Overview of the Special Issue
“Hard-rock Drilling Science: Challenges of Mantle Drilling”

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This special issue titled “Hard-rock Drilling Science: Challenges of Mantle Drilling” introduces several oceanic crust drilling projects related to the International Ocean Discovery Program (IODP) and its recent research results. The topics are broad ranging; they include not only ocean drilling projects but also continental drilling projects, and introduce the latest research and ideas in each field. As the mantle constitutes the largest part of the planet, it has a great impact on all phenomena, especially on the Earth’s surface environment. We have yet to answer the following essential questions: What kind of material comprises the mantle? What is the condition of the mantle? We have no accurate answers to these questions because we have neither reached the mantle nor acquired mantle materials. Mantle drilling is the key to answering these important questions. Our ongoing mantle drilling project aims to penetrate the oceanic crust, which is thinner than the continental crust, in order to reach the top of the mantle at a depth of about 6–7 km below the ocean floor. This project is expected to elucidate some of the most important concepts in Earth science, such as understanding the driving forces of oceanic plate motions and the role of oceanic plates in material circulation within the Earth’s system, which have remained unknown since the idea of plate tectonics was proposed. We hope that this special issue will encourage many early career scientists to participate in mantle research and lead to significant progress in the field.

Mantle drilling is not a new idea, and this project has a long history. Many scientists have contributed to the project since the idea was proposed. Although significant scientific and technological progress has been made, a full understanding has yet to be obtained. Currently, human beings are able to send probes into the solar system and collect samples from the moon and asteroids. In contrast, we cannot collect samples from the mantle, which is only at a depth of several kilometers below the ocean floor, and we cannot even send measuring devices to the mantle. Our experience has shown that this major scientific project will not be easy to implement in the near future. Therefore, it is necessary to perform small drilling projects step by step to complete the overall project. This special issue introduces the scientific importance and purposes of several drilling projects that have been proposed. In the case of mantle drilling at the ocean floor, drilling through several hundred meters of the sedimentary layer deposited on the oceanic plate is only the initial step, and most ocean drilling projects so far have focused on this step. The main issue is the hard-rock layer, the oceanic crust, beneath the sedimentary layer. For this reason, any drilling that targets hard-rock layers such as the oceanic crust is called hard-rock drilling in our community.

This special issue consists of six review articles and two original research articles.

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Michibayashi (2021) focuses on the history of ocean drilling up to the present, especially hard-rock drilling. It is hoped that this article will provide a good reference source in this research field for early career scientists. Even if you are not an early career scientist, it is highly recommended that you read this article before the other articles, as it provides basic information needed for understanding the context of this special issue.

Morishita et al. (2021) introduce the scientific significance and purposes of mantle drilling. The mantle drilling project is driven by a large, international scientific community, which is very diverse, and includes researchers involved in geology, seismology, environment science, and biology. The essence of this special issue has been introduced, which provides a definition of mantle drilling for early career scientists.

Takazawa (2021) introduces the results of a recent ophiolite drilling project in the Sultanate of Oman. Oman ophiolite, which was drilled in the project of the International Continental Scientific Drilling Program (ICDP), is believed to have formed the oceanic crust in the past. Because it is related to the oceanic crust, Oman ophiolite has been repeatedly investigated and presents a good opportunity for us to study the past crust-mantle boundary. This article describes how drilling samples were analyzed aboard the drilling vessel Chikyu. The project is a preliminary study for future mantle drilling.

Ishizuka (2021) introduces the research results of hard-rock drilling at the Izu-Ogasawara Island Arc. In particular, he describes details of a drilling expedition of the IODP in 2014. The author participated in the drilling expedition as a co-chief scientist and led the project. This article describes the formation and evolution of the Izu-Ogasawara Island Arc as revealed by the project, and presents new questions arising from the findings.

Ohara (2021) introduces in detail a study on oceanic core complexes, which are unique structures that appear on oceanic plates. He explains previous studies and a drilling project that may be carried out in the near future. Godzilla Megamullion in the Philippine Sea is the world's largest oceanic core complex, where we can obtain rock samples constituting the lower oceanic crust and the uppermost mantle from this oceanic core complex. Based on a comparison between Godzilla Megamullion and other oceanic core complexes, researching the Godzilla Megamullion complex may help to explain the tectonic history of oceanic core complexes.

Sano et al. (2021) describe an ocean drilling project on the Ontong Java Plateau, the largest igneous province on Earth. Because of its size, the volcano may have been divided into several parts by plate motions after its formation. Reconstructing this divided volcano is important for understanding the formation mechanism. The goal of this ocean drilling project is to obtain samples of fragments of the old plateau, which are essential for reconstructing the large igneous province. The Earth's largest volcanic activity must have had a great impact on the Earth's surface environment, and this is an attractive research subject not only in the field of volcanology but also in other Earth science fields.

Tatsumi et al. (2021) discuss the possibility of the disappearance of oceans in the near future on the time scale of Earth history because of the transport of large amounts of seawater to the mantle after being trapped by the subduction of oceanic plates. They also explain how seawater becomes trapped in the oceanic plate. Drilling into oceanic plates and the mantle just prior to subduction is key to understanding the disappearance of oceans. Although this is not a technically easy drilling project, it is interesting because they argue that the oceans, which have existed for a long time in the Earth's history, could disappear just as they did on the neighboring planet, Mars.

Umino and Kusano (2021) introduce the idea that there are three potential sites for mantle drilling proposed in the IODP. One of them, the drilling plan for off-Hawaii, is interesting.
and significant. It is explained that the mode and rate of plate spreading are closely related to the structure of the oceanic crust, and it is argued that oceanic crust drilling is essential for an understanding of the lithology and density structure of the oceanic crust. Furthermore, it is conceivable that this drilling project will be the first stage of future mantle drilling, and the research results and drilling technology obtained are expected to be utilized in the next stage.

Samples returned have contributed significantly to the development of Earth and planetary sciences. To understand not only various phenomena occurring in the Earth’s interior but also to evaluate the mantle’s effects on the surface environment where we live, it is essential to conduct research in a wide range of fields related to the samples returned from mantle drilling. In this special issue, We introduce readers to some of the activities undertaken by many scientists to achieve this goal. It is impossible to cover a large mantle drilling project that has a long history in this special issue. Each paper includes many references to related studies, and we hope that readers will follow up these references to learn more about research topics that are not covered in this special issue.

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References

Ishizuka, O. (2021): Outcome of hard rock drilling in the Izu–Bonin Arc. *Journal of Geography (Chigaku Zasshi)*, **130**, 527–542. (in Japanese with English abstract)

Michibayashi, K. (2021): History of deep-sea ocean basement drilling programs and contributions to the Earth sciences. *Journal of Geography (Chigaku Zasshi)*, **130**, 461–482. (in Japanese with English abstract)

Morishita, T., Fujie, G., Hirauchi, K., Katayama, I., Kouketsu, Y., Kuroda, J., Okamoto, A., Ono, S., Michibayashi, K., Morono, Y. and Yamamoto, J. (2021): Crucial scientific issues in earth science revealed only by mantle drilling: Understanding the current state of the oceanic plates of a life-bearing planet. *Journal of Geography (Chigaku Zasshi)*, **130**, 483–506. (in Japanese with English abstract)

Ohara, Y. (2021): IODP drilling at the Godzilla Megamullion: The nature of the backarc basin lower crust and upper mantle. *Journal of Geography (Chigaku Zasshi)*, **130**, 543–558. (in Japanese with English abstract)

Sano, T., Tejada, M.L., Nakanishi, M., Hanyu, T., Miura, S., Suetsugu, D., Tonegawa, T., Ishikawa, A., Shimizu, K. and Shimizu, S. (2021): Testing the Ontong Java Nui hypothesis: The largest supervolcano ever on the Earth. *Journal of Geography (Chigaku Zasshi)*, **130**, 559–584. (in Japanese with English abstract)

Takazawa, E. (2021): Achievements and future prospects of the ICDP Oman Drilling Project. *Journal of Geography (Chigaku Zasshi)*, **130**, 507–525. (in Japanese with English abstract)

Tatsumi, Y., Suenaga, N., Yoshioka, S. and Kaneko, K. (2021): Drilling into the mantle: A key to prognosticating the future of ocean planet. *Journal of Geography (Chigaku Zasshi)*, **130**, 585–597. (in Japanese with English abstract)

Umino, S. and Kusano, Y. (2021): Understanding of the spreading and formation of oceanic plates by drilling in the upper crust off Hawaii. *Journal of Geography (Chigaku Zasshi)*, **130**, 599–614. (in Japanese with English abstract)