava land instead of the lowland coastal plains. It seems that the caves were located on the boundary of the postglacial lava flows, granting them advantages in elevation and stability.

[139] Sigurdur Thorarinsson, T. Einarsson, and G. Kjartansson. “On the Geology and Geomorphology of Iceland.” *Geografiska Annaler* 41, no. 2/3 (1959): 167

[140] The definition of Sandur seems to be contested, but it seems that in Iceland the definition of the term is slightly looser. Ahronson in his book also refers to the lowland plain in southern Iceland as Sandur. *Ibid*.

[141] Ahronson, *Into the Ocean*, 77

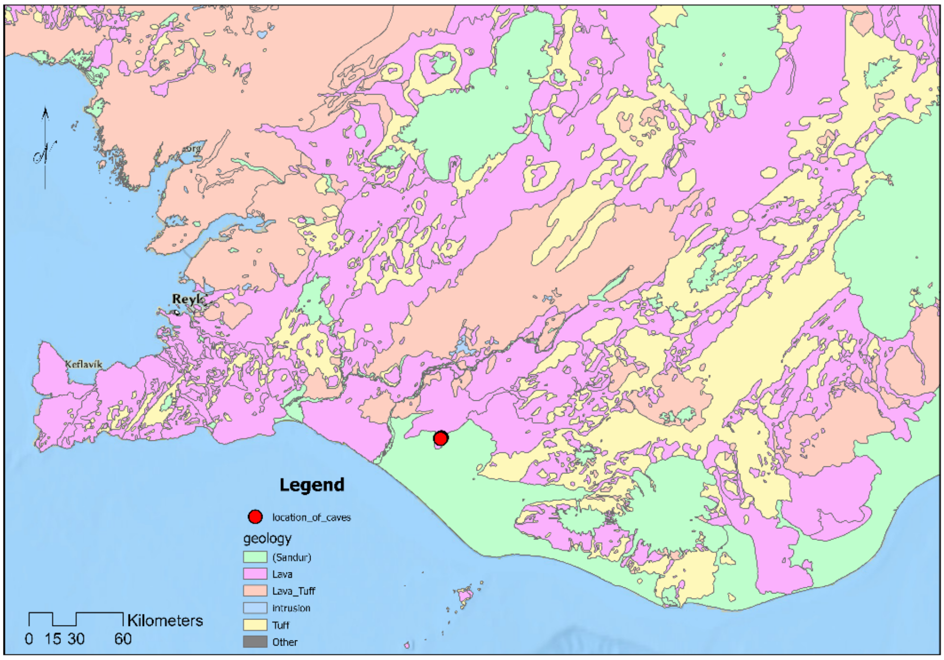


Figure 22. Geologic Map of Southern Iceland

The general location of the artificial caves in southern Iceland seems also to be impacted by the rock type. The artificial caves are dug into sandstones and tuffs. This differentiates them from the dwelling caves in Britain, which, as Marion Dowd points out in her study of Irish caves, were normally natural caves made of carboniferous limestone.[142] Limestone is the leading candidate for natural cave formation; when the acidic rainwater and groundwater are in contact with the rock, it dissolves the calcium carbonate that consists of the limestone, leading to the formation of hollow inner space. However, it is a rock type that is not found in Iceland, a geologically young island that is primarily composed of ingenious rocks such as basalt. In Iceland, naturally occurring large and small lava tunnels or caves can be found within igneous rocks. Igneous rocks are physically harder than sedimentary rocks such as sandstone and limestone. Moreover, many of these lava tunnel caves are too big and too exposed to retain heat. The fact that the cave dwellers in the south did not choose these natural caves but constructed artificial caves in sandstone instead suggests a preference for the particular location and

[142] Dowd, "Caves and Cave Archaeology in Ireland," In The Archaeology of Caves in Ireland, (Oxbow Books, 2015), 48

possibly the desire to control the design of the caves to better suit long-term habitation and ritual use.

Local Landscape

Similar to other manmade caves in southern Iceland, the caves of Hella are located at the edge of the piles of lava flow (Fig. 23). The caves are at a spot that is susceptible to volcanic activity: Hella lies to the south of the stratovolcano Hekla and to the west of Eyjafjallajökull and Katla. Topologically speaking, the caves occupy high ground, overlooking the surrounding lands. The caves are also not far from water sources, which lie to the east. The land to the north of the caves features high-relief topography formed by a meandering river incising into the rock formations, whereas the southern areas consist of flat sandurs.

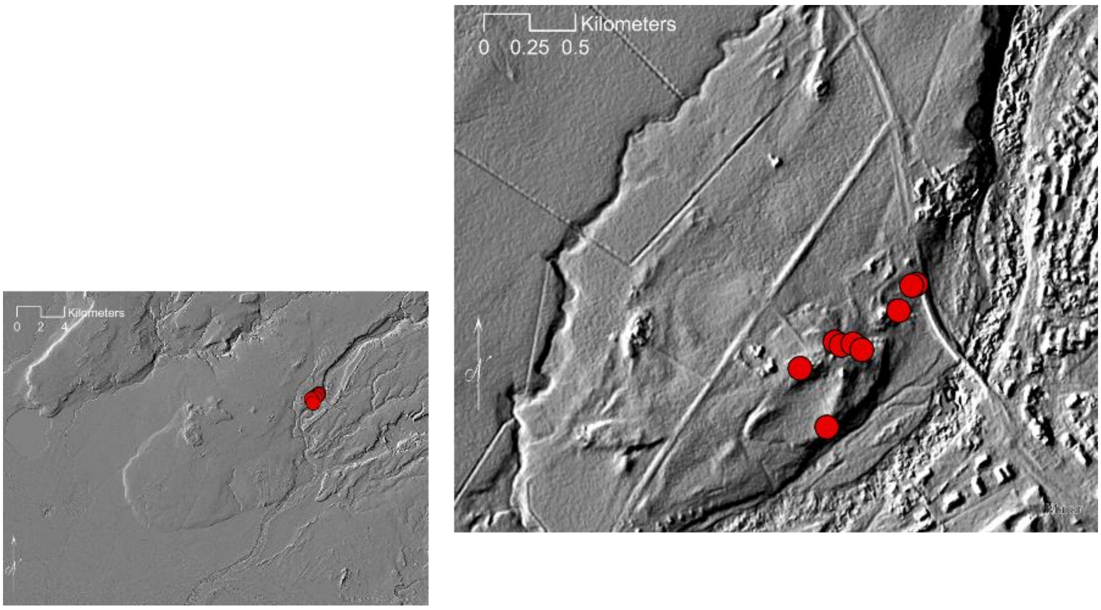


Figure 23. Digital Elevation Model (DEM) map of the region

Among the 12 existing caves, 9 caves are located (Table 7). On the hill of Hella, the caves are carved out at different elevations. Hlöðuhellir, Fjárhellir, Skagahellir, and presumably Lambhellar, are at the foot of the hill; Fjóshellir, Brunnhellir, Brunnhellir, and Kirkjuhellir—located next to each other—are at around 20 feet above the previous three caves.[143] Búrhellir,

[143] The names of the caves are given by contemporary people.

which is now located under a house on the top of the hill, is presumably the highest cave in elevation.[144] All caves except Lambhellar are constructed on the northern side of the hills. The caves that have four caves at the middle elevation are excavated from hill slopes, the sunken entrance hides the caves from plain sight (Fig. 24). While the entrances are half-covered in grasses, they are big and not hard to enter, which indicates that these caves are not made for defensive purposes but are made for needs in everyday life. The slope of the hills shelters the caves from the winds which makes the caves a desirable place to live.

Table 7. Coordinates of the Hella caves

No.	Name	Translation	Latitude (°N)	Longitude (°W)	Elevation (ft)
1	Hlöðuhellir	Barn cave	63.83787	-20.406952	127
2	Fjárhellir	Money cave	63.83784	-20.407171	128
3	Skagahellir	Peninsula cave	63.8373	-20.407816	128
4	Fjóshellir	Barn cave	63.836622	-20.410941	146
5	Brunnhellir	Well cave	63.836548	-20.410639	155
6	Hrútshellir	Ram's cave	63.83658	-20.410061	153
7	Kirkjuhellir	Church cave	63.836452	-20.409614	144
8	Búrhellir	Cage cave	63.836048	-20.412655	
9	Lambhellar	Lamb cave	63.834777	-20.41134	

Figure 24. Half-sunken entrance of one of the Hella caves

[144] Lambhellar is a cave located on private property that we did not have the chance to investigate, but it should have a similar elevation as the lower three caves.

Each cave in Hella has its unique layout (Fig.25). Currently, three caves—Hlöðuhellir (cave no.1), Fjárhellir (cave no.2), and Fjóshellir (cave no.4)—are open for public visit. Among the three caves, Fjóshellir (cave no.4) is worth special attention for its size and the rich cross graffiti it bears. In the late twentieth century, Icelandic historian Árni Hjartarson, Guðmundur J. Guðmundsson, and Hallgerður Gísladóttir complied the existing historical documents and conducted a detailed survey of the existing caves found in southern Iceland.[145] According to their research, *Manngerðir hellar á Íslandi [Manmade Caves in Iceland]*, Fjóshellir is the 7th largest artificial cave found in Iceland, 21 meters in length.[146]

Figure 25. Photo of a Cave location map (taken in the cave Hlöðuhellir)

[145] Hjartarson, Guðmundsson, and Gísladóttir, *Manngerðir hellar á Íslandi*, 22

[146] Caves over 20 meters long are relatively rare, as they note, for a medium-sized cave is about 10 x 4 m2 and the center of the cave normally has a height of one man's height. *Ibid.*, 22, 24

General Description

- Fjóshellir

Fjóshellir, the barn cave, is an elongated cave with two chambers (Figs. 26, 27). It is a cave with a westward orientation, which means that the entrance is on the east side. There is a very clear distinction between functional differences in the two chambers of Fjóshellir. The entrance chamber, which is approximately 11.48 meters in length and 3.53 meters in height, possesses an irregular, somewhat contorted oval ground plan. The ceiling is slightly tilted toward the left, as influenced by the natural geomorphology of the landscape. On the left side of the entrance, there are two flattened surfaces carved into the wall, likely intended as seating areas. An oculus is dug out at the center of the ceiling, providing light sources while facilitating air circulation. On both sides of the walls, small niches for oil lamps are carved out at various heights. The oculus and the lamp niches ensure that the entrance chamber receives ample light both during the day and at night.

In contrast with the irregularly shaped entrance chamber, the inner chamber was constructed with greater refinement. It is smaller and has a more rectangular floor plan. The floor is elevated. The length and height of the chamber are respectively 8.38 meters and 2.51 meters. The inner chamber also has much less natural daylight penetration. An oculus, which is smaller than the one in the daylight chamber, opens at the entrance of the inner chamber. The owner of the cave, Baldur Þórhallsson, told us that this oculus was enlarged when the cave served as a barn house. Another twentieth century modification is the side door on the left side of the chamber. Constructed in 1934, the door was opened for the farmers to slide in crops into the cave.[147] The end of the small chamber, with an unopened oculus on the ceiling, is devoid of natural daylight but full of cross carvings. The ceiling is curved in the semicircular shape of the vault. There are no niches except one at the lower left of the end wall; the niche's low position

[147] Hjartarson, Guðmundsson, and Gísladóttir, *Manngerðir hellar á Íslandi,* 149

makes it unlikely to be designed for lamps. It thus suggests that the end of the cave may have been intentionally left in darkness. The ample cross carvings on the end wall and the two side walls of the inner chamber seem to indicate that the cave was once used by Christians for religious purposes.

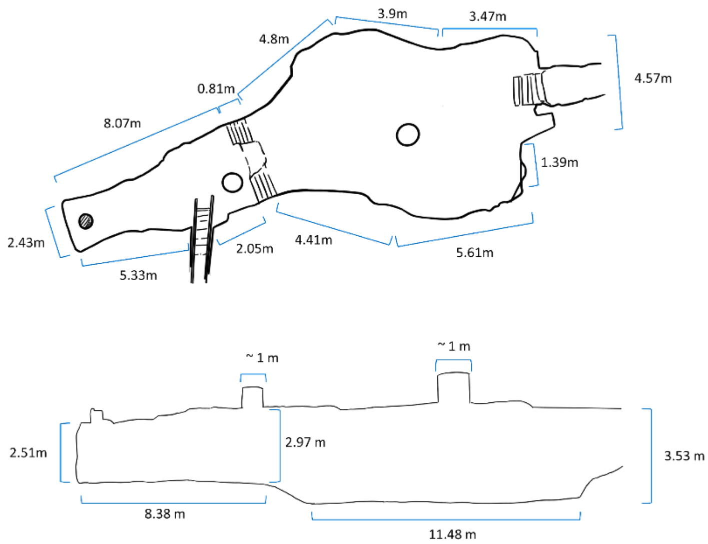


Figure 26. Floor plan and profile plan of Fjóshellir

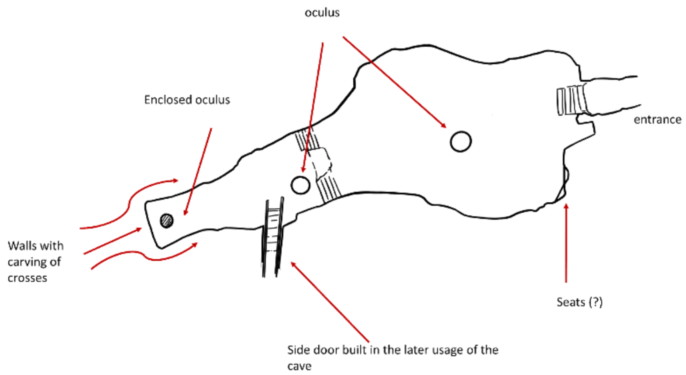


Figure 27. Annotated floor plan of Fjóshellir

Figure 28. photos taken inside Fjóshellir[148]

- Hlöðuhellir and Fjárhellir

Hlöðuhellir and Fjárhellir, cave no.1 and no. 2, are the two adjacent north-south oriented caves at the bottom of the hill. A tunnel that was constructed in 1926 connects the two caves. Hlöðuhellir is an elongated cave with a bench-like structure at the end of the main chamber (Fig. 29). Hlöðuhellir has a west-side chamber with nearly perfect right-angle corners. Compared to Hlöðuhellir and Fjóshellir, Fiárhellir is much smaller and has a lower ceiling. However, it is the only cave that has a well, which is located on the west side of the cave.

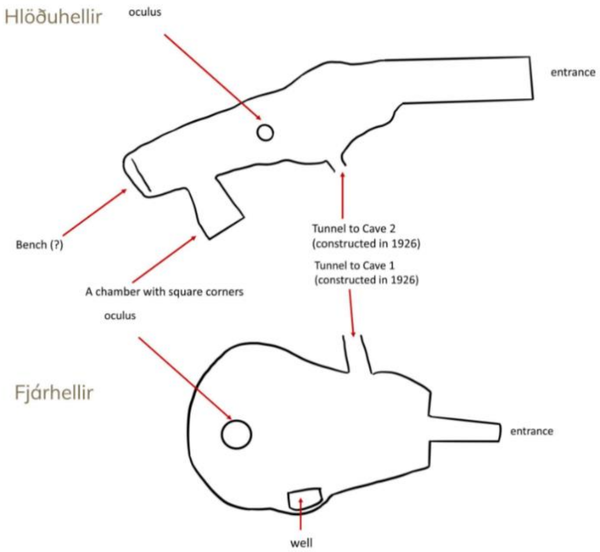


Figure 29. annotated floor plans for Hlöðuhellir and Fjárhellir. The rectangular entrance hallway of Hlöðuhellir is a contemporary construction

[148] more of Fjóshellir interior see the LiDAR models: https://skfb.ly/ oQuxE and https://skfb.ly/ oNWKP

Insular caves and churches

To further investigate the hypothesis of an Insular origin of the Hella caves, I would like to turn attention to the caves in Ireland and Scotland. In the British Isles, early medieval people both utilized natural caves and constructed artificial ones. The natural caves and artificial caves are used for different purposes. In both Ireland and Scotland, natural caves are more commonly chosen as sites for religious retreats. Patrick’s Purgatory on Lough Derg, Co. Donegal, for instance, is a natural cave.[149] On the other hand, artificial caves seem to be more likely to serve the function of storage or refuges.[150] The structure of artificial caves varies depending on the geographic location. The artificial caves in early medieval Ireland, as Richard Warner points out in his study of Irish Souterrains, are very inaccessible and cannot be used for long-term dwellings.[151] Most of the Irish artificial caves are constructed in long, irregular, multi-chamber form and designed to have a height that only allows one to crawl inside.[152] In the meantime, the artificial caves in south-east Scotland—the Southern Pictland—are roomy and have well-paved entrances.[153]

The caves in Hella are accessible, spacious, and simple in their structures. One primary difference Icelandic caves have from Insular caves is that they are artificial structures constructed for dwelling or religious purposes. The size of the Hella caves implies that they were regarded as more than just caves of storage or temporary dwellings, but rather as architecture that with the consideration of the dwellers’ experience in the space. Different chambers are assigned with different functions. This is particularly the case for Fjóshellir, the cave with an inner chamber that the local Icelanders refer to as the “chapel.” Moreover, it is important to note that Hella caves are constructed in a group, which indicates that they may be

[149] Dowd, “Archaeology of the Subterranean World,” 28
[150] Warner, “The Irish Souterrain and their Background,” 116
[151] *Ibid.*, 129-131
[152] *Ibid.*
[153] Warner’s writing is a bit ambitious on whether these caves are artificial or natural, for, as I will later discuss, several Pictland natural caves also fit his description well. *Ibid.*, 129

used by a religious community rather than one or two monks. Hence, I would like to consider the Icelandic caves as a combination of Insular natural caves and monastic community sites.

Insular caves with cross graffiti

Several natural or partly natural and partly artificial sandstone caves in Scotland are found with cross graffiti on their walls.[154] The simple layout of these caves and the somehow random position of crosses on the walls can easily remind one of Fjóshellir. The following examples of Scottish caves will show that there is indeed a paralleling relation between the British Christian usage of the cave and the Icelandic cave dwellers' usage of the cave.

- Wemyss Caves

Wemyss Caves is a group of sandstone coastal caves on the North shore of the Firth of Forth, Scotland. They are naturally carved out by water erosion.[155] Wemyss Caves were initially occupied by Picts, a group of people living in the north of Britain in the early medieval period. Graffiti from various time periods are found, spanning from early Christian crosses to the carvings of the early modern era.[156] In one of the Wemyss Caves—Jonathan's cave—simple linear crosses are found in the end wall of the cave. The basic layout of Jonathan's cave (Fig. 30), coupled with the presence of simple linear crosses, is similar to that of Fjóshellir.

[154] Besides one example from southwest Scotland, all other examples are found in Fifes, south-east Scotland, the region which Warner has noted to have roomy artificial caves.

[155] Euan W MacKie, "Iron Age and Early Historic Occupation of Jonathan's Cave, East Wemyss," *Glasgow Archaeological Journal* 13, no. 1 (January 1, 1986): 74–77.

[156] Deirdre Cameron, *Archaeology InSites*, 2017, https://canmore.org.uk/event/1038195

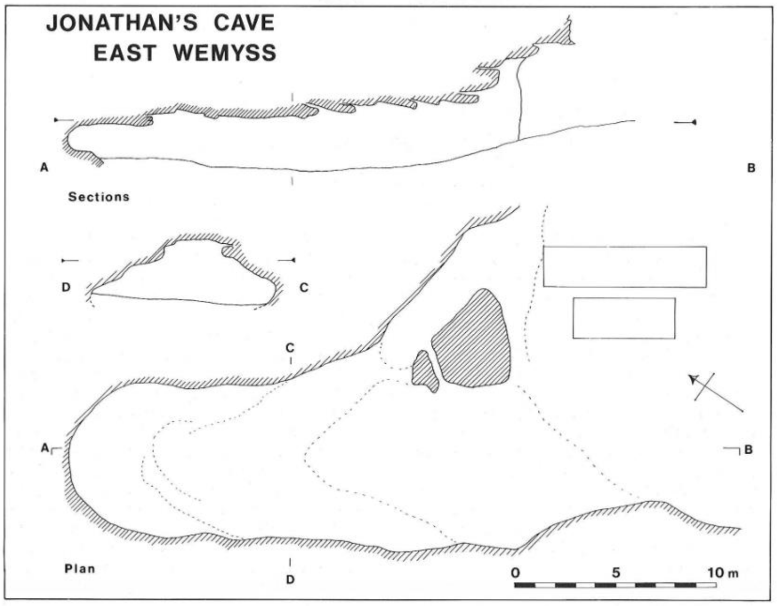


FIG. 1. Plan and elevation of Jonathan's Cave, East Wemyss, Fife.

Figure 30. Floorplan of Jonathan's Cave
(MacKie, "Iron Age and Early Historic Occupation of Jonathan's Cave, East Wemyss")

Besides the similarity between Jonathan's cave and Fjóshellir, the Well cave (Fig. 31) in the Wemyss Caves group is also similar to Fjárhellir (cave no.2, Fig.29) in Hella. Wells were often found in or near early Irish Christian caves. In the tales of early Irish hermits, springs and holy wells are valuable for providing vital sources of life-sustaining water for the hermits and possessing miraculous healing powers for pilgrims.[157] As stated in Chapter 1, the early medieval Scottish Christians are closely connected with Irish Christians. Both Fjárhellir and the Wemyss Well cave in an oval shape and are relatively small. Paraphs are a coincidence, but for both caves the well is located in the left corner. While the possibility is small, it is not impossible that the cave makers of the Hella caves have seen cave structures that are similar to those of the Wemyss caves.

[157] Marion Dowd, "Saintly Associations with Caves in Ireland from the Early Medieval Period (AD 400–1169) through to Recent Times," In *Caves and Ritual in Medieval Europe, AD 500-1500*, edited by Marion Dowd and Knut Andreas Bergsvik, 1st ed., (Oxbow Books, 2018), 116–30

Figure 31. Well Cave 3D model. (http://4dwemysscaves.org/cave/index.php?ccode=wc#)

- Constantine's Cave

Slightly south of Wemyss Caves, Constantine’s Cave is located on the north side of a rocky crag on the shore of Fife Ness. The cave is 3 meters wide at the mouth, 7 meters deep, and about 3.6 meters high.[158] Like Wemyss Caves, they are also Pictish caves occupied by early medieval Christians.[159] The cross carvings are found on both the eastern and western walls of the cave, but they are much more concentrated on the latter wall (Fig. 32). The cross distribution of Constantine’s Cave is close to that of Fjóshellir; for people entering both caves, they would find the majority of crosses located on the right wall and a few crosses located on the left wall.

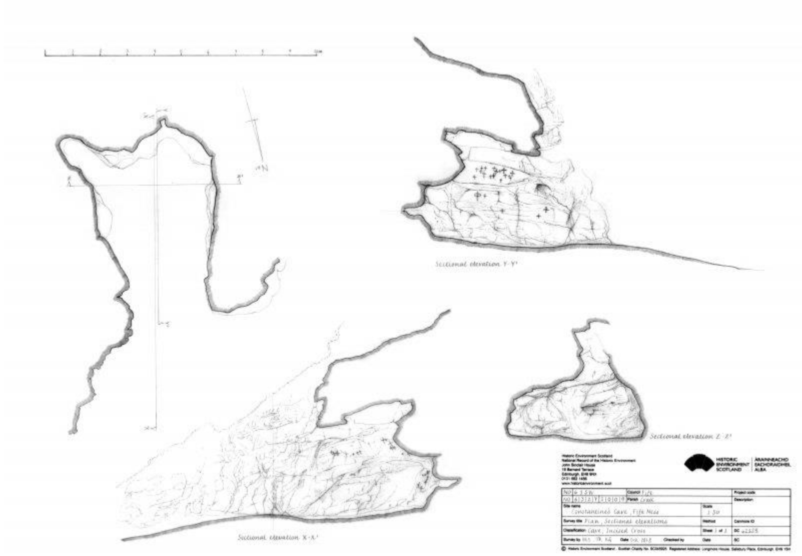


Figure 32. Floorplan of Constantine's Cave (Canmore, http://canmore.org.uk/site/35369)

[158] Nickell, “The Early Churches of Fife,” 63
[159] *Ibid.*

- Caiplie caves

The Caiplie caves are 5 kilometers south of Constantine's Cave. Simple cross carvings are found in Chapel Cave, an artificially enlarged natural cave in Caiplue (Fig. 33).[160] J. Alexandra Nickell in her study of the caves in Fifes points out that the Caiplie caves have been speculated to be used by hermits in Early Christian times.[161]

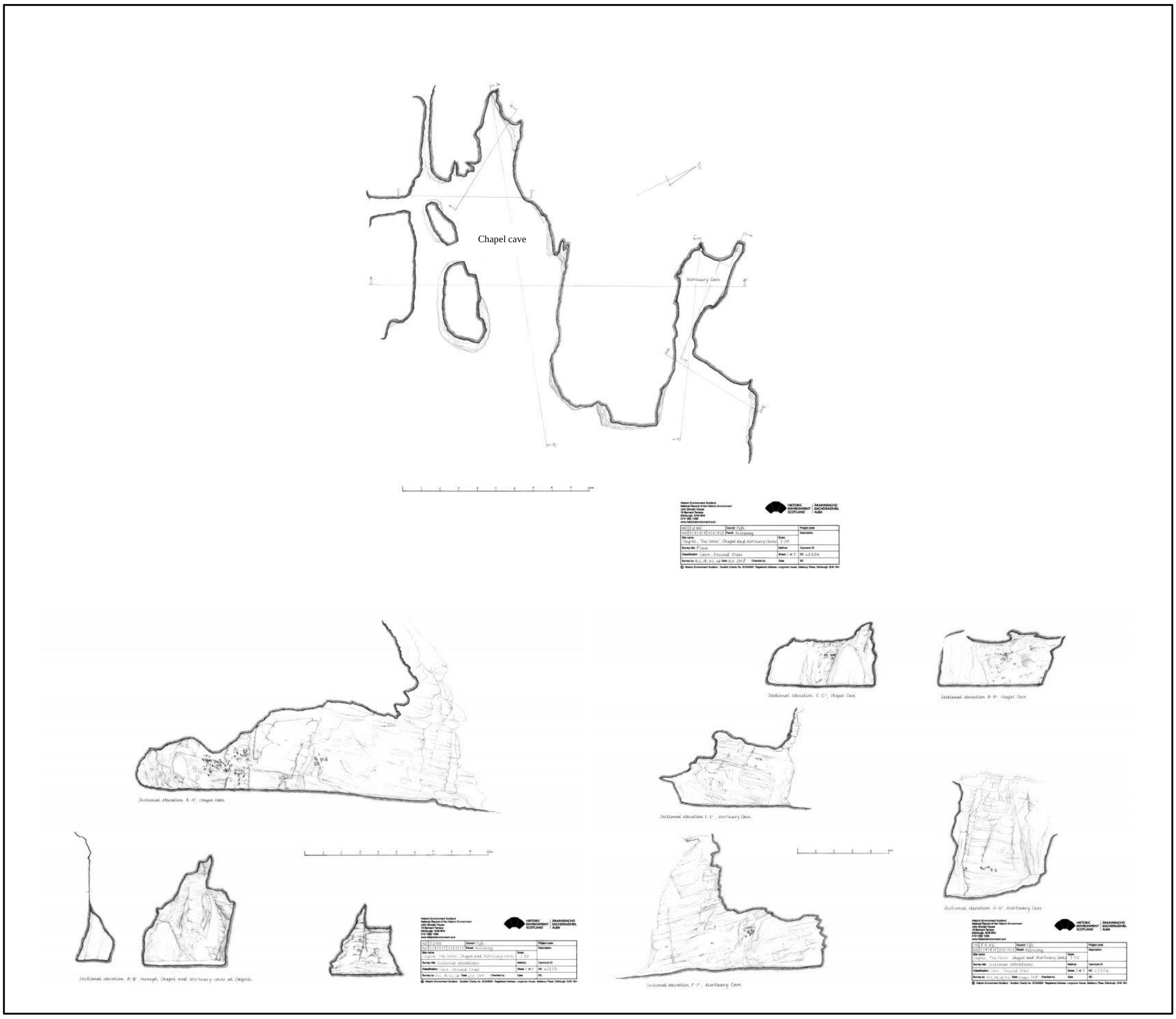


Figure 33 Floorplan, profile plan, and sectional illustrations of the Chapel Cave (https://canmore.org.uk/site/34025/caiplie-the-coves)

[160] Nickell, "The Early Churches of Fife," 136
[161] *Ibid.*, 136-137

- St. Molaise’s cave

St. Molaise's cave is located on the southwest coast of the island of Arran, Scotland. The cave, which is of natural formation, was believed to be the hermitage site of the Irish St. Molaise. The cross carvings of St. Molaise's cave are sparsely distributed on the further end of the cave (Fig.34).[162] Similar to the Hella caves, it also has a partly sunken entrance.

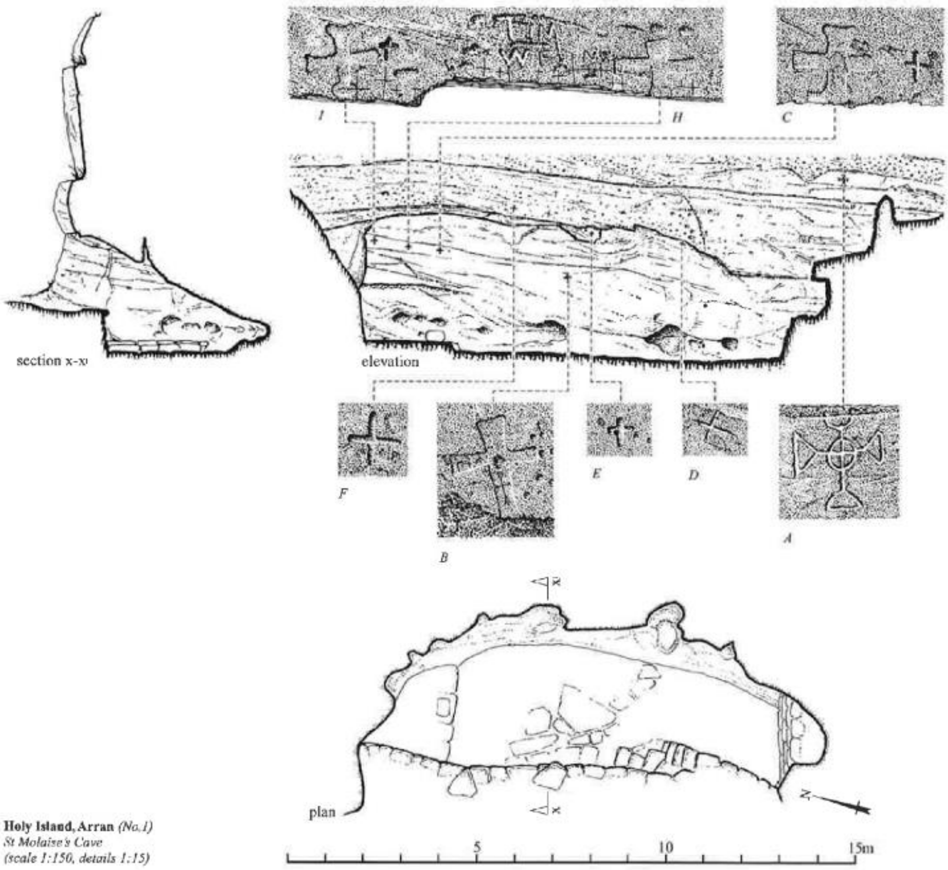


Figure 34. Floorplan, profile plan, and sectional illustrations of St. Molaise’s cave
(Ian Fisher, *Early Medieval Sculpture in the West Highlands and Islands*, 61)

Insular ecclesiastical architecture

To what extent would the Hella caves, particularly the cross-bearing Fjóshellir, function as ecclesiastical architecture? In his book *Herdsmen & hermits: Celtic Seafarers in the Northern Seas*, English archaeologist Thomas Charles Lethbridge mentions two caves in

[162] Dowd, *The Archaeology of Caves in Ireland*, 176

Iceland that he found look much alike "a beehive hut and small rectangular chapel cut into rock" and that he "wonder whether they are not a monastic adaptation to suit the colder climate."[163] Lethbridge compares the caves in Iceland with beehive huts, a kind of Irish architecture that has a Irish name *clocháin*. *Clocháins* are characterized by their round stone construction and corbel-roofed structures.[164] Among the three caves examined in this thesis, however, the well cave Fjárhellir (Fig. 29, cave no.2) is the only cave that roughly fits the structure *clocháin.* Both Fjóshellir and Hlöðuhellir (Fig. 29, cave no.1) are rectangular shapes. However, the two rectangular caves do not bear much similarity with *Dairthech*, the rectangular early medieval Irish church, either.[165] For most *Dairthech* are short in proportions and have an approximate length/breadth ratio of 3:2.[166] Therefore, in terms of the layout, there is no strong correlation between Hella caves and early Insular monastery buildings. However, it does not mean that there is no correlation between them. Until the ninth century, the majority of churches in the northern British Isles were constructed from wood rather than stone.[167] Hence, the identification process is very hard since the beginning.

While Hella caves may not be directly connected to early medieval British ecclesiastical architecture, they indeed bear resemblance to the caves in southeast Scotland. The cross-bearing cave Fjóshellir, in particular, shares similarities with Constantine's Cave and Chapel Cave. If Fjóshellir was modeled after these natural or partially natural caves, its westward orientation may be easily explainable. Due to natural constraints, the religious orientation seems to be much more flexible when it comes to natural caves. Moreover, the direction of the wall with the most

[163] The location Lethbridge mentions is Ægisidu; based on the description he had, it is very likely that he was referring to Ægissíða, where Hella's cave is located. Thomas Charles Lethbridge, *Herdsmen & Hermits; Celtic Seafarers in the Northern Seas,* (Cambridge: Bowes & Bowes, 1950), 85

[164] Harbison, *Pilgrimage in Ireland*, 76

[165] Clare Crowley, "The Origin of the Curvilinear Plan-Form in Irish Ecclesiastical Sites: A Comparative Analysis of Sites in Ireland, Wales and France," Technological University Dublin, (2009): 30-31

[166] Sinead Ni Ghabhlain, "Church, Parish and Polity: The Medieval Diocese of Kilfenora, Ireland." University of California, Los Angeles, (1995): 115

[167] Crowley, "The Origin of the Curvilinear Plan-Form in Irish Ecclesiastical Sites," 30-31

cross graffiti is also different for each cave. This indicates that the orientation is not the primary concern when early medieval Insular Christians transformed the cave site into a religious space. If Fjóshellir was artificially constructed after these natural caves, there may also be less attention to the orientation. Moreover, it is also possible that the cave at its initial construction was planned for some other purposes; it was turned into a church during the time when the monks lived there, just as how the Christians turned the Picts' natural caves into their own religious sites. Nonetheless, if such a transformation indeed happened, it must have occurred at a very early time, perhaps even before the construction of the cave was fully completed. This is because that the cross carvings in Iceland, as I will further elaborate in Chapter 4, are very likely to be early medieval motifs.

Meanwhile, if Fjóshellir was indeed constructed as a formal church, its unusual orientation may potentially reveal the time at which the cave was first made. Even though today the majority of Christian churches are in an eastward position, many early Christian churches set their entrance at the east and the altar at the West in imitation of the sanctuary of the Jerusalem Temple.[168] The Old St. Peters Basilica in Rome, for instance, is made in a westward position. For Rome, it was not until the ninth century that the eastward position was widely adopted.[169] In studying the early medieval churches in Britain, Ian Smith points out that some early churches on the British Isles may not even have an East-West alignment.[170] Therefore, the westward orientation of Fjóshellir could also hold religious significance. It could even serve as a potentially powerful piece of evidence for the argument that the cave was made by early medieval Christians instead of Christians who arrived in Iceland in the tenth and eleventh centuries.

[168] Helen Dietz, "The Eschatological Dimension of Church Architecture," *Sacred Architecture Journal*, vol. 10, 2005

[169] *The Oxford Dictionary of the Christian Church*, edited by Frank Leslie Cross, Elizabeth A. Livingstone, (Oxford ; Oxford University Press, 1997), 525

This is also shown in the statistical analysis conducted by Leone. Isabella Leone, "The Orientation of the Early Christian and Medieval Churches of Rome: a Statistical Study." Atti Del XVII Convegno SIA, 2017.

[170] Nickell, "The Early Churches of Fife," 59

Further Investigation

At the present stage, Fjóshellir shows a greater correlation with the natural caves in southeast Scotland than with the monastic communities. The relationship between Hella caves and the Insular ecclesiastical settlement requires further investigation in various directions. For instance, the function of the unopened oculus is still an unsolved mystery. During the onsite survey of the cave, cave owner Þórhallsson told us that Irish scholars once suggested that the unopened oculus was used for hanging bells, a signature object in Irish monasticism. However, it seems that Irish bells mainly refer to handbells, which, as the name indicates, were not used for hanging.[171] Moreover, further research is also needed in the study of Hella as a potential monastic site. From at least the seventh century onwards most ecclesiastical settlements in Ireland are rounded by one or two ringfort-like enclosures.[172] These enclosures separate the sanctuary from the "secular" world and offer divine protection.[173] However, there is no plainly observable circular fence in Hella. Additionally, the position of Fjóshellir in relation to other caves complicates the study of the site. In medieval Irish ecclesiastical settlements such as Skellig Michael (Fig. 35), the church is supposed to be at the center of the site, manifesting the concept of a "holy of holies".[174] The separation of church and the *clocháins* indicates a hierarchical understanding of the landscape. However, Fjóshellir is located close to other caves and there are no visible external signs that distinguish it from other caves. These are all questions that require further investigation.

[171] Bourke, Cormac. "Early Irish Hand-Bells." *The Journal of the Royal Society of Antiquaries of Ireland* 110 (1980): 52–66.

[172] Nancy Edwards, *The Archaeology of the Early Medieval Celtic Churches: Proceedings of a Conference on the Archaeology of the Early Medieval Celtic Churches, September 2004*, Society for Medieval Archaeology Monograph, (Leeds: Maney Publishing, 2009), 106

[173] *Ibid*., 106

[174] *Ibid*, 106, 120

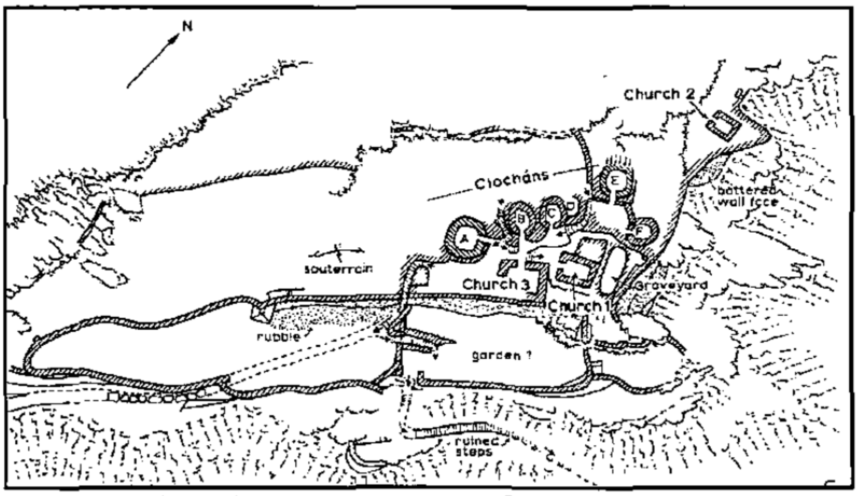


Figure 35. Plan of Skellig Michael (Edwards, *The archaeology of Early Medieval Ireland*, 120)

Conclusion: The Cult of Caves

In medieval Irish literature regarding the lives of the early medieval saints, there are many references to the underground structure "Vaim", the Old Irish word for the cave.[175] For medieval Christian monks, cave-dwelling is the manifestation of living a life of unusual austerity. The experience of solitude is expected as a means to be closer to the divine. As Ahronson and Charles-Edwards note the use of a cave may suggest three different "desires" that the monks may have: "the desire for seclusion; the desire to live a life of exceptional poverty; and the desire to imitate the burial of Christ in a tomb carved in the rock, so as to 'die with Christ' in this world and then rise with him into the life of heaven."[176] There is a strong connection between cave dwelling and monastic austerity in the Insular lands. The artificial caves in Hella, particularly Fjóshellir, may be constructed by the same group of Christians who carve crosses in the Pictish caves. Hence, they may also be endowed with similar significances by their constructors.

[175] Warner, "The Irish Souterrain and their Background," 127

[176] Kristján Ahronson and T. M. Charles-Edwards, "Prehistoric Annals and Early Medieval Monasticism: Daniel Wilson, James Young Simpson and Their Cave Sites," *The Antiquaries Journal* 90 (September 2010): 457

Chapter 4. Experiencing the divine – Cross graffiti in the darkness of Fjóshellir

The potentially most compelling evidence to the hypothesis that the Icelandic caves have an Insular Christian origin is the cross carvings. Simple linear Latin crosses, Greek equal arm crosses, and crosses of other forms were discovered in multiple caves in Southern Iceland, including Fjóshellir.[177] Regardless of the question of whether Fjóshellir is a formal church or not, the presence of the crosses sacralizes the space for the Christian visitors to the cave. In Christianity, cross carvings often serve as markers of sacred space and objects of contemplation. Studying the crosses in the Seljaland caves, Ahronson suggests that the graffiti of simple cross sculptures are "the result of devotional impulse."[178] He links the Icelandic crosses with the Columban Christian communities in Scotland, suggesting that the carvings are adopted from Scottish Christian traditions. In this chapter, I will explore the cross markings in Fjóshellir, where the graffiti has not yet been systematically studied. Are they too related to the Insular Christianity? What symbolic meanings may these crosses convey? To explore the cross carvings, I will first summarize the prominent cross graffiti in Fjóshellir, then compare them with those in north Britain, and then investigate the function and meaning of cross graffiti in early medieval Europe.

[177] Hjartarson, Guðmundsson, and Gísladóttir, *Manngerðir hellar á Íslandi,* 30-31
[178] Ahronson, *Into the Ocean*, 4

Major Crosses in Fjóshellir

The cross carvings in Fjóshellir take various forms and are found on multiple walls in the inner chamber, as discussed in Chapter 3. Whereas some carvings are in visually prominent positions and are easily identifiable, other smaller, more heavily eroded carvings are harder to discern. Sandstone is a rather soft rock, and in certain areas, the wall surface is poorly preserved.[179] In some cases, natural erosion of the rock surface has created natural fissures that are almost cross-like. For the scope of research, this thesis only focuses on the markings that have prominent features of human-carved crosses. While Hjartarson et al. express concern that the crosses on the side walls are more modern modifications, this thesis will consider them in the analysis.[180]

While the forms of the crosses in Fjóshellir vary greatly among themselves, they can be categorized based on carving techniques and structural forms (Table 8). The classification scheme is adapted from a broad category defined by the Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS). The RCAHMS scheme was used by archeologist Ian Fisher in his investigation of crosses on early medieval Scottish sculptures and was also later adopted by Ahronson in his research on the rock-cut crosses at Seljaland.[181]

[179] Hjartarson, Guðmundsson, and Gísladóttir, *Manngerðir hellar á Íslandi*, 27

[180] Hjartarson et al.'s argument is that the side wall crosses are not recorded in the twentieth century sources. However, given that there are only 2 sources in total, it does not prove that the side crosses did not exist. *Ibid.*, 149

[181] Ahronson, *Into the Ocean*, 173

Table 8. Major Crosses in Fjóshellir

Cross type			
simple Sunken Crosses	 Cross A	 cross group B	
linear & sunken cross with circular terminal	 Cross C	 Cross D	 Cross group E
Relief Cross	 Cross F	 Cross G	 Cross H
Outline cross	 Cross I		

Most crosses in Fjóshellir are sunken crosses (Table 8, Cross A-E). The differences in carving techniques and degree of erosion suggest that they were carved in different stages of the cave's construction. For the simple sunken crosses, cross A was carved in a deep "v" shape, meanwhile crosses in group B were likely carved out with some sort of U-Gouge. Some crosses are more weathered than others. While the crosses in Group B, Cross C, and Cross D are both carved in a U-shaped groove, the crosses in Group B have much angular edges. The edges of Cross C and D's grooves appear more worn and eroded. Moreover, Crosses in group E are thinly carved, which suggests that they were made with a different tool. Therefore, the differences between the sunken crosses suggest that cross carving is a sustained practice at Fjóshellir, involving multiple contributors.

The most prominent crosses in the cave are perhaps the relief crosses (Table 8, Cross F-H). The three relief crosses are notably larger compared to the other crosses. Cross F is the only cross that is located at the end wall.[182] Cross G and H were sculpted on the sidewall at the right. Cross G is about the same size and degree of erosion as Cross F, which indicates that they may have been made around the same time; its uneven surface also indicates the possible existence of a crucified Christ. In the meantime, Cross H—sculpted at a rather low height—has a very smooth surface. Like the sunken crosses, the relief crosses also shows the carving of crosses of different time periods.

[182] The family that owns this cave believes that this cross used to be carved with the crucified Jesus on it

Insular cross connection

One prominent feature observed in both incised and sunken crosses in Fjóshellir is the presence of circular terminals. Cross C, D, and Cross Group E all terminate in slightly sunk circular hollows. Two circular terminal crosses were also found in Seljalandshellar (Fig. 36 a, b), the cave Ahronson is studying.[183] Cross with pitted circular terminals appear in a wide range of contexts in Scottish lands. Such types of cross graffiti are found in St Molaise Cave and Jonathan's Cave (Fig. 36 c, d). Slabs carved with a circular terminal cross is found on the remote island Eileach an Naoimh; Monymusk, Aberdeenshire; and on the island A' Chill, Canna (Fig. 36 e, f, g). Moreover, the motif has also been discovered on church walls (Fig. 36 h) in the Church of St Andrew, Scotland. The circular terminal cross motif distributes widely across Scotland, from the southwest islands (St Molaise cave, Eileach an Naoimh, and A' Chill) to the southeast Pictland (Jonathan's Cave and Church of St Andrew) and the northeast (Monymusk). Moreover, it is also a long-standing motif in the early medieval period. Whereas the monastic community on Eileach an Naoimh was established in the mid-sixth century, the Church of St Andrew was built in the ninth to eleventh century and was renovated in the fourteenth century.[184] Hence, it would seem that the circular terminal cross was rather common and popular in the northern British Isles early medieval ages.

[183] Cross A/B3 and Cross B5. Ahronson, *Into the Ocean*, 177-178

[184] Ian Fisher, *Early Medieval Sculpture in the West Highlands and Islands*. Monograph Series (Royal Commission on the Ancient and Historical Monuments of Scotland), (Edinburgh: Royal Commission on the Ancient and Historical Monuments of Scotland : Society of Antiquaries of Scotland, 2001), 30. **And** Norfolk Medieval Graffiti Survey, http://www.medieval-graffiti.co.uk/page119.html

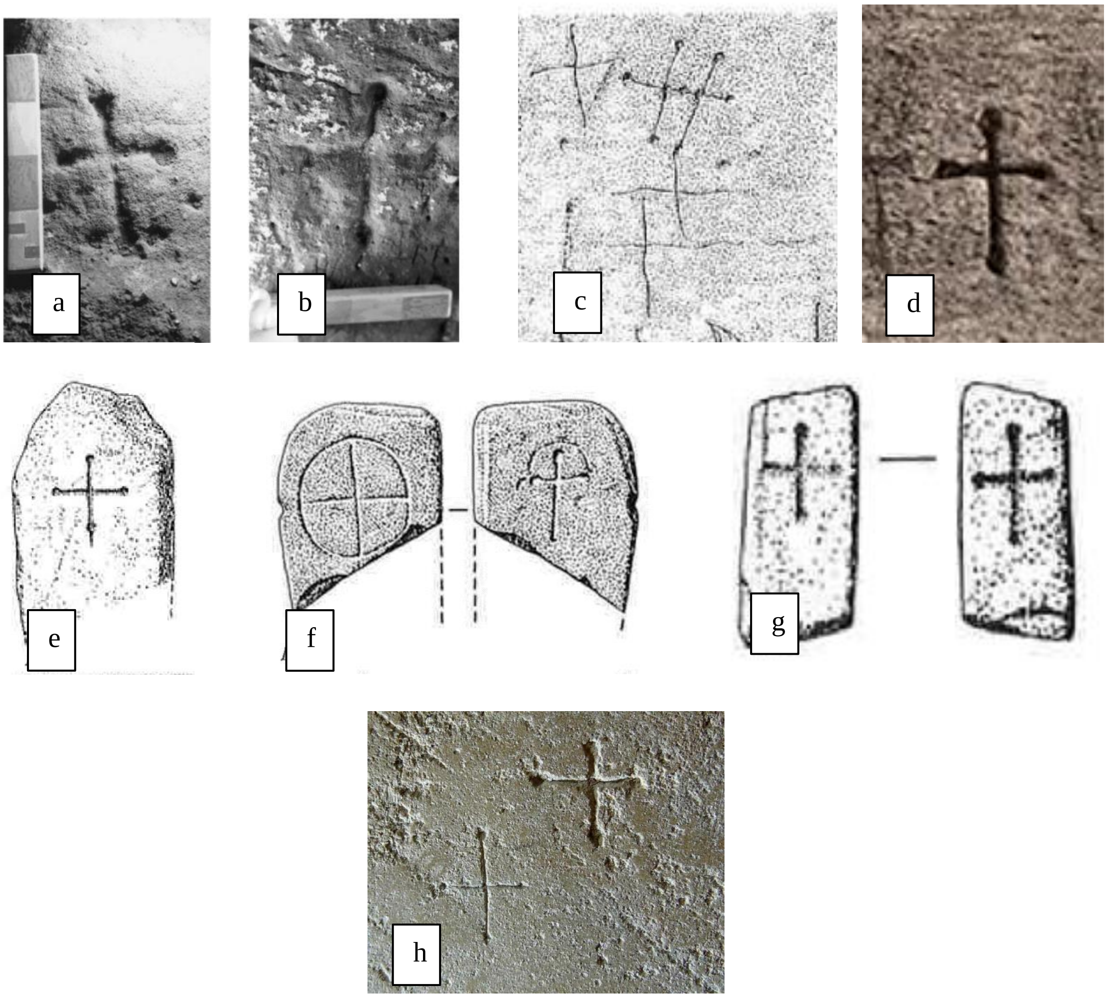


Figure 36. **(a) (b)** cross graffiti in Seljalandshellar (Ahronson, *Into the Ocean*, 177-178); **(c)** cross graffiti in St Molaise cave (Fisher, *Early Medieval Sculpture in the West Highlands and Islands,* 64); **(d)** cross graffiti in Jonathan's Cave. Adopted from Andrew Gibb's illustration. (John Stuart, *The Sculptured Stones of Scotland*, 1867); **(e)** cross slab in Eileach an Naoimh (Fisher, 30); **(f)** cross slab in Monymusk, Aberdeenshire (Fisher, 22); **(g)** cross slab in A' Chill, Canna (Fisher, 96); **(h)** cross graffiti in Church of St Andrew, Scotland (Norfolk Medieval Graffiti Survey, 119)

Additionally, there is one single outline cross on the wall of Fjóshellir (Table 8, cross I). The outline is very shallowly incised. Outline crosses can be found in Scottish papar sites such as Clach an Teampuill, Uidh, Taransay (Fig. 37).[185] However, there are no defining characteristics that can prove that there are links between these two crosses.

[185] Fisher, *Early Medieval Sculpture in the West Highlands and Islands*, 113

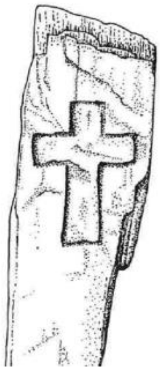


Figure 37. Outline cross, Clach an Teampuill, Uidh (Fisher, 113)

Cross-carving tradition in Insular caves

Cross is a powerful symbol for early Christian monastic communities.[186] Several scholars suggest that the primitive cross marking in the British Isles emerged in the late sixth and seventh centuries and that the relief cross became more popular in the eighth century.[187] The randomly distributed cross graffiti in the previously discussed Pictish natural caves (Fig. 38)—Jonathan's Cave, Constantine's Cave, and the Chapel Cave of Caiplie—in a sense resemble the crosses found in Fjóshellir. Like the crosses in Fjóshellir, for example, crosses in the Chapel Cave of Caiplie (Fig.39) are also found in various degree erosions and of different types. The carvings in the Pictish caves are visually similar to, if not more abundant than, those in the Icelandic caves.

[186] Ahronson, *Into the Ocean*, 158
[187] *Ibid.*, 161

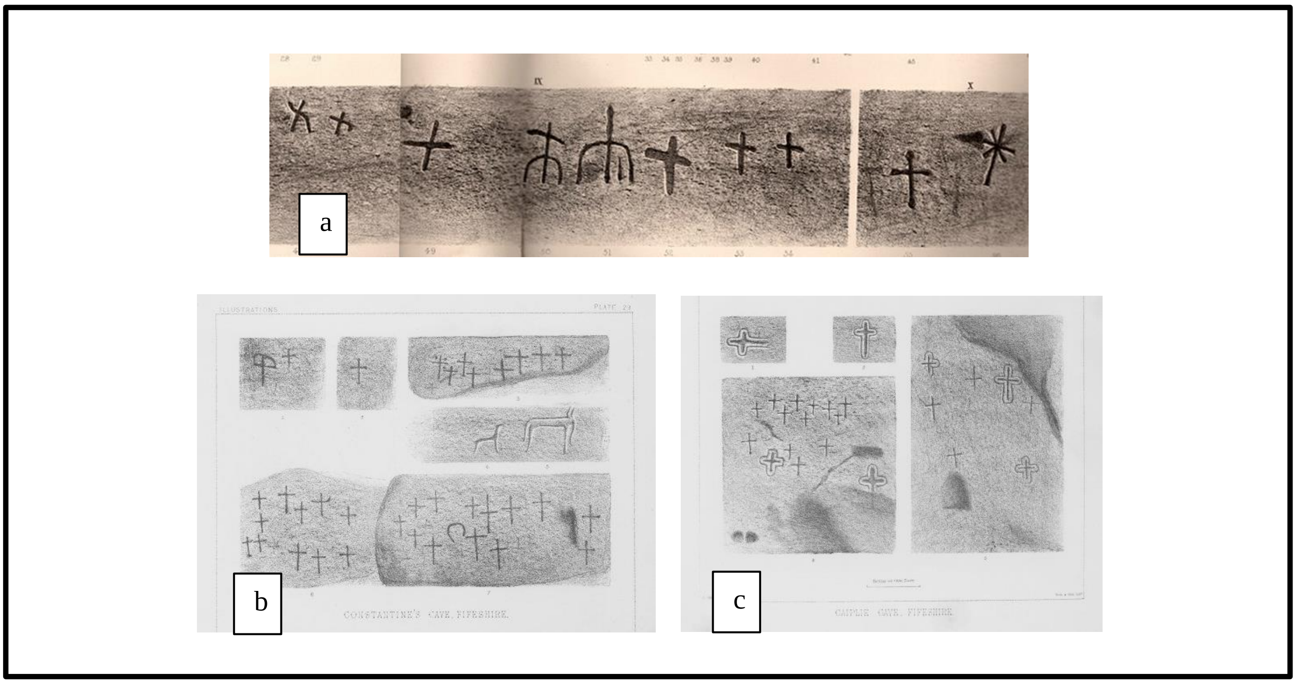


Figure 38. **(a)** Crosses in Jonathan's Cave Adopted from Andrew Gibb's illustration. (John Stuart, *The Sculptured Stones of Scotland*, 1867); **(b)** Crosses in Constantine's Cave (Canmore, http://canmore.org.uk/site/35369); **(c)** Crosses in the Chapel Cave of Caiplie (Canmore, http://canmore.org.uk/site/35369)

Figure 39. Photos of the crosses in and the Chapel Cave of Caiplie, (Historic Environment Scotland, Canmore, https://canmore.org.uk/site/34025/caiplie-the-coves)

The geographical distribution of the circular terminal cross and the similarity between the cross walls of Pictish caves and Fjóshellir indicates that the Columban (papar) monks may be the maker of the caves.[188] The establishment of the Columban school in Scotland starts with Saint Columba's *peregrinatio*, the permanent self-exile in the hope of traveling with Christ ("*pro Christo peregrinari volens*").[189] When Columba got to Scotland, the southwest islands and the Southern Pictland were the two regions of his primary focus of Christianization.[190] In addition to establishing monasteries on the southwest islands, papar monks are seen as the ones who introduced the simple cross motif to Pictland.[191] Moreover, Fisher argues that the circular terminal cross in Monymusk, Aberdeenshire, the northeast edge of the Pictland, is also related to the Columban monasteries.[192] Thus, both the circular terminal cross motif and the utilization of Pictish natural caves might be related to the papar *peregrini*. If both elements are inherently *peregrinatio*-related, then one could naturally come to the conclusion that the Icelandic caves that contain these characteristics are constructed by papar *peregrini*.

Conclusion: Sacred Space and Sacred Cross

If these crosses were indeed made by papar monks, what are the meaning and significance of these graffiti, and why did they make them? In the Middle Ages, cross carvings were used to signify and protect the ecclesiastical land, record one's vow to God, mark one's pilgrimage journey, and sometimes be a result of an act of faith. The somewhat random placement of the crosses in the cave and the variety of cross types indicate that these Icelandic crosses may be a sort of "pilgrim cross." In the Church of the Holy Sepulchre in Jerusalem, there were walls covered in small carved crosses carved by pilgrims who came to the holy city. These crosses attest to the pilgrims' successful journey and record their devotion.[193] Medieval Insular monks are clearly aware of this cult in Jerusalem. Arculf, a pilgrim who visited the Holy

---

[188] For more on Papar see the beginning of Chapter 1

[189] According the Columba's biographer Adomnán. Gougaud, *Christianity in Celtic Lands,* 134

[190] *Ibid*.

[191] Isabel Henderson, "Early Christian monuments of Scotland displaying crosses but no other ornament," (1987) **cited in** Ahronson, *Into the Ocean*, 161

[192] Fisher, *Early Medieval Sculpture in the West Highlands and Islands*, 35

[193] Karen B. Stern, "Carving Graffiti as Devotion." In *Writing on the Wall: Graffiti and the Forgotten Jews of Antiquity*, (Princeton University Press, 2018),36

Land and Constantinople in the 680s, had been to Iona by accident. During his time there, he shared with Adomnán about the cult of the cross, which could have included discussions about the graffiti found there.[194] According to Dicuil, an Irish monk named Fidelsi had been to Jerusalem before 767.[195] It is very likely that the "pilgrim cross" tradition also spread to the British Isles and later to Iceland. Therefore, crosses in Fjóshellir may be carved by multiple *peregrini* as a visual testament of their self-exile journey and an act of devotion.

Moreover, one should also study the relation between the cross and space. The crosses are located in the inner chamber, the area of Fjóshellir which Bergsvik and Down would describe as the "dark zone."[196] It is highly improbable that the inner dark chamber was used as a place of dwelling. As Bergsvik and Dowd point out, "The dark zone is not conducive to habitation because of the need for artificial lighting, low temperatures, and dampness."[197] Instead, the "dark zone" of Fjóshellir is likely preserved for ritual activities. With no natural – and, likely, no artificial—lights, the inner chamber provides a timeless and spaceless zone for the hermits to experience a sense of closeness to God. The idea of retiring to a dark place and experiencing spiritual transformation is found in both medieval Irish folk and Christian traditions.[198] In the early Christian context, darkness might be understood as a state of awaiting the salvation brought by Christ in the "dark, unsavory" world.[199] As Dowd acknowledges, "the recurrence of caves in narratives about the life of Jesus in part reflects the abundance of caves and artificial rock-cut tombs in that part of the world but emphasizes the deliberate symbolic message of bringing light (salvation) to dark (pagan) places"[200] The dark zone therefore

---

[194] He was there due to a due to a shipwreck. Edwards, *The Archaeology of the Early Medieval Celtic Churches,* 163

[195] *Harbison,* Pilgrimage in Iceland 29

[196] Knut Andreas Bergsvik, and Marion Dowd, "Caves and Rockshelters in Medieval Europe: Religious and Secular Use." In *Caves and Ritual in Medieval Europe, AD 500-1500,* edited by Knut Andreas Bergsvik and Marion Dowd, 1st ed., 2. (Oxbow Books, 2018), 2

[197] *Ibid*.

[198] John Carey, "Dark Places and Supernatural Light in Early Ireland," In *The Archaeology of Darkness*, edited by Marion Dowd and Robert Hensey, (Oxbow Books, 2016), 102-3

[199] Dowd, *The Archaeology of Caves in Ireland*, 174

[200] *Ibid*.

becomes the place of becoming, a place where the monks would expect to experience transcendental encounters with the divine.

The position of the crosses in such a private, somehow transcendental space suggests that these crosses must be made for internal, spiritual services. The crosses may be carved out by the *peregrini* as an act of contemplation or a means to develop an intimate relationship with God. The desire to develop an intimate relationship with the divine and enter the sacred realm may relate to the apocalyptic worldview that prevailed in early medieval Britain. As Adomnán wrote in the preface of Vita Columbae, "In these final times of the earth, [Columbia's] name shall be a light to the oceanic island provinces."[201] The oceanic *peregrinatio* and the devotional cross carving may be seen as a response to such belief.

[201] O'Loughlin, *Journeys on the Edges*, 58

Conclusion

Caves, with their seclusion nature, are seen as the gateway to the other world or the dwellings of the divine in many cultures. Monastic use of cave sites is prevalent both in and beyond the early medieval Insular world.[202] My investigation of the visual and environmental clues of Hella caves' origin indicates that seventh to eighth century papar *peregrini* who were from, or might have been to, southeast Scotland may potentially be the makers of the caves. Even though this claim may be too specific to be robust, I hope that the evidence and speculations presented in this thesis can stimulate more discussions about the early medieval British-Icelandic connection.

Multiple pieces of evidence show that the artificial caves in Iceland are indeed somehow related to the early Christians in the northern British Isles. Early medieval literary works reflect the cult of *peregrinatio* in the insular world and that Irish and Scottish *peregrini* have sailed north into the Atlantic in pursuit of a life of religious solitude and austerity. The climatic data indicates that early medieval Iceland may not be as cold as people generally conceived. Similarities are found between the artificial caves in southern Iceland and the Pictish caves with cross graffiti. The shared motif circular terminal cross that has been found on the walls of Fjóshellir may have been carved out as a testament of one's journey abroad, or maybe an act of devotion and prayer in an apocalyptic world. While there is no definite answer to the origin story of the Icelandic caves, it may be safe to argue that these caves at a certain time period have been used by people who were exposed to the Irish and Scottish Peregrinatio culture.

[202] Ahronson and Charles-Edwards, "Prehistoric Annals and Early Medieval Monism," 457

Bibliography

Ahronson, Kristján. *Into the Ocean: Vikings, Irish, and Environmental Change in Iceland and the North*. University of Toronto Press, 2015. https://www.jstor.org/stable/10.3138/j.ctt13x1qtk.

Ahronson, Kristján, and Charles-Edwards, T. M.. "Prehistoric Annals and Early Medieval Monasticism: Daniel Wilson, James Young Simpson and Their Cave Sites." *The Antiquaries Journal* 90 (September 2010): 455–66. https://doi.org/10.1017/S0003581510000028.

Ari Þorgilsson, and Siân Elizabeth Grønlie. *Íslendingabók The Book of the Icelanders. Kristni Saga The Story of the Conversion*. Text Series (Viking Society for Northern Research). London: Viking Society for Northern Research, University College London, 2006.

Bianchi, Giancarlo G., and I. Nicholas McCave. "Holocene Periodicity in North Atlantic Climate and Deep-Ocean Flow South of Iceland." *Nature* 397, no. 6719 (February 1999): 515–17. https://doi.org/10.1038/17362.

Bourke, Cormac. "Early Irish Hand-Bells." *The Journal of the Royal Society of Antiquaries of Ireland* 110 (1980): 52–66.

Brambilla, Elena, and Lynne D. Talley. "Subpolar Mode Water in the Northeastern Atlantic: 1. Averaged Properties and Mean Circulation." *Journal of Geophysical Research: Oceans* 113, no. C4 (2008). https://doi.org/10.1029/2006JC004062.

Castañeda, Isla S., L. Micaela Smith, Gréta Björk Kristjánsdóttir, and John T. Andrews. "Temporal Changes in Holocene δ18O Records from the Northwest and Central North Iceland Shelf." *Journal of Quaternary Science* 19, no. 4 (2004): 321–34. https://doi.org/10.1002/jqs.841.

Caves and Ritual in Medieval Europe, AD 500-1500. 1st ed. Oxbow Books, 2018. https://doi.org/10.2307/j.ctvh1dnwt.

"Constantine's Cave, Fife Ness | Canmore." https://canmore.org.uk/site/35369/constantines-cave-fife-ness.

Crawford, B. E. *The Papar in the North Atlantic: Environment and History: The Proceedings of a Day Conference Held on 24th February 2001*. St. John's House Papers. St. Andrews: University of St. Andrews, Committee for Dark Age Studies, 2002.

Crawford, Harriet E. W., and J. W. Barnes. *Subterranean Britain: Aspects of Underground Archaeology; Contributions by J. W. Barnes [and Others]*. London: John Baker, 1979.

Crowley, Clare. "The Origin of the Curvilinear Plan-Form in Irish Ecclesiastical Sites: A Comparative Analysis of Sites in Ireland, Wales and France," 2009. https://doi.org/10.21427/D7N304.

Cross, Frank Leslie, and Livingstone, Elizabeth A.. *The Oxford Dictionary of the Christian Church*, Oxford: Oxford University Press, 1997.

"Curators of Marine and Lacustrine Geological Samples Consortium. The Index to Marine and Lacustrine Geological Samples (IMLGS). National Geophysical Data Center, NOAA. Doi:10.7289/V5H41PB8," n.d.

Curtin, Lorelei, William J. D'Andrea, Nicholas L. Balascio, Sabrina Shirazi, Beth Shapiro, Gregory A. de Wet, Raymond S. Bradley, and Jostein Bakke. "Sedimentary DNA and Molecular Evidence for Early Human Occupation of the Faroe Islands." *Communications Earth & Environment* 2, no. 1 (December 16, 2021): 1–7. https://doi.org/10.1038/s43247-021-00318-0.

Dicuil. "Liber De Mensura Orbis Terrae.". https://celt.ucc.ie/published/T090000-001.html.

Dietz, Helen. "The Eschatological Dimension of Church Architecture." *Sacred Architecture Journal, The Institute for Sacred Architecture* 10 (2005). https://www.sacredarchitecture.org/articles/the_eschatological_dimension_of_church_architecture.

Dowd, Marion. "Archaeology of the Subterranean World." *Archaeology Ireland* 15, no. 1 (2001): 24–29.

———. *The Archaeology of Caves in Ireland*. Oxbow Books, 2015.

https://www.jstor.org/stable/j.ctt16t8zkc.
Dowd, Marion, and Robert Hensey, eds. *The Archaeology of Darkness*. Oxbow Books, 2016. https://doi.org/10.2307/j.ctvh1dng1.
Easterbrook, Don J. “Geologic Evidence of Recurring Climate Cycles and Their Implications for the Cause of Global Climate Changes—The Past Is the Key to the Future.” In *Evidence-Based Climate Science*, 3–51. Elsevier, 2011. https://doi.org/10.1016/B978-0-12-385956-3.10001-4.
Edwards, Nancy. *The Archaeology of the Early Medieval Celtic Churches: Proceedings of a Conference on the Archaeology of the Early Medieval Celtic Churches, September 2004*. Society for Medieval Archaeology Monograph. Leeds: Maney Publishing, 2009. http://bvbr.bib-bvb.de:8991/F?func=service&doc_library=BVB01&doc_number=019014233&line_number=0001&func_code=DB_RECORDS&service_type=MEDIA.
Filonczuk, Maria K. “Upwelling Southwest of Iceland Due to Quasi-Geostrophic Flow.” *UNITED STATES NAVAL ACADEMY*, 1990.
Fisher, Ian. *Early Medieval Sculpture in the West Highlands and Islands*. Monograph Series (Royal Commission on the Ancient and Historical Monuments of Scotland). Edinburgh: Royal Commission on the Ancient and Historical Monuments of Scotland: Society of Antiquaries of Scotland, 2001.
“Foraminifera - an Overview | ScienceDirect Topics.” https://www.sciencedirect.com/topics/earth-and-planetary-sciences/foraminifera.
Gougaud, Louis. *Christianity in Celtic Lands; a History of the Churches of the Celts, Their Origin, Their Development, Influence, and Mutual Relations*. Translated by Maud Joynt. London: Sheed & Ward, 1932.
Grönvold, Karl, Níels Óskarsson, Sigfús J. Johnsen, Henrik B. Clausen, Claus U. Hammer, Gerard Bond, and Edouard Bard. “Ash Layers from Iceland in the Greenland GRIP Ice Core Correlated with Oceanic and Land Sediments.” *Earth and Planetary Science Letters* 135, no. 1 (October 1, 1995): 149–55. https://doi.org/10.1016/0012-821X(95)00145-3.
Gudmundsson, Hjalti J. “A Review of the Holocene Environmental History of Iceland.” *Quaternary Science Reviews* 16, no. 1 (January 1, 1997): 81–92. https://doi.org/10.1016/S0277-3791(96)00043-1.
Gunnar Karlsson. *The History of Iceland*. Minneapolis, Minn.: University of Minnesota Press, 2000. http://site.ebrary.com/id/10159522.
Harbison, Peter. *Pilgrimage in Ireland: The Monuments and the People*. 1st ed. Irish Studies (Syracuse, N.Y.). Syracuse, N.Y.: Syracuse University Press, 1992.
Helama, Samuli, Phil D Jones, and Keith R Briffa. “Dark Ages Cold Period: A Literature Review and Directions for Future Research.” *The Holocene* 27, no. 10 (October 1, 2017): 1600–1606. https://doi.org/10.1177/0959683617693898.
Hillaire-Marcel, Claude, and Anne de Vernal. “Stable Isotope Clue to Episodic Sea Ice Formation in the Glacial North Atlantic.” *Earth and Planetary Science Letters* 268, no. 1 (April 15, 2008): 143–50. https://doi.org/10.1016/j.epsl.2008.01.012.
Hjartarson, Árni, Guðmundsson, Guðmundur J., and Gísladóttir, Hallgerður. *Manngerðir hellar á Íslandi*. Reykjavík: Bókaútgáfa Menningarsjóðs, 1991. http://www.gbv.de/dms/ub-kiel/043347304.pdf.
Howatt, T. M., and S. E. Allen. “Impact of the Continental Shelf Slope on Upwelling through Submarine Canyons.” *Journal of Geophysical Research: Oceans* 118, no. 10 (2013): 5814–28. https://doi.org/10.1002/jgrc.20401.
Hudson, Benjamin T. *Studies in the Medieval Atlantic*. 1st ed. New Middle Ages (Palgrave Macmillan (Firm)). New York: Palgrave Macmillan, 2012. https://www.loc.gov/catdir/enhancements/fy1609/2012011357-t.html.
Hurrell, James W., and Clara Deser. “North Atlantic Climate Variability: The Role of the North

Atlantic Oscillation." *Journal of Marine Systems*, Impact of climate variability on marine ecosystems: A comparative approach, 79, no. 3 (February 10, 2010): 231–44. https://doi.org/10.1016/j.jmarsys.2009.11.002.

Isolated Islands. NED-New edition, 1. Vol. 14. Central European University Press, 2011. https://www.jstor.org/stable/10.7829/j.ctt2jbn67.

"J. L. Reid, and A. W. Mantyla, World Dataset of Temperature, Salinity, Oxygen, Nutrient Profiles, (1994) Http://Dss.Ucar.Edu/Datasets/Ds543.0/Data/," n.d.

Johnston, Elva. "Exiles from the Edge? The Irish Contexts of Peregrinatio." *The Irish in Early Medieval Europe*, 2016, 38.

Jonkers, Lukas, Geert-Jan A. Brummer, Frank J. C. Peeters, Hendrik M. van Aken, and M. Femke De Jong. "Seasonal Stratification, Shell Flux, and Oxygen Isotope Dynamics of Left-Coiling N. Pachyderma and T. Quinqueloba in the Western Subpolar North Atlantic." *Paleoceanography* 25, no. 2 (2010). https://doi.org/10.1029/2009PA001849.

Jonkers, Lukas, Patricia Jiménez-Amat, P. Graham Mortyn, and Geert-Jan A. Brummer. "Seasonal Mg/Ca Variability of *N. Pachyderma* (s) and *G. Bulloides*: Implications for Seawater Temperature Reconstruction." *Earth and Planetary Science Letters* 376 (August 15, 2013): 137–44. https://doi.org/10.1016/j.epsl.2013.06.019.

Kozdon, R., T. Ushikubo, N. T. Kita, M. Spicuzza, and J. W. Valley. "Intratest Oxygen Isotope Variability in the Planktonic Foraminifer *N. Pachyderma*: Real vs. Apparent Vital Effects by Ion Microprobe." *Chemical Geology* 258, no. 3 (January 30, 2009): 327–37. https://doi.org/10.1016/j.chemgeo.2008.10.032.

Kristjansdottir, Steinunn. *Monastic Iceland*. 1st ed. United Kingdom: Taylor & Francis, 2022. https://doi.org/10.4324/9781003361077.

Lamb, H. H. *Climate, History and the Modern World*. 2nd ed. London ; Routledge, 1995.

"Lamont-Doherty Core Repository (LDCR). 1977: Archive of Geosample Data and Information from the Columbia University Lamont-Doherty Earth Observatory (LDEO) Lamont-Doherty Core Repository (LDCR). NOAA National Centers for Environmental Information. Https://Doi.Org/10.7289/V5M61H7G," n.d.

Lane, C. S., S. P. E. Blockley, J. Mangerud, V. C. Smith, Ø. S. Lohne, E. L. Tomlinson, I. P. Matthews, and A. F. Lotter. "Was the 12.1 Ka Icelandic Vedde Ash One of a Kind?" *Quaternary Science Reviews* 33 (February 6, 2012): 87–99. https://doi.org/10.1016/j.quascirev.2011.11.011.

Leone, Isabella. "The Orientation of the Early Christian and Medieval Churches of Rome: A Statistical Study." *Atti Del XVII Convegno SIA*, January 1, 2017. https://www.academia.edu/45551196/The_orientation_of_the_early_Christian_and_medieval_churches_of_Rome_a_statistical_study.

Lethbridge, Thomas Charles. *Herdsmen & Hermits; Celtic Seafarers in the Northern Seas*. Cambridge: Bowes & Bowes, 1950.

Livsey, Caitlin M., Reinhard Kozdon, Dorothea Bauch, Geert-Jan A. Brummer, Lukas Jonkers, Ian Orland, Tessa M. Hill, and Howard J. Spero. "High-Resolution Mg/Ca and δ18O Patterns in Modern Neogloboquadrina Pachyderma From the Fram Strait and Irminger Sea." *Paleoceanography and Paleoclimatology* 35, no. 9 (2020): e2020PA003969. https://doi.org/10.1029/2020PA003969.

MacKie, Euan W. "Iron Age and Early Historic Occupation of Jonathan's Cave, East Wemyss." *Glasgow Archaeological Journal* 13, no. 1 (January 1, 1986): 74–77. https://doi.org/10.3366/gas.1986.13.13.74.

Mackintosh, Andrew N., Andrew J. Dugmore, and Alun L. Hubbard. "Holocene Climatic Changes in Iceland: Evidence from Modelling Glacier Length Fluctuations at Sólheimajökull." *Quaternary International*, Late Pleistocene and Holocene Investigations in Europe. Internati onal Conference on Past Global Changes (PAGES), 91, no. 1 (May 1, 2002): 39–52.

https://doi.org/10.1016/S1040-6182(01)00101-X.
Marine and Freshwater Research Institute (MFRI), https://sjora.hafro.is/reports/larettar.php?L=B13-2016&T=S
Moffa-Sánchez, Paola, and Ian R. Hall. "North Atlantic Variability and Its Links to European Climate over the Last 3000 Years." *Nature Communications* 8, no. 1 (November 23, 2017): 1726. https://doi.org/10.1038/s41467-017-01884-8.
Moros, Matthias, Eystein Jansen, Delia W Oppo, Jacques Giraudeau, and Antoon Kuijpers. "Reconstruction of the Late-Holocene Changes in the Sub-Arctic Front Position at the Reykjanes Ridge, North Atlantic." *The Holocene* 22, no. 8 (August 1, 2012): 877–86. https://doi.org/10.1177/0959683611434224.
Ni Ghabhlain, Sinead. "Church, Parish and Polity: The Medieval Diocese of Kilfenora, Ireland." Ph.D., University of California, Los Angeles. https://www.proquest.com/docview/304185727/abstract/2337B3A504F64015PQ/1.
Nickell, J. Alexandra. "The Early Churches of Fife : A Gazetteer of Sites." Thesis, University of St Andrews, 2003. https://research-repository.st-andrews.ac.uk/handle/10023/13242.
Northern Studies, The Scottish Society For Northern Studies, vol. 37 (2003)
Norfolk Medieval Graffiti Survey, http://www.medieval-graffiti.co.uk/page119.html.
Ólafsdóttir, Sædís, Anne E. Jennings, Áslaug Geirsdóttir, John Andrews, and Gifford H. Miller. "Holocene Variability of the North Atlantic Irminger Current on the South- and Northwest Shelf of Iceland." *Marine Micropaleontology* 77, no. 3 (December 1, 2010): 101–18. https://doi.org/10.1016/j.marmicro.2010.08.002.
Ólafsson, Haraldur, Markus Furger, and Burghard Brümmer. "The Weather and Climate of Iceland." *Meteorologische Zeitschrift - METEOROL Z* 16 (February 1, 2007): 5–8. https://doi.org/10.1127/0941-2948/2007/0185.
O'Loughlin, Thomas. *Journeys on the Edges: The Celtic Tradition*. Traditions of Christian Spirituality. Maryknoll, N.Y.: Orbis Books, 2000.
Pallacks, Sven, Patrizia Ziveri, Belen Martrat, P. Graham Mortyn, Michael Grelaud, Ralf Schiebel, Alessandro Incarbona, Jordi Garcia-Orellana, and Griselda Anglada-Ortiz. "Planktic Foraminiferal Changes in the Western Mediterranean Anthropocene." *Global and Planetary Change* 204 (September 1, 2021): 103549. https://doi.org/10.1016/j.gloplacha.2021.103549.
Patterson, William P., Kristin A. Dietrich, Chris Holmden, and John T. Andrews. "Two Millennia of North Atlantic Seasonality and Implications for Norse Colonies." *Proceedings of the National Academy of Sciences of the United States of America* 107, no. 12 (March 23, 2010): 5306–10. https://doi.org/10.1073/pnas.0902522107.
Prestel, David. "The Kievan Caves Monastery: What Do Monks Have to Do with the World?" *Russian History* 33, no. 2/4 (2006): 199–216.
Sarah. "Observed Southward Spreading of the Iceland Scotland Overflow Water along the Eastern Flank of the Mid-Atlantic Ridge | OSNAP." https://www.o-snap.org/observed-southward-spreading-of-the-iceland-scotland-overflow-water-along-the-eastern-flank-of-the-mid-atlantic-ridge/.
Saraswati, Pratul Kumar. "Foraminiferal Micropaleontology for Understanding Earth's History," 2021. https://www.sciencedirect.com/topics/earth-and-planetary-sciences/foraminifera.
Schiebel, Ralf, and Christoph Hemleben. *Planktic Foraminifers in the Modern Ocean*. Berlin, Heidelberg: Springer, 2017. https://doi.org/10.1007/978-3-662-50297-6.
Simstich, Johannes, Michael Sarnthein, and Helmut Erlenkeuser. "Paired δ18O Signals of *Neogloboquadrina Pachyderma* (s) and *Turborotalita Quinqueloba* Show Thermal Stratification Structure in Nordic Seas." *Marine Micropaleontology* 48, no. 1 (May 1, 2003): 107–25. https://doi.org/10.1016/S0377-8398(02)00165-2.
Stern, Karen B. "Carving Graffiti as Devotion." In *Writing on the Wall*, 35–79. Graffiti and the Forgotten Jews of Antiquity. Princeton University Press, 2018.

https://www.jstor.org/stable/j.ctt1ztdvrn.8.
Thorarinsson, Sigurdur, T. Einarsson, and G. Kjartansson. "On the Geology and Geomorphology of Iceland." *Geografiska Annaler* 41, no. 2/3 (1959): 135–69.
Thornalley, David J. R., Harry Elderfield, and I. Nick McCave. "Intermediate and Deep Water Paleoceanography of the Northern North Atlantic over the Past 21,000 Years." *Paleoceanography* 25, no. 1 (2010). https://doi.org/10.1029/2009PA001833.
Thornalley, David J. R., I. Nick McCave, and Harry Elderfield. "Tephra in deglacial ocean sediments south of Iceland: Stratigraphy, geochemistry and oceanic reservoir ages." *Journal of Quaternary Science* 26, no. 2 (2011): 190–98. https://doi.org/10.1002/jqs.1442.
Thyr, Nicholas. "Is Iceland Hell? Realism and Reality in the 'Navigatio Sancti Brendani.'" *Proceedings of the Harvard Celtic Colloquium* 38 (2018): 305–24.
Valdimarsson, Héðinn, and Malmberg, Svend-Aage. "Near-Surface Circulation in Icelandic Waters Derived from Satellite Tracked Drifters." *Rit Fiskideildar* 16 (1999): 23–39.
Waelbroeck, C., L. Labeyrie, E. Michel, J. C. Duplessy, J. F. McManus, K. Lambeck, E. Balbon, and M. Labracherie. "Sea-Level and Deep Water Temperature Changes Derived from Benthic Foraminifera Isotopic Records." *Quaternary Science Reviews*, EPILOG, 21, no. 1 (January 1, 2002): 295–305. https://doi.org/10.1016/S0277-3791(01)00101-9.
Wanamaker, Alan D., Paul G. Butler, James D. Scourse, Jan Heinemeier, Jón Eiríksson, Karen Luise Knudsen, and Christopher A. Richardson. "Surface Changes in the North Atlantic Meridional Overturning Circulation during the Last Millennium." *Nature Communications* 3, no. 1 (June 12, 2012): 899. https://doi.org/10.1038/ncomms1901.
Wooding, Jonathan M., ed. *The Otherworld Voyage in Early Irish Literature: An Anthology of Criticism*. Dublin, Ireland: Four Courts Press, 2014.
Wu, Guoping, and Claude Hillaire-Marcel. "Oxygen Isotope Compositions of Sinistral *Neogloboquadrina Pachyderma* Tests in Surface Sediments: North Atlantic Ocean." *Geochimica et Cosmochimica Acta* 58, no. 4 (February 1, 1994): 1303–12. https://doi.org/10.1016/0016-7037(94)90383-2.