The Eruptive History of Death Mountain: A Geological Investigation of a Virtual Volcano Across The Legend of Zelda Series

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Abstract

Enrolment in geology-related courses has declined over the last few decades, in part due to a lack of understanding of the subject and its relevance to contemporary society. Although a popular medium for entertainment, video games also hold significant pedagogical potential to overcome this problem by immersing players in geology-related topics through the portrayal of a broad range of geological disciplines in the medium's dynamic environments. This paper focuses on volcanology as portrayed in Nintendo's The Legend of Zelda series' (1986-present) Death Mountain, a recurring volcanic peak in the franchise. Volcanic features in each game are documented and compared to real-world examples to determine the accuracy of how the volcanism evolves over time across instalments in the series. I argue that the volcanic history of Death Mountain provides a reasonably realistic evolution, beginning with volcanic hazards like rockfalls and lava from an active stratovolcano, and progressing over time to introduce hydrothermal systems. Then, during divergent timelines, Death Mountain's volcanism shifts to either explosive, shallow-water eruptions or to showing evidence of massive explosive activity. Through this, I argue that the popularity of The Legend of Zelda series and the gradual introduction of volcanic features can be used together to change the perception of geology as "boring" and encourage people to study the subject by offering a fun and immersive means to engage with its content.

Keywords

Geology; volcano; The Legend of Zelda; Death Mountain; pedagogy; student engagement.

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Introduction

A recent study by Steven Leslie Rogers et al. (2023) set out to investigate the reasons behind the decline in student intake of geology-related courses by asking prospective students their opinion of the subject. Responses from students not studying geology frequently described the subject as "boring" and "irrelevant" for those wanting to pursue a career outside of the oil industry. On the other hand, responses from students taking geology courses described the subject as "fascinating" and "diverse." However, many of these students only took up the subject after being exposed to it through prior geology or geography classes. With geology courses in decline in the United Kingdom's secondary education system, new, innovative ways of communicating a more accurate portrayal of geology are required to overcome the stereotypes highlighted by Rogers et al. Similar studies have shown that this is not a new problem specific to the United Kingdom but has been a decades-long problem affecting multiple countries, such as Australia (Dekkers & De Laeter, 2001) and the United States (Hoisch & Bowie, 2010; Ortiz-Guerrero & Loizzo, 2023).

In recent years, the idea of using commercial off-the-shelf (COTS) video games to teach geological concepts has gained considerable interest (Clements et al., 2022; Hut et al., 2019; McGowan & Alcott, 2022; McGowan & Scarlett, 2021). The benefit of using such video games is based on their inherent popularity and ability to keep players engaged for hours in gameplay (Dan Floyd, 2008; Van Eck, 2006). Studies have shown that the use of video games can help to promote educational learning through in-game exposure (Brown et al., 2014; Mayo, 2009). The use of video games to teach geology could work to combat the perception that geology is boring and increase student intake. This approach may be effective in attracting prospective university students.

Previous studies on geology in COTS games include investigating inaccuracies in volcanology and palaeontology, finding a common bias towards certain aspects such as the depiction of overly steep stratovolcanoes with excessive lava eruption (McGowan & Scarlett, 2021), and the overrepresentation of fossils of large predatory dinosaurs like the *Tyrannosaurus* or *Spinosaurus* (Clements et al., 2022). In some cases, a single video game can accurately include a range of geological topics, such as volcanology, mineral resources, and hazard management (McGowan & Alcott, 2022). Rolf Hut et al. (2019) also found that non-geologists were just as capable as trained geologists at telling apart fake virtual landscapes from real ones. As such, this study continues this line of thought by focusing on a single virtual video game volcano and investigates how geological changes are portrayed on the chronological timeline of the popular video game franchise, The Legend of Zelda (Nintendo, 1986-present).

For many players, Death Mountain is one of the most iconic and beloved video game volcanoes (Hvorp, 2015; Matthias, 2014; Muir-Taylor, 2022). Since its debut in *The Legend of Zelda* (Nintendo R&D4, 1986) to its most recent appearance in *Tears of the Kingdom* (Nintendo EPD, 2023), Death Mountain has officially appeared in a total of 12 main-series The Legend of Zelda games (Figure 1).[1] This makes Death Mountain one of, if not the most, frequently recurring console-based video game volcanoes. The popularity of The Legend of Zelda series means that Death Mountain has great potential to stimulate the study of volcanology, as players immerse themselves in the volcanic landscape. The recurrence of Death Mountain across numerous games released years apart can have a significant impact on returning players who explored the volcano in previous games and can compare experiences. Not only can this encourage careers in geology (Andrews, 2021), but it could also be used as an educational tool to help boost student engagement through an entertaining medium (Hernandez et al., 2023; McGowan & Alcott, 2022; McGowan & Scarlett, 2021).

The official *The Legend of Zelda: Hyrule Historia* (Nintendo, 2011) and *The Legend of Zelda Encyclopedia* (Nintendo, 2018) provide a chronological timeline for all main series games, up to the release of *Tri Force Heroes* (Nintendo EPD and Grezzo, 2015). After *Ocarina of Time* (Nintendo EAD, 2011c), the story diverges into three timelines: one in which the hero is defeated, one in which he is triumphant as a child, and one in which he is triumphant as an adult, referred to here as the submerged timeline. *Breath of the Wild* (Nintendo EPD, 2017) has been confirmed to sit at the very end of the timelines, but it is unclear which one (Schreier, 2018). Nonetheless, aspects of *Breath of the Wild* and its sequel, *Tears of the Kingdom,* suggest the timelines converged into one again (see Figure 1). With an established timeline across numerous The Legend of Zelda games, the volcanic evolution of Death Mountain can be tracked over time. The release of more modern games set at earlier points in the timeline helps to negate the digital bias against those released on early consoles, which had limited graphics and hazard mechanics available at the time of their development.

[1] For ease of reading, all Legend of Zelda games shall be referred to by their unique title only, removing the *"The Legend of Zelda:"* portion.

Figure 1. The chronological timeline for all main series The Legend of Zelda games. Bold titles indicate the game is set in Hyrule. Games with a volcano symbol next to them indicate Death Mountain is present. Bracket descriptions indicate the first time a particular volcanic feature is found within the series. Modified by the author after Nintendo (2011, 2018).

This paper will follow the eruptive history of Death Mountain through the Zelda timelines from *Skyward Sword* (Nintendo EAD, 2011a) to *Tears of the Kingdom* and assess the realism of the volcanology present. A coherent evolution in the volcanic history of Death Mountain would highlight the educational potential of Death Mountain to inspire and teach accurate volcanological concepts across multiple games. The more accurate the volcanic history, the greater the educational potential, as educators could use the historical continuity of Death Mountain in their teaching materials.

At present, it is common for students to be taught volcanology using numerous case studies, with each event being a prime example of an eruption style or feature. For example, the 1980 eruption of Mount St.

Helens in the United States is the textbook definition of a lateral blast eruption (Crandell & Hoblitt, 1986). Following the eruption, Mount St. Helens developed a lava dome. However, instead of following the volcanic narrative of this one volcano, teachers may use La Soufrière, Saint Vincent, as a lava dome example due to being a more modern case study with detailed observations made during its formation (Stinton, 2023). Although these events may individually be excellent for teaching, in my experience, the use of too many examples can overwhelm and confuse students, causing them to mentally shut down and prevent further learning. Arguably, it is not always possible to rely on a single volcano to repeatedly erupt and create a continuous narrative for students. As this paper will explore, virtual volcanoes—such as Death Mountain—may resolve this issue.

However, the lack of a coherent evolution in the volcanic history of Death Mountain could limit the educational potential to small, isolated features. After all, The Legend of Zelda series is set in a magical fantasy world, within a digital environment. Therefore, the landscape is not constrained by the natural laws of the real world. Instead, Death Mountain's appearance and volcanic activity are limited by the processing capabilities of the console it appears on and the creative input of the game developers. In the *Hyrule Historia* (Nintendo, 2011), *Zelda* director Eiji Anouma mentions that each game's placement within the *Zelda* timeline is an afterthought. Therefore, this suggests that inconsistencies in the timeline are to be expected, especially regarding the scientific accuracy of the evolution of Death Mountain. Only by investigating the volcanology of Death Mountain in multiple The Legend of Zelda games can the educational potential be fully determined.

Methodology

Firstly, information provided by *The Legend of Zelda: Hyrule Historia* (Nintendo, 2011) and *The Legend of Zelda Encyclopedia* (Nintendo, 2018) was used to determine which of the Legend of Zelda games include Death Mountain. From this, the study employs the methodology of Edward G. McGowan and Jazmin P. Scarlett (2021), whereby the author played through the games presented in Table 1.

Title	Console	Year of release
A Link to the Past	Game Boy Advance	2002
Twilight Princess	Wii	2006
Phantom Hourglass	Nintendo DS	2007
Skyward Sword	Wii	2011
Ocarina of Time 3D	Nintendo 3DS	2011
A Link Between Worlds	Nintendo 3DS	2013
The Wind Waker	Wii U	2013
Breath of the Wild	Nintendo Switch	2017
Tears of the Kingdom	Nintendo Switch	2023

Table 1. The Legend of Zelda games and console played by the author.

Throughout each game, volcanic features of Death Mountain were observed and documented, similar to how real-world geological fieldwork is conducted. Features include the geographical location, volcano morphology, hazards, and other volcano related properties. Once identified, features were compared to both the official Zelda timeline (see Nintendo, 2011, 2018) and statements from game developers (Schreier, 2018) to understand the volcanological evolution of Death Mountain. These were then compared to real-world volcanism to determine the accuracy of the features presented. A major consideration is that Death Mountain's volcanic unrest is usually attributed to a monster rampaging on or in the mountain. Once the player vanquishes said monster, the volcanic activity reduces to a level of minor unrest or ceases entirely. The nature of these volcanic triggers is therefore extremely unrealistic and will not be taken into consideration when assessing the realism of each game, but the hazards they create will.

Findings

Even though some of the later games are part of earlier timelines (e.g., *Skyward Sword* was released by Nintendo in 2011, but marks the earliest events of the timeline), Death Mountain does show a gradual volcanological evolution with a diverse range of volcanic features. Death Mountain begins as a stratovolcano, a conical shaped volcano formed by multiple layers of volcanic material from successive eruptions. It typically has a very steep profile of 60° which, though common in video games, is unrealistic in the real world, where volcanic profiles rarely exceed 40° (McGowan & Alcott, 2022; McGowan & Scarlett, 2021). The volcano also displays a small range of hazards, including rockslides and lava flows (*Skyward Sword*). Eventually, visible signs of a hydrothermal system develop through interactions with volcanic activity and water (*Twilight Princess*). Later, caldera-forming eruptions occur, leaving cauldron-like depressions following explosive activity (*Breath of the Wild*).

The Eldin Volcano

Chronologically, Death Mountain makes its first appearance in *Skyward Sword*. In this game, it is known as Eldin Volcano, named after the region to the northeast of Hyrule where it is located. It is not until later in its existence that it is renamed Death Mountain due to the number of people who have died trying to scale it (Nintendo, 2018).

Throughout the events that span from *Skyward Sword* to either *The Adventure of Link* (Nintendo R&D4, 1987) or *Four Swords Adventure* (Nintendo EAD, 2004), depending on the timeline, Death Mountain remains relatively unchanged. The volcano stands tall as an unnaturally steep, sloped stratovolcano, typical of video game volcanoes (McGowan & Scarlett, 2021; see Figure 2). The overly steep nature of video game volcanoes helps them visually dominate a landscape and stand proudly as a key landmark, something Death Mountain does especially well.

Figure 2. Eldin Volcano (later named Death Mountain) in *Skyward Sword*. The volcano is an unnaturally steep stratovolcano, with multiple streams of molten lava and ash clouds emitting from the central vent. This is a typical portrayal of Death Mountain for most of the series. Screenshot by the author.

The main volcanic hazards that befall players are falling boulders, either triggered by rockslides or ejected lava bombs, and pools of molten lava. Rockslides commonly occur on the slopes of volcanoes, especially very steep ones (González de Vallejo et al., 2020), like Death Mountain. They can be triggered by non-volcanic activity, such as rainfall loosening the rocks. However, increased rates of rockslides may be an indication of rising magma causing volcanic tremors that disturb the rocks, or hydrothermal fluids weakening the rocks (Volcano Hazards Program, n.d.). Rocks ejected from the vent, called *tephra* or *bombs*, depending on their size, are evidence of a currently erupting volcano. Regardless of

how they originate, the falling rocks can pose a serious hazard to those traversing a volcano like players do on Death Mountain.

Lava lakes are not as common in the real world as they are portrayed in video games like the Zelda series. There are only a small number of known volcanoes across the globe with long-term lava lakes, such as Erta Ale, Ethiopia (Global Volcanism Program, n.d.). These lava lakes require a constant convection of persistently degassing lava to maintain their molten state, which is quite rare (Witham & Llewellin, 2006).

Hot springs can be found around Death Mountain from *Twilight Princess* onwards. In the real world, hot springs can be found in many volcanic areas across the globe, including Yellowstone in the United States and in Iceland. Water from hot springs is heated by either shallow magma, deep percolating groundwater, or a combination of the two. The heated waters are enriched with minerals and many researchers consider them to have numerous health benefits (Erfurt-Cooper & Cooper, 2009). Within the Zelda series, such benefits are demonstrated by the player regenerating health within the hot springs, as promoted by Gorons (residents of Death Mountain from *Ocarina of Time* onwards) to tourists at their springs (see Figure 3). The addition of hot springs only later within the series could be interpreted as evidence of the magmatic plumbing system beneath the Eldin region progressing, with more magma residing at shallower depths. By the time of *Tears of the Kingdom*, when volcanism is very prominent, there are numerous hot springs located throughout the region.

Figure 3. Link and two Gorons relaxing in a volcanic hot spring in *Breath of the Wild*. They can be differentiated from regular pools of water by their light shade of aquamarine and ability to rejuvenate health. Screenshot by the author.

Death Caldera

Breath of the Wild introduced a new era of Zelda games. Released as the flagship game for the Nintendo Switch, the game aimed to show that portable consoles could still provide high-performance video game experiences commonly associated with television-based consoles, such as the Xbox One or PlayStation 4 (Miller, 2017). At the same time, the game's director, Hidemaro Fujibayashi, wanted to produce a game that provided a true sense of freedom (Stark, 2017). Therefore, the game had an extremely large map full of mountains, valleys, lakes, and numerous other environments to freely explore in an open-world setup.

In line with the director's ideals, the volcanic Eldin region is far larger than in previous games (see Figure 4a). Of significant note is a ring of rocky crags that encircle the main peak of the volcano. The crags are remnants of the old slopes of Death Mountain, which at some point in the past experienced a very large volcanic eruption and collapsed in on itself, forming Death Caldera. Continued volcanic activity at the site has resulted in a new volcanic peak in the middle of Death Caldera (see Figure 4b). Such continued volcanism is typical after caldera collapses (Cole et al., 2005), although growth of new vents occurs at a significantly reduced rate in the real world.

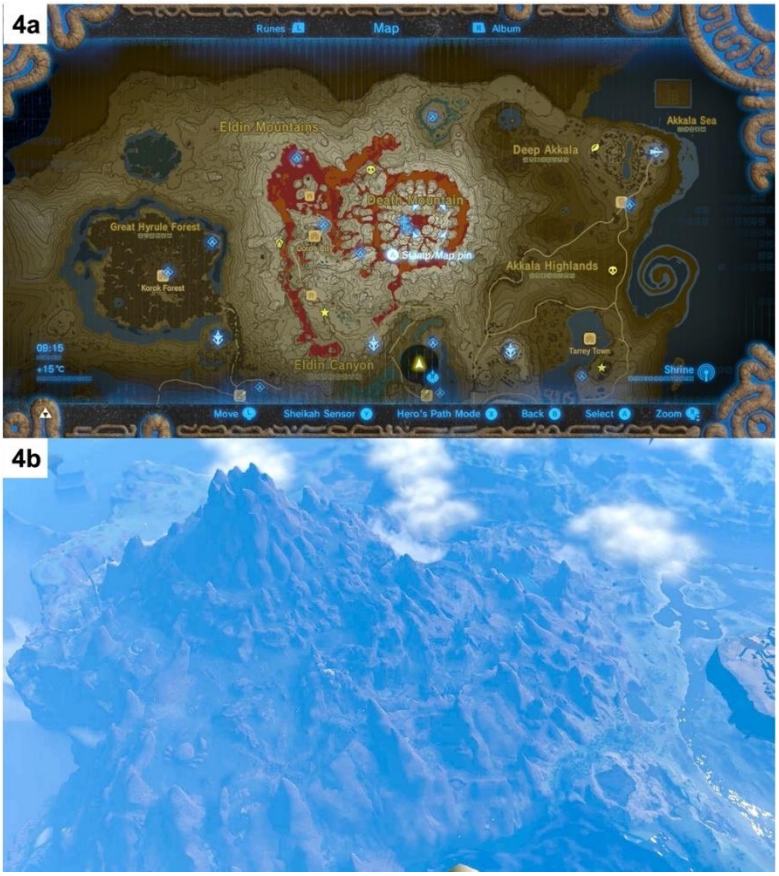

Figure 4. (a) Map of the Eldin region in *Breath of the Wild*. Red areas are covered by molten lava. A ring of lava around the central peak of Death Mountain picks out the Death Caldera crater. (b) A view of the Eldin

region from above in *Tears of the Kingdom*. The lava has now disappeared, but the central peak and caldera margin can still be identified. Screenshots by the author.

As if to prove the excessive volcanism that could have built up the new Death Mountain peak, vast volumes of lava pour out of the central vent. The molten lava then fills up the caldera and spills out into lower regions, resulting in very large pools of molten lava. The largest lava lake is approximately 250 m across, found within Mount Nyiragongo, Democratic Republic of the Congo. Depending on the source given for the map size of *Breath of the Wild*, estimates for the lava lake at Death Mountain range from 500 m (Chubby_Bub, 2017) to 5000 m across (Webster, 2017). This is a common video game trope for lava pools, as their vast size helps to create a sense of danger that must be carefully navigated, adding a colour contrast as well to an otherwise dark and barren landscape (McGowan & Scarlett, 2021). In reality, rivers of lava are prevented from flowing far in a molten state due to the significant temperature difference between the molten lava and the surface atmosphere, causing the surface of the lava to rapidly cool into hardened rock.

Tears of the Kingdom is set a short period after *Breath of the Wild*. Now, the volcano is in a quiet dormant phase. Lava is no longer pouring out of the vent, and the previously vast lava lakes are no longer there. This could be perceived as the lava cooling to form a new layer of rock. However, during the quest "The Hidden Treasure at Lizard Lakes," an elder Goron talks about how two lakes in the north were rumoured to hide some treasure, but then Death Mountain became active, and lava covered the lakes. Now that the volcanic activity has subsided, the lakes are once again visible, thus implying the lava had drained away like water, not cooled like it would in reality.

A new subterranean region, the Depths, is introduced in *Tears of the Kingdom*. Spread across the entire map, the Depths are accessed via numerous chasms found throughout Hyrule, including one in the crater of Death Mountain. While the Depths help visualise the magma reservoir existing beneath a volcano, there is a distinct lack of walls to form a magma chamber. Therefore, no pressure can build up beneath Death Mountain. In addition, feeder dykes cannot be established between the subterranean magma and the surface due to a lack of walls for the magma to ascend through (Marsh, 2015). Both issues mean the volcano should not be able to erupt anymore. The landscape gives the impression that these walls never existed, as there are no structures that could be remnants of destroyed walls. Therefore, the Depths gives a completely false interpretation of the subterranean volcanic system that feeds actual active volcanoes. One explanation could be a developer's decision to make the Depths easier to navigate. In the early stages of the game, the Depths are completely dark, so walls make it confusing for players to explore. Because the chasm at Death Mountain

can be accessed fairly early on, not including any walls around the magma makes the area much easier to navigate for newer players.

In the real world, magma chambers are located at depth and comprise a crystal mush of molten rock (Bachmann & Bergantz, 2008; Marsh, 2015), leaving no voids for humans to explore. There is only one known volcano that is internally accessible to humans, namely Thrihnukagigur in Iceland, where the remaining magma drained back into the deeper depths of the magmatic system (LaFemina et al., 2015). It is currently unknown why Thrihnukagigur is unique in this regard. The morphology of other volcanoes is known to science via seismic tomography, a technique that uses seismic waves to image the Earth's interior or exposed plutonic bodies, i.e., masses of igneous rock that solidified deep underground and are now exposed at the surface by erosion (Bachmann & Bergantz, 2008).

The Submerged Timeline

In the timeline following *Ocarina of Time*, whereby the hero was triumphant as an adult, Hyrule is submerged beneath the Great Sea, transforming Hyrule's tallest mountainous peaks into subaerial islands. This creates the timeline for *The Wind Waker* (Nintendo EAD, 2013b), *Phantom Hourglass* (Nintendo EAD, 2007), and *Spirit Tracks* (Nintendo EAD, 2009). Despite Death Mountain frequently being one of the highest points in Hyrule, none of the subaerial islands are confirmed to be part of the volcanic peaks.

In *The Wind Waker*, Dragon Roost Island and Fire Mountain can be found in a very similar geographical location to Death Mountain in *Twilight Princess*. Therefore, it can be reasonably assumed that the locations are the same, absent official confirmation. Of the two islands in *The Wind Waker*, Fire Mountain displays the most active surface volcanism (see Figure 5).

Figure 5. Fire Mountain (suspected Death Mountain) in *The Wind Waker*. The volcano is currently very active, with a tall fire fountain erupting

from the vent, and multiple rivers of lava pouring into the sea.
Screenshot by the author.

Floods of this scale are not realistic and are instead the product of the game developer's imagination, likely drawing inspiration from ancient myths (e.g., Noah's Flood), or Hollywood movies such as *2012* (Emmerich, 2009). Although this scenario does not realistically depict the true evolution of a volcano, some island volcanoes do eventually become submerged, and their volcanic features can still be compared to those shown in *The Wind Waker*. Now surrounded by seawater, Fire Mountain is prone to hydrovolcanism, i.e., interactions between water and magma. Depending on how the water and magma interact, the eruption style can change. For example, magma interacting with groundwater (phreatomagmatic eruptions) tends to be more explosive and contain more of the older surrounding rock in the deposits than magma interacting with shallow standing water (surtseyan eruptions; Németh & Kósik, 2020). Lava eruptions also occur at emergent and subaerial volcanic islands, producing basaltic to intermediate (48-63% SiO_2) lava fountains and flows, such as those depicted at Fire Mountain in *The Wind Waker* (see Figure 5; Cole et al., 2001; Sohn, 1995).

Fire Mountain's presence in *The Wind Waker* marks the final appearance of Death Mountain in the Submerged timeline, as it is no longer present in *Phantom Hourglass*, and *Spirit Tracks* is set in a new land. Additionally, the Gorons, who previously inhabited the volcano in many games, are in *Phantom Hourglass* found on an island to the southeast of their original location. This may be due to the island being eroded to below sea level (de Silva & Lindsay, 2015), or destroyed by an explosive caldera-forming eruption (Staudigel & Koppers, 2015).

Calling Death Mountain Home

Gorons are a race of hardy, yet peaceful beings. Their natural resistance to heat, as well as their rock-crushing strength, make them perfectly suited to Death Mountain's harsh environment. As a result, they are generally unfazed during times of volcanic unrest and choose to remain. This resembles locals at real volcanoes who refuse to evacuate, wanting to preserve their livelihoods or protect their assets (Barclay et al., 2019; Kelman & Mather, 2008). The Gorons make their first appearance at the volcano in *Ocarina of Time*. By *Twilight Princess*, they have established a mine to extract ore from the volcano. The ore is never specified, although in *Breath of the Wild*, their industry extends to mining precious gemstones (including rubies, sapphires and diamonds), and Rock Roasts, which are rocks the Gorons cook and eat (see Figure 6).

Figure 6. (a) A Goron mining company in *Breath of the Wild* mining an unnamed ore. (b) A Goron vendor located in Goron City in *Tears of the Kingdom* selling sapphires. The vendor comments on how the gems are sold cheaper in the region due to being sourced locally. Screenshots by the author.

Water percolating into the ground around volcanoes can become heated by shallow magma, creating hydrothermal systems. These heated waters can become enriched in metals which, as the water rises and cools, precipitate the metal in concentrated ore veins. Metal ores found within hydrothermal systems can include copper, lead, zinc, gold, and silver (Lipman, 1984), making them key sites for mining companies. These hydrothermal systems are also related to the hot springs previously mentioned. The majority of precious gemstones mined by the Gorons can be found within volcanic rocks. Topaz can crystallise within cavities formed by the cooling of gas bubbles within the lava. For diamonds, rubies, and sapphires, magma from depth can entrain the minerals and bring them to the surface (Kneller, 1990, p. 71).

In *Breath of the Wild*, the Gorons are concerned with the prospect of tourists being deterred by lava bombs from the active volcano and the impact it is having on their economy. Volcanoes are an ever-growing popular geo-tourist destination (You Lim & Flaherty, 2020). However, much like the characters in Zelda, actively erupting volcanoes can deter visiting tourists and cause major economic impacts to local communities

in the real world. Following the 2017 eruption of Mount Agung, Bali, hotels saw an average 28.6% decrease in visiting tourists compared to the previous year (Rhamawati et al., 2018). The 2019 eruption of Whakarri/White Island, New Zealand, which caused the deaths of nineteen people and seriously injured a further twenty-five, has called into question a ban on geo-tourism to active volcanoes to prevent further fatalities elsewhere (Usborne, 2020). Visiting active volcanoes is of particular concern because, although it is possible to determine when a volcano is experiencing heightened levels of activity, it is still impossible to know exactly when a volcano will erupt.

During the events of *Twilight Princess*, the Gorons have denied non-Gorons access to the volcano during the active eruption. However, such actions have not been seen in any other Zelda game. Since the name of the volcano was changed from Eldin to Death Mountain due to the large number of fatalities it has caused, restricting access to the volcano during similar periods of severe unrest is something that Hyrule may want to consider more often.

On the flipside, some eruptions can reverse their initial economic impact, as increased media coverage creates new public interest. For example, the eruption of Iceland's Eyjafallajökull in 2010 grounded thousands of flights, causing major economic damage worldwide (Volcanic Ashfall Impacts Working Group, 2016). Conversely, the volcano has since become a popular geo-tourist destination and has even been responsible for the creation of a visitor centre in Iceland dedicated to the volcano (Erfurt, 2022; Usborne, 2020).

Magmatic Origin

It is currently unknown how long the entire Zelda timeline represents because many of the games do not specify the time between events. A minimum time is given in *Breath of the Wild*, where the events take place 10,000 years after "The First Great Calamity." It has not been confirmed if one year in Hyrule is the same as one year on Earth, but for ease of comparison, it shall here be assumed that it is the case. Regarding "The First Great Calamity," it is not mentioned when this occurred in relation to the other games, and so it is unknown where they fall within the 10,000-year span mentioned. Geologically speaking, 10,000 years is a relatively short period of time and so do not give an indication of the tectonic environment that Hyrule could reside in. For example, the Borrowdale Volcanic Group in the United Kingdom is a 6 km-thick volcanic succession that formed within a volcanic arc system at a subduction zone. It has been estimated that volcanism occurred over a period of 5–20 million years (Kneller et al., 1994; Piper et al., 1997). At the Yellowstone hotspot, super-eruptions (such as those that would create Death Caldera) occurred at a rate of 500,000 to 1.5 million years, with smaller eruptions still happening in between (Knott et al., 2020). Therefore, Death Mountain's static position in the northeast of Hyrule is consistent with both a subduction and a hotspot system.

Death Mountain is separated from the mountainous regions of Hyrule, the Hebra Mountains, by low-lying plains (see Figure 7). In a subduction zone, active volcanoes occur all along the overriding plate, forming island arcs or mountain ranges. This does not fit with the topographic landscape of Hyrule, where volcanism is isolated to a single region. In hotspot settings, active volcanoes only occur directly above the hotspot. As the tectonic plate moves away, volcanism ceases at that point on the surface, leaving behind a chain of extinct volcanoes. This could be the case in Hyrule, with the western Hebra Mountains forming when they were above the hotspot. This would explain how the mountain range formed with very limited evidence of modern volcanism (e.g., Sturnida Lavafalls heating the Sturnida Secret Hot Spring), while the nearby Death Mountain is extremely active.

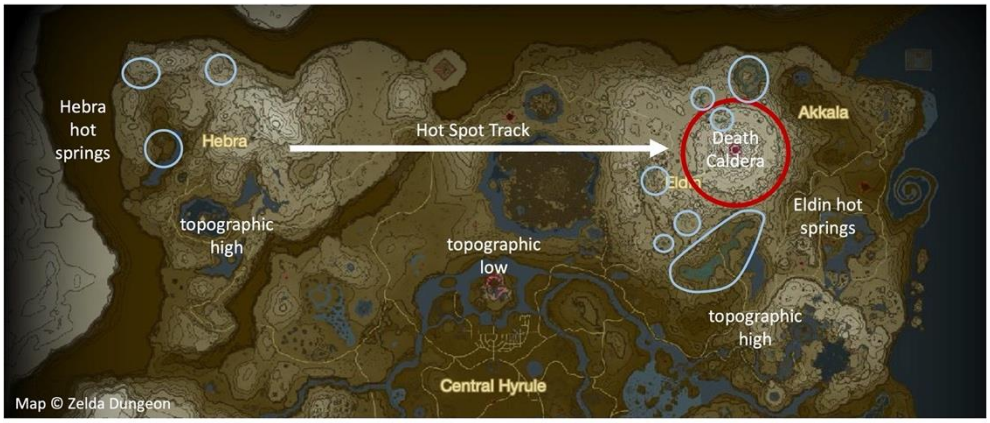

Figure 7. Map of North Hyrule from *Tears of the Kingdom*, showing the location of hot springs (blue rings) in the Hebra and Eldin regions. Increased hot spring population as well as the location of Death Caldera (red ring) suggest the surface expression of the hot spot has moved from Hebra to Eldin. Brighter cream areas indicate topographic highs, whilst darker brown areas indicate topographic lows. Base map was used with permission from Zelda Dungeon.

Death Mountain's incorporation of far-flowing rivers of lava and explosive eruptions suggests it is fed by a bimodal lava system. Bimodal volcanism experiences stark transitions between basaltic (low silica content) and rhyolitic (high silica content) compositions, with a noticeable lack of intermediate magma (Marsh, 2015). Rhyolitic lava is more viscous and results in explosive volcanism, commonly seen during periods of unrest in the games (e.g., *Twilight Princess*). It is more likely that the lava erupted from Death Mountain is commonly rhyolitic, as the highly viscous lava would not flow very far and instead build up the steep, narrow shape of the volcano's slopes (e.g., *Breath of the Wild*). Low viscosity, basaltic lava would then occasionally erupt, producing the extensive rivers of lava that flow far from the volcanic vent (Harris & Rowland, 2015). Bimodal volcanism can occur at a range of tectonic settings, including hotspots (Freundt-Malecha et al., 2001; Lacasse et al., 2007).

Conclusion

Since 1987, Death Mountain has appeared in 12 The Legend of Zelda games. This study presents evidence showing Death Mountain gradually evolving as the magmatic system becomes more prevalent. Up until *Breath of the Wild*, notwithstanding games that are part of the submerged timeline, Death Mountain is presented as a typical stratovolcano that experiences bimodal magmatism. As time progresses, evidence in the form of ore deposits and hot springs shows that a hydrothermal system is developing in the region. The hydrothermal system continues to grow up to *Tears of the Kingdom* when extensive volcanism is found throughout the Eldin region. It is clear from the volcanological evolution of Death Mountain that, starting with *Breath of the Wild*, a significant amount of time has passed since previous games. Not only has the volcanic region increased in size, but the addition of Death Caldera is evidence of a significant eruption in Hyrule's past that has yet to be shown. Such a volcanic eruption in a region like the one in the Zelda games is entirely plausible. Within the submerged timeline, players are shown an alternative life cycle of a subaerial island volcano that eventually erodes away below sea level. Although the origin for the massive flood is not directly comparable to real-world hydrovolcanic environments, merit can still be given to the visual representation of the volcano. With the exception of the submerged timeline, a reasonable volcanic evolution of Death Mountain can be traced. This evolution is something that is not possible to observe in a single real-world volcano due to the geological timescale in which they exist. Furthermore, a coherent evolution of Death Mountain suggests that, whilst Zelda director Anouma's (Nintendo, 2011) claim that each game's position in the timeline is only an afterthought may be true for the early-stage designs, more considerations may have been made in later-stage development to allow for a coherent flow from game to game.

Despite the fact that a coherent volcanic evolution can be observed on a broad scale, individual components present a mixture of accurate and inaccurate volcanism portrayed within many of the Zelda games. Inaccurate representations include typical tropes seen in other commercial off-the-shelf video games, such as *LEGO Marvel Superheroes 2* (TT Games Ltd., 2017)*, Monster Hunter: Generations Ultimate* (Capcom, 2018), and *Subnautica* (Unknown Worlds Ent., 2018), such as unrealistically steep volcanic slopes, excessive volumes of lava that maintain a molten state, and inaccurate interpretations of the interior of a volcano (McGowan & Scarlett, 2021). Because these are all common inaccurate video game volcano tropes, it is most likely the developers have purposely chosen the industry established entertainment value of spectacular graphics over the less conventional immersion of a more realistic representation. Clements et al. (2022) argue that inaccuracies in the representation of palaeontology within video games can have a negative impact on the perception of the subject. Although the inaccurate volcanism found in the Legend of Zelda

games could be perceived to have a similar negative impact, a counterargument can also be made. The appeal of these "overly volcanic" landscapes can help to engage and encourage people to study volcanology, where they can then discover how volcanism truly operates. Evidence supporting how Zelda video games may influence a career choice towards geology can be found, for example, in confessions of volcanologist Robin George Andrews (2021), who states that he was inspired to enter the field after playing *Ocarina of Time*. Additionally, Hernandez et al. (2023)'s guest in their podcast episode "Depths of Death Mountain" used Zelda games to communicate geology concepts to a broader audience. Furthermore, interacting with these virtual volcanic features could facilitate tangential learning and allow players to discover the truth through self-education (McGowan & Alcott, 2022). These examples provide evidence that The Legend of Zelda series can be used to help overcome the negative perception highlighted by Rogers et al. (2023) that geology is "boring" and "irrelevant" to contemporary society by teaching volcanological concepts in an entertaining and engaging way. It is my belief that the results from this paper can be used to further promote the use of video games to encourage continued education within geology-related subjects.

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