Marine geological mapping project in the Okinawa area

— Geoinformation for the development of submarine mineral resources —

Kohsaku ARAI*, Gen SHIMODA and Ken IKEHARA

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AIST has been conducting marine geological surveys in the Okinawa area to construct geological maps since 2008. The chain of islands extending from Kyushu to Taiwan in the Okinawa area is called the Ryukyu Arc, and was formed with the subduction of the Philippine Sea Plate beneath the Eurasian Plate along the Ryukyu Trench. The Okinawa Trough is a back-arc basin formed behind the Ryukyu Arc. Active submarine volcanoes and hydrothermal phenomena are known to exist in the trough. Because large scale mineral deposits may exist in relation to the geological structures, collecting the marine geological information around the area where submarine mineral resources are expected is very effective for grasping the location of resource-rich zone. Being surrounded by sea, Japan is expected to increase marine utilization within the Exclusive Economic Zone (EEZ) in the future. Methods for developing submarine mineral resources based on the geological phenomena are presented as tools for exploiting fundamental geological information.

Keywords : Marine geology, geological structures, Okinawa Trough, back-arc basin, marine mineral resources

1 Introduction

“Marine Geological Investigations on the Continental Shelves and Slopes around Japan” is a special research program of the Agency of Industrial Science and Technology started in FY 1974. As part of this project, marine geological surveys were conducted to obtain geological information on ocean regions around Japan and create 1:200,000 marine geological maps. Surveys of the four main islands of Japan (Honshu, Hokkaido, Kyushu, and Shikoku) were completed in FY 2006. The marine geological survey for the region around Okinawa, for which there was no basic geological information, was started in 2008 (hereinafter referred to as the Okinawa Project). In the Okinawa Project, the region around Okinawa-jima Island was surveyed in 3 years from FY 2008 to 2010, and the northern part of the Okinawa Trough was surveyed during the GH11 cruise in FY 2011. The names of the AIST survey cruises are derived from the name of the organization (G stands for Geological Survey of Japan), the name of the survey ship (H for *Hakurei Maru No. 2*), and the western calendar year in which the survey was conducted. A survey of the ocean region around Okinoerabu-jima, Tokuno-shima, and Amami-oshima islands in Kagoshima Prefecture which began in FY2012 is planned to continue for 4 years. After completion of the large-scale survey of the southern Okinawa Trough, a survey is scheduled of the area around the islands of Southern Ryukyu (Miyako-jima, Ishigaki-jima, and Yonakuni-jima islands).[1]

The planned duration of the Okinawa Project overlaps with a major change in policies for marine development and use in Japan. The Basic Act on Ocean Policy was established in 2007, followed by the Ocean Policy Basic Plan and the Marine Energy and Mineral Resources Development Plan in 2008. Under the Marine Energy and Mineral Resources Development Plan, the commercialization of submarine hydrothermal mineral deposits was set for 2018. Also, the situation of the mineral resources changed greatly because of the worldwide increases in resource prices after the global financial crisis in 2007. With such a background, the importance of submarine mineral resource development increased dramatically. The future utilization of these resources depends on the provision of geological information that contributes to the management, maintenance, and development of Japan’s vast exclusive economic zone (EEZ).

In April 2012, the United Nations approved the majority of Japan’s application for governance over an extended continental shelf area,[2] which was widely reported by the media. This approval covered an area of approximately 310,000 km^2 (Fig. 1), and included the ocean regions of Shikoku Basin, Ogasawara Plateau, Minami-Io-jima Island, and Southern Oki-Daito Ridge. It is expected that these areas will hold significant mineral resources, and sufficient marine geological information is required to identify potential zones of concentration within existing geological structures. Conducting surveys effectively and accelerating the organization of data will therefore serve the national interests of Japan.

In the present study, we report the significance and current practices of organizing basic geological information from

Geological Survey of Japan, AIST Tsukuba Central 7, 1-1-1 Higashi, Tsukuba 305-8567, Japan
* E-mail: ko-arai@aist.go.jp

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the Okinawan ocean region. The survey area of the Okinawa Project includes the Okinawa Trough, an active back-arc basin that contains the Tokara Islands and continuous submarine volcanoes that extend from Kyushu. The basin is renowned for volcanic and submarine hydrothermal activities.[3]-[5] We also discuss the current situation and recent issues facing AIST in the development of submarine mineral resources.

2 Marine geological surveys, and organization and use of geological information

The marine geology map series, published at the end of September 2012, includes 76 sheets based on marine geological surveys (Fig. 2), eight of which show the marine geology around Japan at a 1:1,000,000 scale. The more detailed 1:200,000 marine geology map series was also published, separated into sedimentological and geological maps, the latter of which include magnetic and gravity anomaly maps.

To utilize the research vessel efficiently during AIST marine geological surveys, geophysical observations were primarily recorded during nighttime and sediment samples were taken from the stationary ship during the day (Fig. 3). In these surveys, the aim was to obtain 'uniform data,' defined as data that are systematically and comprehensively collected without any major variation in methods and equipment and of sufficient quality for geological interpretation. The sedimentological maps are based on seafloor surface samples collected using a grab sampler or columnar sampler, and they show the materials being deposited on the sea floor determined from sediment grain size and composition. The grab sampler was equipped with the conductivity depth profiler (CTD), turbidimeter, water sampler, and a submarine camera. Analyses conducted to produce these maps included sedimentology, geochemistry, and oceanography. The marine geological maps are based on seismic reflection profiling and the age of the sampled sediments. These maps display geological structure and stratification, and were created through integrated interpretations of structural geology, seismic stratigraphy, geophysics, sedimentology, etc.

Figure 4 shows the scenario of the flow for basic geological information from data collection to data use. The various data collected during the offshore surveys are published as a database and marine geological maps, and are an important part of the available intellectual infrastructure. Figure 4 provides examples of potential uses for the data and maps, including assessments of geological hazards and submarine resource. The marine geological maps indicate, for example, the presence of faults and their activity, which may be used to assess geological hazards affecting oceanfront buildings. The sedimentological maps may be used for understanding the

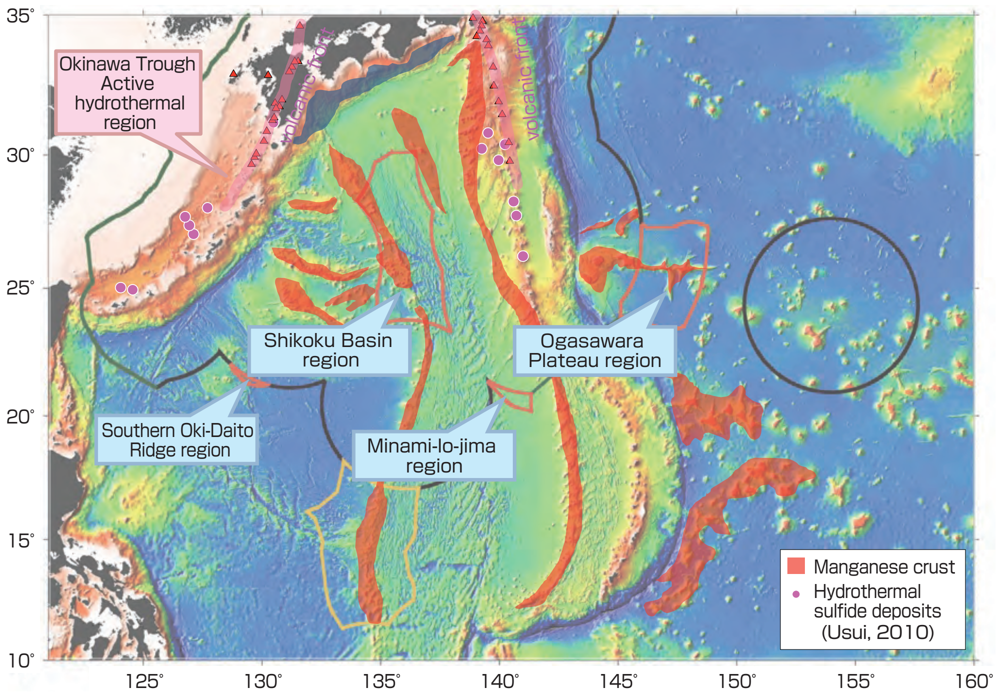

Fig. 1 Map of the sea floor geography around southwestern Japan showing major active hydrothermal areas and approved EEZ extension over the continental shelf

The black line shows the open sea and the green line shows the boundary with neighboring countries. The orange area marks the approved EEZ extension, and the yellow region indicates where the judgment has been postponed [Headquarters for Ocean Policy: *Heisei 24 Nen Ban Kaiyo No Jokyo Oyobi Kaiyo Ni Kanshite Kojita Shisaku* (2004 Situations of the Ocean and the Policies Taken for the Ocean)]. The Okinawa Trough is known for its active hydrothermal activities.[3]

distribution of potential aggregate materials such as sand and gravel, as well as for identifying submarine hydrothermal deposits, as discussed below.

3 Geology and structure of the active Ryukyu Arc and Okinawa Trough back-arc basin

Geological information regarding the islands of the Ryukyu Arc was obtained during the Okinawa Project. Previous studies of the geological stratigraphy of the Ryukyu Arc have concentrated on field surveys of a small land area of the arc, and consequently much of its tectonic history remains unclear. However, marine geological data provided by the Okinawa Project are expected to provide a more detailed understanding.

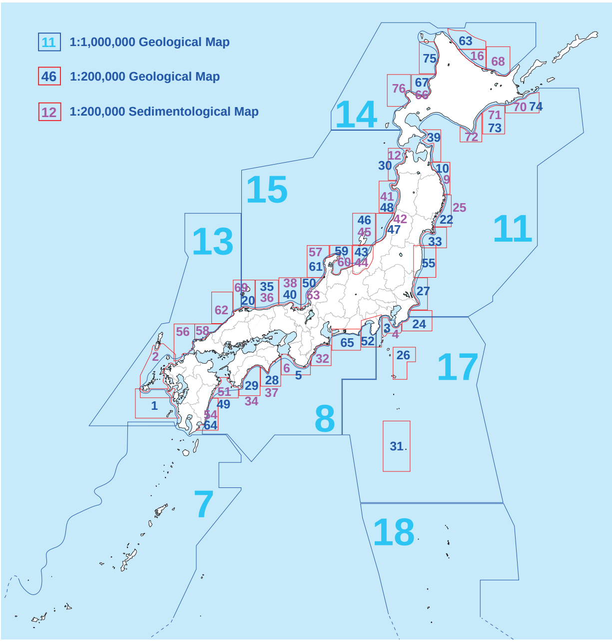

Fig. 2 Publication status of the marine geology maps for ocean regions around Japan
The areas within blue lines are those for which 1:1,000,000 marine geology maps have been published, and the red blocks are areas covered by published 1:200,000 marine geology maps (from AIST URL).

The Ryukyu Arc is a chain of islands that extends for approximately 1,200 km between Kyushu and Taiwan. It is an arc-trench system created as a result of subduction of the Philippine Sea Plate along the Ryukyu Trench. The Ryukyu Trench runs in a northeast-southwest direction, almost parallel to the Ryukyu Island Arc, and reaches a maximum depth of over 6,000 m. The orientation of the Ryukyu Arc shifts to east-west in the southern region (Fig. 5). In contrast to the Nankai Trough subduction zone offshore of Shikoku and Honshu, the fore-arc slope of the Ryukyu Trench is extremely limited, and there is almost no fore-arc basin, and no significant outer-arc ridge. This is possibly due to the difference in the subduction mechanism of the Philippine Sea Plate. The lack of the outer-arc ridge is more conspicuous on the slopes of the Ryukyu Trench north of Okinawa-jima Island than in the middle of the northern region.[7] The Ryukyu Arc can be divided into three regions, based on differences in zonal geological structure: North Ryukyu, Central Ryukyu, and South Ryukyu.[8] The borders of these regions are defined by Tokara Strait and Kerama Gap, a depression over 1,000 m deep that runs northwest-southeast. These structures were formed by normal faulting oriented perpendicular to the axis of the Ryukyu Arc. A number of active normal faults were identified east of Okinawa-jima Island from data collected during the GH08 cruise,[9] with subsequent analysis demonstrating that they developed in shallow areas close to land in the Ryukyu Arc and its upper fore-arc slope. Given that activity on these faults may cause tsunamis, it is necessary to investigate their distribution and activity in more detail. Historical records from Okinawa reveal little evidence of an earthquake and tsunami that caused significant damage. However, the Yaeyama Earthquake and Tsunami of Meiwa 8 (1771) caused major damage in the Yaeyama and Miyako Islands.[10] This emphasizes the importance of evaluating the geological hazards present in the Ryukyu Arc as part of the Okinawa Project.

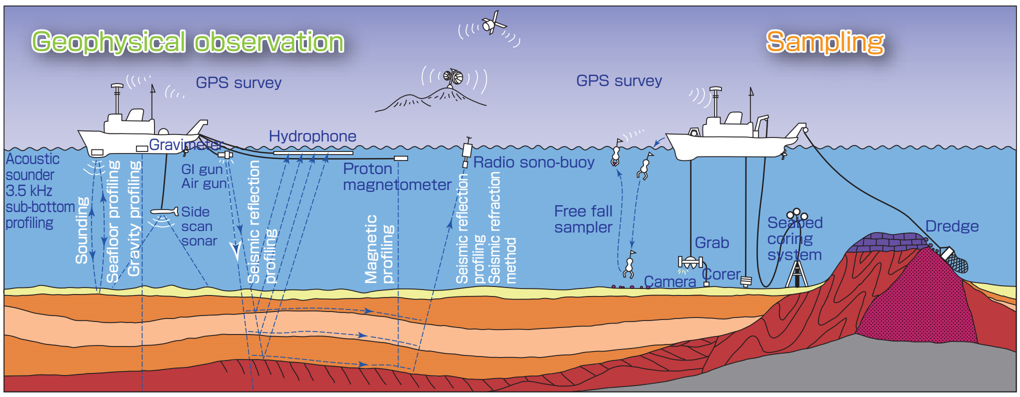

Fig. 3 Schematic diagram of the marine geological survey methods (from Reference [6])
Bathymetric, sub-bottom profiling, seismic reflection profiling, gravity, and magnetic surveys were conducted for creation of the 1:200,000 marine geology maps. Sampling mainly included grab sampling, core sampling, and dredging.

An active back-arc basin, known as the Okinawa Trough, runs almost parallel to the Ryukyu Arc on its northwestern side.[11] The trough is 1,000 km long and 200 km wide, with a depth that gradually increases along the axis from north to south, reaching a maximum of 2,000 m. Although there is some disagreement over when formation of Okinawa Trough began, it is generally considered to have been formed during the Pleistocene, based on evidence from seismic stratigraphy.[12] A volcanic front, including submarine volcanoes, runs from Kyushu to the offshore area northwest of Okinawa-jima Island in the Okinawa Trough.[4][13] While several previous studies have examined the Cenozoic tectonics that formed the Ryukyu Arc and the back-arc basin,[11][14] there is a paucity of data from the northern region, and the tectonics of rifting are not well understood. Therefore, data were collected from the northern Okinawa Trough during the GH11 cruise. The Okinawa Trough is thought to be in an active rifting stage, in which the continental crust is being extended. The northern Okinawa Trough is filled with stratified sediments, with several normal faults cutting the trough (Fig. 6). Rotated fault blocks dip northwest on the northwest side of the trough and toward the southeast on the southeast side,[15] and the sedimentary layer is thinnest in the axial region. The axis of rifting does not necessarily correspond to the areas of deepest bathymetry. In general, the axis of rifting is northeast-southwest, crossing the Okinawa Trough, but it is intersected by en echelon faults.[16] These observations demonstrate the importance of examining underlying geological structure, in addition to bathymetry, to gain a full understanding of the geology of these marine areas.

4 Development of submarine mineral resources

As an example of the use of the marine geological maps, we shall discuss the development of submarine mineral resources. AIST has developed techniques and processes for the sampling and analysis of surface sediments and geological structure below the seafloor. It is believed that geological structures control the area in which minerals are deposited.[17] Therefore, these processes aid the organization of the geological information, which can then be used to identify potential areas of mineral deposits. In particular, marine geological surveys performed over uniform grids by AIST may help discover potential deposits in previously overlooked areas.

Multiple national organizations complete submarine mineral resources assessments using a variety of equipment and technology. The Japan Agency for Marine Earth Science and Technology (JAMSTEC) and various university organizations have conducted submarine mineral surveys, focusing on particular resources and gaining an understanding of formation processes. For example, the Integrated Ocean Drilling Program (IODP) undertook scientific drilling for seabed bacteria in the Iheya-North hydrothermal field of the Okinawa Trough.[18] Japan Oil, Gas and Metals National Corporation (JOGMEC) completed core sampling using the Benthic Multicoring System (BMS), targeting prospective regions for resource development and evaluating deposit sizes. These studies have focused on target resources, whereas AIST studies focus on promising locations. To assess submarine mineral resouces effectively, both strategies are required, and must be conducted with mutual collaboration and cooperation.

The following descriptions are the examples of surveys done in the Okinawa Project. The survey for the development of submarine mineral resources based on the marine geological surveys of AIST and the issues will be explained.

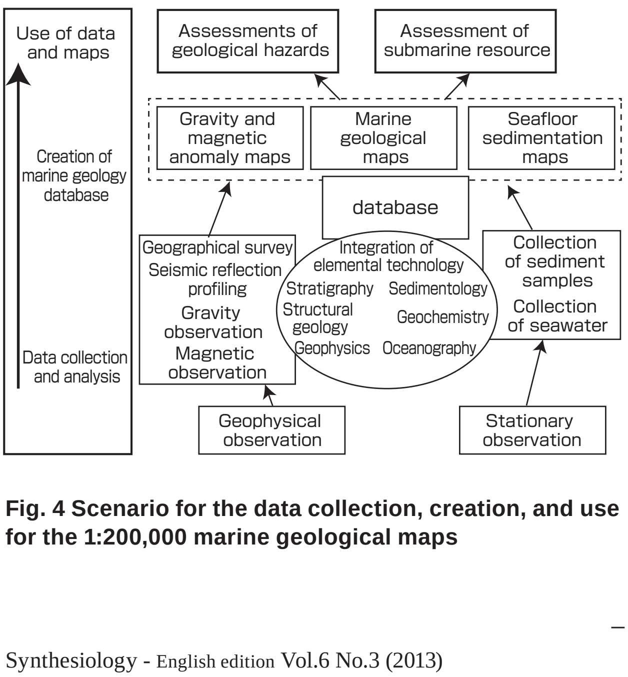

Fig. 4 Scenario for the data collection, creation, and use for the 1:200,000 marine geological maps

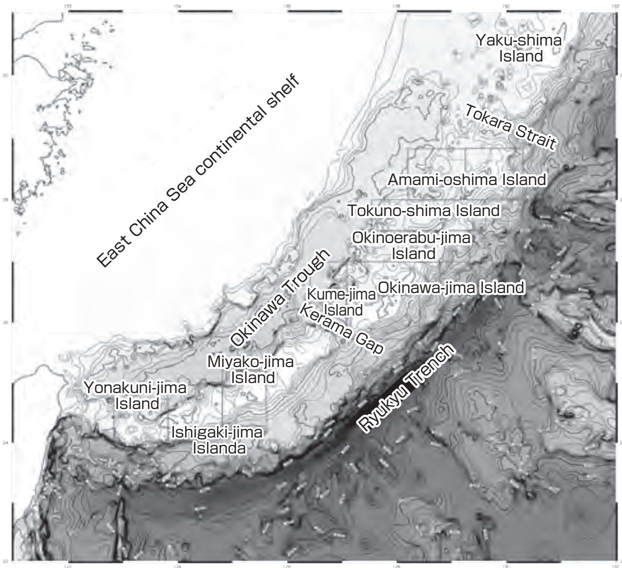

Fig. 5 Maps of the survey area covered in the Okinawa Project, and associated seafloor geography (from Reference [1])

The blocks depict the scheduled survey area for geological maps. As part of the Okinawa Project, ten 1:200,000 geological maps will be created for areas around the island.

4.1 Investigating potential sites in the Okinawa Trough

For this study, we defined potential sites as areas in which the hydrothermal activities currently occur or may have occurred in the past. In the Okinawa Trough, hydrothermal activity may occur at the juncture of the rift axis and intercepting faults, as well as in the calderas of the submarine volcanic front associated with the arc-trench system.[5] Previous surveys around Japan have noted the presence of hydrothermal deposits around submarine calderas and structural depressions in the volcanic fronts of back-arc rifting zones in the Izu-Ogasawara Arc and Okinawa Trough (Fig. 1). Examining the subsurface geological structure, the distribution of fault systems, and the distribution of submarine volcanoes and calderas, may reveal previously unknown hydrothermal deposits in the Okinawa Trough. Moreover, identifying oceanic regions with a similar geological history may help locate mineral deposits in areas that are no longer hydrothermally active. The survey area for the 1:200,000 marine geology maps (Fig. 5) does not extend to the trough surveyed in the Okinawa Project. Therefore, to identify potential sites, it is necessary to expand the survey area to include the back-arc basin of the Okinawa Trough.

4.2 Significance of uniform grid data for discovering potential sites

Marine geophysical surveys are conducted along survey lines perpendicular to the strike of the geological structure or deformation. For the 1:200,000 marine geological maps, survey lines were spaced approximately two nautical miles apart. Data were collected using a narrow multi-beam echo sounder and parametric sub-bottom profiler (SBP), while simultaneously conducting seismic reflection profiling, gravity surveys, and magnetic surveys. The cross line was set at intervals of four nautical miles. By doing this, it was possible to capture geological structures such as faults and fold axes with lengths of 5 km or more. Sediment sampling was conducted at the intersections of survey lines and cross lines. The collection and analysis of such uniform data sets are essential for understanding the whole region, and in limiting the possibility of overlooked structures.

4.3 Current situation and issues affecting the survey of potential sites

4.3.1 Geophysical surveys

The seismic reflection profiling survey is one of the basic methods to know the marine geological structure. The Izena Hole is one potential site for submarine hydrothermal deposits in the juncture of the rift axis and intersecting faults of the Okinawa Trough.[5] Identification of the geological structure of such sites within the back-arc region can be completed using seismic reflection profiling. Using this technique, we succeeded in obtaining cross-sections showing the geological structure of several submarine calderas of the Okinawa Trough during GH09-12 cruises. By combining seismic reflection profiling with rock sampling, gravity profiling, and magnetic profiling, we were able to determine the age, tectonics, and formation mechanisms of the calderas.

However, identifying hydrothermal deposits requires vertical and horizontal resolutions down to several meters, since deposits are composed of mixed sediments from the caldera wall and surrounding area. Also, potential deposits in back-arc basin are generally located in areas with complex topography near caldera walls, and imaging these conventional reflection profiling is difficult. Therefore, additional methods with greater accuracy, such as high-resolution acoustic surveys combined with gravity and magnetic profiling, are required to locate hydrothermal deposits.

4.3.2 Stationary observation surveys

For the conventional sampling, the stationary surveys we conducted included surface sediment sampling over survey grids using a grab sampler, columnar core sampling, and rock sampling using a dredge in steep areas with exposed rocks. The surface sediment samples we collected have not previously been used to search for indications of hydrothermal activity. However, it can be achieved by leaching the sediment samples using a weak acid, and

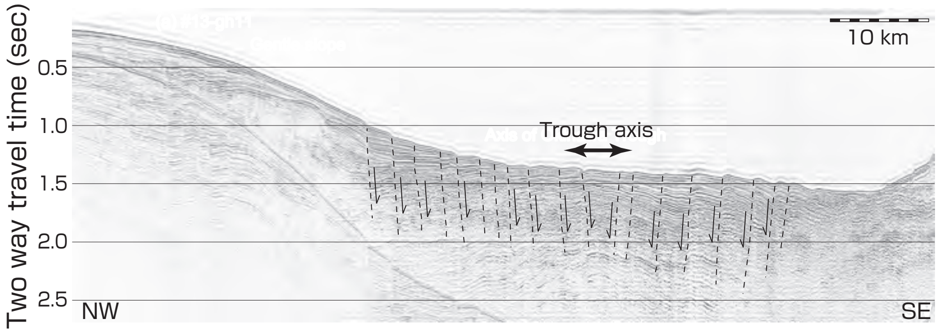

Fig. 6 Cross-section of the seismic profile obtained in the GH11 cruise (from Reference [16])
The seismic profile cross-section perpendicular to the Okinawa Trough. The internal reflectors clearly display stratified sediments, which are intersected by normal faults (dashed line).

selectively dissolving and analyzing sulfides released by hydrothermal activity. We conducted surveys during the GH12 cruise in 2012, using a remotely operated vehicle (ROV) owned by JOGMEC (Fig. 7). The ROV conducted seafloor observations at two outcrops over a distance of approximately 2 km, and collected a total of three samples. The work took approximately 5 hours, including launch and retrieval time. During the ROV survey, seafloor images can be observed in real time, and decisions on sample collection can be made on the spot. Using ROVs for outcrop observation could be the next effective step for identifying potential sites of hydrothermal deposits, although the number of ships capable of undertaking ROV surveys is currently limited.

5 Summary and future prospects

In the present study, we have discussed the current state of the Okinawa Project, using it as an example of how the results of marine geological surveys can be utilized within intellectual infrastructures. We have focused on the contribution of the Okinawa Project to the development of submarine mineral resources.

The Okinawa Project, started in FY 2008, aims to obtain geological information and to contribute to organization of geological information around Japan.[19] The survey of the region around Okinawa-jima Island, one of the most important islands of the Ryukyu Arc, was completed in the first 3 years of the project, and the survey of the region around Okinoerabu-jima Island of Kagoshima Prefecture was started in FY 2012. The Okinawa Project is producing important results that allow for detailed submarine mineral exploration, including an understanding of caldera structure and active submarine faults.

Fig. 7 Remotely operated vehicle (ROV) system on *Hakurei*, the vessel used for the GH12 cruise
In this ROV system, the ROV itself can be released in the ocean using a tether cable, allowing for operation with little preparation time. The ROV allows real-time observation of the seafloor, and the manipulator can be used to collect rock samples from the seafloor.

In the future, the survey range of the Okinawa Project may be extended to include the Okinawa Trough, greatly increasing the possibility of discovering new mineral deposits. However, there are a few issues that may limit this expansion. The most pressing issue is the procurement of vessels capable of conducting surveys along fixed lines and at set sampling points. A wide-ranging survey for submarine mineral resources will also face efficiency and technical issues. To advance national interest, the development of submarine mineral resources must be conducted efficiently and effectively across the boundaries of agencies, ministries, and institutions. It is therefore necessary to construct an efficient research system through collaboration and cooperation that enables mutual utilization of technology and knowledge amongst institutions, including AIST.

Acknowledgement

Marine geological investigations around Japan were continuously carried over to AIST from its preceded organization, the Division of Marine Geology, Geological Survey of Japan, Agency of Industrial Science and Technology. They represent the accumulation of scientific discussions and the development of marine survey methods by both of these organizations. We are grateful for the cooperation of all those involved with the marine geological surveys and research vessels, particularly JOGMEC and its precursor, Metal Mining Agency of Japan.

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Authors

Kohsaku Arai

Completed doctoral course at the Division of Material Sciences, Graduate School of Natural Science and Technology, Kanazawa University in 1994. Joined the Geological Survey of Japan, Agency of Industrial Science and Technology, Ministry of International Trade and Industry in 1997. Senior Researcher of the Institute for Marine Resources and Environment, AIST in 2001; Senior Researcher of the Institute of Geology and Geoinformation, AIST in 2004; and Leader of the Marine Geology Research Group, IGG, AIST from 2010. Engaged in marine geological surveys since joining AIST, and including creation and publication of marine geological maps such as Enshunada Geological Map. Led the survey since the inception of the Okinawa Project. In this paper, summarized the current state of the Okinawa Project and discussed its potential contribution to the development of submarine mineral resource.

Gen Shimoda

Completed doctoral course at the Graduate School of Human and Environmental Studies, Kyoto University in 1996 (Doctor of Human and Environmental Studies). Joined Kyoto Fission-Track Co., Ltd. in 1997. Lecturer of the Institute for Geothermal Sciences, Graduate School of Science, Kyoto University in 1990 (researcher of research institution). Supporting Staff for Priority Research of the Institute of Geology and Geoinformation, AIST in 2001; Researcher of the IGG, AIST in 2005; and Leader of the Tectonics and Resources Research Group, IGG, AIST from 2012. Specialty is solid geochemistry. In this paper, described the marine surveys conducted at the potential sites of submarine mineral resources, as well as proposing solutions to survey issues.

Ken Ikehara

Graduated from the Department of Education, Tokyo Gakugei University in 1982. Joined the Geological Survey of Japan, Agency of Industrial Science and Technology, Ministry of International Trade and Industry in 1982. Leader of the Marine Geology Research Group, Institute of Geology and Geoinformation, AIST from 2005; and Leader of the Marine Geological Map Project; and Deputy Director of the IGG, AIST from 2009. Engaged in marine geological survey of the ocean regions around Japan since joining AIST. Specialty is sedimentology. In this paper, as the leader of the Marine Geological Map Project, proposed the ways in which AIST should concentrate efforts to advance the development of submarine mineral resources.

Discussions with Reviewers

1 Overall

Comment (Shigeko Togashi, AIST)

This paper sheds light on the current situation and issues of the geological marine survey, an AIST effort to organize the geological information in the ocean regions around Japan, carried on by the Geological Survey of Japan, especially focusing on the Okinawa Project. Its content is appropriate for a *Synthesiology* paper, as a discussion of the methodology for organizing the national intellectual infrastructure. In the first draft, there were some insufficiencies in the methodology development, but these were improved in the revised version.

Comment (Masahiro Seto, AIST)

This is a very interesting paper that discusses the significance of the marine geological survey in the Okinawa region from the perspectives of earth science, disaster prevention, and assessment of potential mineral resource sites. I think the content and composition are appropriate as a *Synthesiology* paper. I also hope more surveys will be conducted in the Okinawa region in the future.

Answer (Kohsaku Arai)

The survey around Okinawa region has produced new geoscientific findings. Based on the situation with surrounding countries of Japan in recent years, I believe it is necessary to organize the basic geological information quickly. I hope to improve the efficiency of the organization while maintaining the quality of the AIST survey.

2 Flow from collection to use of basic land information data

Comment (Shigeko Togashi)

For the "flow from collection to use of basic geological information data" and Fig. 4, I think you should add detailed information as a *Synthesiology* paper. Particularly, to the people outside the field, it is necessary to carefully explain the process by which the collected data become sedimentological or geological maps. For example, please add the explanation about the necessity of employing the latest knowledge of sedimentology, structural geology, geophysics, geochemistry, mineralogy, seismology, and others, to conduct interpretations of the sedimentation unique to the region, geological structure, or mineral deposition process. Please state clearly that sedimentological or geological maps are compiled by clarifying the geological phenomena of the target region by "synthesizing" the various "elemental technologies" based on a scientific scenario. Also, in Fig. 4, please indicate the process for integrating the disciplines you deem most important among the aforementioned "ologies" that are the keywords. For the "development of the submarine mineral resources," please clarify what was the objective, how the method was selected, and what you found out. Please show the flow of what is necessary to be known in the future, what selection of methods must be made to achieve this, and what are the issues involved.

Answer (Kohsaku Arai)

I have added details of the flow of geological information from collection to use in marine geological maps. During survey cruises, many researchers are involved in the collection of data and samples, and a variety of academic specialties are required to analyze and interpret these data. Samples do not stay within AIST, but are distributed to the specialists in various universities and other institutions. The marine geological map series is the grand culmination of such efforts.

3 "Uniform data"

Comment (Shigeko Togashi)

You use the expression "uniform data," and since this is an important keyword of this paper, please elaborate on this point. When you say uniform, do you mean, for example, "the data is collected spatially in a systematic and comprehensive manner, the selection and collection methods of the data are done in some standardized way, or a certain level of quality is maintained"?

Answer (Kohsaku Arai)

I have added an explanation of this in section 2.

4 Survey method of fault activity in the the seabed

Comment (Masahiro Seto)

You mention that there are faults that intersect the island arc in the Ryukyu Arc and the upper part of its fore-arc slope. You also indicate the importance of the detailed survey of the fault activity. I think the methods for the survey and assessment of the submarine fault activities must be different from the methods on land. Is there technology and methodology established for surveying the submarine faults? If so, what are they?

Answer (Kohsaku Arai)

Many of the earth's plate boundaries are in oceanic areas, along with associated faults that cause major earthquakes. Activity on these submarine faults may also cause tsunamis. AIST studies that assess these active faults consider them from this perspective. First, the distribution and form of active submarine faults are investigated using the seismic reflective profiler. However, estimating the activity and activity history of these faults may be more important than describing their distribution. Previous research investigating faults activity includes studies in which cores were collected on both sides of the active fault, allowing the history of fault activity to be inferred through comparative changes in sediment layer thicknesses. The activity history of submarine faults can also be derived from the frequency of seismic-related sediment structure (turbidites) occurring in columnar core samples. It is important to use the method appropriate for the individual regions for these surveys, and necessary to accumulate case studies on active submarine faults.

5 Restriction caused by geological structures in locations of mineral deposits

Comment (Masahiro Seto)

In general, which structure or phenomenon do you mean when you say, "the geological structure restricts the potential mineral deposition"?

Answer (Kohsaku Arai)

Potential hydrothermal activity is concentrated in the island arc volcano and the back-arc basin. In the back-arc basin, hydrothermal activity accompanies underground magmatic activity due to the formation of the back-arc rift zone in response to the tensile stress field. It is thought that the locations of structures that are continuous to considerable depths underground (e.g., faults) have high potential for mineral deposits.

6 Characteristics of the marine geological survey of the Okinawa region and future development

Comment (Masahiro Seto)

For the marine geological survey of the Okinawa region that started in 2008, what are the future plans for organizing and publishing the geological maps, and by when will they be done? Also, in organizing the geological maps, I think the originality of the researchers in charge is expressed. What differences in characteristics can we expect for the Okinawa region survey compared to the conventional marine geological survey?

Answer (Kohsaku Arai)

The survey is planned to continue until FY 2019. For the production of the geological maps, we are starting from the regions around Okinawa-jima and Kume-jima islands, where the surveys have already been completed. We hope to publish the maps as they are completed. The primary difference between this region and the other surveys conducted to date is the variation in geological structure, as described in this report. One particularly interesting characteristic that distinguishes this region from the four main islands is the lack of major rivers. Instead of land-derived siliciclastic material, this region is dominated by high bioclastic productivity and carbonate particles derived from coral reefs.