Realistic Mohole using D/V Chikyu

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Abstract

We propose realistic Mohole using D/V Chikyu. The basic policy is to drill a deep, full ocean crustal penetration hole through the Moho, and into the uppermost mantle at a single site formed at a fast spreading rate ridge system, where normal intact ocean crust with the typical Moho discontinuity exists. In order to make the Mohole an operationally realistic, we emphasize to fully use an ability of riser D/V Chikyu; acquiring cuttings and/or mini-core, analyzing mud gas, continuous wall geophysical measurements by a logging tools, and drilling core samples using branch moat. Further, a combination of the Mohole drilling with high quality seismic surveys is an essential approach, because the Mohole drilling provides a deep reference hole for the ocean crust and the uppermost mantle, which allows us to properly interpret the velocity structure obtained from the high quality seismic surveys. On the other hand, the seismic surveys provide us with the similarity and/or the variety of velocity structure in space (or in different crustal age). Further combinations with land studies of ophiolites and laboratory measurements of rocks would provide us with critical information to understand the nature of the crust, the Moho discontinuity, and the uppermost mantle, and also dynamic processes forming the oceanic crust. Moreover, we propose eastern part of the north Hawaiian arch as one of feasible candidates for the Mohole site using D/V Chikyu. A big advantage of this site is that the Moho temperature is expected to be below 150°C; that is much lower than that of oceanic crust with its water depth of 4100-4300m. The final Mohole site should be decided after discussions among the international community with enough geophysical data for all candidates.

Basic policy

We propose realistic Mohole using D/V Chikyu. The basic policy is the same as the 21st Century Mohole; that is to drill a deep, full ocean crustal penetration hole through the Moho, and into the uppermost mantle at a single site to achieve a quantum increase in our understanding of Earth evolution (Ildefonse et al., 2007). This drilling hole will be a deep reference hole of the ocean crust and of the uppermost mantle, because it is the first trial that the human performs. Therefore, the drilling site is required to show normal intact ocean crust with the typical Moho discontinuity formed at a fast spreading rate ridge system; crust formed at a slow spreading rate ridge system should be avoided for the drilling site because of their variety of crustal structure.

Full usage of D/V Chikyu ability

We emphasize to fully use the ability of riser D/V Chikyu in order to make the Mohole an operationally realistic. The concrete plan of the realistic Mohole consists of following three phases.

Phase 1: Drilling with acquiring cuttings as rock samples, analyzing mud gas, and wall geophysical measurements using logging tools (e.g., LWD; Logging-While-Drilling). This way is so-called "well-site geology" and allows us to save drilling time, which results in achieving the Moho penetration more realistically. The cuttings are small (1~4 mm in diameter), but they provide us with the mineral chemistry and the lithology. Further, both of cuttings samples and geophysical measurement data are continuously obtained from the entire ocean crust and the uppermost mantle. Although technical improvements are required to utilize these samples and wall geophysical measurement data effectively for science, the well site geology using D/V Chikyu has already started at the NanTro site, and we will be able to learn those from the actual examples.

Phase 2: Acquiring drilling core samples using branch moat and/or taking mini-core (~1 inch diameter and 2 inches length) from the wall during wire-line logging at the most important sections.

Phase 3: Reserving the hole in order to further drilling and/or to acquire drilling core samples using the branch moat and/or assistance aperture moat drillings at some sections where their importance is newly found from the results of Phases 1 and 2.

Phase 1 and 2 will be performed by the Mohole project, and Phase 3 would start corresponding to a new proposal after achievement of the Mohole. In other words, this hole is placed with a window for the whole crust and the uppermost mantle, and drillings of branch moats and/or assistance aperture moats will be performed by adopting a new proposal for drillings at certain depths in the same way as proposals for drillings at certain places in ocean basins. We believe that this way can be a prototype for ultra-deep drillings using D/V Chikyu.

Integration with geophysical approach

Scientific goals and objectives for the 21st Century Mohole are well documented in

Mission Moho workshop report (2006). We suggest one additional aspect, which is based on recent high quality seismic surveys in the western Pacific using air-gun, multi-channel streamers, and ocean-bottom seismometers. The results of the seismic surveys indicate that Moho discontinuity is not ubiquitously present and the amplitudes of discontinuous reflectors vary in space. Furthermore, velocity structure of ocean crust and of uppermost mantle is not uniform, but it has variety even if it was formed at a fast spreading rate ridge system. Thus, a combination of the high quality seismic surveys with the Mohole drilling results from both the drilling samples and the wall geophysical measurement data, is an essential approach. It is because the Mohole drilling provides a reference for the structure, which allows us to properly interpret the velocity structure obtained from the high quality seismic surveys. On the other hand, the seismic surveys provide us with the similarity and/or the variety of velocity structure in space (or in different crustal age). Further combinations with land studies of ophiolites and laboratory measurements of rocks are required. As the results, these combinations would provide us with critical information to understand the nature of the crust, the Moho discontinuity, and the uppermost mantle, and also dynamic processes forming the oceanic crust.

North Hawaiian arch for the Mohole site

We also propose the eastern part of the north Hawaiian arch (Figure 1) as one of feasible candidates for the Mohole site using D/V Chikyu. The crust was form at East Pacific Rise with half spreading rate of 35-40mm/yr and the crustal age is 80Ma. The north Hawaiian arch is a consequence of flexural uplift of Pacific lithosphere due to the load of Hawaiian island chain generated by the Hawaiian hot spot (e.g. Watts et al., 1985). Then, the water depth of the north Hawaiian arch is 4100-4300m, where the next riser drilling system of D/V Chikyu will be able to drill. An important character of this site is that the crustal age of 80Ma is much older than that of oceanic crust with its water depth of 4100-4300m. As the result, the Moho temperature of this site is much lower; that is expected to be below 150°C based on standard half space thermal model, which is supported by heat flow measurements around this area (~ 60mW/m^{-2}; Figure 1). This low temperature is a big advantage for drilling from the technological point of view and widens the scope of choices available for the borehole measurement and the sampling tools. When the temperature is high enough, only way to drill a hole is to keep the hole cool using water or mud circulation, but the difficulty in long term drilling such as the Mohole becomes serious. On the other hand, we need to avoid recent arch volcanism (e.g. Clague et al., 1990), which is due to lithospheric flexural uplift, although the area of the flood basalts is well mapped using side-scan survey (Normark et al., 1989). It is worth to note that the operational base for D/V Chikyu using a helicopter (< 300 km) can be made in the Hawaiian Islands.

The seismic structure of a candidate area for the Mohole site in the north Hawaiian arch (Figure 1) has not been obtained, but previous studies show some characters of the Hawaiian arch. Watts et al. (1985) showed multichannel seismic reflection profiles across the Hawaiian island chain including the Hawaiian arch. The results show clear Moho reflection in the Hawaiian arch. Further, two-ship seismic refraction study showed 1-D velocity structures (ten Brink and Brocher, 1988; Lindwall, 1991), which are a sort of typical normal oceanic crust. These characters support that this site is a high potential candidate for the Mohole site, but further seismic experiments with modern instruments and techniques are required.

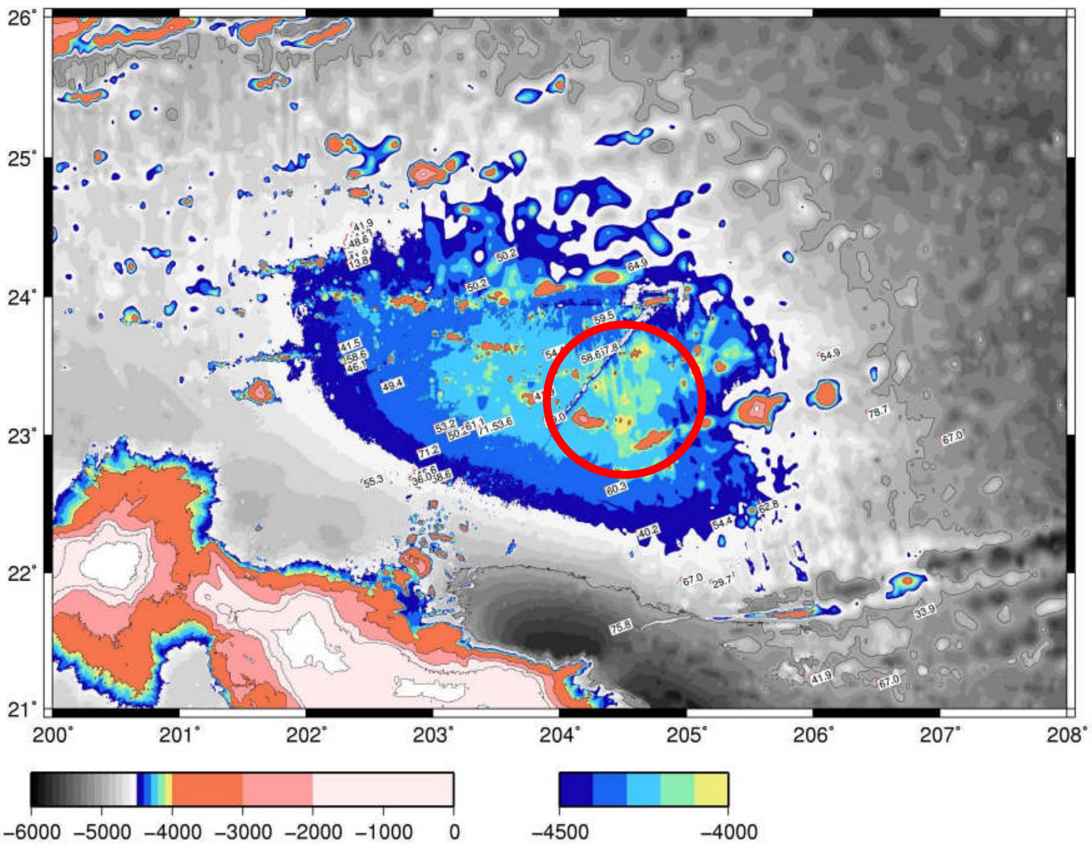

Figure 1. One of feasible candidates for the Mohole site using D/V Chikyu (red circle) in the north Hawaiian arch. The water depth between 4000-4500m is highlighted. The numbers are values of heat flow (mW/m^{-2}) from the global heat flow data base of international heat flow commission.

The final Mohole site should be decided after discussions among the international community with enough geophysical data for all candidates. Detailed seismic velocity structure is especially important; characters of crustal velocity structure, Moho discontinuity (amplitude of reflector; single or multiple reflectors), and uppermost mantle (velocity value and degree of anisotropy) should be discussed for the determination of the Mohole site.

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