INTERNATIONAL OCEAN DRILLING PROGRAMME

PROPOSAL 1122-PRE

Submarine Hazards, Responses, and Eruption cycles from Kikai caldera (SHREK): Impacts and systematics along the Northern Ryukyu arc, Japan

IODP^3 Proposal Cover Sheet

Proposal Title:

Submarine Hazards, Responses, and Eruption cycles from Kikai caldera (SHREK): Impacts and systematics along the Northern Ryukyu arc, Japan

Broad Geographic Area of the Proposal

Kikai Caldera, South of Kyushu. Japan

Project Abstract

Caldera-forming volcanism is one of the most catastrophic geohazards on Earth. Driven by rapid evacuation of large magma volumes from the shallow crust, these eruptions form kilometer-scale collapse depressions and are capable of reshaping regional landscapes and altering planetary climate and ecology. Caldera-forming systems at the land–sea interface generate cascading hazards, including tsunamis, seafloor deformation, and atmospheric shockwaves, yet are poorly understood despite their significant socio-economic risks. The Hunga eruption in 2022 underscored this vulnerability, exposing a global lack of preparedness rooted in incomplete understanding of eruption mechanisms, precursory activity and cyclic behavior of marine caldera-forming eruptions. Marine eruptive records, together with greater knowledge of how external factors (e.g., tectonics, climate, flank collapses) may affect the eruption systematics, are crucial to quantify the hazards of those systems arising for society, economics, and environment.

Kikai Caldera, a large, mostly submarine complex located south of Kyushu, Japan, is an ideal natural laboratory to overcome these limitations. Its most recent caldera-forming event, the catastrophic Akahoya eruption at 7.3 ka, was the largest eruption of the Holocene, which generated tsunamis and pyroclastic flows traveling over water for >80 km to reach mainland Japan, impacting early Japanese society and culture. Yet because of Kikai's vast offshore extent, its eruptive history and caldera cycle dynamics in the extensional Northern Ryukyu region, and their relationship to those of other large calderas of Kyushu, are poorly constrained. Obtaining the buried submarine sedimentary and volcanic record at Kikai to establish robust eruption time series, including eruptive volumes, distribution patterns and geochemistry, and to determine past climate and biological responses, will elucidate if and how repeated large eruptions influence the ecosystem, paleoclimate and oceanography, or vice versa.

To do so, we propose an IODP^3 expedition to drill the subseafloor archives around Kikai Caldera. By recovering continuous marine tephra records and proximal volcaniclastic successions, this project will establish a high-resolution chronostratigraphy of Kikai and Northern Ryukyu volcanism in the Holocene and Pleistocene. These cores, integrated with extensive geophysical profiling, will constrain pre-eruptive magmatic evolution, test caldera cycle models, characterize the current state of magmatic resurgence, and reveal the subaerial, submarine, and over-water transport processes, as well as hydrothermal activity and microbial responses. Ultimately, drilling at Kikai will bridge the critical knowledge gap between marine volcanic observations and land-based geological surveys, yielding quantitative estimates regarding the occurrence, scales, mechanisms, global climate and tectonic feedbacks, and biological impacts of giant arc volcanism.

Scientific Objectives

I) Reveal the links between tectonics, paleoclimate, sedimentation, and volcanism in the Northern Ryukyu arc, and how volcanism may have been spatio-temporally controlled during the evolution of the extensional Northern Ryukyu region and the Quaternary paleoclimate [**S**cientific **O**bjectives 2,3,4,7; 2050 science framework];

II) Determine the dynamics, cycles, triggers and impacts of caldera-forming eruptions from submarine to subaerial, including eruption frequencies, distributions, magnitudes and rates, the mechanisms of caldera collapse, inter-caldera stage volcanism, and links between regional large caldera systems [**SO** 2,7];

III) Quantify how ash alteration and caldera-hosted hydrothermal fluids regulate subseafloor microbial habitats, redox cycling, and ecosystem recovery after repeated large eruptions [**SO** 1,4].

All objectives require data and samples from drill cores to test these specific hypotheses:

1. The Kikai volcanic system has grown through multiple Quaternary caldera cycles, involving more frequent large eruptions than currently known, affecting the seafloor and mainland Japan.
2. The recent lava dome and sediment accumulations within Kikai Caldera record the early inter-caldera stage of the volcanic system and the systematics behind recurrent silicic caldera cycles in coastal volcanic fields.
3. Caldera-forming volcanism in the extensional Northern Ryukyu region includes progressively increasing caldera sizes modulated by external forces from tectonics and climate.
4. Ash alteration and hydrothermal fluids create redox, nutrient, and metal gradients that structure sub-seafloor microbial communities and control biogeochemical recovery after large eruptions.
5. Larger eruptions of Northern Ryukyu arc calderas have modulated and shaped the regional climate and ecology.

Science Communication Plain Language Summary

Giant volcanic eruptions that form large craters, known as calderas, are among the most destructive natural events on Earth. Upon eruption, they rapidly empty their underground magma reservoirs, causing the ground above to collapse. These events do not just reshape local landscapes; they can influence Earth’s climate. By ejecting enormous clouds of ash and gases high into the atmosphere, aerosols resulting from caldera-forming eruptions can reflect sunlight and cause abrupt global cooling persisting for months to years.

The danger is amplified when these volcanoes sit right at the boundary between land and sea. These coastal and underwater volcanoes can unleash a cascade of hazards, including devastating tsunamis, seafloor destruction, and atmospheric shockwaves. The catastrophic 2022 Hunga eruption in the Pacific Ocean reminded the world how unprepared we are for these marine events, largely because their ancient eruptive histories are buried deep underwater and remain a blind spot. Why, how, and over what time scales these eruptions develop and recur are only partly understood.

Kikai Caldera in Japan is the perfect place to study such hazardous volcanic systems. Around 7,300 years ago, Kikai unleashed the largest volcanic eruption of our current geological epoch, creating tsunamis and deposits impacting early Japanese society and culture. The underground processes that breed these rare, giant caldera eruptions are different from common eruptions of smaller volcanoes. However, because much of Kikai is hidden underwater, we still do not know how Kikai´s magma system behaves, how often it erupts over long cycles, what signs it gives off before a disaster, and how it is linked to the other caldera systems on Kyushu, the neighbouring Japanese mainland. Similarly, little is known about how repeated large oceanic eruptions influence the ecosystem, climate and oceanography, or vice versa.

To uncover these secrets, buried beneath the seafloor around Kikai and the Northern Ryukyu arc, we propose an IODP³ ocean drilling research expedition to collect long, continuous sediment cores as marine sediment provide well-preserved record of history, in contrast to the effects of weathering on-land. By studying these seafloor archives for eruptive events and Earth system responses, we can reconstruct hundreds of thousands of years of volcanic activity. This will help us to understand how magma builds up over time, improve our ability to forecast future eruptions, explore the regional global climate and tectonic feedbacks and biological impacts of giant oceanic volcanism and better protect coastal communities worldwide.