The Submersible Research Vessel
SHINKAI 6500

JAPAN MARINE SCIENCE AND TECHNOLOGY CENTER (JAMSTEC)

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CONTENTS


しんかい6500
K. Tsugaoka

Historical Background to the Construction of SHINKAI 6500

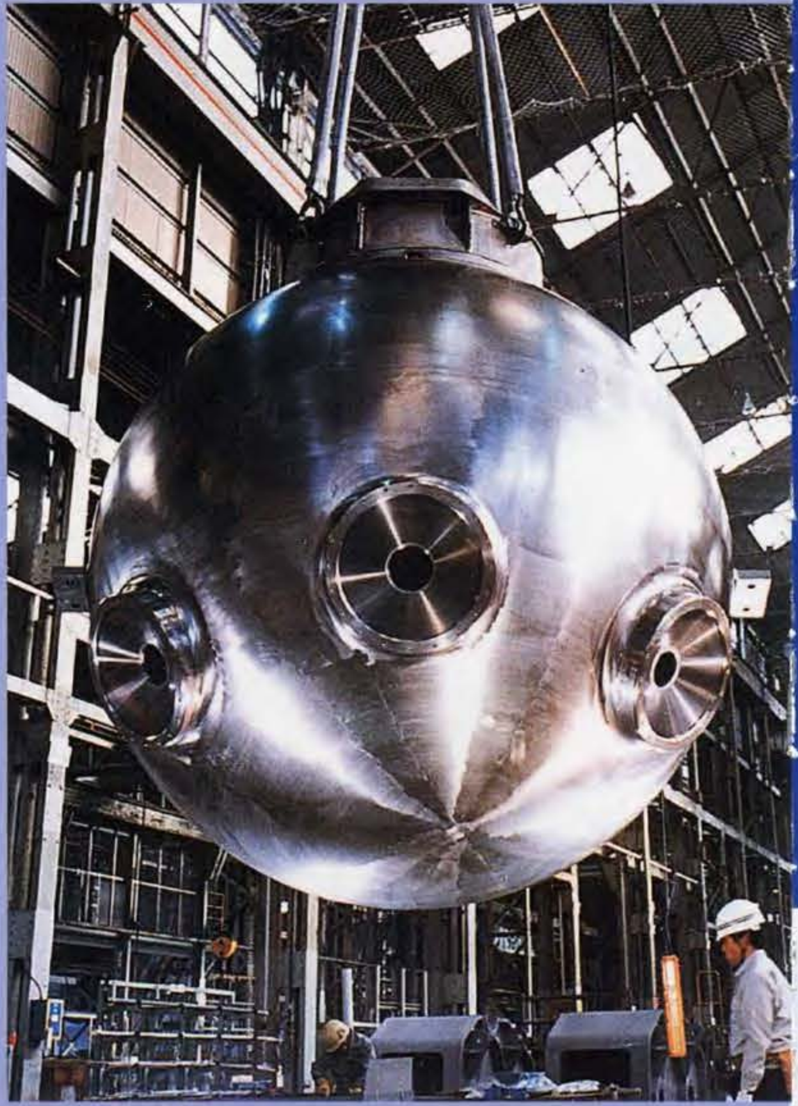
Submersible research in Japan can be traced back to fisheries research conducted by the "Mame" (Midget) Submersible built by entrepreneur Ichimatsu Nishimura before World War II. At the time, this craft reportedly boasted the highest performance in the world, with a maximum diving depth of 200m.

The Japan Marine Science and Technology Center (JAMSTEC), founded in 1971 as a statutory oceanographic research institute under the supervision of the Science and Technology Agency (STA), built manned research submersibles SHINKAI 2000 (maximum depth capability 2,000m) in 1981 and SHINKAI 6500 (maximum depth capability 6,500m) in 1989, thus marking the start of Japan's full scale scientific research using submersibles.

Japan sought a 6,500m diving capability with SHINKAI 6500, while France and the United States constructed their manned research submersibles aiming at 6,000m depth capability, although it was not simply for the purpose of achieving the world's highest-performance submergence. As one of the countries with frequent earthquakes, Japan emphasizes earthquake predictions in connection with deep sea research.

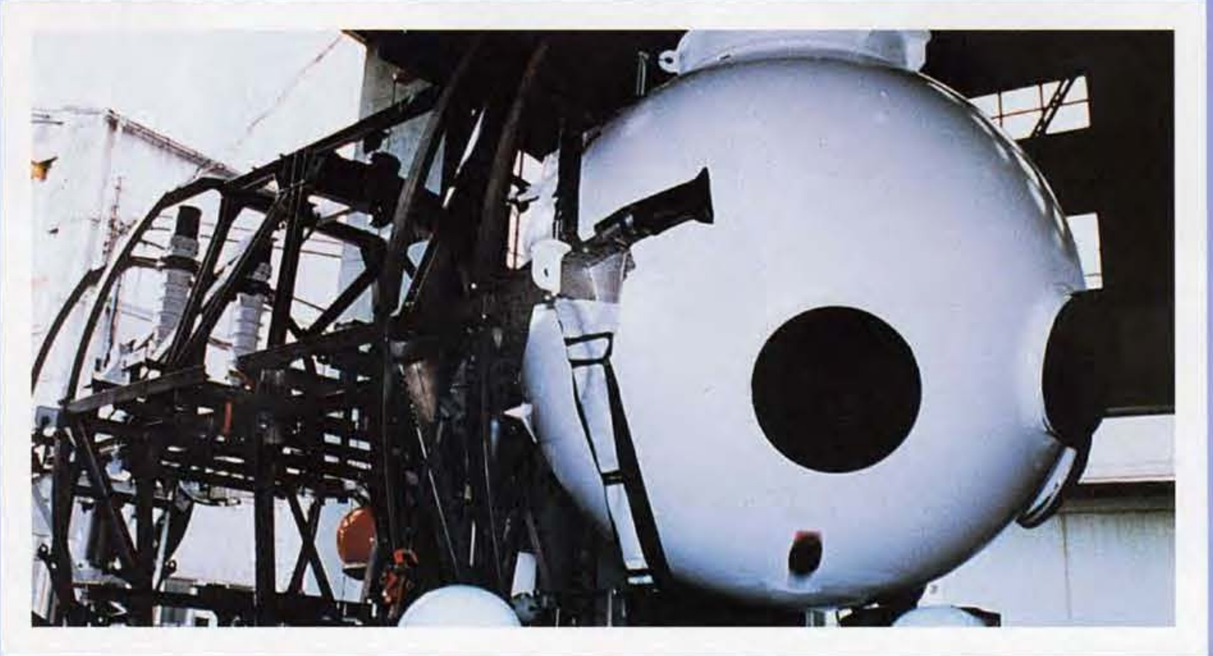
Many of major earthquakes in Japan are related to oceanic plate subduction. The plate moving from the Pacific towards the Eurasian Continent sink under the Eurasian Plate along the coast of Japanese Archipelago. As the plates deform near the trench, where they meet the Eurasian Plate, faults and frictions occur releasing tremors which supposedly lead to a strong earthquake. It has become apparent that the location important to earthquake predictions is 6,200-6,300m deep, right below where the plate deformations begin, instead of the 6,000m deep Pacific Ocean floor along the Japanese Archipelago. This explains why the maximum depth capability of SHINKAI 6500 was specifically set at 6,500m.

(Shin'ichi Takagawa, JAMSTEC)



Completed titanium sphere

SHINKAI 6500 under construction at the Kobe shipyard of Mitsubishi Heavy Industries Co., Inc.



The Launching of SHINKAI 6500

The submersible research vessel SHINKAI 6500 was launched on January 19, 1989 at the Mitsubishi Heavy Industries shipyard in the Hyogo ward of the city of Kobe. Some five hundred people involved in the project witnessed the event.

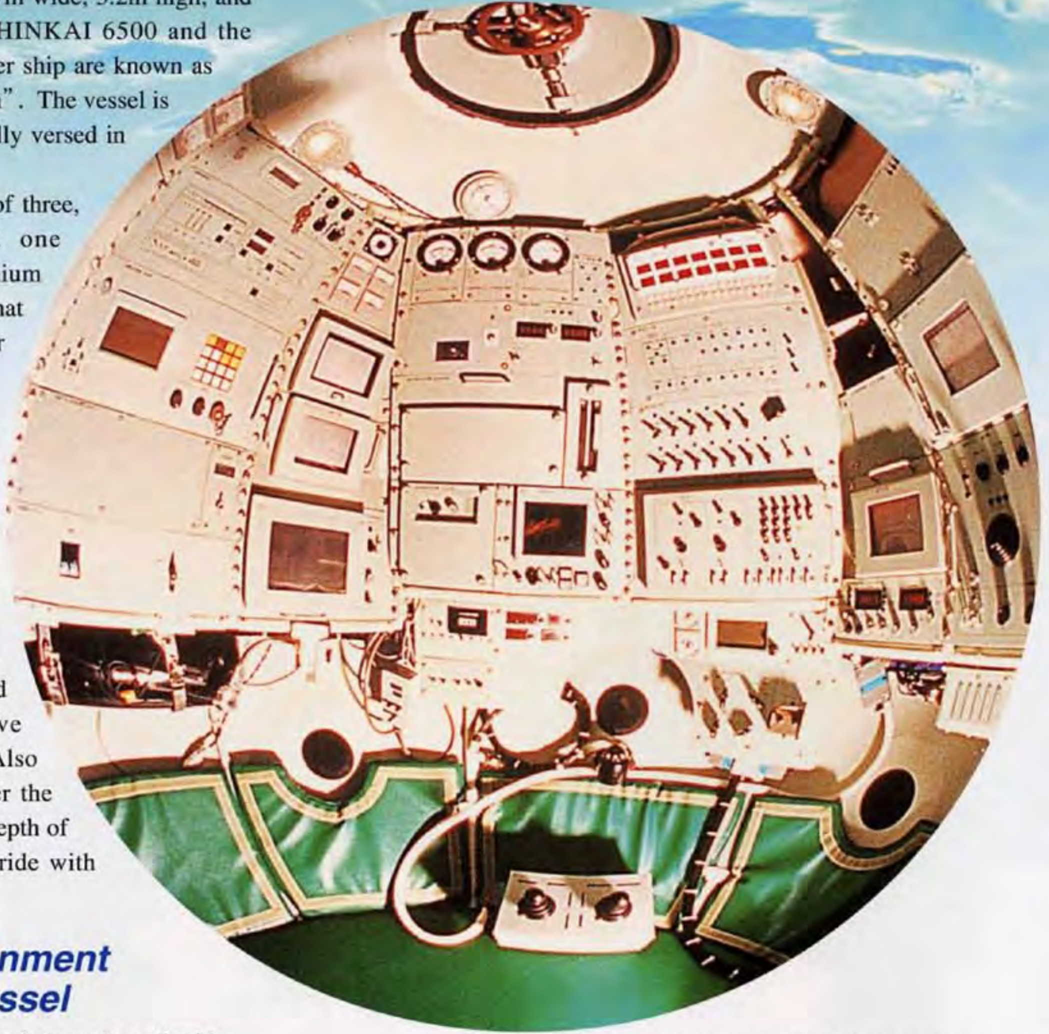
The name SHINKAI 6500 was determined by public participation. At the launching ceremony, the unveiling tape was cut by Toshimitsu Kirihara, a fifth-grader at Tainohata Public Elementary School in Kobe, who was selected to represent all the members of the public who had submitted names.

The Submersible Research Vessel SHINKAI 6500

The SHINKAI 6500 is 9.5m long, 2.7m wide, 3.2m high, and weighs 26tons. The crew of the SHINKAI 6500 and the submersible support crew on the mother ship are known as the "SHINKAI 6500 Operations Team". The vessel is operated by team members who are fully versed in its capabilities.

The SHINKAI 6500 carries a crew of three, two regular crew members and one researcher. The crew rides in a titanium sphere, known as the pressure vessel, that is 73.5mm thick and 2m in diameter inside.

Once the hatch is closed, the vessel can dive to a depth of 6,500m while maintaining an interior pressure of one atmosphere, the same as found on land. Since crew members are not exposed to the effects of water pressure, there is no fear of submarine sickness and no need for special training, so even young children and elderly people would be able to dive down to see the deep sea domain. Also there are no effects from waves under the water, so once the vessel dives past a depth of 10m, it provides a very comfortable ride with virtually no rocking motion.



Inside the submersible at the time of completion

Maintaining the Environment Inside the Pressure Vessel

Human beings consume oxygen and exhale carbon dioxide when we breathe. The vessel is therefore equipped with oxygen canisters to supply the oxygen that is consumed. Oxygen is discharged through distilled water since it is not desirable to discharge pure oxygen directly. The carbon dioxide is adsorbed when the air inside the vessel filters through a container of lithium hydroxide which is connected to a ventilator.

The vessel has three view ports, one to the front and one on either side. The forward port is primarily used by the pilot (the captain or first mate), while the one on the port side is used by the researcher to actually look out at the ocean floor. In some cases, crew members may change places to look through a different port.

When the SHINKAI 6500 was under construction, a one-third scale model of the pressure vessel was fabricated first for collapse testing, in which it was placed under increasing water pressure until it burst. This testing showed that the pressure vessel would break down under the water pressure found at a depth of 13,000m. After the actual pressure vessel was constructed, it was also tested under the water pressure found at 10,000m to confirm that it was more than strong enough to withstand the pressure at an ocean depth of 6,500m.

Principles of Submersion

In order to give the SHINKAI 6500 positive buoyancy, the submersible contains buoyant material with a specific gravity of approximately 0.54. This material consists of hollow glass spheres 100microns or less in diameter set in an epoxy resin. It provides excellent buoyancy because it does not deform or degenerate under high pressure. The buoyant material is installed by packing it into open spaces in the submersible's body and between the equipment.

Before embarking on submersible research, the crew members, researcher, and their equipment must first be weighed. That weight determines the amount of ballast, which is in the form of iron weights. There are two kinds of ballast, ascending and descending, which are slightly different in size. Individual pieces weighing approximately 25kg are combined in sets of ten to fourteen pieces, and the submersible carries four sets. One set weighs about 300kg, so a single voyage requires approximately 1.2 metric tons of ballast.

The SHINKAI 6500 loaded with ballast is lowered to the sea surface. The submersible is also equipped with ballast tanks that can be filled with sea water or air to adjust buoyancy. When the ballast tank vents are opened, air escapes from the top and sea water enters from below, and the submersible begins to dive.

Sunlight reaches approximately 300m beneath the ocean surface in regions with small amounts of suspended matter in the water. When beginning a dive, therefore, it feels as though the sun is gradually going down and evening is setting in.

During the descent, the captain and first mate monitor the onboard instruments and report the depth to the mother ship at 500m intervals. During this time, the captain reconfirms the scheduled dive activities with the researcher.

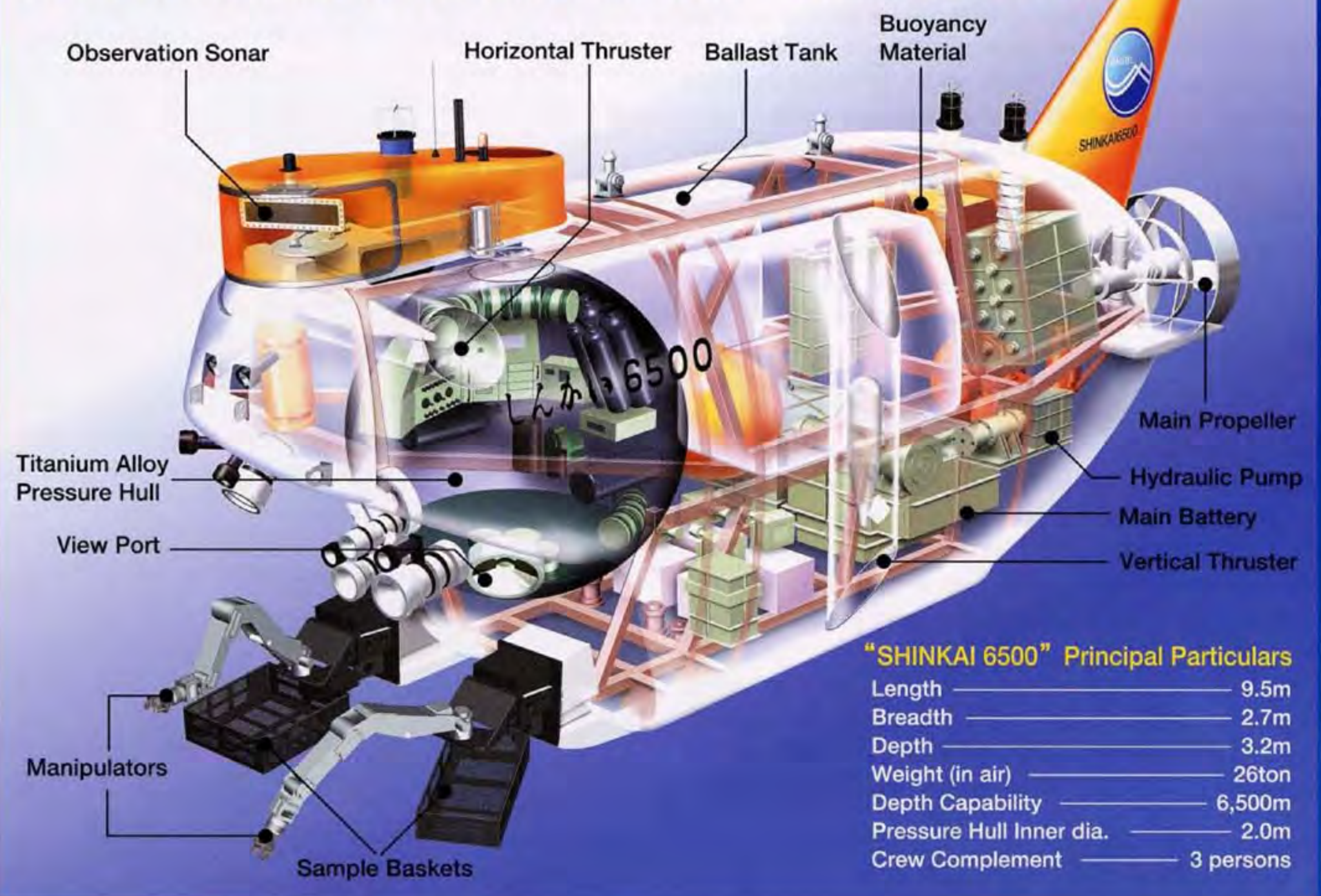
The descent to 6,500m takes about two and a half hours. When the submersible reaches a height of about 100m above the ocean floor, two sets of ballast are dropped and the amount of sea water in the ballast tank is adjusted to bring buoyancy to zero. Then the submersible descends gently to the ocean floor using the vertical thruster. After reaching the ocean floor, the submersible moves using the main propulsion unit located at the stern. The main propulsion unit can swivel 80° both left and right, so it also functions as a rudder.

Visibility in the water is usually about 10-15 m, but at its worst, even the manipulator right before your eyes may not be visible. The ocean floor is not always flat, so in order to maintain the submersible at an ample distance from the bottom, and also because the submersible must be able to stop quickly when the objective is sighted, the speed during research at the ocean floor is kept to approximately 0.5knots (25cm/sec). This is about the speed of a person walking very slowly. Until recently, most dives involved nothing more than submerging, observing, and retrieving samples. Now, however, more complicated tasks are also performed, such as locating observation equipment placed at predetermined spots on the seabed, moving the equipment, and placing it at other locations.

When the research on the ocean floor has been completed, the remaining two sets of ballast are released and the submersible begins to ascend. The time taken ascending is mostly identical to the time for the descent. The atmosphere inside the submersible is usually more relaxed than during the descent because everyone feels more secure after the work of the dive has been completed.

When the submersible reaches the surface, high-pressure air is fed into the ballast tank to jettison some of the sea water in the tank so that part of the vessel will rise out of the water. In this way, the submersible maintains buoyancy while waiting to be recovered, and this is how an eight-hour research dive on the SHINKAI 6500 comes to an end.

The Submersible Research Vessel "SHINKAI 6500"



"SHINKAI 6500" Principal Particulars

Length	9.5m
Breadth	2.7m
Depth	3.2m
Weight (in air)	26ton
Depth Capability	6,500m
Pressure Hull Inner dia.	2.0m
Crew Complement	3 persons

The Equipment on the SHINKAI 6500

The power source of general submersibles are lead or nickel-cadmium batteries. These are either stored in an atmospheric pressure container or, in order to reduce the weight, packed in oil in a container that is equalized at sea water pressure.

The SHINKAI 6500 also uses batteries as its power source. These are silver-zinc batteries that have about three times the energy density of the lead batteries usually used in cars. They are installed in oil-filled pressure-equalized containers. Power from these batteries is used to operate the underwater floodlights, electric motors, hydraulic pumps, and all other equipment.

The submersible and mother ship use an underwater telephone to communicate during dives. An underwater telephone works on the same principle as a radio transceiver, but since radio waves cannot be used underwater, this telephone uses sound waves instead. Sound travels through the water at a speed of approximately 1,500m/sec. This means that during dives to a depth of 6,500m, words spoken over the underwater telephone from the mother ship or the submersible take about four seconds to reach their destination.

Another point is that underwater where the sunlight does not reach, it is not possible to determine one's own position visually. Therefore, the submersible uses obstacle-avoidance forward-looking sonar and bottom-sounding and overhead-sounding sonar to find objects, detect obstacles, and determine the distance from the bottom and from the surface. The submersible also carries a compact gyrocompass to determine its heading and an inclinometer to determine the angle of the submersible's body. Other equipment includes a current meter to measure the direction and force of sea-bottom currents, and CTDV sensor to measure salinity, water temperature, sound velocity, and so forth.

When submersible research requires precise knowledge of position, three transponders can be placed on the sea bottom in the dive area. This allows the exact position to be determined from inside the submersible using an acoustic positioning device.

The progress of sea-bottom research can be recorded by two video cameras and a still camera that can expose 400 frames. One video camera is fixed and the other is movable. The submersible is equipped with seven 250W floodlights for illumination in dark underwater conditions. These floodlights are metal halide lamps that are very bright despite their low wattage.

The submersible has a total information display unit for management of research dive data. This records all data collected during research dives.

(Katsufumi Akazawa, JAMSTEC)

SHINKAI 6500 at the maintenance bldg. , and its batteries

Annual Program for the SHINKAI 6500

The SHINKAI 6500 ordinarily conducts research dives from sometime after April up to November or early December. During this time, fifteen research dives take place on a one-month or month-and-a-half schedule. When the submersible returns to port, preparations for the next research dive are begun, including battery maintenance. Therefore, four research voyages are ordinarily scheduled in the course of a year, with a total of sixty research dives.

After the research dives are completed, the three-month period from December through February is occupied with inspection of the SHINKAI 6500. Every piece of equipment is removed, inspected, and repaired. Regular inspections are carried out once every four years, along with the annual inspections, for more detailed inspections. Once the inspections are finished, test dives and training dives take place during March in order to confirm the inspection work at sea. The training dives are for improving the skills of the SHINKAI 6500 Team members and training new members.

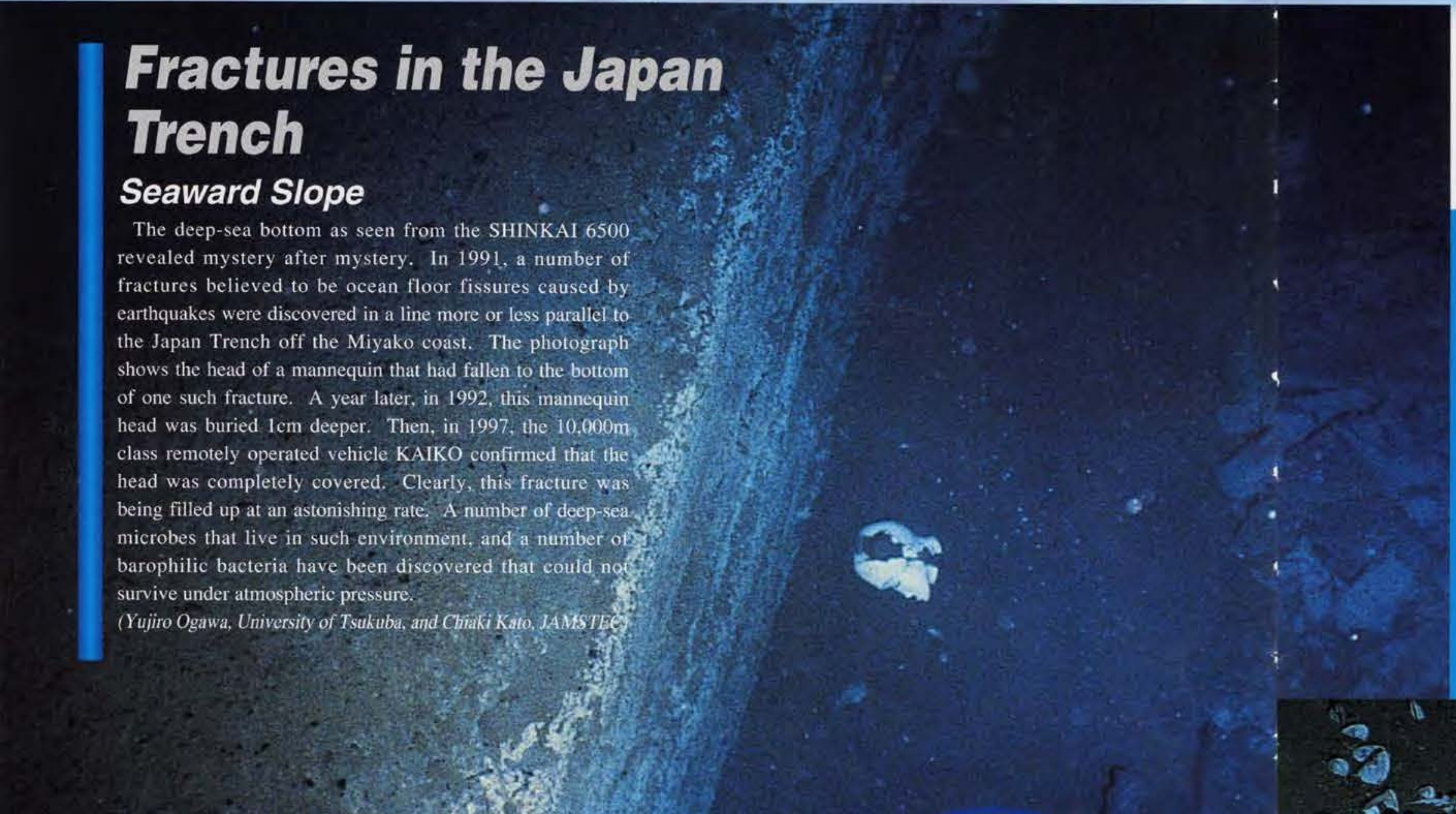
Recovering SHINKAI 6500

One Day's Typical Work Schedule for the SHINKAI 6500

0800	Begin pre-dive checks (about one hour)
0910	Swimmers stand-by
0920	Crew and researcher board the SHINKAI 6500
	Pre-launch checks
	Prepare to raise submersible from hangar, then raise close hatch
	Hoist submersible, swing out, and launch final post-launch check
	Cast off hoist cable and primary cable
1000	Open vent, begin dive
1700	Surface
	Attach primary cable and bring in submersible
	Attach hoist cable, lift submersible, bring inboard, and lower onto trolley
	Open hatch
	Draw submersible into hangar
	Post-recovery check
	Prepare for next dive
Night	Charge batteries

SHINKAI 6500 waiting to be launched

Voyages of the SHINKAI 6500 (1)



Fractures in the Japan Trench

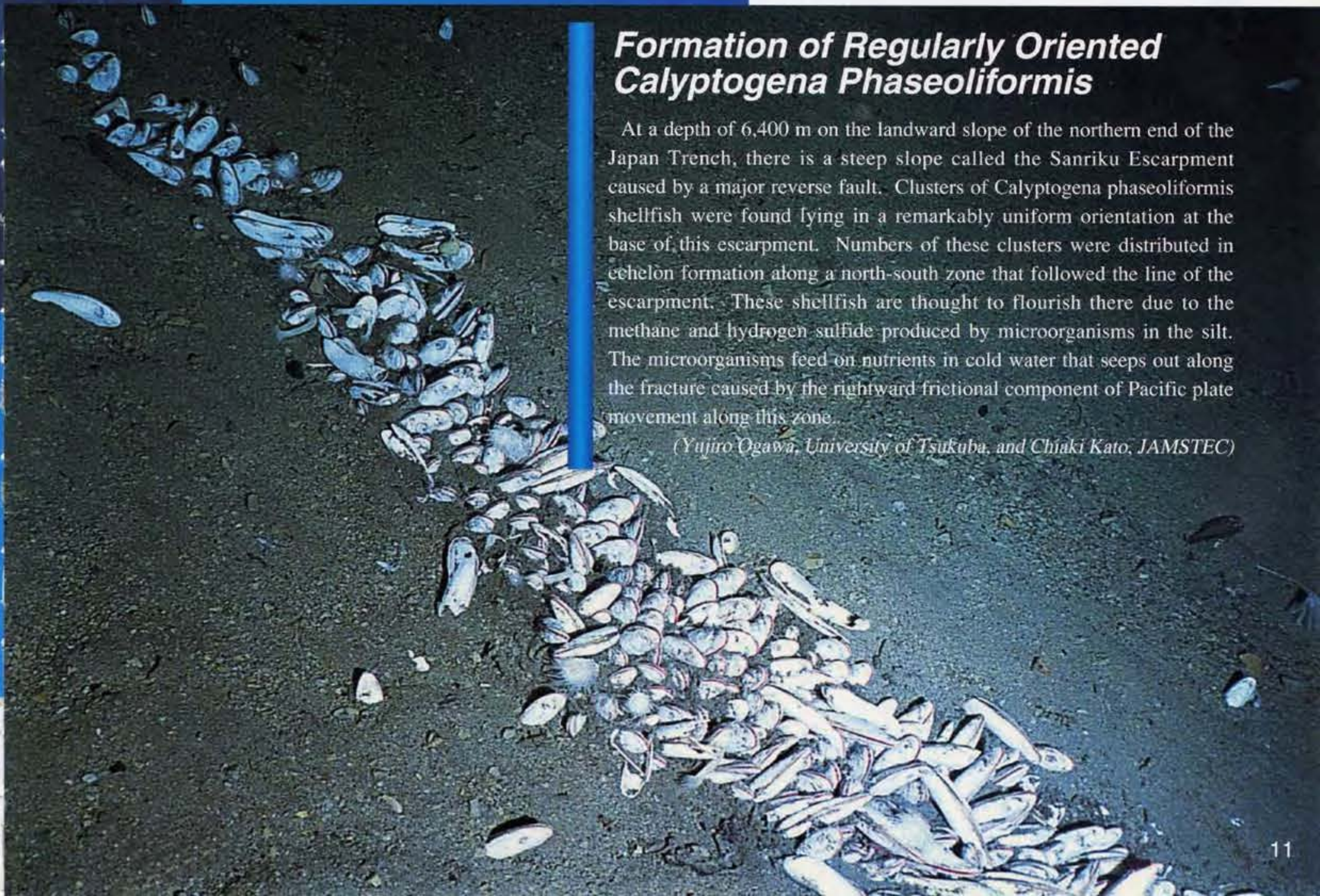
Seaward Slope

The deep-sea bottom as seen from the SHINKAI 6500 revealed mystery after mystery. In 1991, a number of fractures believed to be ocean floor fissures caused by earthquakes were discovered in a line more or less parallel to the Japan Trench off the Miyako coast. The photograph shows the head of a mannequin that had fallen to the bottom of one such fracture. A year later, in 1992, this mannequin head was buried 1cm deeper. Then, in 1997, the 10,000m class remotely operated vehicle KAIKO confirmed that the head was completely covered. Clearly, this fracture was being filled up at an astonishing rate. A number of deep-sea microbes that live in such environment, and a number of barophilic bacteria have been discovered that could not survive under atmospheric pressure.

(Yujiro Ogawa, University of Tsukuba, and Chiaki Kato, JAMSTEC)

Trash sunk into a fracture

Extremely barophilic bacteria



Formation of Regularly Oriented Calyptogena Phaseoliformis

At a depth of 6,400 m on the landward slope of the northern end of the Japan Trench, there is a steep slope called the Sanriku Escarpment caused by a major reverse fault. Clusters of Calyptogena phaseoliformis shellfish were found lying in a remarkably uniform orientation at the base of this escarpment. Numbers of these clusters were distributed in echelon formation along a north-south zone that followed the line of the escarpment. These shellfish are thought to flourish there due to the methane and hydrogen sulfide produced by microorganisms in the silt. The microorganisms feed on nutrients in cold water that seeps out along the fracture caused by the rightward frictional component of Pacific plate movement along this zone.

(Yujiro Ogawa, University of Tsukuba, and Chiaki Kato, JAMSTEC)

Voyages of the SHINKAI 6500 (2)

The Izu-Bonin Trench

Biological Community in Whalebone Habitat and Serpentine Rock

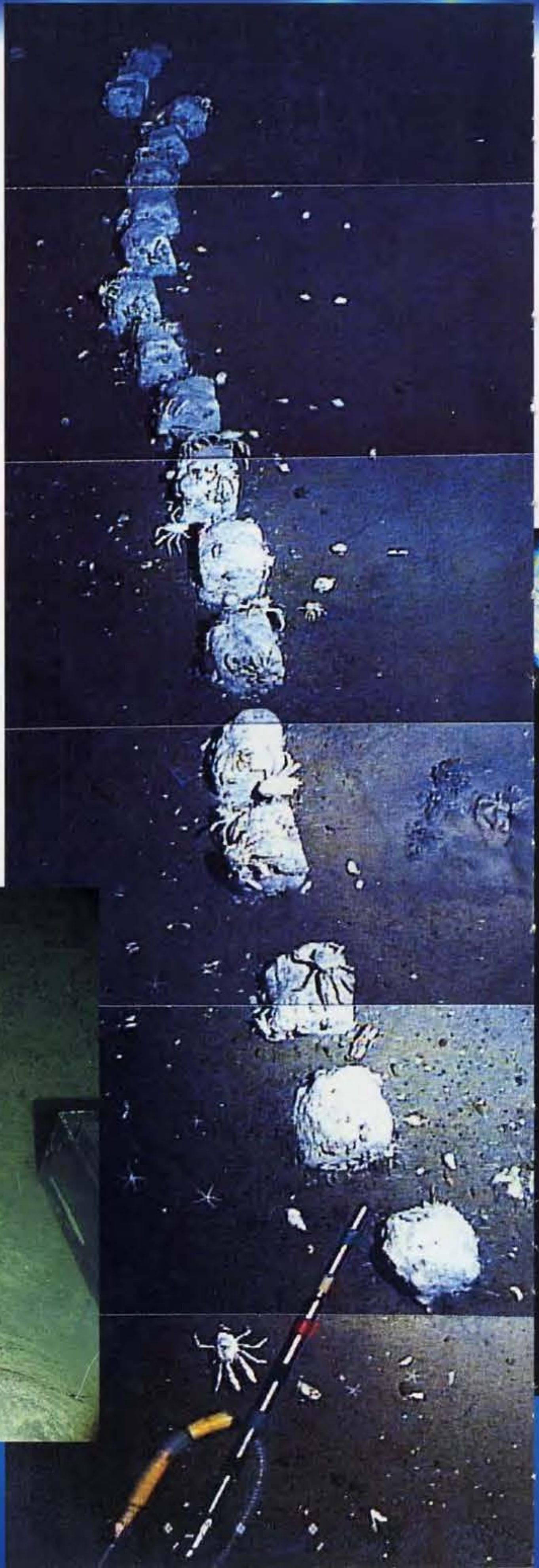
Seamounts (rising 1,000-2,000m from the sea floor with peaks approximately 4,000m deep) line on the slope 40-50km landward of Izu Bonin Trench. The seamounts known as "fore-arc seamounts" are made of serpentine rocks that originate from mantles. Why such rocks exist there remains mystery. While investigating the Torijima Seamount, one of the fore-arc seamounts, a cluster of organisms was discovered around bones of a bryde's whale. A multitude of organisms depend on the bones of the whale whose time of death is yet known.

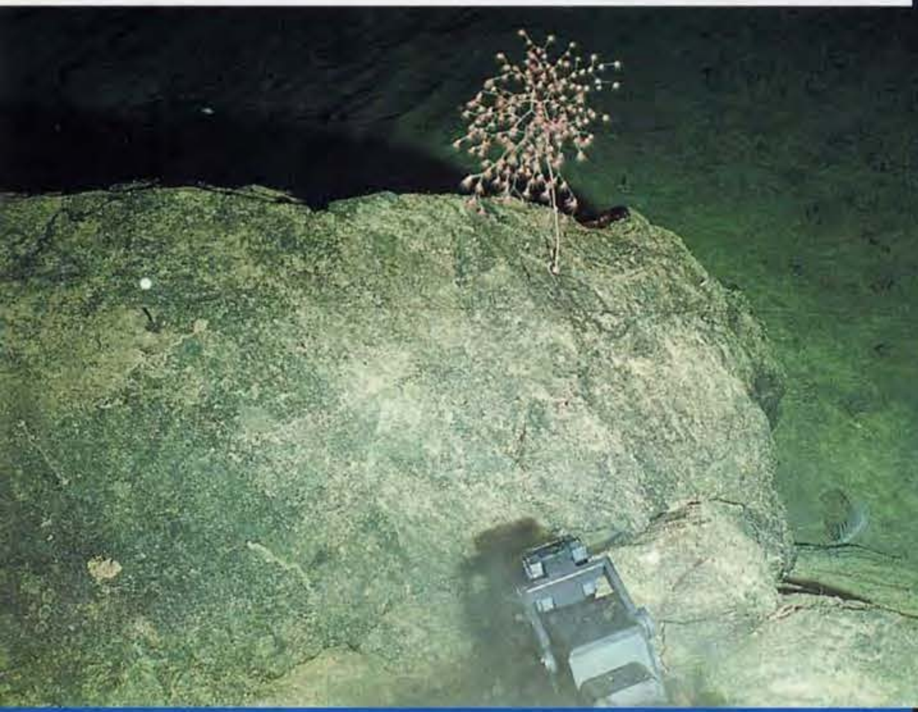
(Hideki Wada, Faculty of Science, Shizuoka University)

The Ogasawara Ocean Plateau (Cretaceous Coral Reef)

The 145th dive took place at the southwest end of the Ogasawara Ocean Plateau adjacent to the Marianas Trench. The photograph (page 13) shows limestone that is exposed on the steep slope which extends from 5,300m deep to 5,740m deep. Research showed that some sections of this limestone contained large quantities of calcareous algae, while others contained large quantities of bivalves and conches. It is thought to be sediments from coral reef lagoon of the early Cretaceous. The limestone's present depth of 6,000m tells us that it has sunk as much as 6,000m since the time it was formed at the surface.

(Eiich Tokuyama, Ocean Research Institute, University of Tokyo)



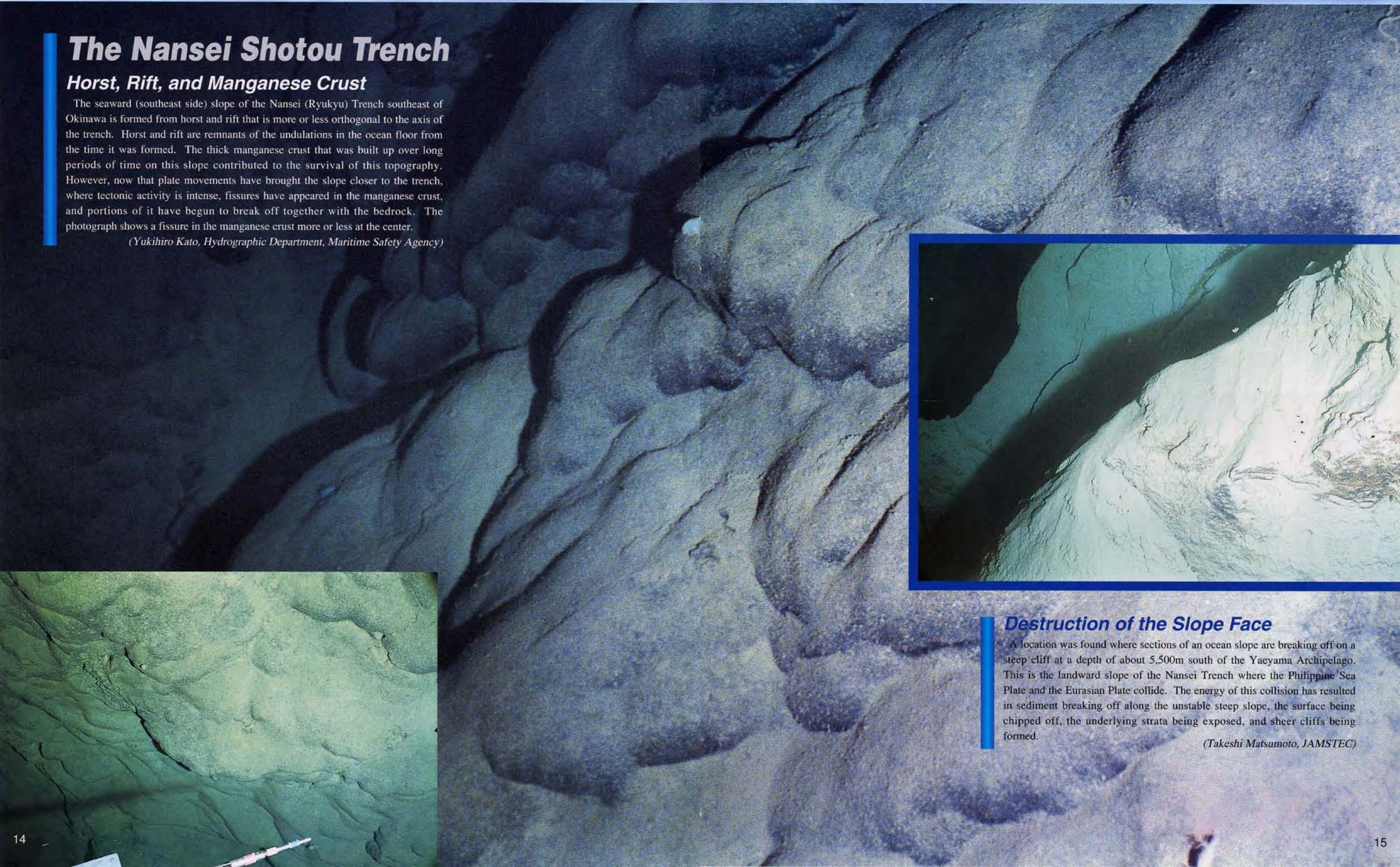


The Nansei Shotou Trench

Horst, Rift, and Manganese Crust

The seaward (southeast side) slope of the Nansei (Ryukyu) Trench southeast of Okinawa is formed from horst and rift that is more or less orthogonal to the axis of the trench. Horst and rift are remnants of the undulations in the ocean floor from the time it was formed. The thick manganese crust that was built up over long periods of time on this slope contributed to the survival of this topography. However, now that plate movements have brought the slope closer to the trench, where tectonic activity is intense, fissures have appeared in the manganese crust, and portions of it have begun to break off together with the bedrock. The photograph shows a fissure in the manganese crust more or less at the center.

(Yukihiro Kato, Hydrographic Department, Maritime Safety Agency)



Destruction of the Slope Face

A location was found where sections of an ocean slope are breaking off on a steep cliff at a depth of about 5,500m south of the Yaeyama Archipelago. This is the landward slope of the Nansei Trench where the Philippine Sea Plate and the Eurasian Plate collide. The energy of this collision has resulted in sediment breaking off along the unstable steep slope, the surface being chipped off, the underlying strata being exposed, and sheer cliffs being formed.

(Takeshi Matsumoto, JAMSTEC)

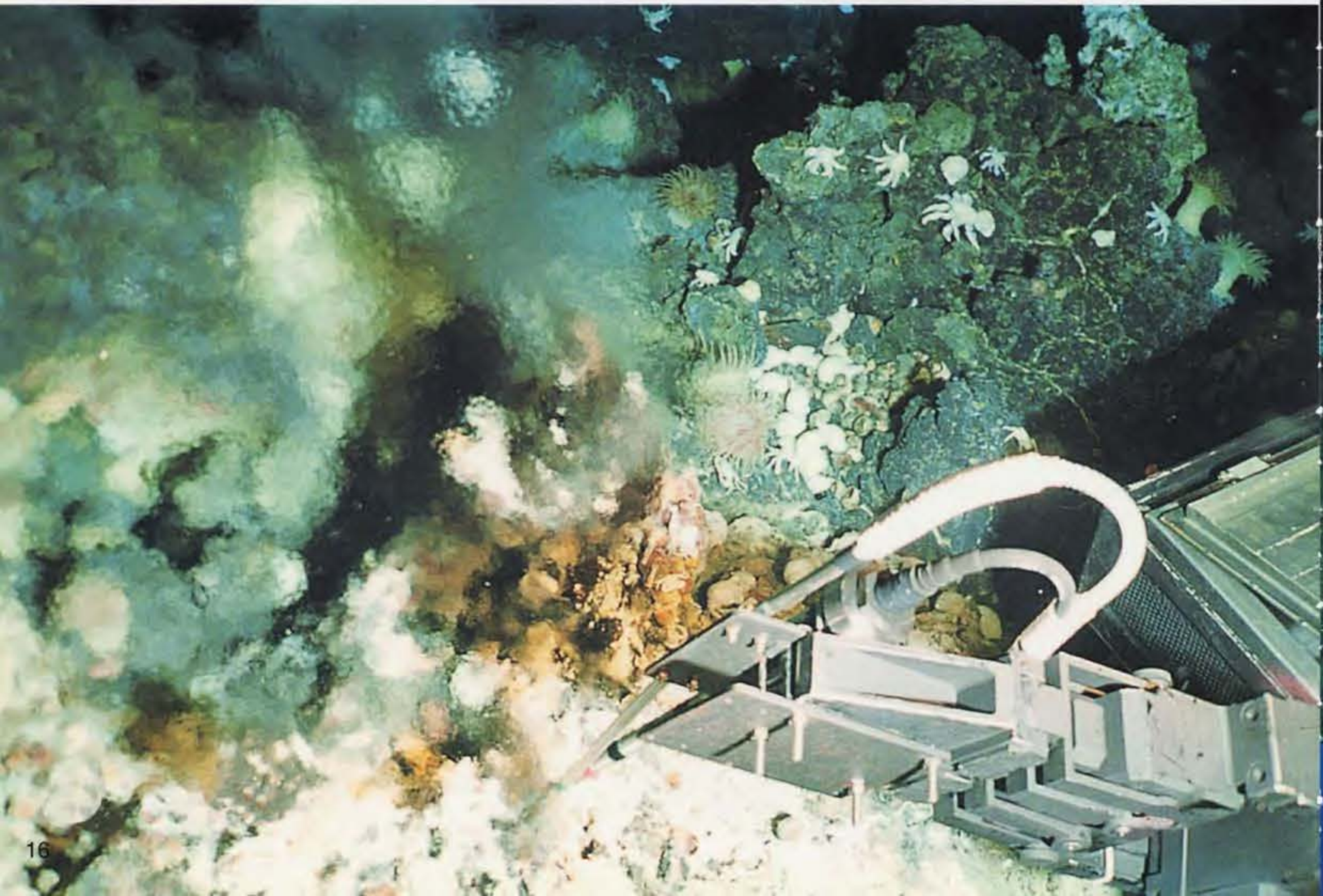
Voyages of the SHINKAI 6500 (4)

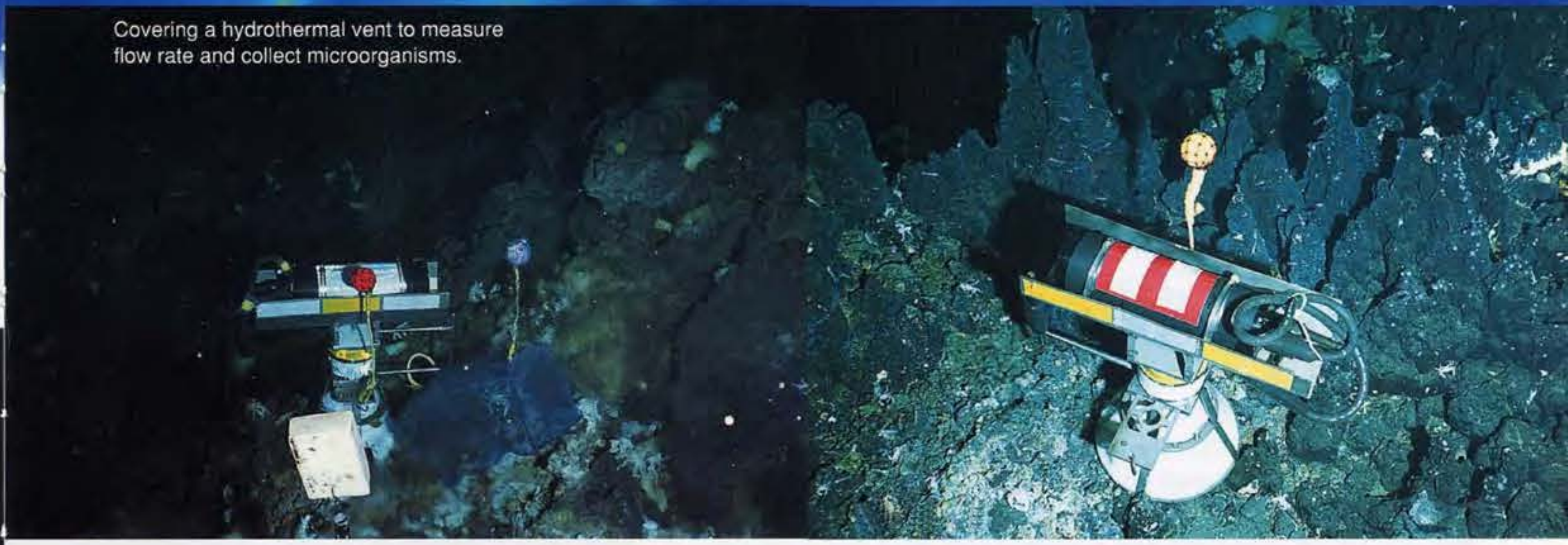
Mariana Trough

"Alice's Springs" Hydrothermal Chimney

This is a transparent hydrothermal fluid and a black bottle-shaped hydrothermal chimney observed at "Alice's Springs" in the central Mariana Trough (18°13'N, 144°42'E, depth 3,602m). On theleft in the photographbelow, you can see the area roiled by the outwelling of hydrothermal fluid (maximum temperature of 280℃). This photograph shows the process of hydrothermal sampling from the vent right in front of the chimney using a thermometer-equipped water sampler attached to the manipulator. Diverse organisms such as sea anemones, conches, crabs, and galatheidae can be seen in the vicinity of the chimney.

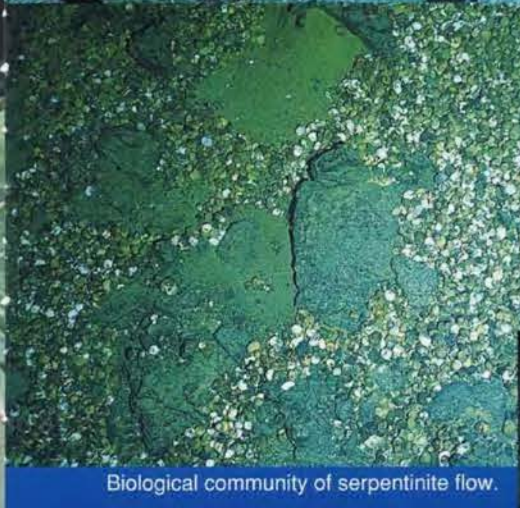
(Toshitake Gamo, Ocean Research Institute, University of Tokyo)





Covering a hydrothermal vent to measure flow rate and collect microorganisms.

Gorgonians growing on fresh basalt.



Biological community of serpentinite flow.

Carbonate baby chimney

Giant sea anemone on carbonic acid chimney.

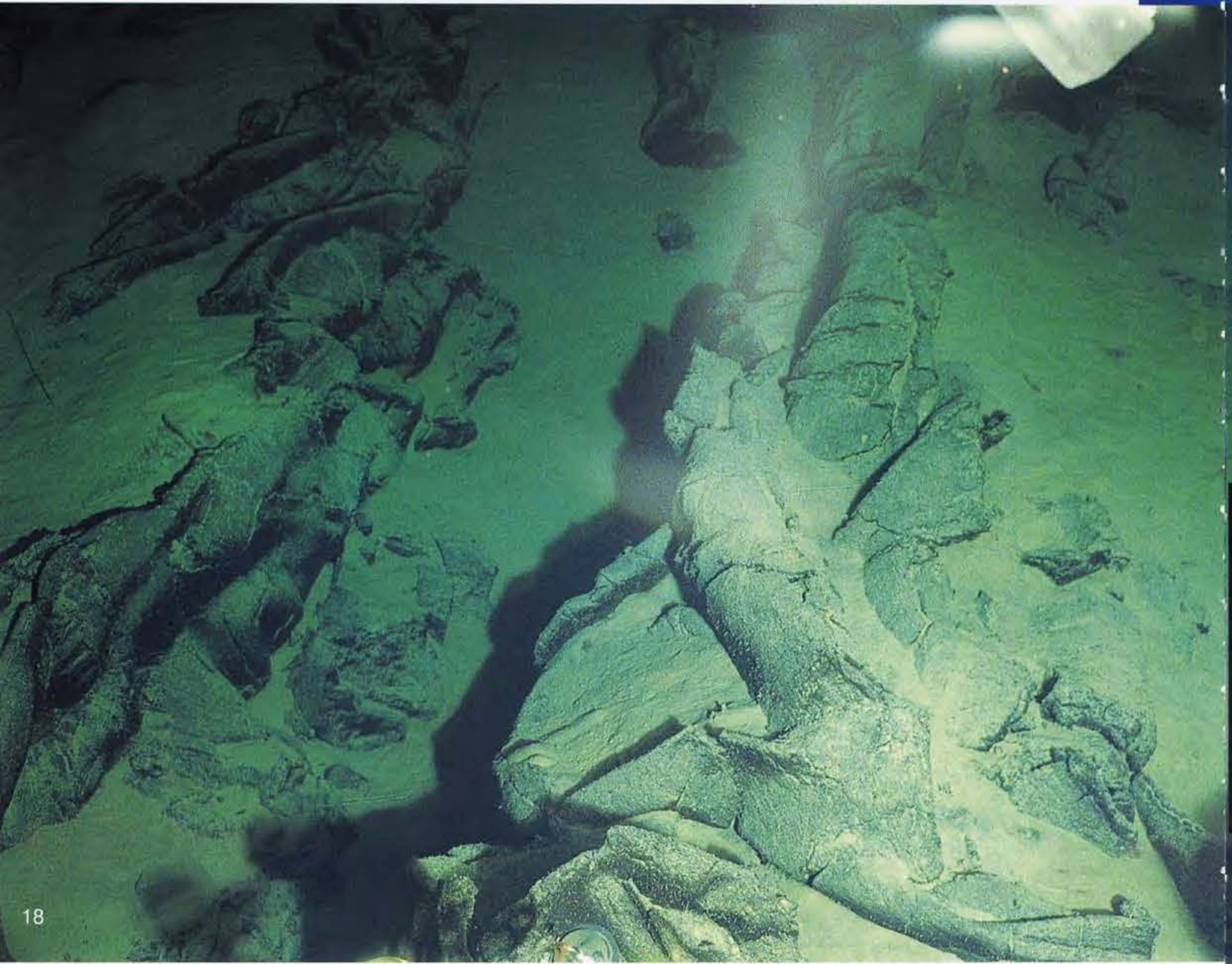
Voyages of the SHINKAI 6500 (5)

Southern Mariana Trough

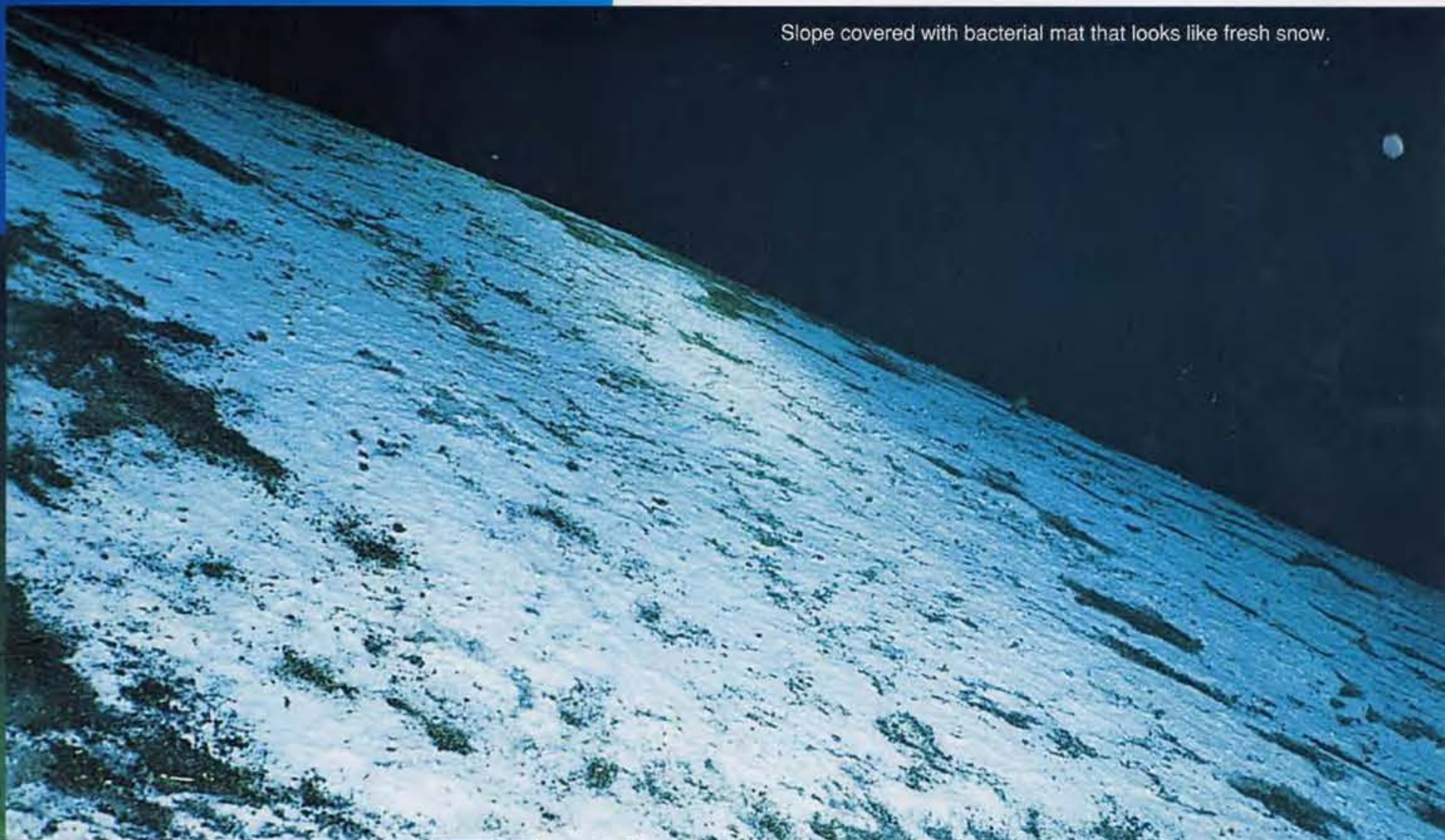
Fissure Extending Along the Deep Seabed

This is one of a number of fracture zones observed where ropy lava (back arc basin basalt of the same composition as the ocean crust) was exposed along the seabed extending outward from the base of a small seamount in the Southern Mariana Trough. The fissure's sharp edge and the thin layer of sediment covering the outcrops indicate that the seabed is in an area of dynamic tensile stress. Hydrothermal activity was also observed by SHINKAI 6500 at the island arc seamounts in this area. These facts prove that ocean crust formation adjacent to the island arc crust is currently in progress.

(Harue Masuda, Faculty of Science, Osaka City University)

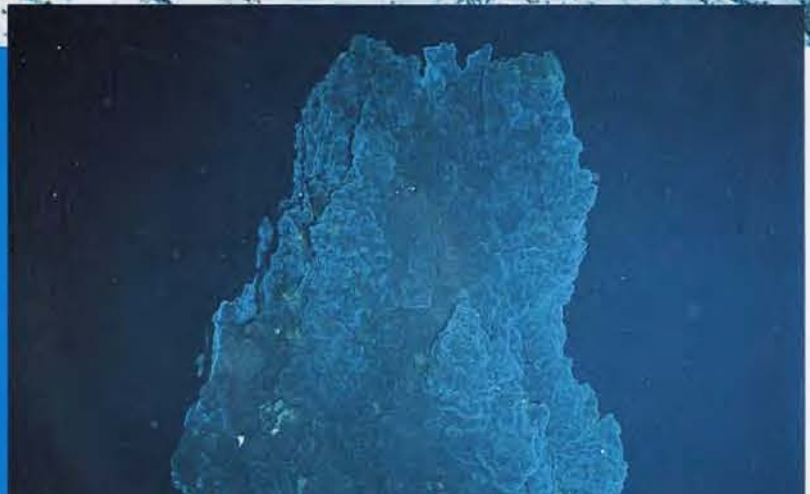


Giant symbiotic gastropod Alviniconcha hesseleri clustering around hydrothermal fluid.



Slope covered with bacterial mat that looks like fresh snow.

Seismometer at the sea bottom.



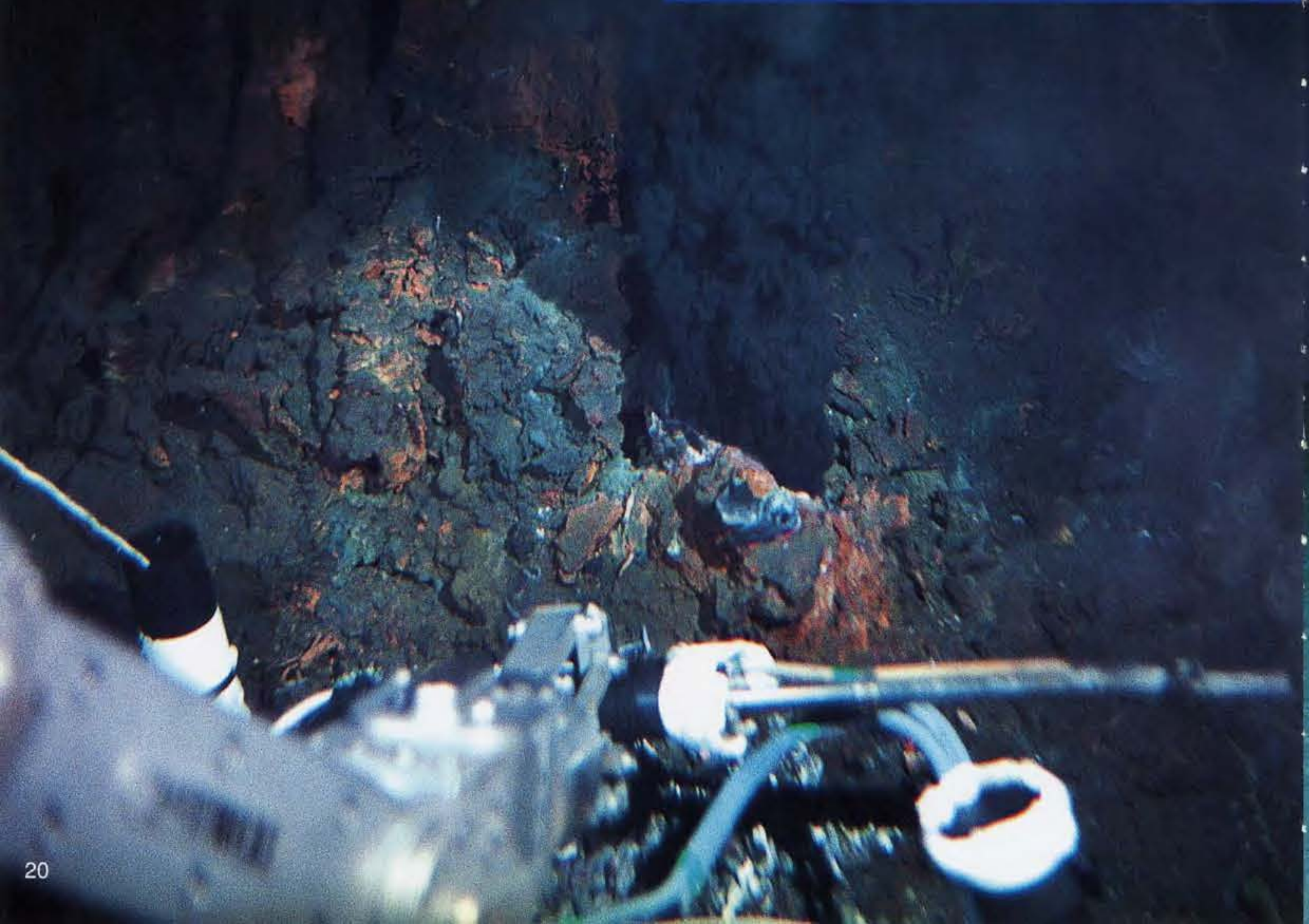
Mid-Atlantic Ridge

Rainbow Site

The photograph below shows a black smoker (depth 2,300m, temperature 360℃) in the Rainbow hydrothermal site (36°13'N, 33°54'W) of the Mid-Atlantic Ridge. The fluid is much darker than those of other sea-bottom hydrothermal systems because it contains large amounts of iron. Numbers of extinct chimneys as much as over 10m high are around this chimney actively venting.

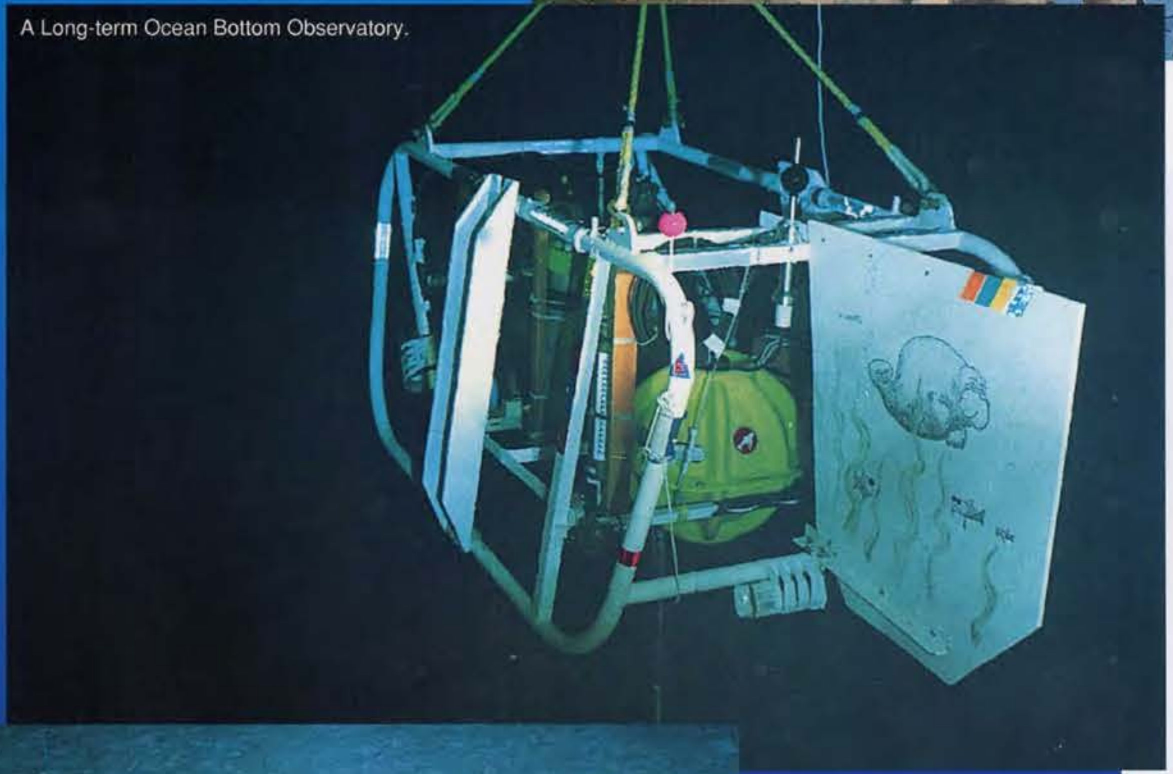
The fluid of this hydrothermal system is not heated by magma but by the heat from transformation of rocks that comprise the mantle exposed on the seabed.

(Hitoshi Chiba, Institute for Study of the Earth's Interior, Okayama University)



Heat flow sensor

A marker for International Ocean Drilling Program.



A Long-term Ocean Bottom Observatory.

Measuring heat flow.

Mid-Atlantic Ridge

TAG Hydrothermal Mound and Kane Fracture Zone

There is a giant TAG hydrothermal mound of 200m across and 50m high, as big as the Tokyo Dome, in the axial trough at latitude 26°N on the Mid-Atlantic Ridge. The two-level, circular conic mound of aggregated sulfides rises up high like a cakestand. 350℃ black smoke vents like steam locomotive exhaust from a nearly 20m high giant black smoker "Laputa" on top of the mound. Eyeless shrimps "Rimicaris" and "Chorocaris" cluster around it.

(Kantaro Fujioka, JAMSTEC)

Pillow lava

Rimicaris exoculata cluster around a black smoker

Deep rocks and deformation caused by fault activity

The East Pacific Rise

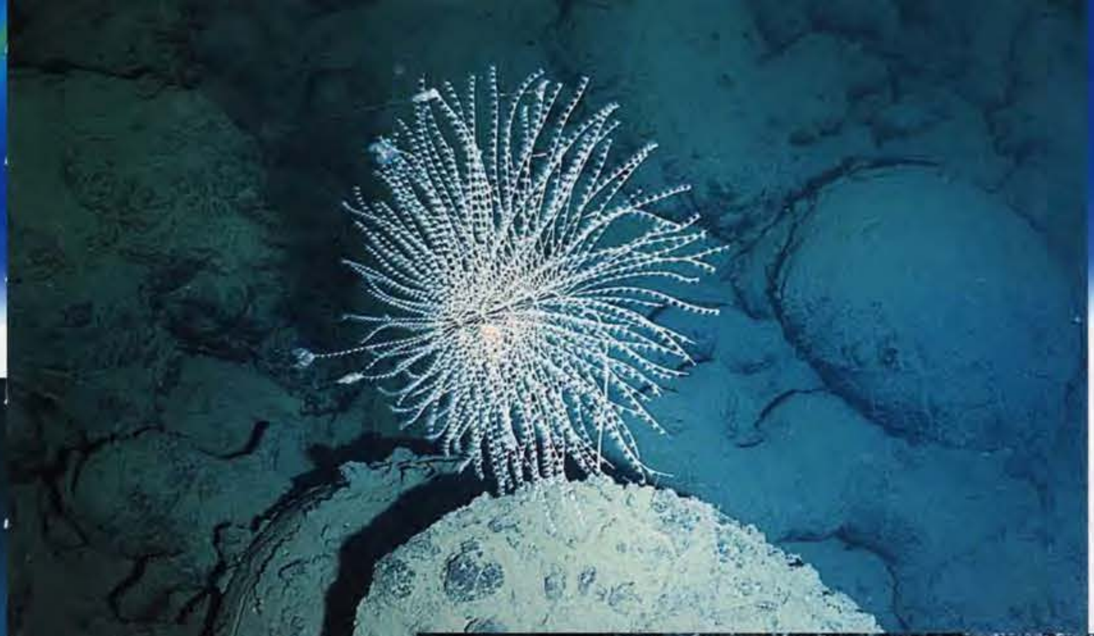
Long-Term Sea-Bottom Observation

When the SHINKAI 6500 first visited this site in 1994, relatively low-temperature hydrothermal fluid was being vented over a wide area. Although, when the submersible returned there three years later, hydrothermal activities and living organisms were all virtually extinct. This is a valuable instance for demonstrating that hydrothermal activities last several years *(see photograph on right).* In order to clarify the temporal variation of hydrothermal activities, observations using the Long-term Ocean Bottom Observatory and hydrothermal flow measurement device were conducted under the Ridge Flux Project.

At the East Pacific Rise, 4,000km off the coast of Chile, volcanic eruptions occur every several years to a decade. A lava flow took place at this location in the early 1990s, and there is a pool of magma less than 1 km beneath the seabed. The gaseous components emitted by this magma are dissolved into the low-temperature hydrothermal and come gushing out.

This torrent is inhabited by numberless fish and small crustaceans. The Ridge Flux Project placed a number of devices here to conduct the world's first year-long sea-bottom observation. The bottom photograph shows one of those devices, an instrument for measuring hydrothermal flow

(Tetsuro Urabe, Geological Survey of Japan)



Large Galapagos tube worms and small tube worms in the roiling water.

Voyages of the SHINKAI 6500 (9)

The East Pacific Rise

A Group of Hydrothermal Chimneys Lined up in a Row

On a peak of the East Pacific Rise at latitude 18°S, there is a trough-like rift that is 200-800 m in width. Inside this are several terraces formed by slippage from normal faults. The rift also contains lava lakes filled with magma and pillars formed when ceilings collapsed. The chimneys are mostly located in a line that follows the direction of the submarine ridge, creating a scene that looks exactly like a tree-lined highway Various names, such as pagoda and birch, have been given to this area.

(Kantaro Fujioka, JAMSTEC)

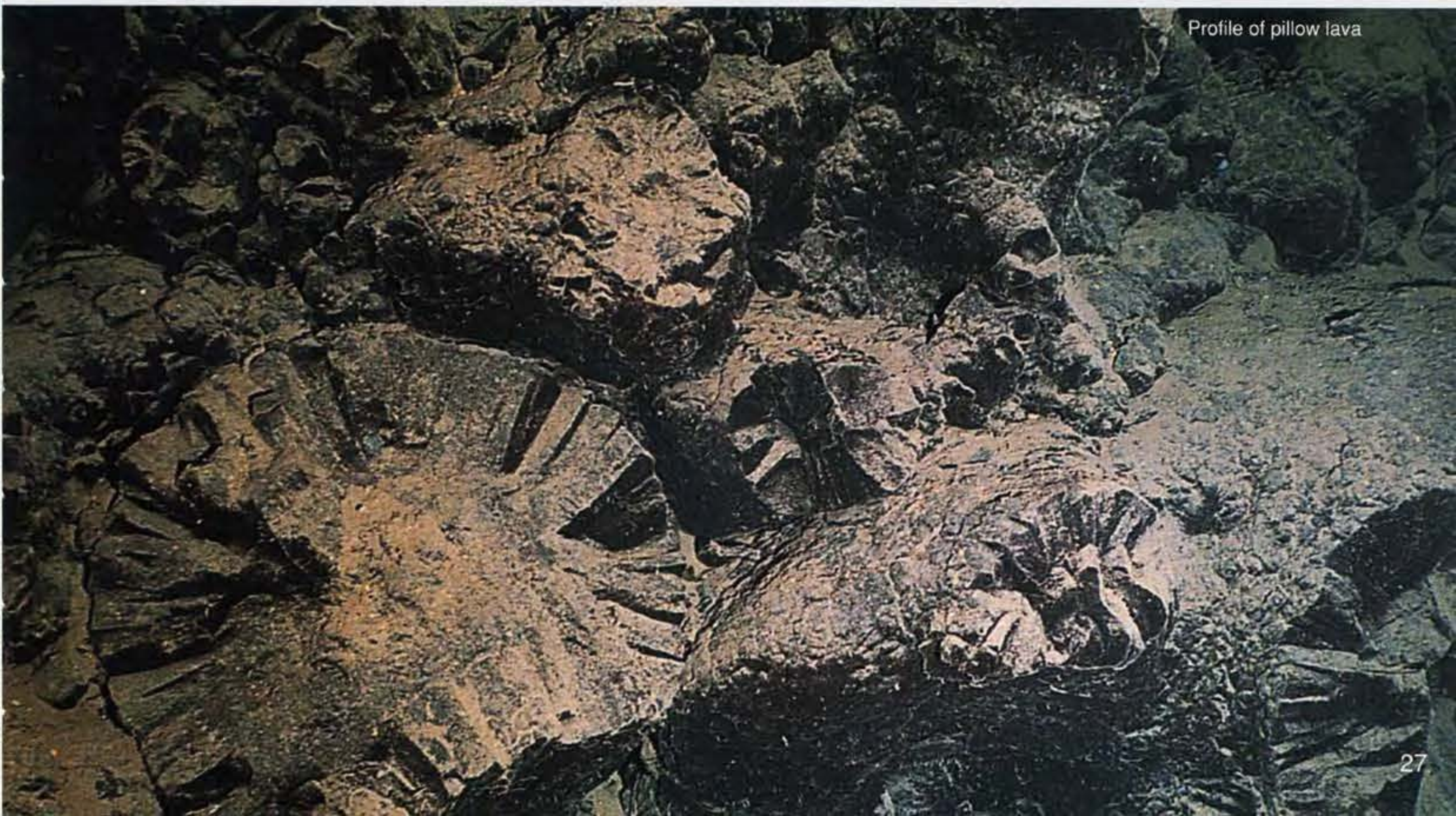

Tripod fish


Collecting hydrothermal fluid


Heat flow sensor


Bythograeid crabs


Lava cooled off and fissured.


Profile of pillow lava

Voyages of the SHINKAI 6500 (10)

The North Fiji Basin

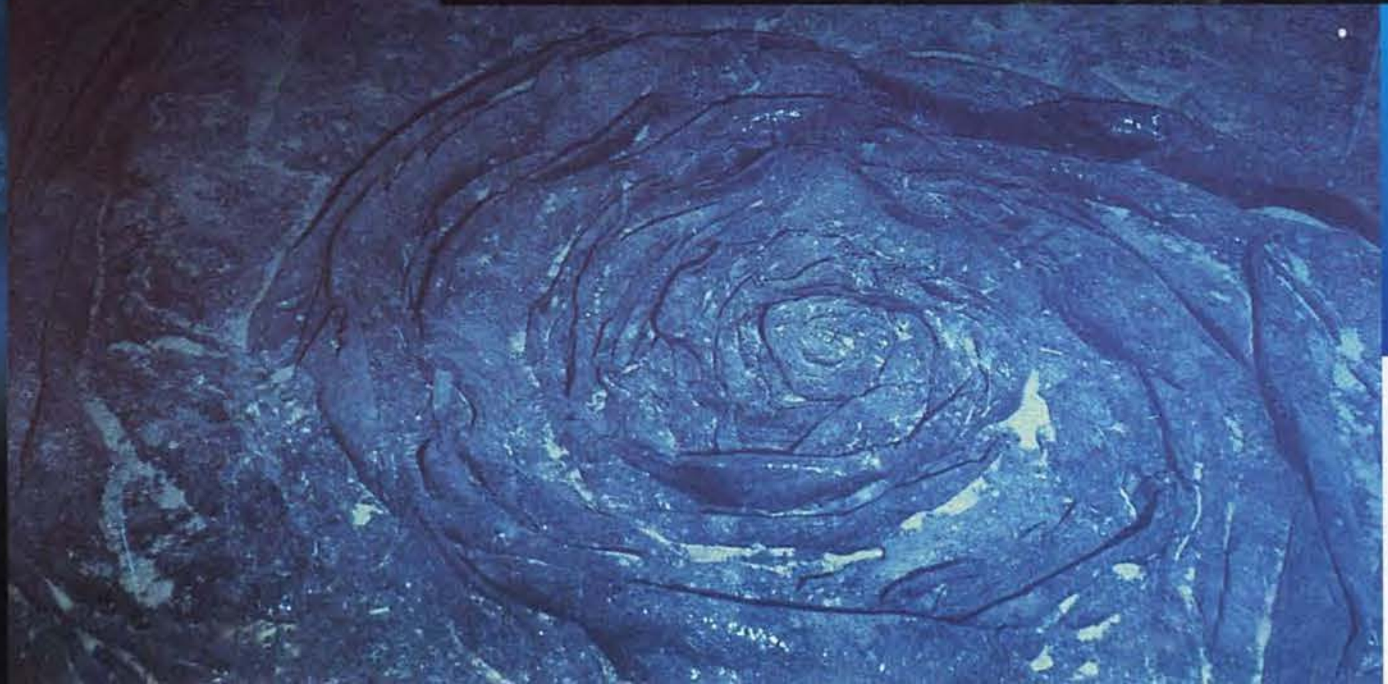
A Variety of Lava

The SHINKAI 6500's first dive outside Japanese waters was for the joint French-Japanese STARMER Program in the North Fiji Basin. Here evidence remains of the existence of a lava lake. The surface of the lava lake came into contact with the sea water and solidified, forming a ceiling a few centimeters thick. This ceiling collapsed after the magma inside flowed out, but sections of it supported by lava columns of some 2m high still remain and they look like propellers on shafts, as shown in the bottom photograph. Close examination shows scattered ceiling fragments around the feet of the lava columns.

In 1989, the French submersible Nautile discovered a giant colony of *bathymodiolus* (a mussel). The SHINKAI 6500 looked for it two years later, but found no trace. As seen in the photograph, only small colonies existed on the extremely fresh lava. It appears that a lava flow occurred during those two years burying the colony, but this knowledge was not available at that time.

(Tetsuro Urabe, Geological Survey of Japan)

Small colony of *bathymodiolus*.



Voyages of the SHINKAI 6500 (11)

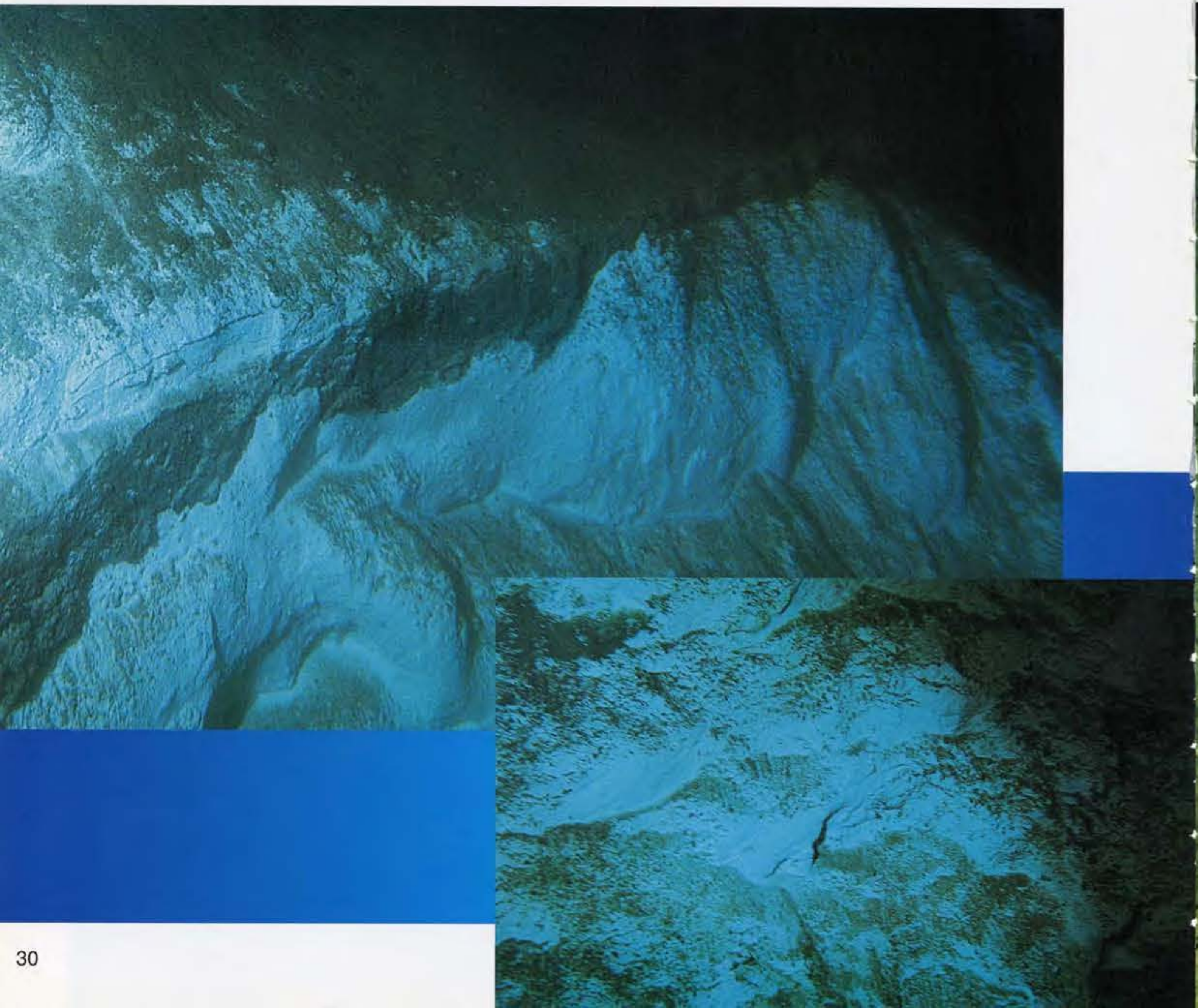
The Palau Trench

A Cretaceous Wall

At a depth of 6,500m in the Palau Trench, there is a wall of stark white limestone *(bottom photograph)*. The existence of this limestone at 6,500m presents a mystery because limestone dissolves at depths greater than 4,500m. Why is limestone found at such a location?

Recent research indicates the possibility that the limestone in shallow waters in the Palau Archipelago collapsed and was carried down into the ocean depths. Possibly the collapse was due to a large-scale earthquake followed by a large tsunami similar to the one that hit the northern coast of New Guinea in 1998.

(Hiroshi Kitazato, Department of Biology and Geosciences, Faculty of Science, Shizuoka University)



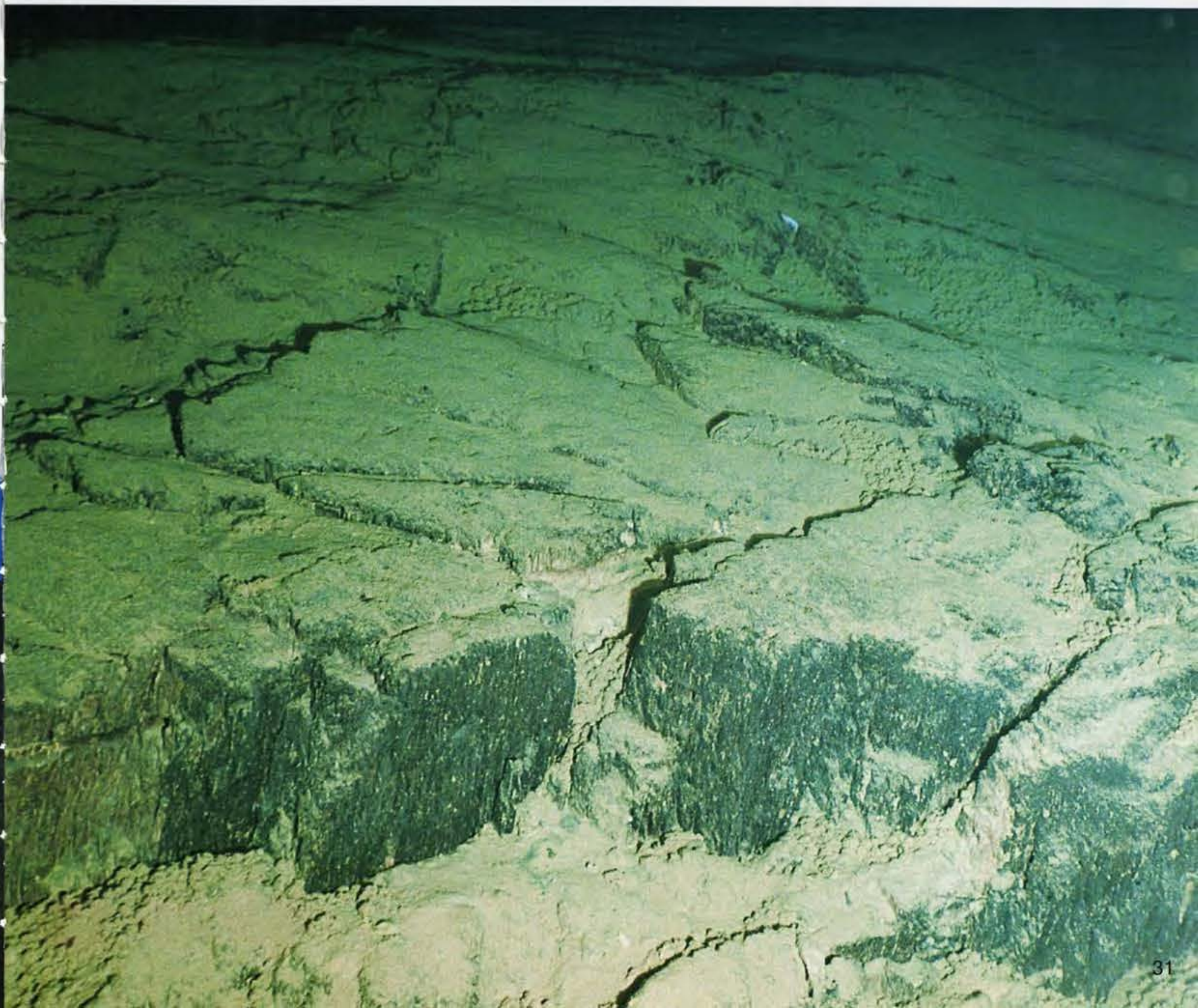
Voyages of the SHINKAI 6500 (12)

The Yap Trench

Serpentinite on the Landward Slope Face

The submersible landed on the mud at a depth of 6,392m. Just as the slope grew steep, outcrops appeared. They were serpentine, very much like the serpentinite flow in Marianas, covered with manganese. Similar outcrops were seen at 6,278 and 6,270m deep and they were either of serpentinite or olivine. A part of the serpentine could have been carried there in a debris flow, but most were outcrops that already existed there.

(Azusa Nishizawa, Hydrographic Department, Maritime Safety Board)



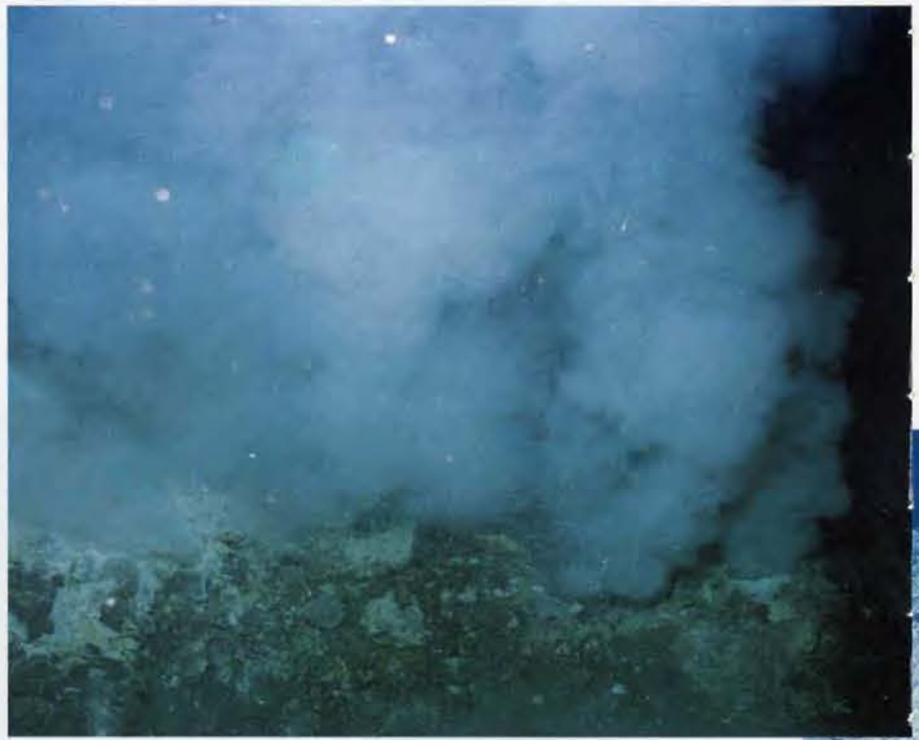
The Manus Basin

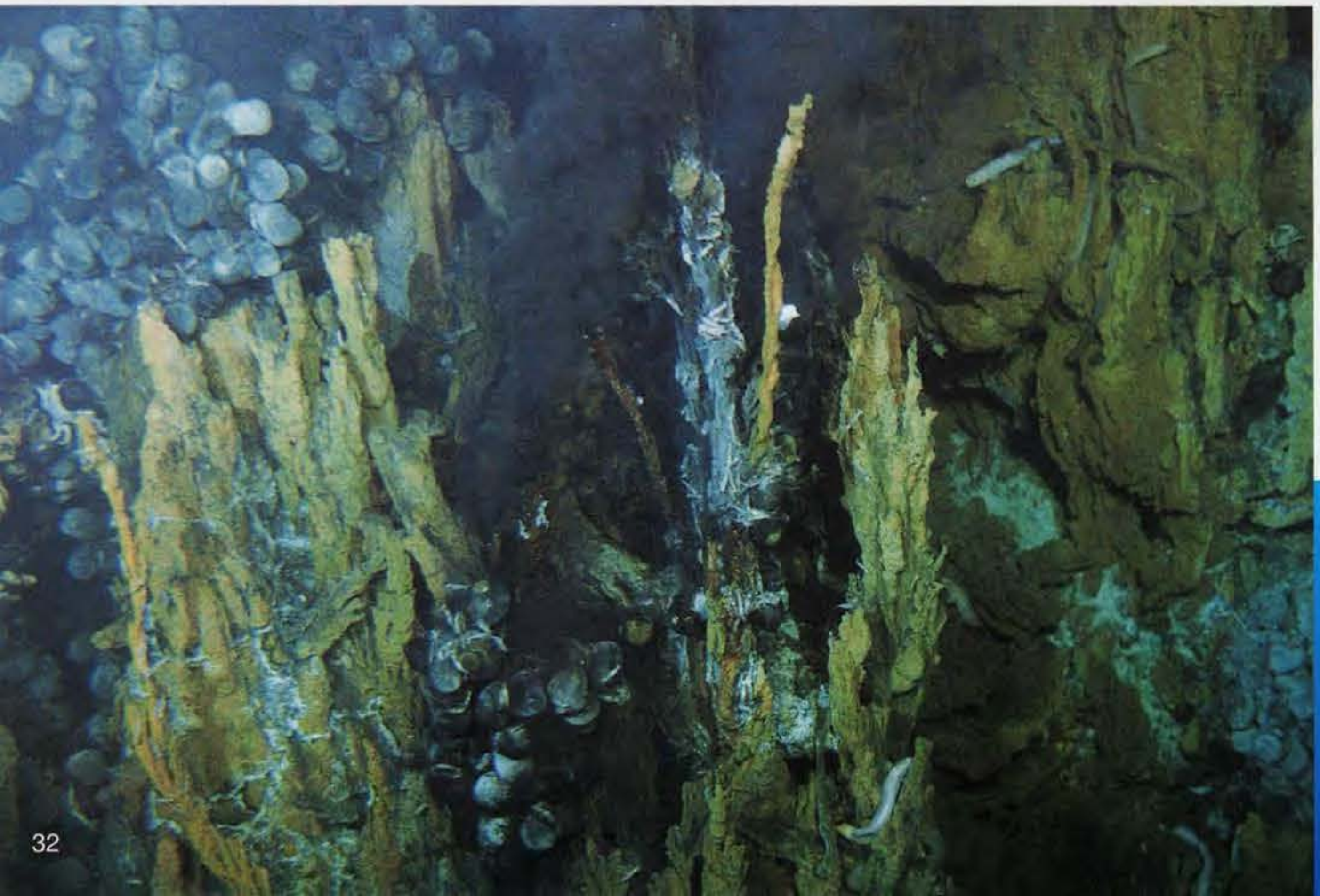
PACMANUS and DESMOS

The deep-sea bottom of the Manus Basin in Papua New Guinea is known for its hydrothermal phenomena and hydrothermal vent communities. The bottom photograph (of a black smoker) was taken at a depth of 1,700m at the PACMANUS site, while the one on the right (of a white smoker) was taken at 1,900m at the DESMOS site. The two sites are barely 20km apart, yet they differ this greatly in appearance.

The chemical compositions of the hydrothermal fluids differ with the physical substance of the magma, and the communities of living creatures that grow there differ with the chemical composition of the hydrothermal fluid.

(Jun Hashimoto, JAMSTEC)





The Indian Ocean

Mankind's First Dive to the Bottom of the Indian Ocean

The first time that mankind reached the bottom of the Indian Ocean was fall 1998, when the SHINKAI 6500 was used for research on the sea-bottom spreading axis known as the Southwest Indian Ridge during MODE'98. Apart from the Arctic Ocean, this is where the world's slowest spreading is taking place. The supply of magma is small and concentrated in one area where fault activity is intense and hydrothermal activity has also been reported, making this a ridge that deserves attention.

Samples were collected from chimneys marking the location of past hydrothermal activity near the top of the seamount where the magma activity is concentrated.

(Hiromi Fujimoto, Ocean Research Institute, University of Tokyo)

MODE'94

Mid-Oceanic Ridge Diving Expedition, 1994

The SHINKAI 6500 carried out fifteen dives at the Kane Fracture Zone during the first Mid-Atlantic Ridge diving cruise (Leg1), June 25-July 24, 1994. Afterward, the Team called at the Woods Hole Oceanographic Institution for an open house and exchange among researchers. Subsequently, fifteen dives were conducted at the TAG hydrothermal mound during the second Mid-Atlantic Ridge diving cruise (Leg2) from July 29 to August 27.

From September 14 to October 19, after passing through the Panama Canal, the SHINKAI 6500 carried out fifteen dives for the first East Pacific Rise diving cruise (Leg3) in the vicinity of latitude 18°S. This was the first time for a JAMSTEC vessel to put in at Valparaiso Harbor in Chile. From October 25 to November 29, the second East Pacific Rise diving cruise (Leg4) was carried out in the same area, making a total of thirty dives in this sea area and completing all sixty dives planned for 1994.


● Participants of the 2nd Mid-Atlantic Ridge diving cruise (Leg2).

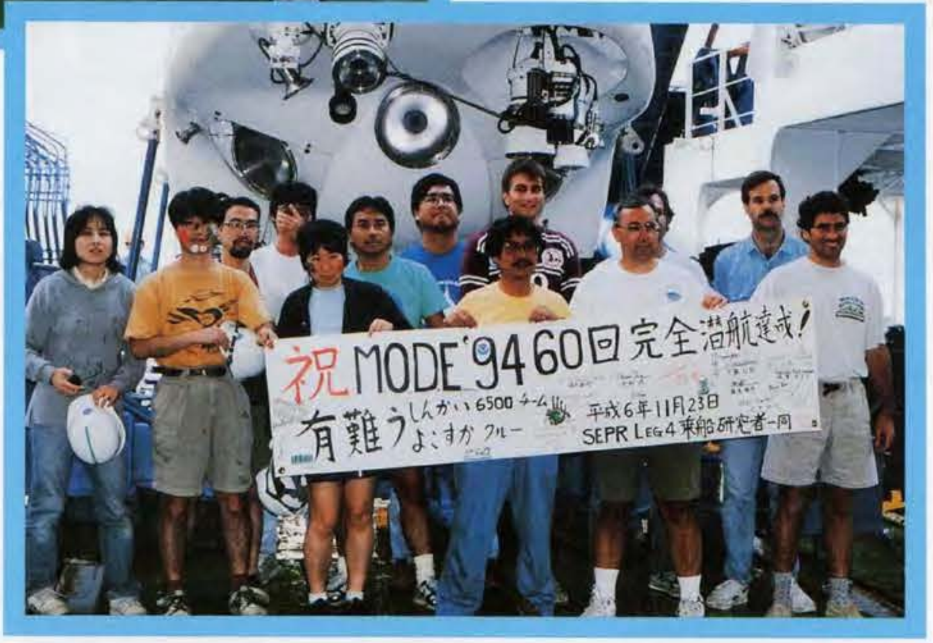

● Side-sliding SHINKAI 6500 in the hanger of R/V YOKOSUKA, which is no long seen today.

● Researchers of the 1st East Pacific Rise diving cruise (Leg3).


● Woods Hole Oceanographic Institution as seen on board R/V YOKOSUKA while bringing the vessel in.

● Researchers of the 1st Mid-Atlantic Ridge diving cruise (Leg1).


● R/V YOKOSUKA at the WHOI pier.



● Researchers of the 2nd East Pacific Rise diving cruise (Leg4).

MODE'98

Mid-Oceanic Ridge Diving Expedition, 1998

The SHINKAI 6500 carried out fourteen research dives at the 15°20'fracture zone on the first Mid-Atlantic Ridge diving cruise (Leg1) of June 17 - July 17, 1998. The Team then put in at Lisbon Harbor in Portugal, to hold an open house at EXPO'98, JAMSTEC's first in Europe, on July 19-20. A total of 9,000 visitors toured the YOKOSUKA and SHINKAI 6500 at the EXPO pier.

The second Mid-Atlantic Ridge diving cruise (Leg2) took place from July 23 to August 23, when fifteen dives were conducted at TAG, Dante's Dome, and Rainbow. Having completed its research dives in the Atlantic, the Yokosuka passed through the Mediterranean Ocean and the Suez Canal, heading for the Indian Ocean. On the way, it put in at Port Louis in Mauritius.

From September 20 to November 18, the SHINKAI 6500 carried out the world's first research dives in the Indian Ocean as a manned submersible. A total of 25 research dives were made at the Southwest Indian Ridge and the Central Indian Ridge throughout Leg3 and 4 in the Indian Ocean.


● Open House at EXPO'98.


● R/V YOKOSUKA at EXPO' 98 pier.


● SHINKAI 6500 submerging into the Indian Ocean.


● EXPO' 98 Japan Pavilion


● SHINKAI 6500 model displayed at EXPO'98 Japan Pavilion


● Ms. Ayako SONO, Chair person of the Nippon Foundation, touring SHINKAI 6500.


● Reception on board R/V YOKOSUKA.


● Placid Indian Ocean

● Participants of the 1st Mid-Atlantic Ridge diving cruise (Leg 1).

● SHINKAI 6500 emblem painted on the EXPO'98 pier by Mr. Tsuyoshi YOSHIUME of SHINKAI 6500 Team.


● Sunset in the Indian Ocean


● Water Front zone of Port Louis, Mauritius. R/V YOKOSUKA moored at the opposite side.

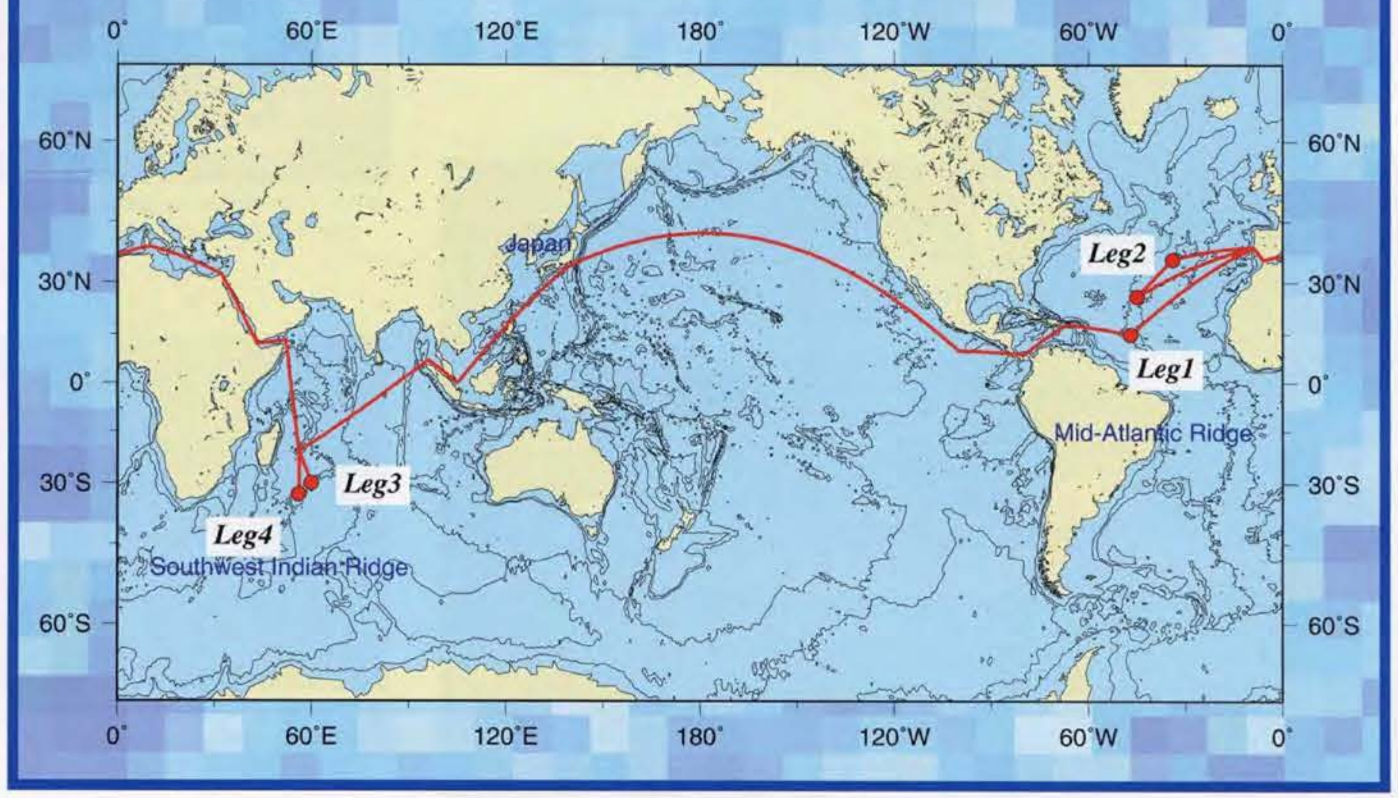

● R/V YOKOSUKA moored at Old San Juan in Puerto Rico.


● "Padrão dos Descobrimentos" in Lisbon, Portugal.

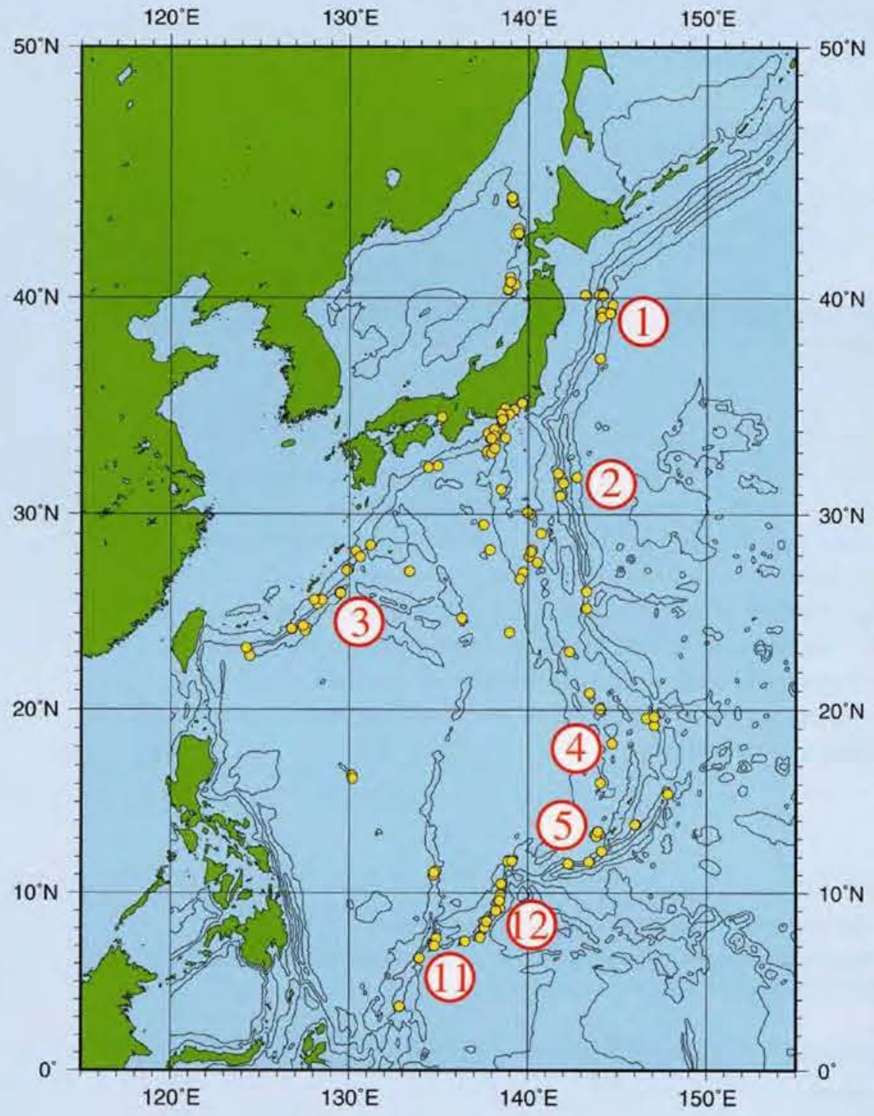
● View of Mauritius.

● Participants of the Indian Ocean Diving Cruise.

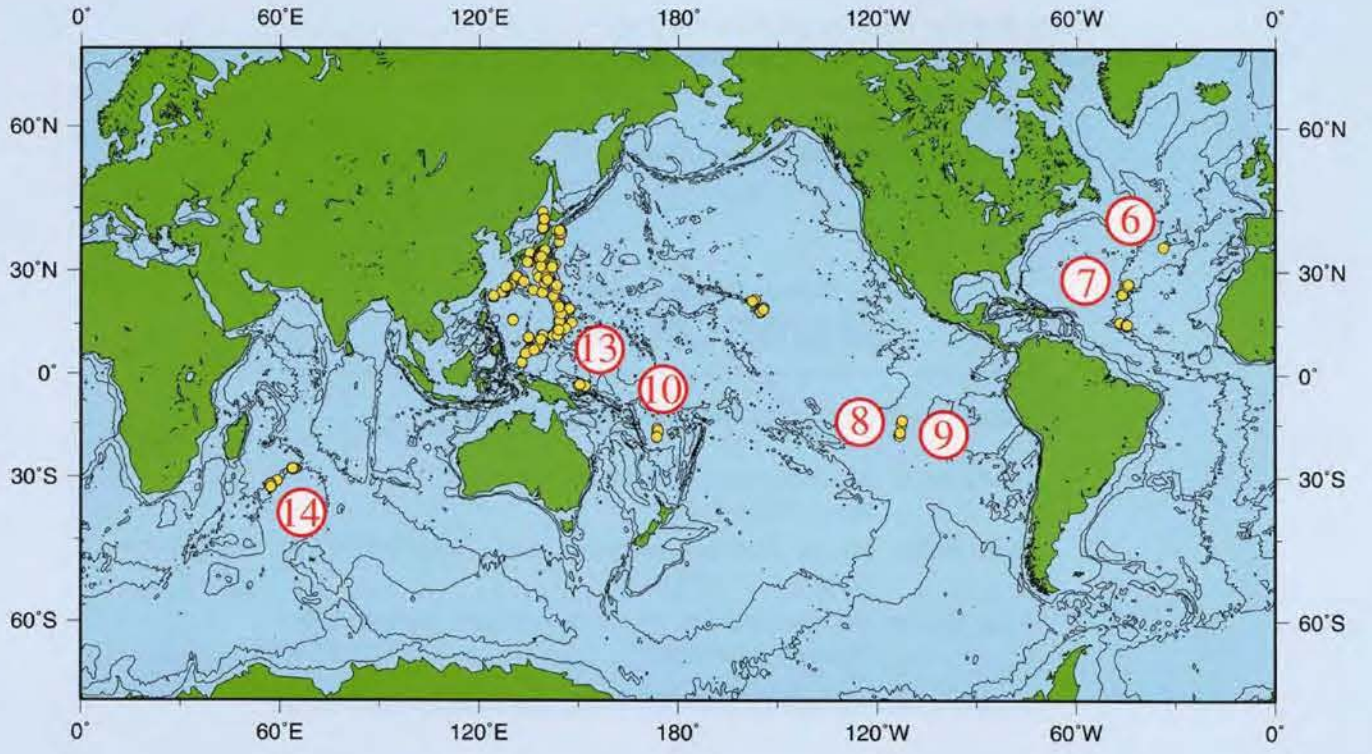
Course of R/V "YOKOSUKA" in MODE'98



SHINKAI 6500 Dive Locations and Sea Areas



①	Japan Trench	(pp.10-11)
②	Izu-Bonin Trench	(pp.12-13)
③	Nansei Shotou Trench	(pp.14-15)
④	Mariana Trough	(pp.16-17)
⑤	Southern Mariana Trough	(pp.18-19)
⑥	Mid-Atlantic Ridge	(pp.20-21)
⑦	Mid-Atlantic Ridge	(pp.22-23)
⑧	East Pacific Rise	(pp.24-25)
⑨	East Pacific Rise	(pp.26-27)
⑩	North Fiji Basin	(pp.28-29)
⑪	Palau Trench	(p.30)
⑫	Yap Trench	(p.31)
⑬	Manus Basin	(p.32)
⑭	Indian Ocean	(p.33)



Editor's Postscript

The SHINKAI 6500 has set numerous records so far, and we are certain that it will keep making records in the future. Taking the vessel's five hundredth dive as an appropriate juncture, we have put together this pamphlet in hopes that it will increase public interest in the deep-sea bottom. We also hope that it will be of some use to researchers' studies in the future.

We have used photographs of the construction and maintenance of the SHINKAI 6500 that are not seen very often, as well as the sea-bottoms explored by SHINKAI 6500 around the globe.

Experts who are most familiar with the dive areas have kindly selected photographs and contributed comments on them. There are, or course, numerous superb photographs besides those in this pamphlet. We hope to introduce them at other opportunities in the future.

We acknowledge with deep gratitude the cooperation given by the researchers and all others concerned in the course of publishing this pamphlet.

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