論文の内容の要旨

論文題目

Accurate muographic imaging of volcanoes by background noise reduction with nuclear emulsions

（原子核乾板の背景ノイズ低減による火山の高精度ミューオグラフィーの実現）

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Muon radiography (muography) is a powerful technique for probing internal density profiles of volcanoes with higher spatial resolutions than other geophysical methods. For this purpose, several types of detectors have been used, such as scintillation detectors, gas chambers and nuclear emulsions. Particularly, the nuclear emulsion is suitable for imaging small and complex structures near the summit, because it has high angular resolutions (a few mrad), weighs light and does not require electricity for operation.

A requirement for muographic observation is to count precisely the number of signal muons which penetrate and emerge from the target mountain. One technical problem with nuclear emulsions, however, is an existence of background noise caused by non-signal particles. These noise particles mimic the muon signals, because the emulsion film is sensitive to all the charged particles passing through it. Although several prior works have tried to subtract the effect of the background noise with empirical models, it is still difficult to reduce the systematic uncertainty in density estimation. To reduce the uncertainty and improve accuracy of muography, it is necessary to understand the characteristics of the background particles and to develop emulsion detectors which can reduce them.

The candidates of the background noise particles are low-energy charged particles induced from secondary cosmic rays. To reduce these low-energy particles, this work proposes the use of the Emulsion Cloud Chamber (ECC). ECC detector is a repeated structure of emulsion films and passive metal plates. This detector makes it possible to reject the low-energy particles, because they are deflected with larger angles in metal plates than penetrating muons. Thus, high-resolution microscopic analysis of the tracks enables us to distinguish signal tracks from noise tracks.

The performance of the background reduction is demonstrated by a test experiment with a prototype of ECC at Showa-Shinzan Lava Dome, Usu, Japan. The prototype is made of twenty OPERA films and nine 1-mm-thick lead plates. It was exposed to cosmic rays at the foot of the dome for 168 days. To analyze the tracks recorded in the detector, I have developed a method for track selection and efficiency estimation. As a result, the particle flux measured by ECC detector is lowered to be half to one-eighth of the flux measured by conventional emulsion detectors. Consequently, the density values derived from ECC detector are consistent with the typical bulk density of volcanic regions.

There are three pieces of evidence to support the validity of the use of ECC detector. First, the muographic results of ECC detector are consistent with the bulk density of Showa-Shinzan lava. Second, a three-dimensional density model estimated from the ECC results and gravity anomaly data agrees well with other geophysical observations in the shape of the lava. Lastly, my numerical simulation suggests that the energy threshold of ECC detector is feasible to reject background particles, consisting mainly of protons, muons and electrons produced by the hadronic interactions and electrons from electromagnetic showers.

In conclusion, I have established a standard method for accurate muography with nuclear emulsions. To be concrete, I have specified the origin of background noise to the low-energy (< 1 GeV) charged particles. Thus, I have developed an analysis method to reduce these noise particles with ECC detector. Subsequently, I have demonstrated the performance of ECC detector by a test experiment at an actual geoscientific target. The method I have established will be useful for designing future muography detectors and inspecting other geoscientific targets.