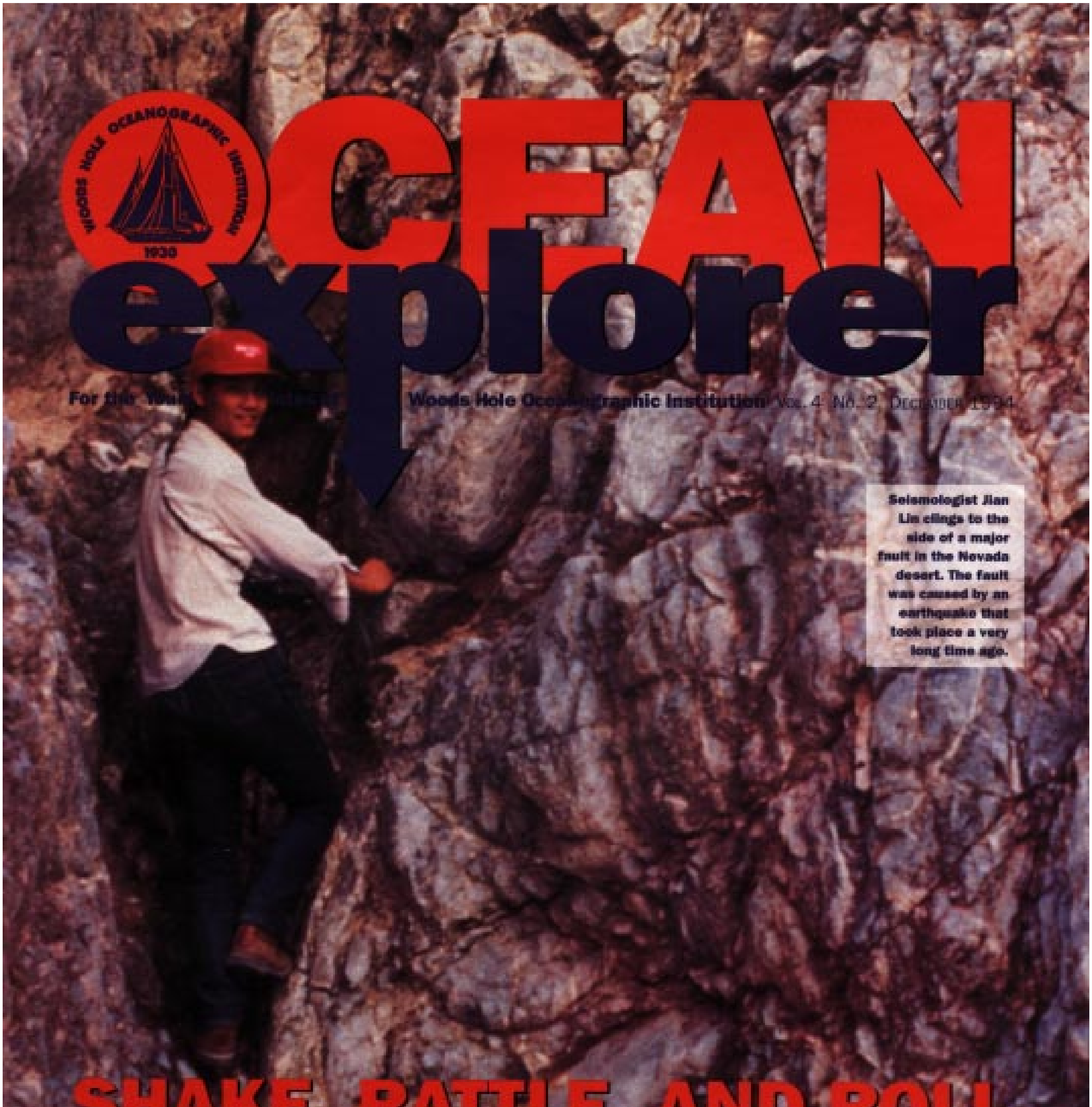


OCEAN explorer

For the ... Woods Hole Oce...graphic Institution Vol. 4 No. 2 December 1994

Seismologist Jian Lin clings to the side of a major fault in the Nevada desert. The fault was caused by an earthquake that took place a very long time ago.

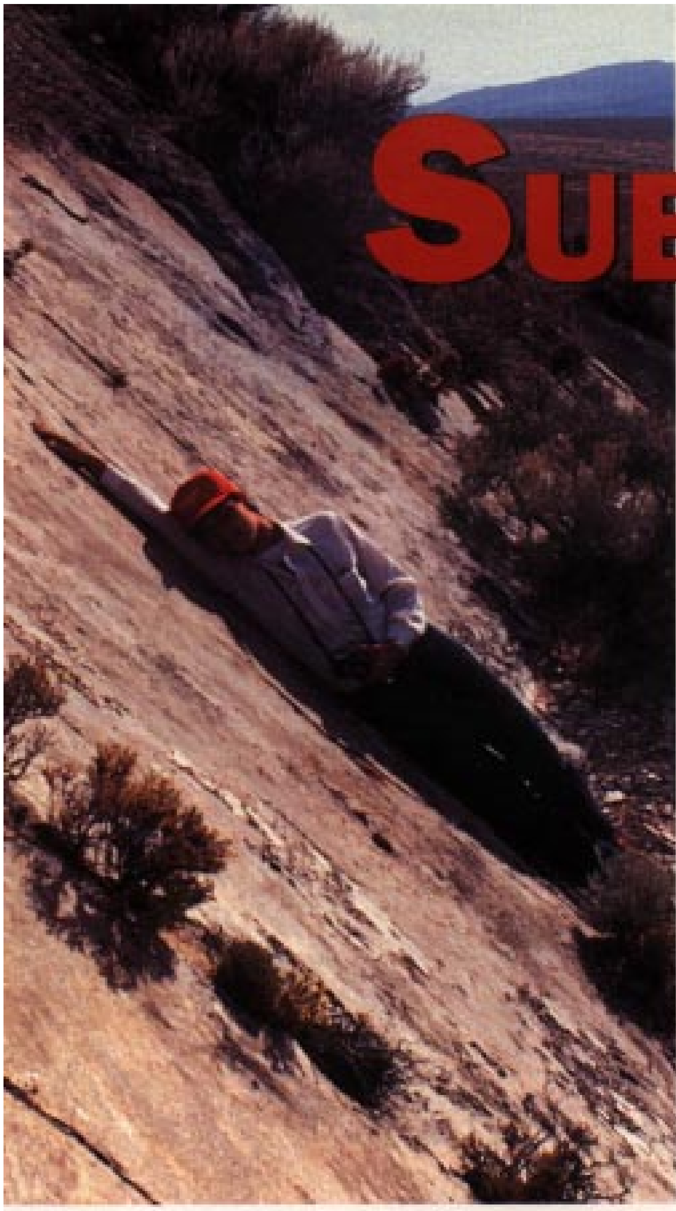
SHAKE, RATTLE, AND ROLL

The earth's surface is not really the firm ground we think it is. Our planet's outer layer, the 70 km-thick crust, is made up of about a dozen separate plates that fit together like the pieces of a jigsaw puzzle. The plates float upon a layer of molten rock that lies beneath the crust.

Deep within the earth, stresses and pressures are created that cause the crust to bend, and finally to snap into new positions. These pressures set the plates constantly in motion, sliding over, under, and past each other at about the speed your fingernails grow. The motions of the plates cause vibrations that are called earthquakes.

Many earthquakes happen on land. But most earthquakes happen on the bottom of the sea. Ninety percent of earthquakes occur at the boundaries of the planet's twelve major plates.

In this issue, *Ocean Explorer* will tell you about new research on earthquakes. We'll travel from the suburbs of Los Angeles to the bottom of the Atlantic Ocean. You'll learn about tsunamis, the dreaded "harbor waves" that can cause more damage than earthquakes themselves. And you'll find out what biologist Charles Darwin had to say about one of the worst earthquakes ever to occur in Chile. Hang on! It's going to be a wild ride!



Jian Lin explores a major surface break caused by earthquakes, "up close and personal."

SUBTERRANE

Scientists Try to Understand the Causes of Earthquakes–by Deborah Kovacs

In 1976, a terrible disaster struck the city of T'an Shan, in the northern part of China. The city was just about destroyed by an earthquake that registered magnitude 7.8 on the Richter Scale *(see page 5)*. More than 250,000 people were killed. Many more were injured. Throughout the country, people were terrified.

At the time, a fifteen-year old boy named Jian Lin was living in a city called Fu Zhou, on China's southern coast. Materials were desperately needed from provinces throughout China to help with the disaster. Jian's province was asked to send bamboo poles and large plastic bags. The bamboo poles were to help survivors build temporary housing. It is the memory of why the plastic bags were needed that still haunts Jian. They were used to bury the dead. "There were so many dead people, supplies were needed from other provinces just for body bags," he said recently.

Almost twenty years later, Jian still thinks about that earthquake quite often. His reaction to it led him to his life's work. In his high school years, Jian became one of a million volunteer "earthquake watchers" and collected such data as daily changes in ground water levels for professional scientists. (Rising and falling water levels may be a clue to activity beneath the crust of the earth.) He was later trained as a seismologist, an earthquake scientist, in colleges and graduate school. Jian is now a scientist at WHOI, trying very hard to understand the mechanisms that cause earthquakes and their aftershocks. He hopes this understanding will eventually allow him and others to predict earthquakes, with some degree of accuracy. "Perhaps if we can tell people what might happen, we can do something so kids in the future won't be as scared as I was," says Jian.

> **"** *I still get scared of earthquakes, even as a scientist, because I don't know enough about them.... In the future, we hope to get some clues as to what the sequence of an earthquake is.* **"**
>
> —Jian Lin

MODEL-MAKER

To help make his predictions, Jian looks at the pattern and sequence of major earthquakes, and builds computer models, "what if" programs, that create images such as the one on page 3. To collect the information needed to build the models, Jian uses seismographs, machines that record underground movement of the earth.

UNDERSEA QUAKES

On land, the effects of weather, waves, atmosphere, human activities, and other factors make earthquakes very complicated to study. So most of the earthquakes Jian studies take place on the ocean floor, along a giant mountain range called the Mid-Atlantic Ridge. "It's cleaner and simpler," he says. "The water has protected the shape of the fault surfaces created by submarine earthquakes." Jian and the other seismologists he works with hope that by studying the effects of earthquakes in a pretty simple system, they can better understand earthquakes that take place on land. "If you start with something very complicated, you'll

AN SLEUTHS...

probably never get the answers," says Jian.

DEEP SEA TO DRY LAND

Recently, Jian and others have also been studying Los Angeles, which has seen many earthquakes in the past twenty-five years. The most recent earthquake in the Los Angeles area took place on January 17, 1994 in Northridge. It measured 6.8 on the Richter Scale. Jian and his colleagues have applied their seafloor earthquake model to the Los Angeles area, trying to understand what's going on deep beneath that city.

"Previously, people were worried about bigger earthquakes from the San Andreas Fault," says Jian. (This 690 km-long crack in the earth's crust has caused many other earthquakes in California.) "They are right. They should be worried about that, because if the San Andreas ruptures, it might rupture at a very large magnitude, as big as 8 [on the Richter Scale].

"But what they did not quite realize was that right beneath the city of Los Angeles, there might be a second kind of fault. This is what we call a blind thrust fault. Blind means that these faults do not get to the surface. Thrust means one large block of earth's crust moves on top of the other block."

Instrument readings indicate that the blind thrust faults lie as much as 12 to 15 km beneath the city. In the late 1980s, Jian Lin, Ross Stein of the United States Geological Survey and Geof King of the Institute de Physique du Globe of France, began to create computerized images of the blind thrust faults that they believe are responsible for the series of earthquakes in that area. The earthquakes that struck in 1992 and 1994 fit right into the pattern.

MICROPLATES

What mechanism drives this blind thrust area?

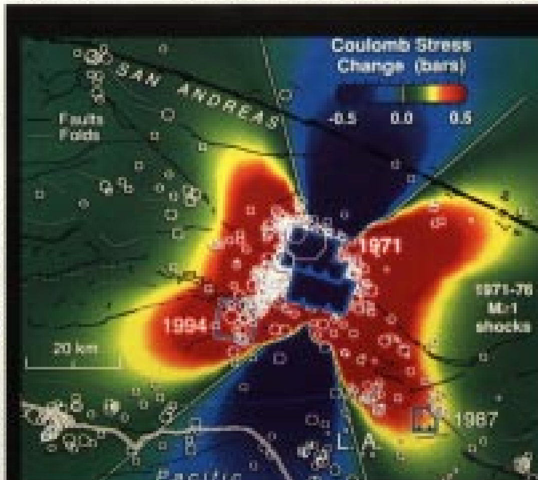
Nobody knows, but people are thinking hard about it. WHOI scientist Hans Schouten thinks that beneath Los Angeles there may lie a 100km by 300km "sliver" of earth's crust called a microplate. Hans thinks the microplate rotates at the fairly fast rate of five degrees per million years. It may move in sudden bursts, causing earthquakes as its edges scrape against other pieces of the earth's crust.

Since the early 1970s, earthquakes of magnitude 5 and up have taken place at many locations near Los Angeles. Hans says, "We have been trying to think up a scheme into which we can fit the major earthquakes that have occurred in that area." The microplate theory may be part of the answer.

"I still get scared when I am in an earthquake, even as a scientist, because I don't know enough about them," says Jian.

Seismosgists are working hard to understand the sequence of an earthquake. This may lead to increasingly accurate predictions of earthquakes in Southern California and many other areas.

Have you ever been in an earthquake? What was it like? Describe your experience, in 100 words or less. Send it, along with a picture of yourself, to Editor, *Ocean Explorer*, Fenno House, Woods Hole Oceanographic Institution, Woods Hole, MA 02543. Your story may show up in a future issue of *Ocean Explorer!*

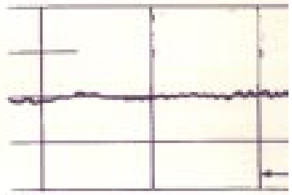


This computer model image *(left)* shows overlapping earthquakes that happened in 1971, 1987 and 1994 in the Los Angeles area. Jian Lin and others believe blind thrust faults beneath the surface of the earth are responsible.

Below is a computer-generated image of a large fault on the seafloor, created by earthquakes.

津波 TSUNAMI

An Earthquake's Dangerous Partner—by Deborah Kovacs

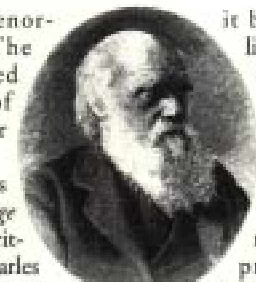


When the earth trembles on the seafloor, waves at the surface are created. If the earthquake is big enough, giant sets of waves called tsunamis (Japanese for "harbor waves") are set off.

Tsunamis are terrifying, and can be deadly. A tsunami roars suddenly from sea to land, at tremendous heights and at devastating speed. A tsunami can cross the entire Pacific Ocean in just a few hours. It can strike land as an enormous wall of water, or as a sudden upwelling of the sea.

A tsunami that struck the village of Kahului on the island of Maui, Hawaii, in 1837 is an example of the disastrous powers of these great waves. In that instance, the sea suddenly and swiftly began to retreat from the bay, as though an invisible giant were drinking it down. Fish left behind lay flapping helplessly on the sand. Some villagers rushed out to pick up the fish.

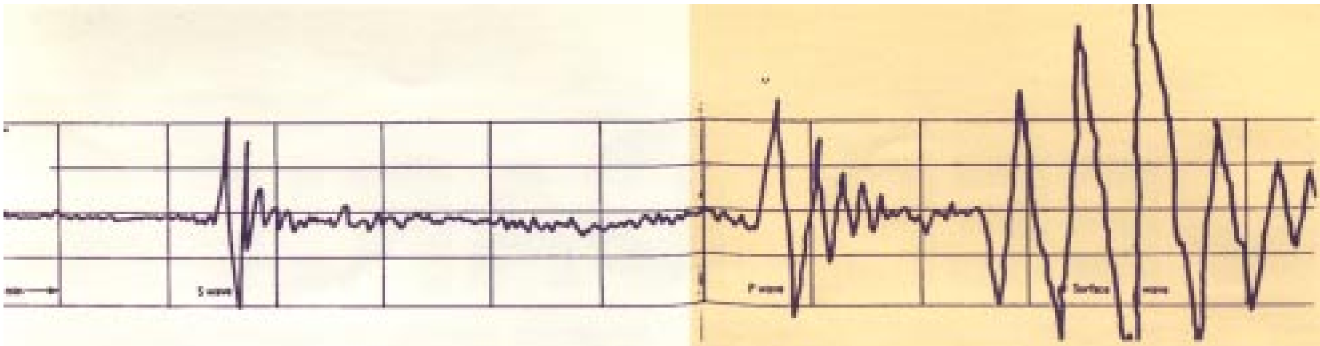
But others had an inkling of what was to come. They ran away from the shore. One person ran up a slope, and turned around to see a shocking sight. The entire village, its houses, its people and its animals, was riding on top of an enormous wave. The tsunami carried the village of Kahului far inland.



In his famous book *The Voyage of the Beagle*, British naturalist Charles Darwin described a tsunami that devastated the coast of southern Chile in February, 1835.

He wrote: "Shortly after the shock, a great wave was seen from the distance of three or four miles, approaching the middle of the bay with a smooth outline; but along the shore it tore up cottages and trees, as it swept onwards with irresistible force. At the head of the bay it broke in a fearful line of white breakers, which rushed up to a height of 23 vertical feet above the highest spring-tides.

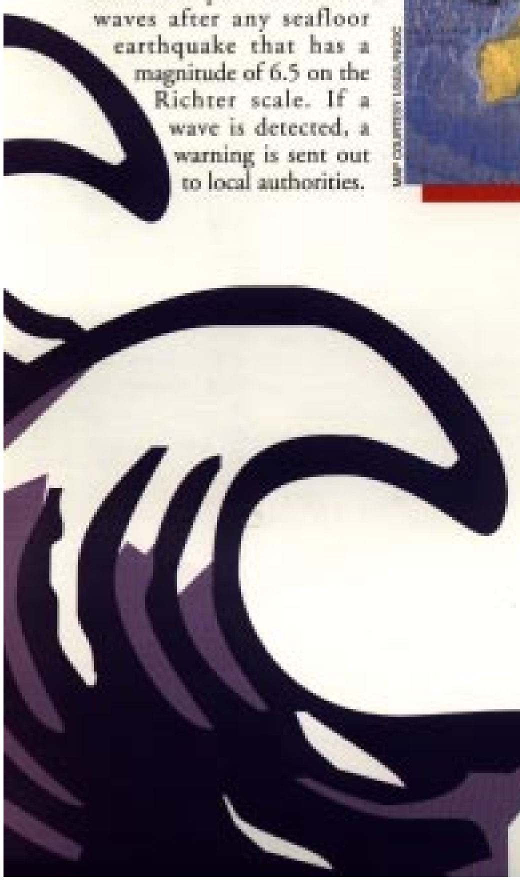
"Their force must have been prodigious; for at the Fort a cannon with its carriage, estimated at four tons in weight, was moved 15 feet inwards. A schooner was left in the midst of the ruins, 200 yards from the beach. The first wave was followed by two others, which in their retreat carried away a vast wreck of floating objects. In one part of the bay, a ship was pitched high and dry on shore, was carried



off, again driven on shore, and again carried off. In another part, two large vessels anchored near together were whirled about, and their cables were thrice wound round each other; though anchored at a depth of 36 feet, they were for some minutes aground....

"Pools of salt-water were still standing amidst the ruins of the houses, and children, making boats with old tables and chairs, appeared as happy as their parents were miserable."

Tsunamis are still a great risk following any major earthquake, but people who live around the rim of the Pacific Ocean are helped by an international warning system that keeps track of ocean waves after any seafloor earthquake that has a magnitude of 6.5 on the Richter scale. If a wave is detected, a warning is sent out to local authorities.



A seismograph (above) records energy waves as they travel from an earthquake's focus deep beneath the crust up to the surface. Primary waves (P waves) reach the surface first, moving at speeds of 5.5 to 8.5 km per second (12,000 to 19,000 mph). They push and pull structures on the surface. Secondary waves (S waves) travel a little slower, at 3 to 4.6 km per second. These waves shake the ground up and down and from side to side. A third type, surface waves, can cause buildings to sway far from the earthquake's focus.


MAP COURTESY USGS/NGDC

Most earthquakes occur at the edges of plates in the earth's crust. This map shows active earthquake areas around the rim of the Pacific Ocean.

MAKING SENSE OF THE MOTION: A SCALE THAT MEASURES EARTHQUAKES

In the 1930s, Charles Richter created a scale, named after him, that describes the intensity of an earthquake by measuring the amount of energy it releases. The scale increases exponentially—that is, an earthquake that measures 3 on the Richter scale is ten times more intense than one that measures 2. The largest earthquake ever measured by this method took place in Japan in 1933. It registered 8.9. By contrast, the January, 1994 earthquake in Northridge, CA measured 6.8.

DEEP, DARK DISCOVERIES

American and Japanese Oceanographers Explore the Kane Fracture Zone—by Tom Gidwitz

JAMSTEC

Yokosuka (above) is *Shinkai 6500*'s mother ship. Measuring more than 100 meters in length, *Yokosuka* cruises at about 16 knots and can accomodate 57 people.

JAMSTEC

Above is the Japanese research sub *Shinkai 6500*. Its name comes from the Japanese words *shin*, meaning deep, and *kai*, meaning ocean, and its maximum diving depth of 6500 meters.

Shinkai 6500—its name comes from the Japanese words for deep, *shin*, and ocean, *kai*, and 6,500 meters, its official diving depth.

More than six kilometers beneath the surface of the sea, a small white and orange submersible inches its way along a steep wall of fractured rocks. The wall of rubble towers thousands of meters above the little sub, while below, unseen beneath the ocean floor, volcanic magma is rising from deep within the earth to form the bottom of the sea.

The little craft is the Japanese submersible *Shinkai 6500*. It's the world's deepest diving manned sub, and it is on an historic mission. For the first time ever, Japanese and American scientists have teamed up to make deep dives on the floor of the Atlantic Ocean.

Shinkai is at the bottom of a hole four times deeper than the Grand Canyon, far below where the sun can reach. Inside the sub, WHOI geologist Bill Bryan and two Japanese pilots watch as the craft's headlights stab through the inky blackness. They peer out the sub's tiny windows to study the chaos of rubble and boulders as big as trucks. They are not the only onces who see this sight.

On the sea surface high above, *Yokosuka*, *Shinkai's* mother ship, is circling. As *Shinkai* makes its closeup view, scientists from WHOI and from Japan Marine Science and Technology Center [JAMSTEC] cluster around television monitors on *Yokosuka's* bridge. They eagerly watch images of the bottom beamed to the ship from *Shinkai*.

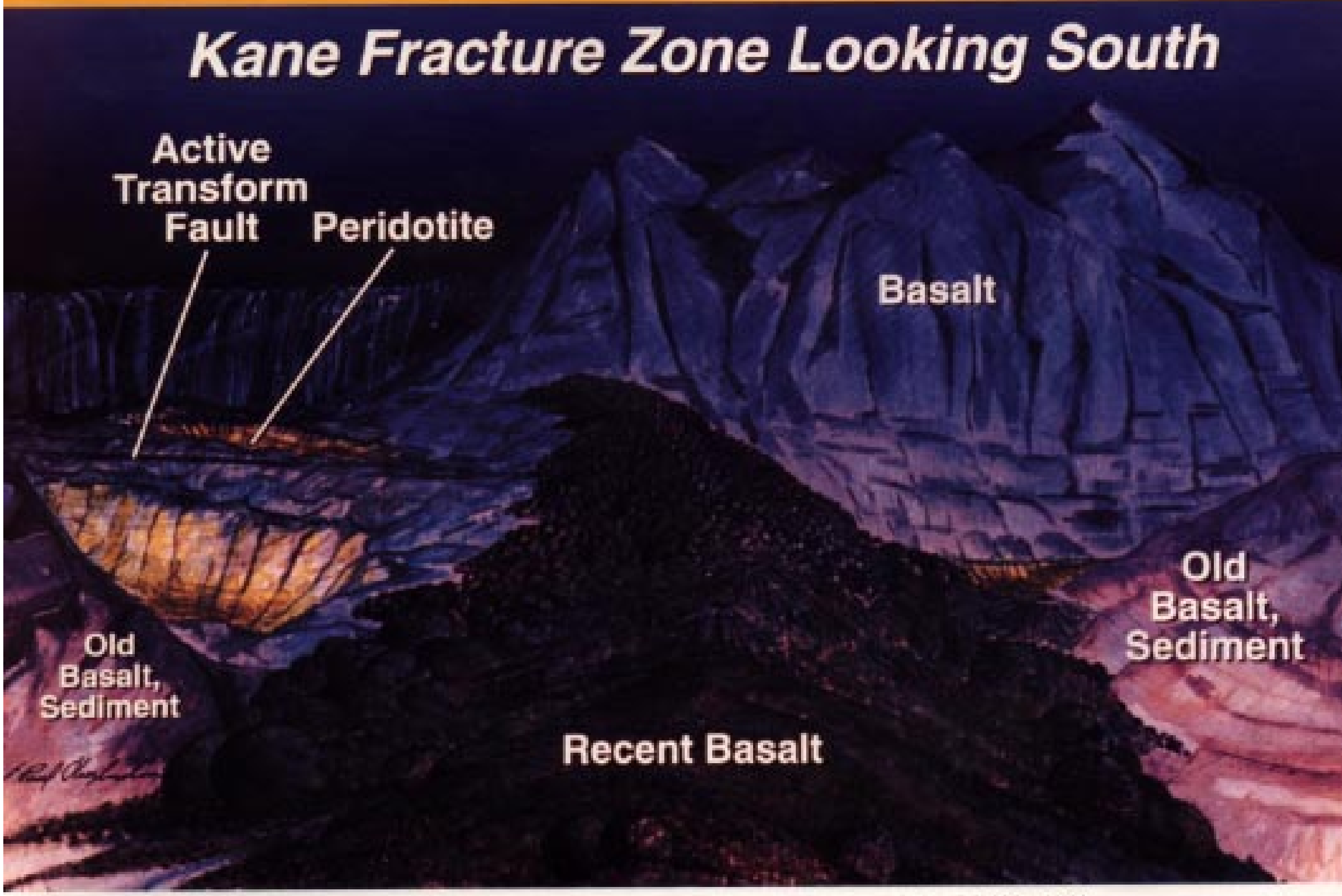
The sub is exploring one of the world's most active earthquake sites, the Kane Fracture Zone, at the heart of the Mid-Atlantic Ridge, part of the 40,000-km seafloor mountain range that circles the globe like the stitches on a baseball.

Here, where two of the earth's giant tectonic plates are spreading apart, a fissure, or long crack called a transform fault, slashes across the spreading seam. Where the ridge meets the transform fault, the tectonic plates scrape past one another. The result is a mix of towering mountains, steep cliffs, fractured sea floor and daily earthquakes.

A DEEP SEA SURPRISE

The Japanese and American scientists have been working around the clock. At night, *Yokosuka* crisscrosses the dive sites, using sound to map the bottom and making measurements of gravity and magnetic fields. Early in the morning, a giant crane lowers *Shinkai* into the water. When the pilots are ready, the sub is released to begin its three-hour descent to a pitch-black area called the Kane Fracture Zone.

There are many fracture zones along the mid-ocean ridge. They can be as much as 10 km wide and 5 km



***Shinkai 6500* took scientists to the Kane Fracture Zone, a seafloor crack deep enough to contain Mt. Fuji (4 km high).**

deep. At these zones, "two geologic processes are having a duel," says Bill Bryan. "The spreading ridge is trying to move apart while the transform fault is slipping horizontally."

It is this duel that creates earthquakes. Small ones happen almost constantly. Large ones take place several times a decade. As the massive blocks of earth's crust scrape past one another and spread apart, mountain ranges are pushed up and valleys are formed.

On this particular dive, scientists aboard *Yokosuka* are watching the television transmission from *Shinkai* with special excitement. They expect Bill Bryan will soon be inspecting thousands of meters of exposed ocean crust along the hole's deep walls. But they are in for a surprise. The ridge cannot be seen at all. Its walls are obscured by countless tons of rubble.

SOLVING A MYSTERY

From inside the sub, Bill studies the broken rocks, wondering where they have come from. A veteran of dozens of deep sea dives, Bill has spent his life studying earthquakes and volcanoes, and wondering about how the earth evolved. He notices the sediment that falls like snow in the deep sea. It has collected on the rubble. In some places, there's four inches of sediment. But in other places, there's no sediment at all. Bill knows that rocks covered with a thick layer of sediment have been still for a long time. Those without sediment have recently moved.

"It was actually a double landslide," says Bill. "The main slide probably occurred several million years ago. I think it was related to a really major earthquake along the fracture zone." But on top of that early landslide, Bill could see many places where the slide had been reactivated. "We could see fresh movement in parts of the slide," says Bill. "I'm quite sure that was related to one of the large earthquakes that has occurred in the zone in the last twenty years."

AN HISTORIC TEAM

WHOI and JAMSTEC scientists made 15 nine-hour dives at the Kane Fracture Zone in July. During the dives, *Shinkai* explored about twenty miles of ocean bottom, making measurements and collecting rock samples on mountain tops, old lava flows, and landslides. Especially interesting to scientists are samples collected of eight to ten-million-year-old volcanic rock called peridotite, which shot up to the seafloor from somewhere beneath the earth's crust, like watermelon seeds squeezed between two fingers.

BUSINESS AS USUAL

Bill Bryan forsees more joint WHOI/JAMSTEC missions in the Atlantic. But for him and his WHOI colleagues, even the novelty of a deep, deep dive in *Shinkai* does not match the excitement of discovering interesting rocks and fresh sea floor cracks. When asked how it feels to be on the bottom of the ocean, he's thoughtful.

"Someone who has never done this before would either be scared out of their wits or awed by the experience," says Bill. "After you've been diving, you know what to anticipate. This enables you to focus more directly on the reasons why you're there.

"It's like asking me how I feel about flying in a helicopter over an active volcano. Well, I've done that quite a few times. For me, it's business as usual," he says with a laugh.