Muon Radiography in Japan

Hiroyuki K. M. Tanaka[1*]

Earthquake Research Institute, the University of Tokyo, Japan[1]

Muon radiography has been evolving for over 50 years: in 1955. E.P. George tried to measure rock overburden of tunnel with muon radiography. L. Alvarez was among the first to evaluate the density resolution of muon radiography quantitatively in his efforts to measure an Egyptian pyramid. From this decisive trial, L. Alvarez was able to ascertain that muon radiography had the potentiality to distinguish the unseen, fluctuating density contrasts inside gigantic objects. However, these surveys were feasibility studies measuring the exterior shape of the object. Until recently the intrinsic value of muons for the purpose of radiography could not be practically exploited since the technology to solve the issues inherent in this process had to be developed.

In this workshop we will focus on current muon radiography surveys of the structure inside volcanoes and seismic faults. The technological developments have contributed to these degrees of improvement in recent muon radiography in the following ways: increasing the solid angle by placing the detector at increasingly closer degrees, improving the SN ratio by shortening the muon track length, increasing the length of observation by designing ever more durable detectors. These efforts have culminated in density contrast images of the internal structure of subsurface crust with interesting results. For instance, the current magma convection hypothesis concurred well with the muon radiography density contrast as measured in the Satsuma Iwojima volcano. Additionally, a three-dimensional image of Asama volcano's conduit was obtained by performing bidirectional tomography with the present techniques of muon radiography. Furthermore, with the goal of expanding the potential for monitoring volcanoes in real time, numerous trials have been completed. The first step in this series of experiments was the 2009 Asama survey. A mass change below the crater floor of Asama was observed in the images obtained before and after an eruption with a time resolution of 2 weeks. In reviewing this data, the Japanese Coordinating Committee of Volcanic Eruption was able to conclude that the eruption event was a small-scale phreatic explosion. The strategy utilized in the before mentioned Asama project has been adapted to the study of a seismic fault located in the Itoigawa Shizuoka Tectonic Line. Time sequential muon radiography (with a time resolution of 1 day) was performed in order to analyze the rainfall permeation that seeps into the fracture zone of this particular seismic fault. We are currently investigating ways to adjust the present system to accommodate one-hour resolved muon radiography. New results from this inquiry will be reported in a session of this workshop.

Unfortunately, with the present analysis method, average densities along a muon path determined via muon radiography has model dependences coming from uncertainty of the muon spectrum, horizontal east-west effect, vertical electromagnetic shower contaminations, and the soft component scattered at surface of the mountain. Such problems must be clarified in order to continue upgrading the capabilities of this technique. There will be some time at the workshop devoted to discussing this topic as well as some of the measures being taken to resolve these complications.