Pre-prososal 951: The middle aged upper crust penetration on the North Arch off-Hawaii MoHole candidate site

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We propose to drill a complete upper crustal section and into the uppermost gabbros in ~80 Ma crust spread at 8 cm/a on the North Arch off-Hawaii (Fig. 1). The goals are to better understand the physical, chemical, and biological architecture and evolution of the oceanic crust, with special reference to the relationship between the diversity of Moho and aging of oceanic lithosphere including the effect of North Arch volcanism, as well as the history of hazardous giant landslides from the Hawaiian volcanoes.

Previous drilling into tectonically undisturbed oceanic crust is limited and skewed to young and slow-spread crust <4 cm/a, with a wide gap of crustal age between 20 and 110 Ma, including the world average age of 63 Ma and spreading rate of 8 cm/a (Fig. 2). Thus, previous drilling of oceanic crust has not sampled representative oceanic crust. The oceanic crust on the North Arch off-Hawaii meets the average spreading rate and the age gap and is ideal to understand the physical and chemical evolution of aged oceanic lithosphere and the diversity of Moho.

The overarching goals to be addressed by drilling are to better constrain

1) the nature of layer 2/3 transition and its relations with the dike-plutonic transition,

2) the relationships between the style of crustal extension and the architecture of the upper crust,

3) the styles and vigor of hydrothermal circulation and alteration with declining temperature in the aged oceanic crust,

4) the physical and chemical evolution of oceanic lithosphere with special reference to the Moho diversity and the North Arch volcanism,

5) the frequency, size and possible failure mechanics of hazardous giant landslides caused by the periodic collapse of Hawaiian shield volcanoes, and

6) the depth limits of microbial life in ~85 Ma aged, hydrated, and cold crust where metabolic strategies have remained completely unexplored.

We have yet to penetrate through the dike-plutonic transition and recover the lower crustal cumulates, which are critical to understand the relationships between lithology and physical property through the

Layer 2/3 transition, and the magmatic accretion and hydrothermal cooling at depth.

The style of crustal extension differs in fast and intermediate spreading ridges, which makes the distinct density structures of the upper crust. Fast-spread oceanic crust comprises dense sheet flows underlain by thin sheeted dikes. This density structure enhances more magma to extrude, allowing the crust to extend solely by magmatic accretion. In contrast, the intermediate-spread crust consists of less dense, pillow-dominant extrusive rocks, yielding an apparent level of neutral buoyancy that traps magma to develop the sheeted dikes below. The crust consequently extends by dike intrusions in the lower levels and by faults in the shallow levels to form axial troughs. The style of crustal extension from magmatic accretion to stretching changes in a spreading rate interval of 7–10 cm/a. The relationship between the plate spreading mode and the resulting oceanic crustal architecture is a key issue for this drilling program.

Aged lithosphere upon subduction is important in generating arc magmas and large earthquakes through dehydration, and ultimately the geochemical evolution of the mantle. Aging of lithosphere also causes the diversity of Moho in the Pacific Plate. Correlation of magma geochemistry, alteration, stress conditions and seismic structures investigated by drilling enables us to understand the relationship between the Moho diversity and the aging of oceanic lithosphere.

The enormous size and rapid growth of Hawaiian volcanoes causes them to become gravitationally unstable and collapse, which have generated some of the largest landslides on Earth and undoubtedly produced colossal tsunami waves.

Drilling into the deep crust would provide the limit of extremophilic biological communities that could survive or once survived at extremely high temperatures or with low nutrient and energy supplies.

Keywords: Oceanfloor Drilling, MoHole, Upper crust penetration off Hawaii, Crustal architecture, North Arch volcanism, Giant landslides

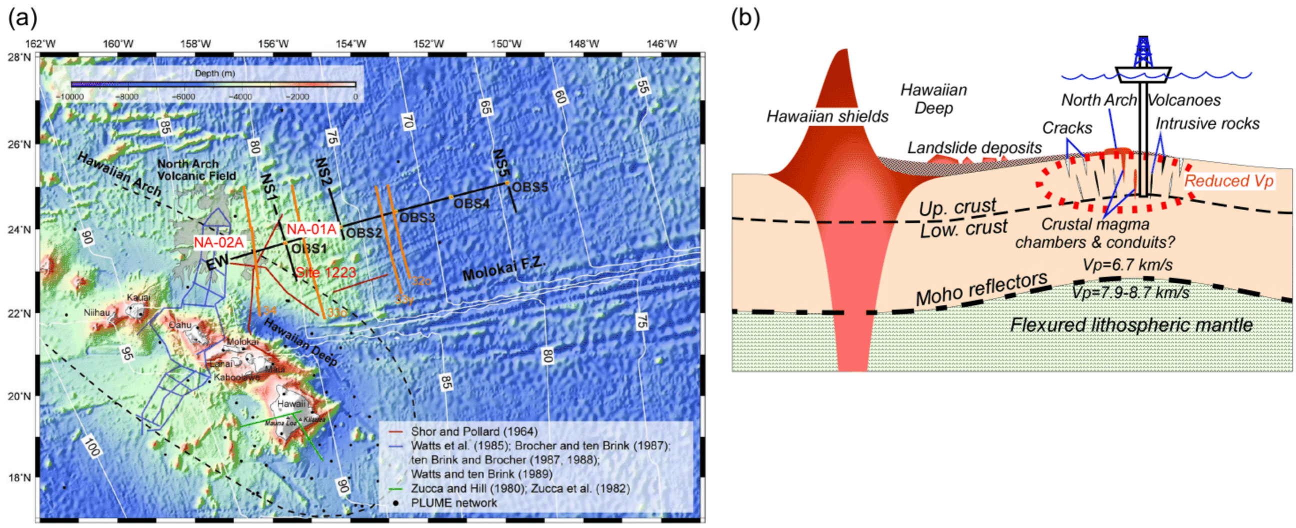

Fig. 1. (a) Proposed drill sites (stars) and the bathymetry of the North Arch volcanic field [after Ohira et al., 2018]. Magnetic anomalies (orange lines) are based on NOAA Marine Trackline Geophysical Data (https://www.ngdc.noaa.gov/mgg/geodas/trackline.html). (b) Flexured lithosphere by the load of Hawaiian volcanoes formed exensional cracks in the shallow levels on the North Arch, which reduces crustal Vps[Ohira et al., 2008]. In contrast, Vp structures in the uppermost mantle are comparable to those in other lithospheric mantle formed at fast-spreading ridges, indicating preservation of the original structures.

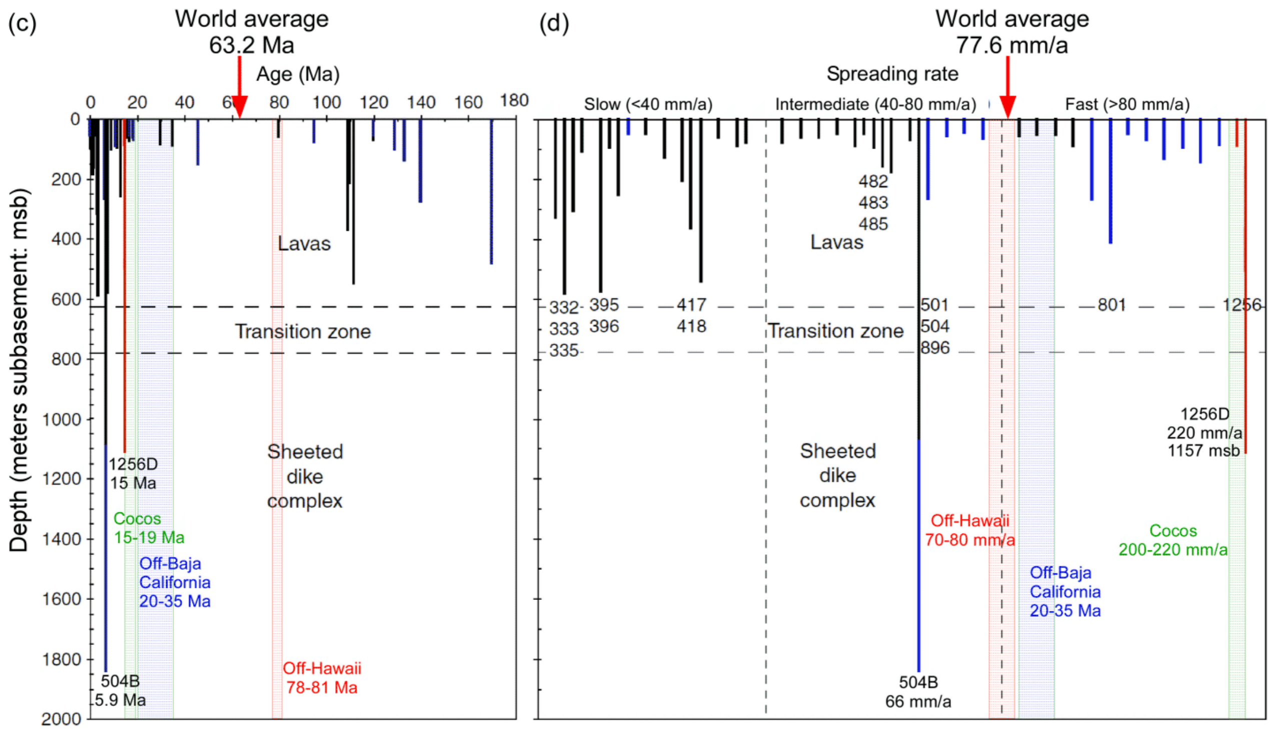

Fig. 2. Ocean drill holes deeper than 50 m into the oceanic basement plotted against the basement age (c) and categorized on the basis of spreading rate that formed the basement crust (d) [modified after Teagle et al., 2006]. World average age and spreading rate are based on the 3.6 min grid data from EarthByte agegrid 2008 [Muller et al., 2008].