

# IODP Proposal Cover Sheet

951 - Full

Hawaiian North Arch Crust

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Title	Drilling Mature Oceanic Crust on North Arch off Hawaii		
Proponents	Susumu Umino, Gregory Moore, Damon Teagle, Steven D'Hondt, Rosalind Coggon, Laura Crispini, Takeshi Hanyu, Nobukazu Seama, Brian Boston, Frieder Klein, Masako Tominaga, Mikiya Yamashita, Michael Garcia, Michelle Harris, Benoit Idefonse, Ikuo Katayama, Yuki Kusano, Yohey Suzuki, Elizabeth Trembath-Reichert, Yasuhiro Yamada		
Keywords	Crustal Architecture, Hydrothermal Alteration, Habitability	Area	North Arch off Hawaii

## Proponent Information

Proponent	Susumu Umino
Affiliation	Kanazawa University
Country	Japan

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## Abstract

We propose to drill using Chikyu on the North Arch off Hawaii, a complete section down to cumulate gabbros of mature (~80 Ma) upper ocean crust formed at a half spreading rate of ~3.5 cm/a. This region is one of the three candidate sites of the MoHole to Mantle (M2M) project. Our overarching goal is to drill a pilot hole to inform the design of a future MoHole and gain experience in deep hard rock drilling with Chikyu.

The formation of new ocean crust at mid-ocean ridges, its subsequent aging over million years leading to subduction, arc volcanism, and recycling of some components into the mantle comprises the dominant cycle of matter and energy on Earth. The average age of the Earth's ocean crust is ~63 Ma and the average age of ocean crust being subducted is ~79 Ma. Although, there are some drillholes in old (>110 Ma) and young (<20 Ma) ocean crust, there is no deep hole (>100 m) into mature intact average age ocean crust that records the full history of seawater-basalt exchange.

With the proposed drilling we will investigate the physical, chemical, and biological architecture and evolution of the ocean crust to test three major hypotheses, that: (1) the North Arch crust spread at an intermediate rate will comprise an intact 740–820 m-thick extrusive sequence with 50:50 pillow and sheet flows, overlying a thick (1,770–880 m) sheeted dike complex (Challenges 8, 9); (2) hydrothermal exchanges between the ocean crust and seawater are episodic and the extent of fluid-rock exchange does not just reflect the age of the crust but external factors that enhance fluid flow and reaction (Challenges 10, 13, 14); (3) in ocean crust cooler than the thermal limit to life, water-rock interactions sustain microbial life as deeply as seawater-derived fluid penetrates (Challenges 5, 6). Drilling will provide additional insights into the North Arch volcanism and the hazardous giant landslides from the Hawaiian volcanoes (Challenges 8, 12).

The drilling operation will be conducted in three stages: Stage 1 coring sediment to below the sediment-basalt interface (Hole A), drilling and coring basement to 1,130 mbsf and setting casing (Hole B); Stage 2 (Hole B) coring and setting casing to 1,730 mbsf; and Stage 3 coring to 2,500 mbsf and penetrating through the Layer 2-3 transition and into the uppermost cumulate gabbros without casing.

## Scientific Objectives

The major objectives of the off-Hawaii drilling are to:

- a. Determine the structure and petrology of the extrusive lavas, sheeted dike complex, upper gabbros, and their correlations with seismic layers, specifically the nature of Layer 2-3 transition.
- b. Investigate the history of deformation and its relationships to spreading, and hydrothermal fluid-flow.
- c. Evaluate the nature of the conductive thermal boundary layer between the axial magmatic chamber and the overlying sheeted dikes and make the first direct observations of the uppermost cumulate rocks.
- d. Evaluate the extent and mode of tectonic disturbance and geochemical alteration by flexure of mature Pacific lithosphere and North Arch volcanism.
- e. Determine a long-term sedimentary record of giant landslides.
- f. Compare hydrothermal alteration of mature (~80 Ma) intact ocean crust with younger (e.g., Holes 504B, 1256D) and older (e.g., Hole 801C), and slow-spreading crust (e.g., Exp. 390/393 South Atlantic Transect).
- g. Determine the nature, relative timing and absolute ages, and formation temperatures of successive alteration minerals, and quantify the extents of hydrothermal exchanges for fluid-mobile elements and volatiles.
- h. Determine the depth limit of low-temperature hydrothermal alteration and quantify the associated chemical exchange.
- i. Investigate the compositions and the extent of microbial communities in vein-filling secondary minerals in the deeper crust and their phylogenetic relationships to microbes in the overlying sediment and in the surface world.
- j. Identify relationships between in situ metabolic gene expression, microbial capabilities under experimental conditions, alteration history, and physical/chemical gradients from the sediment/crust interface to the upper gabbros.

### Non-standard measurements technology needed to achieve the proposed scientific objectives

## Proposal History

Submission Type **Resubmission from previously submitted proposal**

Review Response

IODP 951-Pre "Drilling Middle Aged Oceanic Crust on North Arch off Hawaii" was submitted by Umino et al. in April 2019 and reviewed by the IODP Science Evaluation Panel (SEP) in June 2019. The proposed site is one of the three candidate sites of the IODP 805-MDP "MoHole to Mantle (M2M)" submitted by Umino and 67 co-proponents in April 2012. Following the SEP recommendations to 951-Pre, 951-Full Proposal has been developed by discussions at two workshops: 1) Ancillary meeting at AGU Fall Meeting "Scientific Ocean Drilling Off Hawaii with Chikyu" in December 2019 and 2) "Exploring Deep Oceanic Crust off Hawaii: Workshop for IODP 951-Full proposal development" in June-July 2020, a 4-day virtual workshop that engaged 105 scientists from 16 nations. During the virtual workshop, it has been a consensus among participants that 951-Full should be developed as a pilot hole project for future mantle drilling with Chikyu. The 951-Full proposal submitted here has been established by geologists, geochemists, and geomicrobiologists, resulting in a broader set of fundamentally significant scientific goals than those previously proposed by 951-Pre. In addition, the drilling strategy in 951-Full was prepared by extensive discussions with the mantle drilling promotion office and Chikyu's operational team at JAMSTEC/MarE3, with anticipation toward mantle drilling in the future.

## Proposed Sites (Total proposed sites: 3; pri: 1; alt: 2; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
NA-03A (Primary)	23.673837 -155.674216	4271	110	2390	2500	Primary site; Complete penetration from sediment through extrusive rocks and sheeted dikes into gabbro; underlain by the Moho reflector
NA-04A (Alternate)	23.508483 -155.62134	4268	320	2180	2500	Complete penetration from sediment through extrusive rocks and sheeted dikes into gabbro
NA-05A (Alternate)	23.62863 -155.83891	4316	195	2305	2500	Complete penetration from sediment through extrusive rocks and sheeted dikes into gabbro