A Guide to the Geological Museum

Geological Survey of Japan, AIST

Geological Museum Overview

The Geological Museum has more than 150,000 registered specimens, such as rocks, minerals and fossils collected through the course of the research activities of the Geological Survey of Japan (GSJ) originally founded in 1882. Since its opening at Tsukuba in 1980, the Geological Museum has been introducing the research fruits of GSJ including many geological specimens, and the general geological information to a wide range of visitors.

The displays are arranged mainly for better understanding Japanese geology, while seeing various activities of the earth. The exhibitions are comprised of the entrance hall and four exhibition rooms. The main theme of each exhibition room is as follows:

1st exhibition room: History of the Earth and Life,

2nd exhibition room: Mineral and Fuel Resources and Marine Geology,

3rd exhibition room: How Geological Phenomena Affect Our Life —Earthquakes, Volcanoes, Hot Springs and Geothermal Energy—,

4th exhibition room: Systematic Display of Minerals, Rocks and Fossils.

Some rock specimens which are too large and/or heavy to be placed in the Museum building are exhibited the outside.

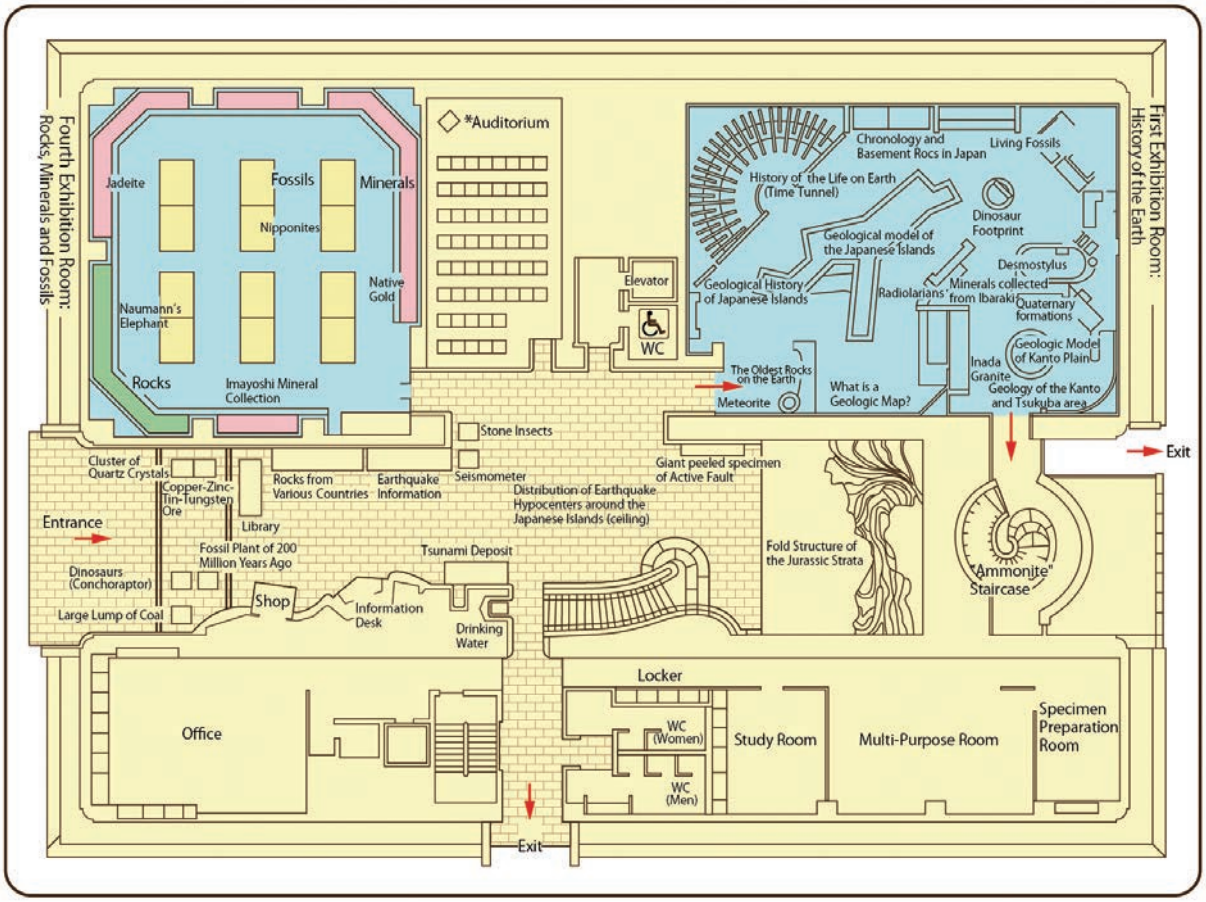
In addition to these thematic permanent exhibitions, seasonal special exhibitions and urgent investigation debriefing sessions are timely placed.

This brochure gives you brief explanations of the exhibition areas.

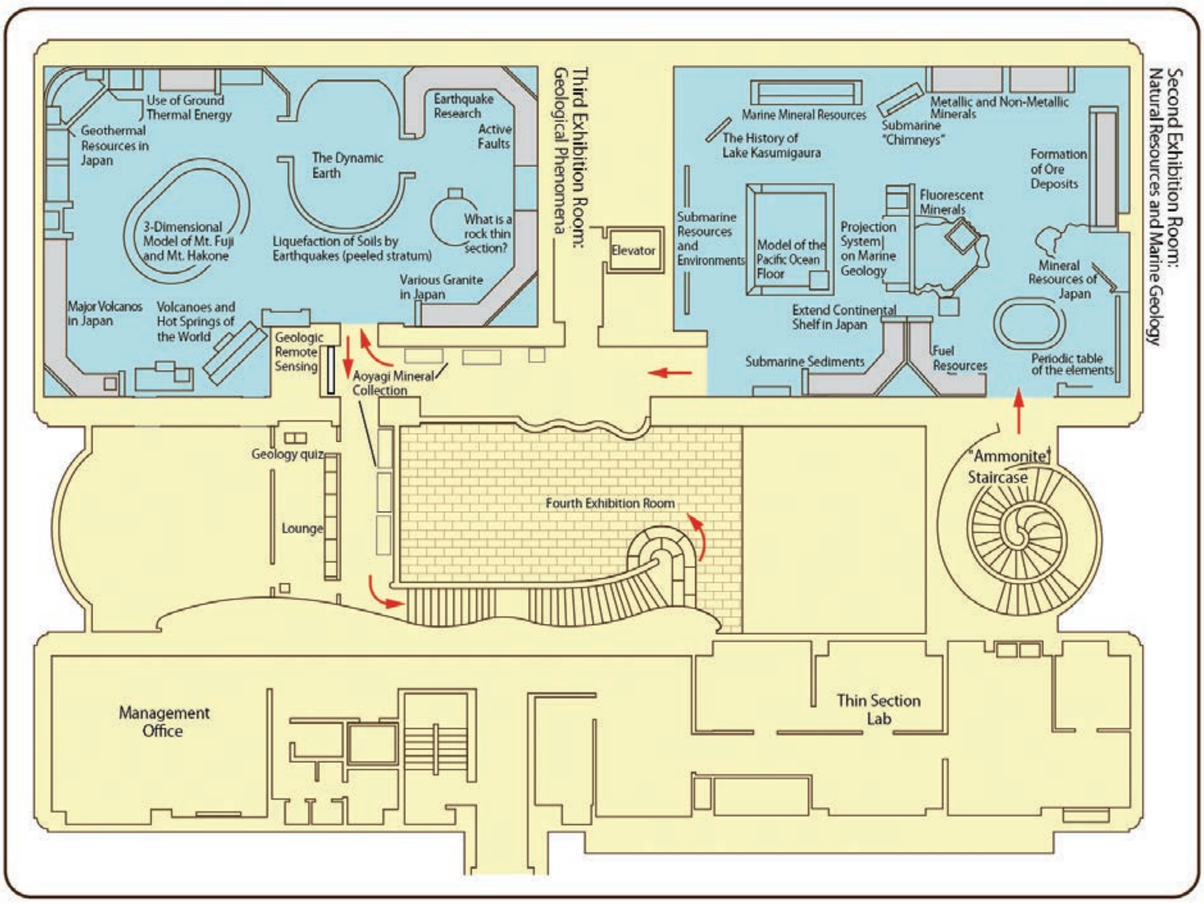
In the entrance hall and exhibition rooms, the QR code explanation system is available by using your smartphone with Wi-Fi setting (for local communication in the Geological Museum). When you want to use this system, please ask the receptionists of the museum about how to use.

Floor maps

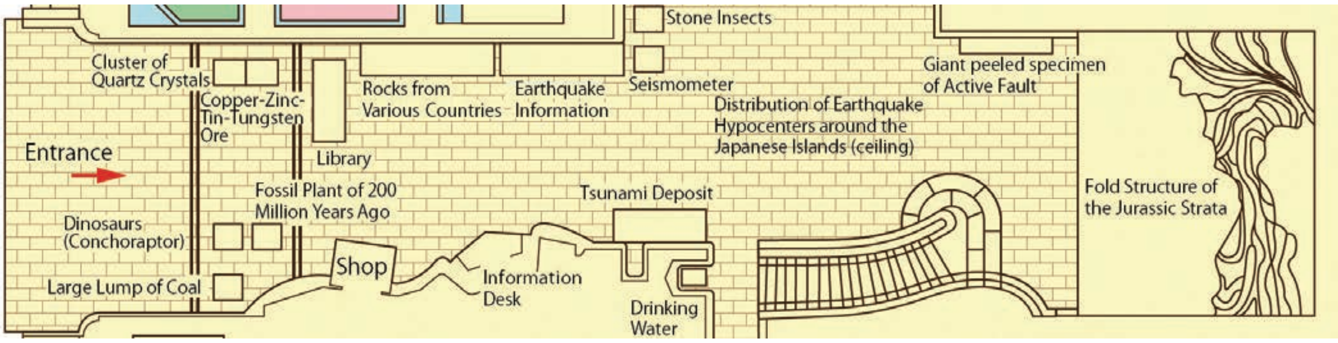
1st Floor: Entrace Hall, 1st and 4th Exhibition Rooms

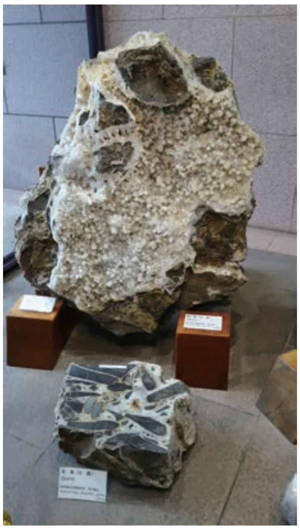


2nd Floor: 2nd and 3rd Exhibition Rooms



【Entrance Hall】





Cluster of quartz crystals

Cluster of Quartz Crystals

This specimen is a cluster of quartz crystals from the Arakawa mine, Akita Prefecture. The Arakawa mine was one of the most productive copper mines in Japan. Although the mine was closed in 1940, fine quartz crystals were collectable from the old mine dumps and the outcrops until 2007. The specimen exhibited was collected in 1998 from a large pocket in a quartz vein developed in the dark grayish host rock.

Large copper-zinc-tin-tungsten ore sample

Large Copper-Zinc-Tin-Tungsten Ore

The large sample next to the above-mentioned cluster of quartz crystals is a polymetallic ore from the Akenobe mine, Hyogo Prefecture.

It is composed of white quartz veins including chalcopyrite (copper ore), sphalerite (zinc ore), cassiterite (tin ore) and wolframite (tungsten ore).

Reconstruction skeleton model of *Conchoraptor*

Dinosaurs (*Conchoraptor*)

This specimen is a replica of a Cretaceous dinosaur, *Conchoraptor*, of which original fossil was collected at Mongolia. *Oviraptor,* a close relative of *Conchoraptor,* is famous for their habit of sitting on eggs in their nests. This replica is restored based on this idea. They also had powerful beaks instead of teeth. The reconstructed figure looks like a bird, doesn't it? It is really thought that *Oviraptor* and their relatives are very close to birds.

Triassic plant fossils

Fossil Plants of 200 Million Years Ago

This exhibition is a two-meter long shale specimen from the Momonoki Formation of the Mine Group, containing abundant fossil plants. The specimen dates the Triassic Period of the Mesozoic Era, about 200 million years ago. It was collected from a road construction site in Mine City, Yamaguchi Prefecture in 1988, and was donated to the Geological Museum by Mine City.

Rocks from Various Countries of the World

The Geological Museum was opened in August 1980. At the time, the Museum received gifts in the form of many rock plates from a number of geological research centers and comparable national institutes worldwide. 48 plates of them are being exhibited on the wall to the left of the Museum's entrance. Each exhibit is labeled with the name of the specimen, together with the name of the institute donated it. All are examples of geological characteristics unique to the countries of their origin. The specimens include rocks not found in Japan. A few of the exhibits are fossil specimens. Please take closer look, and just imagine how varied the geological characteristics of the earth's surface are.

Display of the rock plates

Information of Earthquakes and Video Archives

In this corner, the below-mentioned various information about earthquakes is displayed using three of the four PC monitors. In addition to them, short highlights of video archives, which you can watch at the museum auditorium, are shown on the top left monitor.

Real-time display of ground vibration: The bottom right monitor shows current ground vibration picked up by the seismometer on the floor at your feet. It also shows the time of the latest earthquake, and its seismic intensity and maximum acceleration on the top left corner of this monitor. Try softly stomping your feet and cause a little earthquake. However, please be sure that you don't disturb the people around you. Also, do not touch the seismometer.

Last month's seismicity: The top right monitor shows earthquakes that have occurred around the Japanese Islands and over the world within the last month. The hypocenters are plotted with different colors and symbol sizes according to their depths and magnitudes. By rotating the hypocenter distributions and looking them at from different directions, you can easily recognize their 3D features. The hypocenter distribution of the earthquakes in Japan and surrounding areas clearly shows the seismic activities along the Pacific and Philippine Sea Plates subducting to beneath the Japanese Islands. As for the earthquakes over the world, we can see a belt of high seismic activity along the Pacific Rim.

Information of disastrous earthquakes around the Japanese Islands: The bottom left monitor shows information of about 50 earthquakes around the Japanese Islands that caused significant damages since the 1847 Zenkoji Earthquake. These events correspond to those indicated by the red lights in the hypocenter map on the ceiling of the entrance hall. You can select an event by touching the screen and read its brief description including the occurrence date, location, magnitude and number of dead and missing, although all in Japanese. You can also blink the red light of corresponding event to confirm where it occurred.

Earthquake information display

Peeled Cross Section of an Active Fault

An “active fault” is a fault that has caused — and is likely to continue causing — earthquakes repeatedly. To assess the potential for earthquake generation of an active fault, it is necessary to shed light on its past activities.

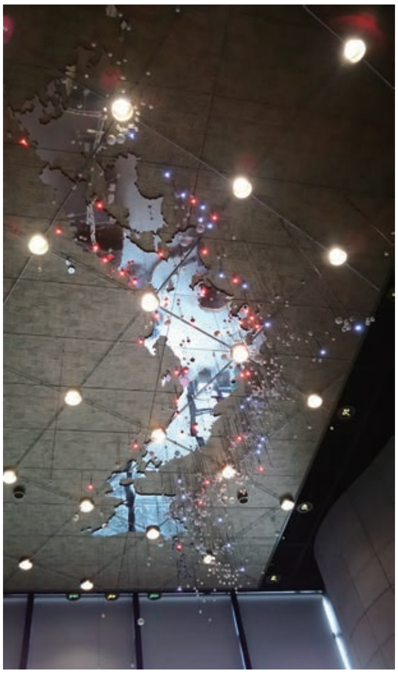
This is a peeled cross section from a trench excavation of the Okaya Fault in Nagano Prefecture, a part of a central portion of the Itoigawa-Shizuoka Tectonic Line active fault system. The left side of the panel is west, and the right side east. There are displacements along the two almost vertical faults on the left-hand side of the panel, along which the eastern side has moved downward. The top of these faults is covered with the surface layer, and it is evident that the most recent event occurred before its deposition. From detailed analysis of the fault displacement pattern and dating the deposition of the strata, it has been confirmed that there have been four earthquakes within the last 7,200 years, and the latest event occurred between 300 and 1,600 years ago. From this exhibit, we can see evidence of the two most recent events.

Peeled cross section of an active fault

Peeled Section including Tsunami Deposits in Sendai

The 2011 Tohoku Earthquake caused enormous tsunami damages to an extensive area of the Pacific coast of eastern Japan. This is a peeled cross section of strata beneath the Sendai Plain that was taken after the earthquake using the Geoslicer technique. The ground surface is covered with the tsunami deposit of the Tohoku Earthquake. The sand layer between the two black peat layers is also a tsunami deposit. Volcanic ash immediately above it is identified as being from the 915 eruption of the Towada Volcano. Taking this into account, together with the results from dating the peat layer beneath it, this tsunami deposit is thought to be from the 869 Jogan Earthquake, which is documented in “Nihon Sandai Jitsuroku”, one of the ancient writings of Japan.

Tsunami deposit from Sendai



Display of the hypocenters in Japan

Distribution of Earthquake Hypocenters around the Japanese Islands

On the ceiling you can see a map of the Japanese Islands as looked up from the interior of the earth. The white balls suspended from the ceiling represent the hypocenters of earthquakes of magnitude 6 or greater that occurred from 1926 to 1976. The length of the string is proportional to the depths of the hypocenters. The white lights indicate major earthquakes of magnitude 7.5 or greater. A number of shallow earthquakes are distributed along off the Pacific coast, and the hypocenters become deeper toward the Sea of Japan and the East China Sea. The red lights indicate earthquakes that caused significant damages since 1847. Brief descriptions of these events are given on the bottom left monitor in the previously mentioned Earthquake Information corner.

Model of a fold structure

Fold Structure Model of the Jurassic Strata

Through the glass window at the end of the hall, you can see a "cliff" showing intensely folded strata. This is a plastic replica of a cliff in the Ojika Peninsula, Miyagi Prefecture, northeastern Japan. The outcrop is composed of alternating beds of sandstone and mudstone of the Jurassic Period of Mesozoic Era (ca. 150 million years ago). The strata were tectonically deformed about 100 million years ago to form fold structure as you see in the model of the cliff.

Stone insects (dragonfly)

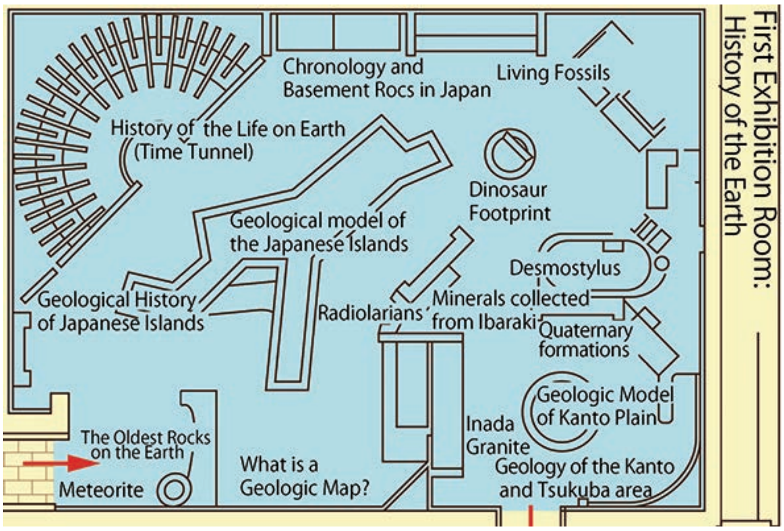
Stone Insects

This insect looks alive, but is made of stone in fact. Its color is original without any additional coloring on the stones from which it was made. The stones have been put together and worked down to the smallest detail.

In geological research, thin sections of rocks, 0.03 mm thick (1/3 the thickness of a sheet of newspaper) are created and examined using a polarizing microscope for petrographic analysis to determine rock types. The technology behind the making of these thin sections is highly sophisticated, and GSJ is the leading national institution with such technologies. An exhibit outlining process for creating the thin sections is displayed in the 3rd Exhibition Room on the 2nd floor.

Here, we exhibited the stone artwork from which the visitors can intuitively grasp the high level of skill required for accurate cutting, bonding and polishing by applying different methods appropriate for creating each sample based on our familiarity with the characteristics of rocks.

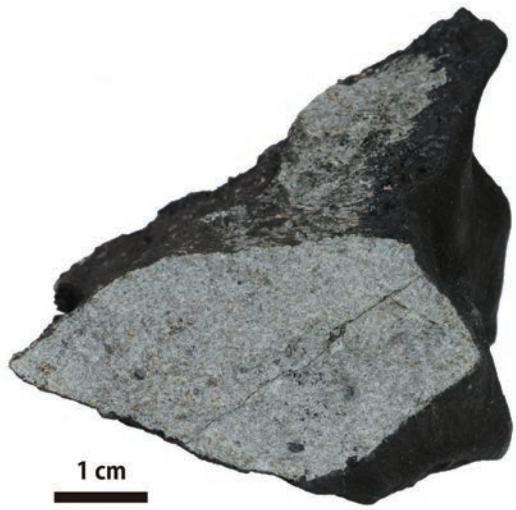
【1st Exhibition Room】



Meteorites

Meteorites are believed to be small rock bodies that failed to become planets, but remained when the solar system was formed. Meteorites are classified into three types: iron meteorite, stony-iron meteorite, and stony meteorite including chondrite and achondrite. Chondrites, the most common type of stony meteorites, are primordial objects having an age of 4.5 to 4.6 billion years old, and always contain spherulitic particles called “chondrule”. From the age of chondrite, the solar system including the earth is thought to be formed about 4.6 billion years ago. Iron meteorite, stony-iron meteorite and achondrite respectively came from core, mantle and crust of their mother bodies that experienced gravitational differentiation.

In the meteorites corner, the Tsukuba Meteorite, which fell around Tsukuba City on January 7th, 1996, is displayed, with other four meteorites from Japan and abroad.



Tsukuba Meteorite no. 13 specimen

The Oldest Rock on the Earth

The earth is believed to be 4.6 billion years old, but how far back can this history be traced from rocks found on the earth? The quest by geochemists worldwide is beginning to uncover the existence of a number of extremely old rocks dating back around 4 billion years or more located at the center of various continents. The rock specimen displayed here is the "Acasta Gneiss" found in Canada. Radioactive dating indicates that this rock was formed 3.962 billion years ago, and the oldest rock on the earth ever found. The oldest mineral around 4.4 billion years old was found in western Australia, and an older rock than the "Acasta Gneiss" may be discovered somewhere on the earth, in future.

The oldest rock on the earth (Acasta Gneiss from northwestern Canada; 3.962 billion years old)

Geological Model of the Japanese Islands

The 3D geological model of the Japanese Islands scaled down to 1/340,000th of its original size and three-time exaggeration in vertical is in the center of the 1st exhibition room. You can hear the Japanese explanations concerning the geological characteristics of each regional area and the major tectonic lines by pressing the button(s) on the panel. The Itoigawa-Shizuoka Tectonic Line, which bisects Japan from east to west, and the Median Tectonic Line, which similarly bisects southwestern Japan from north to south, are clearly marked. Please compare the variation in topography of places where old rocks and sediments are and where younger sediments have spread by referring to the legend: a color chart showing the geology according to rock types and geological ages.

3D Geological model of the Japanese Islands

Geological History of Japanese Islands

Here you can watch two video programs depicting the geological history of the Japanese Islands. You can choose any programs from the following two options (all in Japanese):

(1) Geological history and formation of the Japanese Islands (3'55").

Plate-tectonic evolution of the Japanese Islands.

(2) Geological component of the Japanese Islands (3'42").

Formation of rocks constituting the Japanese Islands by accretion process due to subduction of oceanic plates.

Video menu of the geological history of the Japanese Islands

The History of the Life on the Earth

This exhibit shows the history of the earth in chronological order — Precambrian, Paleozoic, Mesozoic and Cenozoic Eras — arranged like a time tunnel, with representative fossils and rocks from each era on display. In the Precambrian Eon, few visible fossils have been discovered except for stromatolite and Ediakaran biota. During the Paleozoic Era, fungi, algae, ferns, trilobites and fusulinids among others flourished. Gymnosperms' plants, ammonites and dinosaurs flourished during the Mesozoic Era. In the Cenozoic Era, flowering plants and mammals including humans are flourishing. The samples of old rocks displayed here are “Amitsoq Gneiss” from Greenland with the age of 3.8 billion years, and a gneiss boulder of the Kamiaso Conglomerate from Japan. The latter is the oldest rock ever dated in the Japanese Islands and is approximately 2 billion years old. A Permian fusulinid limestone and three large Cretaceous ammonites are also displayed at your feet. You can touch and observe these large fossils in detail.

Time tunnel of the life and earth

What is a Geological Map?

GSJ has been making and publishing a number of geological maps with various scale sizes and purposes. Geological maps provide information on types of rocks below the vegetation and soil. The panel exhibition outlines the process of creating the geological maps as well as some examples of their utilization. Initiatives of publishing a nationwide 1:50,000 scale geological map series are underway. Each map covers an area of about 20 km by 25 km, and the series consists of about 1,300 sheets when it is completed. A single map can be issued after work including field survey totaling about 250 days by GSJ researchers. 765 sheets have been published as of the end of 2016. The 3D geological model of the Japanese Islands was made through compilation of the maps.

Various kinds of the geological maps and their use

Radiolarians and Jurassic Accretionary Complexes in Japan

Radiolarian is one of marine planktons with silica test of less than 1 mm in size, and has lived since Cambrian (older than 500 million years). Morphology of radiolarian tests has changed drastically with their evolution throughout the geological time. This makes radiolarians a powerful tool for determining the geological history of chert and siliceous shale in accretionary complexes, in which specific fossil radiolarians are included. Geologists have clarified that the accretionary complexes are made up of various rocks of ancient oceanic plates, which are finally accreted to continental plates with subduction of the oceanic plates.

This exhibition is comprised of the following displays:

(1) Polished rock plates including visible-sized fossil radiolarians and fusulinids from the Mino Terrane of central Japan to represent the reconstructed columnar section of the oceanic plate stratigraphy of late Permian to Jurassic,

(2) 12 scanning electron micrographs and 3 plastic models for fossil radiolarian species found in the Jurassic accretionary complexes of Japan.

Permian to Jurassic radiolarian fossils from the Mino Terrane of central Japan

Chronology of Basement Rocks in Japan

In this corner, some old rocks, most of which are basement rocks in Japan, are displayed with their locations' map. Geological ages of sedimentary rocks can be determined by fossils found in them. Among them, some microfossils such as above-mentioned radiolarians, foraminifers, and conodonts are powerful tools. However, the ages determined by such fossils are relative. Then, how can absolute ages of the rocks be determined?

Most of elements in rocks have isotopes with the same atomic number but a different atomic mass. Unstable radioactive isotopes change into stable isotopes at a constant rate while emitting radiation. The age of a given rock can be determined by measuring the ratios of radioactive isotopes and their decay products. Its age is called a "radiometric age". Various methods for the radiometric dating have been developed using radioactive isotopes with different half-life periods, and a suitable method is applied depending on the age of the rock sample. The radioactive isotopes commonly used in dating rock samples are as follows: ^{40}K, ^{87}Rb, ^{238}U, ^{235}U, ^{232}Th, ^{147}Sm, ^{14}C, ^{210}Pb.

Chronology and basement rocks in Japan

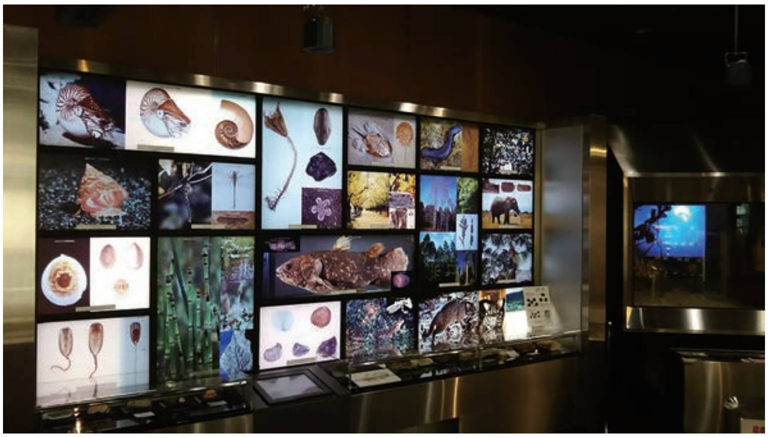
Living Fossils

Living fossils are creatures that prospered from geological ages and the descendants still exist precariously as of today. However, they are spread in a limited area with few kinds of existing relicts. You can see color photographs and explanation texts of 18 types of living fossils through a liquid crystal display in your side.

On the right of these photo-panels, you can see short movies of two remarkable living fossils, horseshoe crab and nautilus, being comparable with two relative extinct fossils, trilobites and ammonites.

Dinosaur Footprint

Dinosaur remains, such as an *Allosaurus* footprint, a fossilized dinosaur egg, feces (coprolite) and several gastroliths are displayed. These fossils help us imagine how dinosaurs lived. The footprint, gastroliths and coprolite are from the Jurassic Period, 150 million years ago, and the egg from the Cretaceous Period, 70 million years ago. Dinosaurs and many other forms of life became extinct in the end of the Cretaceous Period, 66 million years ago.



Pictures and videos of living fossils

Footprint (replica) of Jurassic *Allosaurus*

Desmostylus

Desmostylus is an extinct mammal (not a dinosaur) that lived along some parts of northern coasts of the Pacific Ocean between 23 million and 11 million years ago. This specimen was discovered in a fossiliferous sandstone bed of the Neogene Period in Utanobori, Esashi-cho, Hokkaido. Desmostylians are characterized by their back teeth (molar) shaped like cylindrical pillars bunched together. It is believed that they used the back teeth to consume clams and seaside grasses. However, *Desmostylus* has not been fully revealed and it is a creature with a lot of mysteries.

Reconstructed skeleton model of *Desmostylus*

Geology of the Kanto Region and Tsukuba area

Minerals collected from Ibaraki Prefecture

The northern part of Ibaraki Prefecture is covered chiefly by sedimentary rocks of the Paleozoic to Mesozoic Era, including their metamorphosed equivalents, and granitic rocks. Many localities for mineral collecting have been known in that area, and have attracted many mineralogists and mineral collectors. Mineral specimens collected from whole Ibaraki Prefecture, especially the northern part, are displayed in the glass showcases.

Minerals collected from Ibaraki Prefecture

Geological model of the Kanto Plain

In the middle of the local geology corner is a geological model of the Kanto Plain, a large sedimentary basin of over 5,500 meters deep at its thickest point. Long period ground motion is excited in such a large sedimentary basin when a large earthquake occurs, resulting in large amplitude and long duration oscillation of high-rise buildings. The first button on the model reveals a geological cross-section of the Kanto Plain, and the second button indicates the positions of several deep wells that penetrate to the basement rocks.

Geological model of the Kanto Plain

Tsukuba Science City on Quaternary Formations

The northeastern part of the Kanto Plain is underlain by Quaternary formations, the sedimentary layers of the newest geological age. Layers of unconsolidated sand and mud are overlain by volcanic ash layers called “Kanto Loam”. You can see this succession in core samples taken from a borehole drilled just beneath GSJ.

On the wall is an exhibit of fossils from the Kamiiwahashi Formation of the Shimousa Group. The fossil layers accumulated about 180,000 to 150,000 years ago, and is rich in fossil shells of scallops and oysters. From the types of shellfish found from the layer, we can tell this area was formerly a shallow and moderately warm water bay.

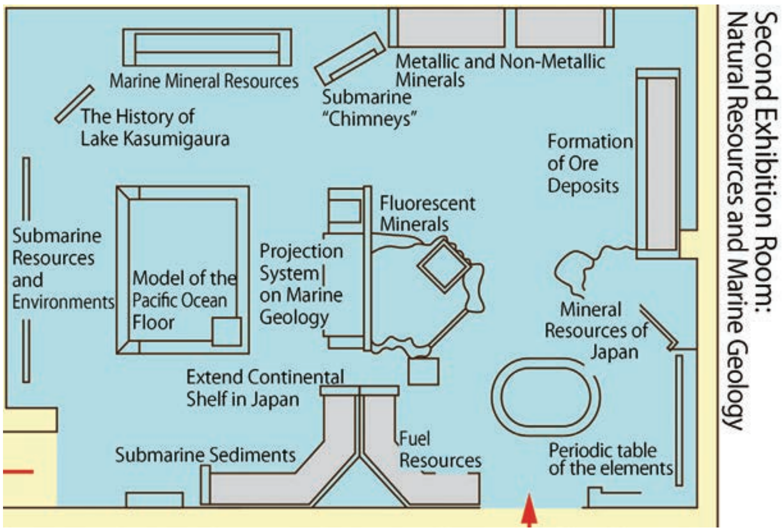
Shell bed of the Kamiiwahashi Formation of the Quaternary Shimousa Group

Inada Granite

Kasama City, located to the north of Mt. Tsukuba, is well known in Japan for the production of building stones called "Inada Granite". The Inada Granite intruded in Mesozoic sedimentary rocks, and trapped many fragments of the preexisting sedimentary rocks called xenoliths. From the large rock panel, try to imagine how the molten Inada Granite went upward destroying much of the preexisting strata.

Inada Granite including xenoliths of sandstone and marble

【2nd Exhibition Room】



Periodic Table of Elements

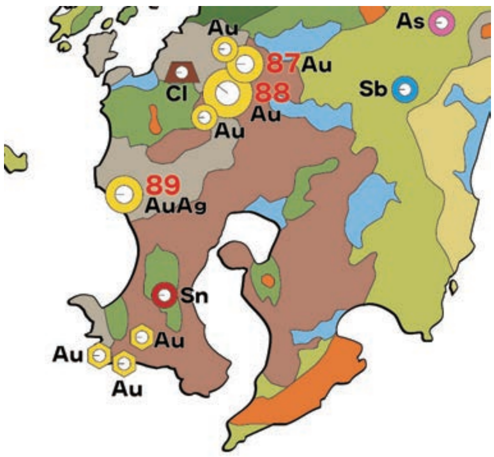
You can see the periodic table of elements near the entrance of the 2nd exhibition room. At the position of each element, a mineral specimen that contains the element as a major component is displayed. Examples of their utilities are also given. On the touch-panel monitor of the right hand, you can see the information of elements, and challenge some quizzes about elements (all in Japanese).

Elements and minerals

Mineral Resources of Japan

Major ore deposits ever mined for both metallic and non-metallic mineral resources are shown on the geological map of Japan. Metals from the domestic mines, most of which have already been closed, contributed for the modernization since the Meiji Restoration and the economic recovery after the World War II. Now, the Hishikari gold mine in northern Kagoshima Prefecture is the only large-scale gold mine in operation in Japan due to the discovery of many ore veins with high gold content.

Non-metallic resources such as limestones, silica stones and refractory clays are mined mostly for the pottery, ceramic and glass industries.



Distribution of mineral resources in the south part of Kyushu, Japan (88: Hishikari gold mine)

Fuel Resources

The exhibition on the left side of the entrance displays various samples of domestic coal and crude oil and a block sample of oil shale collected from U.S.A. Japanese coal occurs in sedimentary rocks of the Paleogene Period, about 65–24 million years ago. Japanese petroleum was formed in the middle Miocene Epoch about 15–10 million years ago.

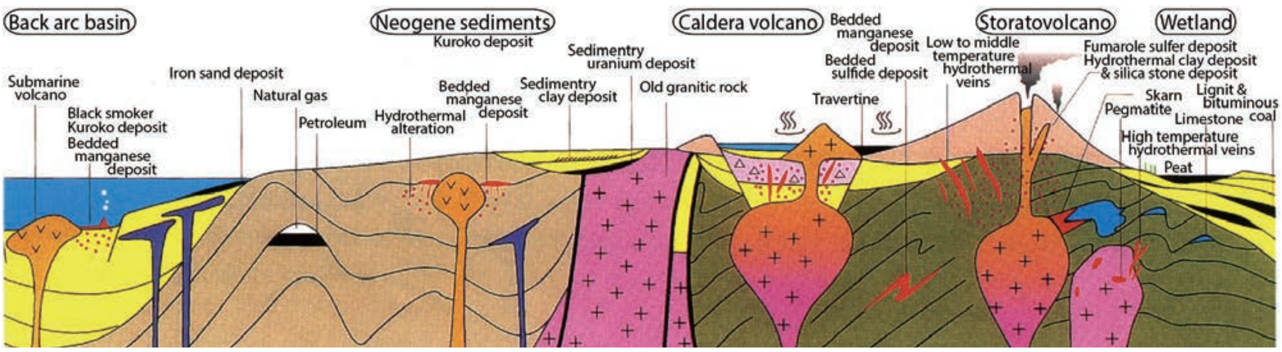
Oil shale contains high quantities of oil. Innovative technologies allowing the production of shale gas and oil from underground shale resulted in a revolutionary increase in energy resources for 2010s U.S.A., and have changed the worldwide distribution of fuel resource prospects and reserves.

Methane hydrates are known as "flammable ice". As demonstrated by the molecular model, it has a unique 3-dimentional structure in which a methane is surrounded by water molecules, and is found within the soil of the deep-sea floor more than 500 m deep. There is high expectation as a next generation energy resource, and research and development for its extraction method is well underway.

Coal, petroleum and methane hydrate of Japan

Formation of Ore Deposits

Special geological conditions are required to produce economically exploitable concentrations of ore minerals. The theory of plate tectonics can successfully explain formation of ore deposits as a part of recycling process in the earth's crust and mantle. The conditions for forming ore deposits, as they are currently understood, are summarized on a single panel on the wall. The glass case below the panel contains typical ore samples from various types of ore deposits.



Geological setting and formation of ore deposits in Northeast Japan

Metallic and Non-Metallic Mineral Resources

There are various types of ore deposits, including metallic and non-metallic minerals, in Japan. However, most of domestic metal mines have been closed. Of all the ore deposits producing metallic minerals, gold deposits attract the most attention and have the highest economic value, as the Hishikari mine. Hydrothermal fluid or water heated by magma is essential for forming the gold deposits. On the right-hand, the exhibition shows how gold deposits can be largely separated into two types depending on the chemical characteristics of the relating hydrothermal fluids: low and high sulfidation types. The low sulfidation type occurs mostly as quartz veins with banded structure developed in volcanic rocks and forms by the activity of hydrothermal solution of near neutral pH. An example of this type mine is the Hishikari mine. On the other hand, the high sulfidation type occurs as vuggy silica-rich rock formed by leaching of volcanic rocks with acidic hydrothermal solution. An example of this type is the Kasuga mine in southern Kagoshima Prefecture. Gold ores and other related minerals are also displayed.

On the left-hand, explanations of mineral deposits of non-metallic mineral resources are displayed, as well as exhibits of mineral ores of limestone, silica stone, feldspars and clays. As having used clay as materials of ceramics, non-metallic minerals have long been used through the ages. In recent years, however, their importance has increased as raw materials for semiconductor base, optical fibers, a variety of sensors and other sophisticated industrial products.

Hydrothermal gold deposits (right) and non-metallic mineral resources (left)

Fluorescent Minerals

The display is comprised of several fluorescent minerals. The fluorescence is a phenomenon in which minerals emit visible light when receiving ultraviolet rays. The lights are emitted when electrons in the minerals return to the ground state from an excited state. Besides fluorite that is a typical fluorescent mineral as its name suggests, calcite, scheelite, malayaite, hyalite, autunite, willemite and so on also show fluorescence. Press the button on the display case and you will see fluorescence of minerals under ultra-violet light. The fluorescence of minerals can provide useful clues in exploitation for ore deposits.

Fluorescent minerals

Submarine "Chimneys"

Submarine hydrothermal deposits are formed at mid-oceanic ridges by activity of magma beneath the ridges. Seawater infiltrating into the ridge is superheated by the hot magma, begins to circulate through fractures, reacts with its surrounding rocks, and becomes saturated with metallic elements. On reaching the ocean floor, the hot and pressurized water is forcibly injected into cold seawater and the metallic elements, such as gold, silver, copper, zinc, and various rare metals, are precipitated out as sulfide minerals on the ocean floor. The deposits form mound and chimney structures, as shown in the glass case.

Chimneys

Model of the Pacific Ocean Floor

In the center of the 2nd exhibition room is a model of the Pacific Ocean floor. Red lights indicate the East Pacific Rise and other mid-oceanic ridges, and blue lights indicate trenches. Magma is ejected along the oceanic ridges and is solidified on contact with seawater to form new crust, which is then carried away from the mid-oceanic ridges as a part of the Pacific Plate at rate of 3–10 cm per year. Portions of the Pacific Plate are being subducted beneath the Japanese Islands. This is a part of the plate-tectonic processes.

On the bottom of the Pacific Ocean, future promising resources including a manganese nodule, submarine hydrothermal deposit and the methane hydrate are unexploited.

Model of the Pacific Ocean

Projection System on Marine Geology

On the large screen behind the model of the Pacific Ocean Floor, you can see slide-show programs on marine geology. The contents are as follows:

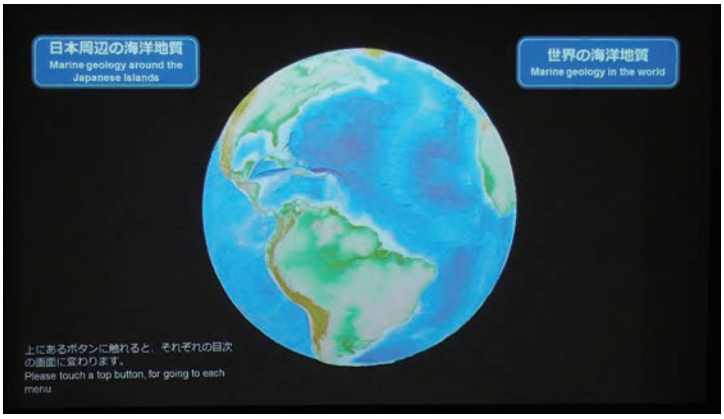
(1) Continental shelf as an exclusive economic zones (EEZ) of Japan (0'45").
Sea-bottom map around the Japanese Islands with the outline of EEZ of Japan.

(2) Marine mineral resources around Japan (1'50").
Submarine hydrothermal eruptional hole and map of seabed mineral resources around Japan.

(3) Sea level and sea current changes during the recent 20,000 years around Japan (1'55").
Coastal maps around Japan, with sea level changes since the last ice age.

(4) Virtual diving in the Izu-Ogasawara trench (1'45").
The virtual sea bottom of the Izu-Ogasawara trench.

(5) Continental drift since 140 million years ago (1'50").
The continental-drift maps during the last 140 million years, from various angles of the earth.



Top menu of the projection system on marine geology

Extended Continental Shelf of Japan

The wall panels show the area of the "extended continental shelf" of Japan, which was recommended by the "Commission on the Limits of the Continental Shelf" of the United Nations on April of 2012. The extend areas were about 310,000 km^2.

Since 2004, GSJ, as a national organization, has been participating in the task to delineate the outer limits of Japan's continental shelf defined by the “United Nations Convention on the law of the Sea". GSJ has contributed to both preparation of the application to extend the continental shelf around Japan and the judgment process. For the purpose, GSJ has developed the best use of knowhow on integration of earth science data on the seas around Japan and the techniques for analyzing rock samplings.

Extended continental shelf in Japan

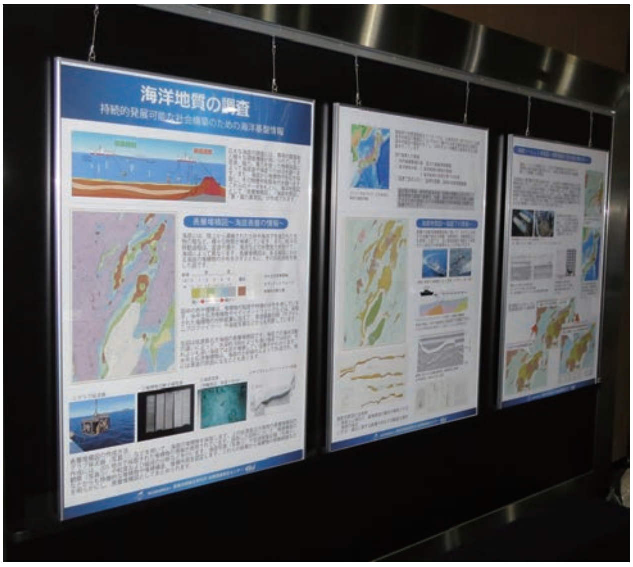
Marine Mineral Resources

The round and black lumps exhibited in the left showcase are manganese nodules. Manganese nodules are found in some areas of the Pacific and Atlantic Ocean floors. They have been formed as a result of slow deposition of metal components around some materials (e.g., stones, shark's teeth and so on) in seawater, eventually growing into round lumps. They only grow a few millimeters in size per one million years. The nodules also contain iron, copper, cobalt and nickel, and are attracting attention as future mineral resources.

Marine mineral resources

Marine Geological Maps

GSJ has been making the 1:200,000 scale marine geological maps around the Japanese Islands. Vast areas of the seabed are efficiently surveyed by exclusive ships equipped with geophysical exploration instruments for acoustic profiling, gravity and geomagnetic surveys as well as tools for sampling rocks and sediments on the sea bottom. The surveys have been completed for the region around the major four islands, and are now underway around Okinawa and the East China Sea.



Marine geological maps

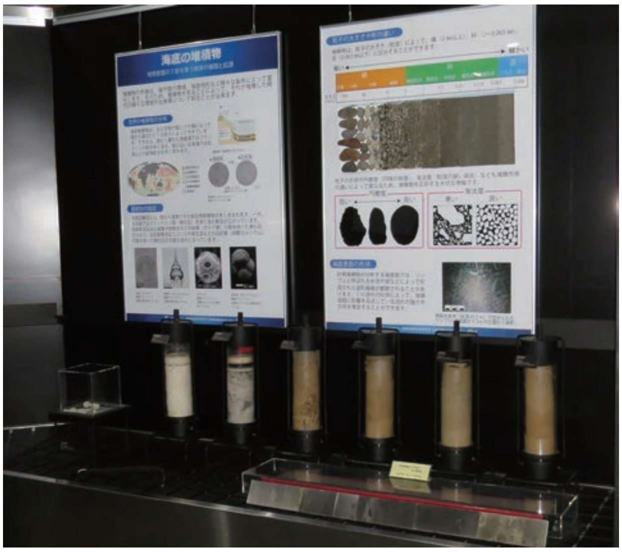
Marine Environmental Research

Marine organisms having calcareous shells or skeletons like corals and foraminifers are very useful for marine environmental research. By analyzing isotopes of oxygen and carbon of their skeletons or shells, GSJ has been investigating the past change of ocean temperatures, and found an evidence of the oldest "el Niño" of about 3.5 million years ago. You can see the fossil and recent coral specimens in front of the explanation panels. You can also see a Precambrian stromatolite, a "fossil" of a colony of cyanobacteria, which is the first microorganism generating oxygen by photosynthesis.

Marine environmental research and coral specimens

Submarine Sediments

Very fine particles such as clay or tests of creatures are deposited on deep seabed distantly from land. On the other hand, land origin mineral particles such as quartz are dominant near the land. In front of the explanation panels, some pelagic sediment samples made of tests of planktons are displayed.



Marine sediments

The History of Lake Kasumigaura

Lake Kasumigaura is the second largest lake in Japan, with an area of 220 km^2. It consists of Nishiura, Kitaura, Sotonasakaura and Hitachitonegawa. The lake was originally an inlet deeply embayed into the present Kanto Plain by the transgression of approximately 6,000 years ago. Short movies (only Japanese narration) in the corner describe the history of Lake Kasumigaura and its water resources, revealed by the studies on the bottom sediments and surrounding platform.

(1) Current Lake Kasumigaura (3'23").
A brief guidance of Lake Kasumigaura.

(2) Formation process of Lake Kasumigaura (6'32").
Geological evolution around Lake Kasumigaura since 120,000 years ago in relation to its formation.

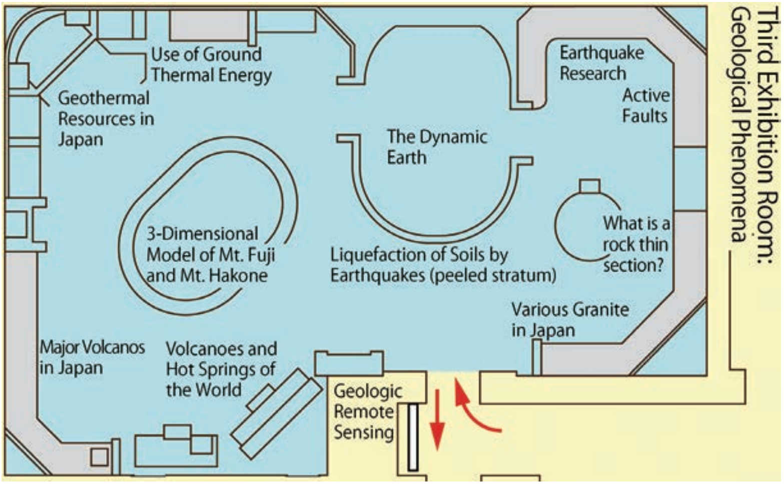
(3) Environmental change of Lake Kasumigaura during 10,000 years (4'26").
Environmental change of Lake Kasumigaura revealed by sedimentology.

(4) Water circulation around Lake Kasumigaura (6'26").
Water circulation around Lake Kasumigaura and utilization of the lake water.

(5) Coastal lakes of Japan (archive).
About 30 coastal lakes in Japan.

Video menu of the “History of Lake Kasumigaura”

【3rd Exhibition Room】



What is a Rock Thin Section?

This display explains processes for making thin sections. A thin section is a rock fragment ground to a thickness of about 0.03 mm and glued on a glass plate for the microscopic observation of the texture of the rock. Making and observing the thin sections need professional skills. You can see photographs of the textures of granite and several other rocks taken under microscope.

How to make thin section

Various Granites in Japan

Granite is one of the major rocks of Japan, and useful for building stones. Granite looks like black sesame scattered on a white background. The black spots and white background are all made of minerals. Granitic rocks are created from magma that was slowly cooled and solidified at a depth of more than several kilometers below ground. When magma with the same composition is cooled rapidly near the surface of the earth, it becomes rhyolite or dacite. You can see several rocks, such as granite, granodiorite, diorite, dacite, and felsic tuff, with weathered granite, in this corner.

Various granites and granitic rocks in Japan

Liquefaction of Soils by Earthquakes (Peeled Stratum)

Liquefaction is a phenomenon wherein a water-saturated and loosely compacted sandy layer temporarily loses its strength due to earthquake shaking, causing the layer to behave like liquid. The lower Tone River region suffered serious damages as a result of liquefaction in the 2011 Tohoku Earthquake. This is a peeled cross section taken from a trench survey conducted in Kozaki Town, Chiba Prefecture, and clearly illustrates the distinctive subsurface structure after liquefaction. A part of the dredged sand layer at the bottom of the panel was liquefied, penetrated the layer of soil above, and formed a sand dike.

Peeled section of liquefaction of soils

3-dimensional Model of Mts. Fuji and Hakone

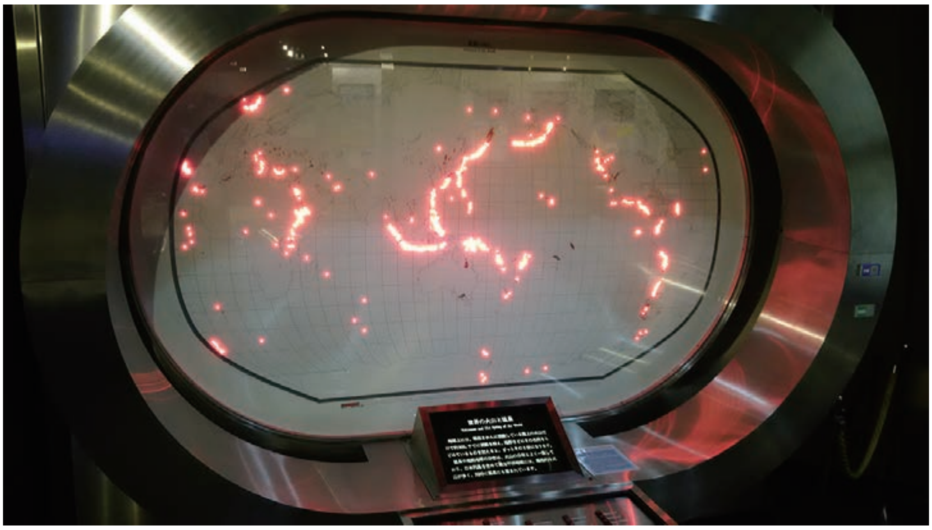
At the center of the 3rd exhibition room is 3-dimensional model of Mts. Fuji and Hakone. Press the button and you can see geological cross sections of the volcanoes. The base of Mt. Fuji consists of two older volcanoes: Mts. Komitake and Kofuji. The present Mt. Fuji has been active since Mt. Kofuji ceased its volcanic activity at about 17,000 years ago and erupted most recently in 1707 to form a new crater, Mt. Hoei. Compared with Mt. Fuji, Mt. Hakone is more complicated in structure and of more silica-rich in rock type, composed primarily of dacite and andesite. Mt. Hakone experienced two stages of caldera formation, followed by the development of dacite lava domes.

Model of Mts. Fuji and Hakone

Volcanoes and Hot Springs of the World

The lights on the global map show locations of volcanoes, hot springs and geothermal areas in the world, when you press buttons on the panel. About 1,500 active volcanoes are known in the world, and unevenly distributed mainly along plate boundaries. 110 active volcanoes are known in Japan at present. Because many volcanoes are distributed to surround the Pacific, this is called a ring of the fire.

The geothermal fields are located very close to the active volcano areas in the world.



Distribution of the volcanoes in the world

Major Volcanoes in Japan

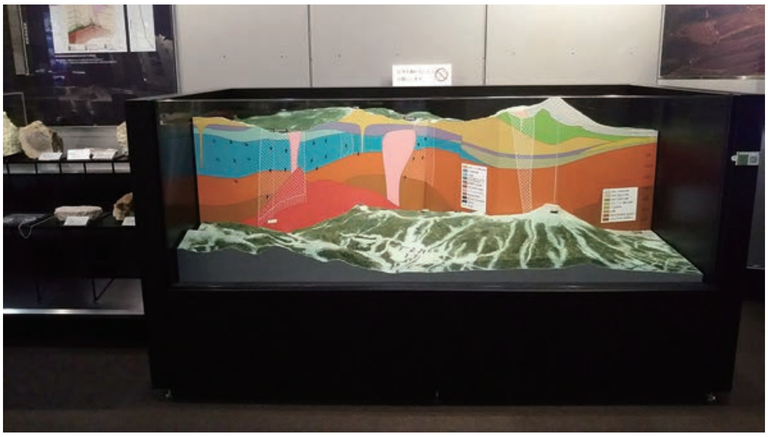
This exhibit features three-dimensional contour model of eight representative Japanese volcanoes along with aerial photographs and rock samples. Many Japanese volcanoes are largely composed of silica-rich volcanic rocks such as dacite and andesite, and tend to form lava domes. The eruption of Mt. Unzen in 1990–1991 is a typical example. Only a very few Japanese volcanoes eject considerable quantities of low-silica basaltic lava, such as Mt. Mihara of the Izu-Oshima Island that erupted in 1986. You can also see short movies (only Japanese narration) on the eruptions of the volcanoes of the Izu-Oshima in 1986 and Miyakejima Islands in 2000.

3D geological model of the Usu Volcano

Geothermal Fields and Geothermal Energy in Japan

39 geothermal power plants, including 18 binary cycle generation plants, are active in Japan as of 2015. The total capacity of those power plants is about 520 megawatts, which is the ninth energy production in the world after U.S.A., Republic of the Philippines, Republic of Indonesia and others.

The Sengan geothermal field, which extends over Akita and Iwate Prefectures, is one of the most productive geothermal fields in Japan. Four geothermal power plants have been constructed in the Sengan geothermal field, i.e., Onuma, Sumikawa, Matsukawa, and Kakkonda. In this display, a vertical cross-section showing the underground geological structure and the hot water circulation is exhibited along the line passing from the Kakkonda and Matsukawa geothermal power plants to the Iwate Volcano. You can see hot water upward flows beneath the two power plants. Minerals characteristic to geothermal alteration and fumarolic areas are also displayed.



3D model of the Kakkonda-Matsukawa geothermal area

Use of Ground Thermal Energy

Ground source heat pump (GSHP) system can be used almost everywhere because they utilize the difference between air and shallow subsurface temperatures. To popularize the GSHP systems, it is essential to understand the subsurface conditions in different areas, and to use a system design best suited to each area's hydro-geological conditions. In this corner, "Geo-kun", a character of the Geological Museum, will tell you (in Japanese) about the use of ground thermal energy, when you push the button of the right-side display box.

Model of using the ground thermal energy

Dynamic Earth

Here you can watch three video programs depicting the living Earth from its birth of 4.6 billion years ago to the present. You can choose any programs from the following three options (all in Japanese):

(1) Earth as the Miracle Planet (3'15")

You can follow step by step the formation of the Earth's ocean, from which the life was born, in comparison with Venus and Mars.

(2) Earth as the Fire Planet (4'00")

The interior of the Earth has maintained huge heat energy since its birth.

(3) Earth as the Life Planet (4'20")

Taking the Himalayas as an example, the video explains how plate movements have changed environments and climatic conditions.

Screen saver of the "Dynamic Earth"

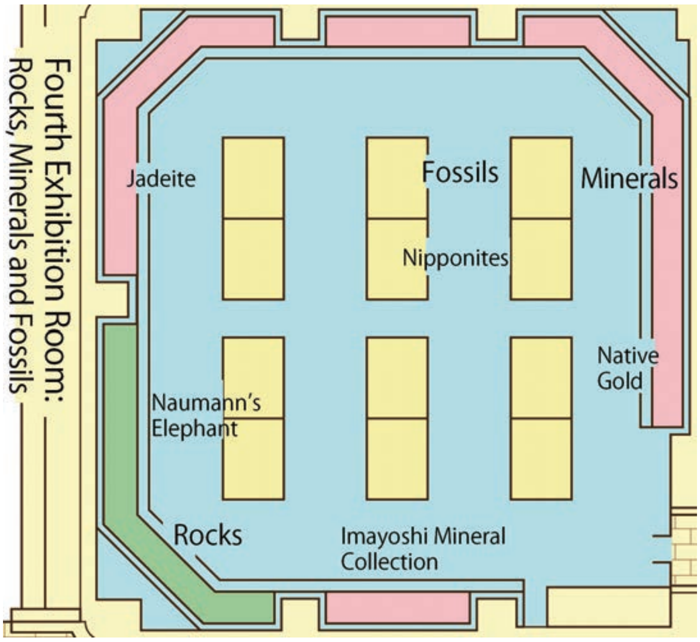
Active Faults and Earthquake Research

Many active faults that may cause disastrous earthquakes if activated are distributed all over the Japanese Islands. Information on the past earthquake activity and associated displacement along active faults is invaluable for evaluating the potential of earthquake generation. Such information can be obtained from direct observation of fault displacements by excavating trenches. The cross section of the Kamishiro Fault appeared on the surface of the Hakuba trench is shown in the right-hand side of this corner. The Kamishiro Fault is a part of the Itoigawa-Shizuoka Tectonic Line Active Fault System that traverses the middle of the Honshu Island from north to south. On November 22, 2014, a magnitude 6.7 earthquake took place on this fault.

In addition to the geological studies of active faults, GSJ has been conducting researches on groundwater level change related to earthquake occurrence as well as experimental studies on deformation and fracture process of rock.

Earthquake research of GSJ and a peeled specimen of an active fault

【4th Exhibition Room】



Minerals

In the 4th exhibition room, approximately 350 mineral specimens are systematically displayed based on chemical compositions. This systematic exhibit, the most complete one in Japan, includes excellent mineral specimens from the Japanese mines most of which have already been closed. One of the most remarkable specimens in this exhibit is the biggest native gold nugget in Japan (362.5 g) from the Shishiori mine, Miyagi Prefecture, as mentioned below. World-famous, giant stibnite crystals from the Ichinokawa mine of Ehime Prefecture are also noteworthy. The displayed specimen is an aggregate of columnar crystals with sword-like terminations. The single, columnar crystal of gypsum from the Udo mine, Shimane Prefecture, reaches 73 cm in length, the largest crystal of this kind in Japan. World-class crystals of deep red, pyroxmangite from the Taguchi mine of Aichi Prefecture also attract attention.

Giant stibnite crystal from the Ichinokawa mine and other sulfide minerals

Rocks

Rock specimens are also kept in glass cases along the wall. In this exhibit are shown more than 130 rock types commonly found in Japan. Sedimentary, volcanic, plutonic and metamorphic rocks are arranged in order of depths, respectively.

Display of the metamorphic and plutonic rocks

Fossils

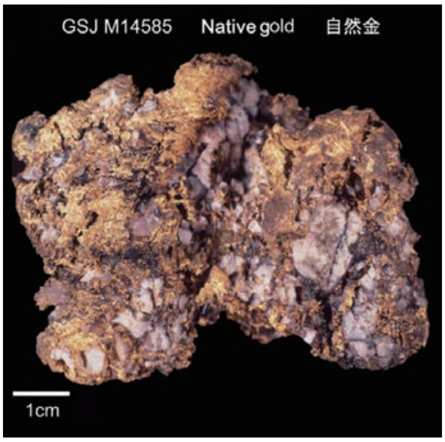
Approximately 600 fossil specimens, mostly from Japan, are housed in the central glass cases, and are arranged in a chronological order. The Paleozoic fossils are mostly corals, fusulinids, brachiopods and trilobites, which are important in determining the geological age of the Paleozoic strata. A rock sample of the oldest stratum in Japan is displayed near the entrance of this room. The sample was collected at Hitoegane, Gifu Prefecture of central Japan, containing Ordovician conodonts, microfossils found in strata of the Paleozoic to the early Mesozoic eras. The Mesozoic fossils include the important index fossils such as ammonites and bivalves (e.g., Monotis, Trigonia, and Inoceramus). The Cenozoic fossils are mostly bivalves, gastropods (snails), fishes, and plants. You can touch the replica of a large tooth of the fossil elephant: the original fossil was discovered at Hanamuro River near this museum.

Display of the Mesozoic fossils

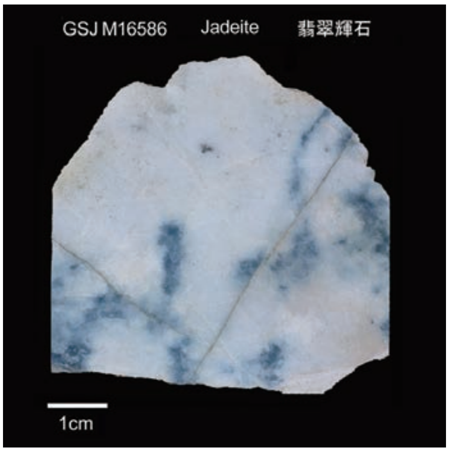
Recommended geological specimens in the 4th exhibition room.

(1) Native Gold (GSJ M14585): This specimen was collected from the Shishiori mine, Miyagi Prefecture, Northeast Japan in 1904, and is the biggest nugget occurred from Japan (total weight including quartz vein: 362.5 g). It is said that the original figure at the time of discovery was six times larger than the exhibited one. Because occurrence of such a big natural gold nugget in a hydrothermal vein is globally rare, it was called "Monster Gold".

(2) Jadeite (GSJ M16586): Jadeite is one of pyroxene group minerals. Jadeitite is a rock composed of jadeite, and has been used as a jewel ornament from about 7,000 years ago. This specimen was obtained from Itoigawa City, Niigata Prefecture, central Japan. Jadeitite is selected to a “Niigata Prefectural stone” by the Geological Society of Japan, and then jadeite and jadeitite to the “Japanese stone” by the Japan Association of Mineralogical Science, in 2016.



Native gold sample from the Shishiori mine, Miyagi Prefecture

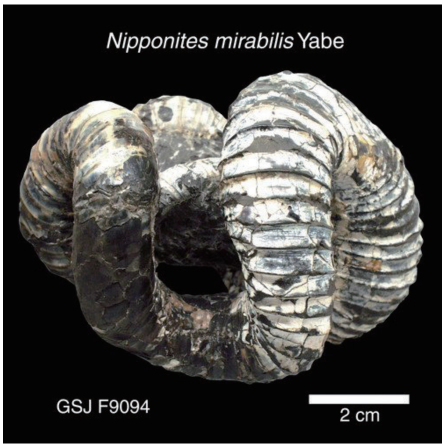


Jadeite from Itoigawa City, Niigata Prefecture

(3) Naumann's Elephant (GSJ F16097): This specimen, occurred from Tsukuba City, is a molar of the Naumann's Elephant, and it is one of the biggest class molars of Japan. Naumann's Elephant, an ancient domestic elephant, lived between about 300 thousand years ago and 20 thousand years ago.

(4) *Nipponites* (GSJ F09094): *Nipponites* is a Cretaceous heteromorph ammonite, and one of the representative fossils of Japan. This seems to be an abnormal winding, but really is a normal winding. This specimen was collected from Hokkaido, north Japan.

Molar of the Naumann's elephant from Tsukuba City, Ibaraki Prefecture



Heteromorph ammonite *Nipponites* from Hokkaido

【Supplementary Exhibition】

Donated Mineral Collections

In the Geological Museum, two donated mineral collections are exhibited. One is the Imayoshi Mineral Collection (selected) in the 4th exhibition room, and the other is the Aoyagi Mineral Collection put in the 2nd floor passage. The whole of the Imayoshi Mineral Collection covers specimens from most major mineral localities in Japan. The Aoyagi Mineral Collection include minerals collected from Ishikawa Town, Fukushima Prefecture, Japan, and many overseas specimens of the beautiful crystals.

Imayoshi Mineral Collection

Aoyagi Mineral Collection

【Outside of the Geological Museum】

Monument Stone with a Nameplate of the Geological Museum

On the left side of the entrance of the Museum, there is a black stone monument with a nameplate, on which kanji characters "地質標本館", meaning the Geological Museum are inscribed. Both the main body and nameplate are made of gabbro from Mt. Tsukuba. The gabbroic rocks occur from the hillside to the top of the mountain. The gabbroic blocks which rolled down to the foot of the mountain are called "Tsukuba ishi" (meaning "Tsukuba stone") used for garden stones. Granite is widely distributed at the foot of Mt. Tsukuba.

Monument of nameplate of the Geological Museum

Both gabbro and granite are plutonic rocks slowly solidified from magma in deep underground. The gabbro of Mt. Tsukuba is 75 million years old, and the granite was formed 68–65 million years ago, younger than the gabbro.

Interesting Patterns in Granites

Interesting patterns in granites can be observed in front of the entrance of the Museum. These patterns in the granites are thought to have been formed through magma flowing at solidification.

<u>Ladder dike in granite (the left side of the entrance):</u>

A columnar structure called "ladder dike" whose longitudinal section looks like a ladder. This large rock plate is a very precious specimen of Miocene granite showing ladder-dike structure, which was collected from Koshu City, Yamanashi Prefecture. In this specimen, a stripe pattern consisting of whitish parts rich in feldspar and quartz and dark parts rich in hornblende and biotite is developed in a cylindrical shape.

The ladder dike has been rarely found in Japan, but typically occurs in Sierra Nevada, California, U.S.A., where continuous ones over 10 m long are observed.

<u>Schlieren in Granite (the right side of the entrance):</u>

This large rectangular rock specimen is a Cretaceous granite collected from Kure City, Hiroshima Prefecture. We can see a dark-colored belt-like pattern on its surfaces, which is slightly undulated in some parts and is broken in some others. This is called "Schlieren", which is made by concentration of mafic minerals such as biotite and hornblende. We can also find a pegmatite consisting mainly of coarse feldspar and quartz together with the Schlieren on the top surface.

A granite specimen with a ladder dike

A granite specimen with schlieren

Hexagonal Pillars of Basalt

Two black hexagonal pillars lying on the right side of the entrance are the basaltic lavas ejected from ancient volcanoes in northwestern Kyushu in 10 to 7 million years ago (late Miocene). These pillars were originally in vertical.

Lava shrinks on cooling and solidification, causing a vertical fracture network called "columnar joint" to form. Horizontal cross section of the columnar joint shows a fracture pattern consisting of regularly packed polygons, typically hexagons like the exhibited specimens.

Hexagonal pillars of basalt

We can see two kinds of large mineral particles (phenocrysts) in these specimens. One is black augite with a maximum size of about 1 cm, and the other is amber colored olivine with 2 – 3 mm in size. The olivine particles sometimes look brown by the effect of weathering. Thus these specimens are augite-olivine basalts.

Piemontite Schist

Four reddish large rocks on the right of the basalt pillars are piemontite schists of the Sanbagawa belt, Shikoku Region. The Sanbagawa belt is a crystal schist zone located just south of the Median Tectonic Line. It ranges from the Kanto Mountains through the Chubu District, Kii Peninsula and Shikoku to Saganoseki Peninsula in Kyushu, and its east-west extension is about 700 km.

The piemontite schists were all taken at the upstream part of the Asemi River, which is one of tributary rivers of the Yoshino River in Shikoku. The Asemi River is a suitable site for research on metamorphic rocks, because it is running in south to north direction, perpendicular to the long axis of the Sanbagawa belt.

Piemontite schists

Piemontite schist is a metamorphosed quartz-rich sedimentary rock. Its unique red color is caused by piemontite, a Mn^{3+}-bearing silicate mineral, and hematite (Fe_2O_3). With the help of color contrast produced by piemontite, we can easily find the fold structure developed in the specimens.

Silicified Wood

Three large stones under the metasequoias are the silicified wood collected from a coal layer of about 40 million years ago in the Bibai coal mine in Hokkaido. Silicified wood is formed by silicification, that is, organic materials of buried trees were replaced by SiO_2 in groundwater containing silicic acid.

The original trees of these specimens are coniferous trees belonging to family Taxodiaceae that lived in marsh environment, and their scientific name is *Taxodioxylon matsuiwa* Watari. The same species' silicified wood is commonly found in the Chikuho and Miike coal mines in Kyushu, and is called "matsu iwa" (pine rock) there.

Silicified woods

Inada Granite with Xenolith

A block of Inada Granite with xenolith of sedimentary rock (hornfels) is displayed at the entrance of the parking lot of the Museum. This block is 120 cm(W)×110cm(D)×100cm(H) in size and 3 tons in weight. As shown in the 1st exhibition room, the Inada Granite intruded into the sedimentary rock with fracturing and thermal metamorphism. The granitic part shows fine-grained aplitic texture at the contact to the xenolith, and flow texture and pegmatite are also found. Please observe it carefully and think what phenomena happened at intrusion.

Inada Granite with xenolith

Stele of Inada Granite

The monument (stele) with "Geological Museum" inscribed in Kanji characters is at the side of the AIST main gate, welcoming every visitor to the Museum. The stele is about 5.5 m in height. It is comprised of the main facies of the Inada granite (coarse-grained hornblende-bearing biotite granite), which is intruded by a dike of dark-colored biotite granodiorite with leucocratic pegmatite at the top. The pegmatite could have been a residual melt differentiated from the melanocratic facies. Biotite is concentrated in the margin of the dike.

The Inada granite was formed about 68 million to 65 million years ago, and it is distributed in about 150 km^2 around Kasama City, Ibaraki Prefecture. The Inada granite is a representative building stone of Japan, used to the walls of the Bank of Japan, Supreme Court and others.

Stele of Inada Granite

Notes

This brochure was edited largely based on the previous guidebook (Haruna et al., 2001). Following great replacements of the displays in the future, we are going to revise this guidebook appropriately.

Finally, we thank to T. Endo, I. Kohl, T. Sawaki, and Y. Watanabe, for creating and improvement of this English guidebook of the museum.

Reference

Haruna, M., Okuyama-Kusunose, Y., Carson, S. and Konishi-Carlson, Y. eds., 2001, *Guidebook of the Geological Museum, English Version (2nd edition)*. Geological Museum, Geological Survey of Japan, 20p.

A Guide to the Geological Museum

1st edition September 2016

2nd edition January 2017

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