

Article

Living with the Active Earth: Perspectives from Japanese Geoparks

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Abstract

This study examines all 48 members of the Japanese Geoparks Network to explore how human societies live with the Active Earth in one of the world's most tectonically active regions. Rather than treating geoparks as separate sites, the study analyzes them collectively in terms of geoheritage, geohazards, hydrological environments, and community-based activities. The study is organized around four interconnected perspectives: (1) local geoheritage and Deep Time, (2) geohazards linking Human Time and Deep Time, (3) human life within Earth-system circulation, and (4) people and local communities connected through geopark participation. The results show that Japanese geoparks collectively preserve records of plate subduction, magmatism, accretion, crustal deformation, uplift, erosion, and hydrological processes that have shaped the Japanese active margin over hundreds of millions of years. These same processes continue to influence contemporary society through earthquakes, volcanic eruptions, water resources, ecosystems, agriculture, fisheries, and regional livelihoods. This nationwide analysis suggests that Japanese geoparks can be understood not only as sites for geoheritage conservation or tourism, but also as places where people recognize and sustain relationships among Earth-system processes, everyday life, and local communities.

Keywords: active margin; earth system; geoheritage; deep time; community participation

1. Introduction

Recent bibliometric analyses have shown that geopark research has expanded rapidly over the past two decades and continues to diversify in both volume and research themes [1,2]. Major research areas include geoheritage and geoconservation [3–6], geotourism [7–10], geoeducation [11–14], and socio-economic studies [15–18]. In addition to these individual research themes, an increasing number of studies have adopted interdisciplinary perspectives that integrate multiple functions of geoparks, such as conservation and tourism, education and regional development, or geotourism and community participation [3,7,13]. Collectively, these interdisciplinary studies have advanced the theoretical framework and practical implementation of geoparks, while also broadening discussion toward geoethical perspectives and the societal roles of geoparks [19–22].

As geopark research increasingly adopts interdisciplinary approaches that integrate multiple functions of geoparks, extending such approaches to broader spatial scales is becoming particularly important for geopark research in active-margin regions such as Japan. Japan is situated within one of the world's most tectonically active regions, where plate subduction continuously generates earthquakes, volcanic eruptions, mountain building, erosion, sediment transport, and hydrological circulation. These processes occur widely



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across the Japanese island arc extending along oceanic trenches and may affect multiple regions simultaneously or successively. Therefore, in order to record, interpret, and communicate Earth-system processes in Japan, it is necessary to examine Japanese geoparks collectively through broad regional cooperation and interdisciplinary perspectives. Such an approach provides an important framework for exploring how people and communities can live with the Active Earth.

This study therefore examines all 48 members of the Japanese Geoparks Network [23] from the perspective of an integrated active-margin Earth system. It combines nationwide analyses of geological characteristics, geoheritage, geohazards, hydrological environments, and community-based activities with practical observations from the Hagi Geopark and the Miné-Akiyoshidai Karst Plateau Geopark [24].

Through this nationwide and integrated approach, the study examines how active-margin Earth-system processes have shaped, and continue to influence, regional environments and human society from an interdisciplinary perspective. The analysis integrates geological characteristics, geohazards, hydrological systems, Earth-system circulation, and community-based activities to explore the roles of geoparks in active-margin regions.

2. Materials and Methods

2.1. Materials

2.1.1. Study Sites

The study encompasses all 48 geoparks of the Japanese Geoparks Network as of April 2026 (Figure 1), including 11 UNESCO Global Geoparks and 37 National Geoparks. Although their designation status differs, all members of the Japanese Geoparks Network are evaluated and managed within a common national framework. The Japanese Geoparks Network promotes activities consistent with the principles and objectives of the UNESCO Global Geoparks programme among both National Geoparks and UNESCO Global Geoparks. Consequently, for the purposes of this study, all 48 geoparks are treated collectively as a single study population.

2.1.2. Rationale for Site Selection

The Japanese archipelago provides an exceptional region for examining relationships between Earth-system processes and human society because it has maintained an active-margin setting for approximately 500 million years. Magmatism, tectonism, accretion, geomorphology, hydrology, and crustal maturation associated with long-term oceanic plate subduction have produced diverse geological records that are essential for understanding active-margin processes and orogenic belts worldwide. At the same time, these processes continue to influence contemporary society through earthquakes, volcanic eruptions, steep landscapes, water systems, ecosystems, and regional livelihoods. For this reason, examining all 48 Japanese geoparks within a common national framework provides a suitable basis for investigating how Earth-system processes are expressed in an active-margin setting through geoheritage, geohazards, environmental conditions, and local community practices.

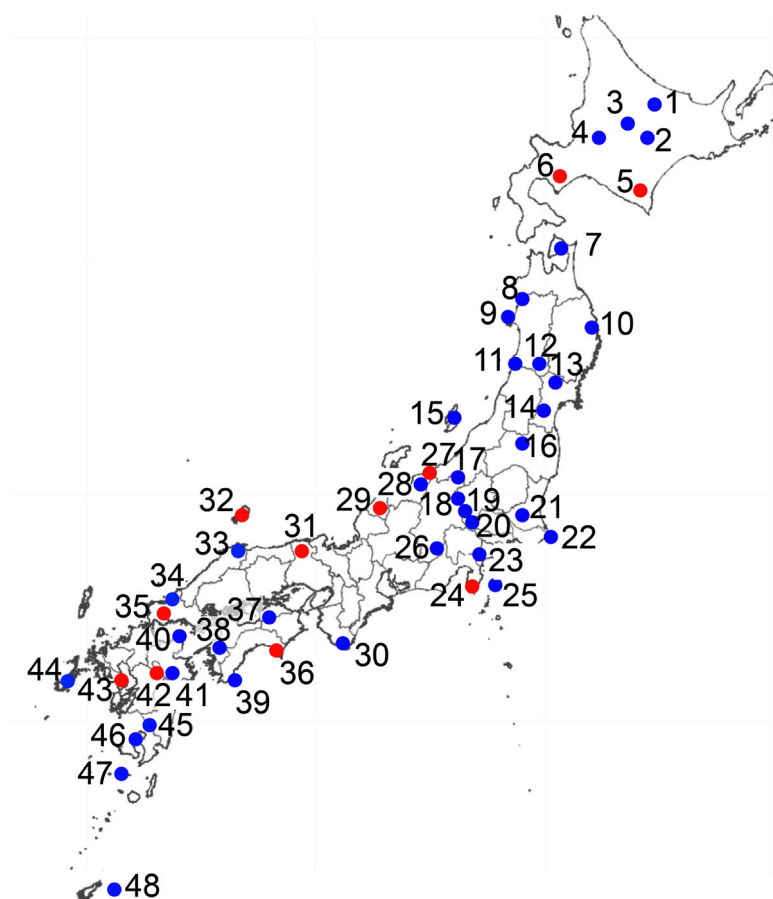


Figure 1. Locations of Geoparks in Japan (after [25]). Red circles indicate UNESCO Global Geoparks, while blue circles represent Japanese National Geoparks. The numbered geoparks correspond to those listed in Table 1, together with their geological characteristics and representative geoheritage.

Table 1. Major geoheritage and representative geological processes in Japanese geoparks. Geopark numbers correspond to those in Figure 1.

	Name of Geopark	Major Geoheritage	Geological Context
1	Shirataki Geopark	Quaternary Obsidian	Arc Volcanism
2	Tokachi Shikaoi Geopark	Active Volcano	Arc Volcanism
3	Tokachidake Geopark	Active Volcano	Arc Volcanism
4	Mikasa Geopark	Cretaceous-Paleogene Deposits	Forearc Sedimentation
5	Mt. Apoi Geopark	Paleogene Peridotite	Arc–arc Collision
6	Toya-Usu Geopark	Active Volcano	Arc Volcanism
7	Shimokita Geopark	Quaternary Volcano	Arc Volcanism
8	Happo-Shirakami Geopark	Neogene Green Tuff	Back-arc Rifting
9	Oga Peninsula-Ogata Geopark	Neogene Green Tuff	Back-arc Rifting
10	Sanriku Geopark	Paleozoic-Mesozoic Formations	Gondwana Origin
11	Mt.Chokai & Tobishima Island Geopark	Active Volcano	Arc Volcanism
12	Yuzawa Geopark	Pliocene Silver Deposits	Arc Volcanism
13	Mt.Kurikoma Area Geopark	Active Volcano	Arc Volcanism
14	Zao Geopark	Active Volcano	Arc Volcanism
15	Sado Island Geopark	Miocene Gold Deposits	Back-arc Rifting
16	Bandaian Geopark	Active Volcano	Arc Volcanism
17	Naeba-Sanroku Geopark	Quaternary Volcano	Arc Volcanism
18	Mt.Asama North Geopark	Active Volcano	Arc Volcanism
19	Shimonita Geopark	Active Volcano	Arc Volcanism
20	Chichibu Geopark	Jurassic Accretionary Complex	OPS Accretion
21	Mt.Tsukuba Area Geopark	Paleogene Pluton	Arc Volcanism
22	Choshi Geopark	Cretaceous Deposits	Forearc Sedimentation
23	Hakone Geopark	Active Volcano	Arc Volcanism
24	Izu Peninsula Geopark	Active Volcano	Arc–arc Collision
25	Izu Oshima Geopark	Active Volcano	Arc Volcanism

Table 1. Cont.

	Name of Geopark	Major Geoheritage	Geological Context
26	Minami-Alps (MTL Area) Geopark	Median Tectonic Line	Major Faulting
27	Itoigawa Geopark	Itoigawa–Shizuoka Tectonic Line	Arc–arc Collision
28	Tateyama Kurobe Geopark	Active Volcano	Arc Volcanism
29	Hakusan Todorigawa Geopark	River and Gorge	Water Circulation
30	Nanki Kumano Geopark	Miocene Forearc Pluton	Forearc Magmatism
31	San'in Kaigan Geopark	Early Pleistocene Columnar Basalt	Back-arc Rifting
32	Oki Islands Geopark	Paleoproterozoic Rocks	Rodinia Origin
33	Shimane Peninsula and Shinjiko Nakaumi Estuary Geopark	Lakes and Wetlands	Lagoon Development
34	Hagi Geopark	Cretaceous–Quaternary Igneous Rocks	Arc Magmatism
35	Miné-Akiyoshidai Karst Plateau Geopark	Carboniferous–Permian Limestone Karst	OPS Accretion
36	Muroto Geopark	Paleogene Accretionary Complex	Sediment Accretion
37	Miyoshi Geopark	Median Tectonic Line	Major Faulting
38	Shikoku Seiyo Geopark	Kurosegawa Tectonic Belt	Gondwana Origin
39	Tosashimizu Geopark	Miocene Forearc Pluton	Forearc Magmatism
40	Oita Himeshima Geopark	Quaternary Volcano	Arc Volcanism
41	Oita Bungoono Geopark	Late Pleistocene Pyroclastic Deposits	Arc Volcanism
42	Aso Geopark	Active Volcano with a Large Caldera	Arc Volcanism
43	Unzen Volcanic Area Geopark	Active Volcano	Arc Volcanism
44	Goto Islands (Shimogoto Area) Geopark	Miocene Sedimentary and Volcanic Rocks	Back-arc Rifting
45	Kirishima Geopark	Active Volcano	Arc Volcanism
46	Sakurajima-Kinkowan Geopark	Active Volcano	Arc Volcanism
47	Mishima Village Kikai Caldera Geopark	Active Volcano	Arc Volcanism
48	Kikaijima Geopark	Holocene Uplifted Coral Reef	Reef Development

2.1.3. Case Study Sites

In addition to the nationwide analysis of the 48 geoparks, this study uses the Miné-Akiyoshidai Karst Plateau Geopark and the Hagi Geopark [24] as case studies to examine how relationships among geoheritage, human life, and local communities are translated into practical geopark activities. The case studies presented in this study are based on publicly available sources, including official geopark websites [26,27], action plans [28], activity reports, and related documents, together with the author's long-term observations of geopark activities through service as a strategic advisor to both geoparks.

2.2. Methods

Geological data were derived from 1:50,000 and 1:200,000 geological maps and the Seamless Digital Geological Map of Japan [29], using web-based services provided by the Geological Survey of Japan, AIST. Topographic data were obtained from web-based map services provided by the Geospatial Information Authority of Japan [30] via its web-based map services. Data regarding geoheritage and the geopark activities were gathered from the official websites of the Japanese Geoparks Network [31], the Japan Geopark Committee, and individual geopark organizations. For the Miné-Akiyoshidai Karst Plateau Geopark and the Hagi Geopark, additional resources were used, including master plans, action plans, application and revalidation documents, activity records of geoguides and local residents, and information obtained through interviews. Together, these datasets provided the basis for the nationwide analyses and case studies presented in this study.

3. Results

3.1. Geoheritage in Japanese Geoparks: Records of Active-Margin Evolution

The geological framework of the present Japanese Islands has developed along the active margin of eastern Asia since the Paleo-Pacific Plate began subducting beneath the South China Block approximately 500 million years ago [32–34]. As a result, much of the geoheritage preserved within Japanese geoparks records geological processes associated with long-term plate subduction and active-margin evolution. Table 1 summarizes the

principal categories of geoheritage representing these processes, while Figure 2 illustrates their relationships within the active-margin Earth system. The figure highlights how plate subduction drives a series of interconnected processes, including accretion, magmatism, continental growth, arc–arc collision, earthquakes, and volcanic eruptions. Rather than representing isolated geological phenomena, these processes together characterize the long-term evolution of an active-margin system and form the geological framework of Japanese geoparks.

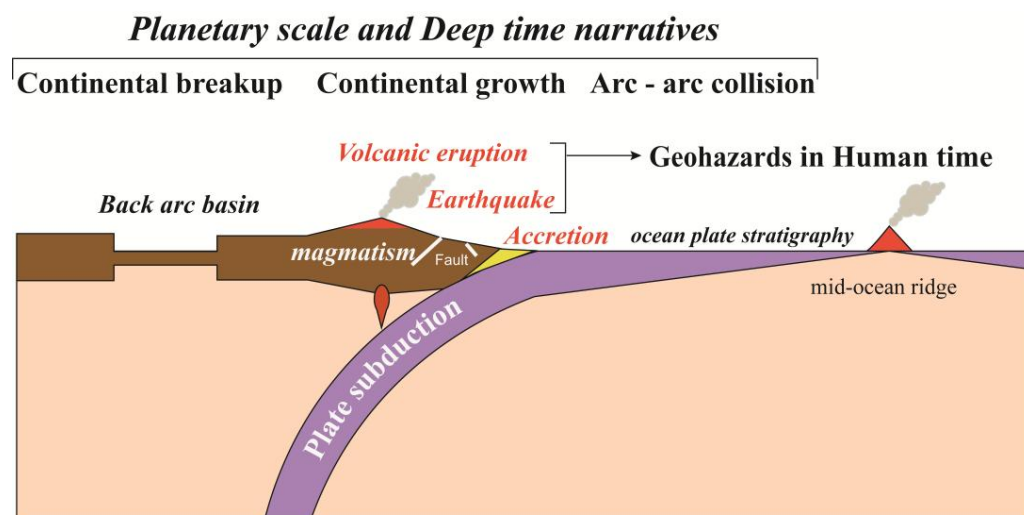


Figure 2. Schematic cross-section of an active margin system and associated geological processes.

The geoheritage preserved in Japanese geoparks collectively records major stages in the evolution of the Japanese active margin (Table 1). One of the most fundamental processes is the accretion of oceanic materials along the trench. Permian, Jurassic, and Cretaceous–Paleogene accretionary complexes are widely distributed throughout Japan and constitute a major component of its geological framework (Table 1; [33,34]). These complexes preserve ocean plate stratigraphy (OPS), mélanges, and trench-fill sediments that document the long-term incorporation of oceanic crust into continental margins [35–37]. They also provide important evidence that the Japanese Islands have developed through repeated episodes of oceanic plate subduction and accretion over geological time.

Another major component of the geoheritage preserved in Japanese geoparks is arc magmatism. During the Cretaceous and Paleogene, widespread igneous activity occurred throughout the Japanese Islands in response to accelerated plate convergence and subduction-related magmatism [38–40]. This represents the most extensive magmatic episode preserved in Japan and is recorded by numerous geoheritage sites associated with granitic plutons, volcanic complexes, and related igneous rocks (Table 1). These igneous rocks document an important stage of continental growth along the active margin.

An additional tectonic transition occurred during the Miocene. This was marked by widespread back-arc basin development around the Japanese Islands. As a result, extensive volcanism, sedimentary basin development, and crustal extension occurred throughout the archipelago. The volcanic and sedimentary successions formed within these basins, known in Japan as the “Green Tuff”, are preserved in numerous geoparks and record this period of intense volcanism, sedimentation, and crustal extension between approximately 20 and 15 Ma. This tectonic reorganization transformed the Japanese Islands from part of the continental margin of East Asia into the island-arc system observed today. At the same time, it also gave rise to multiple arc–arc collisions around Japan. The collision of the Izu–Bonin Arc with the Honshu Arc and that of the Kuril Arc with northeastern Japan

began during this period and remain among the principal tectonic processes shaping the Japanese Islands today [41–46].

The active-margin system remains highly dynamic today. During the Quaternary, the Pacific Plate and Philippine Sea Plate have continued to subduct beneath the Japanese Islands, driving frequent earthquakes, active faulting, and arc volcanism. Over geological time, these continuing tectonic and volcanic processes have also produced abundant geoheritage that records Quaternary active-margin evolution. More than half of Japanese geoparks contain active volcanoes or other geoheritage associated with Quaternary volcanic activity, providing opportunities to observe evidence of these active-margin tectonic processes. At the same time, because the same tectonic processes remain active, they continue to generate earthquakes, volcanic eruptions, and other geohazards. The Japanese active margin therefore illustrates how the same active-margin tectonic processes create geoheritage over geological time while continuing to generate geohazards today.

The geoheritage preserved throughout Japanese geoparks records nearly all major tectonic processes associated with active-margin evolution over the past 500 million years, including oceanic plate accretion, continental growth through magmatism, back-arc basin development, arc–arc collision, and ongoing volcanism and seismicity. These same active-margin tectonic processes continue to generate both geoheritage and geohazards today.

3.2. Geohazards in the Japanese Archipelago: Seismicity and Volcanism

Today, the Pacific Plate and Philippine Sea Plate continue to subduct beneath the Japanese Islands, producing frequent seismic activity, arc volcanism, and active faulting. Although Japan accounts for only approximately 0.25% of the Earth’s total land area, it experiences about 20% of the world’s earthquakes with a magnitude of 6.0 or greater [47]. At the same time, despite its limited land area, Japan hosts 111 active volcanoes, representing approximately 10% of the global total [48]. Active faults are also widely distributed across the archipelago and occur within more than half of Japanese geoparks [49].

Major seismic disasters in Japan are summarized in Table 2. They are broadly classified into plate boundary earthquakes, which occur along subduction zones and may generate large tsunamis, and inland crustal earthquakes, which are generally shallower but can cause severe localized damage despite their smaller magnitude [50]. Representative examples of both earthquake types, together with their associated geoparks, are listed in Table 2. Among them, the 2011 off the Pacific coast of Tohoku Earthquake was the most devastating recent plate boundary earthquake, generating a catastrophic tsunami that caused extensive damage along the Pacific coast of northeastern Japan, including the Sanriku Geopark [51–56]. Seismic activity along the Japan Trench continues today, as demonstrated by the magnitude 7.7 earthquake of 20 April 2026, which generated small tsunamis along the coasts of the Sanriku, Shimokita, and Mt. Apo Geoparks [57].

Table 2. Major earthquake disasters in Japan [47,58].

Year	Name of Earthquake	Name of Geopark	Magnitude	Epicenter Depth	Earthquake Type	Fatalities (Missing)
1995	Southern Hyogo Prefecture Earthquake	–	7.3	16 km	Inland Crustal	6437
2000	Tottori-ken Seibu Earthquake	San’in Kaigan Geopark	7.3	9 km	Inland Crustal	0
2001	Geiyo Earthquake	–	6.7	46 km	Plate boundary	2
2003	Tokachi-oki Earthquake	–	8	45 km	Plate boundary	2 (2)
2004	Mid Niigata Prefecture Earthquake	–	6.8	13 km	Inland Crustal	68
2007	Noto Hanto Earthquake	–	6.9	11 km	Inland Crustal	1
2007	Niigataken Chuetsu-oki Earthquake	–	6.8	17 km	Inland Crustal	15

Table 2. *Cont.*

Year	Name of Earthquake	Name of Geopark	Magnitude	Epicenter Depth	Earthquake Type	Fatalities (Missing)
2008	Iwate-Miyagi Nairiku Earthquake	Mt.Kurikoma Area Geopark	7.2	8 km	Inland Crustal	23 (10)
2011	off the Pacific coast of Tohoku Earthquake	Sanriku Geopark	9	24 km	Plate boundary	ca. 22,000
2016	Kumamoto Earthquake	Aso Geopark	7.3	12 km	Inland Crustal	44
2018	Hokkaido Iburi East Earthquake	Toya-Usu Geopark	6.7	37 km	Inland Crustal	273
2024	Noto Peninsula Earthquake	–	7.6	16 km	Inland Crustal	464

Inland crustal earthquakes are generated by the rupture of active faults within the crust as strain accumulates under the compressional stress field produced by ongoing plate subduction. Because their focal depths are generally shallow, commonly less than 20 km, they can cause severe localized damage near the fault zone [59,60]. Representative examples are summarized in Table 2, including the 2016 Kumamoto Earthquake near the Aso Geopark and the 2008 Iwate–Miyagi Nairiku Earthquake in the Mt.Kurikoma Area Geopark region [61–65]. In addition, major tectonic lines such as the Median Tectonic Line in the Miyoshi and Minami-Alps (MTL Area) Geoparks and the Itoigawa–Shizuoka Tectonic Line in the Itoigawa Geopark are associated with active fault systems capable of generating damaging earthquakes [66,67].

Volcanic disasters associated with Japanese geoparks are summarized in Table 3. Since the 18th century, Japan has experienced 21 volcanic disasters resulting in 10 or more fatalities or missing persons [68]. Representative examples illustrate the diversity of volcanic hazards. The 1926 eruption of Mt. Tokachi generated a snowmelt-induced lahar that caused severe damage in the Tokachidake Geopark and surrounding areas [69,70]. In the Unzen Volcanic Area Geopark, the 1991 collapse of a growing lava dome generated devastating pyroclastic flows [71,72]. Outside geopark regions, the 2014 eruption of Mt. Ontake demonstrated the danger of sudden phreatic eruptions with few recognizable precursory signs, resulting in numerous casualties among hikers [73].

Table 3. Major volcanic disasters in Japan [68].

Year	Volcano	Name of Geopark	Victims	Causes of Fatalities
1979	Sakurajima	Sakurajima-Kinkowan Geopark	150+	lava flow, ballistic ejecta
1783	Asamayama	Mt.Asama North Geopark	1151	pyroclastic flow, debris
1792	Unzen	Unzen Volcanic Area Geopark	ca. 15,000	debris avalanche, earthquake
1822	Usu	Toya-Usu Geopark	103	pyroclastic flow
1914	Sakurajima	Sakurajima-Kinkowan Geopark	28–59	ballistic ejecta, earthquake
1926	Tokachidake	Tokachidake Geopark	144	eruption-induced snowmelt lahar
1958	Aso	Aso Geopark	12	ballistic ejecta
2014	Ontake	–	63	ballistic ejecta

Not all eruptions develop into major disasters. In the Sakurajima-Kinkowan Geopark, Mt. Sakurajima erupted 361 times in 2025, causing only minor agricultural damage [74]. Similarly, the 2000 eruption of Mt. Usu in the Toya-Usu Geopark caused no direct human casualties but damaged roads, railways, and other infrastructure [75]. Mt. Aso in the Aso Geopark also remains active. Its 2021 eruption generated pyroclastic flows extending approximately 1 km from the crater and an eruption column reaching 3500 m above the crater rim [76]. Although recent eruptions have caused limited direct damage, the volcano has experienced repeated caldera-forming eruptions in the past [77].

Tables 2 and 3 summarize representative earthquakes and volcanic disasters associated with Japanese geoparks. These events are generated by the same tectonic and magmatic processes responsible for the geoheritage summarized in Table 1.

3.3. Hydrological Systems in Japanese Geoparks: Water Circulation in Active-Margin Environments

Japanese active-margin environments generate diverse hydrological systems through the combined influence of tectonic uplift, volcanic activity, climate, and topography. Steep mountain ranges produce short, rapidly flowing rivers, while abundant precipitation and snow accumulation sustain large volumes of groundwater and surface water throughout the archipelago. Owing to the generally short residence time of groundwater, most Japanese rivers consist of soft water with relatively low concentrations of dissolved minerals [78,79].

Water circulates through a variety of geological environments before returning to rivers and the sea. Depending on geological and climatic conditions, groundwater infiltrates volcanic deposits, flows through karst aquifers, is seasonally stored as snow and ice in high mountains, or emerges as springs and wetlands. Representative hot spring systems associated with Japanese geoparks are summarized in Table 4, while representative Ramsar wetlands are listed in Table 5.

Table 4. Major hot springs in Japanese Geoparks.

Name of Geoparks	Name of Hot Spring Sites	Type
Tokachidake Geopark	Tokachidake	Volcanic
Toya-Usu Geopark	Toyako, Tennen-Toyoura, Kitayuzawa, Bankei,	Volcanic
Shimokita Geopark	Yakuden, Oma, Osorezan, Ishigami, Kuwahata, Yatate	Volcanic
Mt.Kurikoma Area Geopark	Kurikoma-Kogen, Sugawa, Sugawa-Kogen	Volcanic
Happo-Shirakami Geopark	Hachimori-isaribi	Volcanic
Oga Peninsula-Ogata Geopark	Goga	Volcanic
Yuzawa Geopark	Koyasukyo	Volcanic
Mt.Chokai & Tobishima Island Geopark	Chokai, Yunodai, Sarukura,	Volcanic
Zao Geopark	To-oggata	Volcanic
Bandaisan Geopark	Bandaisan	Volcanic
Tateyama Kurobe Geopark	Unazuki, Meiken Funabasi-Tateyama	Volcanic
Mt.Asama North Geopark	Shikazawa	Volcanic
Izu Peninsula Geopark	Atami, Ito, Yugawara	Volcanic
Izu Oshima Geopark	Oshima	Volcanic
Hakone Geopark	Hakone	Volcanic
Hakusan Tedorigawa Geopark	Hakusan	Volcanic
Hagi Geopark	Hagi	Volcanic
Oita Himeshima Geopark	Hyoshigi	Volcanic
Oita Bungoono Geopark	Mie, Nagayu	Volcanic
Aso Geopark	Aso, Yoshioka, Uchimaki, Kurokawa, etc.	Volcanic
Unzen Volcanic Area Geopark	Unzen	Volcanic
Kirishima Geopark	Kirishima, Nyouken-Anraku, Hinatayama, Tsurumaru	Volcanic
Sakurajima-Kinkowan Geopark	Sakurajima, Shirahama	Volcanic
Mishima Village Kikai Caldera Geopark	Utanhama, Higashi, Sakamoto	Volcanic
Sanriku Geopark	Sanriku, Minami-Sanriku, Ohfunato	non-volcanic
Choshi Geopark	Inubozaki	non-volcanic
Itoigawa Geopark	Himekawa, Itoigawa, Renge	non-volcanic
San'in Kaigan Geopark	Kinosaki, Hamasaka, Yumura, Iwai, Hamamura	non-volcanic
Oki Islands Geopark	Oki	non-volcanic
Nanki Kumano Geopark	Nanki-Shirahama, Shingu, Katsuura, Kushimoto	non-volcanic
Miyoshi Geopark	Matsuogawa	non-volcanic
Tosashimizu Geopark	Ashizuri	non-volcanic

Table 5. Ramsar Registered Wetlands in Japanese Geoparks.

Ramsar Registered Wetlands	Geoparks	Outstanding Features	Vulnerability
Izunuma-Uchinuma, Kabukurinuma	Mt.Kurikomayama Area Geopark	Lowland lakes and marshes formed by sediment damming on a floodplain	Water quality degradation, shallowing, die-off of aquatic organisms, and overgrowth of lotus
Shizugawa-wan	Sanriku Geopark	Ria coast formed in association with crustal uplift	Tsunami impacts caused by the 2011 Tohoku Earthquake
Tateyama Midagahara and Dainichidaira	Tateyama Kurobe Geopark	Wind-beaten wet grasslands formed on a lava plateau	Volcanic gas emissions and runoff of hazardous substances such as mercury
Lower Maruyama River and the surrounding rice paddies	San'in Kaigan Geopark	Reintroduction of the Oriental White Stork, a Special Natural Monument	Wetland restoration challenges from flooding, riverbed fluctuations, and invasive vegetation.
Shinji-ko	Shimane Peninsula and Shinjiko Nakaumi Estuary Geopark	Freshwater lake transformed from an inner bay by sediment damming	Water pollution, eutrophication, and lacustrine hypoxia
Akiyoshidai groundwater system	Miné-Akiyoshidai Karst Plateau Geopark	Subsurface drainage systems flowing through limestone caves beneath a karst plateau	Proliferation of mosses and ferns caused by artificial lighting for tourism

Volcanic regions contain numerous hot springs generated by geothermal circulation associated with Quaternary volcanism. In contrast, many non-volcanic hot springs originate from deep groundwater circulating along active faults and fractured bedrock. Similarly, wetlands develop under diverse geological settings, including volcanic plateaus, floodplains, ria coasts, karst groundwater systems, and coastal lagoons. These examples illustrate the diversity of hydrological environments developed within the Japanese active margin.

Among Japanese geoparks, the Hakusan Tedorigawa Geopark provides a representative example of an integrated hydrological system extending from mountain headwaters to the coastal plain. Snow accumulated on Mt. Hakusan infiltrates volcanic rocks, emerges as springs, sustains the Tedor River (Tedorigawa), and ultimately reaches the Sea of Japan. Along this pathway, water has shaped alluvial fans, terraces, irrigation systems, settlements, agriculture, and regional culture. The geopark interprets these interconnected relationships through a spatial and temporal geostory that links geological, hydrological, ecological, and cultural features across the watershed [17,80–82].

A complementary example is provided by the Hagi Geopark, where groundwater, rivers, springs, and coastal waters illustrate how hydrological systems support everyday human activities. Springs and groundwater have supplied drinking water, agriculture, fisheries, food production, and historical town development, while rivers transport sediment and nutrients from mountainous catchments to coastal ecosystems. Figure 3 summarizes representative examples of these relationships observed within the geopark [83].

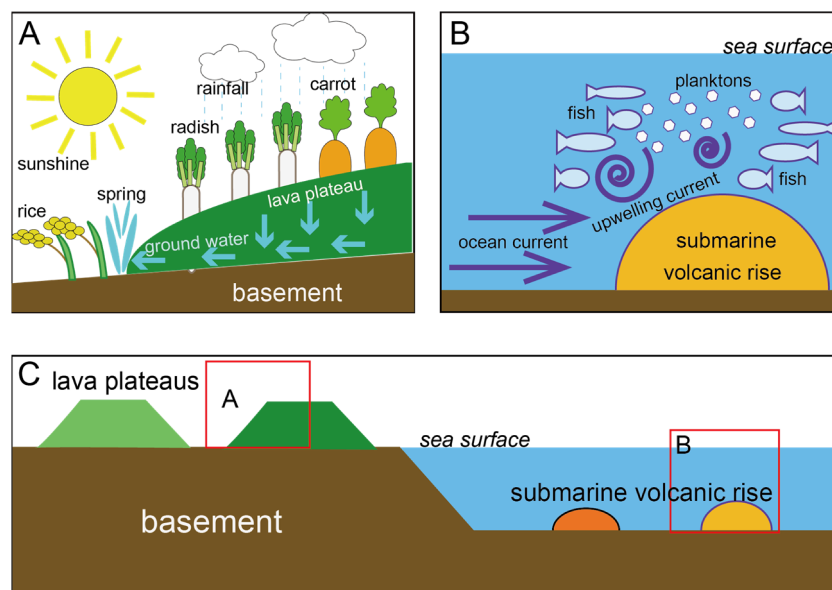


Figure 3. Relationship between volcanic activity and agriculture and fisheries in the Hagi Geopark (after [83]). (A) Lava plateaus and spring-fed lowlands that support agricultural practices. (B) Submarine volcanic mounds that generate upwelling and highly productive fishing grounds. (C) Schematic geological cross section illustrating the land–sea linkage and the locations of panels A and B.

3.4. Community-Based Geopark Practice

The preceding section showed how hydrological environments in active-margin settings support agriculture, fisheries, water resources, and other aspects of everyday life. In the Hagi Geopark, particular attention has been given to the relationships between geological and geomorphological features produced by three stages of magmatic activity and contemporary agriculture, fisheries, groundwater resources, and local culture (Figure 3).

Since becoming a Japanese Geopark in 2018, the Hagi Geopark has developed practical activities that connect Earth processes with local livelihoods, culture, and industries. Rather than presenting geoheritage only as scientific knowledge, these activities provide opportunities for local residents to recognize the value of their environment through everyday life.

Several programs connect geological processes with local food production and food culture. At Hagi Sea Mart, visitors learn how submarine volcanic landforms and marine environments contribute to productive fishing grounds and local seafood. In the “Earth-Eating Cafeteria,” participants enjoy dishes prepared by local chefs while learning how local geology, topography, water, and ecosystems support regional agricultural products, livestock, fisheries, and food culture.

Similar approaches have been developed in relation to local culture and education. Hagi ware, a ceramic tradition with a history of more than 400 years, developed through the use of local geological materials, including weathered granitic soils and volcanic-derived clay resources. Geopark programs introduce the relationships among local geology, clay resources, ceramic production, and regional culture, including the use of traditional climbing kilns. The geopark has also worked with local schools to restore the cultivation of indigo plants once used for traditional dyeing in the Hagi region. Through this long-term geoeducation program, successive generations of schoolchildren learn how local topography, soils, and environmental conditions supported indigo cultivation while contributing to the revival of a regional cultural tradition.

Community participation has also extended to geoheritage conservation. Following rainfall-induced damage to a geosite, local residents requested restoration work. They subsequently learned simple monitoring techniques from a geologist and have continued

to monitor crack widths in the unstable slope by taking turns measuring them with rulers. This activity connects expert geological knowledge with community-based conservation and monitoring practices.

After eight years of practical activities connecting Earth processes with local livelihoods, culture, and industries, the Hagi Geopark developed the Action Plan (2026–2029) [28]. Building on these accumulated experiences, the plan presents a framework designed to encourage greater resident-led participation (Figure 4). The framework positions the secretariat as a hub connecting residents, practitioners, researchers, businesses, schools, and community organizations. It also provides multiple pathways for participation and organizes activities through five core measures.

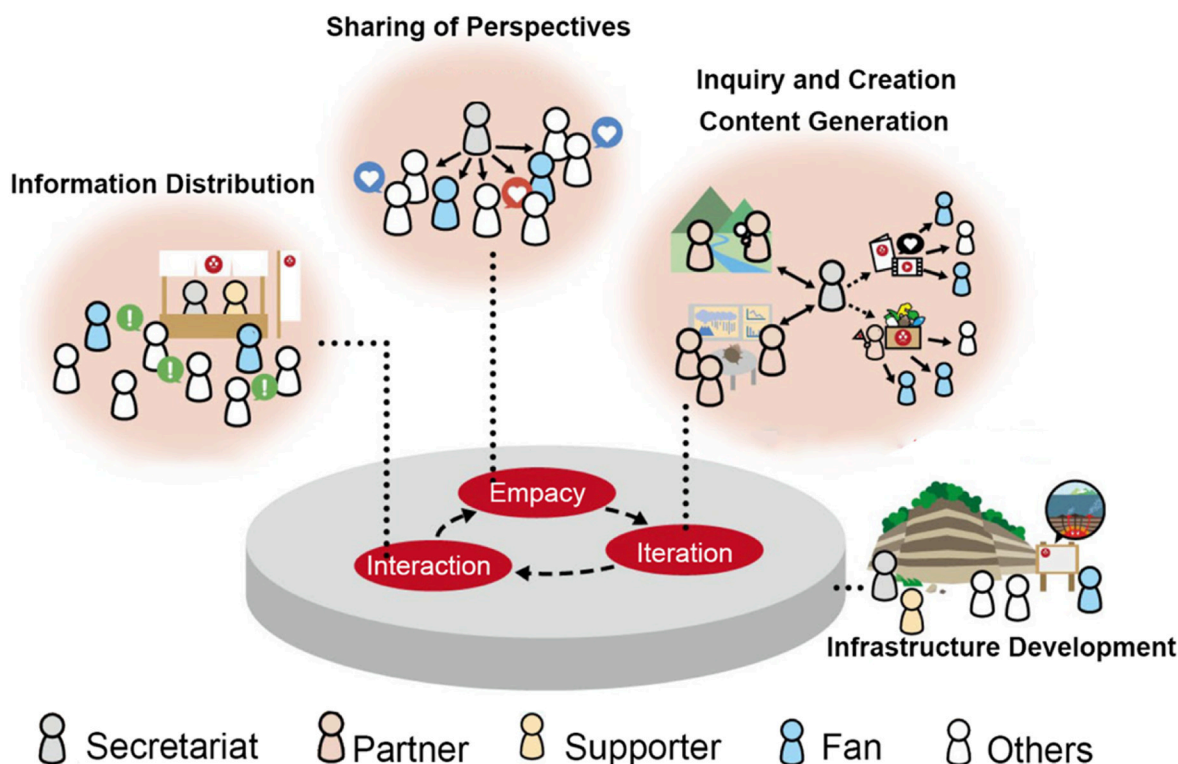


Figure 4. New geopark activities in the Hagi Geopark from 2026 to 2029, based on the Hagi Geopark Action Plan [28]. The model positions the secretariat as a hub connecting diverse stakeholders, including Partners, Supporters, and Fans, and organizes activities through five core measures: infrastructure development, information sharing, collaborative inquiry, content creation, and distribution. Solid arrows indicate the direction of interactions and activities among participants, whereas dashed arrows represent the iterative relationships among the three core activity domains (Empathy, Interaction, and Iteration). Dotted vertical lines indicate that each activity domain is supported by the underlying conceptual framework.

4. Discussion

4.1. Networking Geoheritage Through Deep Time and Earth-System Processes

As presented in Section 3.1, the geoheritage sites distributed across Japanese geoparks preserve diverse geological records associated with the long-term evolution of the Japanese active margin. Although each site possesses its own local geological significance, these geoheritages can also be interpreted as interconnected records of Earth-system processes operating across multiple spatial and temporal scales.

The Japanese archipelago preserves a wide range of tectonic processes related to oceanic plate subduction, including arc magmatism, accretion, arc–arc collision, back-arc rifting, crustal uplift, and erosion [33]. Geoheritage associated with these processes is distributed

throughout Japanese geoparks. For example, the Izu-Bonin Arc preserves ongoing processes related to continental crust formation [41,42,84], while accretionary complexes record the recycling of oceanic materials within plate tectonic systems [33,35–37]. Similarly, arc-collision zones preserved in the Izu Peninsula Geopark and Mt. Apoi Geopark provide insights into long-term continental growth processes [41–46]. Collectively, these geoheritages represent not simply isolated geological phenomena, but interconnected expressions of active-margin Earth-system evolution extending from Deep Time to the present.

Another example is provided by the geoheritage associated with the opening of the Sea of Japan. Miocene volcanic rocks and sedimentary basins distributed throughout Japan record crustal extension, subsidence, and magmatic activity associated with back-arc opening [85]. These records preserve evidence of continental-margin rifting processes that have repeatedly occurred throughout Earth history. Local geoheritage can be interpreted as part of broader tectonic cycles involving continental growth, fragmentation, and reorganization, reinforcing the Earth-system perspective presented in Section 3.1.

This broader interpretation expands the significance of geoheritage beyond local geological descriptions. Individual geosites become components of larger tectonic systems that have continuously shaped the Earth throughout geological history. This perspective allows local geoheritage to be repositioned within broader Earth-system processes and Deep Time.

The same perspective can be extended beyond Japan. The UNESCO Global Geoparks preserve geoheritage representing diverse geological ages and Earth-system processes, including continental rifting, subduction, collision, sedimentation, magmatism, metamorphism, and erosion (e.g., [86,87]). As illustrated in Figure 5, geoheritage preserved in UNESCO Global Geoparks can be interpreted as complementary records of planetary-scale Earth-system processes operating across Deep Time.

Viewed individually, each geopark preserves geoheritage with its own scientific, educational, cultural, and regional significance as a valuable heritage to be conserved for future generations [3–10,12–14,19–22]. However, when connected through the UNESCO Global Geopark Network, these sites also create opportunities to recognize broader relationships among geological processes operating across the Earth system. Through such connections, local geoheritage can be interpreted within a much larger framework extending from the Archean to the present and ultimately into the future.

This perspective is particularly meaningful for Japanese geoparks. Precambrian geological records are extremely limited in Japan because active-margin processes have repeatedly removed, fragmented, or overprinted older geological units through subduction, accretion, tectonic erosion, magmatism, deformation, and uplift [88,89]. Most large-scale geoheritage preserved in Japan is younger than approximately 300 million years. In contrast, the UNESCO Global Geopark Network encompasses geoheritage representing a far broader range of Earth history, from the Archean to the present [90,91]. Through this global network, Japanese geoparks can be connected to geoheritage representing earlier stages of planetary evolution, thereby extending perspectives beyond the active-margin history of Japan toward Earth-system evolution across Deep Time.

An illustrative example is provided by the Miné-Akiyoshidai Karst Plateau Geopark. Geo-guides often ask visitors standing on the karst plateau how many limestone rocks they believe are exposed before explaining that the entire landscape is actually part of a single massive limestone body connected underground. Although individual pinnacles appear isolated at the surface, they are components of a larger geological structure. In a similar way, geoheritage sites distributed across geoparks worldwide may also be interpreted as interconnected expressions of broader Earth-system processes, even when they appear geographically separated.

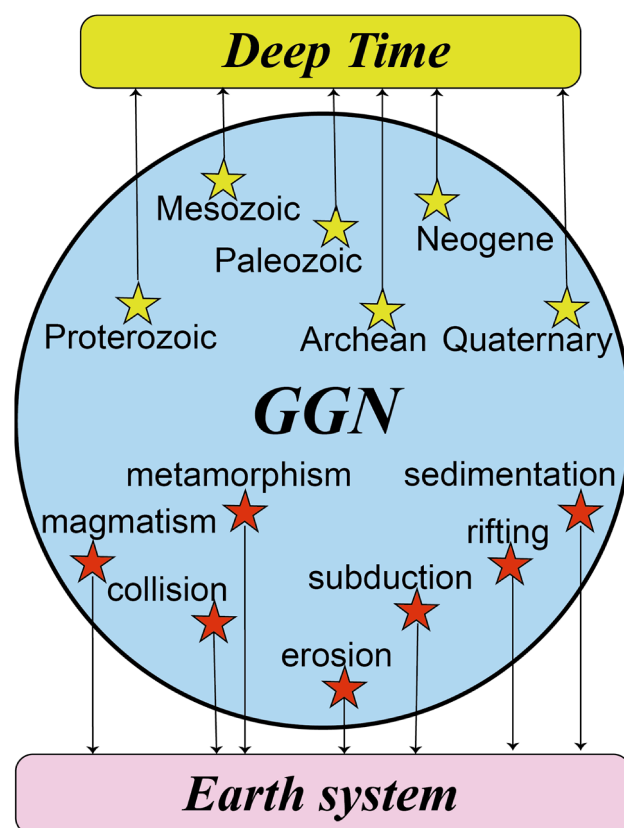


Figure 5. Conceptual representation of geoheritage within the UNESCO Global Geopark Network (GGN). Geoheritage sites preserved in UNESCO Global Geoparks represent Earth-system processes operating across Deep Time. The blue circle represents the UNESCO Global Geopark Network (GGN) as a whole. Red stars represent UNESCO Global Geoparks featuring geoheritage related to major Earth-system processes (e.g., tectonics, magmatism, erosion, and sedimentation), whereas yellow stars represent UNESCO Global Geoparks characterized by geoheritage representing specific geological time periods. Collectively, these geoparks provide a comprehensive perspective on both Earth-system processes and Deep Time.

By networking geoheritage through the framework of UNESCO Global Geoparks, local landscapes can be connected to planetary-scale Earth-system processes and Deep Time. Such expanded perspectives enable people to recognize that familiar landscapes and geoheritage are part of much larger geological processes operating across the Earth system. However, the purpose of these broader perspectives is not simply to extend understanding toward global scales. Equally important is the return of these perspectives to local communities, where they can provide new ways of interpreting the significance of local landscapes, natural resources, environmental conditions, and geohazards.

In this sense, geoparks function not only as places where perspectives expand from local environments toward planetary-scale Earth-system processes, but also as places where these broader understandings reconnect with everyday life. Through repeated movement between local and global perspectives, people may reinterpret familiar landscapes within the broader context of Earth history while grounding Earth-system understanding in lived experience. The present interpretation also resonates with recent discussions emphasizing that geoparks communicate geoheritage through broader meta-narratives linking geological processes with planetary and societal perspectives (e.g., [92]).

4.2. Geohazards on Active Margins: The Temporal Gap Between Human Time and Deep Time

The Japanese archipelago is situated on an active margin, where earthquakes and volcanic eruptions occur repeatedly as consequences of ongoing plate subduction. Because

the Japanese Islands have remained along convergent plate boundaries for approximately 500 million years, similar tectonic and magmatic processes have operated throughout Deep Time. From this perspective, earthquakes and volcanic eruptions may be interpreted not merely as contemporary disasters, but as recurrent geological processes characteristic of active margins.

Geological and historical records indicate that large earthquakes, tsunamis, and volcanic eruptions have repeatedly affected the Japanese archipelago throughout geological time. Recurrence intervals estimated by the Headquarters for Earthquake Research Promotion (HERP) suggest that M9-class earthquakes occur at intervals of approximately 550–600 years, M8-class earthquakes at approximately 109 years, and M7-class earthquakes at intervals of 12–15 years [93]. Geological evidence, including tsunami deposits, trench turbidites, accretionary complexes, and volcanic deposits preserved in Japanese geoparks, further demonstrates that earthquakes, tsunamis, volcanic eruptions, and crustal deformation have repeatedly occurred throughout Deep Time [33,94,95]. These records indicate that geohazards and geoheritage are not independent phenomena, but different expressions of the same tectonic and magmatic processes operating within active margins.

However, the recurrence intervals of the most destructive geohazards are often considerably longer than ordinary human memory, community experience, or administrative planning cycles. Consequently, although active-margin processes operate continuously over geological timescales, their most destructive manifestations are commonly experienced within Human Time as infrequent and exceptional events. This discrepancy creates a temporal gap between geological processes and human perception.

This temporal gap is particularly evident along the Japan Trench and the Nankai Trough, where geological and historical records indicate repeated occurrences of giant earthquakes and tsunamis over periods of thousands of years [93,96]. At the same time, current seismology acknowledges that the exact timing, location, and magnitude of future earthquakes cannot be predicted accurately [97]. For residents living in regions such as the Sanriku Geopark, Muroto Geopark, Nanki Kumano Geopark, and Tosashimizu Geopark, future earthquakes and tsunamis therefore remain both inevitable and uncertain aspects of the active-margin environment.

Earthquakes and volcanic eruptions are recurrent geological processes throughout Deep Time, yet they are often perceived within Human Time as rare and unpredictable events. This discrepancy may contribute to normalcy bias, the tendency to assume that destructive events are unlikely to occur within one's own lifetime or community. While geohazards are experienced intermittently, the environmental benefits generated by active-margin processes—including habitable land, fertile soils, water resources, volcanic scenery, and hot springs—are experienced more continuously in everyday life. As a result, people may gradually perceive active-margin environments as fundamentally stable despite the persistence of underlying geological processes.

As illustrated in Figure 6, destructive geohazards recur repeatedly across Deep Time but are experienced within Human Time as infrequent and unpredictable events, whereas environmental benefits are experienced more continuously. This temporal asymmetry may reinforce perceptions of environmental stability and contribute to normalcy bias.

Human societies have long adapted to living with recurrent geohazards despite this temporal gap. Adaptation has involved not only recovering from disasters after they occur, but also developing practical knowledge, land-use strategies, and cultural traditions that enable communities to live with recurrent geohazards. Following the 1926 eruption of Mt. Tokachi, extensive farmland was buried by volcanic deposits, requiring decades of soil improvement and land restoration before agricultural productivity could recover [98,99]. These examples demonstrate that many benefits associated with active-

margin environments have been maintained through continuous human adaptation and recovery efforts in response to repeated geological disturbances.

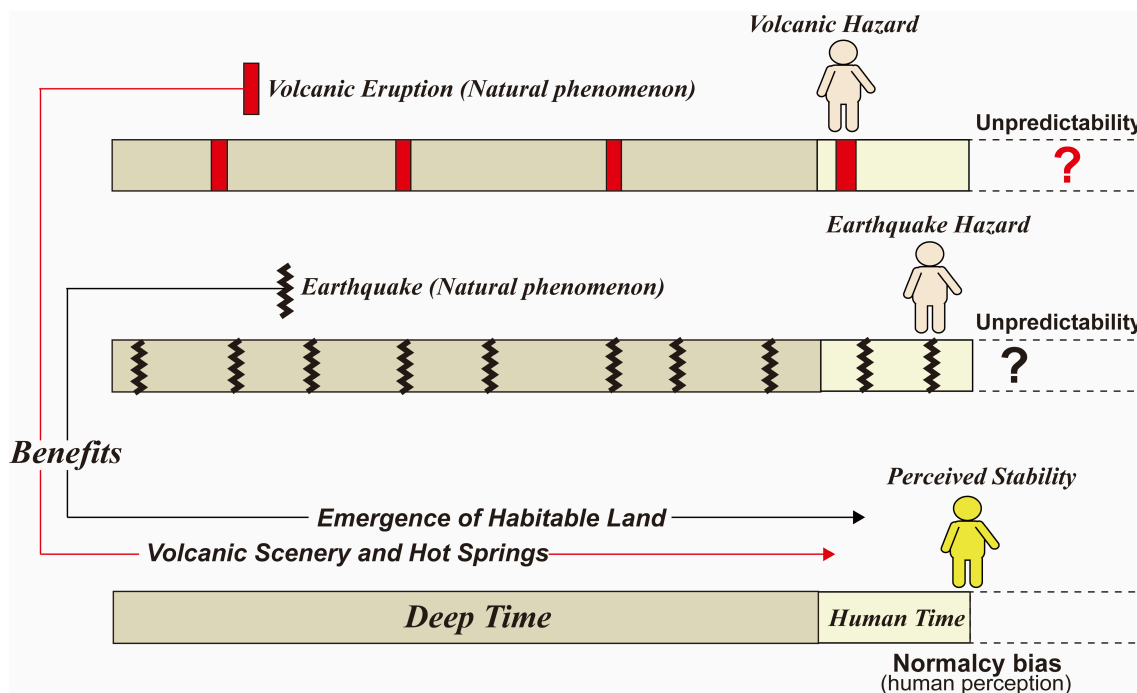


Figure 6. Conceptual illustration of the temporal gap between recurrent active-margin geohazards and human perception.

In addition to physical adaptation, communities have developed cultural mechanisms for preserving memories of rare but destructive events across generations. In the Sanriku Geopark, the traditional teaching of “Tsunami Tendenko” has been incorporated into disaster education and contributed to successful evacuation during the 2011 Tohoku Earthquake and tsunami [100]. Similarly, the story of “Inamura no Hi” preserves collective memory of the 1854 Ansei-Tokai Earthquake and tsunami through local culture and education [101]. Such practices help bridge the temporal gap between infrequent disasters and everyday experience by transmitting hazard awareness beyond the limits of individual memory.

These examples suggest that, as shown in Section 3.2, active-margin environments are shaped by both recurring geohazards and long-term human adaptation. Although destructive earthquakes and volcanic eruptions may be experienced as infrequent events within Human Time, the geological processes underlying them persist continuously throughout Deep Time. Geoparks provide opportunities to recognize that geohazards and environmental benefits are different expressions of the same active-margin processes.

This perspective extends previous studies that have emphasized the role of geoeducation in disaster risk reduction and hazard awareness (e.g., [102,103]). From this perspective, by recognizing recurrent geohazards within the broader context of Deep Time, geoparks may provide practical settings in which the concept of Timefulness can be experienced through local landscapes and everyday life [104].

4.3. Human Society Embedded in Earth-System Circulation

As discussed in Section 3.3, active-margin environments generate diverse hydrological systems, including rivers, groundwater, springs, wetlands, hot springs, and coastal waters. These environments are not merely water resources. They represent pathways through which geological processes influence ecosystems, agriculture, fisheries, and human society.

In this sense, water provides one of the most direct links between Earth-system processes and everyday human life.

Water is indispensable to human life. Approximately 60% of the adult human body consists of water [105], and several liters are exchanged daily through drinking, metabolism, and physiological processes [106]. In many geopark regions, this water originates from groundwater and river systems controlled by local geological and hydrological conditions. Human life is therefore directly connected to the geological environment through hydrological circulation.

The hydrological characteristics of Japan are strongly influenced by active-margin tectonics. Ongoing uplift has produced steep mountains and short, rapidly flowing rivers. Because water residence times are generally short, river water and groundwater often contain relatively low concentrations of dissolved minerals and are commonly characterized as soft water [79]. These hydrological conditions have influenced many aspects of Japanese food culture, including the preparation of rice, tea, and traditional cuisine [78]. In volcanic regions, permeable volcanic deposits store groundwater that later emerges as springs, while karst terrains develop complex groundwater systems through dissolution and underground drainage. Thus, active-margin geological processes influence not only landscapes but also the quantity and quality of water that sustains everyday life.

The Miné-Akiyoshidai Karst Plateau Geopark provides a representative example. At the Beppu Benten area, surface water disappears into limestone through karst conduits and later re-emerges as spring water along a fault zone, supporting rice cultivation on the adjacent alluvial plain [107]. This example illustrates how geological structure, groundwater circulation, agriculture, and community water use are interconnected within a single hydrological system.

These relationships extend beyond water itself to the circulation of materials throughout the Earth system (Figure 7). Through weathering, minerals derived from rocks are released into soils and water systems, incorporated into crops, livestock, and marine organisms, and eventually consumed by humans [108]. Water, dissolved minerals, nutrients, and organic matter continuously circulate among rocks, soils, ecosystems, living organisms, and the atmosphere. Human society participates directly in these circulation systems through food production, consumption, and daily life.

Because materials circulate continuously through Earth-system pathways, substances introduced by human activities may also propagate through interconnected geological, hydrological, and ecological systems [109]. Historical examples in Japan, including mercury pollution in Minamata [110] and cadmium contamination associated with mining activities [111], demonstrate how disturbances introduced into circulation systems can affect ecosystems and human health over long timescales. These examples illustrate that human activities themselves become incorporated into Earth-system circulation.

These observations indicate that human life is not external to the Earth system but embedded within ongoing circulation linking rocks, water, ecosystems, food production, and society. Geoparks provide opportunities to recognize these relationships by connecting everyday experiences with the broader Earth-system circulation that sustains human life.

This perspective builds upon previous work highlighting the importance of geodiversity, geosystem services, and geoheritage in supporting ecosystems and human well-being (e.g., [3–5]). In addition to these perspectives, the present study suggests that geoparks can provide practical settings in which people recognize themselves as participants within the continuous Earth-system circulation linking rocks, water, ecosystems, food production, and human society.

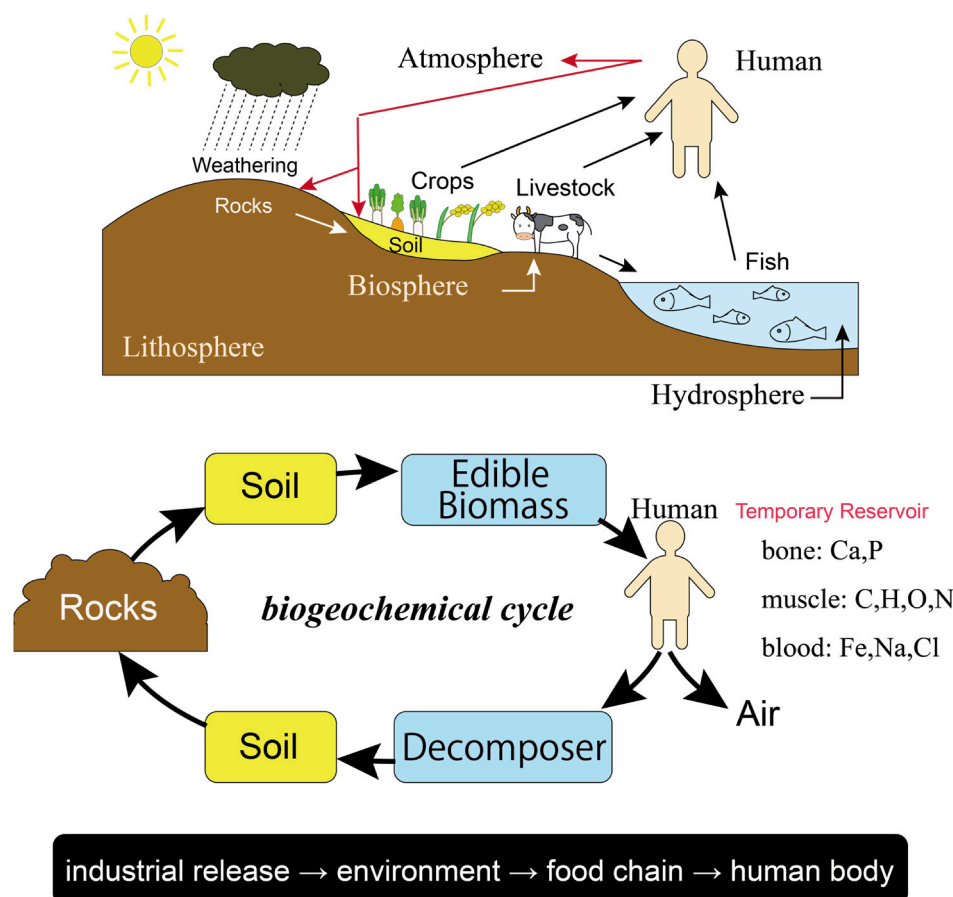


Figure 7. Conceptual diagram illustrating material circulation linking rocks, soils, water, ecosystems, and human society in active-margin environments. Minerals and nutrients released through weathering circulate through ecosystems, food systems, and human life before returning to the environment through Earth-system circulation. The diagram also illustrates how substances released through human activities may re-enter these circulation pathways.

4.4. Geoparks as Spaces for Participation and Community Practice

Many Japanese geoparks are located in active-margin regions characterized by steep mountainous terrain, geographically fragmented settlements, and limited areas of habitable land. At the same time, many of these regions face rapid depopulation, aging populations, and the gradual weakening of local social connections. As increasing numbers of elderly residents live alone or in aging households, challenges related to social isolation, transportation access, disaster vulnerability, and the long-term sustainability of local communities have become increasingly significant.

The 2011 Great East Japan Earthquake and tsunami highlighted the importance of these issues for local communities [56]. In many affected communities, residents were required to make immediate evacuation decisions together with neighbors before official assistance could arrive. Studies of the disaster have shown that communities with strong pre-existing social relationships demonstrated greater resilience during evacuation, shelter life, and long-term recovery processes [112–115]. These experiences suggest that sustainable local communities depend not only on governmental support and physical infrastructure but also on opportunities for participation, mutual support, and the social relationships that are cultivated through everyday community life.

From this perspective, the practical activities presented in Section 3.4 can be understood as more than individual programs in geoeducation, geotourism, conservation, or regional development. In the Hagi Geopark, activities related to local food culture, Hagi

ware, indigo cultivation, and geoheritage conservation all reconnect geological processes with people's everyday lives. Although these activities differ in their immediate objectives, they all encourage local residents to recognize relationships between the Earth and their communities through active participation in everyday life.

The Hagi Geopark Action Plan (2026–2029) further develops this perspective [28]. Rather than positioning the geopark secretariat as the principal actor, the plan proposes a framework in which local residents participate according to their own interests, abilities, and circumstances as Partners, Supporters, or Fans. The role of the secretariat is to support these diverse forms of community engagement by providing opportunities for learning, collaboration, information sharing, and networking. In this way, the Action Plan represents a practical framework through which relationships between the Earth and human society can be continuously translated into locally initiated activities.

Similar forms of community participation can also be observed in other Japanese geoparks. In the Sanriku Geopark, post-disaster reconstruction initiatives have emphasized neighborhood relationships, local participation, and the transmission of disaster memory. In several other geoparks, including the Hagi Geopark, the Miné-Akiyoshidai Karst Plateau Geopark, and the Kirishima Geopark, universal tourism initiatives encourage elderly residents and people with disabilities to participate more actively in geotourism and community activities [107,116,117]. Although these initiatives differ in their immediate objectives, they share a common emphasis on creating opportunities for communication, participation, and collaboration among diverse members of local communities.

Figure 8 summarizes this perspective. Geoheritage provides a foundation for geoeducation, geotourism, conservation, networking, and diverse community activities. Through participation in these activities, relationships between the Earth and human society are recognized and expressed through local practice. At the same time, these activities strengthen connections among people, local communities, and the Earth system while creating opportunities for mutual learning, care, and cooperation across generations and social groups.

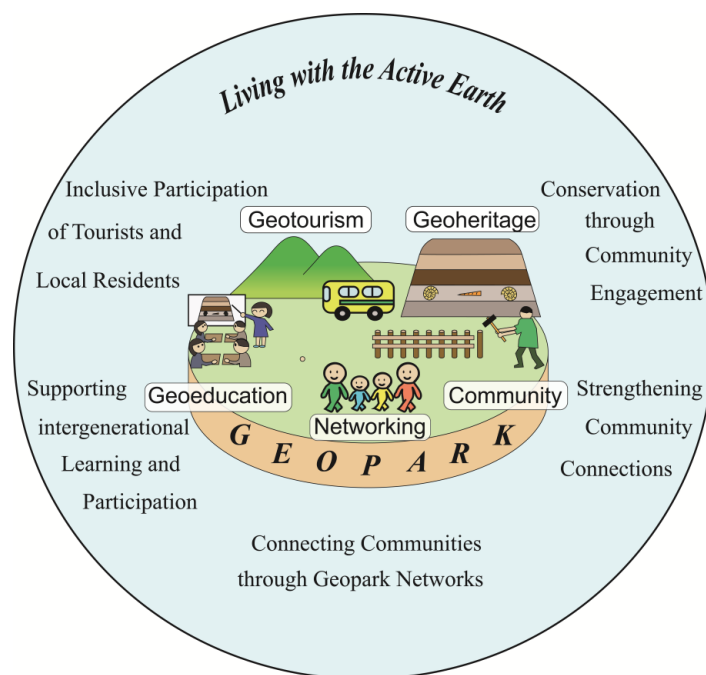


Figure 8. Conceptual model illustrating geoparks as spaces for participation and mutual care within active-margin regions. Through participation in these interconnected activities, relationships among people, place, and local communities may gradually be strengthened, allowing knowledge, experience, and local initiatives to be shared across generations.

Viewed from this perspective, geoparks are not only places for conserving geoheritage or promoting tourism but also practical spaces where relationships between the Earth and human society are translated into education, culture, conservation, local industries, and community practice. Through these diverse forms of participation, geoparks strengthen connections among people, local communities, and the Earth system while contributing to more resilient local communities in active-margin regions.

This interpretation also complements previous studies emphasizing community engagement and participatory approaches in geoparks (e.g., [17,118,119]). The present study further suggests that participation is not only a means of supporting geopark activities but also a continuous process through which relationships among people, local communities, and the Earth system are continually reconnected through everyday practice.

5. Conclusions

This study examined Japanese geoparks situated within one of the world's most tectonically active regions through four interconnected perspectives: geoheritage, geohazards, Earth-system circulation, and local communities. Based on a comprehensive examination of all 48 members of the Japanese Geoparks Network, together with practical observations from the Hagi Geopark and the Miné-Akiyoshidai Karst Plateau Geopark, the study explored how active-margin Earth-system processes are expressed through geoheritage, environmental conditions, and human society.

The results demonstrate that Japanese geoparks collectively preserve diverse records of plate subduction, magmatism, accretion, crustal deformation, uplift, erosion, sedimentation, and hydrological processes that have shaped the Japanese archipelago throughout Deep Time. At the same time, these processes continue to influence contemporary society through earthquakes, volcanic eruptions, water resources, ecosystems, agriculture, fisheries, and regional landscapes. From this perspective, geoheritage, geohazards, and hydrological environments may be understood not as separate phenomena, but as different expressions of Earth-system processes operating across different temporal and spatial scales.

A central contribution of this study is the identification of four forms of reconnection through which geoparks may help bridge relationships that are often separated in everyday human experience. First, geoheritage can reconnect local landscapes with Deep Time by revealing how individual geosites represent long-term Earth-system processes. Second, geohazards can reconnect Human Time with Deep Time by demonstrating that earthquakes, tsunamis, and volcanic eruptions are recurrent geological processes rather than isolated disasters. Third, water environments and Earth-system circulation can reconnect human life with ongoing geological and ecological processes by illustrating how water, food production, ecosystems, and livelihoods are sustained through interconnected material cycles. Finally, geopark activities can reconnect people with local communities through participation, communication, intergenerational learning, and shared engagement with regional environments.

Overall, these findings suggest that geoparks can be regarded not only as places for conserving geoheritage or promoting tourism, but also as practical frameworks for reconnecting relationships among the Earth system, time, place, and human society. Rather than treating geoheritage, geohazards, water environments, and community activities as separate domains, the present study demonstrates that they collectively represent complementary expressions of active-margin Earth-system processes operating across multiple spatial and temporal scales.

Participation provides the practical foundation for these reconnections. Through geoe-ducation, geotourism, geoheritage conservation, disaster learning, universal tourism, and community activities, geoparks create opportunities for people to recognize relationships

between local environments and broader Earth-system processes. In this way, participation functions not merely as a means of communication but also as a process through which relationships among people, communities, and the Earth system can be continuously strengthened and renewed.

By interpreting the Japanese Geoparks Network as an integrated active-margin Earth system rather than simply as a collection of individual geoparks, this study provides a complementary perspective for geopark research. It demonstrates how geological information, geohazards, hydrological environments, Earth-system circulation, and community-based practices can be integrated within a single conceptual framework. This interpretation also complements previous geopark research by emphasizing not only the characteristics of individual geoparks but also their collective significance for understanding long-term relationships between the dynamic Earth system and human society.

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