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Observation of Volcanic Activity During the A.D. 1610 Voyage of the *Discovery*

by

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INTRODUCTION

Henry Hudson, after exploring the river named after him in A.D. 1609, undertook his final voyage (commonly termed the 4th voyage) to the New World in 1610 in the bark Discovery from the Port of London, for the purpose of finding and charting a northwest passage around the northern end of North America. The voyage was a failure in terms of its main object and was ultimately disastrous. After wintering in James Bay, under near-starvation conditions, mutineers captured the Discovery in June 1611 and marooned Hudson, his son, and six loyal members of the crew, who were never heard of again.[1,2] As a consequence, most of Hudson's records were lost or destroyed, making it difficult to decipher many geographical details of this final voyage.

Enroute to the New World, Hudson and his crew spent the period between May 11 and June 1 (O.S.) along the coast of Iceland, and, according to the surviving account by Abacuk Prickett, who sailed with Hudson, they observed an eruption of Mount Hekla. The primary purpose of this note is to critically evaluate, from a geologist's point of view, Prickett's observation of volcanic activity at Mount Hekla, and to clarify seveal enigmatic points in the geographic description of the Icelandic leg of this voyage. If verified, an event at Mount Hekla in 1610 would be a volcanologically significant addition to the intensively studied chronology of eruptions at Hekla.

SOURCES

The main events of Henry Hudson's fourth voyage are recorded by Samuel Purchas in two accounts--the shorter account, "An Abstract of the Journall of Master Henry Hudson, for the Discoverie of the North-west Passage, begunne the seventeenth of Aprill 1610. ended with

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[1]S.E. Morison, 1971, *The European Discovery of America. The Northern Voyages A.D. 500-1600, 612.* (New York: Oxford University Press, 712 p).

[2]G.M. Asher, *Henry Hudson the navigator: The original documents in which his career is recorded*...(London: The Hakluyt Society, 1860), 122-123. Asher lists seven crew members marooned, besides Hudson and his son.

his end, being treacherously exposed by some of his Companie,"[3] and a somewhat longer account, "A Larger Discourse of the same Voyage, and the successe thereof,"[4] written by "Abacuk Pricket"[5] who survived the voyage and returned to England.

Two other short documents remain from Hudson's fourth voyage. One is "A note found in the deske of Thomas Wydowse ...he being one of them who was put into the shallop."[6] The other is a letter from Iceland written home to England, dated May 30, 1610 (presumably O.S.[7]) which was reprinted by Purchas[8] without the author's name. It has been attibuted to Hudson himself by Asher,[9] but was probably written by Thomas Widhouse ("Wydowse.")[10]

The critical passage describing the voyage to Iceland and beyond is the following, from the beginning of Prickett's "Discourse":[11]

> We began our Voyage for the North-west passage; the seventeenth of April, 1610. Thwart of Shepey, our Master sent Master Colbert backe to the Owners with his Letter. The next day we weighed from hence, and stood for Harwich, and came thither the eight and twentieth of Aprill. From Harwich we set sayle the first of May, along the
> *A.D.* Coast to the North, til we came to the Iles of Orkney, from thence

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[3]Samuel Purchas, *Hakluytus Posthumus, Or Purchas His Pilgrimes* (London: Published by William Stansby for Henrie Fetherstone, 1625; reprint, London: AMS Press, 1965), 3:374-377.

[4]Ibid., 377-379.

[5]Referred to hereafter as Abacuk Prickett (the commonly accepted spelling).

[6]G.M. Asher, 136-138.

[7]Dates used in the historical documents cited here are in the Old Style (O.S.): i.e., the Julian calendar used in England until 1752. For the year 1610, the O.S. dates require a correction of +10 days to derive the equivalent date in the New Style (Gregorian) calendar currently in use.

[8]Purchas, Purchas His Pilgrimes, 1625.

[9]Asher, Hudson the Navigator, p. ccx, 135, 285.

[10]Or Widhouse. See John Parker, "Contents and Sources of the *Pilgrimes*," in *The Purchas Handbook*, ed. L.E. Pennington [in press]. Commenting on the origin of the letter to Master Samuel Machem, L.E. Pennington writes "...Purchas says (MacLehose, XIII, 410) that he has prefixed the note found in the desk of Widhouse with "his letter to Master Samuel Machem." It is not at all clear who "his" refers to. John Parker in his chapter on "Contents and sources of the *Pilgrimes*" prepared for the forthcoming *Purchas Handbook* says (pp.90-91) the letter is by Widhouse, and I tend to agree with him." (L.E. Pennington, letter to J.D. Friedman, May 6, 1994).

[11]From Purchas, *Purchas His Pilgrimes*. Marginal notes are those of Purchas.

1610. to the Iles of Faro, and from thence to Island: on which we
Farre Iles. fell in a fogge, hearing the Rut of the Sea ashoare, but saw
Island. not the Land whereupon our Master came to an Anchor. Heere we were embayed in the South-east part of the Land. Wee weighed and
The South-east part of Island. stood along the Coast, on the West side towards the North: but one day being calme, we fell a fishing, and caught good store of fish, as Cod and Ling, and Butte, with some other sorts that we knew not. The next day, we had a good gale of wind at South-west, and raysed the
Westmonie Island. Iles of Westmonie, where the King of Denmarke hath a Fortresse, by which we passed to rayse the Snow Hill foot, a Mountayne so called on the North-west part of the Land. But in our course we saw that
Mount Hecla casteth out fire. famous Hill, Mount Hecla, which cast out much fire, a signe of foule weather to come in short time. Wee leave Island a sterne of us, and
A mayne of Ice. met a Mayne of Ice, which did hang on the North part of Island, and stretched downe to the West, which when our Master saw, he stood backe for Island to find an Harbour, which we did on the North-west part, called *Derefer, where wee killed good score of Fowle. From
**Or Diraford.* hence wee put to Sea againe, but (neither wind nor weather serving) our Master stood backe for this Harbour againe, but could not reach it, but fell with another to the South of that, called by our Englishmen,
Lousie Bay. Lousie Bay: where on the shoare we found an hot Bath, and heere all
An hot Bath. our Englishmen bathed themselves: the water was so hot that it would scald a Fowle.

The first of June. From hence the first of June we put to Sea for Groneland, but to the West wee saw Land as we thought, for which we beare the best part of a day, but it proved but a foggie banke. So wee gave it over, and made for Gronland, which we raysed the fourth of June.

INTERPRETATION

Of the Icelandic place names (fig. 1) mentioned in the Purchas account, the "Iles of Westmonie" are the Vestmannaeyjar archipelago at about 63°25'N, 21°15'W, the "Snow Hill foot" is Snaefellsjökull volcano at 64°48'N, 23°47'W on the Snaefellsnes Peninsula, "Derefer" ("Diraford" of Purchas) is the fjord Dyrafjörður at 65°50'N to 66° and 23°11' to 23°51'W (fig. 1).[12,13] *Hecla* and *Lousie Bay* are discussed in more detail in this note.

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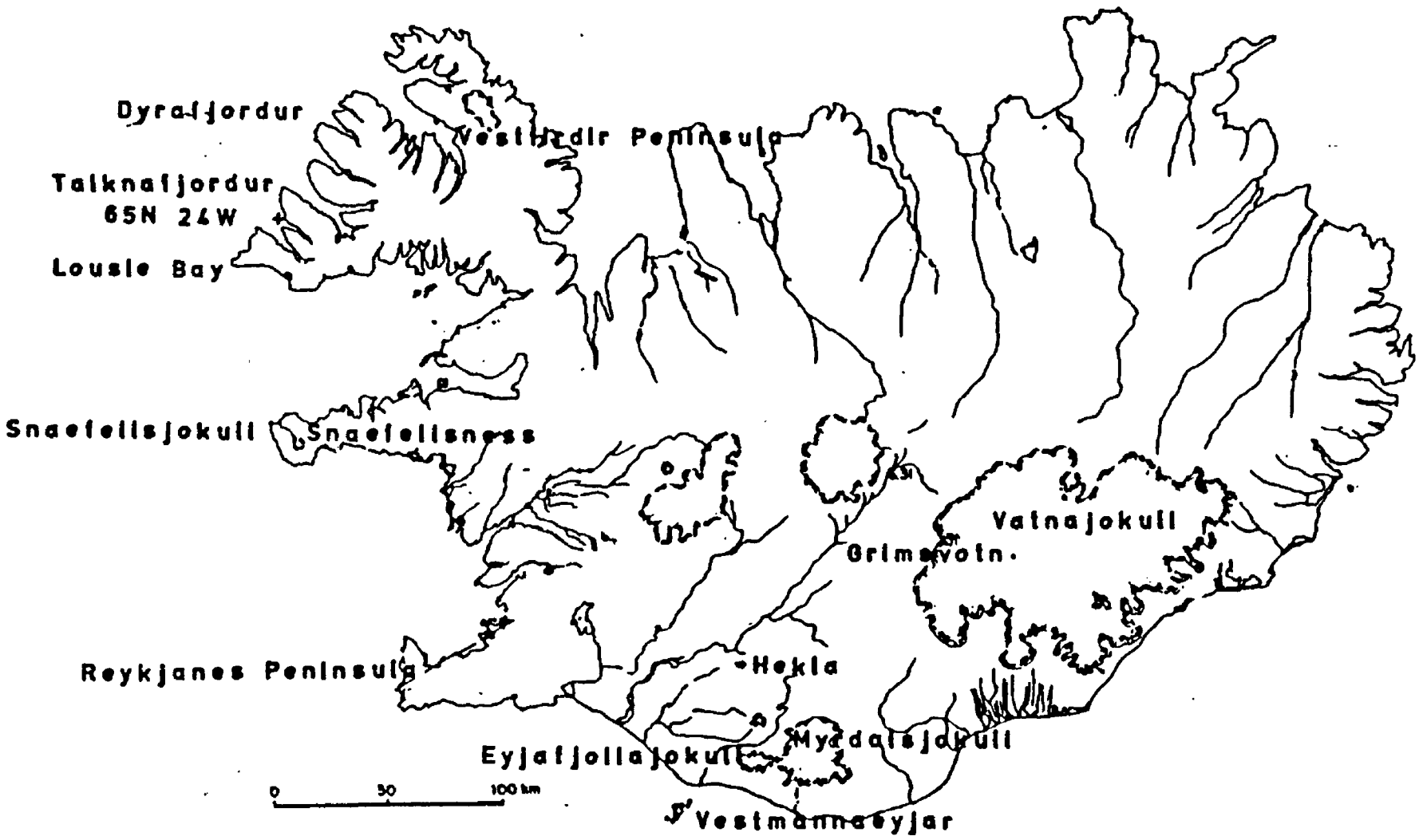
[12]Coordinates given here are based on Guðmundur Kjartansson, *Geological Map of Iceland, Sheet 1, North-west Iceland* (Reykjavík, Central Fund, 1969), scale 1:250,000, drawn by the Icelandic Survey Department and based on *Geodetic Institute Map of Iceland* (Copenhagen). Other sources for latitude and longitude used include the *The Times Atlas of the World*, comprehensive edition (London: The Times, in collaboration with John Bartholomew & Son, Edinburg, 1967) and (Boston: Houghton Mifflin Company, 1967).

[13]Incorrectly given by Asher, *Hudson the Navigator*, 99, as 66°42'N; 24°20'W.



ICELAND

Figure 1. Location and Icelandic place names of features mentioned in the text.

Mount Hekla

"...that famous hill Mount Hecla which cast out much fire, a signe of foule weather to come in short time." How can we interpret this observation, filled as it is with a 17th century seafarer's fears, superstitions, and the search for phenomena believed to portend future weather, yet seemingly straightforward? We consider the following points to be significant:

(1) Prickett's account here appears to be retrospective and deterministic, perhaps to attribute the ultimate disastrous consequences of the voyage to nature or to fate. The account was probably derived from the ship's log or his own journal after the return to England. Asher[14], the leading 19th century scholar on Hudson, suggests that it was evidently written quietly at home.

In the brief "Abstract of the Journall of Master Henry Hudson...," very little material is given on Hudson's observations of Iceland, except for rudimentary navigational facts. Hekla is not mentioned at all. Yet the Widhouse letter home[15] does corroborate some of the Prickett account, e.g., details of the types of "fowle" eaten, the hot springs ("I have seen two hot bathes in Island, and have been in one of them"), and the encounter with the sea ice. Thus, it is incongruous that these observations on Iceland are missing in Purchas's abstract of Hudson's journal, unless they were removed or destroyed by the mutinous crew after Hudson's death to strengthen their own case[16]. Such is the impression given by the Thomas Widhouse[17] note.

(2) As to the Prickett observation itself, it is possible the crew of the Discovery did see an eruption. We assume here that in clear weather, a seafarer was able to see the difference between clouds (even with unusual shapes) and a volcanic eruption cloud.

(3) Although a line-of-sight observation from the starboard side of the vessel from various points between Vestmannaeyjar and the Reykjanes Peninsula would have permitted a view of an eruption cloud or fire fountain from Hekla (64°01'N, 19°35'W) (e.g., see A.S.I. Halland's painting of the 1845 Hekla eruption, as viewed from the Vestmannaeyjar archipelago)[18], it is equally possible that, under favorable conditions, the crew could have

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[14]Asher, *Hudson the Navigator*, XV.

[15]Ibid., 135-136.

[16]D.S. Johnson, *Charting the sea of darkness: The four voyages of Henry Hudson* (Camden, Maine: International Marine [imprint of Tab Books division of McGraw-Hill], 1993, 242 p). Johnson comes to the same conclusion: that the mutineers "...destroyed most of his journal.. [but] left untouched the map Hudson had made of his explorations" (p. 200). "The map drawn by Hudson on his voyage in 1610-1611, survived the mutiny and, on the return of the *Discovery* to England, was sent to Peter Plancius in Holland, where it was engraved and published by Hessel Gerritz" (p. 191).

[17]Asher, *Hudson the Navigator*, 136-138.

[18]Plate preceding page 29 in Sigurđur Thorarinsson, *Hekla, a notorious volcano* (Reykjavík, Almenna Bókafélagiđ, 1970). Original painting on display at National Museum of Iceland, Reykjavík.

seen eruption columns from Eyjafjallajökull volcano (63°38'N, 19°38'W), Katla volcano (63°36'N, 18°59'W) (beneath Myrdalsjökull ice cap), Grímsvötn (64°26'N, 17°20'W) or other volcanic centers beneath Vatnajökull (fig. 1)[19].

(4) Moreover, 17th century nautical charts of northern Europe and Iceland show few details of Iceland's interior, except Hekla, usually mislocated. The best map of Iceland in Hudson's day was that of Bishop Guđbrandúr Thorlákssonof Hólar, drawn before 1585 and published 1590 in *Additamentum IV Theatri Orbis Terrarum* by Ortelius[20] (Plate 1). Thorlákssonʼs map shows a flame-spouting Hekla (Plate 2) with the annotation in Latin "Hekla perpetuis damnata ęstib. et nivib. horrendo boatu lapides evomit" (Hekla, condemned to perpetual fire and ice, belches forth boulders amid horrendous (dreadful) bellowing). It also shows Mydals Iokul (Myrdalsjökull icecap, beneath which the Katla volcanic center is hidden) and Eyafialla Iokul (Eyjfjallajökull icecap which covers another volcanic center west of Myrdalsjökull and near the coast), but it does not clearly distinguish these ice-capped volcanic centers from Hekla and does not identify them as volcanoes. Moreover, these ice-cap glaciers may have been larger in the seventeenth century than they are today.[21] In view of its 1590 publication date, Hudson might have seen the Ortelius maps during his visit to Jodocus Hondius in 1609, before his third voyage.[22] In 1608, Hondius published his 12-sheet Map of the World on Mercator's Projection in Amsterdam (figs. 2 and 3). Almost certainly Hondius had used the earlier Ortelius map set that included the Thorlákssonmap of Iceland or a derivative.[23] Comparison of the Hondius map of 1595 (fig. 2), and even later editions of Hondius, with the Guđbrandur Thorlákssonmap of Iceland reveals the same errors in coastal configuration and other features.

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[19]At latitude 63°30'N., between May 15 and May 17 (O.S.), which was the most likely time of observation of volcanic activity on Hudson's voyage, approximately eighteen hours of daylight would have been available on a cloudless day for observation of a non-incandescent eruption column or cloud and six hours of twilight for observation of an incandescent or illuminated eruption column, cloud, or fire fountains. *Times Atlas of the World*, xxxv.

[20]Harald Sigurđsson, *Kortasaga Íslands frá Lokum 16. Aldar til 1848* (Reykjavík: Bókaútgáfa Menningarsjóđs og Thorajóđvinafélagsins, 1978), plate 1.

[21]"...during the sixteenth and seventeenth centuries the glaciers upon the whole advanced, and some of them were probably near to their maximum in the seventeenth century." Sigurđur Thorarinsson, *The thousand years struggle against ice and fire: two lectures delivered 21 and 26 February, 1952 at Bedford College, London University*: Reykjavík, Bókaútgáfa Menningarsjóđs [Cultural Fund], 1956), p. 14.

[22]Edward Heawood, *Memoir on Map of the World on Mercator's Projection by Jodocus Hondius*, (London: Royal Geographical Society, 1927).

[23]Sigurđsson, p. 263.

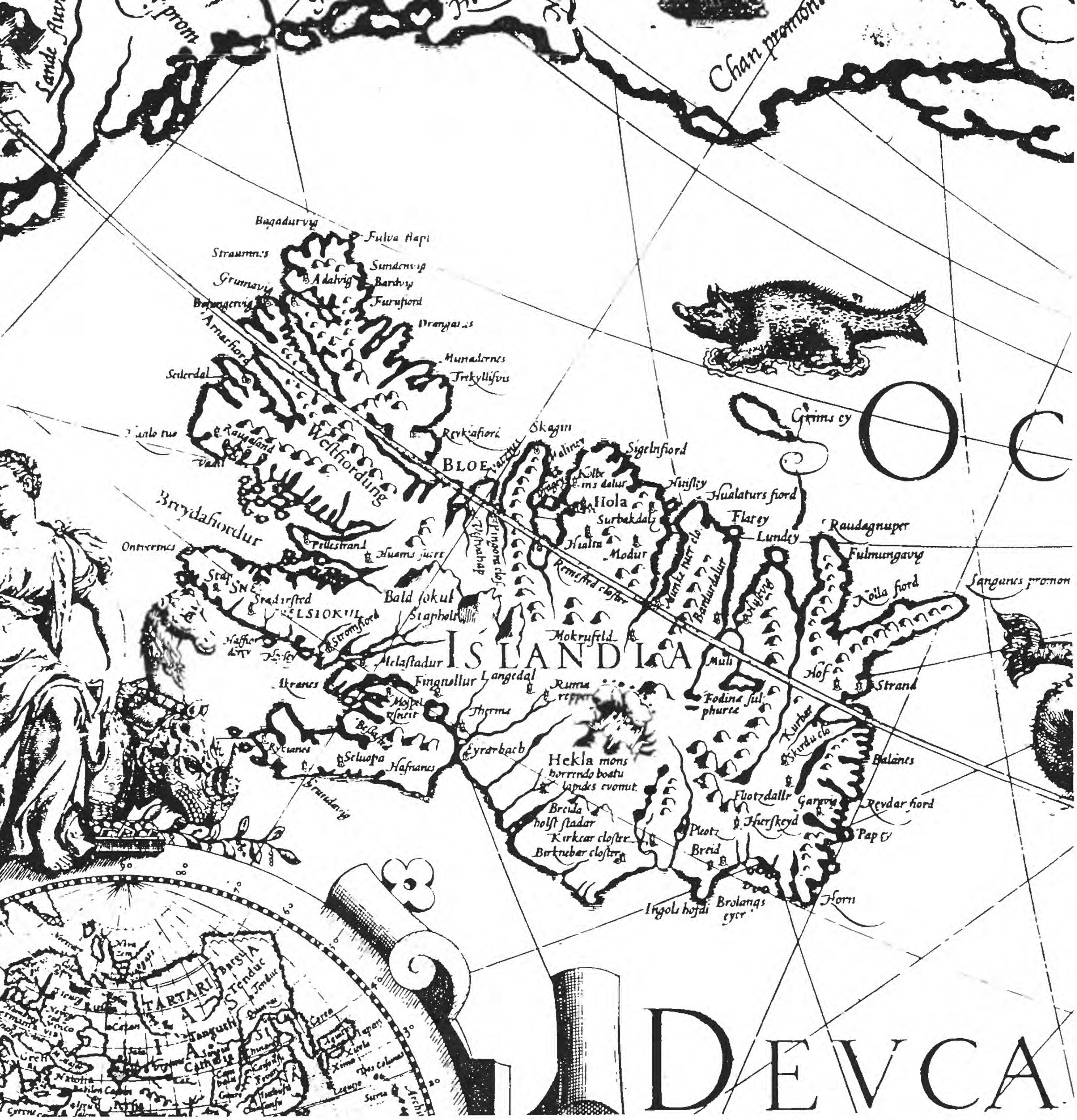

Figure 2. Iceland, as shown on Jacodus Hondius' *Map of the World on Mercator's Projection*, published in 1595.

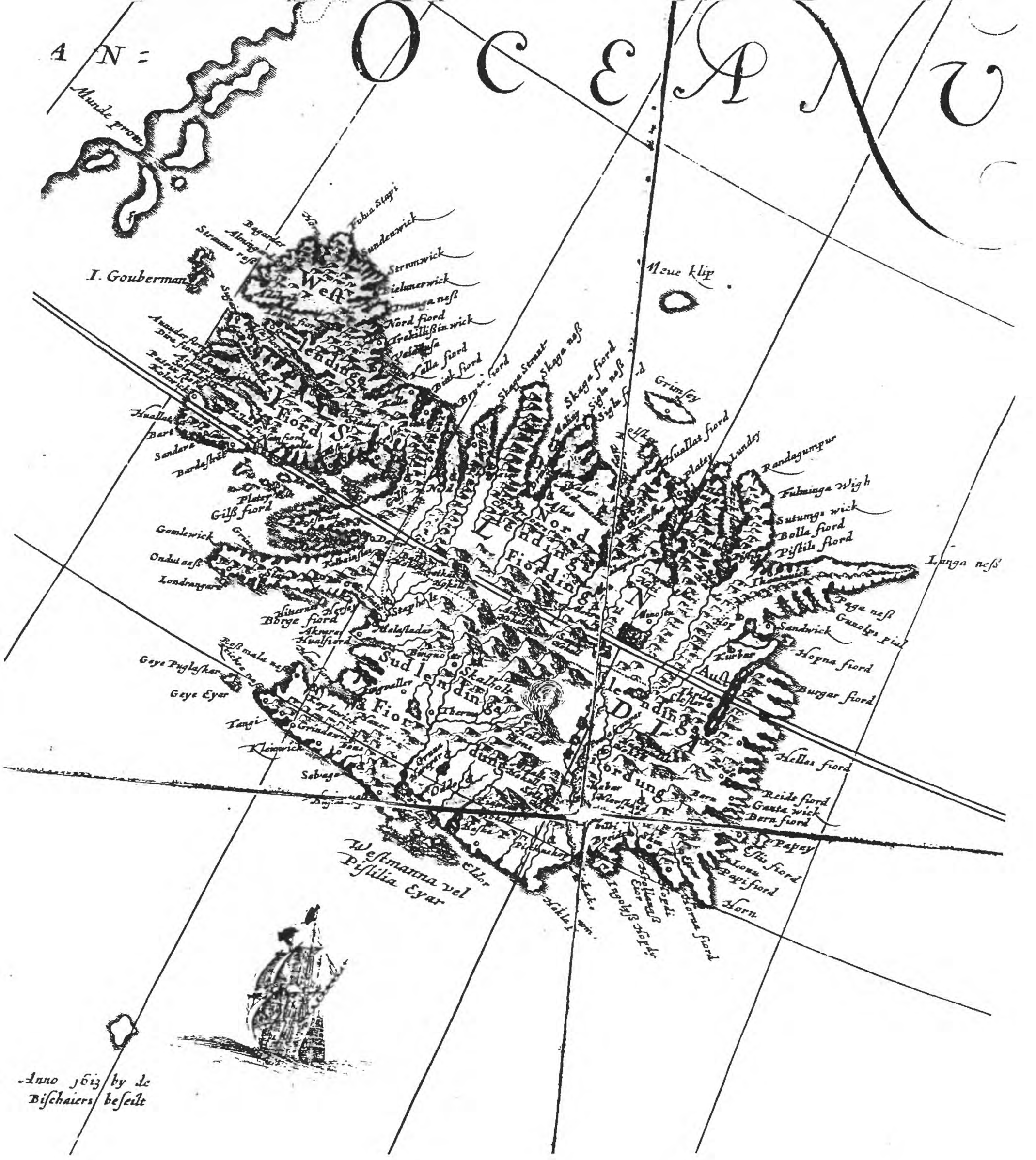

Figure 3. Iceland, as shown on Jacodus Hondius' revision, published after 1613, of his earlier *Map of the World on Mercator's Projection* (cf. fig. 2).

(5) There are other indications that Hudson knew something of Hekla's reputation, but not its exact location. Samuel Purchas quotes Hudson[24] as stating that the Norway-Iceland-Greenland sailing instructions by the 14th century Greenlander Ívar Bárđarson[25] (called by Purchas "Iver Boty") were translated from Low Dutch into English in 1608 "...for the use of me Henrie Hudson." These directions, in a confused way state that "...from Long-nesse on the East side of Island to ... Horn-nesse is two days sayle to the Brimstone Mount." "Long-nesse" is probably the Langanes Peninsula, "Horn-nesse" may refer to Hornafjörđur near Vesturhorn 64°17'N,14°74'W], and the "Brimstone Mount" is Mount Hekla.

(6) The logical inference is that Hudson prepared himself for his voyage(s) with the best available map sources and descriptive writings. At the beginning of the 17th century, though, Hudson, his crew, and any other European mariners whose knowledge of Iceland depended on these map sources and on accounts from English and Dutch fishing and trading expeditions, did not know the exact location of Hekla, nor the existence or location of other volcanoes in Iceland. Lacking an alternative, Prickett or Hudson would have automatically placed any inland eruption at Hekla.

(7) Further, in evaluating the possibility of an eruptive event in the Hekla volcanic system in the year A.D. 1610, it is significant that no chronological reference appears in commonly reliable Icelandic annals, such as those of the Bishop of Skálholt,[26] and that no correlative tephra[27] layer in the soil can be clearly identified lithologically and dated as an A.D. 1610 Hekla (H) layer. The eruption history as given by Thorarinsson records an eruption at Hekla that began in January 1597, lasted six months, and produced a tephra layer. The next eruption at Hekla to produce a tephra layer began in May 1636.

(8) Alternative possibilities for an eruptive event in 1610, however, are not lacking. Tephra records indicate an eruption at Katla, which perforated the Myrdalsjökull icecap in

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[24]Purchas, *Purchas His Pilgrimes*, 13: 163.

[25]See *Det gamle Grønlands Beskrivelse av Ívar Bárđarson* (Copenhagen: Levin and Munksgaard Forlag, 1930).

[26]Sigurđur Thorarinsson, "The eruptions of Hekla in historical times," in *The eruption of Hekla 1947-1948*, ed. T. Einarsson, G. Kjartansson, and S. Thorarinsson (Reykjavík, 1967), 1-170.

[27]"Tephra is a collective term for all airborne pyroclasts produced in a volcanic explosion. Most of the tephra is expanded and fragmented volcanic glass, with variable amounts of crystals, but lithic fragments from older rocks may occasionally constitute a substantial part of a tephra deposit. ...Tephra layers constitute important timeparallel markers or isochrons if they can be recognized with confidence wherever they occur. If their age is known as well, either through written accounts of eruptions or through radiometric dating, they also provide an absolute time scale. Tephrochronology, a dating method based on the identification, correlation and dating of tephra layers, was developed in Iceland during the 1930's and 1940's by the late Sigurđur Thorarinsson. It provides isochrons for multiple use e.g., in geology, biology, glaciology as well as branches outside the natural sciences, such as archaeology, and is now a widely used dating method." From Larsen Guđrun, *Tephra Layers and Tephrochronology: Fifth International Symp. on Water-Rock Interaction* (Reykjavík: International Assoc. of Geochemistry and Cosmochemistry, National Energy Authority, 1986), 51.

1612, and another at the Eyjafjallajökull volcanic center in 1613; but the most likely candidate for the Prickett observation may be an eruption from the Grímsvötn volcanic center, in the Vatnajökull ice cap, which produced an identifiable tephra layer currently dated A.D. 1608. The uncertainty or margin of error attached to this date may be enough to accommodate the difference between A.D. 1608 and 1610.[28]

East Greenland and Polar Sea Ice

On their initial attempt to leave Iceland before putting in at Dyrafjörður, Hudson and his crew were deterred by sea ice. In Prickett's account: "Wee leave Island a sterne of us, and met a Mayne of Ice, which did hang on the North part of Island, and stretched downe to the West, which when our master saw, he stood backe for Island to find an Harbour ..."

"Mayne of Ice" probably refers to the East Greenland or Polar Sea ice. As pointed out by Terence Armstrong,[29] *mayne* (Oxford English Dictionary) is used in the Old English sense of *high seas*, as in the seaward extension in meaning of "the Spanish Main." *Mayne* may also refer to a leading mass of ice, following the derivation of *mayne* from the Old French verb *mener*, to lead[30]. And *mayne* may refer to a force of ice difficult to penetrate (i.e., pack ice[31], or to massive floating ice that is navigable (i.e., drift ice). Prickett's account implies pack ice: it caused a return to Iceland. Curiously, the letter home to Master Machem by Widhouse[32] seems to describe massive drift ice:

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[28]Guðrun Larsen, "Gjóskutímatal Jökuldals og Nágrennis" in *Eldur er í norðri*, ed. H. Thórarinsdóttir, Ó.H. Óskarsson, S. Steinthórsson and Th. Einarsson (Reykjavík: Sögufélag, 1982), 51-65. Also Guðrun Larsen, unpublished data, 1994.

[29]Terence Armstrong (Scott Polar Research Institute, University of Cambridge), letter to Jules D. Friedman, 14 Feb., 1994.

[30]Henry Bradley and W.A. Craigie, *A New English Dictionary on Historical Principles* (London: Henry Frowle, publisher to the University of Oxford, 1908), vol. 6, pt. 1.

[31]Pack ice is "A term used in a broad sense to include any area of sea ice (other than fast ice) regardless of its form or disposition, composed of a heterogeneous mixure of ice of varying sizes and ages, and formed by the jamming or crushing together of pieces of floating ice; the mass may be either loosely or tightly packed but it covers the sea surface with little or no open water." From R L Bates, and J.A. Jackson, *Glossary of Geology*, 3d ed. (Falls Church, Va: American Geological Institute, 1987), 475.

[32]Asher, *Hudson the Navigator*, 135-136. A discrepancy (possibly typographic) in the printed version of the Widhouse letter to Macham can be cleared up here. Widhouse writes "Wee kept our Whitsunday in the *north-east* end of Island..." (emphasis added). Whitsunday in A.D. 1610 (O.S.) was May 27 (Nautical Almanac Offices of the United Kingdom and the United States, *The American Ephemeris and Nautical Almanac and Explanatory Supplement to The Astronomical Ephemeris* {London: H.M. Nautical Almanac Office, 1961]). Because Widhouse refers to the *fowle* eaten (they were obtained

> Wee are resolved to trie the uttermost, and lye onely expecting a faire winde, and to refresh ouselves to avoid the ice, which now is come off the west coasts, of which we have seene whole islands, but God be thanked, have not beene in danger of any. Thus I desire all your prayers for us.
>
> From Island, this thirtieth of May, 1610.

That the expedition was deterred by sea ice so close to the northwest coast of Iceland tells us something significant about the climatic conditions in the year A.D. 1610. The "Mayne of Ice" off the northwest coast of Iceland in mid-June, A.D. 1610 (N.S.), was an indicator of a relatively cool year.[33] The severity of ice conditions and the difficulty of navigation are also aptly noted in the Hudson and Prickett accounts of that part of the voyage in North America not quoted here, particularly in Hudson Bay and James Bay. These accounts give us contemporary observations of sea-ice conditions that were contemporaneous with the climatic cooling (noted especially in northerly latitudes) that occurred after the year A.D. 1550. H.H. Lamb[34] writes that, "After about 1550 the [East Greenland] sea ice increased beyond its previous limits... . After somewhat easier times in the fifteenth and early sixteenth centuries, the sea ice situation near Iceland grew rapidly worse between 1575 and 1600.[35] Bíshop Guđbrandur Thorlákssons map of Iceland (plate 1), drawn before A.D. 1585, depicts massive sea ice off the northeast coast of Iceland during this interval. Variations in the incidence of sea ice at the coast of Iceland since A.D. 870, plotted in twenty-year averages of the number of weeks a year having polar ice at the coast of Iceland, were compiled by Koch[36] from Icelandic records and subsequently extended to 1960[37] (fig. 4). This plot indicates that the 20-year period including the year A.D. 1610 was the seventh or eighth worst 20-year period of sea ice between A.D. 870 and A.D. 1960. In reference to

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at Dyrafjörđur) and the letter is dated May 30, 1610, it is clear that the letter was written from northwest, not northeast Iceland.

[33]Thorarinsson, The Thousand Years Struggle. "...We have a striking correlation between the drift ice [at the coast of Iceland] and temperature graphs... . Drift ice at the coasts of Iceland accordingly means a fall in temperature" (p. 8). "...apparently the drift ice at Iceland is an indicator not merely of the climate of that country but of the climate of the North Atlantic as a whole and the countries bordering upon it" (p. 9).

[34]H.H. Lamb, *Climate: Present, past and future*, vol. 2 of *Climate: Present, Past and Future* (London: Methuen & Co., 1977), 10.

[35]Ibid., 653.

[36]Lauge Koch, "The East Greenland Ice," *Meddelelser om Grønland* 130 (1945): 202, 254, 258. An extensive discussion of the history and geography of the East Greenland ice over the last milennium.

[37]Lamb, *Climatic History and the Future*, 452.

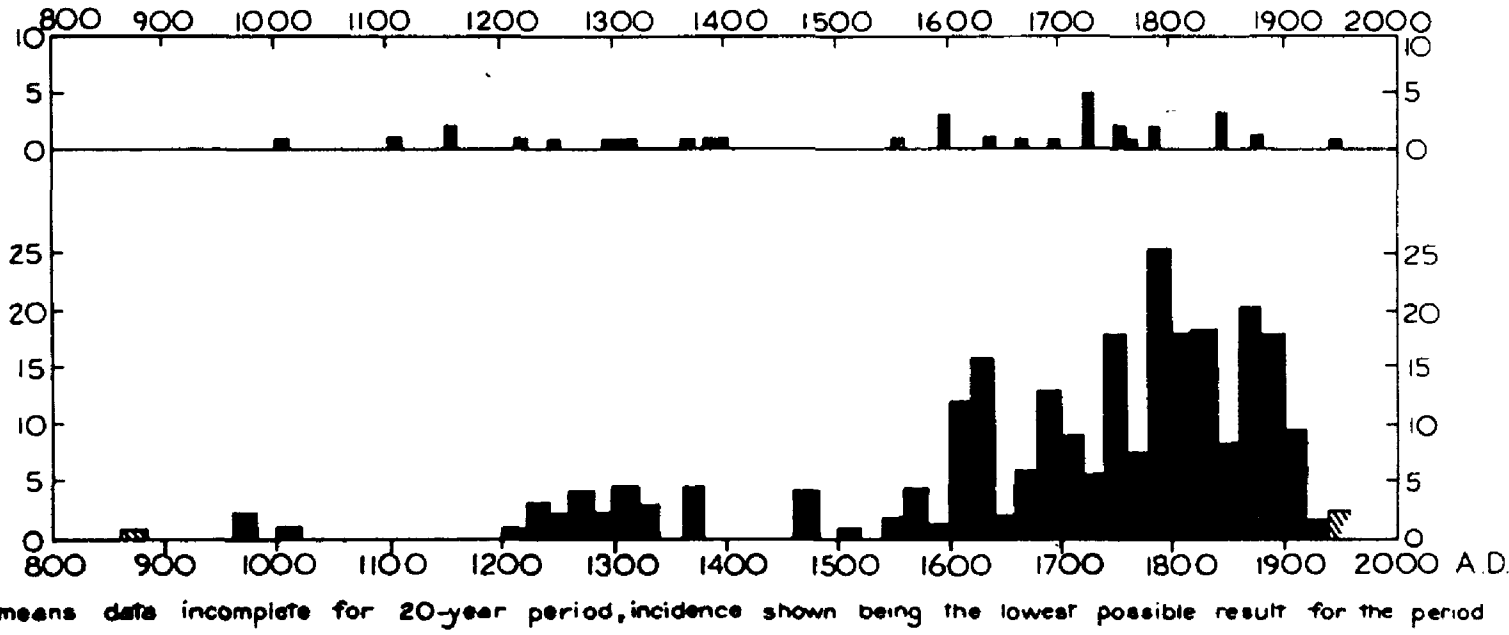

Figure 4. Great volcanic eruptions in Iceland and incidence of Arctic sea ice in that area since A.D. 870. From H.H. Lamb, 1972, *Climate: Present, Past and Future*, v. 1, *Fundamentals and Climate Now*. Sea-ice data from L. Koch, 1945, "The East Greenland Ice," *Meddelelser om Grønland* 130, no. 3.

the East Greenland sea ice, conditions continued to deteriorate and A.D. 1695 was the worst of the 17th century[38].

It is perhaps more than coincidental that this worst ice year of the 17th century followed major eruptions of Hekla in A.D. 1693 and Komaga-Take, Japan in A.D. 1694. Many large explosive volcanic eruptions inject sulfate ions and aerosols (particulates) into the upper atmosphere, where they may reflect or absorb part of the incoming solar radiation and temporarily lower global temperature. Because lower prevailing temperatures (fig. 5) seem to correlate, at least partly, with an increased incidence of sea ice off the coast of Iceland, high-sulfur eruptions could be said to cause an increase in sea ice. In Greenland ice-core chronology, decadal sequences of annual ice layers that contain sulfate ions and that are correlative with years of Icelandic volcanic eruptions show a partial correlation with intense pack ice decades (fig. 4).

High sulfur loading of the atmosphere probably resulted from multiple eruptions in the late 1500's and first decade of the 1600's that included large eruptions at Colima, Mexico in 1585, Kelut, Java in 1586, Hekla, Iceland in 1597, and Huaynaputina, Peru in 1600 (all except Hekla, 1597, are represented in the GISP-2 ice core)[39]. These events might well have accentuated the downturn in prevailing temperatures near the end of the 16th century (fig. 5), part which continued through the time of Hudson's voyage in the early 17th century.[40]

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[38]Koch, "The East Greenland Ice."

[39]G.A. Zielinski et al, "Record of volcanism since 7000 B.C. from the GISP2 Greenland ice core and implications for the volcano--climate system," *Science* 264 (1994): 950, 951.

[40]T.J. Crowley, T.A. Criste, and N.R. Smith, "Reassessment of Crete (Greenland) ice core acidity/volcanism link to climate change," *Geophysical Research Letters* 20, (1993) 211. "Although the volcano-climate correlation on decadal time scales has been weakened, our results provide some support for a correspondence between the strongest [sulfur-producing volcanic] events... and annual-scale temperature departures estimated from tree-ring studies." "The coldest temperatures since 1600 occur in 1601 in the western United States... 1601 is the second coldest year in Fennoscandia". 1601 correlates with the acidity peak linked to Huaynaputina (1600). See also K.R. Briffa, P.D. Jones, and F.H. Schweingruber, "Tree-ring density reconstructions of summer temperature patterns across western North America since 1600," *Journal of Climate* 5 (1992) 746, 747; L.G. Thompson, E. Mosely-Thompson, W. Dansgaard, and P.M. Grootes, "The little ice age recorded in the stratigraphy of the tropical Quelcaya ice cap," *Science* 234 (1986) 361-364; and L.A. Scuderi, "Tree-ring evidence for climatically effective volcanic eruptions, "*Quaternary Research* 34 (1990) 67-85.

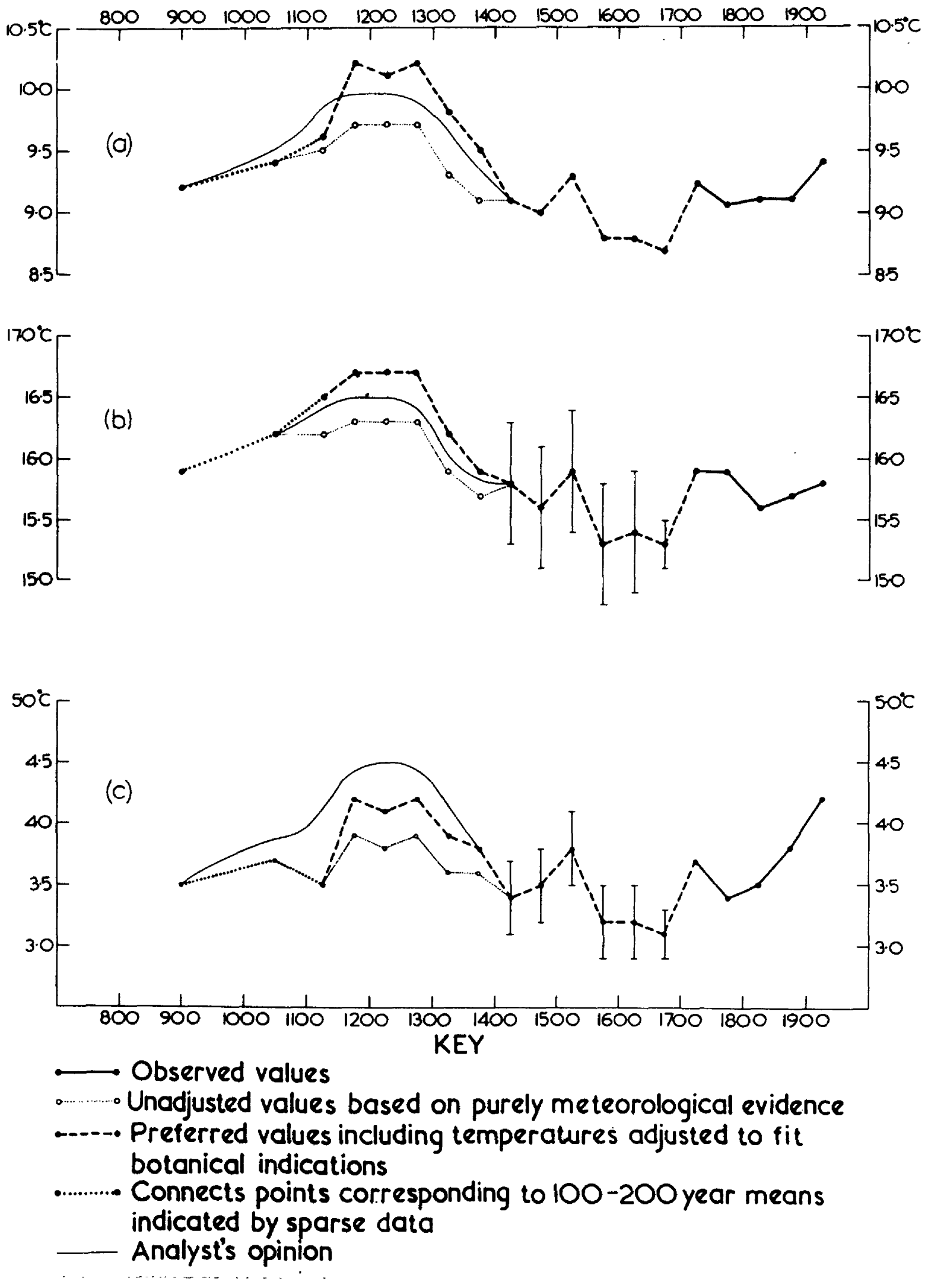

Figure 5. Temperatures (°C) prevailing in central England, 50-year averages: (a) year-round, (b) high summer (July and August), (c) winter (December, January, and February). From H.H. Lamb, 1972, *Climate: Present, Past and Future*, v. 1, *Fundamentals and Climate Now*.

Point of Departure from Iceland

Hudson's point of departure from Iceland on June 1, 1610 (O.S.), has hitherto been uncertain. Asher[41] states, without explanation or confirmatory information, that Prickett's "Lousie Bay" is synonymous with "Breyde Fiord (mostly called Brede Bay on English maps), a large bay on the west coast of Iceland, where some hot springs rise from the bottom of the sea (65°20'N, 23°W)." Asher's coordinates indicate a point a few kilometers southwest of the island Flatey in Breiđafjörđur. Flatey has an anchorage of eight to nine fathoms, but is open to winds from the northwest[42], which had driven Hudson farther south to seek a safe harbor when he could not return to Dyrafjörđur. Several hot springs emanate from the sea floor in this general region, but, on analysis, this identification of *Lousie Bay* is not entirely compatible with the Prickett and Hudson accounts.

From textual analysis of the Hudson and Prickett accounts and an estimate of the *Discovery's* rate of sailing on this voyage, we have six criteria defining the harbor from which Hudson departed Iceland. Prickett's account states (1) that it was "called by our Englishmen, Lousie Bay"; (2) that it was "to the south of" Derefer; and (3) that "on the shoare we found an hot bath" in which "the water was so hot that it would scald a Fowle." Hudson's account states (4) that the departure was from a harbor in "the westernmost part" of Iceland, and (5) that they reached latitude 66°34'N the first day out. (6) On the basis of sailing rates between other points on this voyage, we estimate their daily rate of sailing at approximately 90 statute miles a day, similar to the average distance covered by 16th century ships of approximately 3 to 4 miles per hour, or 84 nautical miles a day, as estimated by Johnson[43].

Although the place name *Lousie Bay* (or its variants) does not occur in a list of Icelandic place names from the oldest extant books of sailing directions and oldest nautical charts (1561, 1568, 1583, 1590)[44], the place names "Luis Bay" or "Lus Bay" are used for two places on Iceland's northwest peninsula on Dutch sea charts from the latter half of the 17th and 18th centuries[45].

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[41]Asher, *Hudson the Navigator*, 99.

[42]*Iceland*, Geographical handbook series, B.R. 504 (Cambridge: Great Britain Naval Intelligence Division, 1942).

[43]Johnson, *Charting the Sea of Darkness*.

[44]J. Keuning, "XVIth century cartography in the Netherlands" *Imago Mundi* 9, (1952): 57-58; J.I. Arnold, *Bibliographie de l'oeuvre de Lucas Jansz Waghenaer, Gent 1880-1890* (Amsterdam: 1061); C. Koeman, "Lucas Janszoon Waghenaer: A Sixteenth Century Marine Cartographer," *Geographical Journal* 131 (1965): 202-217; Sigurđsson, Kortsaga Íslands, 255.

[45]Published by Johannes van Keulen, 1684; Cornelius Gisbert Zorgdroger, 1720; Gerard van Keulen, 1727; C. van Tol, Nieuwe Paskaqart van Hitland tot Ysland, c. 1749; Jan de Vos van Zierikzee, 1761 (Bibliothek der Rijksuniversitet, Leiden).

Johannes van Keulen (1684) and Gerard van Keulen (1727) show "Lus Bay" north of the fjords Isafjörđur and Jökulsfirđir at about 66°25'N, hence north rather than south of Dyrafjörđur, and thus inconsistent with the Prickett account. Jan de Vos van Zierikzee (1761), shows "Luis Bay" or "Luiz Bay" as a fjord at 66°00'N, just north of Patreksfjörđur, south of Dyrafjörđur and closer to the westernmost tip of Iceland. Of the two locations, the second one fits the modern cartographic position of the fjord Talknafjörđur [at about 65°40'N, 24°W], and is the more consistent with both the Prickett and Hudson accounts. Further, there are hot springs *on the shore* at Talknafjörđur, e.g., at Stori Laugardalur five kilometers northwest of Sveinseyri [65°38'N, 23°49'W] and also at Sveinseyri, where anchorage depths are seven to twelve fathoms[46] and a sand spit forms a natural harbor. The highest temperature of the hot springs at Talknafjörđur is now 54°C or ~ 129°F -- not quite scalding, but the temperature of these springs might have declined since 1610, or Prickett might have been engaging in hyperbole. Sailing northwest from Talknafjörđur, the *Discovery* easily could have reached 66°34'N the first day out. Asher's identification of "Lousie Bay" as Breiđafjörđur is inconsistent, more or less, with three points: (1) the Dutch sea chart locations for "Luis Bay," (2) the Prickett statement that the *hot bath* was "on the Shoare," and (3) Hudson's account that the departure was from a harbor in "the westernmost part of Iceland".

Consequently, we suggest here an alternate interpretation that "Lousie Bay," Hudson's point of departure from Iceland on June 1, 1610 (O.S.), was Talknafjörđur.

CONCLUSIONS

A critical evaluation of the 17th century publications of Samuel Purchas in relation to Abacuk Prickett's and Henry Hudson's observations made along the coast of Iceland during Hudson's fourth voyage between May 11 and June 1, A.D. 1610 (O.S.), permits a reassessment of several points previously unchallenged.

The observation of an eruption at Hekla volcano reported by Abacuk Prickett is open to serious question. The lack of corroborative tephra and written records of an event at Hekla in A.D. 1610, and the lack of good 16th and 17th century cartographic information on the existence and location of other Icelandic volcanoes suggest that the Prickett account is in error. An eruption in A.D. 1610 at Grímsvötn or possibly Katla or Eyfjallajökull volcanic centers remains possible, based on dated tephra layers in the soil.

Hudson's encounter with a "Mayne of Ice" off Iceland's northwest peninsula at the end of May 1610 (O.S.) provides us with a heretofore little-noted contemporary and corroborative account of the incidence of the East Greenland and Polar Sea Ice along the coast of Iceland during a period of declining temperatures in northerly latitudes that reflected the climatic cooling of the late 16th and entire 17th centuries. We thus have another indication of and

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[46]*Iceland*, Geographical Handbook series.

explanation for the severity of ice and temperature conditions Hudson encountered in the remainder of his last voyage.

A reassessment of cartographic information on Iceland from the 17th centuries through the present and a reconciliation of map data with the written accounts of Prickett and Hudson suggest an alternate point of departure from Iceland on June 1, A.D. 1610 (O.S.), different from that indicated by Asher in 1860. The "Lousie Bay" locality may actually be Talknafjörđur rather than Breiđafjörđur. Moreover, many of Asher's[47] coordinates for localities in Iceland (e.g., Dyrafjörđur) are in error.

Finally, a critical, comparative reading of the fragments of the documents remaining from Hudson's fourth voyage, in conjunction with map analysis, permits a reconstruction of the chronology (Table 1) of the first part of the fourth voyage from 17 April through 5 June, 1610 (O.S.).

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Although our note is relatively brief, many specialists expressed interest in this project and contributed useful suggestions on source materials in Europe, Iceland, and the United States. We especially wish to acknowledge Loren E. Pennington, Emporia State University, Emporia, Kansas, for his patient help with the Purchas publications and his constructive review comments. Terence Armstrong, Scott Polar Research Institute kindly provided his insight on 17th century terms referring to sea ice. Greg Zielinski, Arctic Research Group, University of New Hampshire, and Ellen Mosely-Thompson, Ohio State University, provided data on volcanic aerosol content and chronology of the early 1600's in Greenland and Antarctic ice cores. M. Susan Powers, U.S. Geological Survey; Barbara McCorkle and Margit Kaye, Yale University; and Lucy B. Burgess, Cornell University, were particularly helpful in obtaining 16th and 17th century maps and atlases for our analysis. We are also indebted to Rev. James W. Skehan, J.S., Weston Observatory, Boston College, who translated the medieval Latin annotation referring to Hekla Volcano on the Map of Iceland by Bishop Guđbrandur Thorlákkson. Donald B. Hoover and Todd K. Hinkley, both U.S. Geological Survey, improved the manuscript with constructive reviews. And we thank our colleagues Guđmundur Pálmason, National Energy Authority of Iceland, and Guđmundur Sigvaldason, Nordic Volcanological Institute, for encouraging us to collaborate on this note.

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[47]Asher, *Hudson the Navigator*.

Table 1. Reconstructed chronology of the first part of Hudson's fourth voyage, April 17 to June 5, 1610 (O.S.).

DATE (OLD STYLE)	LOCATION OR EVENT	LATITUDE	DATA SOURCE
April 17, 1610	Began voyage at Saint Katherine's pool near Tower of London (at location of St. Katherine's dock, 1860) to "Blackewall" (Blackwall Tunnel) on the Thames.	(51°30'18"N)[b]	1,2,4
April 21*	Probable day Henry Greene boarded the Discovery at Gravesend, Kent.	(51°27'N[b] 0°24'E)	2,5
April 22	Coleburne "put into a pinke bound for London" near Sheppey Island, Kent, in the road of Lee, on the Thames.	(51°25'N[b] 0°50'E)	1,2,4
April 23	Sailed from Sheppey Island, Kent, bound for Harwich, Essex.	(51°25'N)[b]	2
April 28	Put in at Harwich, Essex.	(51°57'N)[b]	1,2
May 1	Sailed from Harwich.		2
May 2 (Evening)	Off Flamborough Head, Yorkshire.	(54°06'N)[b]	2
May 5	Sighted Orkney Islands.		1
May 6	Off the north end of Orkney Islands. Variable compass set for 0° magnetic declination.	59°22'N[a] (59°24'N)[b]	1,2
May 8	Faroe Islands sighted.	62°24'N[a]	1,2
May 11	Anchored off southeastern Iceland in a fog, perhaps near Lónsvik bay,[6] then sailed westward.	(64°20'N±)[b]	1,2,5
May 14	Becalmed, perhaps somewhere south of the cape Ingólshofđi. Fishing: caught cod, ling, and halibut.	(63°40'N±)[b]	2,5
May 15	Raised Vestmannaeyjar archipelago. Probably off Heimaey, "...where the King of Denmarke hath a fortress."	(63°25'N)[b]	1,2
May 15-17*	Probable dates of sighting volcanic eruption, attributed to Hekla volcano by Prickett.	(63°30'N±)[b]	1,5
May 17*	Off Reykjanes	(63°51'N)[b]	5
May 18*	Off Snaefellsnes	(64°48'N)[b]	5
May 19*	Off Northwest Peninsula		5

May 20*	First departure from Iceland bound for Greenland. Met "Mayne of Ice" (East Greenland and Polar Sea ice) off the coast of Iceland.	(North of 65°30'N)[b]	1,2,5
May 21*	Returned to Iceland. Put in at Dyrafjörđur. Killed "fowle" (partridge, plover, curlew, teal, mallard and geese).	(65°50' to 66°N)[b]	2,3,4,5
May 23-24*	Second departure from Iceland (from Dyrafjörđur).	(65°50' to 66°N)[b]	2,5
May 25-26*	Returned to Iceland again because of contrary winds and weather. Attempted to reach Dyrafjörđur but were driven south to *Lousie Bay* (Talknafjörđur).	(65°40'N)[b]	1,2,5
May 27	Whitsunday. Found "on the shoare... an hot bath" (Hot springs, possibly at Stori Laugardalur or Sveinseyri).	(65°40'N)[b]	3,4,5
May 30	Widhouse' letter home to England. Probably from Talknafjörđur[7].	(65°40'N?)[b]	3,4
June 1	Third departure from Iceland (from Talknafjörđur), bound for Greenland.	Reached 66°34'N[a]	1,2
June 2		65°57'N[a]	1
June 3	"...we sayled neere some ice."	65°30'N[a]	1
June 4	"...we saw Groneland over the ice perfectly."	65°N[a]	1
June 5	"...we were in 65° still encombred with much ice, which hung upon the coast of Groneland." (Hudson seems to be referring here to fast ice[8] along the East Greenland coast.)	65°N[a]	1

[1] Purchas, *Purchas His Pilgrimes*, 1627, abstract from Hudson's journal
[2] Ibid., Abacuk Prickett's account.
[3] Ibid., Widhouse letter to Master Machem.
[4] Asher, *Henry Hudson the Navigator*.
[5] This paper.
[6] Of the four days between the landfall at eastern Iceland [May 11 (O.S.)] and sighting Heimaey in the Vestmanaeyjar archipelago [May 15 (O.S.], if one day was spent anchored in a fog and one day fishing (perhaps south of Ingólshofði), the remaining two days sailing time would have been adequate for the sea route between Lónsvik and Heimaey. Lónsvik bay, between two prominent headlands, Austurhorn and Vesturhorn, is a good candidate for Hudson's landfall at eastern Iceland.
[7]Having concluded that Breiðafjörður was the correct location for *Lousie Bay*, Asher (*Hudson the Navigator*, ccx) also concluded that Hudson rather than Widhouse wrote the letter to Master Machem from Breiðafjörður. We have found no evidence to support this conclusion.
[8]"...sea ice that forms along and remains attached to the coast... . Fast ice may form in situ from seawater or by freezing of pack ice to the shore. It may extend a few meters to several hundred kilometers from the coast." (Bates and Jackson, *Glossary of Geology*. 235). The East-Greenland coast between 65° and 67°N was during the 17th and 18th centuries, "more persistently ice bound than any other part of the Arctic regions" (Edward Heawood, *A history of Geographical discovery in the seventeenth and eighteenth centuries* (Cambridge: Cambridge University Press, 1912, reprinted Octagon Books, 1965).
[a] Hudson's latitude.
[b] Our estimated latitude.
[*] Estimated date not controlled by documented source (maximum error = ±4 days; probable error = ±2 days).

Plate 1*A*. Left half of Guðbrandur Thorlákssons's map of Iceland drawn before 1585 and originally published in 1590 in *Additamentum IV Theatri Orbis Terrarum*, by A. Ortelius.

Plate 1*B*. Right half of Guðbrandur Thorláksson's map of Iceland drawn before 1585 and originally published in 1590 in *Additamentum IV Theatri Orbis Terrarum*, by A. Ortelius.

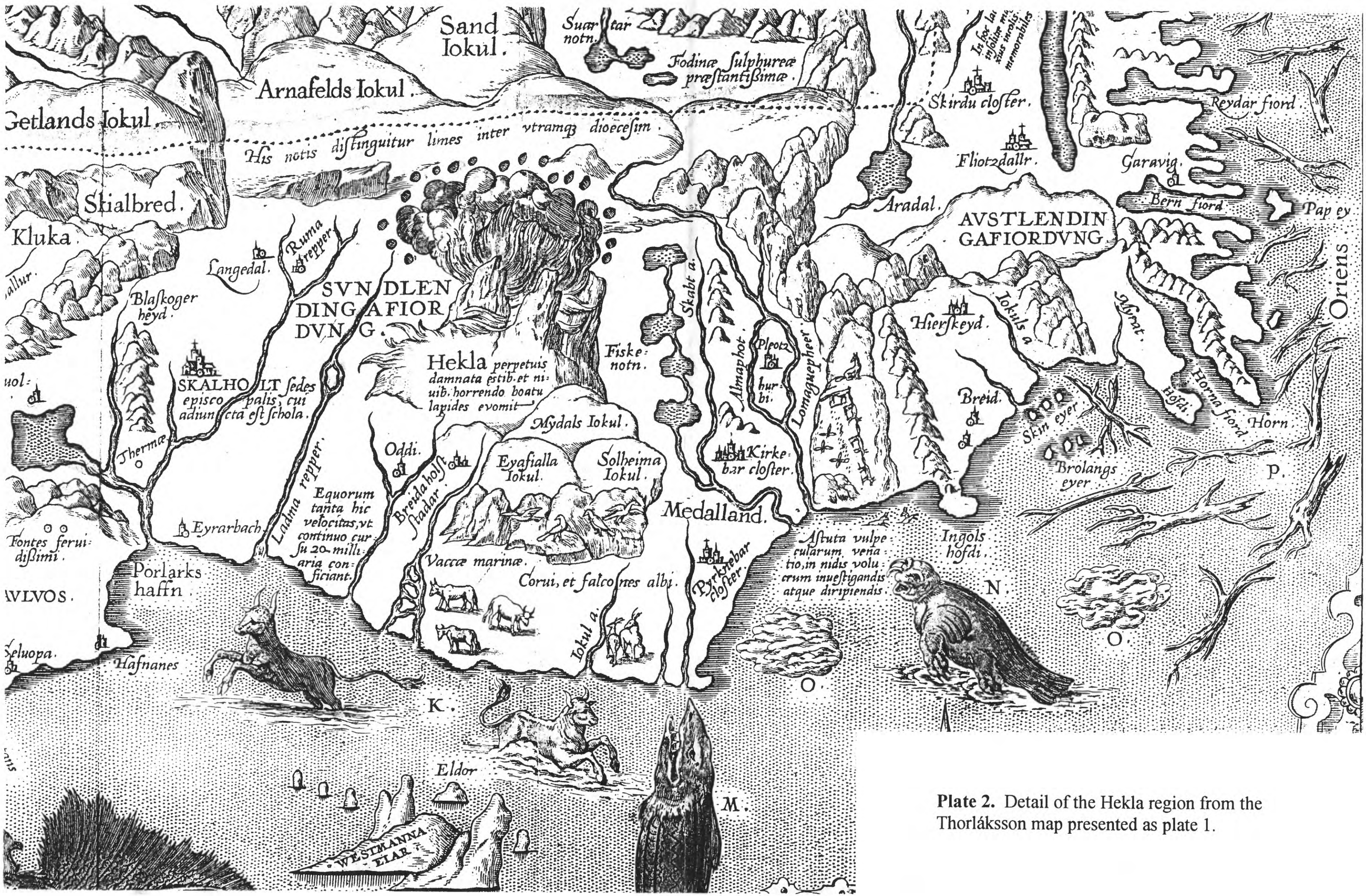

Plate 2. Detail of the Hekla region from the Thorlákssson map presented as plate 1.