【Grant-in-Aid for Scientific Research (S)】

Construction of a new view of the Earth that integrates the environment, life and resources based on the understanding of the phenomenon of asteroid impacts in oceans

Principal Investigator	The University of Tokyo, Graduate School of Engineering, Associate Professor NAKAMURA Kentaro	Researcher Number:40512083
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Purpose and Background of the Research

●Outline of the Research

In this study, (1) high-resolution chemical composition and isotopic analysis of deep-sea sediment core samples and (2) simulation of impact tsunamis will be used to clarify the effect of meteorite impact events in the ocean on the marine environment and biological activities and their role in resource formation (Fig. 1).

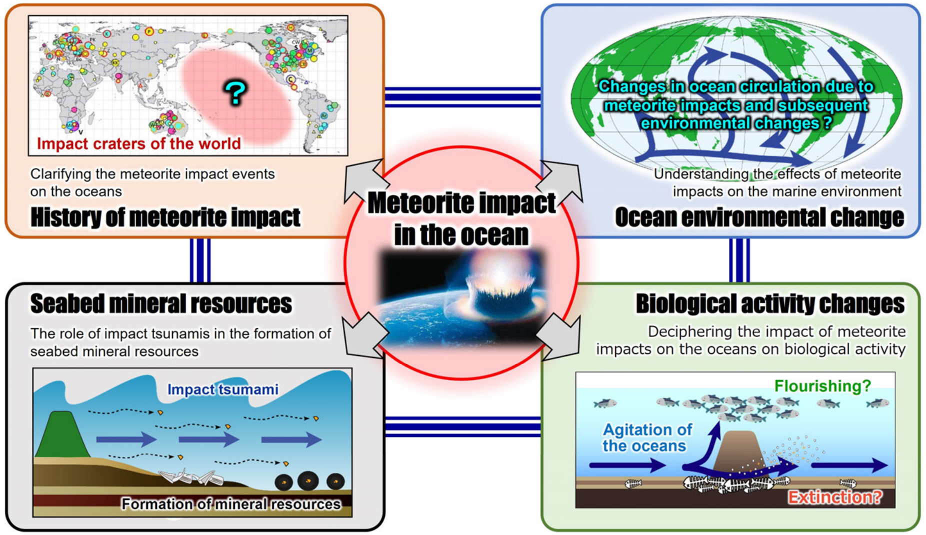

Figure 1. Overall picture of this research.

●Research background

We conducted research on "REY-rich mud," a resource rich in rare earths, which are essential elements for high-tech industries, and "ferromanganese nodules," a resource rich in Co and Ni, which are rare metals essential for lithium-ion batteries, through the Grant-in-Aid for Scientific Research (A) from 2017 to 2021. As a result, it became clear that "erosion," in which layers that should be there are scraped off and lost, is occurring on a large scale with the formation of highly REY-rich mud and that ferromanganese nodules have started growing at the same time, with rock fragments supplied in large quantities from the surrounding seamounts as nuclei.

At depths >5,000 m, deep-sea current cannot be considered to scrape the seabed and scatter rock fragments from the seamount. Based on sedimentological knowledge, this requires water currents of several m/s or more, which are as fast as the flow of a river. However, in practice, only slow water currents on the order of cm/s have been observed on the deep-sea floor. Therefore, a zero-based investigation of this catastrophic phenomenon, which cannot occur under steady-state conditions, led to the concept of tsunamis. Preliminary results of simulations showed that only "impact tsunamis" caused by meteorite impacts in the ocean can generate water currents fast enough for erosion on the deep-sea floor.

To date, research on meteorite impacts on Earth has been limited to impacts on land or shallow oceans, as in the case of the dinosaur extinction, and little is known about meteorite impacts in the ocean, which covers approximately 70% of the Earth's surface. This might be because such impacts on the ocean do not produce craters and because the amount of ejecta produced is very small, making them extremely elusive.

In this study, we aim to elucidate the whole picture of meteorite impact on the oceans and its role in the evolution of the Earth's surface from the perspective of the environment, life, and resources by means of high-resolution chemical composition, isotopic analysis, and tsunami simulation.

Expected Research Achievements

In this study, high-resolution whole-rock chemical compositions are going to be assessed on deep-sea sediments using a laser ablation system to detect erosion surfaces and the impact traces left on them to capture the impact of celestial bodies on the ocean. The ages of the detected impact events will be determined using osmium isotope stratigraphy dating. Simultaneously, tsunami simulations will also be conducted to investigate the physical conditions, such as the location of the impact, the size and velocity of the impacting object, and the type of tsunami generated and propagated (Fig. 2), to quantitatively clarify the impact of tsunamis.

The generation of tsunamis by meteorite impact is believed to cause large-scale disturbances in the vertical and horizontal directions of the ocean. Traces of this large-scale water mass change recorded in pelagic sediments will be chemically traced using Nd and Pb isotopes of seawater origin to reveal the disturbance of the marine environment caused by meteorite impacts. In parallel, the barium isotopes of biogenic material recorded in deep-sea sediments will be analyzed to decipher the rise and fall of biological activity associated with meteorite impact events.

Furthermore, the role of impact tsunamis in the formation of seabed mineral resources will be elucidated. By considering the interaction between high-speed currents induced by impact tsunamis and seamounts, the correlation between meteorite impacts on the ocean and seabed mineral resource formation will be elucidated, which will reveal the governing rules for the distribution of mineral resources on the vast seafloor (Fig. 3).

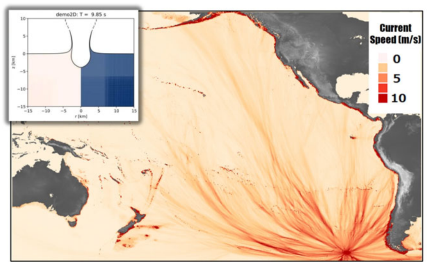

Figure 3. A simulation result of current velocity distribution due to an impact tsunami.

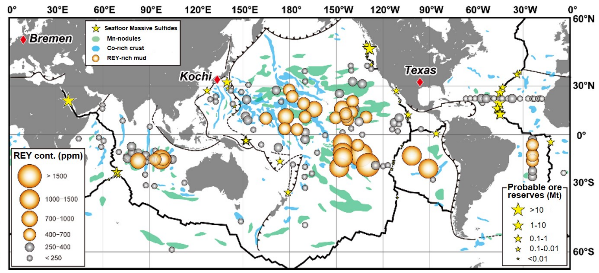

Figure 4. Projected distribution map of the world's seabed mineral resources.

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