4. Unzen Scientific Drilling Project

Unzen volcano is one of the active volcanoes in Japan, located in Southwest Japan behind the volcanic front of the Ryukyu Arc. 1990-95 eruption caused the $ 2 billion damage and took 44 lives. A large-scale collapse of an old lava dome, Mayuyama, during the 1972 eruption results in death of 15,000 peoples around the volcano. The volcano has become the focus of international volcanological attention through its designation as a Decade Volcano by IDNDR (International Decade of Nature Disaster Prevention). In May 1997, an international workshop was held in Shimabara to discuss not only what volcanologists learned from Unzen eruption, but also the feasibility and importance of drilling into the edifice of Unzen, particularly to the conduit of 1990-95 magma (Nakada *et al*., 1997). Following discussions at the workshop, a project was submitted to the Japanese Government to initiate a project using the scientific drilling as a main research tool to understand the growth history, subsurface structure and magma ascending mechanism of the Unzen Volcano. The research team also submitted a proposal to the International Continental Scientific Drilling Project (ICDP) to obtain a partial financial support.

Unzen Scientific Drilling Project (USDP) started in April 1999 as an international scientific research. The project includes not only scientific drillings but also related geological, geophysical and geochemical studies to totally understand Unzen volcano. USDP is a six-year term project and is divided into two phases. Phase I consists of drilling of three boreholes on the northeastern and eastern flanks and at the northern slope of Unzen Volcano, and conducting associated researches mainly to reveal the three-dimensional structure and the growth history of the volcano. Phase II is drilling into the conduit of the 1990-95 magmas to clarify the ascending and degassing mechanism of magmas and to evaluate geophysical and geological models made for the 1990-95 eruptions. Phase I is fully sponsored by the Ministry of Education, Sports, Culture, Science and Technology (MEXT), Japan,whereas the Phase II is a joint venture between MEXT project and ICDP. More than 25 research institutes from Japan, USA, Germany, UK and Taiwan are participating this project.

In Phase I, two vertical drillings (USDP-1: 752 m and USDP-2: 1462 m) were conducted at the northeastern and eastern flanks of Unzen volcano (Fig. 2). These drillings were aimed to reveal the growth history of Unzen volcano and related tectonic background. A third drilling (USDP-3) was conducted at the northern slope as a pilot hole for the conduit drilling in Phase II. USDP-3 is a 45-degree slant hole of 350 m. USDP-1 is located at the northern edge of the Unzen graben, where the base of the Unzen volcano is assumed to have subsided about 600 m beneath the surface. USDP-2, on the other hand, is situated in the middle of the graben, where Unzen products have accumulated as thick as more than 1000 m beneath the surface. As USDP-2 is also within a main course of transportation of volcanic materials form the center of Unzen Volcano, it is expected to recover the continuous record of its eruption history in USDP-2. Total core recovery for two wells was more than 90%, and it was possible to perfectly reconstruct the volcanic history of both sites. Against the expectation of thick piles of lava flows before drilling, many layers of pyroclastic flows and related debris flows were encountered in both wells by drilling. Vesicularity of essential blocks in block-and-ash flow deposits tends to increase with the increasing depth, suggesting more explosive eruptions in the past. The oldest pyroclastic materials of Unzen include vesiculated pumices that are rarely found on the modern surface, revealing very explosive eruptions took places in the beginning of Unzen volcano. Beneath the base of the Unzen products about 680 and 1200 m below the surface in the USDP-1 and 2 sites, respectively, pre-Unzen pyroxene andesite of 0.5 Ma was recovered. Systematic ^{14}C, K-Ar and $^{40}Ar/^{39}Ar$ dating, major and trace element geochemistry, and Sr, Pb and Nd isotopic analyses have been conducted on core samples of both wells, and detailed geologic and geochemical evolution history of Unzen volcano is now under construction. Geophysical measurements were also conducted using these wells, and results are now utilized to construct the geophysical structure of the volcano. During Phase I, intensive geological, geophysical and geochemical studies have been conducted beside drillings. Emphases were put to reveal three-dimensional geological, geophysical and hydrological structure of Unzen volcano and Shimabara Peninsula, and to understand the magma degassing and cooling processes.

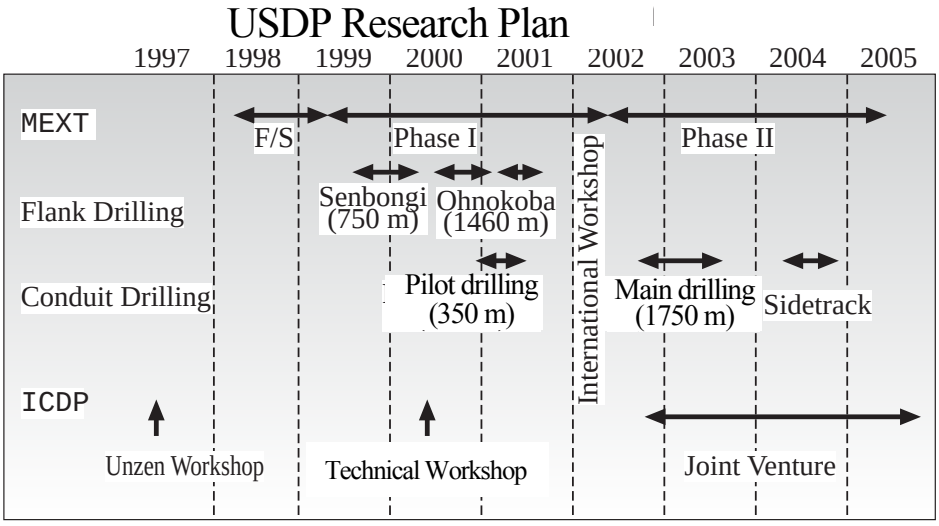

Fig. 1. Research schedule of Unzen Scientific Drilling Project

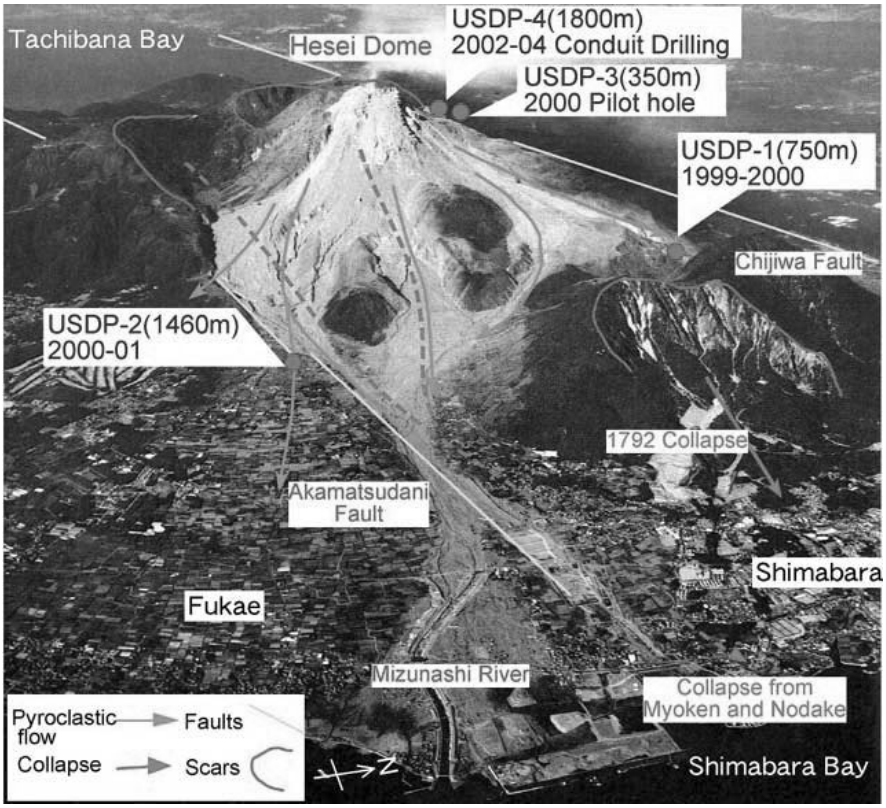

Fig. 2. Locations of drilling sites of USDP

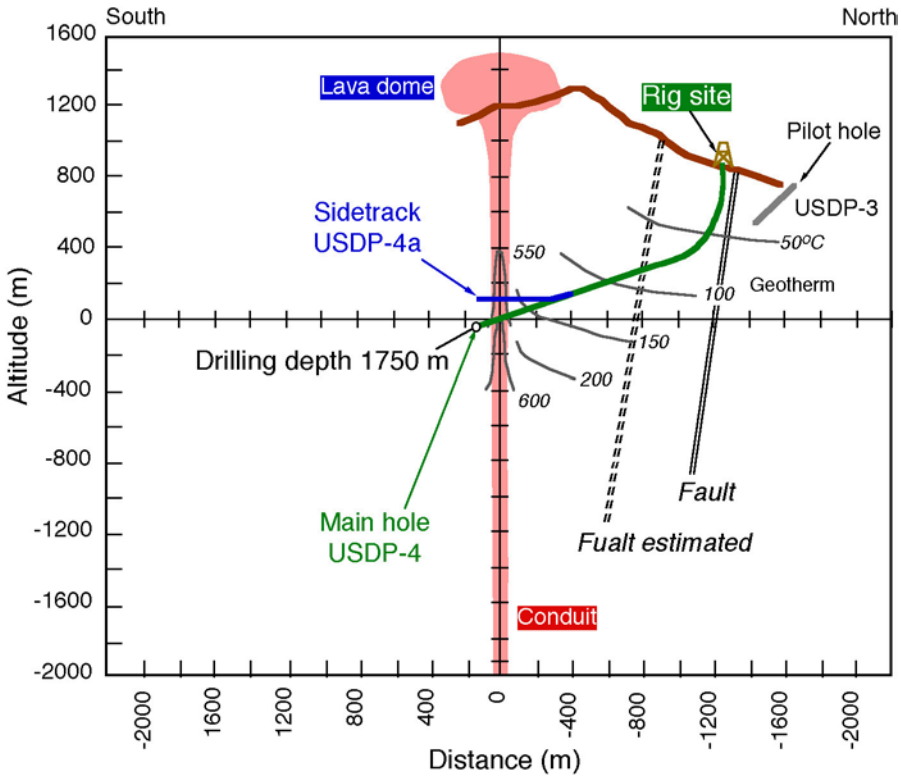

Fig. 3. Trajectory plan of the conduit drilling.

Phase II, started in April 2002, targets the upper part of the conduit through which the lava domes of 1991-1995 eruption were emerged. In the last kilometer of ascent, magma is subjected to an order of magnitude decrease in solubility of water in melt together with more than an order of magnitude increase in melt viscosity, more than two order of magnitude decrease in vapor density, and the onset of crystal growth. This in turn causes huge changes in magmatic properties and is responsible for a number of geophysical phenomena and signals prior or during eruption; i.e., isolated tremor events (1.5-0.5 km deep), low-frequency earthquake events (0.5-0 km), sources of vulcanian explosions and deformation-and-inflation in 1.2 to 0.5 km-depths. These phenomena and signals are thought to reflect magmatic degassing during ascent

and interaction of magma with groundwater in an aquifer below 0.5 km depth. Direct drilling into the conduit in this depth range is critical in order to verify interpretation of monitoring data during eruptions and to understand these important magmatic processes. The conduit is considered to be an east-west trending dike with a length as large as several hundred meters and a thickness of 10-20 m. A 50 m-high rotary rig was constructed at the northern slope of Unzen, 840 m above sea level, and drilling was started normal to the dike in February 2003. The drilling was initiated vertically and increased its inclination with depth, which is the best choice to drill the hot and challenging target at the sea level. The temperature of the conduit center is estimated as high as 600 °C. The hole-bottom temperature during operation of conduit drilling can be controlled at rather low values with a special casing program and mud circulation system, so that we can use the logging tools (temperature probe, bore hole televiewer, etc) even at considerable depth of the conduit. The drilling, associated borehole measurements and sampling will be ended by March 2005.

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