The Potential for Using Video Games to Teach Geoscience: Learning About the Geology and Geomorphology of Hokkaido (Japan) from Playing Pokémon Legends: Arceus

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Abstract.

In recent years, video games, as a geoscience communication tool have gained momentum. Popular commercial video games see millions of people around the world immersed in wonderous landscapes, many filled with real geological features including volcanoes, mineral deposits, and dinosaurs. Even though these features can be overlooked by many players as simple video game tropes, if utilised in educational environments or scientific outreach events, video games have the potential to encourage and stimulate teaching of geoscientific concepts, both in the classroom or in their own time. Here, we focus on the geo-educational potential of *Pokémon Legends: Arceus*, the latest game in the popular Pocket-Monster franchise, *Pokémon*. *Pokémon Legends: Arceus* is set in a fictional landscape, Hisui, that is directly based on the real-world island of Hokkaido, northern Japan. Both formal (peer-reviewed literature) and informal (online websites) resources are used to explore in-game and real-world geological feature comparisons and assess the game's educational potential. This paper demonstrates that a single commercial video game can be used to explore a variety of geological and geomorphological concepts including volcanology, economic geology and hazard-mitigation, with direct real-world examples to support the geoscientific understanding. Applications for this study could be extremely useful for not only increasing interest and facilitating the self-learning of geoscience worldwide, but also for teaching in educational environments. From an educational standpoint, *Pokémon Legends: Arceus* could be used as a powerful tool to help students engage more in their learning by utilising their natural affinity to the popular game and showcasing the many geological and geomorphological features found across the landscape of Hisui.

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Deleted: Released at the start of 2022 on the Nintendo Switch, the game saw over 6.5 million players in its first week explore the virtual open-world landscape of Hisui.

1. Introduction

1.1. Learning via Video Games

Video games are commonly used to teach primary subjects for younger audiences (e.g. basic arithmetic and simple logic-based skills), however, video games have also previously been explored in various advanced educational topics for several years (Adams, 1998; Squire, 2005; Pew Research, 2008; Squire et al., 2008; de Freitas, 2008). In many cases, specifically designed games were developed to teach players about particular topics, focussing the gameplay on presenting players with information required to pass tasks and progress within the game (Shute et al., 2013; Mani et al., 2016; Kerlow et al., 2020). However, the teaching potential of such 'educational' or 'serious' games may be nullified by failing to hold players' attention through sufficiently engaging gameplay (Kerawalla and Crook, 2005; Van Eck, 2006; Floyd and Portnow, 2012). 'Commercial' or 'entertainment' video games on the other hand prioritise engaging and entertaining gameplay over educational learning. This may lead players to miss the educational potential by creating the perception of fictional content (Floyd and Portnow, 2012; Brown et al., 2014). As a result, the prioritisation of entertainment over educational value is a deterrent for those wishing to use video games as educational tools.

The lines between educational- and entertainment-focused gaming are increasingly blurred as real-world events and locations more frequently form the basis of new games (Brown et al., 2014). Video games provide exposure and greater appreciation of base subject matter, with players exploring the real-world implications of the gaming subject (Brown et al., 2014). Because commercial video games capture the voluntary and undivided attention of millions immersed in rich landscapes for extended hours (Mayo, 2009), they are a logical tool for boosting geoscience communication and education efforts.

Video games can be used to achieve educational goals via four different means: (1) using game mechanics to teach specific skills, such as map reading; (2) expanding vocabulary with game narratives; (3) improving social skills such as teamwork and communication; and (4) promoting tangential learning, i.e. self-directed learning inspired by exposure to a topic one already enjoys (Floyd and Portnow, 2012; Turkay and Adinolf, 2012). This study examines only the affective realms of 1, 2 and 4, as area 3 belongs to the realm of multiplayer or forum based games, which *Pokémon Legends: Arceus* is not.

Recent work by Hut et al. (2019), McGowan and Scarlett (2021) and Clements et al., (2022) illustrate how popular commercial games (including *Legend of Zelda: Breath of the Wild* and *Minecraft*) could be used as a form of geoscience communication to promote and educate the wider public, covering topics such as volcanology and palaeontology. If effectively used, commercial video games can become a powerful tool in educational settings, and at outreach events, to stimulate geoscientific education and engagement in students. However, despite the previously mentioned work, both on the use of video games in education in general and those directly applied to geoscience, video games are currently a rare resource tool used to teach geological concepts (Jolley et al., 2022).

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Video games also have further benefits to those with learning difficulties, (for example, attention deficit hyperactive disorders (ADD/ADHD) or dyslexia), who struggle to maintain focus using more conventional educational methods (Griffiths, 2002; Marino and Beecher, 2010; García-Redondo et al., 2019). In most cases, studies have shown video games improve a student's measured attention, as tested using the d2 test measures of attention, and motivation towards formal learning (García-Redondo et al., 2019). Additional benefits also include improved language comprehension and mathematics skills (Franceschini et al., 2013), mental agility, strategic reasoning (García-Redondo et al., 2019), time management and planning and organization (Bul et al., 2016).

1.2 Background of Pokémon Legends: Arceus

Released worldwide on the 28 January 2022, *Pokémon Legends: Arceus* is part of the eighth generation of Pokémon games spanning over a 25-year period. The game was extremely popular, selling over 6.5 million copies worldwide during the first week of release, making it the fastest selling game of the franchise at the time of writing (Knezevic, 2022).

Each set series of video games in the Pokémon franchise are set in a unique region, which are based on a real-world location. This not only inspires the design of the explorable game map (including layout, geography and environments), but also the Pokémon (based on real and mythological animals associated with that region), clothing, culture, food, and architecture. The first four generations are set in fictional versions of Japan, while later generations are based on other countries and states, including New York, USA (*Pokémon Black/White*) and the United Kingdom (*Pokémon Sword/Shield*; O'Farrell, 2018). The fictional region of Hisui in *Pokémon Legends: Arceus* is directly based on the island of Hokkaido, Japan (Nintendo, 2022). Hokkaido is used as inspiration for the *Pokémon Diamond/Pearl* games which are set during modern day, meaning that *Pokémon Legends: Arceus* is set in the past of the same region (Wikipedia, 2022).

Part of *Pokémon Legends: Arceus*' popularity lies in the game's graphics, which provides some of the most modern and realistic visuals seen in the franchise to date. Additionally, the gameplay has dramatically shifted from a fixed formulaic style with set paths for players to follow, to providing several open-world biomes for players to freely explore to research the Pokémon in their natural habitats.

Pokémon Legends: Arceus' combination of improved three-dimensional graphics and real-world inspiration, makes it an excellent choice to explore the educational potential of video games on geographic and geological features. It is important to note that even though much of the player base is likely to be classified as non-geoscientists, players are still likely to be able to identify differences between fake and realistic landscapes to inform their learning (Hut et al., 2019).

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By comparing real-world and in-game features, this paper aims to explore and test if a single video game can be used for a variety of educational topics. By doing so, the apparent 'realness' of the features can be assessed. This paper intends to be used as an example – in addition to the other 'geo-gaming' literature – to highlight how commercial video games could be applied in an educational setting (facilitated learning) and encourage the player's own self-learning (tangential learning; Floyd and Portnow, 2012; Brown et al., 2014) of geoscientific topics (e.g. McGowan and Scarlett, 2021; Clements et al., 2022).

2. Methods

Authors identified geological and geomorphological features, including active volcanoes, crater lakes and peninsulas, which were tied to key moments within the game's main narrative. This approach is inspired by McGowan & Scarlett (2021), where geoscientific features are identified in popular commercial video games and then compared to real-world examples. Features and areas that are a necessity for progression, therefore guaranteeing player-interaction, are particularly addressed. Features encompass extremely visible landmarks, including volcanoes, or frequently referred to locations that contain geological context in their name.

Real-world counterparts of the in-game features were identified based on geographical location and physical characteristics. Comparisons between the literature content and in-game appearance were made to determine if they form suitable explanations for the inspiration behind each feature.

It should be noted that *Pokémon Legends: Arceus* was developed to be played by the general population and not specifically for academic specialists. Therefore, informal sources (for example, Wikipedia and online magazines) will also be used alongside peer-reviewed literature as players potentially prefer this type of resource (Nisbet and Scheufele, 2009) or may be unable to access scientific papers behind paywalls.

3. In-Game Features

When comparing the in-game map of Hisui and that of Hokkaido, Japan, including topographic and geological maps (Ayalew et al., 2011), striking similarities in the topography and coastal outline are seen (Fig 1). Therefore, players can identify locations within *Pokémon Legends: Arceus* based on their relative geographic location and similarities (e.g. volcanic craters identifiable in topographic maps) and the literature reviews can provide additional geological understanding to the features (Table 1).

3.1. Obsidian Fieldlands

The first open area players may explore is the Obsidian Fieldlands: a lush grass land, with hilly ground in the centre, a large, forked river cutting northeast to southwest and a dense forest in the south. The locality's name suggests obsidian naturally occurs on this part of the island.

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Indeed, obsidian is a common volcanic material found on Hokkaido, having at least 21 confirmed primary sources of the glass across the island (Izuho and Sato, 2007). In contrast to Hisui, however, the majority of sites are located in the northeast of Hokkaido, around the Kitami Mountains, over 100 km from the Ishikari Lowland (Fig 2a; Izuho and Sato, 2007; Akai, 2008) - where the Obsidian Fieldlands are paralleled in *Pokémon Legends: Arceus* (Fig 1 and 2b).

The obsidian of Hokkaido was an important resource to Palaeolithic inhabitants on the island, where it was shaped into microblade tools. Such tools were created between 26-10 ka (Akai, 2008; Yakushige and Sato, 2014), and were widely transported across the island, including the Ishikari Lowland and Honshu, Japan's main island (Yakushige and Sato, 2014). X-ray fluorescence analysis of the obsidian microblades from the Ishikari Lowland allows individual tools to be traced back to their primary origin, including Akaigawa, ~40 km to the west, and Shirataki, over 170 km northeast (Akai, 2008).

An additional homage to Hokkaido obsidian is in the newly released *Pokémon*, Kleavor. It can be obtained using black augurite (a fictional mineral) or caught in the wild. Despite black augurite being fictional, its item design and Kleavor's mirror obsidian. Furthermore, the official description of Kleavor states Hisuians used the chipped pieces of stone that fell off Kleavor as tools (Pokémon Legends, 2022), evoking the use of obsidian tools by Hokkaido's indigenous inhabitants.

Whilst the name, Obsidian Fieldlands, suggests obsidian would be naturally present in this region, this is false. Instead, obsidian was likely transported from elsewhere on the island, suggesting the name is more of a homage to the once important resource to the Palaeolithic inhabitants.

3.2.1 Cobalt Coastlands

The Cobalt Coastlands, found on the east coast of Hisui, is another open access area (Fig 1a). As with the Obsidian Fieldlands, one could expect cobalt to be found in this coastal region. However, cobalt is mined in the central regions of Hokkaido, not on the east coast (Khoeurn et al., 2019). This draws into question the use of 'cobalt' in the area's name. Is it purely a catchy use of alliteration, or is there greater geological influence?

The area's name could be related to the popular tourist destination known as the Blue Pond (Fig 1b), a man-made pond famous for its "cobalt" blue waters (Biei Tourist Association, 2017; Smart Magazine, 2018). Following the 1988 eruption of Tokachi-Dake volcano, concrete dams were built to divert volcanic mudflows (lahars) away from populated areas (Ministry of Land, Infrastructure, Transport & Tourism, 2016; Smart Magazine, 2018). Lahars are amongst the deadliest volcanic hazards, ranking third (primary lahars) and forth (secondary lahars) out of thirteen, based on total number of fatalities (Brown et al., 2017). Not only can they flow tens to hundreds of kilometres from the flanks of a volcano, but secondary lahars can occur years after the primary event (Brown et al., 2017). An

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unexpected result of the hazard-mitigation was that aluminium-rich spring water from the volcano was also diverted, leading to formation of a pond with a distinctively blue hue (Smart Magazine, 2018).

While the Blue Pond is in central Hokkaido, not near the east coast where the Cobalt Coastlands are in *Pokémon Legends: Arceus* –a number of larch trees were drowned by the pond, turning silvery-white as they died (Smart Magazine, 2018). Such trees are found within the southern part of the Cobalt Coastlands in the area named Deadwood Haunt (Fig 1a), which contains numerous ghost type *Pokémon*, possibly a tribute to the drowned trees of the Blue Pond (Fig 3). This adds further merit to the idea that the Cobalt Coastlands are based upon the popular tourist destination.

3.2.2 Veilstone Cape – Volcanic Chains, Arches and Caves

One of the most prominent geomorphic features in the Cobalt Coastlands is the Veilstone Cape, a tall, narrow rocky headland (Fig 1a). On Hokkaido, the comparable feature is known as the Shiretoko Peninsula (Fig 1b). The real-world peninsula is the result of several overlapping volcanic complexes (Neogene to Holocene in age) that form the Kuril Volcanic Chain, running NEE-SWW from central Hokkaido to the eastern end of Shiretoko Peninsula (Minato et al., 1972). The volcanic chain constitutes part of the Kuril Island-arc System – a 1175 km arc system produced by the subduction of the Pacific Plate along the Kuril Trench (Khomich et al., 2018) - and through submarine volcanism, uplift and continued terrestrial volcanism resulted in the steep topography along the Shiretoko Peninsula (Chakraborty, 2018).

Along the Veilstone Cape in *Pokémon Legends: Arceus*, caves and arches cut through the coastal cliff (Fig 4a). While the comparable erosional features in Hokkaido are not as well reported as other elements mentioned in this paper, the cause may be due to the Shiretoko Peninsula being much wider and less steep than the in-game Veilstone Cape. As the fictional cape (Fig 4a) is taller and narrower than its real-world counterpart, it would be easier for coastal erosion to create the prominent arches seen at the end of the peninsula. Travelling inland the arches decrease in size, eventually forming only sea caves, where the coastal waters have yet to erode through and connect both sides, cleverly demonstrating the progressive evolution and formation of natural sea arches (BBC, 2022; Fig. 4b).

The major inaccuracy of Veilstone Cape is the size of the headland. In the real-world, the Shiretoko Peninsula is much longer, wider and has a gentler profile. However, this is likely a calculated resizing by developers to ensure the headland remains visually impressive without making it feel like a chore for players to traverse, something for which games with large maps can receive bad reviews for (Tassi, 2018).

3.2.3. Firespit Island – Active Volcano

Off the coast of the Cobalt Coastlands, in the northeast of the region, is Firespit Island (Fig 1a and 5a). This is a fictional location without a real-world equivalent in Hokkaido. Firespit Island is a large volcanic edifice, likely to be a stratovolcano due to its steep, conical slopes, tectonic setting and this being the most common type of video game volcano (McGowan and Scarlett, 2021). It has a

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distinguishable crater rim that is taller in the east, presumably the product of a violent explosive eruption that destroyed the rest of the cone (Fig 5a). To the west is a gap in the outer slopes and a shallow fan reaching into the sea. These pieces of evidence suggest a sector collapse and/or lateral blast modified the morphology of the main edifice and produced a debris avalanche (Romero et al., 2021).

Lava pours out of the vent of a new volcanic cone within the centre of the collapsed edifice (Fig 5b), which is one of the most common volcanic attributes seen in video games (McGowan and Scarlett, 2021). Post-collapse volcanism is common in volcanoes around the world, including Anak Krakatoa (Indonesia), Mt St Helens (USA), Soufrière Hills (Montserrat) and Bezymianny (Russia) (Girina, 2013; Watt et al., 2012; Watt 2019). However, lava flows produced in these post-collapse craters is typically highly viscous and does not 'pour out' of the vents (Carr et al., 2022). After progressing further through the storyline of the game, the lava ceases and solidifies into a mass within the vent forming a plug (Fig 5c).

Even though it is typical for mafic stratovolcanoes in arc settings, like that of Hokkaido, to rapidly build themselves upwards, producing steep slopes, typically between 21° – 40° (Romero et al., 2021). The old edifice and central vent on Firespit Island exceeds this, producing an unrealistically steep slope and cone (Fig 5). This is another common trope of video game volcanoes, with other overly steep stratovolcanoes also seen in *Legend of Zelda: Breath of the Wild* and *Monster Hunter: Generations Ultimate* (McGowan and Scarlett, 2021).

3.5. Spirit Lakes – Flooded Calderas

The storyline takes players to three lakes found across Hisui (Fig 1a). Upon reaching the islands in the centre of Lake Verity in the Obsidian Fieldlands (Fig 6a) and Lake Valor in the Crimson Mirelands (Fig 6c), a character named Volo explains that many believe these lakes formed after volcanoes erupted and craters later filled; the geographical locations of the two Hisuian lakes suggests they are the in-game versions of Lake Tōya (Fig 6b) and Lake Kussharo (Fig 6d) respectively.

The description of Lake Verity's formation (in the game) mirrors the series of six continuous rhyolitic caldera-forming eruptions which produced Lake Tōya and the < 80 m-thick Tōya Ignimbrite around 110 ka (Fig 6b). The first five events were phreatomagmatic, suggesting the presence of a pre-caldera lake (Machida et al., 1987; Goto et al., 2018). Post caldera volcanism (around 40-45 ka) produced Nakajima, an andesitic to dacitic dome complex in the centre of the lake (Goto et al., 2018).

Lake Kussharo (Lake Valor equivalent) is also situated within Kussharo Caldera (Fig 6d). The last major caldera-forming eruption is estimated around 30 ka (Fujiwara et al., 2017). Like Tōya Caldera, a post-caldera dome complex formed, producing a dacitic to rhyolitic island (Smithsonian, 2013a), alongside an additional caldera complex, the Atosanupuri Caldera, within the eastern half of Kussharo Caldera during the Holocene (Fujiwara et al., 2017).

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In both scenarios, the geomorphology of the Spirit Lakes and the descriptive dialog in *Pokémon Legends: Arceus,* accurately portrays features of real-world caldera lakes and post-caldera lava domes on Hokkaido.

3.6. Coronet Highland – Volcanic Peaks

The centre of Hisui houses a large mountainous area known as the Coronet Highlands where the tallest mountain on the island, Mount Coronet is located (Fig 1a). It can be presumed that the real-world equivalent is Mount Asahi, a 2,291 m stratovolcano within the Daisetsuzan Mountain Range, part of the Daisetsuzan volcano group, a complex of numerous stratovolcanoes and lava domes (Smithsonian, 2013b).

The Coronet Highlands are a barrier of progress in the modern day setting of *Pokémon Diamond/Pearl/Platinum* and likely represent the roughly north-south trending Hidaka Mountains on Hokkaido (Fig 1b). The Hidaka Mountains were initially formed through the collision of Eurasia and North American plate boundaries approximately 13 Ma within the Hidaka collision zone (Niida, 2010; Ichihara et al., 2019).

The Coronet Highlands also contain a "special magnetic field" that allows the evolution of certain *Pokémon*, such as Nosepass. Lodestones, a rare form of magnetite (Mills, 2004), is thought to be driven by lightning remanent magnetization, allowing them to be found at the Earth's surface as opposed to at depth (Wasilewski and Kletetschka, 1999) and were previously used in compasses. They are therefore a likely inspiration for Nosepass, which is noted to always point north and is checked by travellers to get their bearings (Bulbapedia, 2022).

3.7. Lake Acuity – Lagoon

Lake Acuity is the third Spirit Lake found within Hisui (Fig 1a and 7a). Unlike the two previously mentioned flooded caldera Spirit Lakes (Section 3.5), Volo does not say this lake formed due to a volcanic eruption. Instead, the character states it contains seawater, but does not know whether this is related to its geography, or a *Pokémon*. This hints at a different origin for Lake Acuity.

The origin of Lake Acuity is difficult to determine from in-game visuals alone because they are similar to the previously mentioned lakes (a topographically circular lake with an island in the middle), so it could be assumed it is also a flooded caldera with a central lava dome complex (Fig 6a, c and 7a). However, when consulting a geological map (Fig. 1c), no volcanic features are found in the real-world region, supporting the hint that Lake Acuity did not form in the same way as the other two Spirit Lakes and instead has a non-volcanic origin.

The lake is the most northern in Hisui, and therefore can be assumed that its real-world equivalent is Lake Onuma, Wakkanai (Fig 7b), the most northern lake in Hokkaido (Fig 1b). Due to Lake Onuma's proximity to the ocean at Soya Bay, tidal inflows can bring seawater into the lake (Ministry of the

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Environment, 2015). Despite none of the literature directly stating the lake's origin, it is more akin to a coastal lagoon than a volcanic lake and explains the change of descriptive dialog.

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4. Discussion

4.1. Tangential Learning about Hokkaido

Pokémon Legends: Arceus utilises a wide range of resources to communicate geological features to the player, including maps, physical structures/graphics, and dialogue from characters. These details may be used to facilitate learning and stimulate curiosity about the geology of Hokkaido. From the topics covered in this paper, *Pokémon Legends: Arceus* can be used to teach volcanology, hazard-mitigation, economic geology and more (Table 1). Whilst this knowledge was mostly applied to Hokkaido, the general principles could also be transferred to other similar geological settings around the world.

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While not every topic covered was explored in detail, this is realistic of the expectations for a player to do online searches to quickly understand more about features they have seen in the game. At the same time, these seem to be sufficient to gain a basic understanding of this region's basic geology and geomorphology.

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It is not logical to expect every player to share enough interest in geoscience-related topics to stimulate any desire for tangential learning. However, as noted by Floyd and Portnow (2012), even if only 0.1% of players conducted online investigations into a single feature mentioned herein, *Pokémon Legends: Arceus* would have facilitated a modicum of geoscience learning for >6,500 people worldwide.

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Even in situations such as understanding the use of 'cobalt' in the name of the Cobalt Coastlands, where the outcome was not as conclusive as others (e.g. the flooded caldera lakes with direct real-world equivalents), players are presented with the opportunity to learn about both mining on Hokkaido and lahar risk-management, while critically analysing the in-game evidence to draw a conclusion.

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There is also the possibility that the opportunity to learn about the real-world equivalents of game features could stimulate further interest to pursue additional tangential learning. For example, learning that Lake Verity/Lake Tōya formed due to a caldera-forming eruption, players could continue to research the volcanism of Hokkaido by investigating Firespit Island due to its very prominent volcanic features (crater, active vent, molten lava, etc), or the similar looking Lake Acuity and discover its non-volcanic origins. This could even expand into players conducting tangential learning on features not specifically found in the game, or on a larger scale (e.g. plate-tectonics and island-arc formation that resulted in the formation of Hokkaido).

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Caution is warranted when using video games in educational settings as the potential for learning misinformation is high. For example, players are informed that two of the three caldera lakes formed via volcanic activity, however the third lake is suggested to be possibly formed through different, unmentioned means. A caldera lake is defined by the volcanic activity that led to its formation, however

Deleted: should still be taken when using video games for education as not every aspect included is factually correct and may result in accidental learning of false information… For example, Lake Acuity is a good example, p…layers are informed on …hat two previous occasions that…f the three caldera lakes formed via volcanic activity, however the third lake it would not be difficult to assume the third would be any different…s suggested to be possibly formed through different, unmentioned means., especially when all three lakes have similar visual appearances. … [21]

due to the lack of volcanic activity in northern Hokkaido, there is merit to the change in descriptive dialog.

In addition, over-exaggeration is often found in popular media including video games to provide a more entertaining experience through 'speculative fiction' and artistic liberty (Shaw, 2014; Politopoulos et al., 2019). Such evidence was found in *Pokémon Legends: Arceus* in the overly steep volcanic slopes on Firespit Island. Unrealistically steep volcanic slopes are a common over-exaggerated feature of video game volcanoes (McGowan and Scarlett, 2021). It is efforts such as those demonstrated here that allow for the apparent accuracy and authenticity of features found within a medium to be assessed and then utilized in educational settings, as opposed to simply assuming learning will take place regardless of the quality of representation.

Furthermore, tangential learning through commercial gameplay can also be conducted using other games. For example, numerous mineralogical items are considered resources in video games that can ultimately lead to players better understanding the real world. A case of this was presented by Robb (2013) when interpreting mineral deposits in *Elder Scrolls V: Skyrim*, or the numerous games covered by Clements et al., (2022) on palaeontological topics.

4.2. Using Video Games in Geosciences

Despite professional instructors rarely utilising video games to teach geological concepts (Jolley et al., 2022), this example illustrates how they can be used to teach about a wide range of topics in an engaging way. Compared to other literature on the subject matter that investigates a single topic across numerous commercial video games (McGowan and Scarlett, 2021; Clements et al., 2022), the focus of this paper, shows how one game can introduce several geoscientific topics and potentially spark additional interest. This should reassure geoscience educators that they do not require access to multiple different video games to provide sufficient examples for their course.

The shift to online-based and hybrid learning following the COVID-19 pandemic has led to increasing reliance on newly-developed teaching methods including virtual field trips (MacKay, 2020; Bond et al., 2021) and other digital resources (Pringle et al., 2017; Jeffery et al., 2021). Video games can augment this new education paradigm. The use of virtual learning, including video games, holds numerous benefits, including increased accessibility for students who cannot attend field-based teaching due to costs or physical disabilities, as well as the ability to visit high-risk locations (Stainfield et al., 2000; Pringle et al., 2017).

The high standards of graphics, gameplay and internal functions of commercial video games takes considerable time and funding (Mayo, 2009) which educators cannot be expected to invest themselves. However, specific areas or features can require significant amount of gameplay to reach, meaning that alternatives should be investigated. YouTube or Twitch streams have access to thousands of video game walkthroughs, meaning one could select the appropriate video that covers the desired location or feature to show students in the classroom, without needing to own or play the game. The downside to this is

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reduced control over what is shown and no opportunity for students to directly engage in gameplay. Educators could also set homework to investigate the geology observed in a video game (either through direct gameplay or via videos), with further prompts and questions to help guide the students learning and promote tangential learning at home.

Pokémon Legends: Arceus also provides players with opportunities to develop other skills. For example, providing the player context to practice map reading skills and exposure to the utility of topographical maps.

Pokémon Legends: Arceus could also prove to be useful for geoscience communication to the wider public at geoscience outreach events. The game has a generally relaxed gameplay style and quick-to-understand controller mechanics, therefore, the game could be offered to non-geoscientists at outreach events, allowing them to casually under the tutelage of a geoscientist. *Pokémon Legends: Arceus* is also rated PEGI 7, meaning it is appropriate for everyone over the age of seven, and so accessible to a wide range of people.

5. Conclusion

Pokémon Legends: Arceus includes a wide range of geological and geomorphological aspects within its design, drawing direct inspiration from features found on Hokkaido. This ability to directly compare virtual and real-world counterparts could stimulate tangential learning in players should they be curious enough. Whilst an entire curriculum cannot be covered using *Pokémon Legends: Arceus*, it offers an additional way of *communicating* the science found in numerous geoscientific topics to the player/student.

Though care must be taken, either through using resources such as this one or a prior demonstration of the game to ensure appropriate information is being taught. The exposure potential of geological and geomorphological concepts through video games could be widespread. If only a small fraction of the player base conducts such learning, because the game is so popular and sold millions of copies, *Pokémon Legends: Arceus* can potentially facilitate learning about Hokkaido's geoscience for thousands of players worldwide. This reach can be extended by using the game as a prompt in classrooms to increase student engagement.

Furthermore, the popularity of commercial video games within the wider public could be leveraged at outreach events to enhance general understanding of and engagement with regional geoscience topics. Specifically, *Pokémon Legends: Arceus* can be used to engage people with Hokkaido's geology in an entertaining way. In the proper context, a single popular commercial game has the potential to be a powerful tool for geoscience communication and education.

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Data Availability

All data was collected through playing *Pokémon Legends: Arceus* on the *Nintendo Switch*. Additional background information about the game can be found at https://legends.pokemon.com/en-us/ . We do not have permission from the developers to share free access to the game. However, they are all publicly accessible to purchase.

Author Contribution

Conceptualization: McGowan & Alcott. **Methodology:** McGowan & Alcott. **Investigation:** McGowan & Alcott. **Formal Analysis:** McGowan & Alcott. **Resources:** McGowan & Alcott. **Data Curation:** McGowan & Alcott. **Writing – Original Draft:** McGowan & Alcott **– Reviewer Edits:** McGowan & Alcott. **Visualization:** McGowan. **Supervision:** N/A. **Funding Acquisition:** This project is not directly funded; however, E. G. McGowan is funded by the NERC CENTA DTP studentship. L. Alcott is funded by a Hutchinson Postdoctoral Fellowship from the Yale Institute for Biospheric Studies.

Acknowledgment

We would like to thank Marc Reichow for taking time out of his busy schedule to review this paper during the draft phases. Additionally, we would like to fund our funding bodies; E. G. McGowan is funded by NERC CENTA DTP, and L. J. Alcott is funded by a Hutchinson Postdoctoral Fellowship from the Yale Institute for Biospheric Studies.

Competing Interests

The authors declare that they have no conflict of interest.

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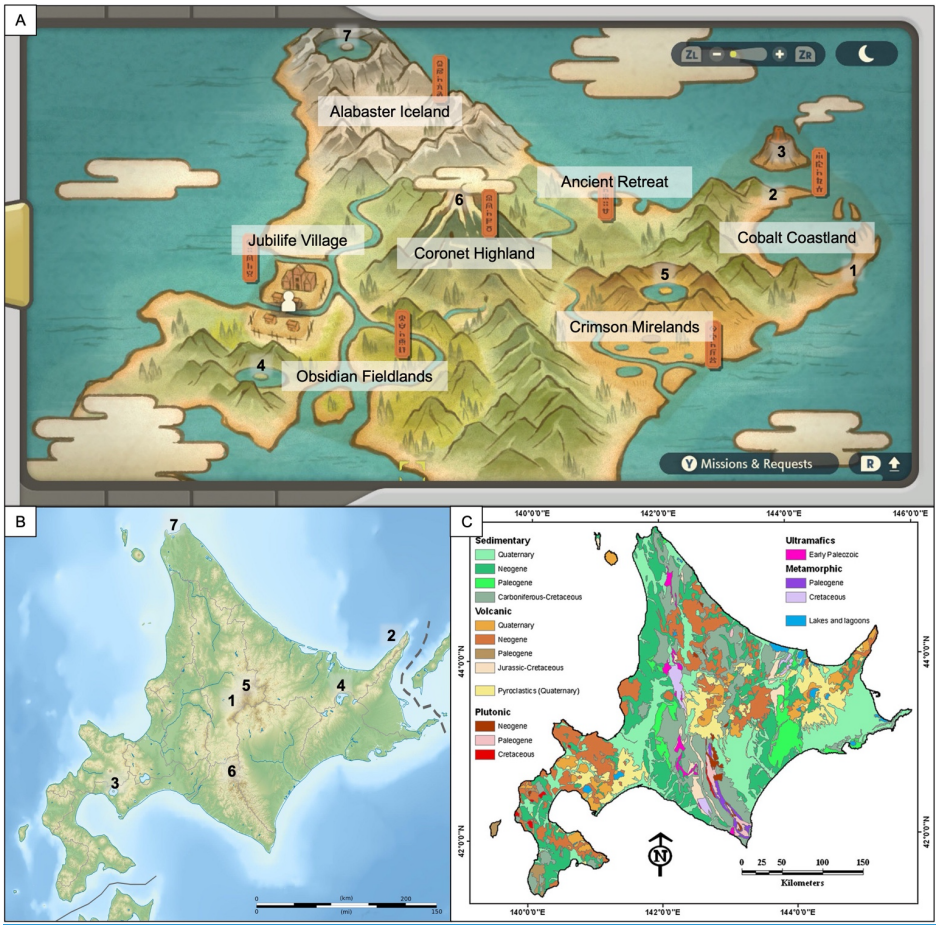

Figure 1: Topographic maps of Hisui, *Pokémon Legends: Arceus* and Hokkaido, Japan. (A) Annotated in-game map of Hisui from *Pokémon Legends: Arceus.* Note the non-traditional angle of viewing and artistic style (1) Deadwood Haunt, (2) Veilstone Cape, (3) Firespit Island, (4) Lake Verity, (5) Lake Valor, (6) Mt Coronet, (7) Lake Acuity © The Pokémon Company (2022). (B) Terrain map of Hokkaido, Japan (1) Biei Blue Pond, (2) Shiretoko Peninsula, (3) Lake Tōya, (4) Lake Kussharo, (5) Mt Asahi, (6) Hidaka Mountains (7) Lake Onuma (Bourrichon, 2019). (C) Geological map of Hokkaido, Japan (Ayalew et al., 2011).

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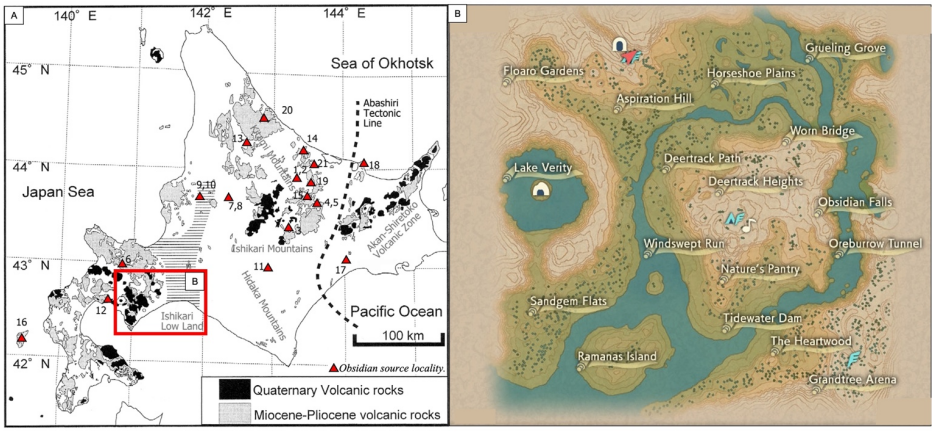

Figure 2: (A) Map of Hokkaido showing the source locations of all 21 recorded obsidian sites (red triangles) across the island (Izuho and Sato, 2007) and the location of the Ishikari Lowland that the Obsidian Fieldlands (red box) is based on in *Pokémon Legends: Arceus*. (B) A zoomed-in game map of the Obsidian Fieldlands (zoomed-out version in Fig 1a) from *Pokémon Legends: Arceus* © The Pokémon Company (2022).

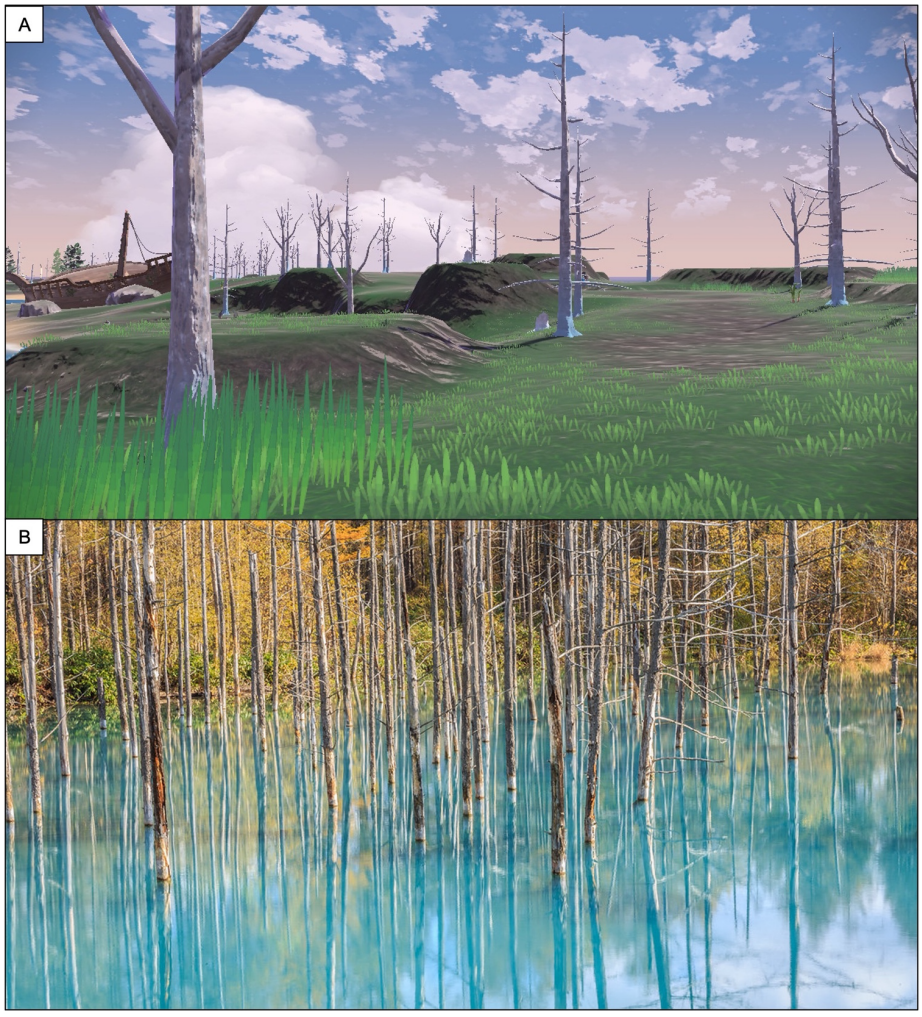

Figure 3: Comparison image of in-game and real-world inspiration. (**A**) White trees found in Deadwood Haunt, Cobalt Coastlands in *Pokémon Legends: Arceus* (Fig 1a,1), © The Pokémon Company (2022). (**B**) Photograph of dead larch trees, Blue Pond, central Hokkaido (Fig 1b.1) (Gilad Rom, 2015).

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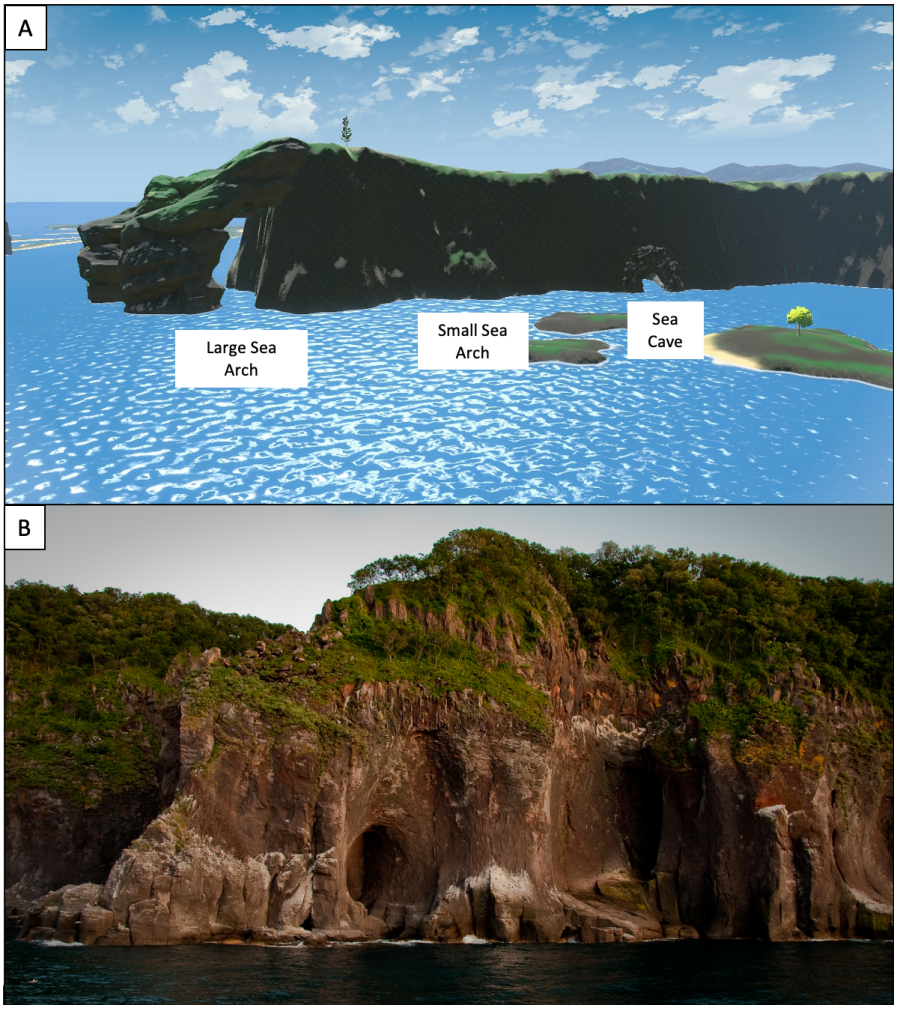

Figure 4: Sea arches and sea caves that can be found along Veilstone Cape in Cobalt Coastlands, *Pokémon Legends: Arceus* (Fig 1a.2), © The Pokémon Company (2022). (B) Photograph of coastal arches found along the Shiretoko Coast (Fig 1b.2) (civ33, 2009).

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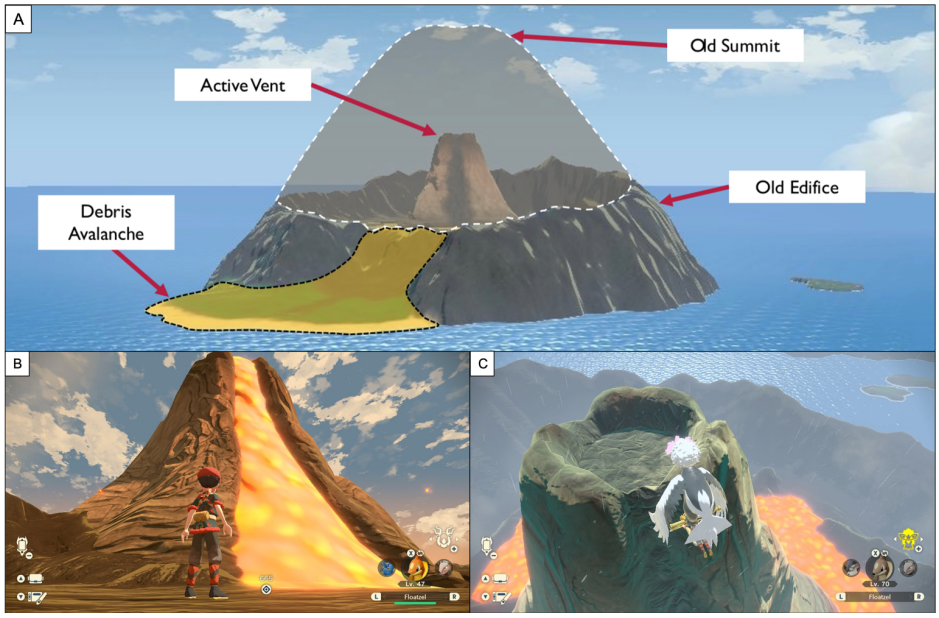

Figure 5: Images of the volcano, Firespit Island, located in the Cobalt Coastlands in *Pokémon Legends: Arceus* (Fig 1a,3) **(A)** Annotated schematic of Firespit Island showing a hypothetical look of the volcano pre-sector collapse and highlighting the resulting debris avalanche. (**B**) Close up of the steep, central active vent with lava flowing out (**C**) Volcanic plug that forms after the lava eruption ceases. © The Pokémon Company (2022). There is no direct comparison for this volcano found on Hokkaido, Japan (Fig 1b).

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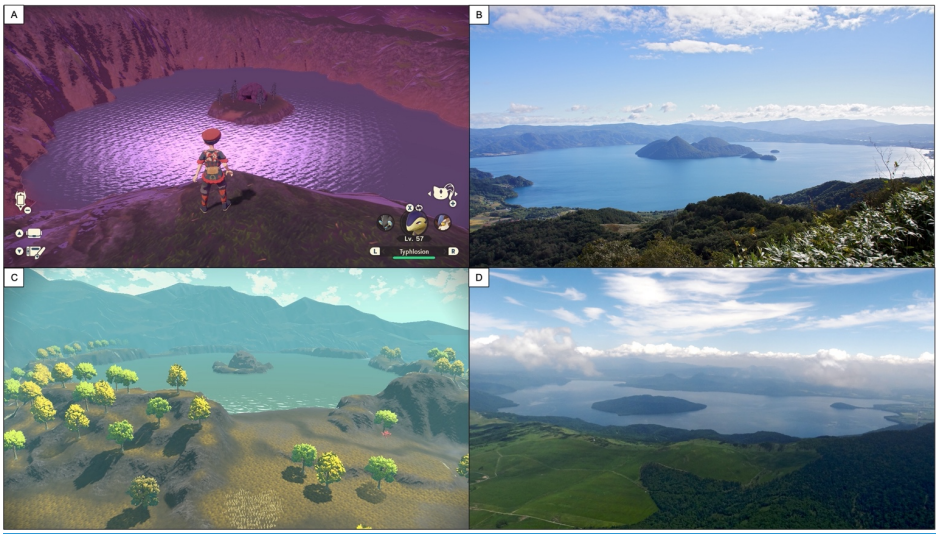

Figure 6: Comparison image of in-game and real-world inspiration. (**A**) Lake Verity, Obsidian Fieldlands, with caldera rim and lava dome island in *Pokémon Legends: Arceus* (Fig 1a.4) © The Pokémon Company (2022). (**B**) Photograph of Lake Tōya, Hokkaido, with Nakajima Island, Japan (Fig 1b.3) (633highland, 2013b). (**C**) Lake Valor, Crimson Mirelands, with caldera rim and lava dome island in *Pokémon Legends: Arceus* (Fig 1a.5) © The Pokémon Company (2022). (**D**) Photograph of Lake Kussharo, Hokkaido, with Nakajima Island, Japan (Fig 1b.4) (633highland, 2013a).

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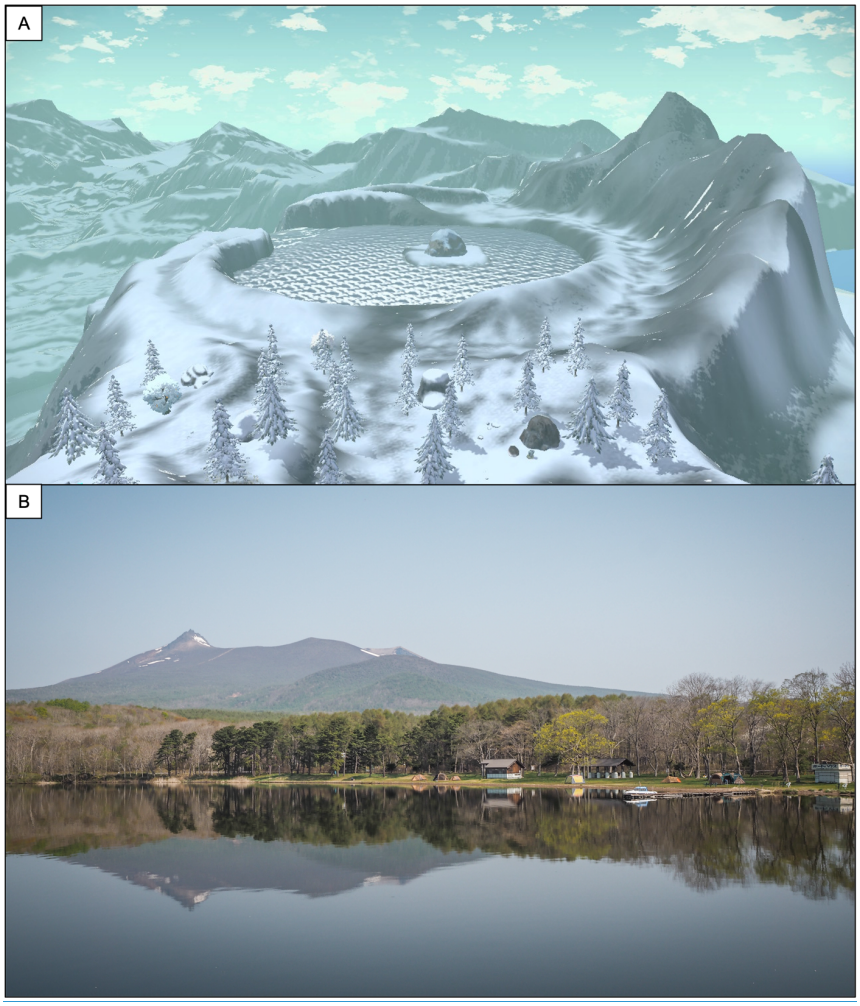

Figure 7: Comparison image of in-game and real-world inspiration. (**A**) Lake Acuity, Alabaster Iceland, a high-seat, crater-like lake with a central island in *Pokémon Legends: Arceus* (Fig 1a.7) © The Pokémon Company (2022). (**B**) Photograph of Lake Onuma, Hokkaido, (Fig 1b.7). Lake Onuma does not have a central island (Thompson, 2015).

Table 1: Summary of author interpretations of the geological and geomorphological features selected within *Pokémon Legends: Arceus*, based on in-game visuals or prompts, versus the geological understanding of the features post-literature review.

In-Game Features	Geological interpreted of features pre-literature review	Geological understanding of feature post-literature review	In-game features realistic based on comparison to post-literature review?	Topic
Obsidian Fieldlands *(Location Name)*	The area is named after obsidian, volcanic glass, that can be found naturally occurring in this area.	Hokkaido obsidian sources are considerable distance away. Instead, the obsidian found here are Palaeolithic tools.	Close. Direct link to obsidian glass, however, is local presence has a more archaeological origin than geological	Physical volcanology, Archaeology
Cobalt Coastland *(Location Name)*	Cobalt was concentrated into economic deposits in the east of the island due to hydrothermal systems related to the local volcanism.	Cobalt can be found on Hokkaido; however, it is not a primary mined metal. Instead, the name is likely a result of a "cobalt" blue pond formed because of lahar-mitigation dams diverting a volcanic spring.	Plausible. However, an alternative solution is more justifiable.	Economic Geology, Physical volcanology, Hazard-mitigation
Veilstone Cape *(Peninsula & Sea Caves)*	Island-arc volcanism related to the subduction of the Pacific Plate underneath the Eurasian Plate. Or extreme erosion of softer rock either side of the peninsula. Erosion of the peninsula is evident in the sea cave and arches present.	The peninsula is the result of island-arc volcanism (submarine and aerial) and tectonic uplift due to the subduction of the Pacific Plate underneath the Eurasian Plate. Sea caves and arches present.	Yes. Additional information helped to expand on the pre-literature interpretation.	Physical volcanology, Plate Tectonics, Erosional Processes
Firespit Island *(Active Volcano)*	Active volcanic island off the east coast of Hokkaido. During a previous explosive eruption, the volcano experienced a sector-collapse. Post-collapse volcanism continues.	There is no volcanic island off the east coast of Hokkaido to directly compare to. However, literature on volcanic sector-collapses support most in-game visuals, except for overly steep slopes.	Yes. Although literature reviews on other, non-Hokkaido volcanoes was required.	Physical Volcanology

Spirit Lakes – Lake Verity & Lake Valor *(Crater Lake)*	Both lakes formed due to a caldera-forming eruption, creating a depression that was later infilled by water. Post-collapse volcanism created lava dome islands.	Lake Tōya is found at the location of Lake Verity. Lake Kussharo is found at the location of Lake Valor. Both formed due to caldera-forming eruptions and have post-collapse lava dome complex islands.	Yes. Additional information helped to expand on the pre-literature interpretation.	Physical Volcanology
Coronet Highland – Mt Coronet *(Mountain)*	Tallest mountain on Hisui. Possibly formed due to volcanic or tectonic processes related to the subduction of the Pacific Plate underneath the Eurasian Plate.	Mt Asahi is the tallest mountain on Hokkaido and is located similarly to Mt Coronet. It is a stratovolcano, part of the Daisetsuzan volcano group, a result of the underlying subduction of the Pacific Plate.	Yes. Additional information helped to expand on the pre-literature interpretation.	Physical Volcanology, Plate Tectonics
Lake Acuity *(Lake)*	Like the previous Spirit Lakes, Lake Acuity formed due to a caldera-forming eruption, creating a depression that was later infilled by water. Unknown reasoning for the presence of saltwater.	There are no volcanoes located in this area of Hokkaido. However, the most northern lake (possible lagoon) is low-lying and close to the sea. During stormy weather, saltwater can flow upstream into the lake.	No. Using similar in-game visuals to previous caldera lakes prompts a false interpretation. In-game dialog alone is also inefficient to draw an accurate interpretation of lake's origin.	Coastal Geography