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Where northern land and ocean meet

Island Arc

- Rocks, Minerals, Ore Deposits, Fossils, Strata, and Their History -



Exhibition of Academic Specimens

- Earth Science -

The Hokkaido University Museum for the Earth Sciences

Exhibition of Academic Specimens

EARTH SCIENCE OF "THE ISLAND ARC"
- WHERE NORTHERN LAND AND OCEAN MEET -

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Cover: The Hokkaido University Museum occupies the remodeled building of the former Faculty of Science, built in 1930. The three-story stairwell of the main corridor has been called the "Einstein Dome". Four reliefs on the wall are Fruit, Sunflower, Bat, and Owl, symbolizing Morning, Noon, Dusk, and Night, respectively. It is believed that they indicate devotion to research and education of the pioneering faculty throughout the whole day.

The background is olive green peridotite from the Hidaka Mountains.

(N. Minoura)



The Einstein Dome

EARTH SCIENCE OF "THE ISLAND ARC"

- WHERE NORTHERN LAND AND OCEAN MEET -

Rocks, Minerals, Ore Deposits, Fossils, Strata, and Their History

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Preface

Surrounded by the Sea of Japan, the Okhotsk Sea, and the Pacific Ocean, Hokkaido Island lies in an extensive island arc reaching to Honshu and to the Kuriles, the Aleutians and even to the American continents. Thus, Hokkaido is situated in the arc-trench system and constructed of many kinds of rocks, minerals, ores, and fossils of those once-living things that perished over a period of 150 million years from the Cretaceous ~ Cenozoic eras. The samples and data belonging to the Graduate School of Science at Hokkaido University are related to this "Arc Orogeny" event.

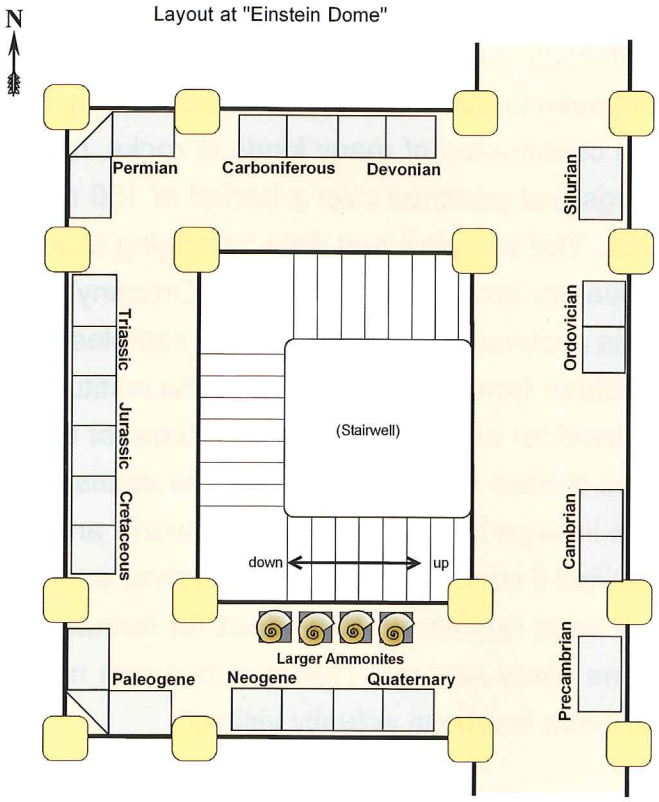
The accumulated treasures, both samples and data, are the visible outcome of academic research from the foundation of the institution. Our objective has been to create a new method for exhibiting these treasures for the benefit of the widest range of visitors. We have chosen as many life-sized specimens as possible in order to allow visitors the feeling of a linkage between the natural world and the objects they are viewing. We would be gratified if visitors thought of themselves as visiting the actual site from which the specimen has been recovered. New ideas for forthcoming exhibitions are generated when visitors come away saying, "This is a museum not only seen, but also heard, and its on-site research locations actually visited".

Outline of Exhibitions

Exhibitions of academic specimens are to be found on the third floor of the Museum. They are classified into two parts, one of which is located around the central corridor, known as the "Einstein Dome", the other in the Exhibition Hall, immediately south of and adjacent to the Dome.

Exhibitions in the "Einstein Dome"

On display are varieties of Precambrian to Quaternary fossils, each housed in one or two see-through glass covers on a 1.2 m x 0.8 m wooden case with drawers. Thirteen such cases are arranged counter-clockwise with older to younger specimens, and clockwise younger to older from the top of the steps. The number of specimens in each case depends on specimen size, averaging 15 to 20.



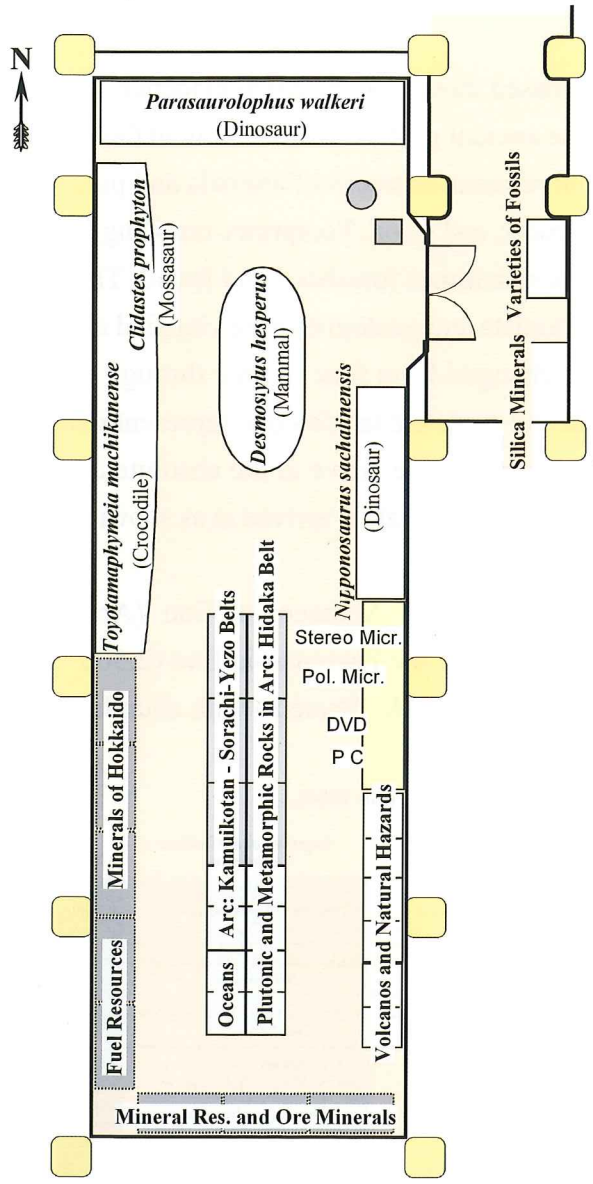
Exhibition Hall, (S-330)

Upon entering the hall, a large skeleton of the Miocene (ca. 15 Ma) mammal *Desmostylus hesperus* is on exhibition. The late Prof. T. Nagao excavated it in 1934, and a short movie recording the event is available for viewing. A reconstructed skeleton of Cretaceous (ca. 72 Ma) *Nipponosaurus sachalinensis*, also excavated from Sakhalin in 1934 is seen along the wall left of the entrance. Facing *Desmostylus* is Cretaceous (ca. 74 Ma) dinosaur *Parasaurolophus walkeri* of Alberta, Canada. Along the wall facing the entrance are two skeletons of Pleistocene (ca. 0.7 Ma) crocodile *Toyotamaphimeia machikanense* from Osaka, Japan and Cretaceous (ca. 70 Ma) mossasaur *Clidastes pyrophyton* from Kansas, USA.

Six open cases displaying about 40 large rocks from the Hidaka Belt, the Kamuikotan Metamorphic Belt, and the Sorachi-Yezo Belt are at the center of this hall. All of these specimens are cut and polished, the largest being 60 cm x 50 cm x 25 cm, and weighing 80 kg. Rocks of the Hidaka Belt are arranged in series, with those from deeper levels in front and the shallower in back. A 50 cm x 40 cm rock slab of the Sorachi-Yezo Belt showing apparent unconformity associated with basal conglomerate is one of the rarest specimens yet found. Following this are specimens from ocean floor deposits, including manganese nodules and nanno and microfossils.

Minerals mainly from Hokkaido rest on glass shelves to the right of the large rock slabs. Included

Layout in the Exhibition Hall



are Teineite, Todorokite, Jokokuite, Kanoite, Okhotskite, and Mikasaite, all of which are new minerals discovered and reported on from Hokkaido. Sedimentary fuel resources in Hokkaido are displayed next to the minerals. Exhibited also is coal from the Ishikari Coal Fields, most of which have now been closed. Crude oil and natural gas are on display from the new Yufutsu Oil and Gas Field, whose commercial production started in 1997. Metal and non-metal ore deposits are displayed on glass shelves along the south wall of the hall. Among the ore deposits, gold and silver ore (Gin-guro) from the Koryu Mine at Eniwa weighs about 80 kg. A corner shows volcanic eruptions and hazards, as well as hazard maps of Mt. Komagatake and Mt. Usu. Also shown are 50 to 60 cm diameter pyroclastics that erupted from Mt. Unzen and Mt. Usu in 1991 and 2000, respectively.

Two polarized microscopes will invite you into the colorful world of rocks and minerals under polarized light. You can freely watch a short video converted from 16 mm films recording the 1934 *Desmostylus* excavation in Sakhalin, and several videos taken during investigations of the 2000 eruption of Mt. Usu, Hokkaido, Japan. You will discover many other academic specimens at other exhibition corners on the first floor under "Life" and "Northern Biota".





Fossils and a History of the Earth

Paleontology is the science of life in the geologic past, based mostly on the fossil evidence. Fossils are remains or traces of organisms that have lived in the ancient past, embedded now in the earth's crust (sedimentary strata). Most fossils are such partial remains or traces of animals and plants as shells, bones, carapaces, egg shells, tree trunks, leaves, roots, and so on. Footprints, crawling traces, gastroliths, dwelling sites, or even animal excrement is sometimes fossilized and found. Through investigating many kinds of fossils and strata, paleontologists and geologists have clarified a rather detailed history of the earth. Animals and plants have changed from time to time through earth's history and over a vast time span. These changing biota and strata are tabulated to represent relative ages. Mainly by means of accurate radioisotope measurements, we arrive at the absolute ages of rocks. Combining both relative and absolute ages, a geologic time scale is arrived at as shown in the table below.

Earth's history is divided into three eons in ascending order: the Archaeozoic Eon (Archean) (formation of the earth~2,500 Ma), with very few life records; the Proterozoic Eon (2,500~543 Ma) with a few evidences of life; and the Phanerozoic Eon (570 Ma~Present) with abundant life records. Archean and Proterozoic together are called the Precambrian Era. Since it is supposed that the earth was formed at around 4,600 Ma, a detailed early history of the earth has not been unveiled. The oldest rock is estimated to be about 3,800~3,900 Ma old.

The Phanerozoic Eon is subdivided into Paleozoic, Mesozoic, and Cenozoic Eras. These three are subdivided into the following periods: the Paleozoic into Cambrian, Ordovician, Silurian, Devonian, Carboniferous, and Permian; the Mesozoic into Triassic, Jurassic, and Cretaceous; and the Cenozoic into Tertiary (Paleogene and Neogene) and Quaternary. Every period is then subdivided into a few or several epochs, which are further subdivided into ages.

Geologic Time Table

Era	Period	Global Events, Fossils	Representative Exhibited Specimen	(Ma)
Cenozoic	Quaternary	"Age of Man" Glaciations, Climatic fluctuations	Mammoth, *Toyotamaphimeia*	1.6
	Neogene	"Large" Mammals. Globaly warm climate.	Marine mollusks, Land mammals *Desmostylus*	23.7
	Paleogene	Rain forest of Gymnospermae and Angiospermae	Marine Mollusks, Land Mammals, Land Plants	66.4
Mesozoic	Cretaceous	Mass Extinction at K/T First Angiospermae	Ammonoidea, Dinosaur, Marine reptiles, *Nipponosaurus*	144
	Jurassic	"Age of Dinosaurs" First "Bird"	Ammonoidea, Ichthyosaurs, Pterosaurs, *Archaeopteryx*	208
	Triassic	First Dinosaur Development of Reptiles	Ceratites, Bivalvia, Pteridophyta Crinoidea, *Utatsusaurus*	245
Paleozoic	Permian	Mass Extinction at P/T. Gigantic coral reefs, Fusulinids	Rugosa, Brachiopoda, Gastropoda, Fusulinida, Goniatites.	286
	Carboniferous	Gymnospermae and Pteridophyta Forests: Origin of Coals Gigantic Insecta and Amphibians First Reptiles	Rugosa, Brachiopoda, Goniatites, Fusulinida, *Lepidodendron*	360
	Devonian	"Age of Fish" Brachiopoda, Tabulata Rugosa. First Amphibian and Pteridophyta.	Trilobites, Rugosa, Tabulata, Brachiopoda, Crinoidea, Fish	408
	Silurian	"Age of Coral Reefs" First Land Plants.	Tabulata, Rugosa, Trilobites, *Eurypterus*	438
	Ordovician	Oldest Vertebrata (Agnatha) First Nautiloids, Graptolithina	Trilobites, Graptolithina, Brachiopoda, Orthoceras.	505
	Cambrian	"Age of Trilobites" Burges Biota Explosive Evolution	Trilobites, Archaeocyathids Burges Fauna	570
Precambrian	Proterozoic	Ediacara Fauna (650Ma) Early multi cellular animal Oldest Eukariote (1,000Ma)	Stromatolite, Ediacara Fauna Banded Iron Formation (BIF)	2500
	Archean	Oldest Protokariote (3,500 Ma) Oldest Rock (3,800 Ma) Origin of the Crust (4,200 Ma) Birth of the Earth (4,600 Ma)		4600

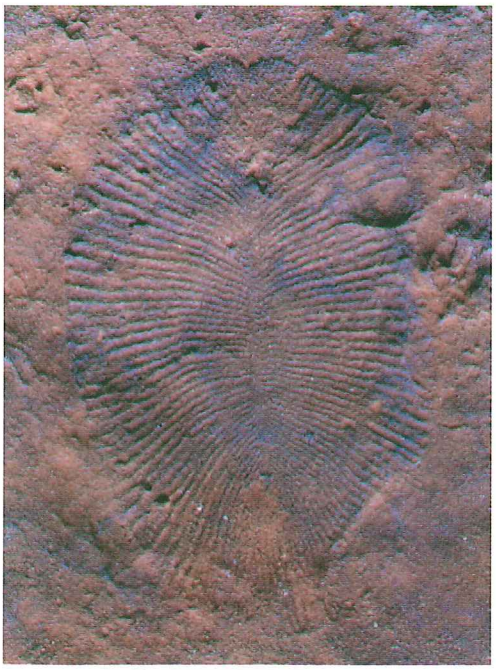
Ma = a million years ago

The Precambrian Era

Formation of our planet Earth is believed to have been made of cosmic dust and cosmic debris. Specimens are exhibited in the Precambrian display, indicating that some meteorites most certainly originated from cosmic debris.

Some of the oldest fossils known to man are minute bacteria. From about 3,000 Ma a certain type of limestone, "stromatolite", formed by "cyanobacteria" (blue green algae), is widely known throughout the world. The culmination of stromatolite formation together with Banded Iron Formation (BIF) around 2,800 Ma would definitely indicate the accumulation of oxygen in seawater, resulting in the precipitation of a vast volume of iron oxides.

The rarity of true "fossils" in Precambrian strata makes it extremely difficult to explore their life habitat during this extremely long span of earth's history. It is apparent that a vast volume of stromatolite formation with the associated photosynthesis allowed the freeing of oxygen in the sea and atmosphere during the period from about 1,300 to 1,000 Ma. The apparent multicellular Precambrian fauna was first found at Ediacara Hills, South Australia, in 1947. The taxonomic position of many of these organisms, dated around 650 Ma, is still unknown, however. Similar fossils are presently known from several other localities. The number of species does not exceed 200 altogether, quite a limited diversity when spread out over the world, as compared with the post-Cambrian or present biota.



Dickinsonia costata, Palaeomedusae? UHR 32177. 10 cm dia.
Loc.: Ediacara Hills, South Australia.
Plastic cast of the type specimen.



Xuefengia xupuensis. Unknown animal. UHR 32004. 5.5 cm dia.
Loc.: Yunnang Prov., China.

Paleozoic Era (570~245 Ma)

Cambrian Period (570~505 Ma) "Age of Trilobita"

This period was so named in 1835 by Sedgwick after "Cambria", the ancient name for Wales. More than 10,000 species of fossils are known from Cambrian strata, with still more increasingly found. They represent almost all known phyla, excepting vertebrata. This is called "Cambrian Explosive Evolution". Among the many phyla, trilobites predominate, at more than 60 % of all known Cambrian fauna throughout the world. Colonies of sponge-like animals, archaeocyathids and stromatopoloids developed into rather small-scale "reefs" in shallow seas.

Middle Cambrian Burges fauna from the Canadian Rocky Mountains reveal diverse soft-bodied animals not usually preserved. Such diverse fauna are presently known from several areas around the world.

Redlichia chinensis. Trilobita. UHR 32019. 3.5 cm long.
Loc.: Shushang, Shandong Prov., China.



Drepanura sp. (Bat stone) Trilobita. UHR 32027. 15 cm high.
Loc.: Shandong Prov., China.
Resembles flying bats.



Ordovician Period (505 ~ 438 Ma)

So named in 1879 by Lapworth for the "Ordovices", an ancient tribe in Wales. Trilobites are predominant as in Cambrian, and reefs consisting of tabulate corals, brachiopoda, stromatopoloids, and calcareous algae are well developed. In and around these reefs, orthoceras, blastoid, crinoidea, and early gastropoda lived. Planktonic graptolithina, their ancestors appearing during the Middle Cambrian, floated in offshore seas. The earliest vertebrata, agnatha (jawless fish), appeared during this period.

The oldest fossils known in Japan are Ordovician, although details of their origin and distribution are yet unknown.

***Phyllograptus* sp.** Graptolithina. UHR 32041. 2 cm long
Loc.: Oslo, Norway.



Tetragraptus quadribrachiatus. Graptolithina. UHR 32159. 3 cm long.
Loc.: Vendigo, Victoria, Australia.





Lituites litius. Nautiroidea. UHR 32030. 12cm long.
Loc.: Hunan, China.

Silurian Period (Gotlandian) (438~408 Ma) "Age of Coral Reefs"

Named in 1839 by Murchison for "Silules", the aborigines of ancient Wales. Rugose coral first appeared during the Middle Ordovician, proliferated, and built large-scale reefs together with tabulate corals, stromatopoloids, crinoidea, bryozoas, and brachiopoda. The first land plants are evident late in this period. An increase of fish at this time paved the way for the Devonian to be known as the "Age of Fish". Evolution of the graptolithina *Monograptus* was so rapid that a precise detailed age determination has been established by numerous *Monograptus* species.

Many rugosa and tabulata corals, brachiopoda, and trilobites are found from Iwate, Gifu, and Kochi Prefectures in Japan.



***Orthoceras* sp.** Nautiloidea. UHR 32064. 16 cm long.
Loc.: Gotland, Sweden.
Simple septa and a central connecting canal is characteristic.



***Ketophyllum* sp.** Rugosa (Tetracoral). UHR 32053. 15 cm dia.
Loc.: Storacaso, Gotland, Sweden.
One of the largest solitary corals.



***Halysites* sp.** (Chain Coral). Tabulata. UHR 32057. 17 cm wide.
Loc.: Bisby, Gotland, Sweden.
Transverse section appears to be chainlike.

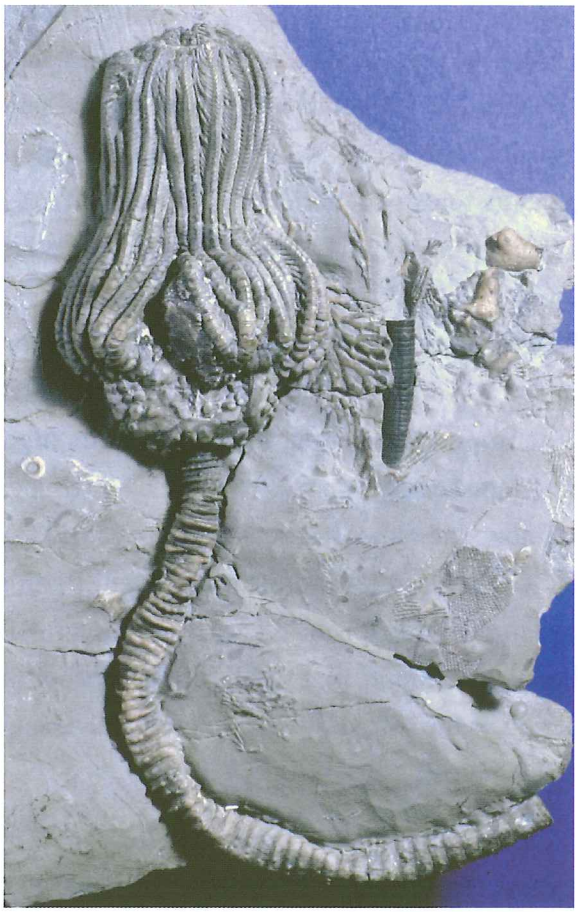
Devonian Period (408~360 Ma) "Age of Fish"

Named by Sedgwick and Murchison in 1839 for Devonshire in England.

Rugosa and tabulata corals proliferated in shallow seas, and large-scale reefs developed worldwide. Trilobites apparently declined. Real forests appeared on land and the amphibians followed. For the first time the earth was covered by green and the first land animal (amphibian) appeared.

Old Red Sandstone (ORS), characterized by a worldwide regression in the Late Devonian, contains a vast number of non-marine fish.

The Devonian in Japan is mostly marine and closely associated with the Silurian. Many small-scale patched reefs are reported, although abundant plant fragments would suggest a rather near land environment. Fauna and flora are rather scarce, except for trilobites, brachiopods, rugosa, tabulata corals, and several crinoidea.



Arthrocantha carpenteri.
Crinoidea. UHR 32151.
13 cm high.
Loc.: Sylvania, Ohio, U S A.



Calceora sandarina. (Slipper Coral). Rugosa (Tetracoral).
UHR 32163. 3.5 cm wide.
Loc.: Alnif, Morocco.



Paraspirifer bownockeri. Brachiopoda.
UHR 32161. 4.5 cm wide.
Loc.: Sylvania, Ohio, U S A.
Shells are pyritized.

Carboniferous (Mississippian and Pennsylvanian in USA) Period (360~286 Ma)

Named in 1822 by Conybare and Phillips after Coal Measures in English coal fields.

The first reptile and fusulinid appeared during this period. More than 50 % of the world's coal production is from this system, as the name implies. Such coal was generated mainly by gigantic forests of pteridophyta (wood-ferns), 30 m tall or higher. Gigantic dragonflies with a wingspan of 70 cm flew in and around such forests. Just off the seashore, gigantic "coral reefs", consisting of tabulata and rugosa corals, brachiopoda, bryozoa, and calcareous algae, developed everywhere.

Among the rather restricted Paleozoic in Japan, the Carboniferous and the subsequent Permian are most widespread. The raw material for Portland cement, limestone formed during this period, is the sole self-sufficient mineral resource of Japan today.

Lepidodendron aculeatum. Lycopsida. UHR 03280. 7 cm wide.
Loc.: Waldenburg, Germany.





***Clysiophyllum* sp.** Rugosa (Tetracoral). UHR 32096. 4.5 cm dia.
Loc.: Scotland.



***Petalaxis* sp.** Rugosa (Tetracoral). UHR 32098. 8 cm wide.
Loc.: Russia

Permian (Dias) Period (286~245 Ma)

Named by Murchison in 1841 for Permi in Russia. In Western Europe, the two-fold development of this system is characteristic of what was formerly called Dias.

Following the Carboniferous, rugosa corals, fusulinids, brachiopods, crinoids, bryozoa, and calcareous algae formed "coral reefs" in shallow seas. Among these, fusulinids produced gigantic types. On land, in addition to pteridophyta (ferns) the gymnospermae (pines and conifers), first appearing during this period, formed into giant forests. In these forests such large primitive reptiles as anthracosaurs crawled.

At the end of the Permian, a worldwide large-scale regression caused "Mass Extinctions", the largest in earth's history. A vast number of classes, orders, families, genera, and species, including all members of fusulinids, trilobites, goniatite, rugosa, and tabulata, became totally extinct. Most of the brachiopoda and crinoidea also sank into oblivion and very few genera survived.



Euconospira nipponica. Gastropoda. UHR 30638. Holotype. 11 cm dia.
Loc.: Kadosawa Quarry, Nabeyama, Kuzuu, Tochigi Pref., Japan.
One of the rarest specimens preserving radial "color pattern".



***Parafusulina* sp.** Fusulinida. UHR 32347. 12 cm wide.
Loc.: Grass Mountain, Texas, U S A.



Leptodus richithohofeni. Brachiopoda. UHR 12123. 38 cm wide.
Loc.: Imo, Rikuzen-takata, Iwate Pref., Japan.
Outer shells are dissolved and internal brachidiums left.

Mesozoic Era (245~66.4 Ma) "Age of Reptiles"

Triassic Period (245~208 Ma)

Named by F. von Alberti in 1834 for such three-fold development of this system in Germany, as Bundsandstein, Muschel Kalk, and Keuper.

Following the Permian mass extinction, newer types of such invertebrates as ceratites (most reliable index fossil of this period) markedly increased. Other newer types of gastropoda, pelecypoda, and corals (hexacoral) appeared. Gigantic amphibians of stegocephals crawled in the forests of gymnospermae and ferns, but became extinct at the end of this period. Marine reptiles such as ichthyosaurs and plesiosaurs, and land reptiles such as dinosaurs, appeared early and late, respectively. The oldest mammal is first known in the middle of the Triassic.



Ceratites nodosus. Ceratitina. UHR 01187. 8 cm dia.
Loc.: Lunville, France.



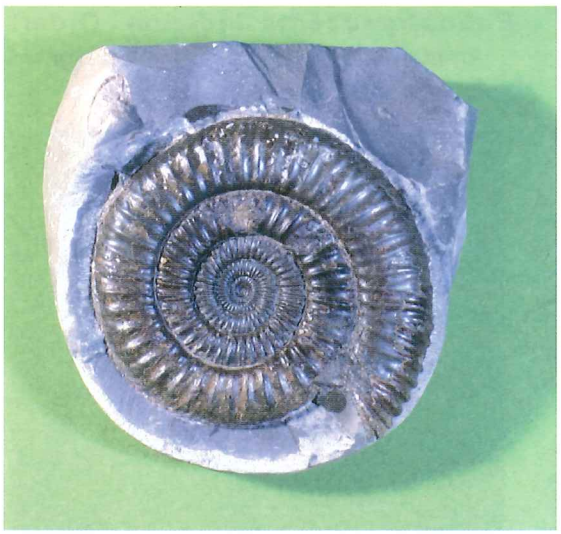
Ceratites haradai. Ceratitina. UHR 03298. 26 cm wide.
Loc.: Inai, Miyagi Pref., Japan.
Severely deformed by tectonic strain after burial.

Jurassic Period (208~144 Ma)

Named by Brongniart in 1829 after the Jura Mountains on the Franco-Swiss border, where the system is typically well developed.

Tropical to subtropical climates prevailed throughout the world during the Jurassic. On land, tropical rain forests of gymnospermae and pteridophyta proliferated worldwide. In and around these forests existed a wide distribution of such large dinosaurs as *Allosaurus*, *Brachiosaurus*, *Iganodon*, *Stegosaurus*, and *Anchylosaurus*, among others. The well-known *Archaeopteryx* was found within Late Jurassic Solnfohen lithographic limestone in Germany. In marine environments, large-scale coral reefs developed widely, and such marine reptiles as ichthyosaurs and plesiosaurs flourished the wide world over. Cephalopoda ammonoids and belemnites swam on the surface of the ocean. The oldest known pelagic sediment formed on the "true" ocean floor is Jurassic.

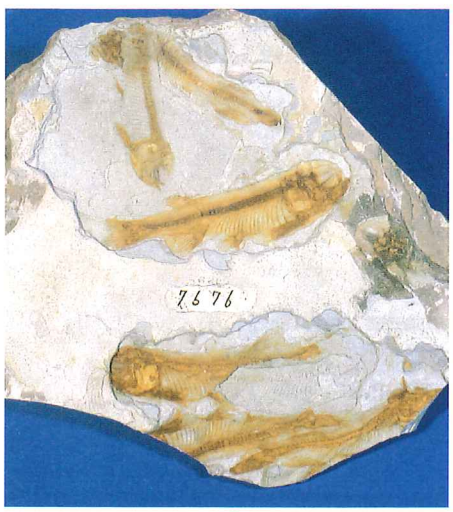
***Dactylioceras* sp.** Ammonoida. UHR 32168. 10 cm dia.
Loc.: Wittby, England.



Ginkgoides digitata. Ginkgoares. UHR 08587. 4.5 cm wide.
Loc.: Kuwasima, Shiramine, Ishikawa Pref., Japan.



Lycoptera davidi. Osteoglossoidei. UHR 07676. 5 cm long.
Loc.: Liaoning, China.



Ichthyosaurus* cfr. *communis. Class: Ichthyopterigia. UHR 31685. 38 cm long.
Loc.: Dorsetshire, England.



Cretaceous Period (144~66.4 Ma)

Named in 1822 by d'Halloy after Crete; the meaning is "chalk" in Latin.

Gigantic dinosaurs ruled the land as flying reptiles did the sky, with plesiosaurs and mossasaurs controlling the marine environment. Swimming in the sea, ammonoids cephalopoda flourished, with some growing as big as 2 m or more in diameter. Belemnites rather declined. Newer types of gastropoda and pelecypoda increased over those in the Jurassic.

The first angiospermae plants (flowering trees) appeared at mid-point in the Cretaceous. Mammalian species increased but remained rather small in size.

Toward the end of this period, one of the biggest mass extinctions took place, probably caused by the impact of a meteorite 2 or 3 km in diameter. All dinosaurs, plesiosaurs, ammonoida, and many other animal species became totally extinct.

The main source rocks of such major oil and gas fields as the Middle East, the Persian Gulf, and Argentina are thought of as belonging to the Cretaceous.

Nipponosaurus sachalinensis. Class: Ornischia. UHR 06590. Holotype. 18 cm wide.
Loc.: Kawakami Coal Mine, Sakhalin.
Internal view of the left upper and lower jaws and partial skull.



Eubostrycoceras indicum. Order: Ammonoidea. UHR 32305. 8 cm high.
Loc.: Obira, Hokkaido, Japan.





***Cyrenopsis* sp.** Class: Bivalvia. UHR 32135. 17 cm wide.
Loc.: Coober Pedy, Australia.
Precious opalized clam shells.

Cenozoic Era (66.4 ~ Present) "Age of Mammals"

Tertiary Period

Paleogene Period (66.4~ 23.7 Ma)

Modern mountain ranges, such as the Alps, Himalayas, and Andes, began their uplift during the Cenozoic Era. In Japan, broadleaf forests and coniferous trees spread out over wide areas and the major coalfields of Kyushu and Hokkaido were formed.

Many ancestors of present day mammals appeared, though most were rather small as compared with present forms. They spread rapidly over the entire globe; hence the Cenozoic Era is called the "Age of Mammals".



Sinohadrianus ezoensis. Subclass Testudinata. UHR 13632. Holotype. 23 cm long.
Loc.: 19th Incline, Bibai Coal Mine, Bibai, Hokkaido, Japan.

In the marine environment, rapidly evolving planktonic foraminifera and nanno planktons flourished. These are most useful as tools for determining detailed bio-horizons of marine sediments.



Amynodon watanabei. Order: Artiodacthyra. UHR 13631. Holotype. 24 cm long.
Loc.: R. Horonitachibetsu-gawa, near Showa Coal Mine, Numata, Hokkaido, Japan.



Sabalites nipponica. Class: Angiospermae. UHR 32114. Holotype. 45 cm wide.
Loc. Bibai Coal Mine, Bibai, Hokkaido, Japan.
Specimen proving Hokkaido was much warmer at that time.

Neogene Period (23.7~1.6 Ma)

Rigorous volcanic activities commenced in the circum-Pacific region during the Neogene, including those in the Japan Arc. They have continued through the Quaternary and right up to the present. The opening of the Japan Sea started sometime about 15 Ma. The climate was



Fortipecten takahashii. Class: Bivalvia. UHR 32301. 18 cm wide.
Loc.: R. Horoshintachibetsu, Numata, Hokkaido, Japan.

warm globally during the early Neogene, continuous from the Paleogene. Toward the end of this age, however, a cyclic change of warming and cooling occurred. Extremely diverse mammals ruled the entire earth and many grew to gigantic size.



Right: ***Vicarya japonica***. Class: Gastropoda. UHR 30302. 9 cm high.
Loc.: Tokunari, Ishikawa Pref., Japan.
Left: ***Vicarya callosa***. Class: Gastropoda. UHR 04604. 7cm high.
Loc.: Mizunami, Gifu Pref.
Opalized internal cast of a gastropoda.

Quaternary Period(1.6 Ma~Present) "Age of Man"

Quaternary deposits were formed as alluvial plains and their peripheral hills. Volcanic activities have continued since the Neogene, and many active volcanoes exist even now. The amplitude in climatic change increased over that of the Tertiary during four to six glacial/interglacial periods. The sea level was lowered up to 100 meters during the maximum glacial age, whereas it was raised more than 100 meters during the interglacial age. Although large-scale topographic features had not changed, location of the shoreline had significantly shifted with the rise and fall of these sea levels.

Fauna and flora of the Quaternary Period are rudimentarily the same as those of present day biota, though hundreds of larger mammals became extinct, most probably due to the activity of man. Sea level changes and climatic fluctuations caused large scale shifts of biota repeatedly, but of rather short duration. For example, the many elephant teeth dredged from the Seto Inland Sea of Japan would indicate that this seafloor was then dry land inhabited by many elephants and other mammals.



Mammuthus primigenius. Order: Proboscidea. UHR 30628. 22 cm long. Gyp. cast.
Loc.: 100m north of Kogoshi Elementary School, Erimo, Hokkaido, Japan.

Mammuthus primigenius Order: Proboscidea. Left: Body Hair. UHR 30636. Right: Flesh. UHR 30637.
Loc.: Siberia, Russia.





Large Fossil Skeleton at the Hokkaido University Museum

The Hokkaido University Museum and the Division of Earth and Planetary Sciences of the Graduate School of Science preserve more than 30,000 registered fossil specimens. Unregistered specimens and those awaiting registration exceed 20,000. Among these, the Miocene large mammal *Desmostylus hesperus*, the Cretaceous dinosaur *Nipponosaurus sachalinensis*, and the Triassic ichthyosaur *Utatsusaurus hataii* are some of the most important and precious specimens.

Desmostylus hesperus

Reconstructed skeleton (by T. Kamei, 1968) of *Desmostylus hesperus*. 1.7 m high x 3.5 m long.



Excavated in 1934 and 1936 from Sakhalin Island (Japanese Karafuto) by the late Prof. T. Nagao and his team, this specimen was then thought to be a near complete skull and skeleton of the first such species in the world to be uncovered. It was thought of as having fins, and was compared to such marine mammals as the sea lion, sea cow, or seal, and related to land mammals such as the rhino and hippo. The specimen indicates that this species had peculiar teeth and four stout legs, although still a mysterious animal. Nagao described it as a new species of *Desmostylus mirabilis* in 1938. A recent study now identifies it as identical to *D. hesperus*.



Tusk and Teeth of *Desmostylus hesperus*. 15 cm long. UHR 32140. Loc.: Temblor Formation, Coalinga, California, U. S. A.

Nipponosaurus sachalinensis

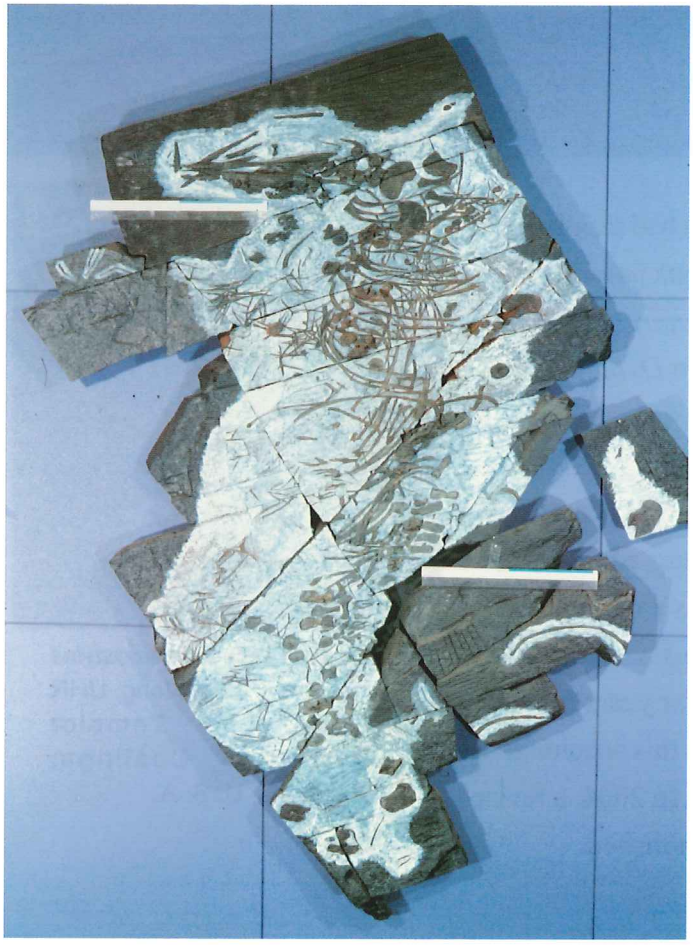
Nipponosaurus also was excavated during 1934, comprising almost 60 % of the entire skeleton of a young adult. In 1936 this skeleton was described by Prof. Nagao as a new species of the Hadrosaurian dinosaur, *Nipponosaurus sachalinensis*. Unfortunately, World War II and the post-war years produced chaotic conditions in Japan, for which reason this specimen has taken 50 additional years to be reinvestigated. In 2004, a revised description was accepted and will soon be published.



Reconstructed skeleton of *Nipponosaurus sachalinensis*. 3.8 m long.

Utatsusaurus hataii

Excavated in 1982 from Miyagi Prefecture, one of the earliest and most complete skeletons of Ichthyosaur, *Utatsusaurus hataii* is still under investigation, though its plastic cast is displayed at the entrance hall to the Faculty of Science Building.



Utatsusaurus hataii. Ichthyosauria. UHR 32123. Scales are 30 cm long.
Loc.: Ara, Ogatsu, Miyagi Pref., Japan.
Plastic cast of the entire skeleton.

Earth Sciences in the Island Arc

The Pacific Ocean is rimmed by deep and narrow submarine hollows called "trenches", as for example, the Japan Trench. Outside the trench landward, an arched arrangement of islands is distinct and is known as an "island arc". The Japanese islands are typically an island arc. Furthermore, beyond the island arc approaching the continent is a "marginal sea", of which the Sea of Japan is a primary example. Such combination of trench, island arc, and marginal sea is an essential geological feature of the western Pacific.

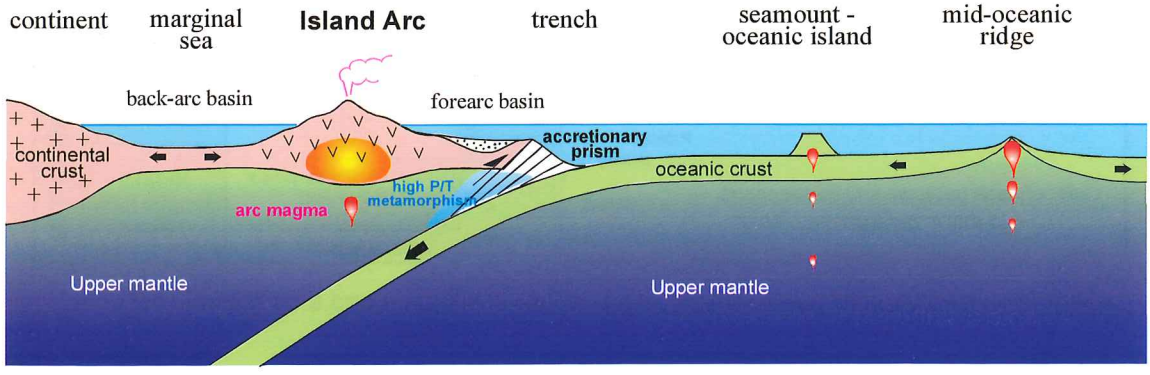
Introduction

At the trench location, an oceanic plate developed at a far mid-oceanic ridge meets the continental crust and subducts beneath it to form a deep and narrow depression. Because of the deposition of young low-density sediments in the depression, a negative gravity anomaly occurs around the trench, and heat flow is lowered due to the relatively cold subducting oceanic plate.

In an island arc, active cone-shaped volcanoes are arranged in arch-form, some of which actively erupt a large volume of silica-rich andesitic magma. Such a volcanic belt occurs landward far from the trench, but no volcanoes exist in an area close by the trench. The boundary line between such a belt and the volcano-free area is called a "volcanic front". The volcanic front corresponds to the 150 km depth contour line of a deep seismic plane. In an island arc, seismic zones deeper than 150 km are also observed, besides shallow ones of less than 100 km which cause so-called "direct-hit earthquakes". Hypocenters of a deep seismic zone are concentrated on the upper surface of subducting oceanic plates; therefore, depth of the seismic zone increases from the trench-side as it moves toward the continent. This combination of an active volcanic belt and a deep seismic zone is highly characteristic of the island arc.

A sea area incompletely separated from the ocean by islands or by a peninsula at the continental margin is called a "marginal sea" (in a broad sense). The typical marginal sea is bounded by an island arc, convex as viewed from the open sea, diverse as to its origin and development. In the case of the Sea of Japan, the Okhotsk Sea, the Mariana Trough, and the Okinawa Trough, these

Model of island arc and the arc-trench system.



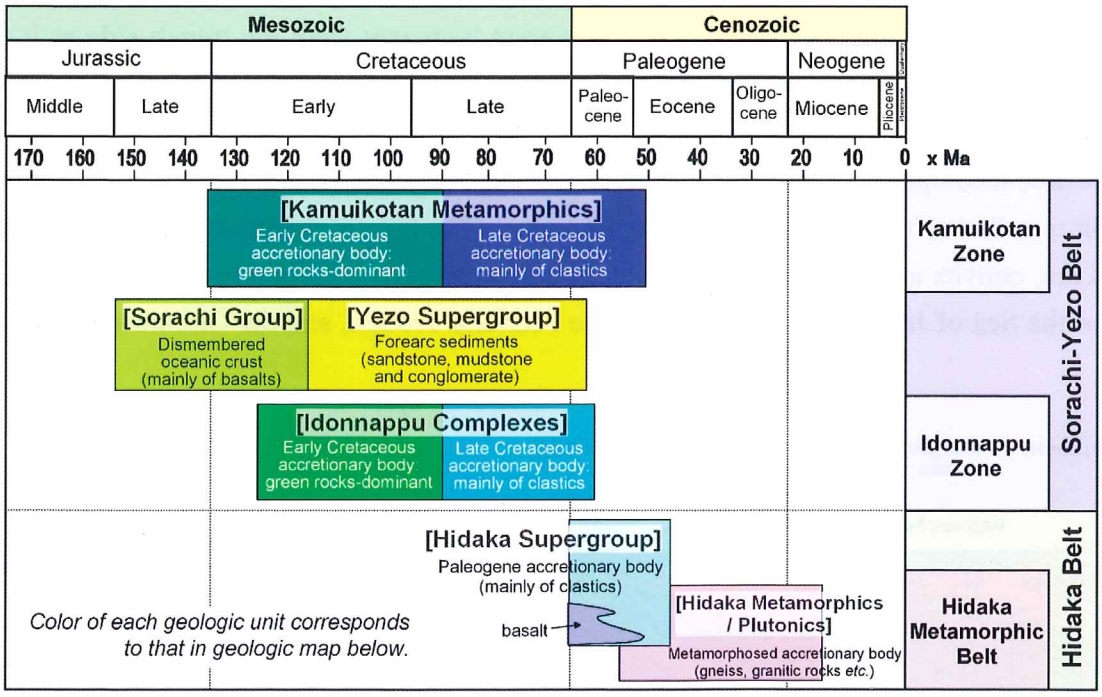
were generated by the rifting and opening of a back-arc extensional region. Back-arc opening is now still active in the latter two above. The Bering Sea, on the other hand, was formed by the trapping of old oceanic crust. All marginal seas are characterized by thick sediments and flooring of the oceanic crust.

Geological Framework of Central Hokkaido and the Arc-Trench System

The Pre-Neogene basement rocks of central Hokkaido were formed by the subduction of an oceanic plate in the Cretaceous to Early Paleogene time frame (Ca. 140~50 Ma ago), but opinions vary for classification on the development of its geologic bodies. An example of geologic division based on recent studies is given here.

Understanding the geology of pre-Neogene strata and rocks in Hokkaido involves a concept of the "arc-trench system". In a plate-margin where an oceanic plate is subducting (the subduction zone), geologic and geographic zonal arrangement takes the following order oceanward: volcanic or island arc, to fore-arc basin, to accretionary belt, to trench. This arrangement is just a presentation of the "arc-trench system". The accretionary belt is formed by surface offscraping of the subducted oceanic plate and its underplating onto the bottom of the continental or island-arc plate. The forearc basin is a marine basin between a volcanic arc and an accretionary belt.

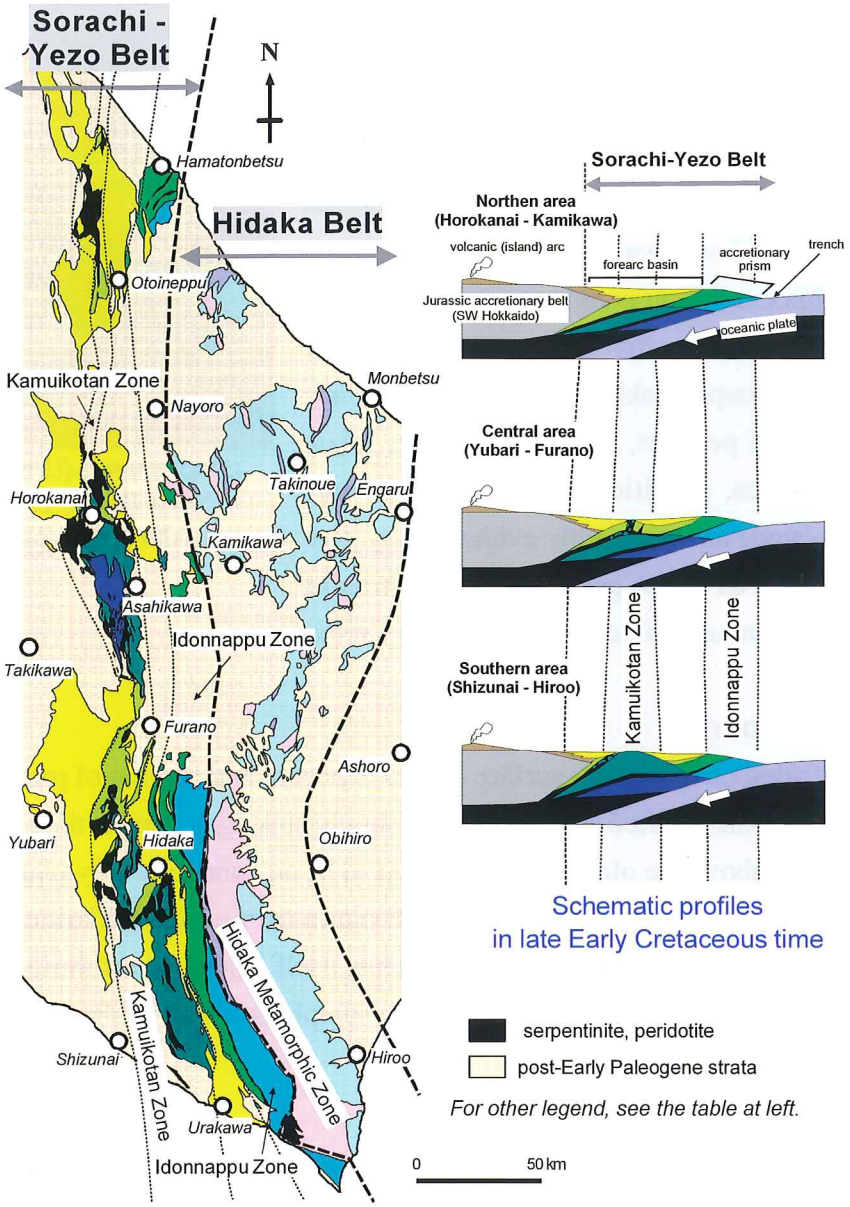
Associated with a westward subduction of the oceanic plate in Cretaceous - Early Paleogene Hokkaido, the "Sorachi-Yezo Belt", which consists of Cretaceous accretionary bodies and forearc sediments, and the "Hidaka Belt", made up mainly of Paleogene accretionary bodies, are considered to have been formed adjacently.



Geologic distribution of pre-Tertiary rocks in central Hokkaido and their tectonic scheme.

At the center of the Sorachi-Yezo Belt, rocks uplifted from a depth of 10~25km or more from the subduction zone are exposed in zoned fashion. Such rocks are composed of a large volume of basalts accreted from the oceanic plate, high-pressure type crystalline schists, amphibolites, and serpentinites of upper mantle origin. This area is called the "Kamuikotan Zone".

Thus, central Hokkaido is an important area for understanding the inner state and development processes of plate subduction.



Geologic division of central Hokkaido.

Rocks and Strata of the Yezo Supergroup

The Cretaceous "Yezo Supergroup" widely distributed in central Hokkaido were deposited in the sea (Yezo Basin) lying between the continental margin (or volcanic arc) and the trench. The Yezo Basin was a fertile sea where many life forms (ammonites, inoceramids, and marine reptiles such as plesiosaurs) once lived. The Yezo Supergroup deposited in this sea is "a book" about 8,000 m thick, recording the history of sea and land in central Hokkaido 100 Ma ago.

Here are exhibited samples of unconformity and conglomerates, both of which present tectonics in the Yezo Basin.

Conglomerates:

The Yezo Supergroup is composed mainly of rather fine-grained sediments such as mudstone and sandstone, but conglomerate beds containing pebble-clasts, cobble-clasts, or larger size clasts are

also observed. Pebbles were primarily transported by river and settled at or around the estuarine area. These coarse-grained sediments were sometimes collapsed and moved as submarine slide to be resedimented in an offshore area.

This exhibition conglomerate sample was collected from the basal part of a Middle Yezo Group at Takino-sawa in Hidaka. Many kinds of pebbles, such as andesite, felsic volcanics, granitic rocks, and calcareous mudstone are abundantly evident. They give us clues as to the geologic composition of mountainous source areas during the Cretaceous.



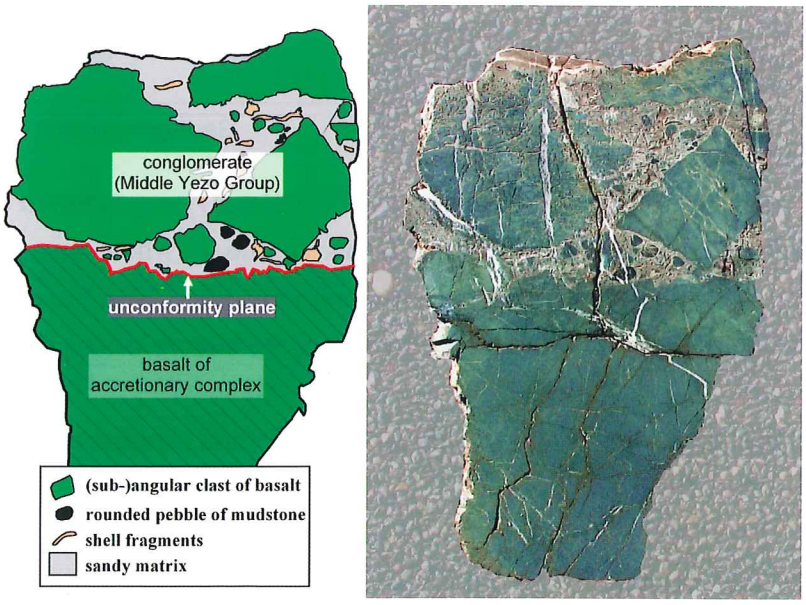
Conglomerate (UHRG00009) at base of the Middle Yezo Group. Locality: Takino-sawa in Hidaka. Width of the specimen: 50 cm.

Unconformity:

Uplifting on the earth's surface causes exposure and erosion of previous strata on land or in coastal areas. If the uplifted and eroded area should sink again, and if the new strata should be re-deposited and lie above the old, the result is said to be an "unconformity plane".

Exhibited is a sample of one such plane formed in Hokkaido about 100 Ma ago (late Early Cretaceous). A rare opportunity presents itself when unconformity phenomena can be observed as a single specimen. For this reason, the sample is scientifically very valuable.

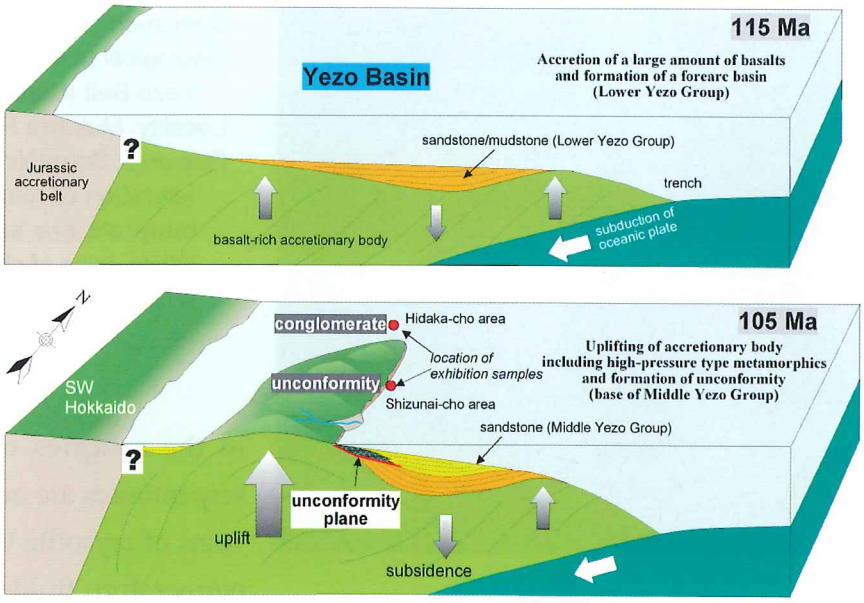
The lower half of the specimen (a greenish monochrome) is basalt of an accretionary complex formed about 120 Ma ago (Early Cretaceous). In the upper half, we observe a basal conglomerate of the Middle Yezo Group (Ca. 100 Ma), greenish angular to subangular basalt fragments in a light-colored matrix. Rounded pebbles of black mudstone and shell fragments are also seen within the matrix, showing the deposition to have been formed in a shallow marine environment.



Basal unconformity in the Middle Yezo Group (UHRG00001). Locality: Kuzure-sawa, a branch of the Shunbetsu River in Shizunai. Height of the specimen: 28 cm.

Model for the Yezo Basin:

The accretionary body is made of trench-fill sandy/muddy sediment, pelagic sediment (chert), and basaltic slabs, which have subducted from trench to a deeper zone of the earth's interior. Therefore, the accretionary bodies formed at a deeper zone in central Hokkaido 100 Ma ago, were rapidly uplifted a distance of more than 10 km to build a rocky coast, washed over by raging waves of the sea.



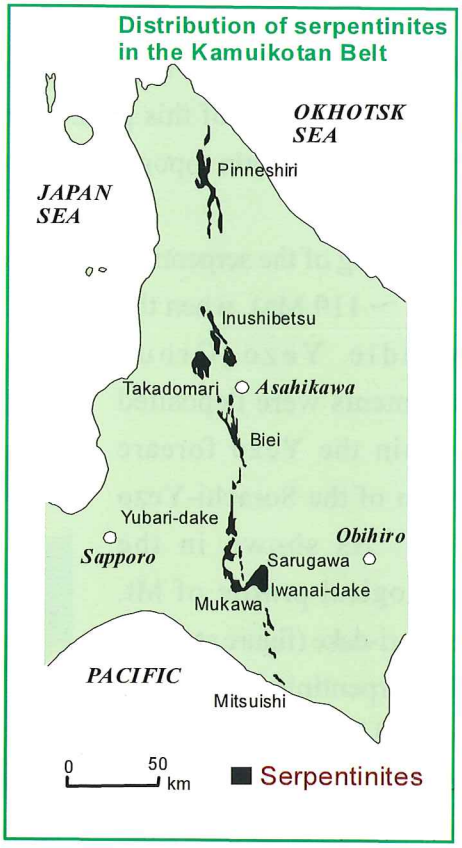
Restoration of the Cretaceous Yezo Basin.

Serpentinites and High-Pressure Type Metamorphic Rocks in the Kamuikotan Belt

Massive and Mélange Serpentinites

A number of serpentinite masses are exposed in the Kamuikotan Belt, from the southern area near Mitsuishi on the Pacific coast, through the Mts. Yubari-dake and Ashibetsu-dake areas, to the northern areas near Pin-neshiri, along the central-axial zone of the Sorachi-Yezo Belt. Large bodies of massive serpentinite occur at the Sarugawa in Hidaka, at Mukawa in Hobetsu, and at Takadomari and Inushibetsu in northwestern Asahikawa.

Serpentinites are well known as highly altered rocks from upper mantle peridotites. Primary olivine, orthopyroxene, and spinel are often preserved in serpentinized peridotite, indicating that the source rock for serpetinite has been mostly dunite and harzburgite. It is well known that the primary olivine and orthopyroxe alter into serpentine minerals during hydration generated within a shallow lithosphere. As shown



Map showing distribution of serpentinites in the axial zone of the Sorachi-Yezo Belt.

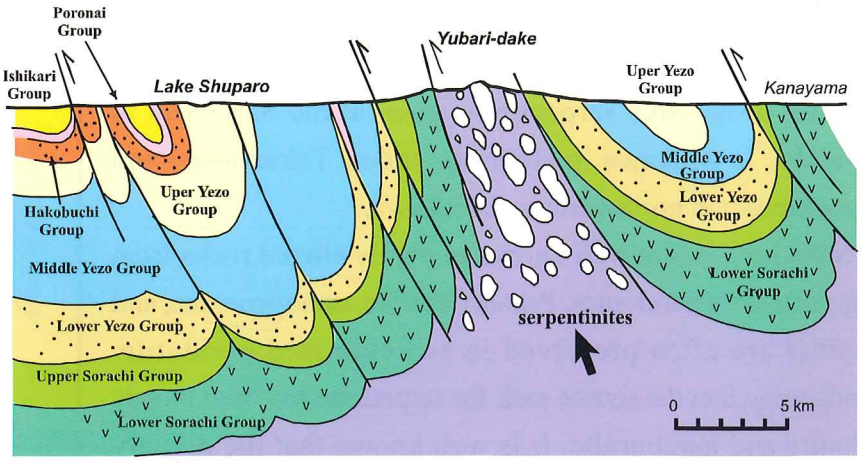


Serpentinite. Specimen No. K0007.
Specimen size: 21 cm in diameter.
Geological unit: Mukawa serpentinite, Sorachi-Yezo Belt (Kamuikotan Belt)
Locality: Mukawa River, Tomiuchi, Hobetsu.
Remarks: Serpentinite modified after hydration-alteration of harzburgite. Major constituent minerals are serpentine and magnetite. White veins of chrysotile can be seen cross-cutting the serpentinite.

in the samples on display (photo at left), serpentinites are occasionally crosscut by white veins of crysotile which crystallized from high-temperature fluids that penetrated into cracks within the host serpentinite.

Some serpentinite masses are known as serpentinite mélange complexes containing various sizes of exotic blocks embedded in high-pressure type metamorphic rocks, basaltic pillow lavas of the Sorachi Group, and other crustal blocks in the serpentinite matrix. The mélange complexes are considered to have formed when the exotic blocks were incorporated into the mélange serpentinite during uplift from the upper mantle. Mt. Yubari-dake's serpentinite mélange is one of the most famous examples of this phenomenon, comprising a wide range of exotic blocks and creating beautiful mountain topography. The area was established as a national "Natural Monument" in 1996.

Uplifting of the serpentinite mélange complex was probably generated during the Early Cretaceous (120 ～ 110 Ma), when the Middle Yezo Group sediments were deposited within the Yezo forearc basin of the Sorachi-Yezo Belt. As shown in the geological profile of Mt. Yubari-dake (figure at right), the serpentinite mélange is located just at the axis of the anticline, where stratigraphic units of the Sorachi Group and Yezo



Geological profile of Mt. Yubari-dake (W to E), showing a typical mode of occurrence for mélange serpentinite intruded into the anticline axial zone in the Sorachi-Yezo Belt.

Supergroup all incline westward at the western wing of the anticline.

High-Pressure Type Metamorphic Rocks

Considerable numbers of these metamorphic rocks appear in close association with the serpentinites. Some typical index minerals, which indicate high-pressure and low-temperature for conditions of crystallization, have been reported from the serpentinite areas. Glaucophane and riebeckite are representative minerals contained in blue schists such as glaucophane and riebeckite quartz schists individually. Jadeite (Na-pyroxene), lawsonite, and aragonite are also representative index minerals crystallized within blue schists, epidote amphibolites, garnet amphibolites, and other rock types.

It is well known that high-pressure type metamorphic rocks are one of the significant geological components of arc-trench systems generated through subduction of a low-temperature oceanic lithosphere. Some typical rock specimens are displayed.



Glaucophane Schist. Specimen No. K0003.
Specimen size: 18 cm in diameter.
Geological unit: Kamuikotan metamorphic rocks, Sorachi-Yezo Belt.
Locality: Etanbetsu Pass, Horokanai.
Major constituent minerals: glaucophane (dark blue), epidote (yellowish green), and plagioclase (white).



Pelitic Schist. Specimen No. K0005.
Specimen size: 17 cm in diameter.
Geological unit: Kamuikotan metamorphic rocks, Sorachi-Yezo Belt.
Locality: Panke-horonai River, Ashibetsu.

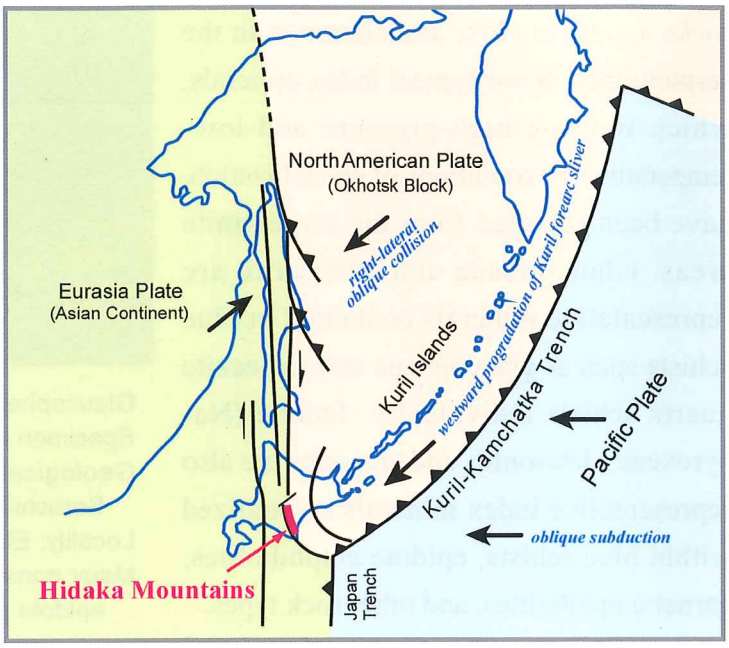


Garnet-Quartz Schist. Specimen No. K0001.
Specimen size: 17 cm in diameter.
Geological unit: Kamuikotan metamorphic rocks, Sorachi-Yezo Belt.
Locality: Mt. Horai, Mitsuishi River, Mitsuishi.
Major constituent minerals: garnet (pink), actinolite (dark green), and quartz (transparent white).

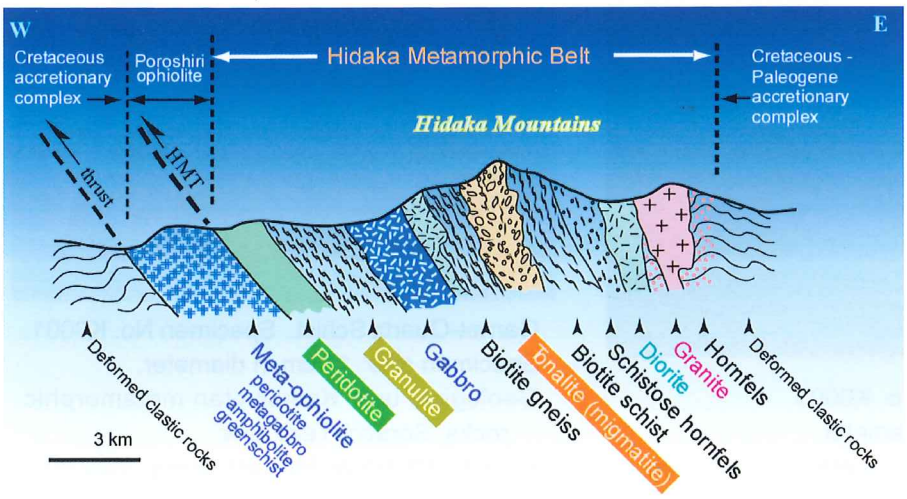
Hidaka Mountains: Rocks Generated in Deep Lithosphere beneath the Island-arc

The Hidaka Mountains are made up mostly of metamorphic and plutonic rocks created at about 50 to 14 Ma. The rocks form a beautiful zonal arrangement in a N-S direction along the range, whose geological name is the "Hidaka Metamorphic Belt". The mountains are located just on the boundary between the North American Plate and the Eurasian Plate. The geological event of mountain building started at about 13 Ma. It is reasonably explained that the event was formed by the Kuril Island-arc's collision at the SW rim of the North American Plate against the eastern edge of the Eurasian Plate.

Map showing structural setting of the Hidaka Mountains.

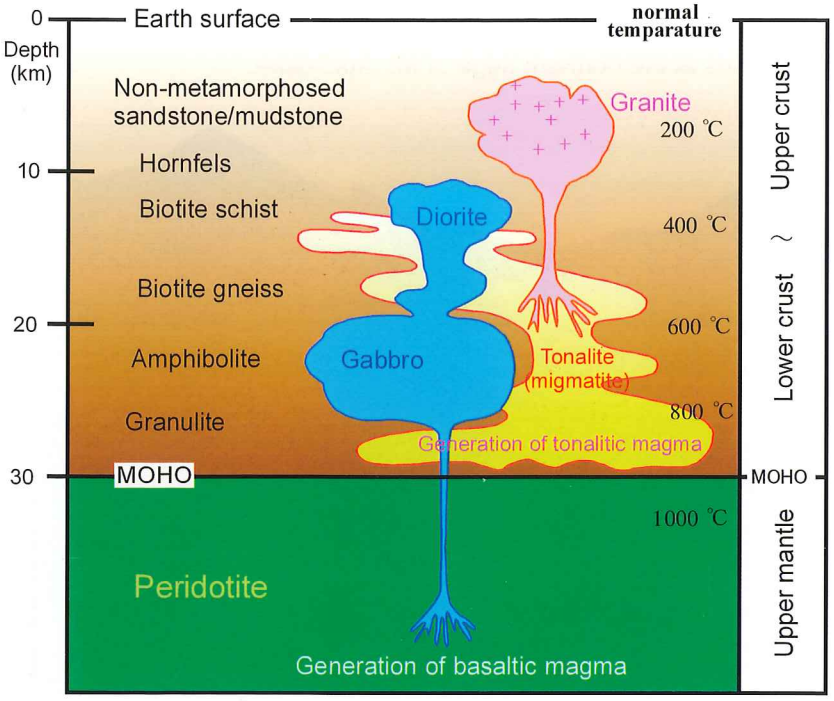


As shown in a geological profile of the Hidaka Range (below), a continuous succession derived from the lithosphere beneath the island-arc is exposed along the mountain chain, showing a nicely arranged pile of peridotites, granulites, amphibolites, biotite gneisses, biotite schists, hornfels, and non-metamorphosed sedimentary rocks. This corresponds to a lithological change in the lithosphere beneath the island-arc from the uppermost mantle, into a deeper level of the crust, and down through the middle crust into a shallower lithospheric level.



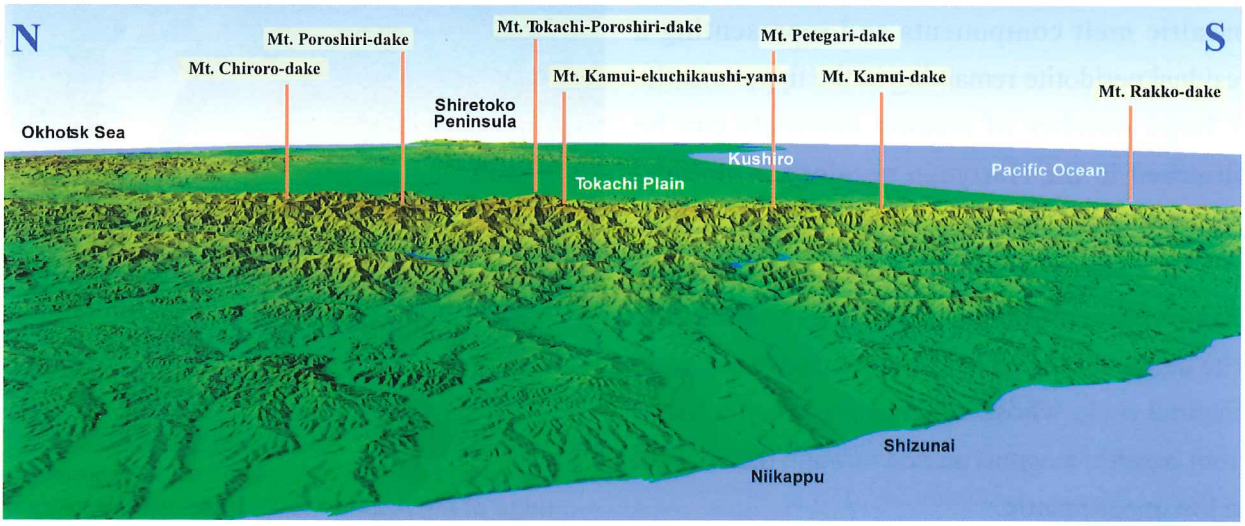
Geological profile of the Hidaka Range, showing a continuous lithological change from west to east.

The pressure-temperature estimations for formation of metamorphic rocks suggest that the Hidaka mountains were developed in a very high geotherm, whose gradient probably exceeded 34 °C / km. The



Schematic profile, showing magmatic activities and metamorphism generated in the Hidaka lithosphere at the stage of maximum geotherm.

estimated geothermal gradient is obtained from the estimations of P = 25 km and T = 850 °C for granulites. Large amounts of tonalites are found in the Hidaka Mountains, which are considered to have been derived from granulites in their deep crust. We also have large amounts of gabbros, diorites, and granites within various P-T grade metamorphic rocks. The occurrence of tonalites and other plutonic rocks also supports a very high geothermal model obtained from P-T estimations. The figure above shows a genetic relationship between magma activity and metamorphism, which might have occurred during the maximum geothermal stage in the Hidaka lithosphere. The schematic profile as shown in the figure is considered to be quite similar to the lithosphere estimated for the Japanese Islands, having a very high geothermal gradient. The total sequence of geological units observed in the Hidaka Mountains is called the "Hidaka Island-arc" in this pamphlet.



Bird's-eye computer-graphic view of the Hidaka Mountains from offshore Niikappu, altitude 10 km. Processed by M.Kawamura using *Kashmir3D*.

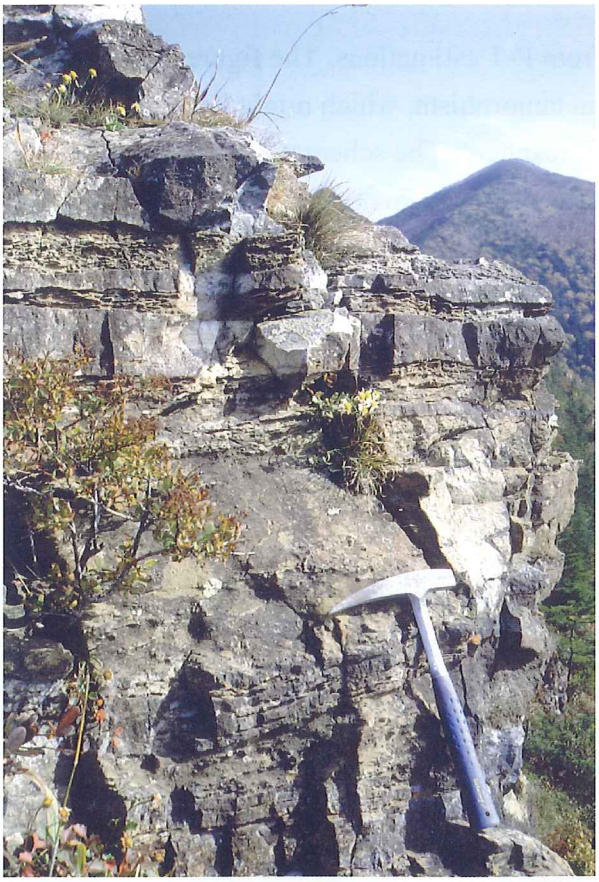
A spectacular view of the peridotite mountains at the northern ridge of Mt. Apoi-dake.



Horoman Peridotite

At the south end of the Hidaka Mountains, a well layered peridotite complex is exposed around Mt. Apoi-dake. The rocks originated in the upper mantle, a source portion of basaltic magmas.

The fact that the upper mantle peridotites are source rocks for basaltic magmas produced after partial melting of the source peridotites is well known. The harzburgite displayed here contains poor pyroxenes, suggesting a depleted nature for basaltic melt components and representing a residual peridotite remaining in the upper mantle. A large number of magma channels can be observed in the Horoman peridotite complex. Photo at right showing gabbroic mafic layers presents one of the best examples of basaltic magma channels formed within the upper mantle. The dunite displayed here represents a larger scale channel rock, whose olivines were crystallized from basaltic magmas passed through the channel in the upper mantle.



Well-layered peridotite exposed on the western ridge of Mt. Apoi-dake. Plagioclase lherzolite and dunite interlayered with gabbroic mafic rocks. (Peak in background is Mt. Apoi-dake.)



Harzburgite. Specimen No. H0002.
Photo width: 9 cm.
Geological unit: Horoman peridotite complex, the Main Zone of the Hidaka Metamorphic Belt.
Locality: Horoman River, Samani.
Major constituent minerals: olivine (olive green), orthopyroxene (brown), clinopyroxene (emerald green), and spinel (black).



Dunite. Specimen No. H0001.
Specimen size: 60 cm in diameter.
Geological unit: Horoman peridotite complex, Main Zone of the Hidaka Metamorphic Belt.
Locality: Furukawa-no-sawa, Horoman River, Samani.
Major constituent minerals: olivine (olive green), spinel (black), and orthopyroxene (greenish brown).

Metamorphic Rocks in the Lower Crust of the Hidaka Island-arc

High grade metamorphic rocks of the Hidaka Mountains originated from the late Cretaceous to the Paleogene in the arc-trench system. The original rocks have been recognized as sedimentary rocks (sandstone and mudstone), containing a small number of exotic blocks derived from seamounts and oceanic islands such as basaltic pillow lavas, chert, and limestones, all of which were incorporated into



Granulite. Specimen No. H0004.
Specimen size: 32 cm in diameter.
Geological unit: Lower zone (Zone IV) of the Hidaka Metamorphic Belt.
Locality: Horobetsu River, Urakawa.
Major constituent minerals: garnet (pink), hypersthene (brown), cordierite (bluish green), biotite (dark brown), and plagioclase (white).



Andalusite-Biotite Gneiss.
Specimen No. H0006.
Specimen size: 48 cm in diameter.
Geological unit: Lower zone (Zone III) of the Hidaka Metamorphic Belt.
Locality: Pon-Nikanbetsu River, Erimo.
Major constituent minerals: andalusite (pale pink), biotite (dark brown), plagioclase (white), and quartz (transparent).

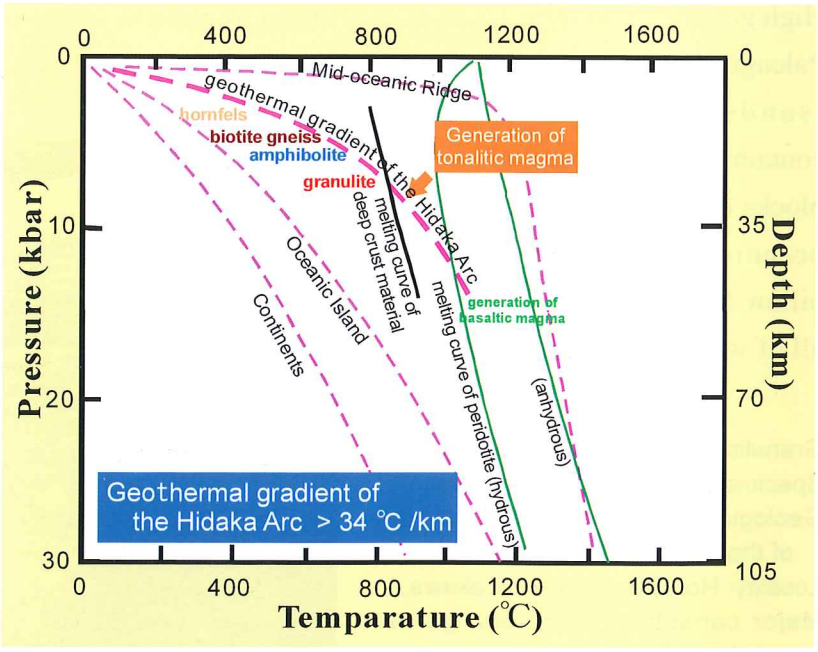
the accretionary complex formed in the arc-trench system.

Granulite represents a high-grade metamorphic rock formed at the deepest level of the Hidaka crust. The temperature and pressure estimations of T = 800 °C and P = 7.5 kb (24 km in depth) have been obtained from the geothermo-barometry for granulite assemblages. Granulite contains considerably large grains of garnet, hypersthene, and cordierite, and forms a nicely crystallized gneiss.

Biotite gneiss contains many euhedral crystals of andalusite, which is characteristically pale pink. Andalusite is an index mineral of metamorphism, suggesting a high temperature of T = 500 °C and a pressure of P = 3.5 kb.

Magmas Generated by the Melting of Granulites

The geothermal gradient of the Hidaka island-arc, estimated by geothermo-barometry for Hidaka metamorphic rocks, is shown in the pressure-temperature diagram (red broken line in figure at right). It is evident from the diagram that estimated pressure-temperature conditions for a series of representative metamorphic rocks such as hornfels, biotite schist, bitote gneiss, amphibolite, and granulite are all plotted along the line of the Hidaka geotherm. Additionally,



Pressure-temperature diagram showing the Hidaka geotherm.

the diagram suggests a possible melting of granulites, as the geotherm intersects the melting curve applied for deep crustal rocks. It is probable that tonalitic magmas were generated at conditions in the lowermost crust, where the Hidaka geotherm exceeds 850 ℃ (melting point for Hidaka granulites).

Tonalite is a common type of plutonic rock composed mainly of plagioclase, quartz, and biotite. Large grains of bluish green cordierite are sometimes found in the tonalities. Characteristically, large numbers of residual blocks and fragments of granulite are intermixed with the uniform tonalite, suggesting a close genetic relationship, as shown in the photo at right.



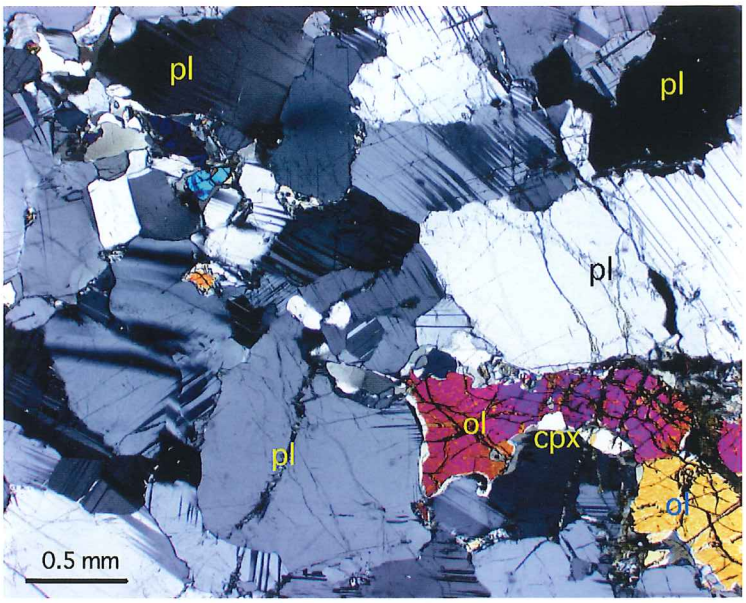
Cordierite Tonalite. Specimen No. H0007.
Specimen size: 32 cm in diameter.
Geological unit: Middle tonalite, Main zone of the Hidaka Metamorphic Belt.
Locality: Nikanbetsu River, Erimo.
Major constituent minerals: biotite (dark brown), plagioclase (grayish white), quartz (transparent), and cordierite (bluish green).

Magma Chambers in the Hidaka Island-arc

Basaltic magmas generated in the upper mantle may form large magma chambers within the crust beneath an island-arc. The gabbros observed indicate that the Hidaka Mountains are considered to have been crystallized in such a magma chamber. Gabbro exposed along the Panke-nuushi River is one of the well studied specimens having a chemical composition close to that of the Mid-Oceanic Ridge Basalt (MORB).



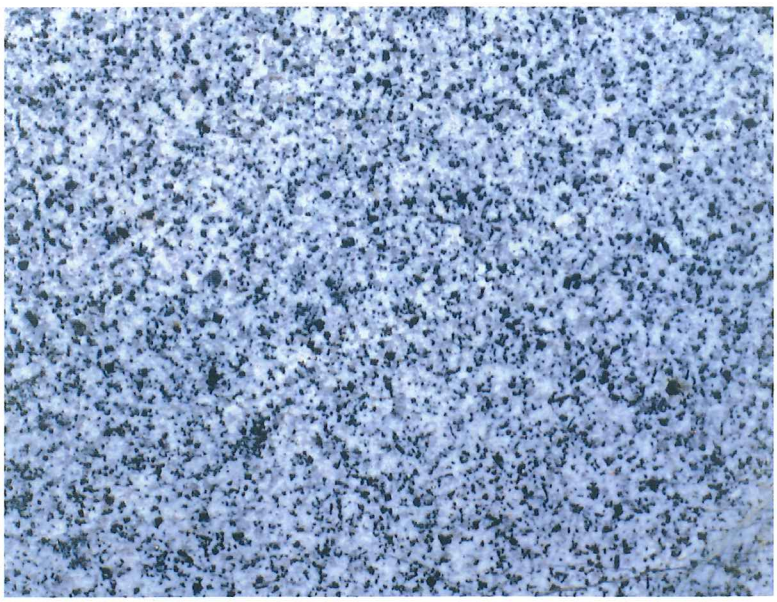
Anorthositic Gabbro. Specimen No. H0014.
Specimen size: 40 cm in diameter.
Geological unit: Panke-Nuushi gabbro complex, Main zone of the Hidaka Metamorphic Belt.
Locality: Go-no-sawa, Panke-Nuushi River, Hidaka.
Major constituent minerals: plagioclase (grayish white), olivine (dark green), and clinopyroxene (dark brown).



Photomicrograph of anorthositic gabbro (No. H0014), showing a typical cumulate texture composed mostly of cumulus plagioclase (pl), intercumulus olivine (ol), clinopyroxene (cpx), and amphibole. (Seen under crossed polarized light).

The representative specimen of anorthositic gabbro displayed here is composed mostly of plagioclase with small amounts of olivine, clinoyroxene, and amphibole. Under the microscope can be seen a typical cumulate texture having large anhedral grains of cumulus plagioclese in association with small grains of intercumulus olivine, clinopyroxene, and amphibole. Such a cumulate texture well suggests the crystallization sequence which is considered to have proceeded in a reasonably large magma chamber.

Large granite intrusives are observed on the eastern flank of the Hidaka Range. The name "Mikage-ishi" is familiar among those acquainted with building stones, having a beautiful surface pattern composed mostly of biotite, plagioclase, alkali-feldspar, and quartz. This granite is a typical acidic plutonic rock crystallized in an acidic magma chamber. It is not difficult to imagine that a large size granitic magma chamber has lain within a shallower level of crust beneath the Hidaka Island-arc.



Granite. Specimen No. H0010.
Photo width: 15 cm.
Geological unit: Upper granite, Main zone of the Hidaka Metamorphic Belt.
Locality: Toyoni River, Hiroo.
Major constituent minerals: biotite (black), plagioclase (grayish white), alkali-feldspar (white), and quartz (transparent).

Minerals from Hokkaido

About 4,000 minerals are found on earth, including 850 from Japan. In Hokkaido, 400 minerals are reported extant, among which are eight new ones - Todorokite, Teineite, Kanoite, Okhotskite, Jokokuite, Mikasaite, Toyohaite, and Watanabeite.



Native Sulphur from Mt. Shiretoko-Iou

Chemical formula: S
Locality: Mt. Shiretoko-Iou

Mt. Shiretoko-Iou, located on the central Shiretoko Peninsula, erupted in 1936. Molten sulphur flowed down its slopes and solidified around branches of trees such as dwarf Siberian pine. During this eruption, the volcano spewed forth intermittently about 200,000 tons of sulphur over an eight month period. Molten sulphur flowed down to the Kamuiwakka River and filled it for a distance of about 1.5 km. This sample was collected from the site, and described by its collector as "a drop of sulphur that had splashed down and solidified, with branches formed to resemble a beautiful efflorescent flower".

Native Tellurium

Chemical formula: Te
Locality: Teine Mine, Sapporo

Japan's discovery of native tellurium took place at the Teine Mine (Sapporo) in 1929. The mineral was found in the druse of a barite vein as small gray crystals with a strong metallic luster. It contains selenium, and some parts of the samples had changed to tellurite.

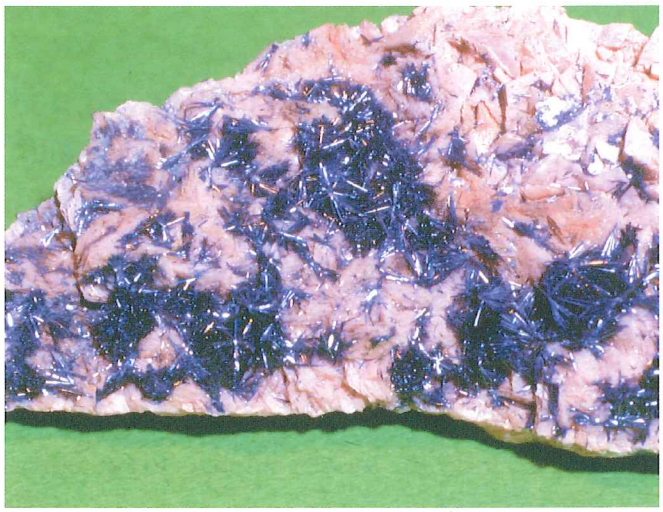




Jokokuite

Chemical formula: $MnSO_4 \cdot 5H_2O$
Locality: Jokoku Mine, Kaminokuni

Jokokuite is a sulphate mineral, discovered by Dr. Matsuo Nanbu of Tohoku University in 1977. The mineral is formed as stalactite, whose maximum length is 5 cm with maximum diameter of 5 cm. Its color is pale pink, but kept at room conditions, it is altered to a whitish mineral through dehydration.



Jamesonite

Chemical formula: $Pb_4FeSb_6S_{14}$
Locality: Toyoha Mine, Sapporo

Jamesonite is rarely found with stibnite in the sulphide mineral zone of rhodocrosite (pale pink). The whitish gray columnar crystals are stibnite and the dark hue indicates an aggregate of jamesonite.

Anorthite

Chemical formula: $CaAl_2Si_2O_8$
Locality: Kuttara Lake, Shiraoi



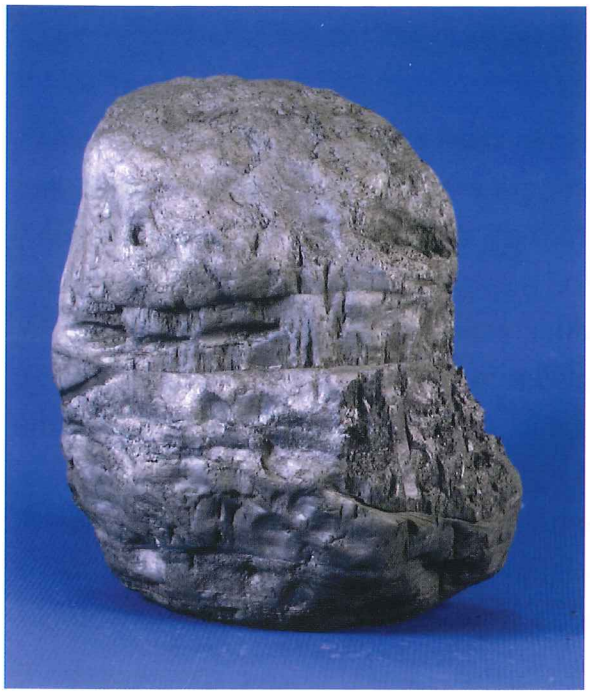
The Kuttara volcano has a caldera lake 3.5 km in diameter surrounded by a somma. Anorthite samples in the picture were collected from a volcanic ash layer on the eastern slope of the somma. Average size anorthite is 2 or 3 cm; its maximum extends to 5 cm. It is made up of many crystals with twin penetrations, or of an aggregate of small crystals.

Teineite

Chemical formula: $CuTeO_3 \cdot 2H_2O$
Locality: Teine Mine, Sapporo



Teineite was found by Dr. Toyofumi Yoshimura in 1936. This mineral is originally of a transparent bluish coloration; the metamorphosed part, however, shows up as a greenish blue.



Todorokite

Chemical formula: $(Mn,Ca,Mg)Mn_3O_7 \cdot H_2O$
Locality: Todoroki Mine, Akaigawa

Discovered by Dr. Toyofumi Yoshimura in 1934, todorokite is a manganese oxide mineral showing itself black with a graphite-like luster. Because of its relative plasticity, the many dimples on the sample surface are fingerprints made by careless handling. It is a very famous and important mineral because of its status as a major constituent in deep-sea manganese nodules.

Kanoite

Chemical formula: $MgMnSi_2O_6$
Locality: Tatehira Mine, Kumaishi

Kanoite was discovered by Dr. Hideo Kobayashi of Hokkaido University in 1977. The name was given in honor of Dr. Hiroshi Kano of Akita University. Its color is pale reddish brown with a vitreous luster. It occurs in manganiferous metamorphosed sedimentary rock.





Mikasaite

Chemical formula: $Fe_2(SO_4)_3$
Locality: Ikushumbetsu, Mikasa

Discovered by Mr.Shoichi Matsuda of Mikasa City, and by Mr. Kazuo Kobayashi and Mr.Koji Hasegawa of the Mikasa City Museum, mikasaite was reported as a new mineral by Dr. Hiroyuki Miura, Mr. Tadao Hirama, and Dr. Kiyoaki Niida in 1993. It occurs as a sublimate around fractures from which coal gas escapes. In its whitish brown color can be seen aggregates of fine porous crystals.

Mineral Resources and Ores

Ore deposits, so necessary in supplying the indispensable metallic resources for modern culture and life, are classified into the three categories of magmatic, sedimentary, and metamorphic, based on the processes of their formation. Magmatic deposits, intimately related to magmatic activity, have been exploited on a small scale in Japan but in numerous amounts. Sedimentary deposits were formed with clastic sand and clay in a submarine, lake, or river environment, where placer gold, platinum, and iron-sand deposits belong. Metamorphic deposits are formed by metamorphic action upon these elements in the manner described, under extreme pressure and high temperature.

This exhibition sets forth various ore specimens representative of those collected in Hokkaido. Gold ores, recently attracting special interest, are also on display in the same corner, not only from Hokkaido and other locations in Japan, but from overseas sources as well.



Gold and Silver Ore

Locality: Koryu Mine, Eniwa, Hokkaido

Gold is considered to have precipitated with quartz in the fractures of host rocks from an ascending high temperature and in sulfur-rich water ("Hydrothermal Water"), due to boiling and/or mixing with ground water in a shallow environment.

The sample at left reveals a characteristic occurrence of quartz accompanying small amounts of adularia and clay minerals in variable colors and textures, with a concentration of gold and silver minerals in black bands, commonly called "Gin-guro". Data on the K-Ar age of adularia associated with gold and silver would indicate the formation of this ore at about 0.9 to 1.2 million years ago, and related to young hot-spring activity.

Native Gold

Locality: Chitose Mine, Chitose, Hokkaido



Discovered in 1933, the Chitose Mine is an epithermal gold and silver vein deposit situated west of Lake Shikotsu. During its operation from 1937 to 1986, 21 tons of gold and 86 tons of silver concentrates were produced. The total weight of crude ore reached 170 tons during the same period.

In highly concentrated areas, native gold grains are sometimes visible to the naked eye. This specimen is native gold crystallized in a quartz cavity of highly concentrated ore. It is composed of tabular and whisker crystals.

Mercury (Cinnabar) Ore

Locality: Itomuka Mine, Rubeshibe, Hokkaido

The Itomuka Mine is located at Fujimi alongside National Highway 39 in Rubeshibe. In March 1936, a storm hit Hokkaido and did serious damage to the forest in this area. A new road was then constructed on the slopes of Mt. Muka for the purpose of clearing away the fallen timber, whereupon a new mercury deposit was discovered at the scene of construction. From 1936 to 1973, the Itomuka Mine produced 3,249 tons of mercury, and its volume of crude ore was said to be the highest in the Far East.



The ore deposit of this mine was brought about by hydrothermal activity in the Miocene, resulting in native mercury and cinnabar, with a high ratio of native mercury to cinnabar at 7:3. The specimen's reddish hue is cinnabar, but spots of native mercury are also visible.

Rhodochrosite

Locality: Yakumo Mine, Yakumo, Hokkaido



The Yakumo Mine is located at the upper reaches of the Namari River, a tributary of the River Yuhrappu. A record amount of gold, silver, and lead were produced here under the name of the Yuhrappu Mine in the 1770's. From 1916 to 1969 it produced mainly manganese as the Yakumo Mine.

This ore deposit consists of scores of rhodochrosite veins, implying the presence of sphalerite and galena. It is well known for yielding beautiful crystals of rhodochrosite. Columnar shaped rhodochrosite crystals are arranged in radial form on the polished surface of the specimen. These radial growth crystals are called "comb texture" or "colloform texture", and they assume kidney or breast-like shapes on the growth surface. The texture is considered to be an indication of crystallization having taken place under hydrothermal conditions. Several stripes of dark color can be seen on the specimen surface, signifying formation under multiple stages of crystallization.

Galena and Sphalerite Ore

Locality: Toyoha Mine, Sapporo, Hokkaido

The Toyoha Mine is situated at Jozankei, southwest of Sapporo, and it is still operating today as the biggest lead-zinc mine in Japan. The ore was formed as a vein type hydrothermal deposit.



The specimen shown comprises galena and sphalerite, main products of this mine. The silvery white crystal is galena and the brownish is sphalerite. In addition to these minerals, copper, manganese, gold, and silver are also produced, in addition to many rare elements such as indium, tin, and gallium, among others. The mine can therefore be regarded as a polymetallic ore deposit. The amount of indium produced is said to be the highest in the world, a boon for today's high-tech industrial society.

Hematite Ore

Locality: Riddarhyttan, Sweden



Many iron and copper mines are known to exist in central Sweden. Among them is the Riddarhyttan Mine, producing mainly magnetite and hematite. Discovered about the 14th century as an outcropping polished by glaciers, it had been operated as an open-cut mine for centuries.

Comprising a leptite layer of Proterozoic origin, since P. Geijer's investigation in 1923 it has been regarded as a skarn deposit. A new opinion on strata-bound iron deposits has appeared recently, however, a consequence of which is that its origin has not been settled. The specimen shows tightly folded hematite layers intercalating with thin co-folded layers of skarn minerals such as amphibole and garnet.

Strata-bound Copper-rich Sulfide Ore ("Kieslager" Ore)

Locality: Motoyasu Mine, Ehime Prefecture



Strata-bound types of copper-rich sulfide ore deposits in Japan occur mainly in the regional metamorphic belt (Sanbagawa Metamorphic Zone) of oceanic mafic volcanic rocks ("green rocks") and are a kind of massive sulfide deposit strongly confined within strata.

The ores consist mainly of pyrite, pyrrhotite, and chalcopyrite, accompanied by small amounts of bornite, sphalerite, and magnetite, bearing massive compact and stratified features.

The sample at right was collected from the Motoyasu mine adjacent to the famous Besshi Mine, traditional bearer of the famous "Besshi-type Ore". It shows a beautifully concordant folded structure with metamorphosed green rock as host.

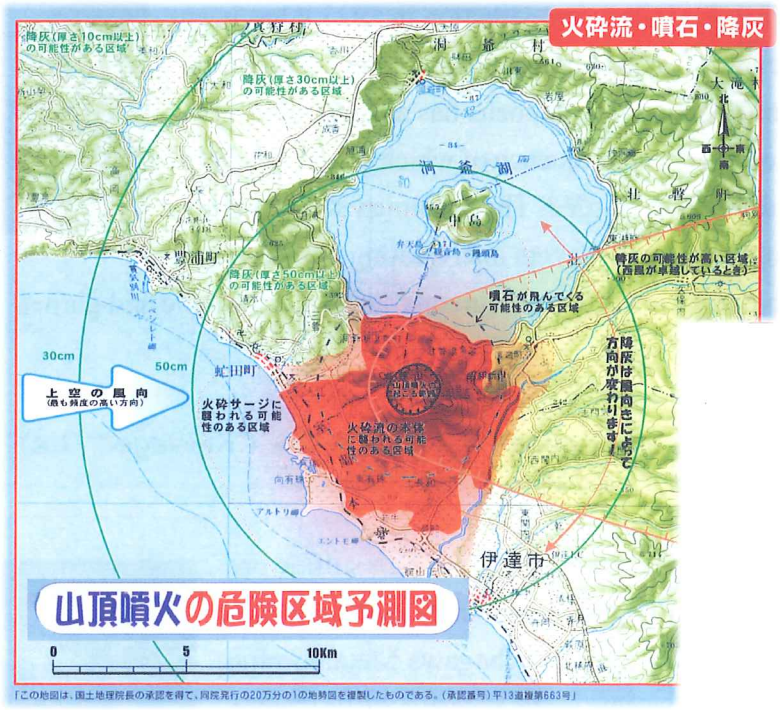
Volcanic Hazards

In addition to geological studies, basic scientific research on volcanic eruptions has been undertaken at Hokkaido University using various kinds of monitoring techniques, with a view towards mitigating volcanic disasters. Our research targets are not only the active volcanoes in Hokkaido, but also those in selected volcanic regions around the world.

Usu Volcano

The first historical eruption of the Usu volcano occurred in 1663, following 8,000 years of dormancy. Eight eruptions have been recorded since. Fallout of pumice and ash, the generation of pyroclastic flow, and growth of a lava dome are the major eruption types expressed by this volcano. Secondary lahar due to rainfall is also common. Two eruption centers exist, one at the summit of the volcano and the other on its flank. Precursory seismic activity has started less than a week prior to eruptions heretofore (except in the case of 1944-45 eruptions), but it lasted only 32 hours in the 1977 eruption. The most hazardous phenomenon at Usu has been the generation of pyroclastic flows. As a result of the eruption in 1822, a total of 103 people were killed in the Irie area at the southwestern foot of the volcano. The community was then relocated 2 km westward; it has since grown into the

A part of the Usu Volcano hazard map published in 2002.





Fallout pumice from the Usu Volcano, 1977
Sample number: 822-12
Diameter of the specimen: 8 cm.
Geologic unit: Eruption sample from the Usu Volcano (Us-1977- Ⅱ) August 7, 1977,
Sampling location: Toyako Hot Springs

residential area of Abuta.

With the help of historical documents and eruption materials currently on record, it is possible to estimate future eruption scenarios and hazardous areas surrounding the volcano. The Usu Volcano Hazard Map displayed in the exhibition room was edited by local town officials and then distributed to all residents around the volcano. Editorial assistance on the map was given by volcanologists at Hokkaido University.

Precursory seismic activity and ground deformation began three and a half days prior to the 2000 flank eruption. The hazard map was used for evacuating 16,000 residents in the danger zone. Nobody was killed or injured as a result, although 200 families lost their homes. A revised hazard map was published in 2002.

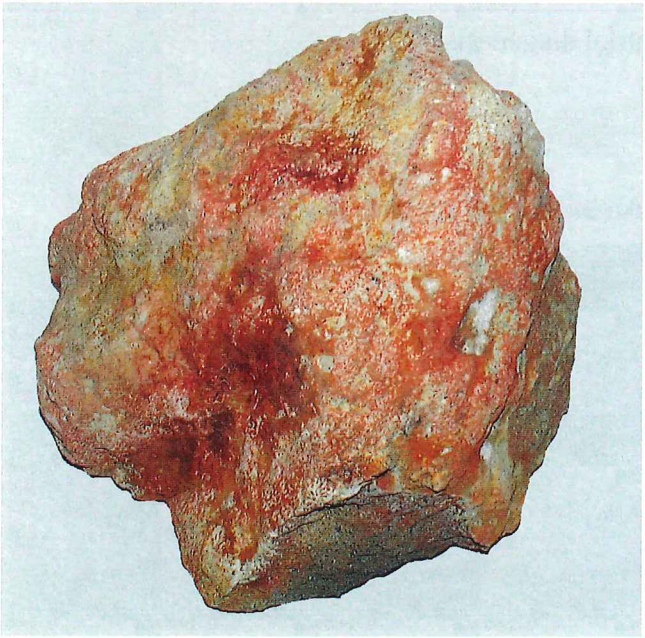
A scientist collecting volcanic gas from the crater of Mt. Komagatake, 1966



Hokkaido Komagatake

Hokkaido Komagatake is one of the most active volcanoes in Japan. Major eruptions have occurred four times during its history. The year 1640 marked the first major eruption after 5,000 years of dormancy. It started with a sector collapse and associated tsunami, followed by pumice fallout and a pyroclastic flow. Further pyroclastic eruptions occurred in 1694, 1856, and 1929. Small-scale phreatic explosions occurred frequently within a 10 year period prior to the 1929 eruption. Phreatic explosions have taken place frequently since 1996, suggesting the possibility of another major eruption soon.

The rock sample displayed is pumice, collected from the pyroclastic flow deposit of 5,500 years ago. Most of the specimen consists of vesiculated natural glass. Immediately after magma was ejected from the crater, volcanic gas vigorously separated from the new rising magma and was quenched to form natural glass. The reddish hue is a result of the high temperature oxidation of natural glass.



A juvenile pumice fragment collected from the pyroclastic flow deposit.
Sample number: TU9862103
Diameter of the specimen: 38 cm.
Geologic unit: Ko-f pyroclastic flow deposit, Mt. Komagatake, Hokkaido
Sampling location: Dumping ground at Mori in Hokkaido

Coal and Petroleum in Hokkaido

Eocene Bituminous Coal from the Yubari Coal Mine

The photograph at right shows bituminous coal from the Yubari Coal Mine in Hokkaido, one of the most representative in Japan. Yubari coal was formed from the remains of vegetation that grew in the Eocene as long as 35 to 50 million years ago. Hokkaido Eocene coal is composed mainly of two macerals, vitrinite and degradinite. The homogeneous and shiny surface is vitrinite maceral derived from the woody tissues of higher land plants. The less shiny part with a slight lamination is degradinite, for which Japanese Paleogene Tertiary coal is famous. The genesis of degradinite is not well known, but it is suggested that its significant presence in Tertiary coal can be related to the remarkable propagation of angiosperm after the Cretaceous, and biodegradation of higher plant remains at the water/sediment interface. Degradinite is chemically characterized by a high atomic H/C ratio, showing abundant aliphatic structures rich in hydrogen. Hokkaido Paleogene coals and coaly mudstones rich in degradinite are well known as effective petroleum source rocks that generated oil and gas during the period of burial diagenesis.



Sample No. E-98C002
Sample Name: Bituminous coal
Geologic Age: Eocene, Paleogene Tertiary
Locality: Yubari Coal Mine, Ishikari Coal Field

A historical surface outcrop of the coal beds (24-shaku Bed) at the Yubari Coal Mine



Crude Oils from the Yufutsu Oil and Gas Deposit

In the photograph may be seen crude oils from the Yufutsu oil and gas deposit off Tomakomai in Hokkaido. These oils have been classified into two types according to the geologic ages of their source rocks. Oils produced in the Neogene sedimentary basins off the western coast of Hokkaido derive mainly from marine zooplankton and phytoplankton of the Miocene age. Oil and gas deposits are also present in Paleogene sedimentary basins west of the Hidaka Mountains and on the Pacific side of Hokkaido. Paleogene oils originate mainly from higher landplants of the Eocene age. Yufutsu crude oil is one of the most typical Paleogene crude oils in Hokkaido.

The pale brown crude oil (left in photograph) is high-wax crude, rich in paraffinic hydrocarbons accumulated into porous conglomerates of the Paleogene Ishikari Group and from the shear zone of Cretaceous granite. The dark brown crude at right is comparatively rich in asphaltene, obtained from reservoir rock of the Neogene Takinoue Formation. Both crude oils contain significant biomarkers such as diterpenoids and oleanoids, indicating their higher land-plant origin.

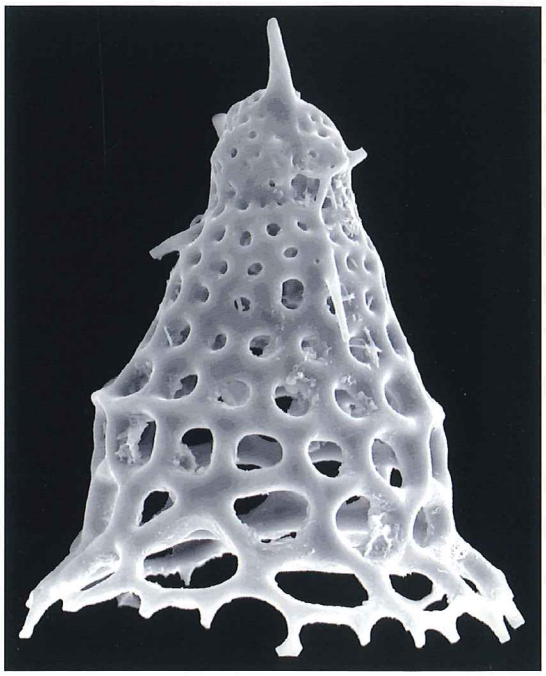


Sample No. E-98P001, E-98P002
Sample Name: Crude oil
Geologic Age: Eocene, Paleogene Tertiary
Locality: Yufutsu oil and gas deposit, Tomakomai, Hokkaido
Oil samples were provided by the Japan Petroleum Exploration Co., Ltd. (JAPEX)

Marine Geology

Marine Microfossils

Marine microscopic organisms having hard components are major contributors to deep-sea sediments. They have occurred and do occur abundantly in a very wide range of geological ages and marine environments. Most marine microfossils have minute shells composed either of calcite (and/or aragonite) or of opaline silica. Major calcareous oceanic microplankton are foraminiferida and coccolithophorida; major siliceous oceanic microplankton are radiolaria and diatoms.



Radiolaria:

Radiolaria are planktonic sarcodinid protozoans with elaborate skeltons constructed of amorphous opaline silica or strontium sulfate. Ranging from 50 to 400 μ m in size, most inhabit the near-surface waters (50 to 200 m in depth). They occur abundantly and in diverse shapes as microfossils in deep-sea sediments.

The photograph shows a *Cycladophora davisiana* Ehrenberg, taken from surface sediments at a depth of 3,613 m off the Shakotan Peninsula of western Hokkaido in the Sea of Japan.



Foraminifera:

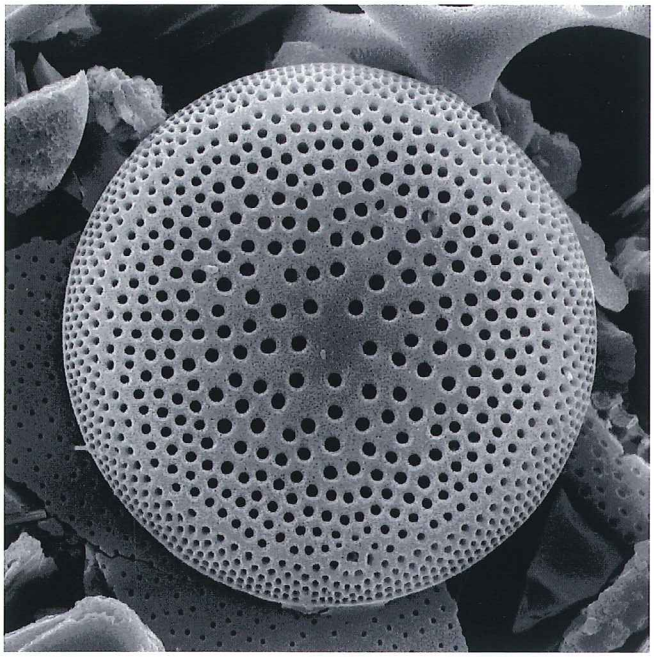
Foraminifera are shell-bearing protozoans ranging from 50 to 400 μ m in size. Planktonic foraminifera live in the upper 200 m of the marine water column in normal salinity. The benthonic foraminifera live in or near the sediment-water interface. The tests of foraminifera are made of calcium carbonate except for benthonic foraminifera, whose tests are made of cemented grains of sand and aragonite.

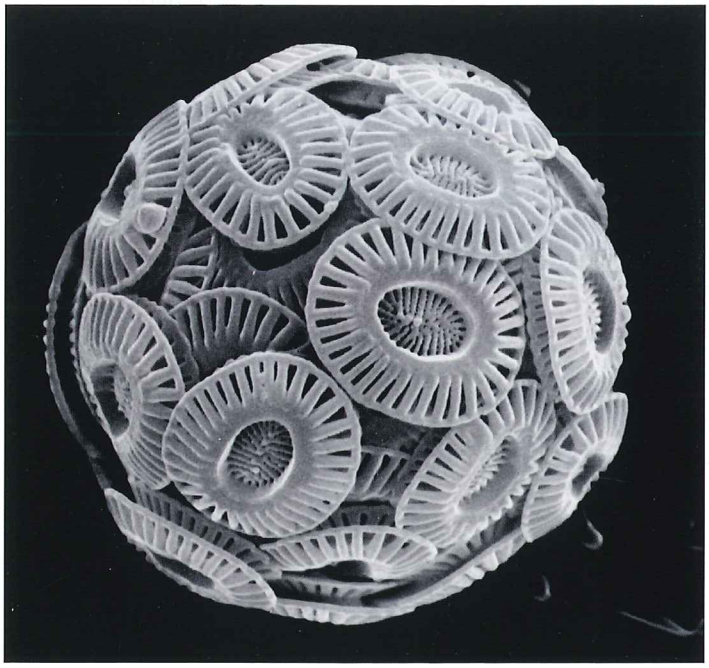
The photograph shows an *Elphidium excavatum* (Terquem) forma *clavata* Cushman of benthonic foraminifera, taken from the bottom of the ocean off eastern Hokkaido.

Diatoms:

Diatoms are unicellular golden-brown algae, characterized by an external box-like skeleton (or frustule) of opaline silica. Most diatom frustules range between 10 and 100 μ m in size. Diatoms are a major primary producer in the food chain, confined to the photic zone in marine and fresh waters. With a wide range of habitat adaptation, they tolerate multiple environments, and occur as planktonic or benthonic.

The photograph shows an *Actinocyclus curvatulus* Janisch, taken from DSDP Site 580 in the northwestern Pacific.





Photos of miscrofossils above were provided by Takuya ITAKI, Hiroyuki TAKADA, and Kazuko USAMI (*Grad. Sch. Env. Sci. Res. Earth, Hokkaido Univ.*)

Calcareous Nannofossils:

Coccolithophorida are a biflagellate, unicellular, golden-brown algae. They are photoautotrophic and primary reproducers in the oceans, living in the upper 150 m of the water column. Each organism (the entire cell) is called a coccosphere, usually spherical and ranging from 2 to 25 μ m in diameter. Each coccosphere contains about 20 coccoliths covering its surface. Each coccolith measures 2 to 10 μ m in diameter, and they are found separately in sediments.

The photograph shows an *Emiliania huxleyi* (Lohman) Hay and Mohler, taken from the surface water of Kinkazan off Miyagi Prefecture.

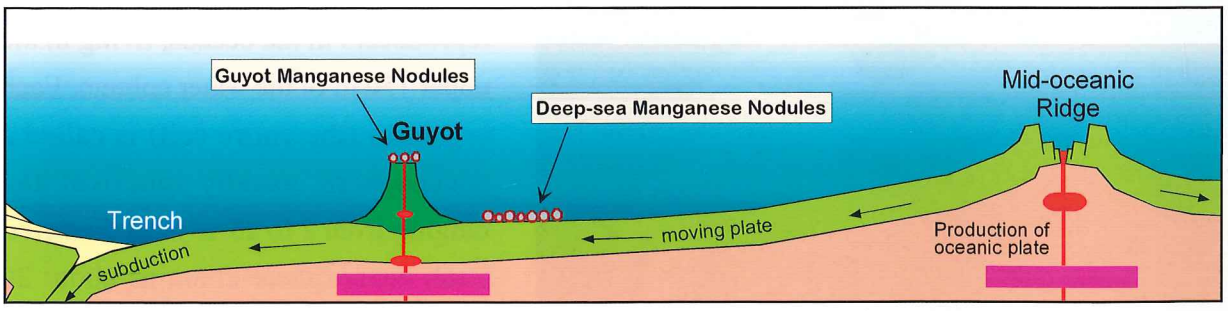
Manganese Nodules

Manganese nodules are black or brown agglomerations of manganese oxide and iron oxide, commonly 1 to 10 cm in diameter. Nodules are layered concentrically, like onions, around a central nucleus of variable composition, and contain highly concentrated manganese, iron, nickel, copper, and cobalt. The nodules grow slowly, causing prolonged contact between the ferromanganese oxides and seawater. They are most commonly found either in surface sediments of the deep-sea floor or at the top of guyots where the sedimentation rate is less than about 0.1mm per 1,000 years in well-oxygenated bottom conditions.



The photograph shows manganese nodules about 15 mm in diameter, dredged from the top of a guyot (2,200 m in depth) off southeastern Minami-Torishima Island. These nodules contain Mn (17.4 %), Co (0.47 %), Ni (0.36 %), and Cu (0.07 %).

Cross Section Showing Movement of Lithospheric Plate and Manganese Nodule Formation



Information for the Guests

Location: The "Einstein Dome" and the Exhibition Room (S-330) on the 3rd floor of the Hokkaido University Museum, North 10, West 8, Kita-ku, Sapporo.

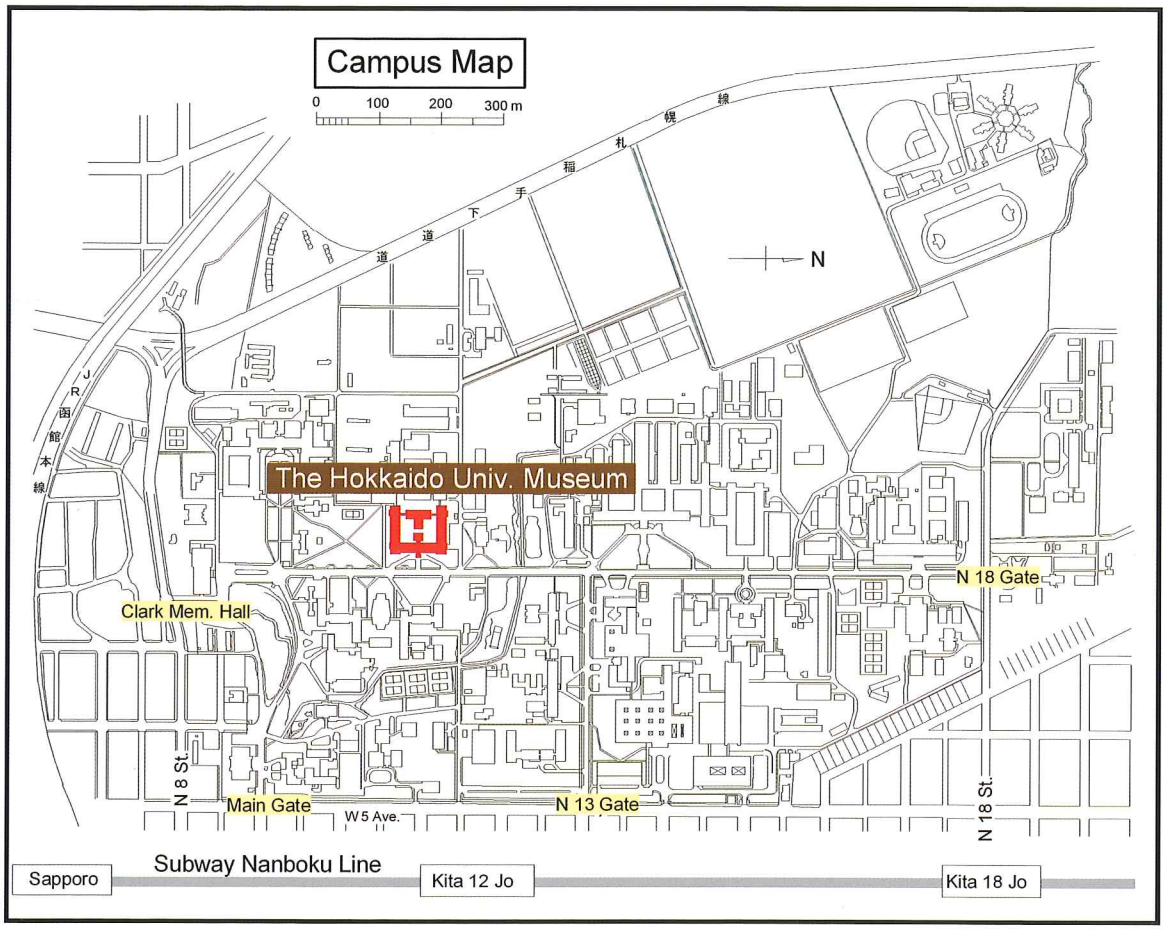
Open 9:30 AM to 4:30 PM, Tuesday ~ Sunday (June through September).
Open 10:00 AM to 4:00 PM, Tuesday ~ Sunday (October through May).
Closed Mondays, except when a holiday falls on Monday; the museum will then be closed on Tuesday.
Admission Free.

Visit us by public transportation or on foot. No parking space for guests, except for the handicapped.

Guests are requested not to take close-up photographs of the specimens.
Uncovered specimens may be touched, but PLEASE DO NOT TOUCH the large skeletons.

Museum web site: http://museum.hokudai.ac.jp
E-mail address: webmaster@museum.hokudai.ac.jp

For more information, call 011-706-2658, fax 011-706-4029, or write to:
Office of The Hokkaido University Museum
N-10, W-8, Kita-ku, Sapporo 060-0810 JAPAN




THE HOKKAIDO
UNIVERSITY MUSEUM