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The illusion of volcanoes

Sakurajima is among Japan's foremost active volcanoes. Sakurajima had erupted frequently through its southern peak, Minami-dake, until about 2000, when it fell dormant for 10 years. In 2009, the volcano once again came to life, erupting through Showa Crater, a parasite volcano on Minami-dake. In a single year, the volcano erupts over 1,000 times, with an average of three times per day. Therefore, it logically follows that an eruption should be visible at least once each night.

In mid-May of 2015, I was informed of some perfect spots from which to take photos by Hiroto Hiramine, a graduate student of volcanology at Kagoshima University. On the 2nd night, on the 17th, the spot I chose was a high vantage point near Tarumizu, seven kilometers from Showa Crater. Just after twilight, I affixed my camera to my tripod and settled in to wait for an eruption. Alone, I would have been tired of watching after just 30 minutes, but having another person with whom to talk helped pass the time. Beneath the starry sky, we spoke in intermittent whispers of everything from volcanology to idle gossip.

It's an eruption! At 23:18, I turned my eyes to Showa Crater and saw dark-red lava arc skyward in a parabola and land on the mountainside. In time, the lights of Kagoshima that framed the mountain were obscured by its eruption. In the midst of the tumult, lightning flashed, illuminating the smoke. Just when I thought the eruption was over, there was a second bolt … This photo is produced from the cumulative effect of that 90 seconds of light—a glimpse into a world far different from the one I saw firsthand.

Photography/text　Motomaro Shirao

The Mt. Fuji, Solitary Mountain

Early 20th century's novelist Osamu Dazai had worked at Tenka tearoom in front of the Mt. Fuji. In June 2013, Mt. Fuji was recognized as a World Heritage Site (Cultural Site). This mountain is renowned throughout the world as a symbol of Japan—and yet, geologically, it is shrouded in mystery.

Text/ Dr. Yuka Masaki
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Dark Red Solitary Mountain

Japan's loftiest peak, Mt. Fuji, is adorned with a tapestry of ever-changing color throughout the seasons. Although visitors from the world over may visit for a glimpse of its beautiful form, it remains bashful, frequently hiding itself behind banks of clouds. When the mountain is blessed with a perfectly clear weather, it reveals itself to be a magnificent peak of peerless blue. Osamu Dazai describes this phenomenon in his short story "One Hundred Views of Mt. Fuji":
"*In the middle, stood Mt. Fuji, and below, Lake Kawaguchi spread out pale and cold. The mountains in the foreground crouched quietly on both sides, as if cradling the lake itself.*"

Photo/Motomaro Shirao

The Mt. Fuji reaches 3,776 meters at its summit and has crater of 100 to 130 meters in diameter, with a depth of approximately 237 meters. It is composed of cooled lava and pyroclastic sediments to make conic shape, and it's called "stratovolcanoes."

Although it looks piercingly blue from a distance, up close, Mt. Fuji's bare surface reveals itself to be dark red. Mt. Fuji is a continental volcano composed of basalt; the degree of iron oxidation in the basaltic lava turns the mountainside red to dark red. The blue color of Mt. Fuji as viewed from afar is due to the dispersion of light from particulates in the air.

Lava flow created fifth lake

Mt. Fuji was originally a collection of several active volcanoes. Repeated eruptions over the past 100,000 years (and more) have given the area a mountainous shape.

A record of Mt. Fuji's eruptions have been documented since the Shoku Nihongi, recorded in the early days of Japan's Heian period, over 1,000 years ago. Of the eruptions it describes, two particularly large-scale eruptions were recorded: the Jogan eruption of 864 and the Hoei eruption of 1707. In the Jogan eruption, bright red lava welled from Mt. Fuji's chasms and cracks. The Hoei event, however, was an explosive eruption that spewed clastic material, such as pumice.

Mt. Fuji's long history of eruptions gradually crafted a cenote formation, into which spring water and rain water flowed to create beautiful lakes—the famous Fuji Five Lakes: Lake Motosu, Lake Shoji, Lake Sai, Lake Yamanaka, and the aforementioned Lake Kawaguchi.

In fact, it is said that there were originally only four lakes surrounding Mt. Fuji. The Aokigahara lava that erupted in the Jogan era flowed into the lost giant lake, the Se-no-Umi. The Aokigahara lava drowned over half of the Se-no-Umi, creating Lakes Shoji and Sai.

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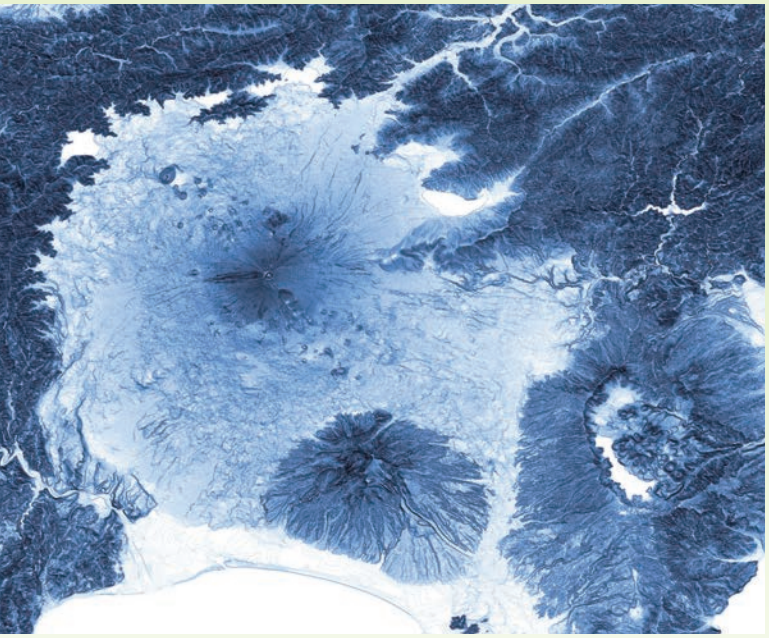
The Hoei eruption as depicted by "Illustrations of the Hoei Eruption at Mt. Fuji" (Shizuoka Prefectural Central Library)

A mountain shrouded in mystery

"There's actually a lot we don't know geologically about the volcano that is Mr. Fuji," says Prof. Masato Koyama, Shizuoka University. Over the years, Prof. Koyama has become the leading authority on Mt. Fuji research, conducting geological surveys on the renowned mountain. He notes that research on



Emphasizing the topography around Mt. Fuji reveals the numerous eruption craters at the site. Inclined survey map of Mt. Fuji and Hakone (Koji Wakita and Makoto Inoue)

Mt. Fuji lags remarkably behind research on other volcanoes in Japan.

One frequently-cited reason as to why geological research on Mt. Fuji has been so delayed is the poor condition of the sample rock. For example, even if rocky outcrops are exposed through road construction or landslide, it is only for an extremely short period of time. Weathering works quickly, and the specimen soon loses its distinctive characteristics. Moreover, as Mt. Fuji is a massive mountain, the survey area is similarly enormous. For these reasons, it is difficult to follow the history of Mt. Fuji, particularly prior to recorded human history.

Meanwhile, current observations of Mt. Fuji are frequently conducted with installed GPS stations. GPS can instantly analyze moving of the earth's crust. Numerous high-precision seismographs that can sense earthquake activity are also positioned around Mt. Fuji, whereas laser surveys via aircraft have provided a detailed map of the terrain.

However, predicting Mt. Fuji's eruptions is still considered to be extremely difficult—and when we are able to predict the eruption, the ensuing torrent of lava remains a pressing issue. When the eruption finally occurs, how do we respond? This is an issue we must address as prediction technology improves.

Trekking through eruption history

Are you aware of the bulge that is present on Mt. Fuji—halfway up the mountain?

This bulge is located on Mt. Fuji's southeastern side. In 1707 (year 4 of the Hoei era), Mt. Fuji experienced a major eruption, 49 days after the Hoei Earthquake (Mw = 8.7-9.3, Nankai subduction zone). During those 49 days, rumbling was heard from within the mountain. After the eruption, people would have realized immediately that the shape of mountain had changed. The huge eruption created the Hoei Crater and Mount Hoei (elev. 2,693 m). In particular, the Hoei Crater is renowned as the largest crater created in Mt. Fuji's history.

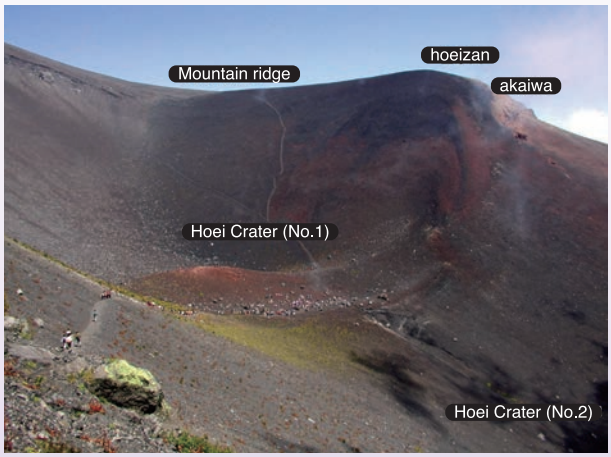
The Hoei Crater encompasses three craters, labeled Crater 1, 2, and 3. They are labeled in order of elevation. The Crater 1 is the highest and actually the newest to be created and, at 1.3 kilometers across, the largest of the three.

If you would like to enjoy a geological tour of Mt. Fuji, Dr. Koyama recommends a course around Mount Hoei, where you can see the history of Mt. Fuji's eruptions. The route consists of a hiking trail that takes 1 hour to walk for one way from the bus terminal. The trail also travels near Mt. Fuji's tree line, and the scenery takes some intriguing, unexpected turns along the way. You can survey not only the crater but also the peak of Mt. Fuji, making for a most magnificent view. You can even enjoy the experience on a day trip from Tokyo.

The allure of Mt. Fuji

Mt. Fuji's peak is covered with a cap of snow nearly year-round. At the beginning of autumn, the influx of visitors has almost ceased, and a hush falls over the mountain. It won't be bustling with pilgrims and tourists until July of next year. The season during which you can easily visit Mt. Fuji is short.

Among the peaks of Japan, the dark-red Fuji is frequently seen as a mountain whose only distinguishing characteristic is its height. However, it is Mt. Fuji's veil of mystery that lends it its unique character—soaring high, alone above the crowds, with only the plants underfoot to keep visitors company. Perhaps a famous words of Osamu Dazai best sums it up: "*The evening primrose suits Mt. Fuji well.*"

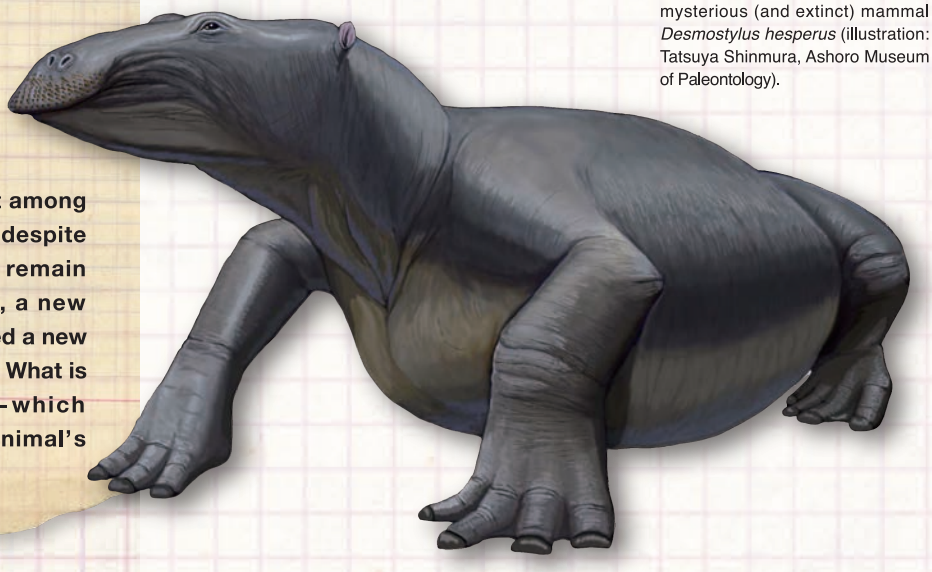


Left: Mount Hoei and the Hoei Crater. The reddish-brown rock surface is exposed. Right: Mt. Fuji's peak. (Photo: Masato Koyama)

Was the extinct Desmostylus a good swimmer?

— New research sheds light on the life of this ancient creature —

***Desmostylus* is among Japan's most famous paleorganism. A staple of school textbooks, it could be said to be considered a mascot among the people of Japan. However, despite its popularity, many mysteries remain surrounding this animal. Now, a new method of research has unraveled a new aspect of the *Desmostylus*'s life. What is the nature of this research—which focuses, of all things, on the animal's swimming abilities?**



Reconstruction illustration of the mysterious (and extinct) mammal *Desmostylus hesperus* (illustration: Tatsuya Shinmura, Ashoro Museum of Paleontology).

About 16 million years ago, Japan's shores were inhabited by odd mammals with long lips, hippo-like torsos, and four fat, powerful legs. Their most striking features were their molars, which grew together in bouquet-like bunches.

This animal was dubbed the "*Desmostylus*." These creatures inhabited the North Pacific coast and grew to almost 2.5 meters in length. Their fossils are found in particular abundance in Japan, and thus they are known as one of Japan's emblematic ancient creatures.

Did they live on land, or at sea? That's a question.

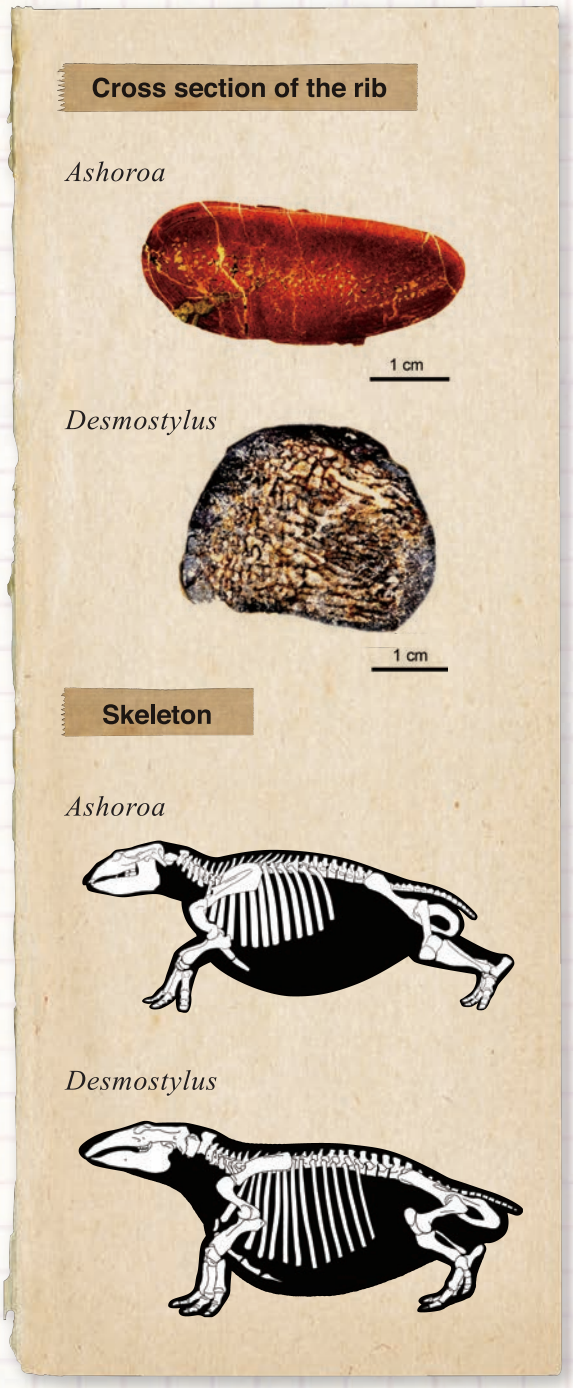
Their friends are known as "Desmostylians" for their unique tooth shapes. There are five reported genera and 11 reported species of Desmostylians. Besides *Desmostylus*, other representative Desmostylians include *Paleoparadoxia*, who sports a relatively short nose and a different configuration for its "pillars" of teeth, and the more primitive *Ashoroa*. It is possible to view restored skeletons for many Desmostylians, including *Desmostylus*, in natural history museums across Japan. Desmostylians lived from the Pliocene (approximately 28 million years ago) to the Middle Miocene (approximately 11 million years ago). They are members of the mammalian group Afrotheria and cousins to manatees, hyraxes, elephants, and aardvarks.

Desmostylians are also known as bizarre creatures shrouded in mystery.

The foremost mystery about these animals is how they lived. A jumble of opinions has been offered regarding the mammals' lifestyles. Three major hypothesis have emerged: that they lived on land, like the polar bear; that they lived underwater, like the manatee; and that they split their lives between both environments. Each theory, however, lacks conclusive evidence, and so the habitat and food sources of Desmostylians cannot be ascertained.

Against the backdrop of these mysteries, another is offered in that there are no mammals currently alive with the same style of teeth as the Desmostylian molars. Therefore, it is difficult to offer conjecture as to the Desmostylians'modern-day descendants. Another reason for the creature's enigmatic reputation is that Desmostylian forms have been reconstructed in multiple shapes, with their postures and stances undetermined by their restored skeletons. As researchers' morphological reconstructions differ, it is difficult to deduce these creatures'lifestyle habits from structural clues.

"Therefore, I thought that we needed to approach this problem



Cross-section view of the ribs of a *Desmostylus* and an *Ashoroa*. The bones of the *Desmostylus* are hollow (illustration provided by: Shoji Hayashi, Okayama University of Science). The skeletal illustration is provided by curator Tatsuya Shinmura from the Ashoro Museum of Paleontology.

from a different angle than we've taken in the past," says Dr. Shoji Hayashi, Okayama University of Science.

Slicing the bones for a better view

In a research he presented in spring 2013, Dr. Hayashi focused on the bones' organizational structure.

It was pointed out that originally, differences in the internal structures of animals' bones appeared depending on their biotopes.

For example, creatures that live on land generally have hollow bone structures that combine minimized weight with flexibility. Moreover, manatees and dugongs that live near the shore in shallow seas see their bones become more densely-packed. This is presumed to spring from the need to make their bones heavier and less buoyant so that they can feed on seafloor seaweed as their primary food source. In addition, deep-sea animals, such as whales, have bones with interiors that are hollow, like sponges. This can be interpreted as the bones becoming lighter so that their owners can swim at higher speeds.

"However, these ideas actually haven't gone beyond pattern identification," Dr. Hayashi says. "We haven't actually confirmed via data if differences in bone structure are produced by an animal's living environment."

Therefore, Dr. Hayashi and his colleagues have cut bones from 62 species of extant animals—humeri, femurs, ribs, vertebrae, and more—to perform complete examinations of their cross-structures. As a result, they have confirmed, at least, that the bones of animals that live in coastal regions are dense, whereas the bones of deep-sea animals have a sponge-like structure.

But now we come to the *Desmostylus*. When the team cut the bones of a *Desmostylus*, it found that its bones had a sponge-like structure. In other words, the *Desmostylus* was a deep-sea animal. The bones of the Ashoroa and Paleoparadoxia Desmostylians, conversely, were tightly-packed—those of a coastal animal.

What it means to be a "good swimmer"

There are massive differences in form between the *Desmostylus* and other deep-sea creatures. The limbs of animals, such as whales, resemble fins, but their bodies are streamlined to minimize water resistance. However, although the *Desmostylus* may have sponge-like bones, its extremities are clearly confirmed to be fingers, and its body shape is far from streamlined. Moreover, a specimen of the deep-sea *Desmostylus* and the coastal *Paleoparadoxia* were discovered in the same stratum in the Akan in Hokkaido. In other words, the habitats of these creatures were clearly not divided.

Dr. Hayashi explains: "In view of this point, we might call *Desmostylus* not a 'deep-sea creature,'but a 'creature capable of deep-sea movement.'In other words, though it may have lived in the same place as other Desmostylians, the *Desmostylus* was a particularly 'good swimmer.'"

The bones of the primitive *Ashoroa* are dense, but those of the evolved *Desmostylus* are spongiform; this indicates that as time passed, Desmostylians took on a more aquatic aspect. This tendency toward spongiform bone structures in evolution is also seen in whales.

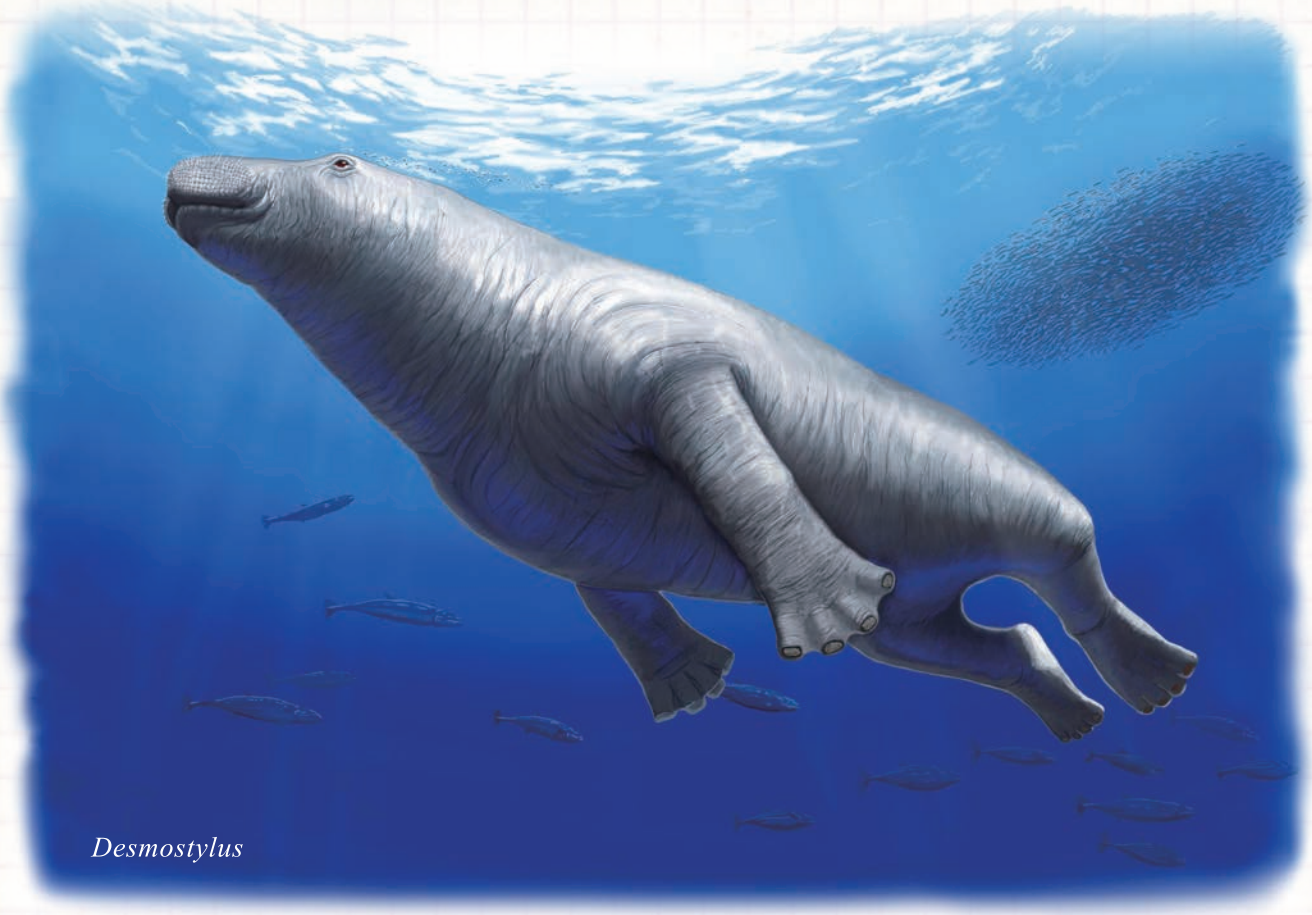
"Like cetaceans and Desmostylians, mammalians returning to the sea in a secondary sense might have experienced bone evolution before body streamlining and the appearance of genuine fins" (Dr. Hayashi).

In addition, a recent research has clarified that *Desmostylus* hatchlings had bones that are relatively dense. In other words, there is the possibility that as the body of the *Desmostylus* matured, it came to "specialize" in swimming.

Another "piece of the puzzle"

A research that has already been presented has attempted to guess *Desmostylus*'s food sources using isotope analysis of its teeth. According to this research, it is possible that *Desmostylus* ate coastal seaweed or invertebrates, such as shrimp.

At a glance, the results of this dental isotope analysis would appear to contradict those of the bone structural analysis by Dr.



The habitat of the Desmostylians, as clarified by the recent research. The *Ashoroa* and *Paleoparadoxia* lived in coastal regions and were not particularly strong swimmers. Conversely, there is the possibility that the *Desmostylus* was quite good at swimming (illustration: Tatsuya Shinmura, Ashoro Museum of Paleontology).

Hayashi's team. However, Dr. Hayashi says that "if we regard *Desmostylus* as 'merely a good swimmer,' one can consider there to be no contradiction."

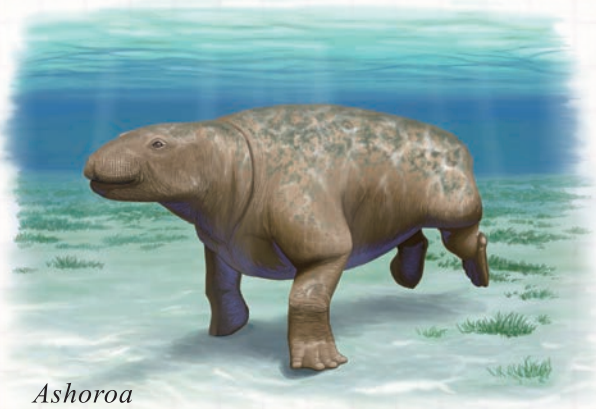
"Recent research is another piece of the puzzle that will assemble the full portrait of this mysterious creature," continues Dr. Hayashi. Frankly, these research results alone cannot dispel all the mysteries surrounding *Desmostylus* and its cousins. Specifically, the restoration of their life orientations remains a great enigma.

To life orientations, feeding habit analysis via isotope research, and other existing research, we can now add this new research perspective of bone organizational structure. To see the complete portrait of *Desmostylus*, much more data, including other geologic information, will most probably be required.

Meanwhile, this new research method of bone organizational structure analysis seems poised to yield data that could offer further clues to various extinct animals and their life orientations. If this new perspective can shed some light on the differences between not only ocean animals, but land animals as well, that will make the research all the more valuable.

Cooperation/ Dr. Shoji Hayashi, Department of Biosphere-Geosphere Science, Okayama University of Science.

Text: Ken Tsuchiya is a science writer and president of Office GeoPaleont. He has been a reporter and an editor for numerous scientific publications. He specializes in earth science, particularly geology and paleontology. His recent work includes Kaii Koseibutsu Kou (Consideration that Mysterious creatures from Paleontology; Gijutsu Hyohron) and Koseibutsu Misuterii Shiriizu (Extinct Plants and Animals Mystery Series; Gijutsu Hyohron), etc.


Ashoroa


Paleoparadoxla

"The Memorial Monument to the River Mouths Tsunami Following the Great Earthquake"

A Message to You, Hundreds of Years in the Future

The Lessons of the Tsunami: The Idea of "Monument Renewal"

Seven years have passed since the Great East Japan Earthquake. The great tsunami is the epitome of the old saying, "Disaster strikes when you least expect it"—it is a disaster that we can hardly imagine in reality. Those who did indeed experience it, who saw homes and neighbors washed away, wished to not see those losses repeated—they wanted to tell future generations what they had learned. However, no matter how great the disaster, memories will eventually grow distant and fade away. How should these lessons be passed down so that they are not forgotten in a hundred years—or in a thousand? Our ancestors attempted to solve this problem through the use of stone monuments to carry messages across the centuries to the present.

In Memorial of the River Mouths Tsunami Following the Great Earthquake

In Osaka, a stone monument stands at the foot of Taisho Bridge. Made of approximately two meters of granite, it is inscribed with the words, “In Memorial of the Tsunami Following the Great Ryokawaguchi Earthquake.” The surface of the monument is covered with messages engraved into its surface; the contours of the black inscriptions are clear and nearly undimmed by time. But the stone was carved in 1855, erected after damage from the tsunami in the previous year.

One-hundred sixty-three years ago seem an inconceivably long amount of time to us. But it is the ease with which this pillar can be read that ensures our ancestors’ wisdom to keep memory of the disaster undimmed.

A loose translation of a summary of the text reads as follows:

On the fourteenth day of the sixth month of the Kaei era (July 9, 1854, at about midnight), there was a great earthquake (the Iga-Ueno earthquake). The people of the town of Osaka lived in fear of aftershocks for four or five days and weathered sleepless nights.

On the fourth day of the eleventh month of the same year (December 23, about 8:00 a.m.), a great earthquake (the 1854 Tokai earthquake) occurred. The people took refuge in empty lots and small boats. The next day, on the 5th (December 24, about 4:00 p.m.), a great earthquake (the 1854 Nankai earthquake) occurred. The damage was extensive, and shortly afterward, a tsunami struck. The Aji River and Kizu River were flooded, and the canals were inundated with muddy water four shaku (about 120 centimeters) deep. Anchored boats were swept away, and wrecked many bridges.

Within a very brief period, many lives were lost, and many were injured. We are told that during the great earthquake 147 years ago (the 1707 Hoei earthquake: the Tokai-Tonankai-Nankai triple megaquake), many who stayed aboard small ships when the tsunami struck were fatally drowned. However, almost no one in the present has heard of these stories , and now, yet again, many lives have been lost in the same place. Such a tragedy will probably happen again in the future.

We now believe that when a great earthquake occurs, a tsunami will always follow, and so we never go out in our boats at such a time. The tsunami will not only advance from the open sea; it will sometimes well up from the bottom of the sea floor near the coast, from riverbeds, and from fields near the ocean shore (referring to liquefaction).

So that those who come after us may understand that the tsunami differs from an ordinary storm tide, and to pay tribute to the memory of the dead, we write this here. Please, those who are thoughtful, every year, refresh this inscription with sumi ink so that the text may be yet easily be read.

The tsunami of the Aqua Metropolis

The commercial city of Osaka is renowned as the Aqua Metropolis. In Edo-era Osaka, the veritable mesh of canals was covered even in the heart of the present city. Countless ships—cargo ships and more—crowded its waters, following the Kizu and Aji Rivers from Osaka Bay to the central canals.

Once a tsunami advances on these waterways, the ships follow the river channels inward and become lethal weapons, smashing bridges to pieces. Osaka has been ravaged countless times by tsunamis.

The stone monument at the Taisho Bridge records knowledge from the three earthquakes that occurred in the year 1854 and the experiences gained from it, focusing on damage from the tsunami following the 1854 Ansei Nankai earthquake. Particularly extensive detail is provided on the Ansei Tokai earthquake that occurred on November 4 (estimated at magnitude (M) 8.4) and the Ansei Nankai quake (M 8.4) on the following day.

Even more so than the detailed description of events, one’ s eyes are drawn to the monument’ s final sentence. Let us turn again to a colloquial translation of the text:

Please, those who are thoughtful, repaint these words every year with sumi ink so that the text may be yet easily be read.

Even now, 163 years later, these words from our ancestors are kept alive by modern-day citizens. Every year, during the Jizo-Bon Festival in August, a memorial service is held for the dead, and the monument is repainted with sumi ink.

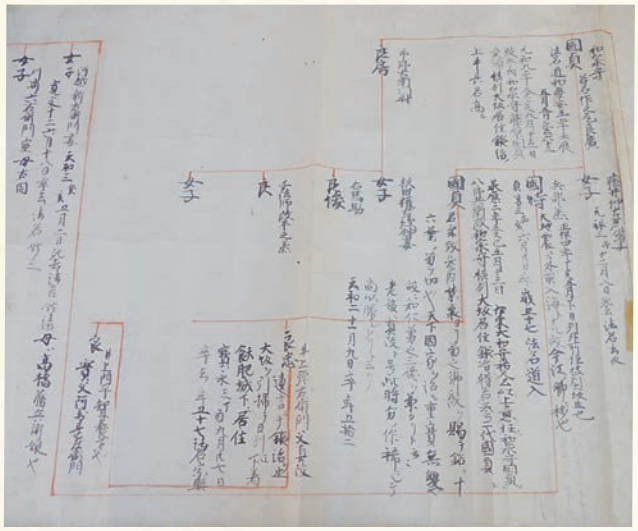
However, maintaining this custom has not been easy. Originally, the stone monument stood by the ferry pier of the Kizu River. The narrow waterway that flowed beside the monument was reclaimed, however, and the area is now Sennichimae Street with a bridge switched from the ferry. Every time the bridge has been rebuilt, the street has been widened, or the subway has undergone construction, the stone monument has been relocated.

The tradition has been kept alive throughout all this, however—and that is due in great part to the monument’s directive that the townspeople become involved in its upkeep every year.

The Tontokoro Earthquake Memorial Monument

Another example of the tradition of “renewing a stone

For the Tontokoro Earthquake Memorial Monuments, only the seventh monument, the newest one, differs in the stone used to construct it. The first through sixth are made of clastic rock, while the seventh, erected in 2007, is made of granite. According to Head Priest Inoue, this reflects local trends in the stones used for tombstones. Previously, Kiyotake tuff collected in-town was the primary material used for tombstones, but recently, imported granite is the more frequent choice. Kiyotake tuff originates from the Ito pyroclastic flow from the eruption of the Aira Caldera approximately 29,000 years ago—it comes from shirasu soil, in other words.



The family genealogy at Saikyo Temple.

monument" that has been maintained with a longer interval of renewal is in Miyazaki, at the Tontokoro Earthquake Memorial Monument.

Beside the Miyazaki Sports Park, packed with sports teams for thier spring training, lie seven stone monuments in a corner bounded by the national highway and the prefectural road. The monuments commemorate the Tontokoro earthquake (M 7.6), which occurred in the second year of the Kanbun era (1662), with its hypocenter in the Sea of Hyuga. Every 50 years since the placement of the first marker, new monuments have been erected, which have been used for continual memorial services and protected from weathering for over 350 years.

The Tontokoro earthquake occurred in the dead of night—at about midnight. A family genealogy in Saikyo Temple in Tontokoro village contains the following description:
"Because of the earthquake, Tontokoro was swallowed by the sea, and we moved to Imae."
The massive tsunami and large-scale land subsidence led to a large area of land near the mouths of the Kiyotake and Kaeda Rivers being submerged, creating a bay. These monuments are at the old site of Saikyo Temple; the temple is currently located about 1 km from the site.

The submerged area was a grain-producing region in the domain of Obi, so the damage was a huge blow to both farmers and the feudal government. A river levee was subsequently built by the domain, helping revive the rice paddies. However, the area remained a muddy wetland owing to the lingering land subsidence until the mid-1940s to the mid-1950s.

Among the seven Tontokoro Earthquake Memorial Monuments, the oldest two have crumbled. The stone monuments become larger, starting with the third oldest, and they sport the names of sponsors, such as village heads and district representatives. The second through fifth monuments host scriptures, all of which are strongly memorial in character; the sixth, which marks the 300th anniversary of the deaths, offers a message in the name of the mayor of Miyazaki city, stating that the fading of memory should be held in check by memorials to "pass a message on to future generations." The message on the seventh monument follows suit, its inscription dedicated to "communicating the importance of disaster prevention to future generations."

"Renewing" the monuments: Modern-day attempts

While these monuments have remained since olden days, there are also monuments that have been newly built. In the town of Otsuchi in Miyagi Prefecture, a wooden monument communicating the lessons of the Great East Japan Earthquake was erected in 2013. At the proposal of a local high school student, the local area came together to build this monument. As this monument is made of wood, it will ultimately rot; therefore, it is "renewed" every four years to communicate its message to future generations.

The wisdom of our ancestors in renewing these monuments is assuredly successful in communicating a message across the years. However, as local connections fade, preserving and maintaining these monuments become no easy task. The human and economic responsibilities tend to fall to volunteers.

The Memorial Monument to the Ryokawaguchi Tsunami Following the Great Earthquake featured at the start of the article is managed by elderly citizen volunteers. An increasing number of locals are completely unaware of the monument. Therefore, the local organization that has maintained the monument across generations, the Town Boosters of West Sanchome, Saiwai-cho, Naniwa Ward, compiled a publication commemorating the monument. These efforts have been successful, and the monument has been recognized as tangible town cultural property. The Boosters thought that the ensuing subsidy from the government would put an end to management woes, but that relief was short-lived: owing perhaps to other economic issues, the subsidy was cut off after the initial year, and the Boosters once again were forced to rely on volunteer operations.

Renewing the Tontokoro Earthquake Memorial Monuments in Miyazaki has so far fallen mainly to municipal governments, but they have unfortunately refused to maintain the seventh monument because of its religious nature. Therefore, the Kibana Boosters' Club, a local aid society, has stepped in. "It would be simple for the temple itself to do it, but it would be a meaningless act without the involvement of the community," says Head Priest Ryotatsu Inoue of Saikyo Temple.

Head Priest Inoue explains a family genealogy at Saikyo Temple that contains an account of the Tontokoro earthquake.

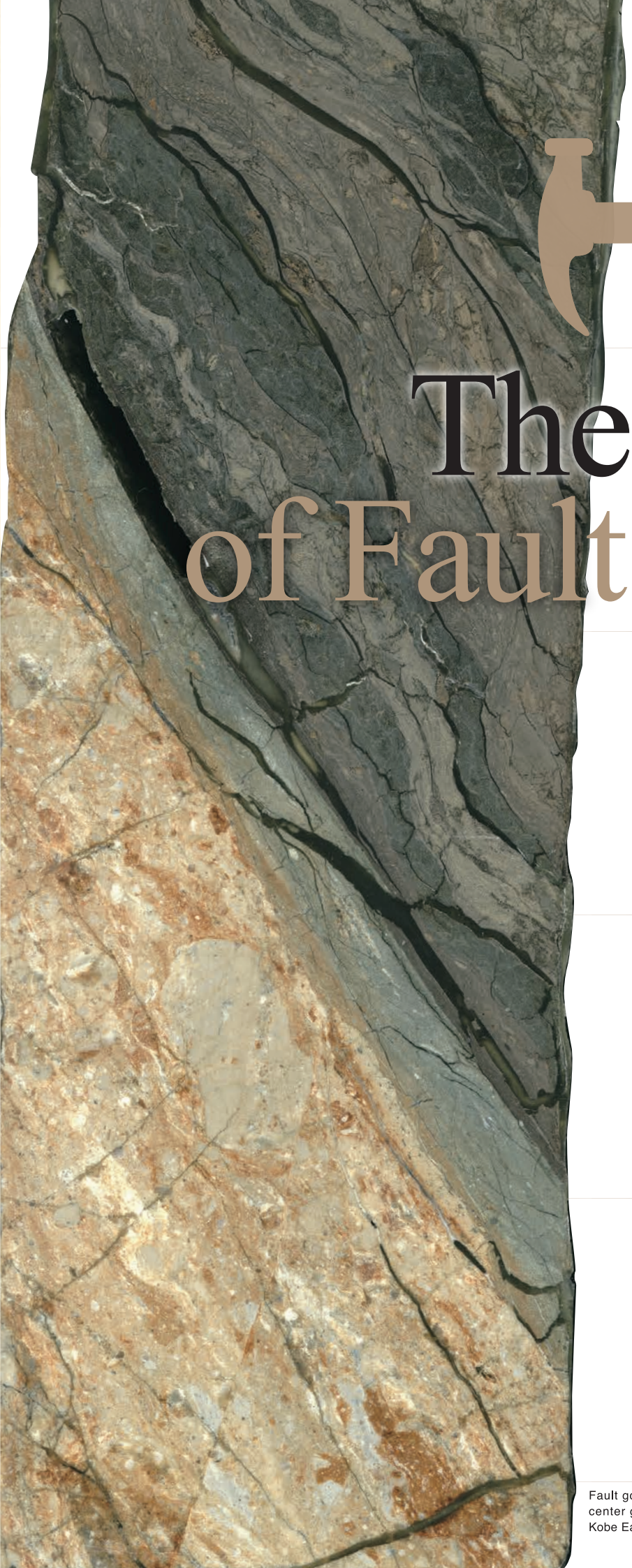
Communicating across the generations

The Osaka Memorial Monument to the Ryokawaguchi Tsunami Following the Great Earthquake has been updated every year for 163 years; Miyazaki's Tontokoro Earthquake Memorial Monuments have been updated every 50 years for 356 years. Both continue to tell of unlucky experiences to future generations. Further, Otsuchi's wooden monument, which is updated every four years, represents a new signpost marking the passage of time.

The lessons that can be learned only by weathering disaster are included in "the silent, wordless language of stone and wood." We can only hope that they will play even a small part in protecting our grandchildren from tsunamis that will perhaps visit in the future. g

Cooperation/ Ryotatsu Inoue, Hiroshi Yasuoka.
References/ Takeshi Nagao, 2012; Kuniyo Kawabata, Geolge, 2013.

Yujin Kitamura/ Assistant Professor in Geology at Kagoshima University. Chief Editor of Geolge. He has joined expeditions of Drilling Vessel Chikyu three times and worked on fault rocks and marine geology.



Art Created by Nature

The World of Fault Rocks

"Fault rocks" are stones that record the movement of faults. Careful polishing of these stones reveals their exquisite structures, whose beauty and color are packed with information on fault movement. Here, we will provide an academic introduction to these precious rocks.

Reference/ The mechanics of earthquakes and faulting, Christopher H., Scholz

What is a "fault rocks"?

It is well-known that earthquakes are produced by faults. But have you ever seen what actually happens at a fault?

The term "fault" refers to strata slipping so as to become dislocated or severed. When fault slippage occurs, the strata and rocks involved are crunched and transformed—destruction that the strata and rocks subsequently record. Rocks that have indeed recorded fault movement in this manner are called "fault rocks."

Almost all of the fault outcrops that can be observed have been converted to weak clay, and the detailed structures in the fault rock cannot be visualized. To see the structures more easily, polished sections are created. Polished sections are rock specimens that are cut in half, whereupon their surfaces are polished. A wealth of information from an earthquake can be extracted from the structural recorded in polished fault rock sections—the direction of fault motion and slippage, the degree of destruction caused, and more. Geologists researching

Fault gouge and cataclasite of the Nojima Fault. The center greenish gray layer the zone that has caused Kobe Earthquake of 1995 (M7.3).

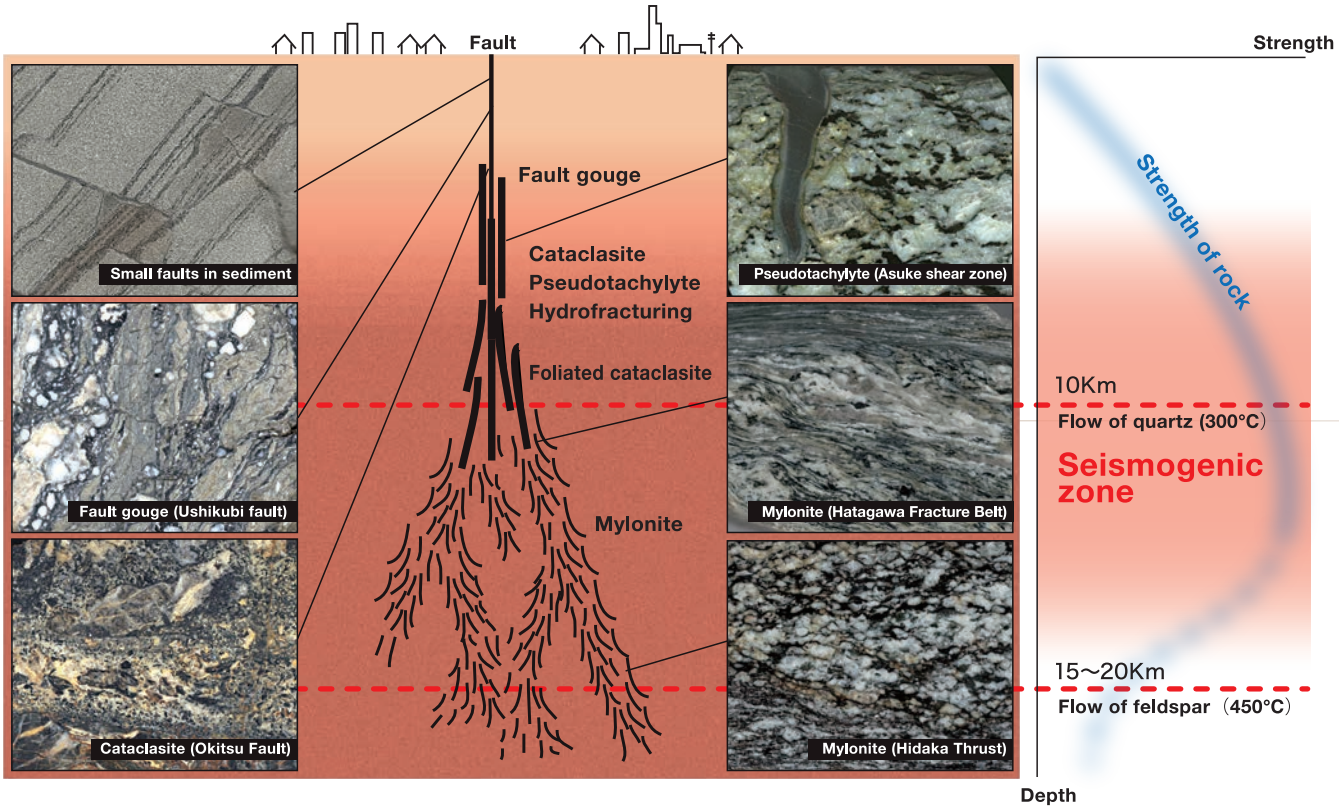


Fig. 1 Differences in fault rocks depends on their fault formation environments. The deformation style of a fault rock relates with the strength of fault forming minerals, and mineral strength degreases with temperature. Flow texture is predominant at deep high temperature depth, and brittle cataclasites are well observed at low temperature depth.

earthquakes create polished sections of fault rocks, observe and analyze their structures, and extract information during the earthquake.

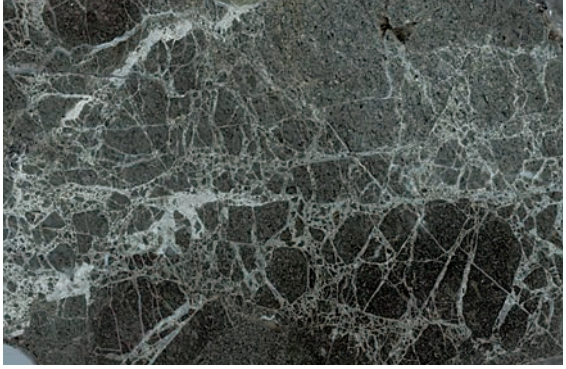
Earthquakes usually occur deep underground. Cracks sometimes appear on the surface as active faults, but the fault rocks that have recorded the conditions that generated the fault are situated deep underground, where it is usually impossible to retrieve them. Therefore, researchers either try to obtain harvest fault rocks through drilling or use the fault rocks that have risen to the earth's surface via tectonic deformation to research the mechanisms that generate earthquakes or the history of a stratum's movement.

Earthquake or not ?

A fault rocks is classified by their deformation style and components. For example, the "pseudotachylite" is composed of melted minerals via frictional heat during seismic slip; they are known colloquially as "earthquake fossils." The "pseudo" in the rock's name comes from its resemblance to the genuine tachylite formed from the rapid cooling of magma from volcanic activity. Fault rocks are capable of recording not only rapid seismic slip but the slow deformation occur deep within the earth. The deformation style of the fault rock depends on the temperature and pressure related to depth (see Fig. 1).

If the forces acting on a rock near the earth's surface, the minerals that compose the rock will be fractured brittle . These fault rocks are called "cataclasite," meaning "destroyed rock." If clay minerals are included within cataclasite, the clay portions will deform plastically without being destroyed, but strong minerals such as quartz and feldspar will be crushed. In this situation, the laminate structure of the fault rock will be visible, and the fault rock is then called "foliated cataclasite."

In high-temperature areas exceeding 300 °C (at a depth of approx. 10 km), even quartz will deform by plastically. (It's somewhat like how syrup will harden at low temperatures but stretch and deform as the temperature rises.) In these regions, if forces act upon a rock such as granite that is largely composed of quartz, the rock will overall undergo plastic deformation and become a fault rock called "mylonite." In these circumstances, however, minerals such as feldspar remain hard and brittle and will therefore break. If we move to regions where temperatures exceed 450 °C, not only quartz but materials such as feldspar will begin to deform in a plastically. Overall, rock will flow more smoothly, and at deeper depths, the earthquakes that cause rocks to break and



Hydro fractured sedimentary rock around the MTL.

Mylonite in MTL.

Fault gouge in Ushikubi Fault.

fracture have difficulty occurring. At depths of 20 km or more, earthquakes very rarely occur owing to lack of rock strength. Therefore, the appearance of the fault rock tell us the depth and earthquake condition of the fault

Fault rock variation

Many faults—from major to minor develop in Japan. The Median Tectonic Line (MTL), which divides Japan islands is the longest on-land active fault in Japan. Such large fault is used to be exhumed from various depth in each area, and the characteristics of its fault rocks varies according to differences in local geological features and formation depth.

In the Shikoku region, the MTL is developed within the sedimentary Izumi Group strata, and some fault rock is composed of cataclasite with high hydraulic pressure in sediment. In central Japan, the MTL is developed between high-pressure metamorphic Sanbagawa Belt schist and high-temperature metamorphic Ryoke Belt gneiss. In such deep fault rock, mylonite of metamorphic rock predominates and it exhibit an overall greenish color; they produce new minerals in reaction to fluids, creating beautiful, colorful patterns.

Let's go see some fault rocks!

Fault rocks used in research are stored as research specimens and therefore are usually not readily available to view. However, at the MTL Museum in the Minami Alps Geopark, visitors can view fault outcrops and polished sections of fault rocks. Why not take a long look at the museum's beautiful fault rock specimens—and reflect on the fault movements that have produced past earthquakes and shaped Japan?

Cooperation/ Dr. Hidemi Tanaka
Photo/ Dr. Hidemi Tanaka, Dr. Arito Sakaguchi, Dr. Kiyokazu Oohashi

Science writer/ Dr. Kuniyo Kawabata, JSPS research fellow at Kagoshima University, structural geologist. She lives in front of active volcano Mt. Sakurajima (See p1-2).

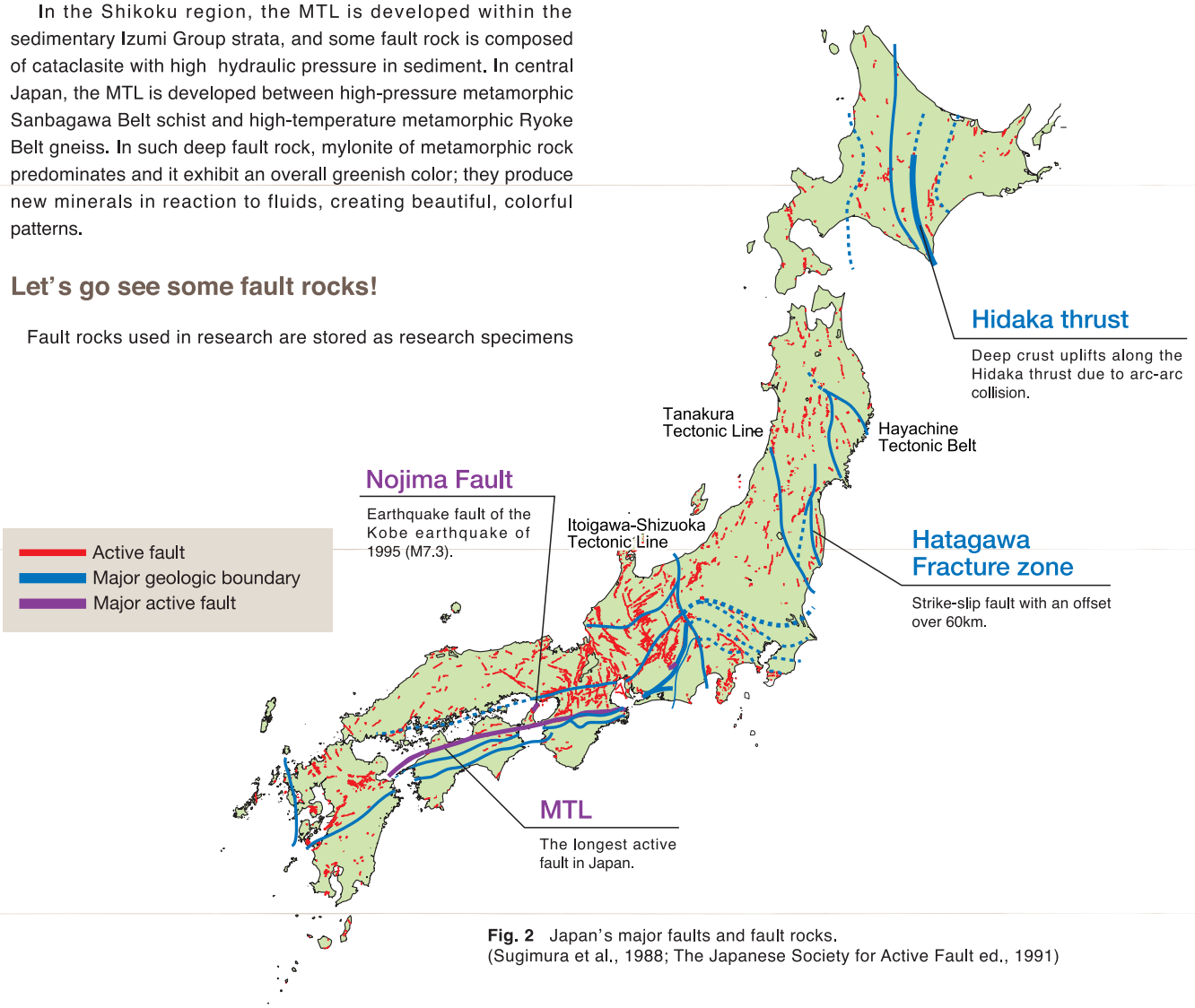


Fig. 2 Japan's major faults and fault rocks.
(Sugimura et al., 1988; The Japanese Society for Active Fault ed., 1991)

The “Tagoto Moon”

**In the valley of northern Chikuma in Nagano,
central Japan, designated as one of Japan’s Places of Scenic Beauty,
lies the Important Cultural Landscape of "Obasute".
Ascend Mt. Kamuriki, you will see 1,500 terraced rice fields.
The image of the moon reflected in the water
was known by the name of "Tagoto Moon" since the Edo era.
"Tagoto" means each and every rice fields in Japanese.**

Science writer/ Yuko Okayama, Science communicator who has a master's degree in volcanology and now working at Miraikan -The National Museum of Emerging Science and Innovation to deliver science to public in various approach.

Rice fields illuminated by —and reflecting—the moon

Long ago, a feudal lord who hated the elderly issued a proclamation: “once a person reaches 60 years of age, he or she must be abandoned and left to die.” One night, a lone, young man carried his mother upon his back and climbed up Mt. Obasute. He left her deep in the mountains and turned around to go home in complete darkness. Just then, his mother said: “I broke off branches from the trees along the road and threw them away during the journey here; follow them to find your way home.” Moved by the affection of his mother’s protective love even as he was leaving her to die, the man resolved to defy the lord’s fiat and brought his mother back home.

This story comes from the *Tales of Yamato* from Japan’s Heian era, and is the source of the name "Obasute" which means “grandmother-abandonment”. The scene of the story, the long-gone Sarashina village, first appears in literature in *Collected Japanese Poems of Ancient and Modern Times*, completed in the year 905.

“*Seeing the moon over Mt. Obasute at the village of Sarashina, I feel disconsolate*” (*author unknown*)

Even to a calm, clear heart, the sight of the moon’s cold reflection brings to mind grief and sorrow. Obasute’s connection with the moon is well-established in poetry; enshrined in many waka poems, its legacy as the land of the full moon persists to this day and age. Why is the moon so beautiful here? Is it because of the presence of countless mirrors that reflect the moon’s light?

Originally, terraced fields were constructed to cultivate rice in Japan, which is rife with steep, mountainous areas. The terraced fields at Obasute were built on particularly steep ground—they appear to be a staircase to heaven. The magnificence of this lyrical sight has led to its recognition as one of Japan’s Top 100 Terraced Rice Fields.

The origin of Obasute’s terraced rice fields

Many of Obasute’s terraced rice fields are created using landslide morphology. This is because the fields are naturally deep-plowed owing to their abundance of water. In landslides, large clumps of soil mass gradually move downward; this creates hollows in the upper sections of land that gather water. The same process also creates the *oike* reservoirs that provide water to the Tagoto Moon area. Originally, the *oike* were wetlands, but as the use of terraced fields expanded, manual labor came to be involved, and the *oike* became artificial.

Terraced rice fields are generally hosted by valley areas, but those in Obasute are located on mountain ridges. Over thousands of years, rainwater and landslides have transported a great deal of soil mixed with clay along the ridge lines of the uneven landslide topology. Normally, these ridge lines would be poor in organic material owing to the presence of sedimentary layers with insufficient clay, but it is because of the above origins that Obasute is blessed with fertile earth.

Hiroaki Tsukahara, Professor Emeritus in Seismology at Shinshu University, says, “Obasute’s charm lies in sight of the terraced rice fields on its ridges and the Nagano Basin below.”

The Tagoto Moon —reflecting hearts across the ages

Since its commemoration in the Noh comedy book *Tokusa* (1578), the image of the Tagoto Moon, established in Japan’s Warring States era, has been popularized in haiku and other poetry, travel writings, ukiyo-e woodblock prints, and more. In 1688, a poet Matsuo Basho commemorated his visit with a haiku: “*A face comes to me / an old woman weeps alone / moon as companion.*” In the mid-1800s, a sort of sightseeng guidbook titled *Collected Illustrations of Famous Places on the Road to Zenko Temple* depicts terraced rice fields and a moon-viewing party.

The Tagoto Moon in Ukiyo-e by Utagawa Hiroshige (1853). The multiple moon reflected in each and every terraced fields. Collection: Nagano prefectural museum of history.

The project members try to keep tilting giant mirrors following the moon to make the Tagoto moon.

The Edo-era *ukiyo-e* artist Utagawa Hiroshige, a famous ukiyo-e artist in Edo-era, also created multiple works featuring the terraced rice fields. Of great interest is that these works do truly depict a “Tagoto” Moon—in other words, as suggested by the word “tagoto” (meaning “in every field”), the moon is reflected in each and every rice terrace. In reality, however, multiple moons are never reflected at the same time on the surface of a horizontal body of water. Perhaps this, though, is the true Tagoto Moon—the image that lingers in our hearts.

Following Edo-era art, literature, and sightseeing, the Taisho-era and Showa-era travel boom cemented Obasute’s Tagoto Moon in the popular consciousness. Evidence of this lies in Tagoto’s Moon Recreation Project.

In 1936, for the mid-autumn celebration of the 250th anniversary of Basho’s famed visit, a moon-viewing event was held. I spoke with Fumiko Azegami, the daughter-in-law of the event’s organizer, Goyu Azegami. She said that water was stored to reflect the moon, even harvesting the rice early; scaffolds were built, and visitors sat in the fields and balconies to watch the moon. Visitors gathered from all over Japan, and it was a huge affair. The event was commemorated at the time in newspapers with photos.

Actually, there is someone who maintains the tradition of the Tagoto Moon Recreation Project to this day: the Shiori Hometown Boosters’ Committee chairman, Osamu Baba. However, the recreation uses not water, but giant mirrors. Even without early rice harvesting and cultivation, tilting the mirrors at just the right angles is said to be able to recreate the event. About 60 people of local high school students and volunteers were involved and supportive owing to the invocation of Obasute. The precision in mirror placement get better each year.

To preserve history and culture for future generations

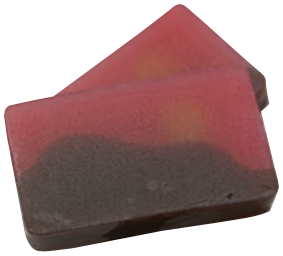
It is no small matter to preserve Obasute’s terraced rice fields. About 30 years ago, land improvements were conducted that folded 10 terraces into 1 to facilitate the use of heavy machinery. The terraces were, as a result of this process, ruined. How can terraced fields be maintained when they are incompatible with waterways, or roadways, or machinery? Moon-viewing committee chairman Masafumi Mori took action, urging the city to pitch in with locals and help with the fields’ upkeep. A system of ownership for the fields, sold on the attractions of the scenery and the agricultural experience, is being hammered out, but in reality, the practical considerations are formidable. The average age of committee members, who are mainly retirees, is over 70 years. The competing interests of scenic land, sightseers, and local farmers are incompatible.

No solutions have yet been found to the issues that accompany the aging of Japan’s population. There are, however, those who are still striving to protect their hometown also known as "Sarashina" and attempting to drum up support. Calling themselves the “Sarashina Renaissance,” these citizens want to communicate the appeal of Sarashina to the world and are attempting to gather a wide variety of backers—company presidents, head priests, news reporters, artisans, and more—to bolster the effort. A head of the committee Yoshikuni Otani has written approximately 250 internet articles covering history, culture, nature, local activities, and more in Sarashina—a veritable host of topics.

This article, meanwhile, has covered the profundity of the Tagoto Moon and the passionate feelings we all have toward our hometowns. In Mr. Baba’s words, these feelings resound in our hearts “always and forever.” For hundreds of years, the Tagoto Moon has served as a timeless reflection of our souls—and it perhaps will be handed down as part of our lives for generations to come.

An interview with Mayor Okada

“For the Chikuma River, a raised-bed waterway throw in the town, the terraced rice fields have served as natural dam—and therefore play a vital role in disaster protection. Obasute, the ‘City of the Moon,’ has the full support of the townspeople, and with the help of many, these fields will yet thrive. The local government’s ultimate weapon is nature. The magnificent Chikuma River lies at the heart of the city of Chikuma—we are practically the Republic of the Chikuma River! It is more than a tourist attraction—it is the pride of the people who live here. And if we can’t make ourselves happy with our urban planning, then where are we?” says the mayor with a smile.



“Shin-Sarashina,” the *yokan* cakes of Toraya

I stopped by Mr. Baba’s company to take a look at some materials and was treated to a teacake—a *yokan*, a traditional Japanese jellied cake made of red bean paste. The local cake was dubbed the “Shin-Sarashina” and came from the old shop Toraya. “What hospitality!” I thought. Once I bit into the rising moon straight out of the *ukiyo-e* print *Kyodaisan mt.* my taste buds were greeted with an exquisite sweetness.

Special Report!

International Earth Science Olympiad in Mie, Japan

Mie Prefecture, August 2016: The site of the International Earth Science Olympiad. High school students from all over the world have gathered for this event—and Arito Sakaguchi, editor-in chief of *Geolge*, is there to provide full coverage. Our special report lies below.

ITFI presentation.

Gold medalists of Japan.

Congrats!

Everyone gets along swimmingly at the send-off party. One of the best features of the Olympiad is how it does not end with the individual medal competition.

After a three-year break following the Great East Japan Earthquake (2011), the International Earth Science Olympiad has made its long-awaited return to Japan. A hundred representatives from 26 countries have gathered together in Mie Prefecture—the largest number of participants in the history of the event. Japan sent nine high school students in total: four representatives and five observers. The observers were not eligible for medals but could participate in the competition.

The Earth Science Olympiad is a test of notetaking and practical skills. Topics covered include geological features, climate, oceans, geophysics features, and astronomy. The competition tests not only knowledge but the ability to apply it. For example, in the geological survey section, competitors are expected to field a barrage of questions without hesitation at outcrop: is this schist or gneiss? Is this a joint of fault? Can you identify this fossil? How much a strike and a dip? Even college students would hesitate at some of these queries—but not these players. Even the curve balls are batted back in the blink of an eye. The total points per match are tallied, and the medals are thus awarded. Japan's competitors take home three golds and one silver—the best showing in history.

However, the true appeal of the Olympiad lies in not only in the medal competitions, but also in the International Team Field Investigation (ITFI), a field investigation event featuring mixed international teams. The teams consist of five to six members from various countries, and each site calls for research into a different topic. A bus takes participants to each investigation site, where they gather the necessary data within a time limit. Each team is to present results by the next day via a poster and oral presentation—it's a grueling schedule.

Participants must fervently communicate, think, collect data, debate, and draw conclusions with teammates from different countries and linguistic backgrounds. As the project proceeds, bonds between teammates form rapidly. When the winning ITFI team is called to the stage at the final day's awards ceremony, teammates hug each other's shoulders and join hands in celebration. Their smiles are truly moving. Despite linguistic and cultural barriers, the participants' shared love for earth science shines through—and they have met comrades with whom they can share true triumph. This Olympiad was filled with emotion—truly one to remember. g.

They are estimating size, shape and number of beach pebble.

Communication is a key for international group work.

One day before the final day.

Last spurt to the ITFI presentation.

Cross-cultural exchanges are also one of enjoyment.

Cover

Yufu River Gorge

The Yufu River Gorge is located midway up the Yufu River, Oita, Japan which finds its source in the Yufu and Tsurumi Mountains and flows to the south. The gorge spans about 12 kilometers, with cliffs composed of weakly-welded pyroclastic deposits from the Yufu River extending to a depth of 60 meters. These pyroclastic deposits erupted 600,000 years ago, in an apparent initial volume of 200 km^3.

I headed out for the shoot in mid-May of 2015. I traveled about an hour from the village of Yufuin, and left my vehicle in the parking lot. From there, I descended a 60-meter staircase to the cliffs below. Then I changed into a wetsuit, and with the help of my guide, Hiroaki Tanaka, I waded into the water up to my waist. In 30 minutes, I arrived at the narrowest point of the gorge—only two meters wide. There, after a two hours' wait, I finally saw the first rays of the morning sun.

Photography/text Motomaro Shirao: Photographer and sceince writer. Many photo atlas and graphical science books of volcanology, geology and astronomy are published. Chair of selection committee of Planet Earth photo contest, Geological Society of Japan.

The Geological Society of Japan

The Geological Society of Japan (JGS) is an academic society representing Japan's geology and was established in 1893 to contribute to advancement of science through promoting studies and diffusion of information in the field of geosciences. The JGS has over 3700 members, including researchers, educators, and engineering technicians. Members belong to one of seven branches. Activities of the JGS include the organization of meetings and excursions, scientific and educational publications, and the presentation of prizes. Because the 2018 is the 125th anniversary of the JGS, we make International version of Geolge that is published for dissemination and education in Japanese since 2012.