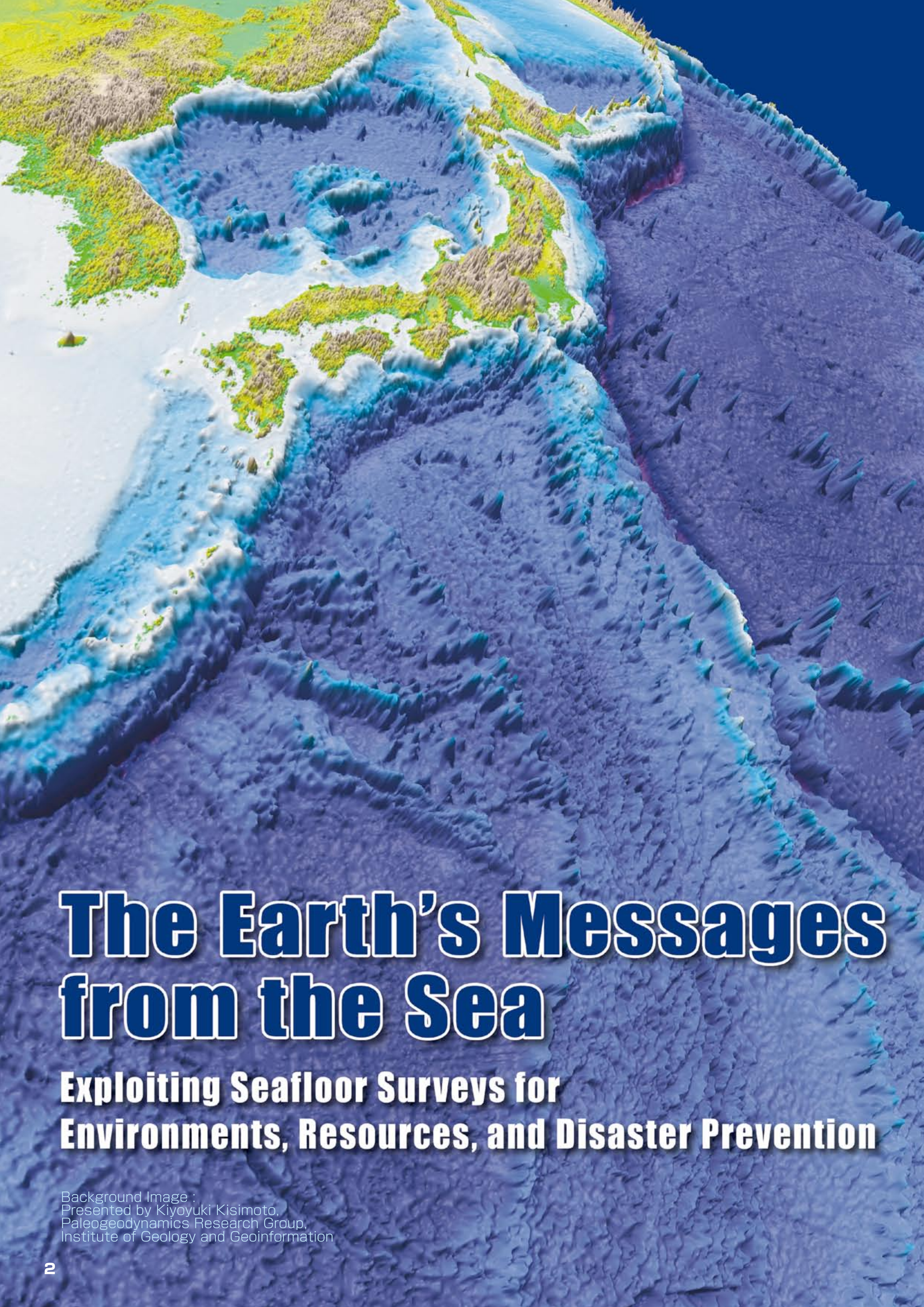
# The Earth's Messages from the Sea

## Exploiting Seafloor Surveys for Environments, Resources, and Disaster Prevention



# The Earth's Messages from the Sea

## Exploiting Seafloor Surveys for Environments, Resources, and Disaster Prevention

Background Image :
Presented by Kiyoyuki Kisimoto,
Paleogeodynamics Research Group,
Institute of Geology and Geoinformation

# Marine Research
## Understanding the Sea is Understanding the Earth

Akira Nishimura
Deputy Director, Institute of Geology and Geoinformation
Manabu Tanahashi
Deputy Director, Institute for Geo-Resources and Environment

### The sea

The earth is a huge complex system of material and energy cycles. The sea accounts for 70 percent of the earth's surface and has an average depth of 3,800 meters. As it plays a key role in driving a system by accumulating and transporting vast amounts of heat and materials, it has a big impact on buffering or accelerating a global environmental change.

The majority has not been developed yet though, a lot of resources lie on the sea bottom, the boundary of seawater and solid earth. These are formed with the reaction between liquid and solid materials in their large scale circulation. In addition, dynamic crustal movements under the sea cause serious disasters to us like occasional earthquakes and tsunamis.

### Various problems of sea

The sea, similar to the land, is confronted with various problems, such as resources development, environmental preservation, disaster prevention, etc. Moreover, the tension increases between countries with the keen interest in the area surrounding Japan. Because these problems are caused by the vastness of an undeveloped resource under the sea, and related to the territorial power politics among coastal states, it is very difficult to solve it soon. However, any self-regard behavior to the interests in the sea is not allowed. Those sea area and resources are places that the human race should share with the coastal countries. It is necessary to allocate the coastal country the development right and the care and custody according to international rules. AIST participates in the investigation used for a scientific judgment in the outer limits of legal continental shelf of Japan.

### Research for understanding the sea

These special articles describe AIST's activities for understanding the sea, for example, surveys for getting basic information about geological and structural features under the sea and submarine resources, current status of surveys and technology development of methane hydrates capturing spotlights as a new resource, and approach to the conservation and restoration of coastal environments.

AIST has several research units to address such problems associated with nature. Many fields are required to understand a variety of oceanic phenomena in the global system and to exploit them for the forecast of future environmental changes and the evaluation of the effect of development. In addition to these surveys, AIST is conducting various kinds of sea-related research, such as interaction between the sea and atmosphere, assessment of roles of seawater circulation for the global environment, and extraction of useful ingredients from seawater and the use of marine organisms.

### Profits from the sea and its future

Since AIST, the former Agency of Industrial Science and Technology, started a systematic investigation of the sea around Japan and the central part of the Pacific Ocean about 30 years ago, research for understanding the sea has been based on field observation and surveys.

In order to utilize or develop resources and space, profits of the sea, and to return the polluted sea to the healthy sea able to produce profits, it is essential to understand the whole system by various means.

There are many unknown things in the sea. These special articles are part of approaches to the solutions, and we hope that many people read them and are interested in the sea.

# Examining the Seabed

Ken Ikehara
Leader, Marine Geology Research Group, Institute of Geology and Geoinformation

In the end of 2004, a wide range of the Indian Ocean seaboard suffered from the earthquake occurring off Sumatra, Indonesia and its accompanying tsunami. The hypocenter was under the sea off Sumatra, and the largest crustal movement occurred on the seafloor. When we try to investigate the state of the movement, we face a difficulty due to a thick layer of water (seawater) between the seabed where the crustal movement occurred and the sea surface on which we can travel normally. The seawater not only cuts light to make the seabed dark but also applies high pressure to make it difficult to observe the strata or to acquire samples from there.

In order to know the states of the seabed and its inside, we have developed and repeatedly improved various tools, which has gradually made such difficult surveys possible.

## Investigating the seabed and organizing the resulting data

We use sound to get the topographical features of the seabed and its inside. First of all, we forecast the direction and size of faults and the geological structure in a sea area to be investigated to determine the course of our research ship. It is called traverse line. The ship goes along the traverse line and simultaneously emits sound at various frequencies. We continuously receive and record the sound reflected from the seabed and its inside to get a cross-sectional view showing the inner structure of the seabed, which is called an acoustic survey profile. The acoustic profile with finer resolution but lower penetration is obtained using the acoustic wave (sound) with higher frequency. Therefore, to get desired information, we select and use a survey system best suited to each sea area to be investigated. We examine the resulting cross-sectional images to identify surfaces showing remarkable unconformity (discontinuous planes due to intermittent reflected sound). Moreover, we compare the discontinuous plane with that derived from the adjacent traverse line to check the connection of strata under the seabed and their classification. In this survey, we also examine faults and folds (layer structure having gaps and curved layers) under the seabed to clarify the distribution and origin.

In the second stage, we collect sediments and rocks from the seafloor to identify the key components of the strata classified by the acoustic survey. We lower a metal box called a "dredge" to the seabed and collect stones, sand, mud, and others into the box. This method is the simplest but has disadvantages; collected samples are placed in disorder and identifying the sampling position is difficult. To address these problems, we install a depth sensor in the dredge to measure the depth at which the metal case hits the seabed.

As described above, we can make a map

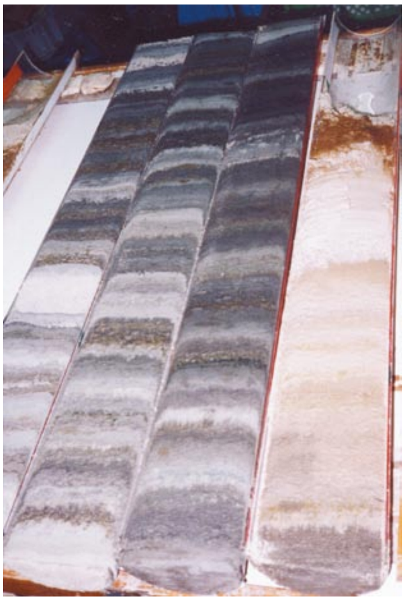


Photo : Sediment core samples collected from the seabed. These cores are deposits from the Philippine Sea and consist of dead diatoms shown as a clear stripped pattern.

showing the geological features (ages and lithofacies) of the target sea area by identifying stratigraphic sequences (how strata are piled) from the resulting acoustic survey profile and relating them to information about collected rocks. This map is called submarine geological map.

Moreover, to know the structure of the top layer of the seabed and the recent sedimentary status, we collect a large amount of deposits. To do this, we use various tools attached to

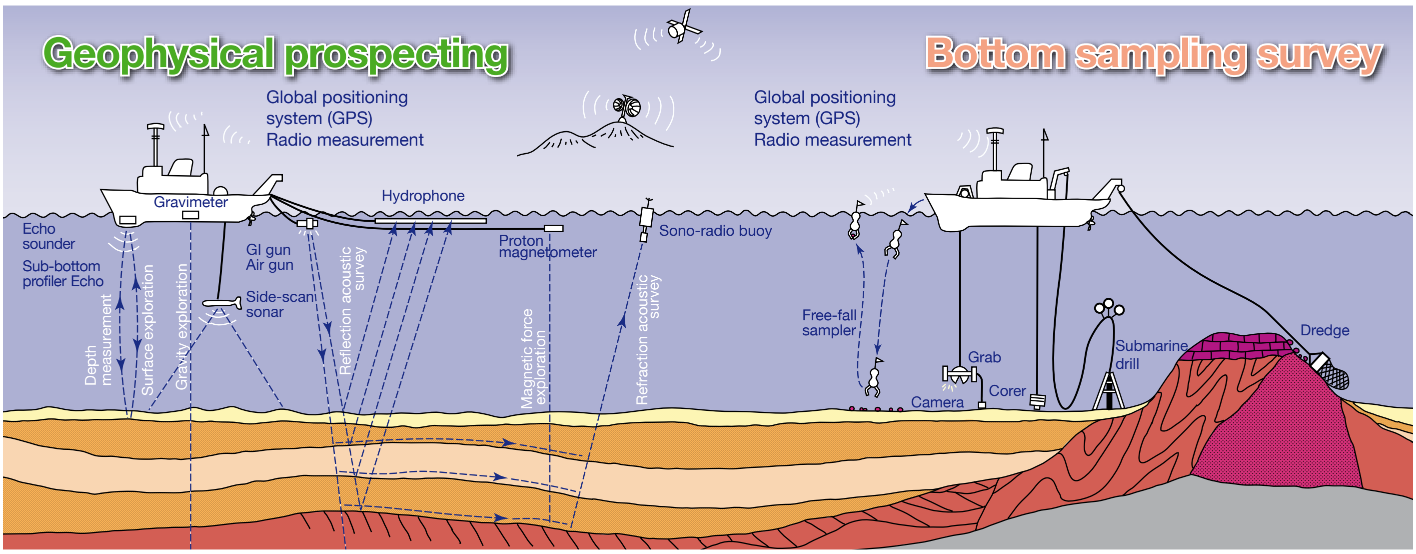



Figure 1 : Illustration of how to examine the seabed

# Survey for Establishing the Outer Limits of the Continental Shelf

## Surveying Basement Rocks Forming the Continental Margin

Makoto Yuasa
Researcher, Institute of Geology and Geoinformation

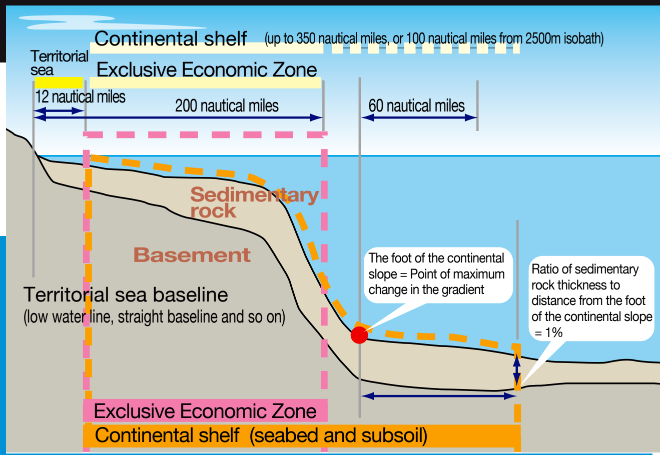



Figure : Continental shelf defined in the United Nations Convention on the Law of the Sea
The Convention provides the definition of the continental shelf different from that of earth science. Namely, it defines that the continental shelf of a coastal state comprises the seabed and subsoil within the outer edge of the continental margin or those within 200 nautical miles from the territorial sea baselines where the outer edge of the continental margin does not extend up to that distance. As shown in the accompanying figure, the outer edge is delineated either by a line connecting fixed points not more than 60 nautical miles from the foot of the continental slope or by a line connecting fixed points at each of which the ratio of sedimentary rock thickness to the distance from the foot of the continental slope is at least one percent.

The survey for establishing the outer limits of the continental shelf defined in the United Nations Convention on the Law of the Sea is carried out by the authorities concerned under Cabinet Secretariat's coordination. Such seafloor survey consists of three areas: precise bathymetric, crustal structure, and bed rock surveys, which are assigned to Japan Coast Guard, the Ministry of Education, Culture, Sports, Science, and Technology plus Japan Coast Guard, and the Ministry of Economy, Trade, and Industry respectively. AIST is responsible for a part of the bed rock survey by means of drilling. The purposes of this survey are to sample rocks from two hundred and several tens of locations under the sea around Japan, to determine whether the samples are similar to basement rocks forming the Japanese islands, and to provide geological grounds for the possibility of the extension of the continental shelf.

The outcomes of the survey mentioned above, together with existing earth scientific data on the sea area, are to be used in order to grasp a spatial stretch of the continental shelf defined in the Convention and to prove its continuity from the landmass. Finally, the government will use the resulting information to make a submission to the Commission on the Limits of the Continental Shelf established under the Convention for delineating areas beyond 200 nautical miles over which Japan has sovereign rights to develop natural resources of the seabed and subsoil. The deadline for the submission is May 2009. AIST makes efforts to survey the sea area and to compile and organize information used for establishing the outer limits of the continental shelf.

the end of a rope paid out from the research ship. A "grab sampler" is used to collect deposits from the surface layer. AIST installs a submarine camera, water sampler, thermometer, and turbidimeter in it to collect not only the deposits but also various data related to the sedimentary processes.

Submarine deposits may present various historical records, for example, past changes in the oceanic environment and slope failures caused by earthquakes. We put a pipe several to ten meters long into the seafloor to precisely analyze the resulting sediment core samples. We make a map showing the distribution of deposits by examining the grain sizes, composition, and ages, as well as the acoustic survey records of the top layer of the seabed. This map is called surface sedimentological map.

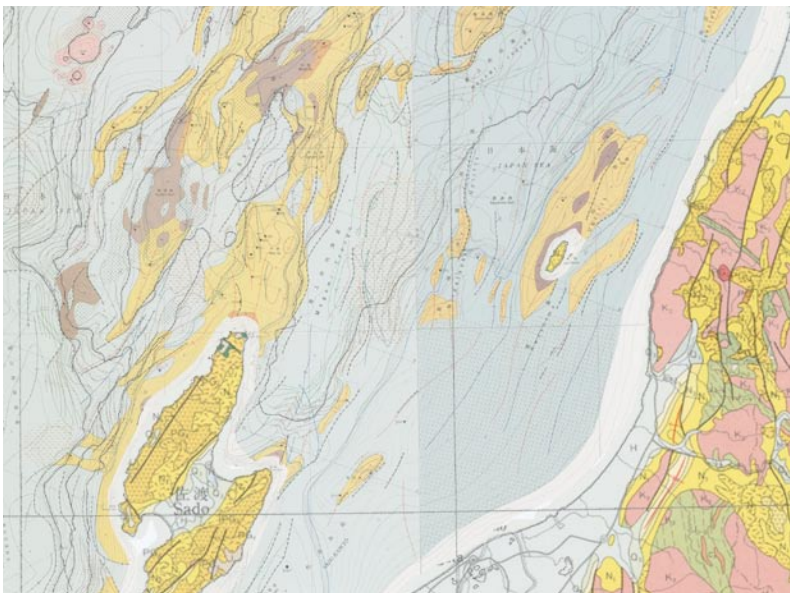


Figure 2 : An example of submarine geological maps (the Japan Sea around Sado)
This map shows the exposure of old and bent strata, and active faults along the Sado Ridge.

### Geoinformation derived from submarine geological maps

AIST has conducted surveys to make the submarine geological maps of sea areas around Japan for more than 25 years. The resulting maps (eight 1:1,000,000-scale maps and forty eight 1:200,000-scale maps) not only present basic information about the territorial waters of Japan but also are used as fundamental data for the following work: evaluating active faults, analyzing crustal movements, developing submarine resources, utilizing the seabed, and researching material cycles in the sea area and its environments.

Of the resulting data, part of acoustic survey profiles and sampled deposits are disclosed as a research information database (RIO-DB: http://www.aist.go.jp/RIODB/db085/).

We will make further efforts to present our fruits and hope that valuable geoinformation collected by our seafloor surveys will be used in various fields.

# The Sea and Earthquakes

Yukinobu Okamura
Leader, Subduction-zone Earthquake Recurrence Research Team, Active Fault Research Center

## Research on earthquakes occurring under the sea

The world was terribly shocked at the energy of the tsunami following the earthquake that occurred off Sumatra in the end of 2004. This earthquake, one of subduction zone earthquakes, occurred by the Indian Ocean plate subduction beneath the island arc of Andaman, Nicobar, and Sumatra.

Since the similar plate subduction zones lie along the Pacific Ocean side of the Japan islands, trench-type earthquakes have occurred every several tens to hundreds of years. According to past literature and geological evidences, they have occurred on a 100- to 200-year cycle on the Pacific Ocean side of the southwestern Japan, 300 to 500 years in the Sagami trough, and several tens of years to 100 years on the Pacific Ocean side of the northeastern Japan and Hokkaido. However, the ordinary subduction zone earthquake has a magnitude of smaller than nine, and the Sumatra earthquake having a magnitude of greater than nine is very rare.

Earthquakes occurring under the sea including subduction zone earthquakes are followed by tsunamis. In Japan, it is known that large earthquakes and tsunamis have sometimes occurred in the eastern margin of the Japan Sea, for example, the earthquake off the southwestern Hokkaido in 1993, which brought a serious disaster to the Okushiri island, the Japan Sea earthquake in 1983, and the Niigata earthquake in 1964. However, the earthquake history of the Japan Sea is not clear because their recurrence interval is very long (1,000 years) and past literatures is a little.

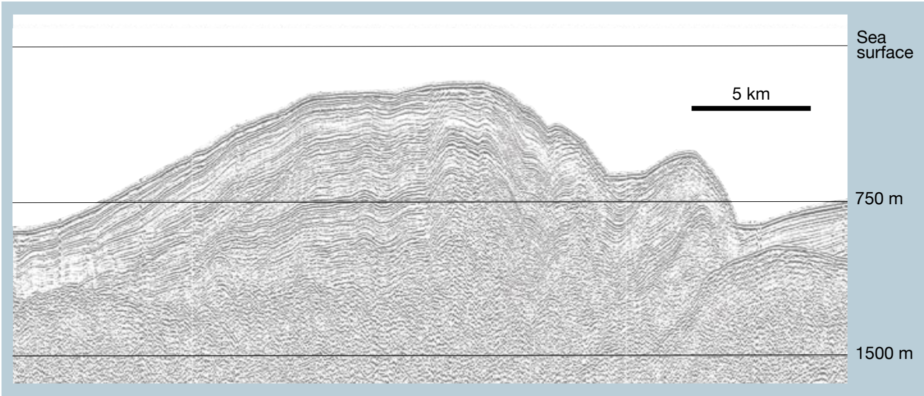


Figure 1 : An example of reflection profiles of one of anticlines the Sado ridge in the eastern margin of the Japan Sea

## Seismic faults under the sea found by ocean surveys

AIST has continued efforts to clarify the features and history of earthquakes by examining the geological structure of the eastern margin of the Japan Sea and past seismic records remaining in deposits on the seabed. As described on the previous page, the geological structure of the seafloor can be examined by acoustic survey (seismic exploration). This method employs low-frequency sonic or seismic waves well propagating in water and strata, and is used in a wide range of surveys from submarine topographical exploration to the investigation of the geological structure of the seafloor. The acoustic survey presents the geological profile (reflection profile) of the seafloor (see Figure 1). This profile shows the geological structure including faults and folds, and allows us to know their distribution and ages.

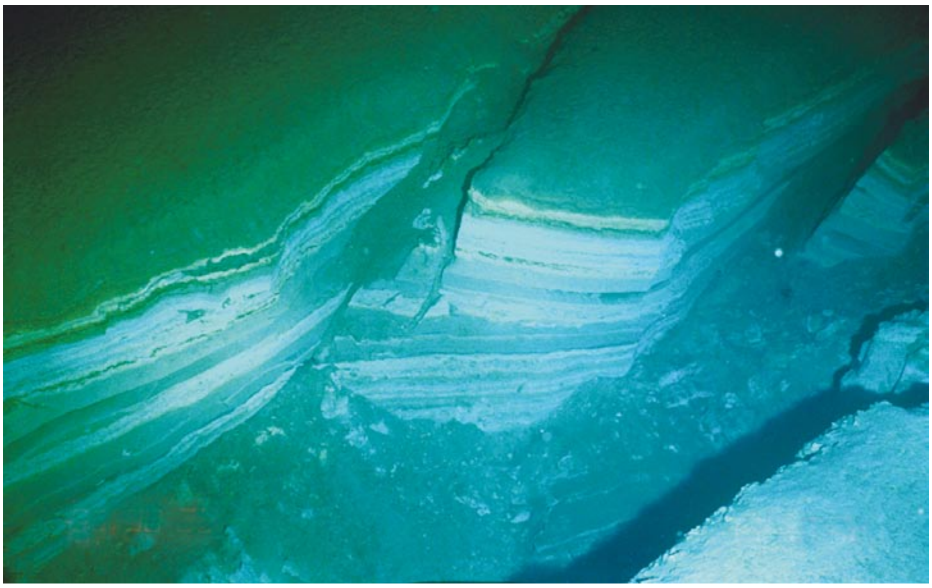


Photo : Crevices formed by earthquakes off the southwestern Hokkaido and observed by a submarine sible
Presented by Japan Agency for Marine-Earth Science and Technology

## Fault surveys in the Japan Sea

The eastern margin of the Japan Sea features reverse faults (underground structures yielded by compressive stress) distributed all over and asymmetrical anticline structures (convex and curved underground structures caused by compressive stress) formed in the upper crust. The anticline structure allows us to estimate the locations and extensions of underground faults.

As shown in Figure 2, the distribution of faults and folds was given by investigation of the whole eastern margin of the Japan Sea with this method. A hypothesis was proposed in 1983; the eastern margin of the Japan Sea was a convergent boundary, and right after the proposal, an earthquakes occurred in the middle of the Japan Sea, which made the hypothesis very popular. However, detailed geological surveys proved that the eastern margin was not a simple plate boundary. Figure 2 tells that faults and folds are distributed in a wide range from the seabed of the east edge to the land, and that their density is high in some zones. Since these faults have been active for the last 300 million years, there is a high possibility that they will cause earthquakes in future. Note that this method cannot find the cycle of respective earthquakes. All the faults shown in the figure will not always produce earthquakes, but we believe that the larger the fault, the larger the earthquake, resulting in serious disasters. AIST has already started working on researches to clarify the history of the key faults.

As described in the column below, a try to read seismic records from turbidity current deposits has been used from long ago. Recent research uses a submersible to observe the seafloor destroyed by earthquakes (see the accompanying photo) and to find the seismic history. Such a series of research tells that the main faults in the east edge of the Japan Sea have generated earthquakes for a cycle of 1,000 to 2,000 years. However, a substantial error is included in estimating when they occurred.

### Trying to clarify the history of active faults under the sea

To find the precise history of active faults under the sea, it is necessary to know what occurred under the sea upon earthquakes and how they are recorded geologically, and then to work on a way to identify the correct age of the seismic records remaining under the sea.

Since the importance of such research has been understood for the last ten years, it has advanced greatly. However, research on the history is not yet perfect. It is necessary to continue technology development and surveys in the future.

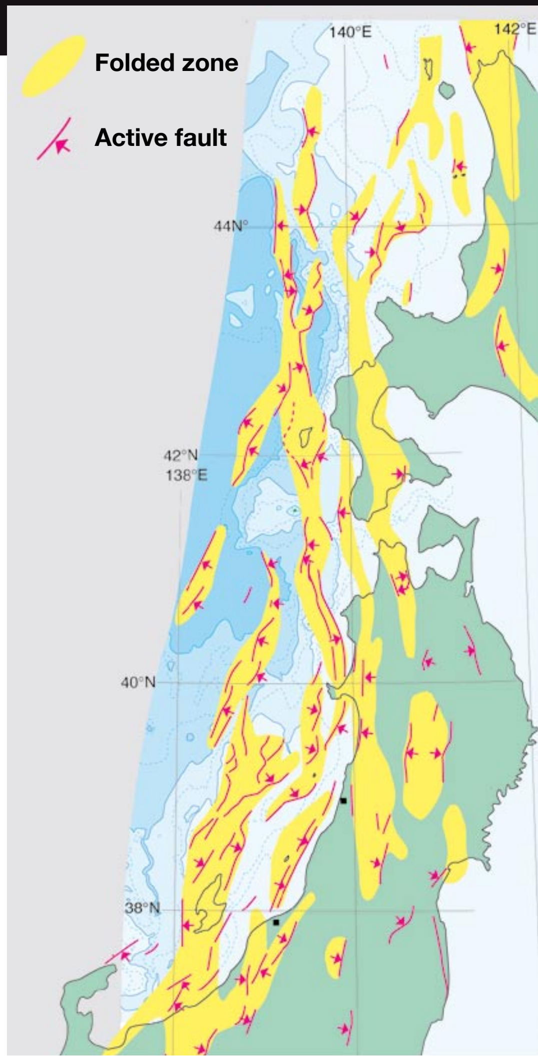



Figure 2 : Distribution of faults and folds in the eastern margin of the Japan Sea

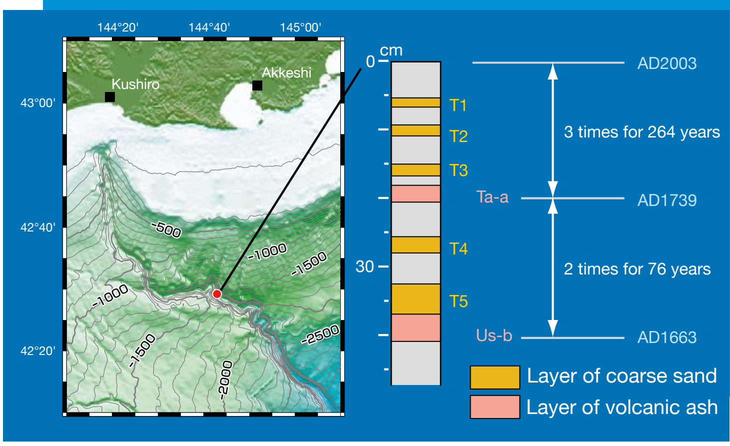
## Seismic History Derived from Landslide Layers under the Sea

Atsushi Noda
Orogenic Process Research Group, Institute of Geology and Geoinformation

Strong earthquakes sometimes cause a landslide under the sea. In this case, a layer of coarse-grained sand deposited on the shallows flows down along the slope. The offshore seafloor normally consists of light and fine mud, but is covered with the coarse sand delivered by the landslide, which results in a new layer of the sand. Such deposits are called turbidites. It is impossible to form a layer of coarse sand on the seafloor over 1,000 meters deep unless a special event like a landslide occurs. Accordingly, we can know the frequency of earthquakes by examining layers of coarse sand between layers of fine mud, that is, we can estimate the seismic history.

The accompanying figure shows data given by samples collected from the bottom of the Kushiro submarine canyon developing off Kushiro on the Pacific Ocean side of the eastern Hokkaido. Collected from the seabed about 2,000 meter deep, these samples contained five layers of coarse sand and two layers of volcanic ash within a depth of 40 cm. Chemical composition analysis said that the volcanic ash came from two volcanoes: Tarumai (Ta-a in 1739 a.d.) and Usu (Us-b in 1663 a.d.). The ages of the volcanic ash allow us to assume that five landslides occurred for the last 340 years in this area, which means that strong earthquakes occurred every 70 years.

Using the method above presents information about earthquakes not recorded in historic times and seismic history in the prehistoric age, which is very helpful to long-term earthquake prediction.



# Energy Resources under the Sea

Sumito Morita
Fuel Resource Geology Research Group, Institute for Geo-Resources and Environment

## "Burning ice," a fuel resource under the sea

Japan is surrounded by the sea. We extract and use fossil fuels from the seabed, for example, oil, coal, and natural gas. However, the energy resources we can get from there is poor, so we import most of necessary energy resources from abroad. But now, the spotlight is on a new energy resource under the sea around Japan. It is methane hydrate, a substance like ice given by combining water and methane at low temperature and high pressure. Methane hydrate is called "burning ice" because it contains flammable methane.

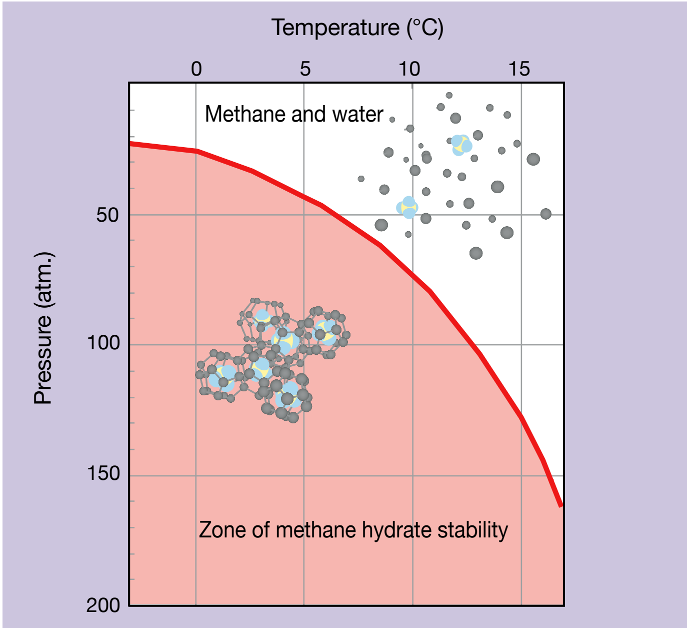



Figure 1 : Temperature and pressure for making methane hydrate stable

## Characteristics of methane hydrate

Methane hydrate has advantages over the conventional resources on the following three points:

- $CO_2$ emission is low because the main component is methane.

  Methane discharges $CO_2$ but the amount is reduced by 30 percent as compared with oil, or 45 percent as compared with coal. Therefore, methane hydrate is recognized as one of environment-friendly energy resources having lower greenhouse effect.

- The burning ice lies widely below the sea bottom around Japan.

  We estimate that the amount of methane hydrates lying around Japan is about 100 times larger than the annual consumption of natural gas in Japan. Methane hydrate is a new type of fuel resource and is promising in Japan having poor energy resources.

- The amount of methane per unit volume is very large.

  Methane hydrate has crystal structure in which methane molecules ($CH_4$) are put in cages of water molecules ($H_2O$) formed by hydrogen bonding (see Figure 1). If the crystal is dissolved, the volume of methane gas to be discharged is about 170 times larger than that of the frozen state.

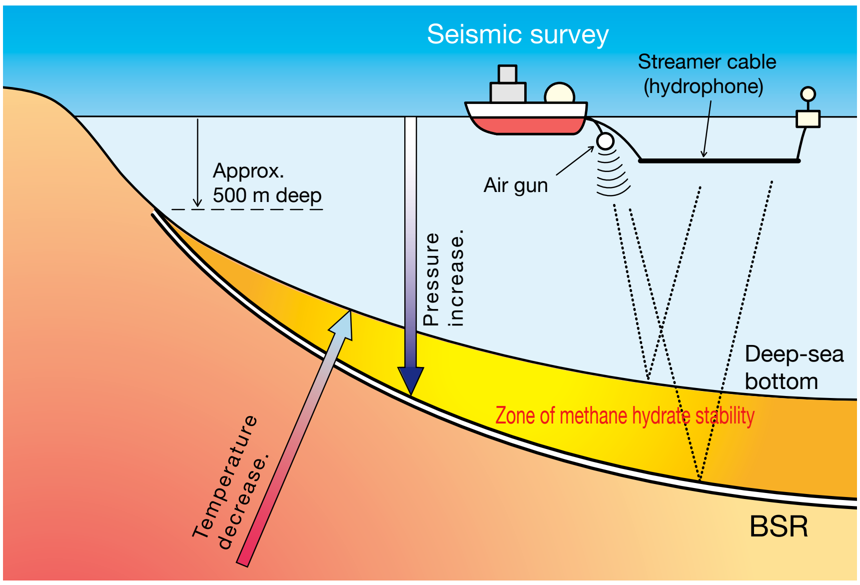



Figure 2 : Illustration of the reflection seismic survey
Methane hydrate is stable under the deep sea because of low temperature and high pressure. The base of methane hydrate stability can be often identified as a BSR.

Accordingly, methane hydrate has high value to use as a substitution for oil and coal and is expected as a future energy resource.

## Exploration of methane hydrate

When surveying the distribution of methane hydrate below the seafloor, we can take advantage of its physical properties. At the present time, reflection seismic survey is mainly used. An artificial seismic wave generator such as air gun installed in a research vessel radiates strong impulsive sounds toward the seabed. Successively, receiving and processing the wave signals reflected from the strata presents a geological structure map below the sea bottom.

This map generally shows a reflector between the methane hydrate bearing beds and the lower beds since there is a contrast of acoustic impedance (given by density x wave

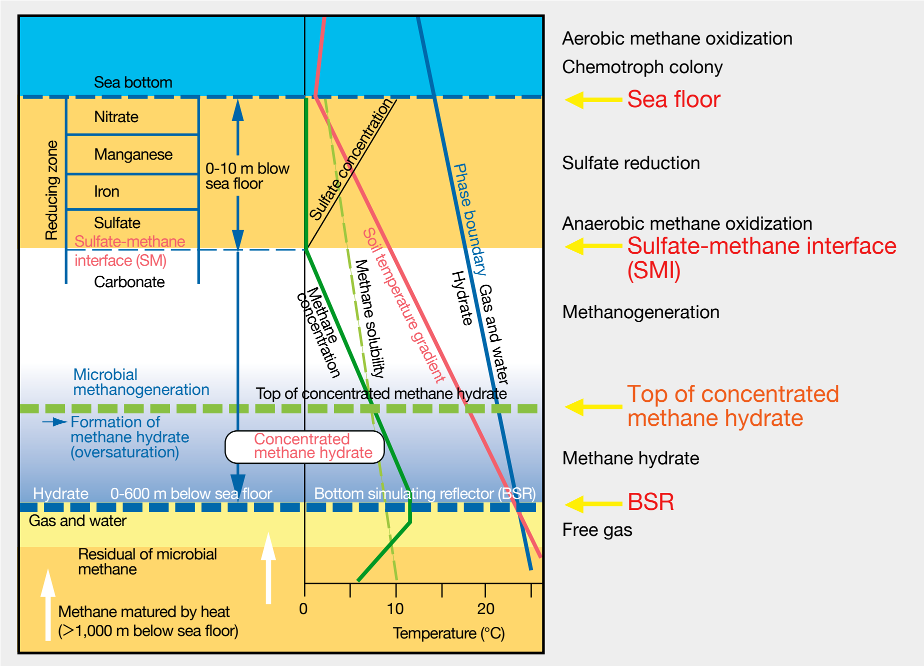



Figure 3 : Illustration of geochemical reactions in shallow strata below the sea floor
Geochemical investigation searches SMI by reducing gradient of sulfate concentration in pore water and estimates the top of the hydrate deposits and saturation of the methane hydrate.

velocity) between both of the beds. Since there is a contrast of acoustic impedance (given by density x wave velocity) between the methane hydrate bearing beds and the lower beds, this map generally shows a reflector at the boundary of the beds. The reflector is almost isobaric. It doesn't necessarily appear in parallel with surrounding strata, but in parallel with the sea bottom, so it is called bottom simulating reflector (BSR) (see Figure 2).

The BSR can be used to find an area of distribution of methane hydrate and the bottom of the being area.

### New investigation method

Recently, the spotlight is on a geochemical investigation being examined. This method utilizes variations of chemical composition in pore water made mainly by microbial activity in relatively shallow portions under the seabed.

First, a columnar sediments core is recovered to check the chemical changes of pore water with depth, and from the reducing gradient of sulfate concentration, we find a sulfate methane interface (SMI).

Next, methane concentration which increases with depth from the SMI is estimated. It is to theoretically find the top of the hydrate deposits and saturation of methane hydrate, both of which cannot be detected by the seismic survey (see Figure 3).

The geochemical investigation can be basically applied to a piston core even less than 10 meters long, therefore, it is expected that data to be accumulated in the future will make this method more effective.

### Approach to practical use

As a core laboratory, AIST is now involved in the Research Consortium for Methane Hydrate Resources in Japan (MH21), a national organization for developing the methane hydrate resources. We work on the investigation of distribution of methane hydrate including the above-mentioned methods and on the development of technologies for future production.

## Research and Development on Production Technologies of Natural Gas from the Methane Hydrate Resources

Hideo Narita
Director, Methane Hydrate Research Laboratory

The project on the exploitation technology development has been started since 2002. The purpose of the project is to establish technologies to produce natural gas from methane hydrate resources reserved under the sea bottom offshore Japan. To implement the project, the MH21 Research Consortium was established. AIST newly formed Methane Hydrate Research Laboratory in the spring of 2005 to develop production methods according to the properties of the reservoirs.

The properties of the reservoir of methane hydrate deposits are changed along with the progress of the production. Therefore, it is important to clarify fundamental physical properties and dissociation behaviors of the methane hydrate layers by establishing the in-situ measurement technologies. And the production simulator is developing based on the modeling of the behaviors. The Consortium completed the analysis of logs based on test boring in 2004, and is now conducting core tests and analyses. The outcomes given so far suggest that methane hydrate deposits lying under the sea around Japan are very productive. The onshore production test is preparing at permafrost areas in Canada to verify the developed production technologies, furthermore, offshore production test is scheduled around Japan.

Containers for natural cores collected by the test boring from "the Off-Tokai ~ Off-Kumano"

# Mineral Resources under the Sea

Kokichi Iizasa
Group Leader, Seafloor Geoscience Group, Institute of Geology and Geoinformation

## Distribution and features of marine mineral resources

The Japan islands are surrounded by oceans, such as the Pacific Ocean and Japan Sea, and get many blessings from the sea. Since surveying marine mineral resources has concentrated in special regions only, many sea areas are left untouched. However, the investigation ever made tells that there are various kinds of unexploited mineral resources.

In general, the mineral resource refers to those mined currently and commercially, for example, placer deposits including monazite or tin, oil, and natural gas. This article introduces future resources most people do not know.

Most marine mineral resources produced currently and commercially are distributed under the shallows. However, the “potential marine mineral resources” to be described here lie under the sea over 1,000 meters deep. These resources are very unique and contain large amounts of various metal elements, for example, “manganese nodules” (polymetallic nodules), plate-like “manganese crusts,” and massive “hydrothermal sulfides.” Figure 1 shows the distribution of these resources identified in the south sea of Japan.

## Manganese nodule

A manganese nodule is a spherical mass 1-10 cm in diameter and includes a large amount of manganese oxides (see Photo 1). An English oceanographic research ship first found it over 130 years ago. At that time, the manganese nodules were not regarded as marine mineral resources, but they were thrown into the spotlight as resources 40 years ago, and since that, many surveys have taken place all over the sea. As a result, it was found that manganese nodules including large amounts of copper and nickel were distributed under the sea 4,000-6,000 meters deep off southeastern Hawaii. Many countries have come to possess mining sites for future commercial production. According to a certain calculation, the total volume of manganese nodules lying all over the sea is 500 billion tons, which is an enormous amount of resources.

## Manganese crust

Manganese crusts lie under the sea where seamount deposits are scarce. They are

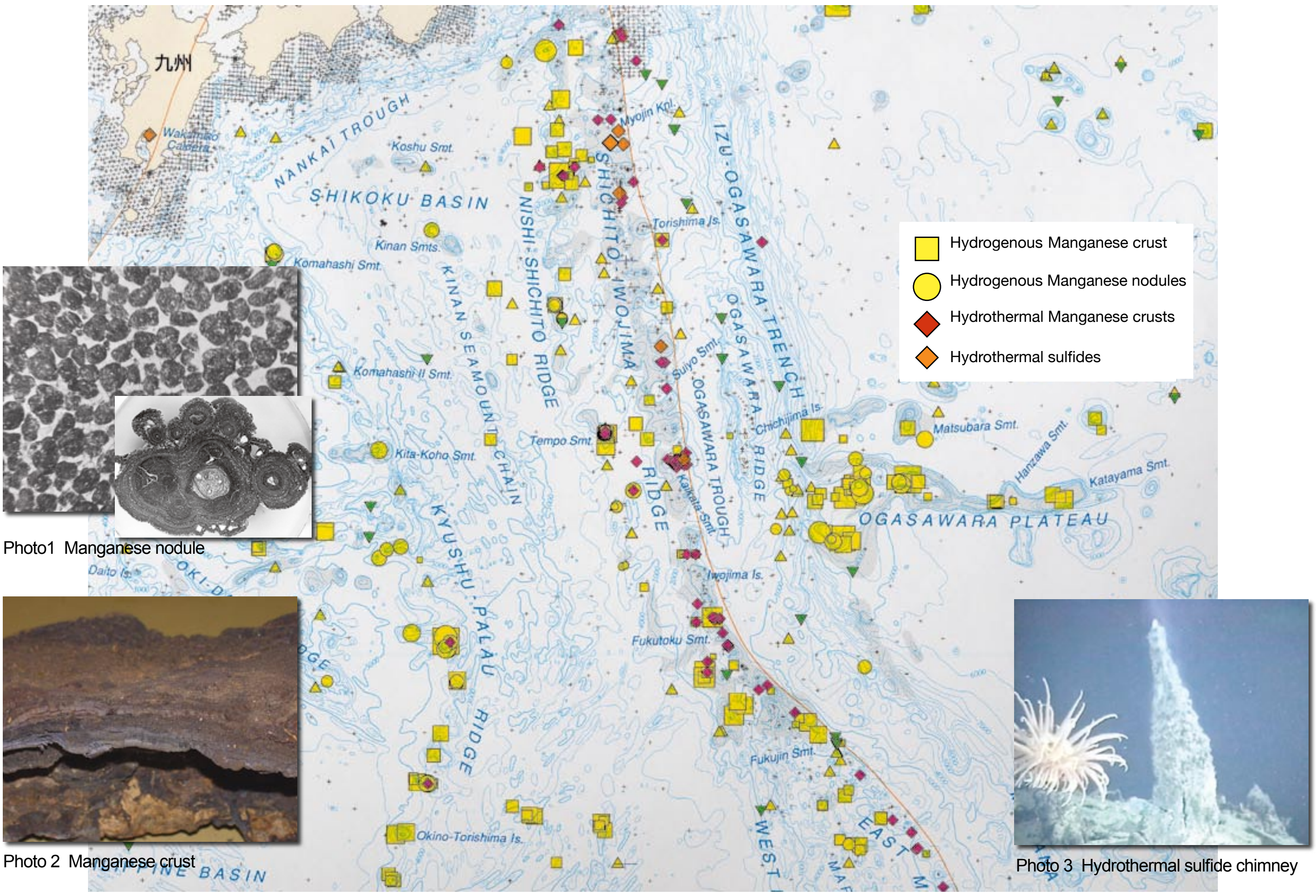



Photo1 Manganese nodule

Photo 2 Manganese crust

Photo 3 Hydrothermal sulfide chimney

Figure 1 : Distribution of potential mineral resources under the south sea of Tokyo (source: Usui, Iizasa, and Tanahashi, “Mineral Resource Distribution under the Sea around Japan” (1994), and the map is retouched)

# Dream of Large-Scale Deep-sea Mining for Practical Use

Tetsuo Yamazaki
Seafloor Geoscience Group, Institute of Geology and Geoinformation

Commenced in 1981 and hosted by Ministry of Economy, Trade, and Industry (the former Ministry of International Trade and Industry), a large-scale project, "R&D of Manganese Nodule Mining System," employed a towing nodule collector, which used a pipe string for the functions of both the collector towing and transportation of extracted manganese nodules from the seafloor to surface. The collector reflected the technology level of those days, and the project used it to conduct ocean trial test in 1997, the final year of the project (see the accompanying photo).

However, the technologies have developed remarkably in the past quarter century as follows:

1. Ocean navigation technology (GPS, etc.)
2. Ship position holding and control technology (dynamic positioning)
3. Submarine positioning technology (SSBL, etc.)
4. Submarine acoustic technology (side-scan sonar, ultrasonic sensing, etc.)
5. Submarine cable technology (umbilical cable, etc.)
6. Submarine robot technology (ROV, AUV. etc.)

Photo : Nodule collector for ocean trial test, which was used by the large-scale project, "R&D of Manganese Nodule Mining System"
Length : 13.2 m, width : 4.6 m, height : 5 m,
weight in air : 26.8 t, and weight in water: : 12.4 t

These technologies let our dreams come true; we have almost succeeded in realizing a nodule collector that moves by itself to extract manganese nodules. Since the self-propelled mechanism can be generally applied to the extraction of deep-sea mineral resources, it is expected to play a key role to mine cobalt-rich crusts and Kuroko-type seafloor massive sulfide deposits, whose distribution and mode of occurrence vary greatly by area. To put deep-sea mineral resource development to practical use, it is necessary to review the mining system based on the self-propelled mechanism.

manganese oxides similar to the manganese nodule mentioned above and adhere to bedrocks to form plates 0.5-10 cm thick (see Photo 2). Including a large amount of cobalt, the manganese crusts are also called cobalt-rich crusts. At the present time, oceanographic research bodies in Japan and many other countries are surveying manganese crusts to apply for future mining sites under the sea.

### Hydrothermal mineral deposit

These two marine mineral resources described above lie under the deep sea or on seamounts, which are relatively inactive. On the other hand, various mineral resources are yielded by hydrothermal activities in the active region, for example, mid-ocean ridges from which an oceanic plate goes out and expands, as well as the sea around Japan where the plate sinks. In island arcs, submarine topography, such as back arc basins and submarine calderas, develops, and magma and hot water are in activity. The submarine topography contains hydrothermal mineral deposits consisting of chimneys and massive sulfides including gold, silver, copper, zinc, iron, and lead (see Photo 3). Since these hydrothermal mineral deposits were formed along the mid-ocean ridges and the spreading axis of back arcs and in their circumference in ancient times as well, they are found in old strata all over the world and mined commercially.

### Possibility of commercial production

Because the current submarine metallic deposits are similar to the metallic deposits formed in geological times, the achievement of commercial mining is affected by various requirements: the potential amount of metallic deposits to be mined has to be competitive with that of resources on land; the metallic deposits must exist not far from the shore; efficient mining technologies must be developed; and environmental preservation technologies have to be established. Moreover, the commercial production is affected by society and economy, for example, trends of metal prices in the market. Hydrothermal sulfides including gold, silver, copper, lead, and zinc as well as cobalt-rich manganese crusts sometimes exist in the shallow sea within the exclusive economic zones, which is advantageous for development.

Japan holds mining sites of manganese nodules off southeastern Hawaii, and is making preparations for mining manganese crusts on seamounts. Regarding hydrothermal sulfide deposits around Japan, some sites are already applied for mining.

It took a very long time to find the resources even though the survey concentrated in special areas where there was a high possibility of presence. To realize the commercial production of marine mineral resources, it is increasingly important to develop more effective submarine exploration methods, taking full advantage of knowledge ever assimilated, and to identify promising areas in a short time.

# Preservation and Recovery of Coastal Environments

Akira Hoshika
Leader, Coastal Environment and Monitoring Research Group,
Institute of Geology and Geoinformation
Director, Collaborative Research Team for Eco-technology of Seto Inland Sea

## Awareness of the importance of coastal environment recovery

The human race continues living while getting blessings yielded by various ecosystems on the earth. In the past, a calculation was made to evaluate the value of the ecosystem service to money. This calculation tells that the area of the highest value is a coast including estuaries, tideland, and submarine forests, and is valued at $20,000 per hectare in a year. For example, the Seto Inland Sea has the shallows of 2,600 km2, which offers blessings corresponding to 570 billion yen. This area is 10 meters deep or less and includes estuaries, tideland, and submarine forests. This is only a calculation result, but it is certain that we get extraordinarily great benefits from the ecosystem of coasts.

Since pollution problems became obvious in 1960s, we have lost many habitants in the coastal areas and the number of coastal species has decreased tremendously (see the accompanying figure). In recent years, we have been aware that the functional degradation of the ecosystem causes a serious loss, which is not compensated by the blessings of our economical activities. Accordingly, it is strongly required to regenerate our sphere of activities utilizable in a sustainable manner, by restoring coastal environments and recovering the functions of the ecosystem.

Along with such a movement, the report “Discussion on New Environmental Preservation and Creation Measures for the Seto Inland Sea” was submitted by the Seto Inland Sea Environmental Conservation Council in January 1999, and the “Law for the Promotion of Nature Restoration” was enforced in December 2002. The movement of environmental restoration and regeneration is being accepted as an essential trend following conventional measures for regulated environmental preservation and control.

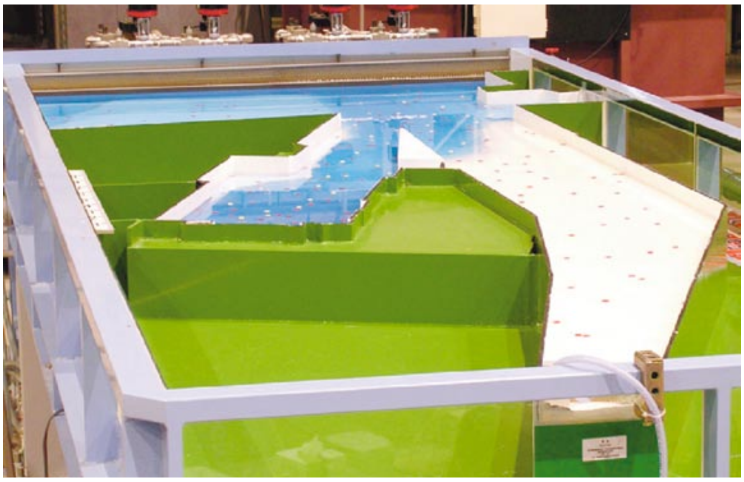


Photo : Hydraulic model experiment for destroying density stratification in Kitadomari Harbor, Osaka Bay
Kitadomari Harbor (your side) is filled with blue water showing seawater. It is clear that density stratification is formed when the seawater is covered with water (transparent) flowing out of Yamato River (front right).
Presented by Munehiro Yamasaki, Coastal Environment and Monitoring Research Group

# Coastal Environment Restoration by Creature’s Power

Terumi Tanimoto
Coastal Environment and Monitoring Research Group,
Institute of Geology and Geoinformation
Collaborative Research Team for Eco-technology of Seto Inland Sea

Submarine forests are very important as a bed for forming a variety of biota, supporting coastal ecosystems, and purifying water. However, reclamation and water pollution have lost wide-area Zostera beds, particularly in the shallows. In recent years, activities to regenerate lost natural environment are encouraged, for example, the “Law for the Promotion of Nature Restoration” is in effect. However, the sea sand mining —necessary to construct Zostera beds— is being prohibited in the Seto Inland Sea. Therefore, a new attempt has started; the blast-furnace slag discharged from ironworks substitutes for beach sand to construct artificial Zostera beds.

In December 2003, we conducted a test with blast-furnace slag to construct artificial Zostera beds in Mitsukuchi Bay, Yasuura-cho, Hiroshima Prefecture. In June 2004 (six months after), some test regions showed a seven-fold increase of Zostera and eggs of bigfin reefsquid are laid there (see the accompanying photo). After one year, we knew that the artificial bed had the same type and amount of benthos as the natural Zostera bed.

The Zostera beds offer comfortable places to living things, and as a result, the activities of the living things will restore the coastal environment. We need to develop technology with which Zostera beds are constructed more easily.

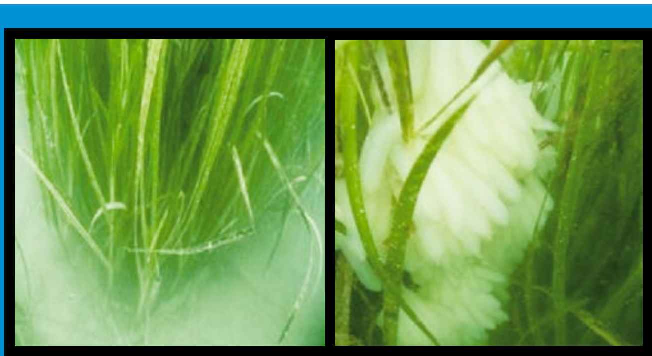


Photo : Zostera showing a seven-fold increase (left) and eggs of bigfin squid laid in a test region (right)

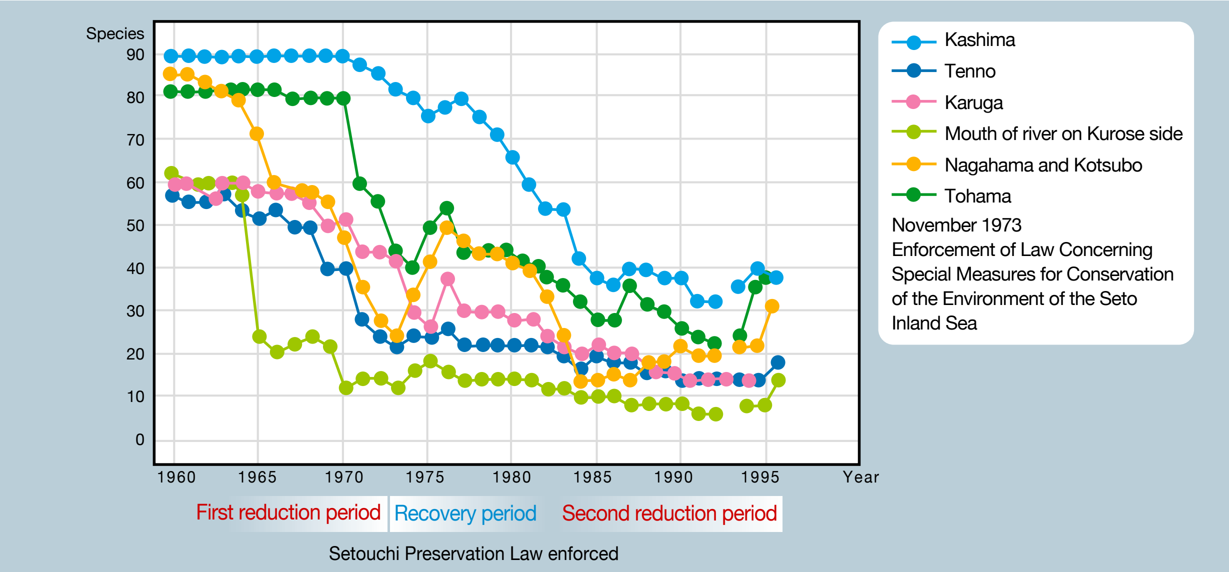



Figure : Changes in the number of coastal species around Kure-shi, Hiroshima Prefecture (source: Ichiro Yuasa's paper in 2002)
Such long-term data is rare and valuable.

## Environmental restoration similar to disease treatment

Environmental problems are often compared to diseases. Therefore, the restoration of environments is equal to medical treatment for diseases. The treatment needs symptom diagnosis and cause analysis. Moreover, it needs post-treatment examinations and preventive measures.

In many cases, coastal environments degrade when their substance circulation systems do not function well. This means that environmental restoration and regeneration are equal to the regeneration of the substance circulation system, and fist of all, it is necessary to find the causes of environmental degradation. Note that the mechanism of substance circulation is very complicated, and it takes a long time and a great deal of labor to analyze the mechanism. As a result, complete solutions are not always given.

Even if there are such problems, we must restore and regenerate environments in many areas. Doing nothing offers no solution. It is necessary not only to develop applicable technologies but also to combine existing technologies according to purposes and targets. It may be said that the latter is an emergency measure.

## Technologies for and problems in environmental recovery

It is said that more than 200 technologies have been proposed or actually used to restore the sea environment. The typical includes the construction of artificial tideland, beaches, Zostera beds, and shallows. Engineering methods are used to improve the quality of water, for example, permeable structure and flow regime control (see Photo 1). To improve the bottom quality, dredging and sand injecting technologies are used. Moreover, technologies using benthos or microorganisms are in the R&D stage but promising.

Recently, the industry, academy, and government form joint projects for the full-fledged restoration and regeneration of the coastal environment, for example, "Action Plan for Recovering the Bay of Tokyo," "Environmental Creation Project" in the Bay of Ago, and "Project for Packaging Optimal Environment Restoring Technologies" in Amagasaki Harbor.

However, there are many unknown things in the environmental restoration field, and a question of right or wrong is not yet answered. We still have many problems to be addressed: "Is environmental restoration agreed to?", "Who is responsible?", "Scale, procedures, and necessary technologies?", "Is effect sustainable and stable?", and "Is another ecosystem disturbed?".

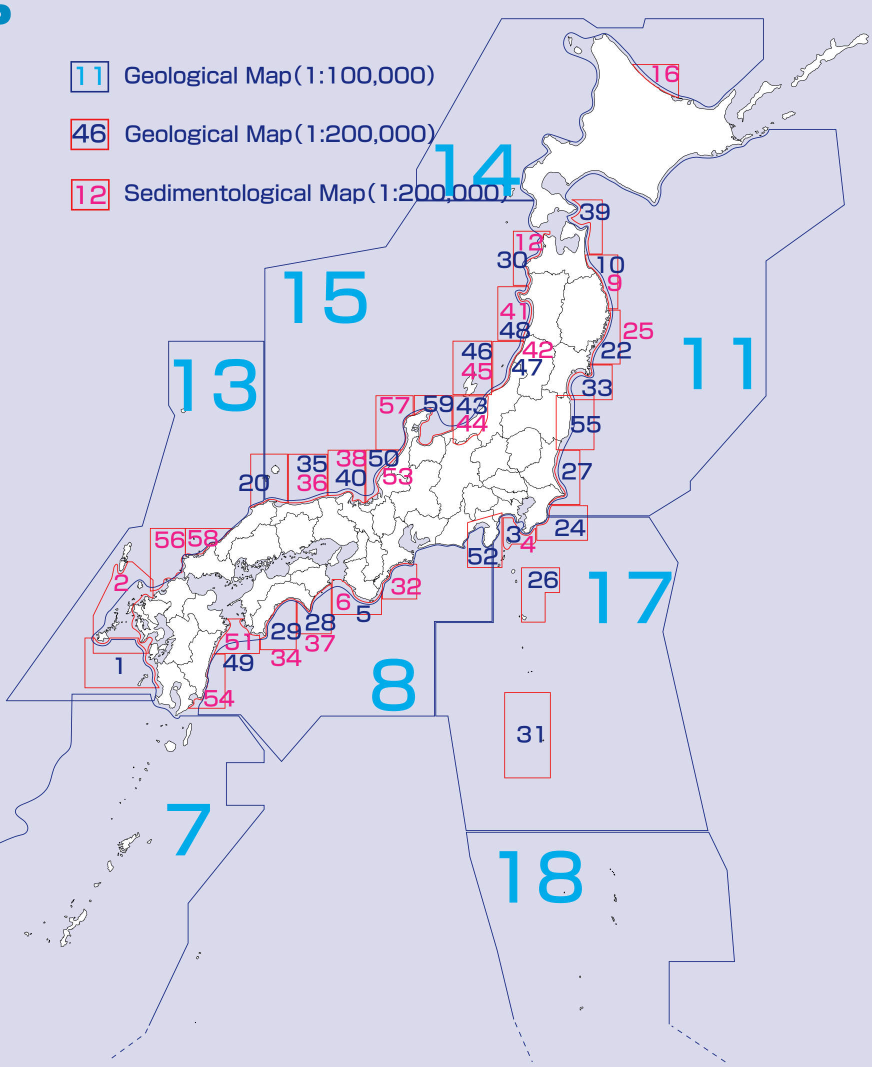
Development of ecotechnology is essential: It enables us to reduce energy consumption, make use of environmental resources for a long time by taking full advantage of the power of nature and ecosystems, and coexist with environment in harmony. For that purpose, contributions of ocean science are much expected.

References:
• Ichiro Yuasa, "Environmental Changes in the Seto Inland Sea—Now and Past—Human and Environment," Vol. 28, pp. 21-27 (2002)
• Yasushi Kurihara, "Ecosystem of and Ecotechnology for Estuarial and Coastal Areas," Tokai University Press, pp. 335 (1988)
• R. Costanza et al., "The value of the world's ecosystem services and natural capital," Nature, vol. 387, pp. 253-2510 (1997)
• Yasunori Kozuki, Takashi Nakanishi, Takaaki Shigematsu, and Koji Otsuka, "To Establish How to Select Environment Restoring Technology," Ecosystem Engineering, No. 6, pp. 53-89 (2001)

# MARINE GEOLOGY MAP

## 1:200,000 Geological Map Sedimentological Map

No. 1 Submarine Geological Map Around Koshikijima Island
No. 2 Bottom Sediment Map, Tsushima and Goto Islands Area
No. 3 Sagami-Nada Sea and its Vicinity Submarine Geological Map
No. 4 Sagami-Nada Sea and its Vicinity Sedimentological-Map
No. 5 Geological Map of the South of Kii Strait
No. 6 Sedimentological Map of the South of Kii Strait
No. 9 Sedimentological Map of Offing of Hachinohe
No.10 Geological Map off Hachinohe
No.12 Sedimentological Map of Nishi-Tsugaru Basin
No.30 Gological Map of Nishi-Tsugaru Basin
No.16 Sedimentological Map off Mombetsu, Hokkaido
No.20 Geological Map of Oki Strait
No.22 Geological Map off Kamaishi
No.25 Sedimentological Map of off Kamaishi
No.24 Geological Map of the East of Boso Peninsula
No.26 Geological Map of the Northeast of Hachijojima
No.27 Geological Map of Kashima-nada
No.28 Geological Map off Muroto-zaki
No.37 Sedimentological Map Offshore of Cape Muroto
No.29 Geological Map of Tosa-wan
No.34 Sedimentological Map of Tosa-wan
No.31 Geological Map of Sumisu and Torishima Rifts, Izu-Ogasawara Arc
No.32 Sedimentological Map of Kumano-nada
No.33 Geological Map off Kinkasan
No.35 Geological Map of Offshore of Tottori
No.36 Sedimentological Map Offshore of Tottori
No.38 Sedimentological Map Offshore of Kyo-ga Misaki
No.40 Geological Map Offshore of Kyo-ga Misaki
No.39 Geological Map off Shimokita Peninsula
No.41Sedimentological Map West of Akita
No.48 Geological Map West of Akita
No.42 Sedimentological Map of the Vicinity of Awashima
No.47 Geological Map of the Vicinity of Awashima
No.43 Geological Map South of Sado Island
No.44 Sedimentological Map South of Sado Island
No.45 Sedimentological Map North of Sado Island
No.46 Geological Map North of Sado Island
No.49 Geological Map South of Bungo Strait
No.51Sedimentological Map South of Bungo Strait
No.50 Geological Map Offshore of Gentatsu-se
No.53 Sedimentological Map Offshore of Gentatsu-se
No.52 Geological Map of Suruga Bay
No.54 Sedimentological Map Hyuga-nada
No.55 Geological Map of Off Shioya Saki
No.56 Sedimentological Map Hibiki-nada
No.57 Sedimentological Map West of Noto Peninsula




## CD-ROM Geological Map / Sedimentological Map

No.58 Sedimentological Map of the Vicinity of Mishima (CD)
No.59 Geological Map East of Noto Peninsula (CD)

## 1:1,000,000 / 1:2,000,000 / 1:3,000,000

No. 7 Geological Map Around Ryukyu Arc (Scale : 1:1,000,000)
No. 8 Geological Map off Outer Zone of Southwest Japan (Scale : 1:1,000,000)
No.11 Geological Map of the Japan and Kuril Trenches and the Adjacent Areas (Scale : 1:1,000,000)
No.13 Geological Map of the Southern Japan Sea and Tsushima Straits (Scale : 1:1,000,000)
No.14 Geological Map of the Japan and Okhotsk Seas around Hokkaido (Scale : 1:1,000,000)
No.15 Geological Map of the Central Japan Sea (Scale : 1:1,000,000)
No.17 Geological Map of the Northern Ogasawara Arc ( Scale : 1:1,000,000)
No.18 Geological Map of the Southern Ogasawara and Northern Mariana Arcs (Scale : 1:1,000,000)
No.19 Free Air Gravity Anomaly Map of the Central Pacific (Scale : 1:2,000,000)
No.21 Manganese Nodules Distribution in the Central Pacific Ocean (Scale : 1:2,000,000)
No.23 Marine Geological Map Around Japanese Islands (Scale : 1:3,000,000)

# People live with the Earth better, if we know about our Planet better

Eikichi Tsukuda
Research Coordinator for
Geological Survey and Applied Geoscience

Social requirements of geoinformation have changed from age to age. When the Industrial Revolution began three hundreds years ago, information on natural resources such as minerals, oil and coal was a top priority. After the Oil Shock in 1970's, alternative energy was eagerly sought. Then, prevention and mitigation of natural disasters attracted public interest. In recent years, conservation of safe water resources and prevention of global warming are becoming major issues.

This transition owes to change of public awareness for the earth and its environment. The human race, who has been abusing the earth by developing and utilizing its resources since its appearance, finally realized that the planet has a limit on its tolerance. Now, we can not carry on our life without a global view. Considering the finiteness of our fragile planet, we have to find a way to the sustainable development of our society.

To create a sustainable society, it is very important to precisely assess and predict the impact caused by human activity or natural phenomena. Elucidation of the earth's history and knowledge of the present earth are essential to predict the future path of our planet. The local problems are closely related to the global issues and vice versa these days. We have to recognize it and learn more about the earth to live harmoniously with it.

Putting up the slogan saying "People live with the Earth better, if we know about our Planet better", we the National Institute of Advanced Industrial Science and Technology aim to build a sustainable society. We would like to contribute to the safety and security of the people with our knowledge and experience. For this purpose, we will keep providing and organizing highly precise predicted geoinformation by developing our technology.

**http://www.gsj.jp/**

### Geologic Map Series

- QUADRANGLE SERIES 1:50,000
- GEOLOGICAL SHEET MAP 1:75,000
- GEOLOGICAL SHEET MAP 1:200,000
- GEOLOGICAL SHEET MAP 1:500,000
- 1:2,000,000 MAP SERIES
- 1:1,000,000 MAP SERIES
- ASIA AREA GEOSCIENCE MAP
- DIGITAL GEOSCIENCE MAP (CD-ROM)
- NEOTECTONIC MAPS
- TECTONIC MAP (STRIP MAP OF THE FAULT SYSTEM )
- GEOLOGICAL MAPS OF VOLCANOES
- MISCELLANEOUS MAP
- WATER ENVIRONMENT MAP (CD-ROM)
- HYDROGEOLOGICAL MAPS
- GRAVITY MAP
- TOTAL INTENSITY AEROMAGNETIC MAPS
- MINERAL RESOURCES MAP
- GEOLOGICAL MAPS OF COAL FIELDS OF JAPAN
- GEOLOGICAL MAPS OF OIL AND GAS FIELDS OF JAPAN
- ISOGAL CONTOUR MAPS OF GEOTHERMAL AREA
- INDEX MAPS

**http://www.gsj.jp/Map/**

## The Earth's Messages from the Sea

Exploiting Seafloor Surveys for Environments, Resources, and Disaster Prevention



**Cover Photo**
Geological Research Vessel "Hakurei-Maru" and Mt.Fuji
(At the Port of Shimizu, Shizuoka Prefecture in 1997)
Photo by Takeshi Sato (Professor of the Tokai University)


AIST NATIONAL INSTITUTE OF ADVANCED INDUSTRIAL SCIENCE AND TECHNOLOGY (AIST)

**Publication Office, Public Relations Department, AIST**
AIST Tsukuba Central 2, 1-1-1 Umezono, Tsukuba, Ibaraki, 305-8568, JAPAN
Tel:+81-29-862-6217 Fax:+81-29-862-6212 E-mail:prpub@m.aist.go.jp http://www.aist.go.jp/

**Geological Survey of Japan, AIST**
AIST Tsukuba Central 7, 1-1-1 Higashi, Tsukuba, Ibaraki, 305-8567, JAPAN
Tel:+81-29-861-9122 Fax:+81-29-861-3672 E-mail:secr@gsj.jp http://www.gsj.jp/

Japanese version of the articles in this pamphlet were originally published as the feature articles in the 2005-8 issue of AIST Today.
Printing December 2005