5 Conclusions: A Modern Perspective on the Laki Eruption

Over the months that the Laki fissure brought misery and darkness to Iceland, much had happened elsewhere. The invention of "flying machines," balloons fueled by hot air or hydrogen, heralded a new era: that of aviation. Another volcano, Mount Asama, worsened an already dire famine for the people of Japan. In Europe, a once-in-a-lifetime celestial spectacle, a spectacular meteor that scorched a trail across the atmosphere, amazed onlookers. The United States of America became a fully recognized and independent nation.[1] As the volcano simmered down, the world outside Iceland trundled on.

Iceland's unique geology is a consequence of its location; it sits on the Mid-Atlantic Ridge and on a mantle plume. It is only when we consider deep time that we come to realize that the interminable mechanisms of geology still shape Iceland; it is a country in flux. Icelanders were challenged by their new homeland from the moment they first set foot on the island, which resulted in hard-won resilience. While the settlers were undoubtedly accustomed to ice and snow, this island presented them with the unfamiliar: expressions of volcanism. Iceland is one of the most volcanically active countries in the world. Although these "fires" do not feature heavily in the Icelandic sagas, we can assume that volcanic eruptions occurred as frequently back then, during the first few centuries after settlement, as they do today: that is to say, every three to five years. By the turn of the first millennium, the settlers understood that previous eruptions had produced the layers of lava on which they stood.[2] It is remarkable how few Icelanders lost their lives as a direct consequence of a volcanic eruption over the past 1,150 years, given that they live so close to 30 active volcanic systems.[3]

Iceland is located just below the Arctic Circle; its raw climate became all the more volatile with the onset of the Little Ice Age in the mid-thirteenth century. Settlers adapted to these new conditions by adopting a mixture of agriculture (mostly grass growing) and animal husbandry, supplemented by foraging in the highlands. They were, consequently, able to absorb some of the environmental shocks presented by this wild new landscape. However, when several unfavorable events transpired simultaneously, such as an epidemic or an epizootic, sea ice traveling far south, or a volcanic eruption, a subsistence crisis was not far off.

The eruption of the Laki fissure lasted from 8 June 1783 to 7 February 1784; it produced almost 15 cubic kilometers of lava and 122 megatons of sulfur dioxide and other volcanic gases. It was, undoubtedly, an exceptional environmental event; after eight

1 Franklin 2011: liv.

2 Lacy 1998: 15.

3 Guðmundsson et al. 2008: 263.

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months of activity, its lava covered 600 square kilometers. How did the Icelanders cope with this? The lava consumed farmsteads and churches in the Síða region in southern Iceland, but no human lives were lost to it directly. However, ash and gases poisoned fields, ponds, rivers, animals, and even the desperate human population. The Icelanders lost 76 percent of their horses, 79 percent of their sheep, and half of their cattle between 1783 and 1785.[4] Starvation, malnutrition, and increased susceptibility to disease followed; around 10,000 Icelanders, one-fifth of the population, perished. The Laki eruption did not take place in a vacuum; in Iceland and beyond, it served to aggravate pre-existing social and political problems.[5]

Significant flood basalt events are rare: they occur only twice per millennium. The last large-scale flood basalt event before the Laki eruption, Eldgjá, happened in the 930s, just after the settlement of Iceland had begun. Through trial by volcanic fire, Icelanders have, throughout their history, learned how to fend for themselves and identify ways to mitigate the effects of volcanic eruptions. Isolated by hundreds of kilometers of ocean, they forged a communal resilience rather than a dependence on Copenhagen: help, in the form of resources or refuge, often came from areas within Iceland that were less affected.[6]

In 1783, Iceland was a Danish dependency. Merchants came in the spring with goods and returned to Copenhagen in the late summer or autumn, carrying news and various exports. For this reason, only in September 1783 did word of the disaster reach the Danish capital. By that time, it was too late in the season to send help, which only arrived in the spring of 1784. Icelanders were left alone to bear the brunt of the eruption. Bureaucratic hurdles put in place by the Danish central administration prevented an efficient crisis response. The hardened inhabitants of Iceland dealt with the calamity visited upon them without help or aid for almost a year. A gargantuan natural catastrophe, the *móðuharðindin*, was worsened by inaction.

The jet stream carried the ash and gases beyond Iceland: what impact did the Laki eruption have on the Northern Hemisphere? In Europe, contemporaries first observed unusual phenomena in the sky as early as mid-June 1783. Most notably, these included hazy skies, a red sun, and severe thunderstorms. Numerous earthquakes, subterraneous rumblings, sulfuric smells, heat waves, and even meteor sightings characterized the summer of 1783. The dry fog made the sun look “blood-red” at sunrise and sunset; it eclipsed the stars and reduced visibility at times to a distance of two kilometers. It affected plants, causing them to wither prematurely. Metal surfaces also fell victim to the haze, often turning green and rusty overnight. Moreover, these gases and particles affected human health. Myriad issues were documented, including respiratory problems, headaches, sore eyes, and itchy throats. That many records of

4 Henderson 1818: 275; Fisher, Heiken, Hulen 1997: 170; Oppenheimer 2011: 286.

5 McCallam 2019: 218.

6 Dugmore, Vésteinsson 2012: 76.

the summer of 1783 exist bolsters the idea that unusual weather is much more likely to be recorded in detail than typical weather.

What makes the summer of 1783 even more interesting is that this volcanic eruption transpired unbeknown to those outside of Iceland. The dry fog was observed in the Northern Hemisphere from North America to western China and from the Arctic to North Africa; it perturbed weather patterns far beyond these regions and its origin was a mystery. The thick and sulfuric dry fog that had blanketed most of Europe throughout the summer moved many to think about the weather. The concurrence of all these unusual phenomena was a point of interest for both the intellectual elite and the citizenry more broadly.

How were the dry fog and the other phenomena perceived? It is often not explicitly said that the population was frightened; however, the sheer volume of records suggests a high level of concern. Naturalists developed theories and newspaper editors, by all appearances, felt obliged to print them, at times alongside their own speculations. As well as immediate health concerns, Europeans broached the question of whether these phenomena were portents of things to come. They wondered whether a fog like this had occurred in the past. Those who cared to look found several precedents in chronicles and the recollections of the elderly.

Concerning the media landscape, newspapers allowed for a form of collected knowledge that could be shared, aided by a rise in literacy, allowing many to participate in the debate. Moreover, newspapers were often read aloud in public spaces for those who were illiterate. It was also possible for readers to send letters or comments to a newspaper in response to specific reports. In many ways, the mediascape was not dissimilar to today's, with misinformation often creating confusion. However, it is likely that most stories aimed at having a calming effect on the population. Historian Matthias GEORGI reported a similar result in his study on the impact of real and imagined earthquakes in England in 1750.[7]

The weather and unusual phenomena were omnipresent in the discourse during the summer of 1783. However, once the dry fog had passed in August and September 1783, it quickly became yesterday's news. Just as today, people were fickle; by September, the media discourse had shifted to something new. Had the search for the origin of the dry fog continued into September, the truth may have been uncovered sooner. Nevertheless, we should not be too judgmental, or future generations may look back at us with an equally deprecating eye. Indeed, engagement with the media at present has intensified: news is quickly forgotten, and people are perhaps more distracted and fickle than ever.

My contribution is a detailed account of the Laki eruption's impact on the Northern Hemisphere and the German Territories in particular. German sources reveal a multifaceted picture of the Laki eruption's effect on the continent. The dry fog was visible in the German Territories: there were regional differences and some short interruptions,

7 GEORGI 2009: 55. He only came across one report that clearly aimed at stoking fears.

but, in general, it remained from around 16 June to September or possibly October 1783. It is challenging to ascertain whether reports from after this period document instances of the dry fog in question or regular, wet, and seasonal fog.

What explanation strategies did contemporaries develop? In 1783, the Enlightenment inspired naturalists to search for the meaning behind observed phenomena. There was no shortage of fantastic ideas regarding the origin of the fog. These included a theory involving lightning rods, one that suggested a subterraneous revolution was the source, another that blamed volcanic eruptions within the German Territories, and even one that proposed the fog had its genesis in the tail of a meteor. The dialogue was versatile and international: discourse analysis of these phenomena shows that postulations that originated in one country often inspired those in other countries. Many explanations influenced one another and gradually became intertwined. Theories prompted rebuttals, the most famous of which were the scathing criticisms of DE LALANDE's claim that the fog had been caused by rain and flooding. Most naturalists refused to accept that such an extraordinary weather event could have an ordinary explanation. The scientific curiosity that was sparked prompted experiments and increased the will to further develop the scientific disciplines.

Various interpretations of the turbulent events of the summer co-existed: some commentators thought it to be a sign of the imminent apocalypse, although this was rare. Naturalists attempted to assuage these fears whenever they arose. Many interpretations were fluid and not mutually exclusive. One could hold that a given phenomenon had a scientific explanation and simultaneously believe that it was ultimately the manifestation of God's will. Far away from continental Europe, but not outside the Enlightenment's sphere of influence, Jón STEINGRÍMSSON – the "fire priest" – held such views: given his profession as a Lutheran pastor, naturally, he interpreted the events that unfolded in his parish religiously. God disapproved of the inclinations of his parishioners, and so, with ample warning, He sent lava to their doorstep. That God had given enough notice was proof of His mercy, as was the lava's slow flow. Such religious interpretations did not stop STEINGRÍMSSON, a student of the Enlightenment, from observing nature and conducting experiments. He threw stones into the lava to see whether they would melt; they did not, and with this he reassured his parishioners of the robustness of the land they lived on.

The coexistence of fluid interpretations was common during the Enlightenment. Previously, historians believed that the eighteenth century in Europe was a period of transition, a shift away from religious interpretations of events in favor of rational and scientifically sound explanations. This is not strictly true; competing ideas continued to exist.[8] Religious and scientific explanations at points complemented each other.[9] Just as earthquakes shook the lands of the European continent, so too did the

8 WEBER 2015: 14–16.
9 JAKUBOWSKI-TIESSEN 1992: 79.

Enlightenment and the transformative processes of the natural sciences shake the intellectual world.

Several modern historians have studied the existence of contrary ideas during the Enlightenment period in Europe. Christian PFISTER has demonstrated that it is misguided to assume one pattern of interpretation instantly replaced another.[10] Dieter GROH, Michael KEMPE, and Franz MAUELSHAGEN agree with this notion and argue that the eighteenth century was characterized more by the plurality of ideas and interpretations than the displacement of previously long-held beliefs by new thinking.[11] Manfred JAKUBOWSKI-TIESSEN and François WALTER demonstrate that seemingly contrary views were routinely held by one person, just as contradictory discourses coexisted throughout the eighteenth century and beyond.[12] My findings, based on discourse analysis of the debate about the unusual weather witnessed in the summer of 1783, are congruent with these studies. They also demonstrate that many attempts were made to find an overarching theory that would explain as many of the strange phenomena as possible. Religious doctrine and scientific reasoning were often used in tandem to explain whatever mystery presented itself.[13] This practice is called *physicotheology*.[14]

The Enlightenment was not one continuous episode but rather a multifaceted movement with regional and temporal differences. Although many different explanations circulated simultaneously, naturalists failed to find the inalienable truth about the origin of the dry fog, which increased the likelihood that religious interpretations would coexist with scientific ones.[15]

Applying the concept of societal teleconnections allows for the analysis of the far-flung effects of the Laki eruption, including those that only occurred some time after. Indeed, this concept also allows me to cast a wider net and shine a light on the real and imagined consequences of the eruption and the physical, emotional, and intellectual responses; some of which were intertwined with one another. The eruption was indeed responsible for the Laki haze, bizarre blood-red sunsets, and sulfuric smells. What is still contested is whether it precipitated the numerous thunderstorms of the summer of 1783 and the colder-than-average seasons that followed. Today we know that the heat of that summer occurred coincidentally and independently from the Laki eruption, and it would likely have been warmer still had the eruption not occurred.[16] Given the temporal proximity of the heat wave and the dry fog, it is unsurprising that naturalists in 1783 saw a connection between the two.

10 PFISTER 2002: 215.
11 GROH, KEMPE, MAUELSHAGEN 2003: 26; MISSFELDER 2009: 93–94.
12 JAKUBOWKSI-TIESSEN 1992: 107; WALTER 2010: 72.
13 WEBER 2015: 359.
14 ALT 2007: 34; REITH 2011: 92; BLAIR, GREYERZ 2020.
15 WEBER 2015: 359.
16 ZAMBRI et al. 2019b.

The echoes of Iceland's formation, etched in its landscape, reveal a process that usually remains hidden under the ocean. In Iceland, naturalists could witness the "cycles of collapse and renewal" that shape our planet.[17] Since the late eighteenth century, scientists have used the very landscapes around them to develop more sophisticated theories about the Earth's formation. The study of Icelandic geology was a ponderous and perilous undertaking. Given the deadly and tumultuous aftermath of the Laki eruption, it is unsurprising that it was more than a decade before the naturalist Sveinn PÁLSSON explored the highlands in an attempt to document Iceland's natural history. As we now know, PÁLSSON was the first person to set foot on the Laki fissure in the vast and rugged Icelandic highlands. He wrote a detailed report about this trip and the rest of his expedition. This should have settled the debate over the dry fog's origin. Circumstances, however, conspired against PÁLSSON, and so the fog of ignorance lingered.

The Tambora eruption of 1815 triggered the following year's cold summer; this was only brought to light in 1913. As the link between the Tambora eruption and the cold summer of 1816 remained obscure for some time, this event did nothing to elucidate the matter at hand: that being, the mystery of the fog of 1783.[18] It would take a century of progress and an eruption at Krakatau, 100 years hence, to finally reveal the origin of this mist. Had the Laki eruption and the fog been connected before Tambora erupted, it would have undoubtedly shed light on the events of 1816. As environmental historian Liza PIPER puts it, it is often "only with the benefit of historical hindsight that we can see the manifold ways" that a volcanic eruption like Tambora can affect the environment, economy, and society.[19]

When was a connection between the Laki eruption and the dry fog of 1783 firmly established? An Icelandic geologist, Þorvaldur THORODDSEN, discovered PÁLSSON's written work in an archive in Copenhagen in the 1870s. In 1883, Krakatau erupted with a blast that was audible thousands of kilometers away; telegraphy spread the news of the eruption far and wide. Scientists and amateur weather observers took note of strange atmospheric phenomena and brilliant sunsets around the globe. The idea that a distant volcanic eruption could affect regions far away from the actual volcano led some geologists, such as Amund HELLAND and Þorvaldur THORODDSEN, to think about the Laki eruption and the dry fog. Both visited the Laki fissure in the late nineteenth century. Between 1783 and 1883, knowledge about volcanic eruptions and geology increased significantly. From 1883 to 1888, the British Krakatoa Commission set out to compile as much information as possible about a colossal eruption on the other side of the world that they believed influenced the very skies above them. The nature of their investigation led them to revisit the events of 1783.

17 OSLUND 2011: 44–45.
18 The connection was made by American physicist William Jackson HUMPHREYS in 1913; KRÄMER 2015: 26.
19 PIPER 2009: 117.

Laki's legacy is the story of a century-long mystery solved. Its legacy is also a contradiction: In Iceland, it was the worst disaster in history, whilst in mainland Europe, it was all but forgotten by September of that year. The eruption is better remembered in mainland Europe today, 250 years later, than in the years immediately following it. Its cultural legacy was all the more subtle: the tumultuous summer of 1783 found its way into William COWPER's poem *The Task*, in which he commented on the Calabrian earthquakes and the dry fog. He writes:

> [. . .] Fires from beneath, and meteors from above, portentous, unexampled, unexplained, have kindled beacons in the skies, and th' old and crazy earth has had her shaking fits more frequent, and foregone her usual rest. Is it a time to wrangle, when the props and pillars of our planet seem to fail, and Nature with a dim and sickly eye to wait the close of all? [. . .][20]

Another example of a poem that mentions the strange weather of that summer is Peter Gottlieb LINDEMAYR's poem *Hänts Leutel sagts mä do*. However, apart from a few mentions in poetry, the fog does not seem to have inspired other art, such as paintings – at least none that have survived to the present day; the strange weather of 1783 did not leave much by way of cultural memory. Physical reminders exist of the upheavals after the eruption: numerous floodmarks scattered here and there along several European rivers indicate the great heights the water reached on those fateful days in 1784. The records and chronicles remain; the mist was the backdrop to many an important story and the catalyst to countless more.

Continental Drift, Plate Tectonics, and Mantle Plumes

In 1783, natural scientists struggled to find scientific principles that shed light on what they were witnessing. Volcanism was scarcely understood; theories were cobbled together by scientists with what little information they could glean from observations. Over the succeeding century, the understanding of geological mechanisms grew and the enigma of the volcano unraveled. Undoubtedly, two of the greatest leaps forward came in the twentieth century: the idea that the continents are in flux and the discovery of mantle plumes. Both of these concepts are crucial to the understanding of Icelandic volcanism.

With the help of a map, it is easy to imagine that Africa and South America were once bound together before they were torn apart by seafloor spreading, a process that continually creates new seafloor on both sides of the Mid-Atlantic Ridge. Furthermore, fossil evidence and occurrences of similar rock formations on lands separated by a vast ocean point to a prehistoric supercontinent. In light of these findings, in 1912, the German polar explorer, astronomer, and meteorologist Alfred WEGENER (1880–1930) formulated the theory of continental drift. In 1915, he published his book

20 COWPER 1785, book 2.

Die Entstehung der Kontinente und Ozeane (The Origin of Continents and Oceans).[21] WEGENER's ideas were treated with scorn; he died on an expedition to Greenland in 1930, many years before the significance of his theory was appreciated.[22]

In the 1950s, new technologies enabled scientists to work out the age of the seafloor based on the effect of the periodic reversal of the magnetic poles. They proved that seafloor closer to the divergent boundary of the mid-oceanic ridges is younger than that which is further away. Subsequently, in the 1960s, the theory of *plate tectonics*, a refinement of the theory of continental drift, was established. Bathymetric data collected from ships also enabled scientists, such as Marie THARP (1920–2006), to draw maps of the ocean floors; this revealed the presence of mid-oceanic ridges in oceans around the world, amounting to a total length of 65,000 kilometers.[23] Plate tectonics became a major focus of subsequent scholarship; with this theory, scientists made significant progress.[24]

Canadian geologist J. Tuzo WILSON, who brought about this change with his seminal 1965 paper on plate tectonics, had published another paper on mantle plumes two years prior.[25] American geophysicist W. Jason MORGAN built upon WILSON's work on mantle plumes and published two papers on the topic in 1971 and 1972.[26] Understandably, the study of plate tectonics took precedence over other avenues of research. Only in the 1990s did the theory of mantle plumes really gain momentum.[27] Although some geoscientists still question the existence of the Iceland mantle plume, its presence is generally accepted.[28]

American geophysicist David T. SANDWELL, in an attempt to explain why the theory of plate tectonics took so long to be accepted, reasoned thusly: throughout early modern history and most of modern history, naturalists and geologists explored the Earth backward. Scholars speculated using land-based observations; with this method, they developed ideas on the formation of the Earth.[29] Ideally, one should begin with planetary-scale

21 WEGENER 1915.

22 KEHRT 2013, Biography of Alfred WEGENER.

23 SEARLE 2013: 1.

24 There are several publications that detail the history spanning from the theory of continental drift to plate tectonics; ORESKES 2003; FRANKEL 2017.

25 WILSON 1965; WINCHESTER 2005: 99–112.

26 MORGAN 1971; MORGAN 1972.

27 CONDIE 2001: xi, 1.

28 See DAVIES 1999. Those who question the existence of the mantle plume include, for instance, Don ANDERSON (2007) and Gillian FOULGER (2010). For more debate on the topic of the existence of mantle plumes, see: PARK 2010: 53–54; GROTZINGER, JORDAN 2017: 325–327; FRIEDRICH et al. 2018: 156–188. E. R. LUNDIN and A. G. DORÉ argue that the large igneous province might have been caused by the plate break-up rather than a mantle plume; LUNDIN, DORÉ 2005. Many geoscientists, however, have accepted that mantle plumes play a substantial role in the formation of flood basalt events: MORGAN 1971; VINK 1984; COURTILLOT et al. 1988; WHITE, MCKENZIE 1989; COFFIN, ELDHOLM 1994; JULL, MCKENZIE 1996; SAUNDERS 1997: 46.

29 SANDWELL 2003: 334.

observations and then test these theories on smaller-scale environments. In early modern times, naturalists extrapolated theories of the Earth's formation from studies of the continental crust. They were unaware that continental crust was much older than oceanic crust. Some continental crust is up to four billion years old. In contrast, oceanic crust is rarely older than 200 million years and is much lighter. When push comes to shove, oceanic crust gets subducted deep into the Earth's mantle. One of the first scholars to develop theories on a planetary scale was the Austrian geologist Eduard SUESS (1831–1914), who formulated ideas about the orogeny of the Alps and the existence of a supercontinent called Gondwana.[30] It was only in the second half of the twentieth century that substantial technological advances allowed scientists to read the geology of planet Earth more effectively: satellites in space measured the motion of the tectonic plates, and seismometers reliably identified earthquakes at plate boundaries, even at depths of almost 700 kilometers.[31]

History and Geology

Geology, like history, is inescapable. Even those who live in aseismic regions of the world cannot escape its influence. The eyes that witnessed the fog were stung by its elements, and the tongues that uttered prayers and contrived explanations, tasted its sulfur. Those in the German Territories and beyond were not mere witnesses to the happenings of the summer of 1783: they also took part.

Why is an environmental history of a volcanic eruption important? A study of a volcanic eruption is an ideal platform for combining different disciplines, such as environmental history, climate history, history of science, and the natural sciences. The processes that produce a volcanic eruption are geological; these processes impact the surrounding landscape, the chemical makeup of the atmosphere and, therefore, the weather and climate. All this can have repercussions on societies near and far.

It is fascinating to study eighteenth-century naturalists' comprehension of volcanic eruptions and how their knowledge changed over time. In the future, our current understanding of science will provide historians with a snapshot of our time as well. Modern science is not a "repository of unalterable truth." As historian of geology Rhoda RAPPAPORT puts it, "[o]ur task as historians is to study when and why men thought as they did."[32] An understanding of modern geology and climate allows one to appreciate the evolution of science over the past 250 years.

Geology should play a more significant role in environmental history; it shaped the land that shaped history. Interdisciplinarity, however, is a two-way street. As geology is

30 SUESS 1883.

31 SANDWELL 2003: 345.

32 RAPPAPORT 2007: 131.

important to history, so too is history important to geology. History reveals the consequences of geological phenomena on society. Without an interdisciplinary approach, many connections within this story would have remained obscure. As historians, we often view past events through the eyes of those who experienced them. An interdisciplinary approach offers fresh perspectives on established topics and opens new doors, particularly to abstract issues and those at the crossroads between the environment and society. Should we not cast an eye over the episodes of history from a different, current perspective? Exploring the history of volcanoes through the lens of a geologist can reveal eruption styles or patterns of activity that took place thousands of years ago and have gone unrecorded. Moreover, if an active volcano has a lengthy recurrence period, generations of people may believe it to be extinct, with grave implications.[33] A greater understanding of natural phenomena can shed new light on old questions, just as it did a century after Laki. This same logic applies to climate history: studies like this one may reveal extreme weather events and climatic patterns that have not yet occurred in historical times. Interdisciplinarity does not dilute the potency of the disciplines involved; instead, it elevates them. It affords the scholar the chance to discover answers just outside the realm of their individual pursuit and offers the historian, specifically, a higher-resolution view of the past.

Science helps establish not only why something happens but also where it can happen and whether it will happen again. It tells us that earthquakes can occur around Aachen and that reports of an earthquake there in 1783 are likely true. Geologists are able to produce this knowledge, which helps historians critically assess contemporaries' statements rather than taking them at face value. Science provides incontestable evidence that the Gleichberg did not erupt in 1783 and explains why *jökulhlaups* take place after sub-glacial eruptions. Through geology, we can appreciate how large igneous provinces might have formed in many parts of the globe; indeed, this is an area of research also relevant to the understanding of extraterrestrial geology. Large igneous provinces, and perhaps mantle plumes, play significant roles in the evolution of Mars and Venus. Unlike on Earth, plate tectonics does not play a role on these planets.[34]

This environmental history of the Laki eruption can help historians of other periods identify signs of volcanic eruptions, possibly far from their actual source. I list various observable indicators of volcanic activity in Chapters Two and Three. In recent decades, natural scientists have established a good chronology of historical volcanic eruptions using ice cores, tree rings, and other proxies.[35] Historians and volcanologists

33 DUGMORE, VÉSTEINSSON 2012: 73, 79.
34 CONDIE 2001: xi–xiii, 88–95.
35 SIGL et al. 2015.

endeavor to determine the exact place and time of the eruptions they study.[36] Proxies can indicate when an eruption transpired, with an uncertainty of plus or minus five years. Historical sources, however, are high-resolution sources that can pinpoint events down to an exact day.

Relative to those volcanic events that occurred earlier, we are reasonably well-versed in the chronology of the Laki eruption. From the perspective of climate history, it is a luxury to know an eruption's exact start and end dates. The sources show that one event can be interpreted differently in different regions or even by different authors within the same region. Consequences of volcanic eruptions include withered vegetation, blood-red sunsets, respiratory problems, sore throats, and stinging eyes. Historians can look out for mentions of one or more of these in their sources as they scour the past. Volcanic cooling is another consequence; however, this is often harder to pinpoint, particularly within the Little Ice Age.

Through close collaboration with geologists and volcanologists, historians can reconstruct a more reliable chronology of past volcanic eruptions. Proxies such as ice cores, tree rings, sediment layers, and historical sources can aid in the search for as-yet-undiscovered volcanic eruptions. Thanks to ice core records, we have a good idea of when significant volcanic eruptions happened in the last two millennia; however, scientists have yet to identify the locations of all these eruptions. In 1808/1809, a tropical eruption occurred that was comparable to Tambora in scale, yet we are in the dark as to its location.[37] Knowledge of previously unknown eruptions at particular volcanoes can help us improve our understanding of recurrence periods. It could lead us to conclude that the next eruption at a particular volcano might occur much sooner than previously estimated; this would give local populations time to prepare for this event.

In 2010, Iceland's volcanism made global headlines when Eyjafjallajökull erupted (VEI 4).[38] The eruption's ash plume filled Europe's skies for several days; one consequence was the grounding of all transatlantic air traffic, stranding seven million passengers. The estimated cost of this for related industries was 4.7 billion USD.[39] If a long-lasting volcanic haze, similar to the dry fog of 1783, were to occur today and linger at altitudes

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36 One example of such a collaboration is the group Volcanic Impacts on Climate and Society (VICS) from Past Global Changes (PAGES). Positive recent examples are the identification of the location of the 1258 Samalas eruption (LAVIGNE et al. 2013) and the 1458 Kuwae eruption in Vanuatu (GAO et al. 2006, although these findings have recently been disputed by HARTMAN et al. 2019). Medieval sources also give indications of perturbed weather patterns and unusual natural phenomena: BAUCH 2017.

37 Alvaro GUEVARA-MURUA et al. (2014) found descriptions of a haze and an afterglow of the sun between December 1808 and February 1809 in primary sources from Colombia and Peru, indicating that the eruption probably took place in late November or early December 1808.

38 Global Volcanism Program: Eyjafjallajökull.

39 DAVIES et al. 2010; ELLERTSDÓTTIR 2014: 129–137.

of eight to 12 kilometers, the situation for the aviation industry would be appreciably worse. Ash particles can cause abrasions on airplanes, damage navigational instruments and engines, and even induce engine failure.[40] Recently, airplane manufacturers have started to develop sophisticated infrared and ultraviolet cameras, aptly named "Airborne Volcanic Object Imaging Detectors (AVOID)," that can help pilots avoid encounters with ash.[41]

This is just one obvious potential consequence of a future eruption; undoubtedly, there are many more. Indeed, as elements of our global economy are so intertwined and interdependent, one economic woe will probably beget another. Living in a significantly more interconnected and globalized world has many advantages; however, a globalized economy is quite vulnerable to the vicissitudes of nature, such as volcanic eruptions. The wind direction and atmospheric conditions will determine the regions affected by the next large Icelandic eruption. If this theoretical eruption occurred when circulation patterns were different, for instance, in another season, there could be unexpected outcomes. The next flood basalt event in Iceland has the potential to be much bigger. A larger eruption could produce more lava and gases, have a prolonged eruption period, and have an even more significant impact on health and the environment.

While it is likely we will know the location of a future volcanic eruption almost instantly, it is still essential to consider the history of knowledge of past volcanic eruptions in future studies. Technology such as telegraphy enabled the relatively fast spread of news about the Krakatau eruption in 1883; however, this was not the case in the pre-modern period. Future studies should investigate when links were established between other volcanic eruptions and their corresponding visible phenomena.

Future Research

This book elucidates the complex mindset of contemporaries in the late Enlightenment and how they perceived and interpreted the phenomena they witnessed; contemporary accounts also reveal how the authors' own health, or that of the people around them, was affected. The fears they expressed, directly or indirectly, reflect common concerns of the time. A detailed analysis of the descriptions of the phenomena written by contemporaries reveals complex and, at times, contradicting perceptions of reality. Over time and across different regions the dry fog had different intensities, which means that not all phenomena were experienced everywhere. In

40 Guðmundsson et al. 2008: 252; USGS, "Volcanic Ashfall Impact Working group: Aviation"; Guffanti, Casadevall, Budding 2010. In 2014, no guidelines defined when a volcanic plume of sulfur dioxide is hazardous for air traffic: Schmidt et al. 2014a.

41 Davies 2014.

the future, a qualitative study of how countries other than Germany, Britain, or France perceived the dry fog would be very desirable.

John GRATTAN, Sabina MICHNOWICZ, and Roland RABARTIN suggest that the Laki eruption was responsible for the deaths of millions of people in India and Egypt: they argue that it affected monsoonal rains, which, in turn, resulted in famine and drought. Consequently, they call the Laki eruption "one of the greatest natural disasters in human history."[42] Burial records for France and Britain reveal an elevated mortality rate in the late summer and autumn of 1783 and in the winter and spring of 1784. They suggest that an estimated 36,000 extra deaths occurred in France and England after the eruption.[43] A careful analysis of burial records from parishes across different regions in the German Territories and other parts of Europe in 1783 and 1784 would establish a clearer picture of the mortality rate during the Laki eruption and its aftermath.[44] This mortality spike had regionally different expressions; therefore, it would be interesting to determine whether it struck elsewhere in Europe and, if so, where. It would be particularly interesting to examine whether an excess mortality rate occurred soon after a thick, dry fog with a sulfuric smell was reported. In many regions, there was a time lag of a few months between the peak of the dry fog and the onset of the mortality crisis. Burial records from this time vary drastically; these records only sometimes include information on a cause of death, information which could be helpful to establish whether the Laki haze was responsible. Such a study would be useful for today's health and civil protection ministries to plan for mitigation in the face of the next large Icelandic volcanic eruption.

Further research into the perceptions of the cold winters and seasons that followed 1783 would also be advantageous.

The Bigger Picture: Lessons for the Present and Future

In modern Iceland, Jón STEINGRÍMSSON's knowledge was put to good use. In 1973, an eruption took place on the populated island of Heimaey. The island is part of the Vestmannaeyjar volcanic system at Iceland's southernmost tip.[45] The volcano *Eldfell* (literally the "fire mountain") started erupting and a fissure opened up a mere 200 meters from the closest house. Within the first six hours, almost all 5,300 residents had been evacuated to the Icelandic mainland; the Icelandic State Civil Defense Organization had prepared for a scenario like this.

42 GRATTAN, MICHNOWICZ, RABARTIN 2007: 156–157, 157 (quote).

43 WITHAM, OPPENHEIMER 2004; COURTILLOT 2005: 636. During the 2003 heat wave, an extra 16,000 people died; the Laki haze probably caused excess mortality of a similar, if not greater, magnitude.

44 WITHAM, OPPENHEIMER 2004; GRATTAN et al. 2005; MICHNOWICZ 2011.

45 Catalogue of Icelandic Volcanoes: Vestmannaeyjar; ÞÓRARINSSON et al. 1964.

The eruption lasted for about five months, emitted toxic gases, and boiled the seawater wherever the lava entered the ocean.[46] At that time, STEINGRÍMSSON's descriptions of the water from the rivers cooling down the lava flow in Kirkjubæjarklaustur inspired Icelandic geologist Thorbjörn SIGURGEIRSSON to suggest that seawater be pumped onto the lava, which cooled the top layer and slowed its flow. The eruption ended in early July 1973, having destroyed approximately 40 percent of the town.[47] The lava flow that entered the sea formed an ideal natural barrier for Heimaey's harbor, protecting it from the North Atlantic waves.[48] The response to the eruption has inspired other cities prone to these problems to follow the Icelanders' proactive example.[49]

The dry fog and the many unusual phenomena of 1783 presented contemporary naturalists with a significant, abstract problem of unknown origin. People are afraid of the unknown; this fear can be debilitating. Perhaps this explains the fixation on local explanations. It took no effort to see something in the vicinity and point a finger. If no local explanation sufficed any theory that provided an answer, even from further afield, would do. That the origin of the fog could be established was the critical factor. If the fog over Europe could be put down to the simple process of precipitation and evaporation, then the fear, too, would evaporate. If the fog was explained away as the mists from the tail of a comet then perhaps it, like the fireball that streaked across the sky, would be finite and end rather soon. And if it was the Calabrian earthquakes that had caused the fog, then at least the source of the problem could be defined.

Today, we live in a world of uncertainty. This uncertainty leads us to grasp for the familiar and the safe. It is easy to understand why someone would want to willfully and knowingly tread water if the future seems threatening. A familiar short-term solution can look decidedly more attractive than a long road of tough choices. Concerning efforts to tackle climate change, it is true that perhaps some may be afraid not of inaction but of action, especially if this action is sure to threaten their livelihood. All of us must, however, face the unfamiliar. To reduce anthropogenic climate change, humankind must make certain sacrifices that we have, until now, been unable to.

When the fog of 1783 dispersed, so did the search for its origin. If we are not constantly confronted with climate change as a problem, perhaps we will neglect the quest for a solution. The unfortunate fact is that if we are not all looking for an answer then, collectively, we have forgotten the question and an answer may elude us. During the Laki eruption, small pockets of intellectuals were left unsatisfied by most

46 SIGURGEIRSSON 1973; ÞÓRARINSSON et al. 1973; WILLIAMS, MOORE 1988: 9; FURMAN, FREY, PARK 1991; LACY 1998: 13; MATTSON, HÖSKULDSSON 2003; Catalogue of Icelandic Volcanoes: Vestmannaeyjar.

47 LACY 1998: 13.

48 THORDARSON 2010: 285.

49 WILLIAMS, MOORE 1988: 18.

theories and sought answers in the unfamiliar; they were not unsettled by carrying with them the burden of a question for so long. The contemporaries of 1783 could not have prevented the fog but perhaps today we can proactively tackle the threats of anthropogenic climate change.

Many accepted truths coexisted in 1783, but accepted truths can sometimes lead us astray. Even those who proposed that an Icelandic volcanic eruption had caused the unusual weather often could not dismiss the accepted truth at the time: that the Calabrian earthquakes were to blame. The distinction between the accepted and actual truth is crucial today. In 1783, a far-flung volcanic eruption had a seemingly improbable impact on Europe, but this *actual* truth remained unknown. In many ways, this can be related to anthropogenic climate change. While the scientific consensus is that fossil fuel emissions have changed and are still changing the planet's climate, some still dismiss this because it does not agree with their accepted truth.

The challenges of the past can seem remote in the present. Modern amenities and technologies can give us a false sense of security. The basic nature of the human experience has not changed since 1783: we still breathe air, and we still rely on agriculture to produce our food. Both fresh air and vegetation could be compromised by the pollution caused by a future Icelandic eruption. This prompts the question: have we learned from the Laki eruption of 1783? Today, generally speaking, Europeans are better nourished and healthier than the Europeans of 1783; our atmosphere, however, is much more polluted. Many more people have asthma today, which creates a larger group that is potentially at risk during a volcanic pollution event. Demographic changes have led to much larger percentages of elderly people in the population, who are also at risk in the event of an eruption.[50]

Fortunately, some countries are already planning for this kind of scenario: for instance, the United Kingdom has listed a Laki-style Icelandic eruption on the National Risk Register for Civil Emergencies.[51] The German Federal Office of Civil Protection and Disaster Assistance has a similar risk analysis list; the specifics are not public, but it includes volcanic eruptions. In the event of a future volcanic eruption that affects Germany, the different state governments would respond individually. The federal government can, however, offer assistance. In the past, Germany's civil protection system has successfully tackled major events, such as flooding in 2002 and 2013.[52] Proactive measures could

50 Guðmundsson et al. 2008: 251, 264.

51 Cabinet Office (UK), 2017: 25–26.

52 Personal correspondence with Alexander Esser, Federal Office of Civil Protection and Disaster Assistance | Bundesamt für Bevölkerungsschutz und Katastrophenhilfe, Referat II.1 – Grundsatzangelegenheiten des Bevölkerungsschutzes, Ehrenamt, Risikoanalyse, Abteilung II – Risikomanagement, internationale Angelegenheiten. More information on the air quality stations can be found in Umweltbundesamt 2013; the case of the Eyjafjallajökull eruption is discussed on pages 78–79.

include the development of tephra-resistant airplane engines, suitable face masks, or methods of protecting crops from acidic pollution.[53]

It is important to draw hope from the dramatic stories of past challenges.[54] Trials of the past can serve to fortify us, embolden us, and provide us with the courage to overcome our present challenges. Icelanders and many other inhabitants of the Northern Hemisphere in 1783 had fewer means and lesser technology than we do today, but they endured. The thirst for knowledge was very much present in the late eighteenth century. Many cherished the discoveries made in the different fields of science: 400,000 people braved the cold in Paris in December 1783 to witness the flight of the hydrogen-filled *La Charlière*; many enthusiastically embraced the idea of the lightning rods; and Sveinn PÁLSSON wandered through the challenging terrain of the Icelandic highlands to further human understanding of Iceland's natural history. The thrill of discovery still exists today and is something inherent in humanity, which inspires optimism.

The events of that extraordinary year – 1783 – encourage us not to underestimate human kindness: some Icelanders gave shelter to their neighbors as ash fell from the sky; many Danes participated in fundraising efforts to help the Icelanders in their hour of need; the fishermen who discovered the Nýey eruption were genuinely worried about the fate of the Icelanders and made sure to check on them; newspapers were committed to informing their readers, believing that adequate information would stop them from panicking; and in the winter of 1783/1784, churches collected money for people affected by the severe flooding.

Outlook: The Present and the Future

The 200-Year Anniversary of the Laki Eruption

How did the memory of the Laki eruption evolve over two centuries? Much had changed over that period: most notably, on 17 June 1944, Iceland had become an independent republic. In the early twentieth century, the Icelandic economy broke out of the cycle of poverty and stagnation due to the mechanization of its fishing industry.[55] After the Second World War, Iceland was on the fast lane to becoming a truly modern nation. In 1949, it became a founding member of NATO. Two years later, it agreed to enter into a defense treaty with the US, which led to huge investment in the country's

53 Some developments are already underway. In the aftermath of the 2010 Eyjafjallajökull eruption, special jet engine coatings were tested to resist volcanic ash damage: DREXLER et al. 2011.

54 MAUCH 2019.

55 KARLSSON 2000b: 239–242, 287–291; MAGNÚSSON 2010: 30–31.

infrastructure.[56] Iceland also utilized its natural resources by using sand and gravel for construction and by harnessing geothermal energy.[57] In 2018, Iceland had around 350,000 inhabitants.[58] The number of tourists coming to Iceland rises almost every year: 303,000 tourists visited in 2000, 489,000 in 2010, 807,000 in 2013, and 2,224,603 in 2017.[59] Tourism has become an integral part of the economy. Today, Iceland is part of Europe and "a thoroughly modern country."[60]

Figure 66: A stamp commemorating the Laki eruption, released in 1970, featuring a painting by Sveinn ÓLAFSSON.

The many reports and descriptions of this eruption, and the fissure itself, torn into the landscape, immortalize the event which caused so much hardship and pain. In 1970, a painting of the Laki fissure by Sveinn ÓLAFSSON featured in a stamp that was created as part of a nature conservation series, *náttúruvernd* in Icelandic. As part of this series, iconic images of several other Icelandic volcanoes had previously been turned into stamps to celebrate the country, such as Hekla, Surtsey, and Eldfell. The stamp (pictured here as Figure 66), according to historian Karen OSLUND, presents the volcano as an unthreatening feature of the landscape, a mere spectacle that complements the bright blue sky on the horizon. The fissure is still visible and reminds Icelanders and foreigners alike what nature, specifically Icelandic nature, is capable of. In the eighteenth and nineteenth centuries, volcanic eruptions were often depicted as awe-inspiring, destructive forces of nature; ÓLAFSSON's painting puts the unique landscape at center stage. Volcanoes are no

56 LACY 1998: 233–249; KARLSSON 2000b: 313–318, 336–341; MAGNÚSSON 2010: 232–235; OSLUND 2011: 26. On the strategic importance of Iceland during the Cold War, see: WHITEHEAD 1998; INGIMUNDARSON 2011.
57 LACY 1998: 18–19.
58 LACY 1998: 3–8.
59 Icelandic Tourist Board, Tourism in Iceland in Figures, 2018.
60 OSLUND 2011: 27.

longer a symbol of destruction or despair. “Icelandic nature is extreme, unpredictable, and even wild, but people live within this wilderness, and their character has been formed by the struggle with this nature.”[61]

It is not the nature of the Icelandic landscape that has changed since the eighteenth century but, rather, how the Icelanders see it. They no longer consider volcanic eruptions as catastrophes; instead, they view them with pride and awe. Now, with a curious eye, they can study and understand their country and its moods and, in doing so, protect their people and property.[62] In 1975, the Laki fissure was deemed a natural monument. It is now part of the Vatnajökull National Park, which was established in 2008 and is Europe’s largest. It covers 13,200 square kilometers and includes the entirety of Vatnajökull as well as some surrounding land, including Eldgjá.[63]

Figure 67: “Lakagígar” by Finnur Jónsson, 1940. The painting was turned into a stamp in 1983.

61 Oslund 2011: 53–54.
62 Oslund 2011: 58–59.
63 Vatnajökull National Park: Lakagígar, Langisjór and Eldgjá brochure and map, 2011; Baldursson et al. 2018.

In 1983, Finnur JÓNSSON's painting of the Laki fissure was also turned into a stamp (Figure 67) to commemorate the 200-year anniversary of the eruption. OSLUND further observes that during the first half of the twentieth century, the portrayal of Icelandic nature changed – instead of focusing on the human perspective, depictions now focus on nature itself. The landscape is celebrated in its own right, as is the triumphant struggle to overcome the challenges presented by this wilderness. The ever-present threat of volcanic eruptions is part of this rugged island's unique character.[64]

Skafáreldahraun – The Laki Lava Field

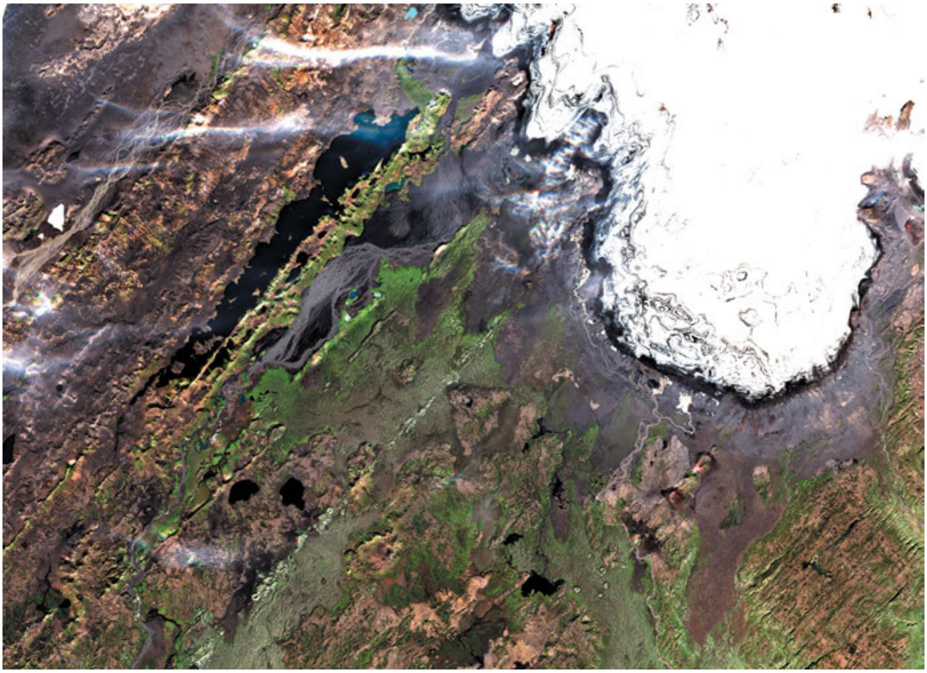

Figure 68: A satellite image of the Laki fissure and Vatnajökull.

The Laki fissure is one of several in southeastern Iceland. Satellite images and drones change our understanding of remote landscapes and make it easier to grasp the geological forces that have shaped our planet (Figure 68). Eldgjá, the Great Þjórsá Lava, and the Laki eruption are the three largest terrestrial basalt eruptions of the last 10,000 years.[65] Eldgjá and Laki combined produced more than half of all the lava

64 OSLUND 2011: 52–53, 60.
65 THORDARSON, HÖSKULDSSON 2008: 198.

ejected from Icelandic volcanoes since settlement in the ninth century.[66] The lava produced by these eruptions precipitated some of the longest postglacial lava flows on the planet.[67] The fissures produced by the Eldgjá and Laki events are parallel and quite close to one another, marking the rifting area of the Eastern Volcanic Zone. The remnants of these eruptions are still visible in the landscape of the highlands between Vatnajökull and Mýrdalsjökull. Laki alone left 600 square kilometers of lava fields which, over time, have been blanketed in moss (Figure 69).

Figure 69: The Laki fissure in 2016. The southwestern part of the fissure, as seen from Mount Laki.

The Laki lava field is known as *Skafáreldahraun* (Figure 70). The lava morphology of its surface is unique; the lava field does not solely consist of *pahoehoe lava*, which is smooth, fluid basaltic lava, nor *'A'ā lava*, which is rough, rubbly basaltic lava. Therefore, the term *rubbly pahoehoe* was introduced to describe and differentiate it from other types of lava fields.[68] Its green moss grows very slowly in the harsh climate of the Icelandic highlands and is always under threat from a constant stream of plodding hikers.[69]

Today, lava fields are a tourist destination and have, in recent years, been marketed as such. One can even buy lava-field-shaped candy called *hraun* (lava field) in the Icelandic supermarket: it is a puffed rice cake covered in chocolate.[70]

66 THORDARSON, HÖSKULDSSON 2014: 131.
67 THORDARSON, HÖSKULDSSON 2008: 211.
68 GUILBAUD 2005.
69 Katla Geopark Project: 10.
70 OSLUND 2011: note 51, 186.

Figure 70: *Skafáreldahraun*, the Laki lava, 2016.

Once, it took a few days on horseback to get from Kirkjubæjarklaustur to the Laki fissure. Today, you can make that journey within three hours. The distance of 50 kilometers is exceptionally rough, with dirt roads that are often flooded. "The public is encouraged to visit [. . .], under certain conditions," states the brochure for Vatnajökull National Park, where the Laki fissure is located. The brochure further clarifies that one condition is adherence to a protection order put in place to help visitors "enjoy the area without damaging the volcanic features or vegetation."[71] Action was necessary as the ever-increasing number of visitors was having a detrimental effect on the environment. Visitors to the National Park are asked to stay on the wooden walkways built by volunteers.[72]

Accompanying signs warn visitors of the consequences of stepping on the moss. Nevertheless, a lot of plants near the walkway have turned brown or are dead because tourists have stepped on them too often (Figure 71).

From the moment of settlement, Icelanders began to clear land for grazing; happily, the felled trees also met their fuel needs. As a consequence, much of Iceland's forest cover was lost. Without trees, the soil dried up and was subsequently eroded by the elements. Soil erosion, aridification, and desertification are huge problems in today's Iceland. Presently, 40 percent of Iceland is considered "severely eroded."[73] In 1989, the Ministry for the Environment and Natural Resources was founded. It had two goals: to utilize natural resources and preserve the environment.[74] Naturally, future volcanic eruptions, severe storms, avalanches, or floods might hinder some of these efforts.[75]

71 Vatnajökull National Park, Lakagígar, Langisjór and Eldgjá brochure and map, 2011.

72 Lacy 1998: 47–48. Volunteers work toward preservation by building paths to prevent tourists from stamping on the vegetation; Kleemann 2016.

73 Streeter, Dugmore, Vésteinsson 2012: 3665.

74 Lacy 1998: 47–48.

75 Hjálmarsson 2009: 214–216.

Figure 71: An information sign and a footpath near one of the Laki craters.

Mount Laki was formed by volcanic activity under a thick layer of ice, possibly in 4550 BCE (± 500 years).[76] In 1783, a fissure formed in this exact spot. In the future, another fissure and a crater row might form somewhere parallel to the Laki and Eldgjá fissures.

Just as Iceland is being wrenched apart by geological forces, Europe has, throughout its history, been wrenched apart by different rulers, economic interests, religious beliefs, or ideological frameworks. Iceland's remoteness shielded it – for the most part – from these often bloody conflicts. Day by day, centimeter by centimeter, Iceland grows; it is a great stage where a drama featuring earthquakes, eruptions, and volcano-tectonic rifting episodes that Icelanders simply refer to as "fires" is unfolding.[77]

Over the past 1,150 years, Icelanders have learned to understand the quirks of their homeland. They have seen many mortality crises but have always picked themselves up and started anew. Icelandic society has never collapsed despite interminable volcanism, a volatile climate, centuries of foreign rule, poverty, demographic crises, and economic setbacks. Today, the country is well-prepared to deal with the moods of its fire-spitting landscape. Icelanders are still only tenants of the land. Volcanoes remain the natural kings and queens of Iceland; they can be violent, eccentric, and despotic, but they can also be benevolent, supplying Iceland with hot pools and almost unlimited geothermal energy.

76 Einarsson, Sveinsdóttir 1984: 48. Information on the Botnahraun eruption can be found in the "eruptive history" section in Global Volcanism Program: Grímsvötn.
77 Steingrímsson 2002: 3.

Iceland and Its Volcanoes in the Future

Iceland is one of the most active volcanic regions on our planet.[78] The different volcanic systems are monitored continuously. Since the Gjálp eruption at Grímsvötn in 1996, every eruption has been predicted by seismic activity, which gives civil defense authorities some time to evacuate people from the threatened parts of the country. Technological and economic improvements in Iceland have undoubtedly saved many lives; only two fatalities directly linked to volcanism occurred in Iceland in the twentieth century. Increasing tourism places not only the fragile moss at risk but also the tourists themselves; some volcanoes, such as Hekla, a popular hiking spot, often give very little warning before erupting.[79]

By monitoring and analyzing Iceland's volcanoes and geology, experts have learned a lot. We know, for instance, that the Grímsvötn volcanic system is in a high-frequency eruption period, which will last, it is estimated, for another 50 years. It is predicted to peak between 2030 and 2040. Bárðarbunga follows a similar pattern of high- and low-frequency periods. Both systems are above the center of the Iceland mantle plume. Major rifting episodes occurred at Bárðarbunga in 1477 and at Grímsvötn between 1783 and 1785, both of which coincided with high-activity periods.[80]

Recent fissure eruptions in Iceland include the Holuhraun eruption, which began in 2014 and lasted until 2015 and was part of the Bárðarbunga volcanic system, and the 2021 Geldingadalir and 2022 Fagradalsfjall eruptions on the Reykjanes Peninsula.[81] These eruptions were small compared to Laki.[82] Webcams were quickly installed nearby to broadcast the eruption worldwide. Many scientists flew to Iceland to witness this impressive event first hand. Smaller flood basalt events, such as the Holuhraun eruption, happen roughly every 40 to 50 years. Fortunately, in Iceland, large flood basalt events, such as Laki or Eldgjá, take place only every 200 to 500 years.[83] They produce extraordinarily large amounts of lava, disgorged from magma chambers and deep-seated magma reservoirs. Based on observations made during historical times, it is estimated that within one Icelandic volcanic system the recurrence period of flood basalt events is likely to be hundreds or even thousands of years.[84]

From historical descriptions, researchers know that a future Laki-style eruption may be preceded by increased earthquake activity days or even weeks before it begins. Due to the lack of instrumental records from 1783, we do not know whether the

78 BYOCK 2011: 27.

79 GUÐMUNDSSON et al. 2008: 251, 255, 263.

80 THORDARSON, LARSEN 2007: 138, 143.

81 Veðurstofa Íslands: "Fagradalsfjall Eruption," 2021; Global Volcanism Program: Krýsuvík-Trölladyngja.

82 Holuhraun produced about 1.5 cubic kilometers of lava and occurred in a relatively remote area.

83 SCHMIDT et al. 2015b.

84 THORDARSON, LARSEN 2007: 138.

system would likely show inflation or dilation. Still, it appears likely it would show one of these characteristics prior to an eruption.[85]

In Iceland, the most severe volcanic events we can expect are of three different sorts. The first is a major flood basalt event similar to the Laki eruption. The second is a VEI 6 Plinian-style eruption, such as the one that occurred in 1362 at Öræfajökull. Luckily, eruptions like these only occur once or twice per millennium. The third is volcanic activity at Katla, which is almost guaranteed to be followed by *jökulhlaups*, potentially threatening the residential and agricultural areas to the west.[86]

Flood basalt eruptions, like the Laki eruption, are low-probability but high-impact events. Depending on meteorological conditions, they have the potential to affect regions as far away as southern and eastern Europe. Outside Iceland, the Netherlands, Belgium, and the United Kingdom may be among the worst affected areas.[87] Economic losses from volcanic eruptions and their consequences are to be expected in the near future.

Today, famine is not a great danger for Icelandic society. Agriculture is more stable, and the nation's wealth allows it to import goods from elsewhere. However, infrastructure such as roads (particularly Highway 1, which surrounds the island and is a key transportation route), power lines, telecommunications equipment, and industrial complexes could be affected by a large eruption. Iceland is sparsely populated; around 70 percent of all Icelanders live in or near Reykjavík. Fortunately, the Reykjavík metropolitan area is safe from lava flows, except for the suburbs in the very south and east.[88] Volcanic pollution, however, and the discomfort it brings upon those with respiratory problems may be more difficult to avoid.[89]

At the end of the last ice age, the vast ice sheet that covered Iceland began to retreat; an immense weight, and thus pressure, had been removed from the land and mantle below. This change led to a rebound effect, which may have destabilized the magma chambers.[90] The ice melt increased the magma production in the magma chambers below by a factor of 30, compared to the production rate during glaciation.[91] During the early Holocene, there was an increase in volcanic activity in Iceland, which geophysicist Magnús GUÐMUNDSSON and his colleagues describe as "a major peak in volcanism and lava production."[92] This prompts the question of whether another increase in volcanic activity can be expected now that Iceland's glaciers are retreating due to anthropogenic climate change.

85 Catalogue of Icelandic Volcanoes: Grímsvötn.

86 GUÐMUNDSSON et al. 2008: 251.

87 SCHMIDT et al. 2011: 15710–15714; ÁGÚSTDÓTTIR 2015: 1674; HEAVISIDE, WITHAM, VARDOULAKIS 2021.

88 GUÐMUNDSSON et al. 2008: 251, 263.

89 CARLSEN et al. 2021.

90 GUÐMUNDSSON et al. 2008: 265.

91 PAGLI, SIGMUNDSSON 2008.

92 GUÐMUNDSSON et al. 2008: 265.

During the Little Ice Age, a larger area of Iceland was covered in ice as the glaciers surged during the coldest periods. Glaciers are permanent ice caps consisting of dense ice and snow; they exist even during the summer.[93] Today, only four glaciers are left in Iceland, of which Vatnajökull is the largest, covering an area of 8,000 square kilometers. Iceland's glaciers have been retreating for over 100 years; over the next one or two centuries, it is possible they will disappear entirely. Since 1890, Vatnajökull has been continuously retreating and has lost around ten percent of its ice mass.[94] In 2019, for the first time, Iceland officially mourned the loss of a glacier, Okjökull, to anthropogenic climate change.[95]

Geoscientists Carolina PAGLI and Freysteinn SIGMUNDSSON estimate that an additional 0.014 cubic kilometers of magma are produced under Vatnajökull every year due to the thinning of the ice shield.[96] The changes caused by melting glaciers will primarily affect the Eastern Volcanic Zone: Grímsvötn, Bárðarbunga, and Katla. This volcanic zone is already Iceland's most active. Vatnajökull's ice shield today measures 50 kilometers in radius; it was 180 kilometers after the last glaciation. As ice shields melt, their influence on magma production within magma chambers is lessened.[97] In the long run, when Iceland loses most of its ice, there will be a substantially decreased chance of *jökulhlaups* threatening human and non-human lives and infrastructure.[98]

In 1783, the people of Iceland could only react to the eruption and mitigate its ill effects; this approach to the disaster has been the only option for most of human history, and it is a habit that is hard to break. Today, we have the opportunity to be more proactive in our approach to natural calamities; perhaps we should embrace this opportunity. If we only react to environmental disasters and mitigate their deleterious consequences, we may feel like we are in a duel with nature, bogged down in a constant struggle. A proactive approach would feel more like a cooperation with nature. The danger posed by Icelandic volcanic eruptions is ever-evolving, but so too is our understanding of them.

93 SIGURÐSSON 2005: 242–248.

94 GUÐMUNDSSON et al. 2008: 265; PAGLI, SIGMUNDSSON 2008.

95 JAKOBSDÓTTIR 2019.

96 PAGLI, SIGMUNDSSON 2008.

97 MACLENNAN et al. 2002; GUÐMUNDSSON et al. 2008: 265; ÁGÚSTDÓTTIR 2015: 1674.

98 Similar effects can be expected from presently ice-capped stratovolcanoes that will lose their ice cover over the next decades and centuries, such as Mount Erebus in Antarctica or the Aleutian volcanoes in Alaska: GUÐMUNDSSON et al. 2008: 265; PAGLI, SIGMUNDSSON 2008.