JAMSTEC 国立研究開発法人 海洋研究開発機構
Japan Agency for Marine-Earth Science and Technology

Research Institute for Marine Geodynamics

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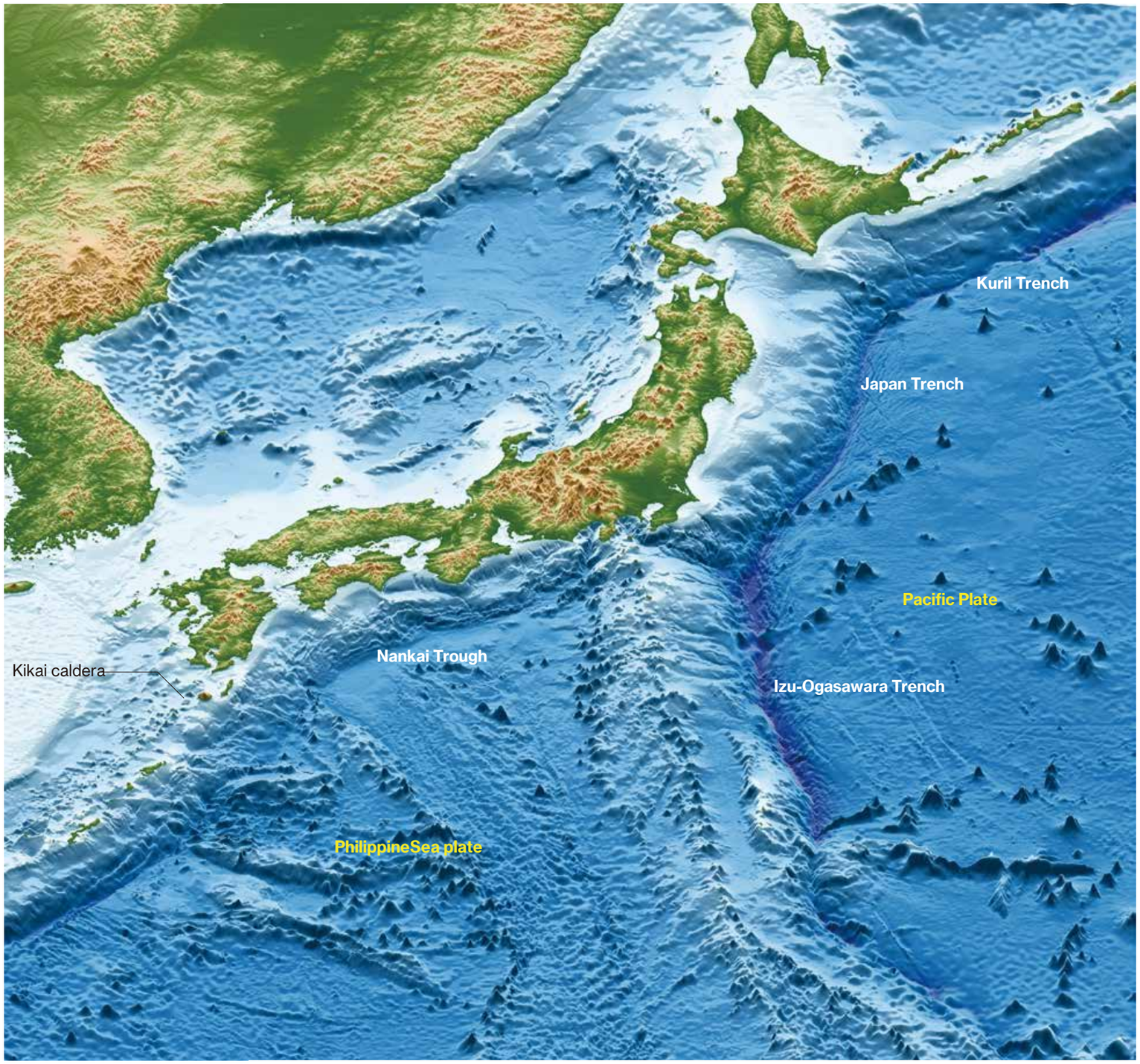
Disaster Mitigation for Oceanic Earthquakes and Volcanic Eruptions

The surface of the earth, though usually calm and stable, can be disturbed suddenly by earthquakes and volcanic eruptions, thus causing disasters that can have huge impacts on society and humanity as a whole. At the Research Institute for Marine Geodynamics, in collaboration with universities and research institutions both in Japan and overseas, we conduct various surveys and observational studies, particularly in areas of concern for reoccurring earthquakes. These studies have been conducted to contribute to the reduction of disasters caused by earthquakes and volcanic eruptions. We strive to contribute to national safety and security by further improving the marine research and data analysis technologies that have been developed by the JAMSTEC (e.g., surveys/observational studies, monitoring, and simulations) by understanding the current conditions of earthquakes and volcanic activities and by clarifying the reality of these situations.

We have also begun to promote the development of observational research in countries that are subjected to repeated earthquakes and volcanic eruptions, as well as the application of the corresponding research results.

Director-General
Shuichi Kodaira

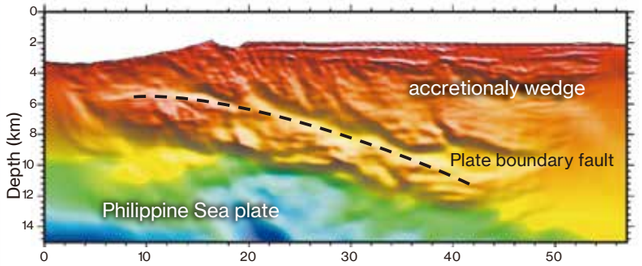
A submarine topographic map of the Japanese archipelago. The Pacific Plate is subducting at the Kuril and Japan trenches, and the Philippine Sea Plate is subducting at the Nankai Trough, thus resulting in powerful earthquakes at these subduction zones as these plates slide beneath continental tectonic plates. Volcanic islands, such as Nishinoshima, and submarine volcanoes line the Izu-Ogasawara Trench,Where the Pacific Plate subducts beneath the Philippine Sea Plate.



Elucidating Submarine Earthquake and Volcanic Conditions and Future Predictions for Disaster Reduction

The Research Institute for Marine Geodynamics includes the Subduction Dynamics Research Center, the Research and Development Center for Earthquake and Tsunami Forecasting, and the Volcanoes and Earth's Interior Research Center. At the Research Institute for Marine Geodynamics, these three centers collaborate to advance research and development, and to provide information to the government and related organizations with the aim of reducing the impacts of natural disasters.

Research vessel: KAIMEI.



Sub-seafloor physical distribution off Kii Peninsula according to subseafloor structural surveys.

Subduction Dynamics Research Center

Elucidating conditions in the seismogenic zone via observational studies

At the Subduction Dynamics Research Center, we use wide-area seabed research vessels such as KAIMEI to investigate the properties of the subsurface faults and rocks of the Nankai Trough, Japan Trench, and Kuril Trench. The history of previous earthquakes and tsunamis in addition to the present situation of the seismogenic zone are also investigated. Furthermore, we collaborate with Asian and Pacific countries to construct and operate a participatory global earthquake and tsunami observation network.

Real-time tsunami forecasting system based on seafloor water-pressure fluctuations.

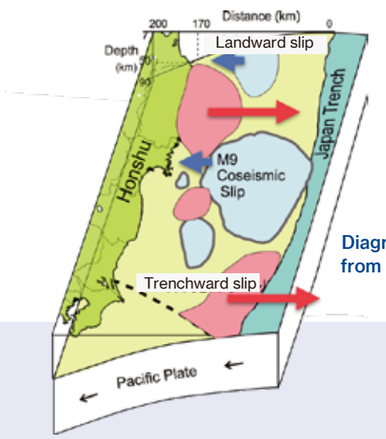
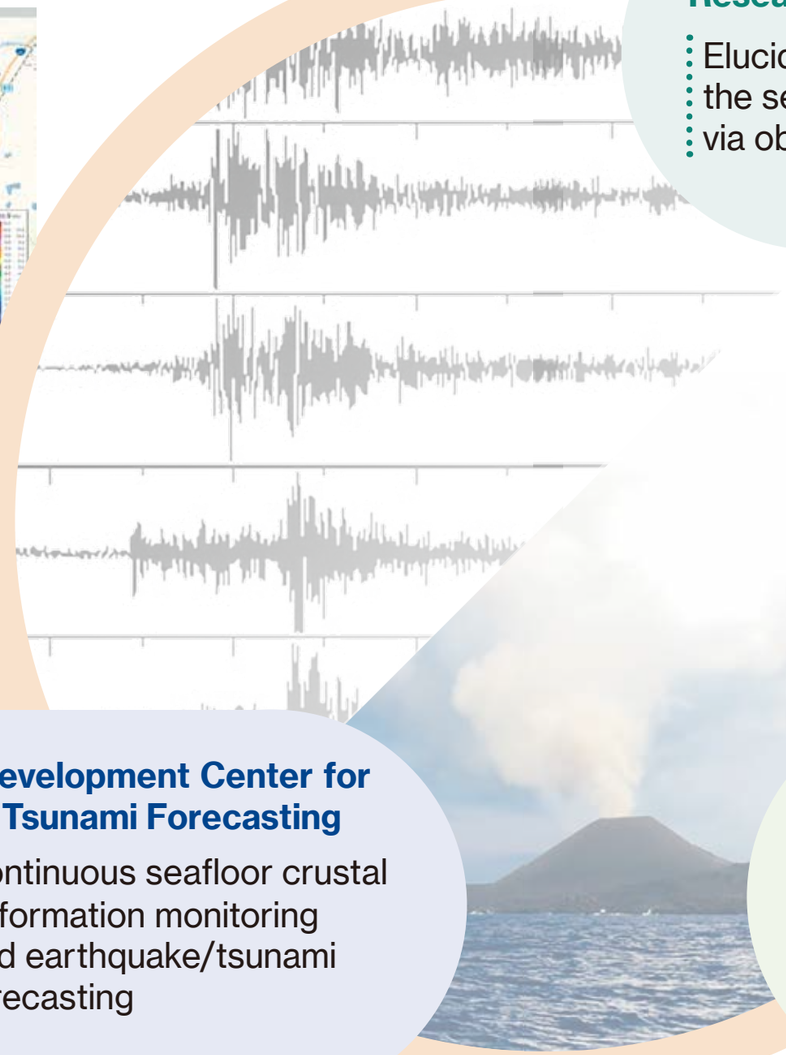
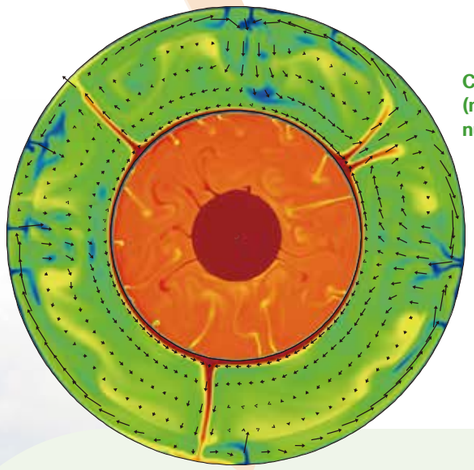


Diagram of post-seismic slips from 4/23/2011–12/10/2011.





Convective motion of Earth's interior (mantle and core) according to numerical simulations.

Laser ablation inductively coupled plasma mass spectrometer (LA-ICP-MS) uses to determine rock compositions.

Research and Development Center for Earthquake and Tsunami Forecasting

Continuous seafloor crustal deformation monitoring and earthquake/tsunami forecasting

The Research and Development Center for Earthquake and Tsunami Forecasting is developing a system to continuously monitor seafloor crustal deformation at the bottom of the Nankai Trough. We will also capture data (e.g., from surveys by the Subduction Dynamics Research Center of subsurface structures), build a model on a supercomputer that reproduces earthquakes and tsunamis, and predict the near-future state of the seismogenic zone.

Volcanoes and Earth's Interior Research Center

An integrated understanding of volcanic activity and Earth's interior

The Volcanoes and Earth's Interior Research Center, in collaboration with the other two centers, is advancing sea floor research and developing a further understanding of the actual conditions of volcanic islands and submarine volcanoes. We are also elucidating the internal circulation of materials and conducting research to gain a comprehensive understanding of Earth's interior and volcanic activity.

Subduction Dynamics Research Center

Explorling the Seismogenic Zone

Illuminating Structure and Physical Property of the Seismogenic Zone by High-resolution Surveys

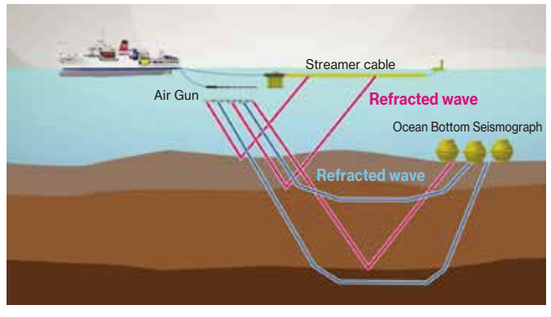
At the Subduction Dynamics Research Center, we aim to understand structure and its relation to the seismic activity in the subduction seismogenic zone. In order to achieve this goal, we conduct marine seismic surveys utilizing research vessels such as R/V KAIMEI, and we are constructing detailed structure models.

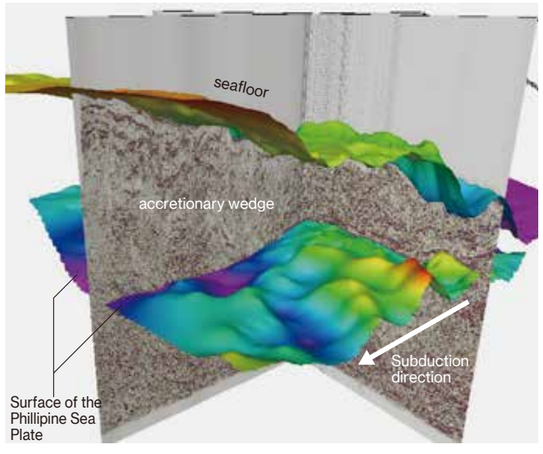
Marine seismic surveys are conducted by emitting acoustic waves from a controlled source (air gun) mounted on the research vessel. The signals are captured by a seriese of hydrophones contained in long electric cables (streamer cables) towed by the research vessel and seismographs installed on the sea floor (ocean bottom seismograph: OBS). After a detailed analysis, the subseafloor structure can be depicted. The maximum length of streamer cables on JAMSTEC research vessel, KAIMEI, is 12 km. They should be capable of depicting the plate boundary fault in the Nankai Trough seismogenic zone with high precision. By towing multiple streamer cables simultaneously, KAIMEI is capable of complex 3D geologic imaging.

Surveys utilizing OBS can capture the seismic velocity beneath the sea floor. The seismic velocity variations reflect rock types and conditions, which are keys to understand the seismogenic behaviou along the plate interface.

We are illuminating structure and physical properties of the seismogenic zone in the Nankai Trough, the Kuril Trench, and the Japan Trench by high-resolustion marine seismic surveys.

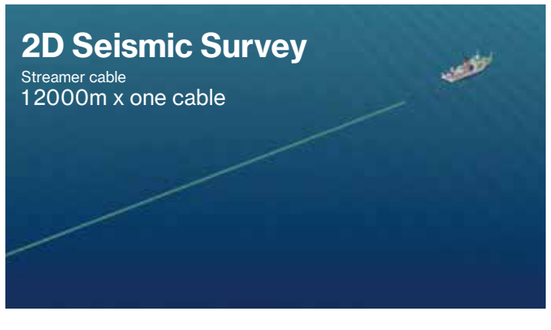
Schematic diagram of marine seismic surveys.





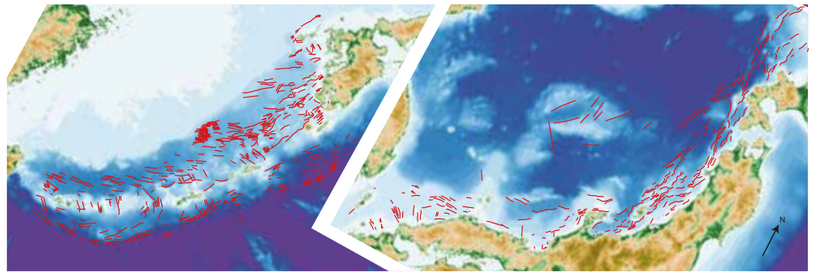
subseafloor structure of the Nankai Trough.
Surface geometry of the subducting Philippine Sea Plate in the Nankai Trough from Shionomisaki through the Kii Channel (blue indicates deeper areas, and red indicates shallower areas).

Marine seismic survey by KAIMEI with streamer cables.



Mapping Offshore Faults

The Subduction Dynamics Research Center started an initiative to create an oceanic fault map. Marine seismic surveys around the Japanese archipelago have conducted by various universities, research institutions, and companies, as well as JAMSTEC. These survey data have been collected and reanalyzed using new techniques. Then, location and length of active faults are evaluated and mapped based on universal standards. The occurrence probability and potential scale of earthquakes and tsunamis in each offshore region are estimated based on this map. It will provide basic data for disaster prevention.



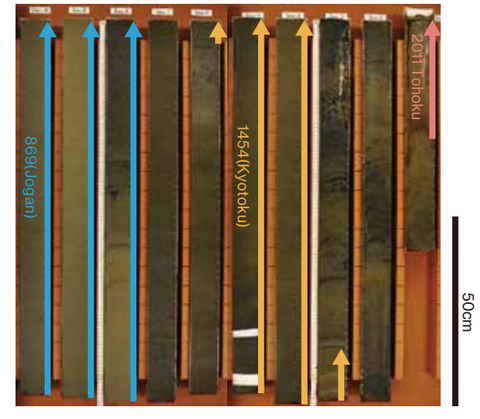
Offshore fault map.
Cite ETOPO1: doi:10.7289/V5C8276M

Investigating the History of Huge Earthquakes and Tsunamis

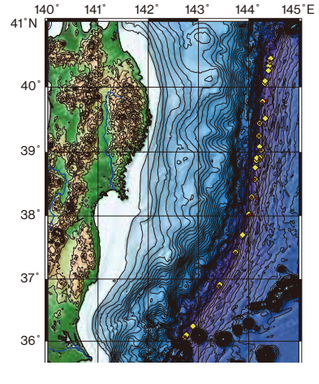
It is important to know the history of past huge earthquakes and tsunamis for better understanding of nature of seismogenic zone. Past occurrence data is also useful for improving the precision of computer-based earthquake/tsunami reproduction simulation models.

Submarine turbidity flow is induced by significant seafloor shaking of huge earthquakes. That is transported to deep sea floor and accumulates as earthquake evidence. 10-m length sediment collection off Miyagi found two event deposits during past 1,000 years record. They correspond to earthquakes in 1454 CE (Kyotoku 3) and 869 CE (Jogan 11)

KAIMEI's giant piston corer provide an opportunity to collect the longer sedimentary records of approximately 40 m. IODP (International Ocean Discovery Program) cruise in Japan Trench using KAIMEI is planed in 2020. The Subduction Dynamics Research Center participates in this project to make coring at tens of locations from the northern end to the southern end of the Japan Trench, and we aim to elucidate the historical occurrence of huge earthquakes and tsunamis over the past 10,000 years in the Japan Trench. Moreover, we plan to investigate a similar history in the Kuril Trench and the Nankai Trough.



Evidence of earthquakes in the Japan Trench. Sediment samples collected
(approximately 10 m below the sea floor offshore of Miyagi Prefecture. Core depth increases from the upper right to the bottom left.).



Coring sites of IODP Expedition 386 research expedition (2020).

Research and Development Center for Earthquake and Tsunami Forecasting

Continuous Seafloor Crustal Deformation Monitoring and Earthquake / Tsunami Forecasts

Continuous Real-Time Monitoring of Seafloor Crustal Deformations

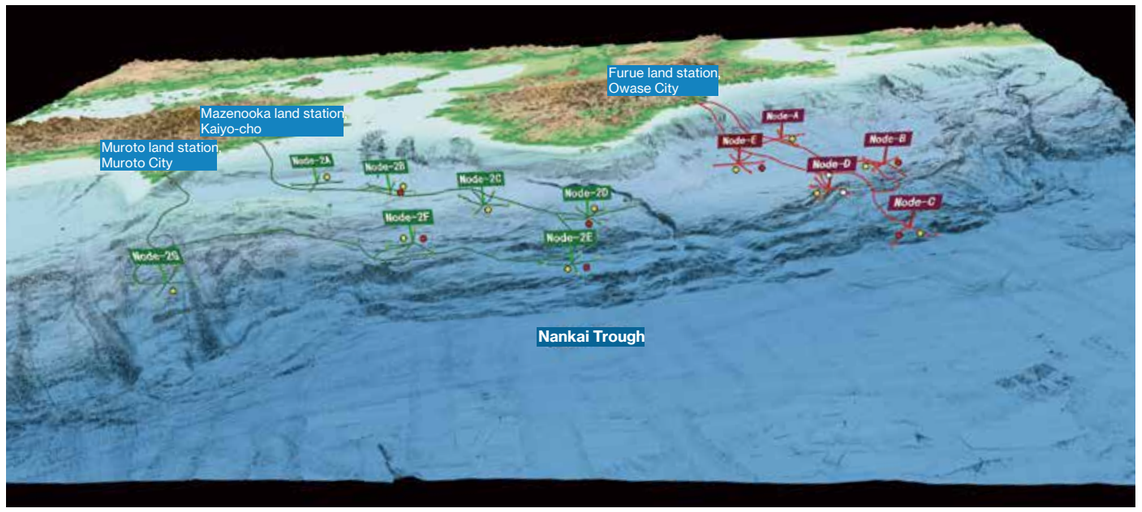
The Research and Development Center for Earthquake and Tsunami Forecasting (FEAT) is developing a continuous real-time wide-area monitoring system for seafloor crustal deformations along the Nankai Trough in order to forecast earthquakes and tsunamis.

JAMSTEC installed the “Dense Oceanfloor Network System for Earthquakes and Tsunamis (DONET)” that consists of 51 sites equipped with seismographs and water-pressure gauges on the seafloor in the rupture areas of the Nankai and Tonankai earthquakes. These sensors are connected via cable to the shore to conduct continuous real-time earthquake and tsunami monitoring.

Borehole measurements are effective to enhance the accuracy of seafloor crustal deformation monitoring. JAMSTEC has continued to conduct drilling expeditions offshore of Kill Peninsula using the deep-sea scientific drilling vessel CHIKYU. Currently, 3 long-term borehole monitoring systems have been installed in boreholes several hundred meters below the seafloor, and continuous real-time crustal deformation monitoring is taking place by connecting with DONET. In the future, we plan to install similar monitoring systems in boreholes several hundred meters below the sea floor at 3 sites off the Kii Channel using CHIKYU, which will also be connected to DONET. In addition, we plan to use the research vessel KAIMEI's Giant Piston Corer to create boreholes about 40 m below the seafloor at 6 sites, install seafloor crustal deformation observation equipment, and connect them to DONET.

Furthermore, we are developing new technologies for low-cost monitoring of the expansion and contraction of the earth's crust over a wide area by using optical fibers on the seafloor and in boreholes with measuring incidence and reflected light.

A pore-pressure gauge installed in the long-term borehole monitoring system to detect crustal deformations.



Borehole observation sites conducting continuous real-time monitoring of seafloor crustal deformations with connecting DONET.

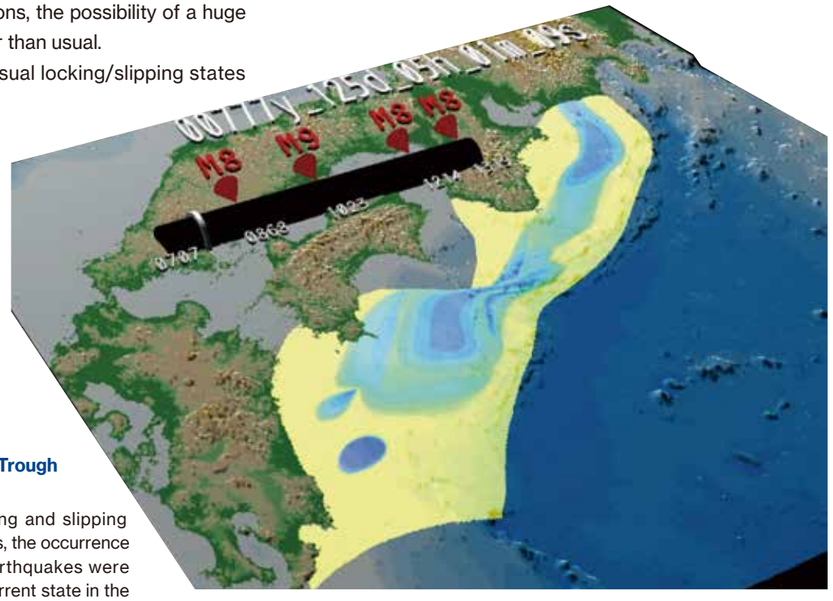
Near-future Forecast of the Fault State in the Seismogenic Zone

By utilizing models that reflect the subsurface structure and physical property data estimated by the Subduction Dynamics Research Center to analyze seafloor and continental crustal deformation data, we grasp the current state of the fault locking/slipping. Furthermore, we aim to estimate the fault strength and the stress acting the fault in order to forecast near-future fault locking/slipping state.

In the shallower and deeper portions than the seismogenic zone along the Nankai Trough, “slow slips” of several centimeters to tens of centimeters over the course of weeks or months occur. Ordinary, slow slips occur intermittently, at times the slip area invades the seismogenic zone, or the slow slips irregularly occur with expanding the slip area after M6-7 earthquakes. In such situations, the possibility of a huge earthquake is thought to be higher than usual.

We thus aim to detect such unusual locking/slipping states by collecting data from seafloor crustal deformation monitoring systems.

Along the Nankai Trough, there are known cases of Nankai earthquakes that occurred one and a half days and two years after the Tokai or Tonankai earthquakes. After a huge earthquake, we will identify the ruptured and unruptured areas, and forecast the possible size and range of future earthquakes and associated tsunamis. Moreover, after the first earthquake, the slow slip expands into its surroundings, leading to the possibility of future earthquakes. We will monitor and forecast these slow slips and advance research development so that we can provide information regarding future earthquakes.



Conventional simulation of Nankai Trough earthquakes.

Blue and yellow indicates the locking and slipping regions. In the conventional simulations, the occurrence intervals and rupture patterns of earthquakes were reproduced. We aim to understand current state in the seismogenic zone and forecast near-future state by utilizing subsurface structural survey data and seafloor crustal deformation data.

Tsunami Forecasting System Including Storm Surges and Submarine Landslides

JAMSTEC has constructed a real-time tsunami forecasting system utilizing DONET. This system has already been introduced in Wakayama and Mie Prefectures, Chubu Electric Power, and Kagawa University. JAMSTEC has been managing it in collaboration with the National Research Institute for Earth Science and Disaster Resilience. The real-time tsunami forecasting system uses offshore water pressure observation data from DONET to transmit real-time information that is useful for disaster prevention such as coastal tsunami height, arrival time, and inundation area.

However, DONET water pressure gauge shows high pressure not only during tsunamis but during storm surges due to the atmospheric depressions such as typhoons as well. Submarine landslides can generate large tsunami in a comparatively small area. Thus, we are continuing to improve the real-time tsunami forecasting system by distinguishing between storm surges and tsunamis as well as our ability to forecast tsunamis from landslides.

Volcanoes and Earth's Interior Research Center

An Integrated Understanding of Volcanic Activity and the Earth's Interior

Exploring the Actual Conditions of Oceanic Volcanoes

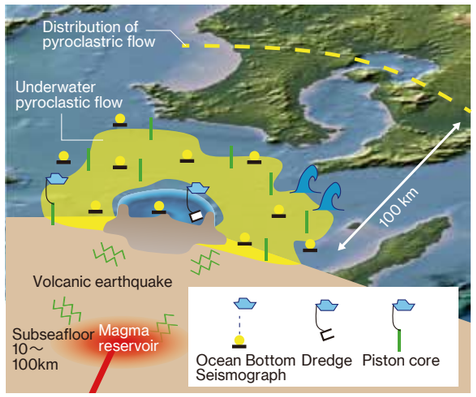
Research on oceanic volcanoes, such as submarine volcanoes and volcanic islands, lags significantly behind that on land volcanoes. Consequently, there are concerns that a sudden oceanic volcanic eruption could cause a larger disaster than would otherwise be expected. Thus, the Volcanoes and Earth's Interior Research Center is advancing research aimed at forecasting oceanic volcano disaster occurrence, evaluating impacts for the global environment, and reducing disasters.

In collaboration with the Subduction Dynamics Research Center and Kobe University, we will deploy ocean bottom seismographs (OBS) in a high-density arrangement at the Kikai Caldera located on the sea floor south of Kagoshima. We will observe earthquakes for up to one year, and use these observations to investigate the subseafloor structure at 10–100 km depths. If a magma reservoir exists at this location, our data should reflect its presence.

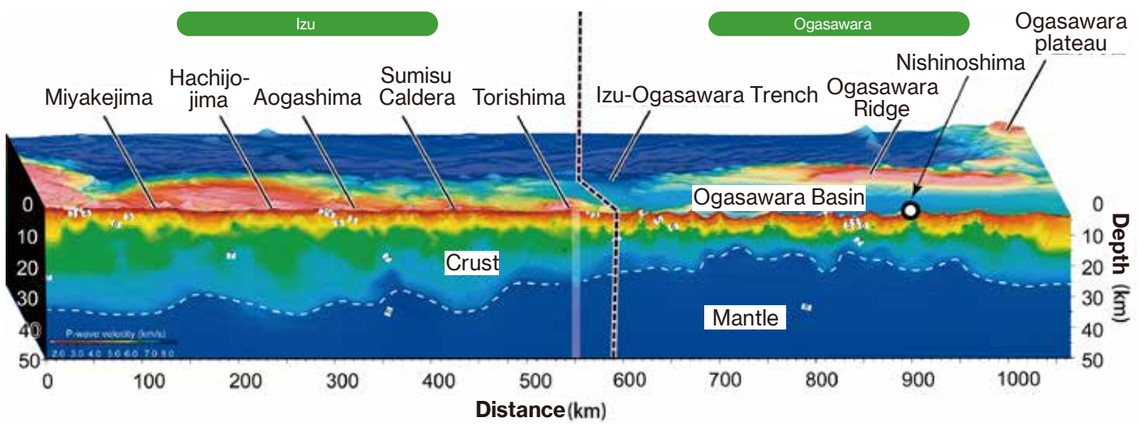
In order to monitor the current conditions of oceanic volcanoes, we will install water-pressure gauges capable of measuring the vertical movements of the sea floor and ocean bottom electro-magnetometers (OBEM) that are sensitive to subseafloor temperature fluctuations. To retrieve the OBEM data generated at the sea floor, we will develop an unmanned data acquisition system in collaboration with Kobe University and the Earthquake Research Institute at the University of Tokyo.

While the current state of volcanic activity can be monitored from geophysical observations, exploring past eruptions at these volcanoes is similarly important to forecast possible future volcanic activity. Volcanic rocks and ash distributed on the seafloor around oceanic volcanoes should provide a record of their history of volcanic activities. We will therefore survey oceanic volcanoes such as the Kikai Caldera and the Izu-Ogasawara arc to collect volcanic materials using research vessels. Petrological and geochemical analyses will be performed on the collected rocks and sediments to understand past eruption activity and the cause of magmatism at different oceanic volcanoes.

Kikai Caldera survey plan.



Lava collection by the remotely operated vehicle HYPER-DOLPHIN.



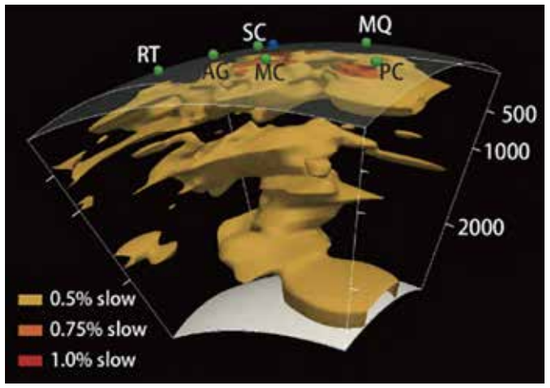
Studying the Earth's Interior to Determine Why Volcanoes Form

In order to forecast future volcanic activity based upon scientific grounds, we must not only understand phenomena that occur close to the Earth's surface but also the cause of those phenomena within the Earth's interior. Volcanism on and around Japan is induced by plate subduction. The key factor in forming magmas at a subduction zone is the transport and subsequent release of water from the hydrated subducted plate. Because the melting temperature of mantle rocks is lowered significantly by the presence of water, magmas are generated above the subducted plate and supplied to the crustal magma chambers beneath the volcanoes.

Magma type tends to vary according to the distance from the trench. It is hypothesized that these variations are caused by compositional differences between water released at shallow depths close to the trench and water released at the deeper part far from the trench. According to previous JAMSTEC surveys, magma types are understood to vary from north to south along the Izu-Ogasawara Trench. A possible cause of this phenomenon is suggested to be changes in the material composition of the subducting sediment along a north–south transect.

In addition, within the Earth's interior, we are observing seismic wave propagation speeds and electrical conductivity to infer mantle convection and heat and material cycling. By comparing lava compositions from volcanoes at subduction zones, which are input regions for the Earth's interior, with lava compositions from volcanoes located at output regions such as hot spots and mid-ocean ridges, we can know how material is cycled between the atmosphere, the ocean, and the Earth's interior. This information may also be useful for improving our understanding of global climate change.

Actual plate conditions and their birth, movement and subduction processes remain significant open questions within the field of Earth science. We will continue our drilling surveys under the IODP (International Ocean Discovery Program) using our deep-sea drilling vessel CHIKYU to come closer to solving these mysteries, and investigate why specific types of volcanoes emerge in these regions.



Upwelling flow of mentle beneath hot spot volcanoes.

Subsurface structure beneath the hotspots in French Polynesia in the South Pacific as derived from seismic tomography.

Diagram of volcano formation at subduction zones.

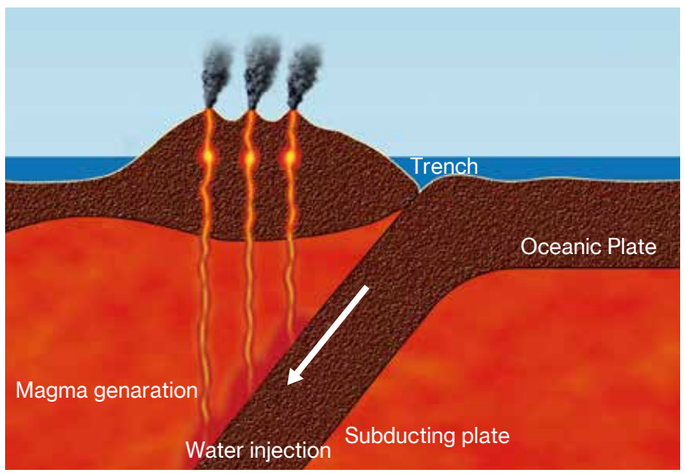


Diagram of material cycling in the Earth's interior.