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Subsurface structure and volcanic activity of Mt. Usu

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Geophysical explorations have widely applied to investigate subsurface structure of volcanoes. First significance of the explorations in volcanic areas is to reveal rock types, facies and physical conditions of subsurface materials. To constrain physical properties of subsurface medium is also important to enhance monitoring of active volcanoes. For example, detailed velocity models directly contribute to hypocenter locations. In addition, it is important to reveal subsurface structure to clarify how the subsurface structures affect dynamic magmatic processes such as magma movements and eruptions, because these phenomena are determined by interaction between magma and host medium.

Mt. Usu is one of the most active volcanoes in Japan. Nine eruptions of felsic magma have occurred since 1663. These eruptions have accompanied intense precursory earthquakes and remarkable ground deformations. In recent eruptions, information for revealing subsurface magma movements has been accumulated by scientific observations. Furthermore, geophysical explorations and geological researches have done for geothermal explorations. These contribute to reveal shallower structure of the volcano. Here we show subsurface structure of Usu volcano and its controls on magmatic activities such as subsurface magma movements and eruption locations.

Geological basement in the region is Pre-Neogene sedimentary rocks, granodiorite and hornfels. Overlying Neogene layers are composed of middle Miocene volcanic rocks, upper Miocene clatstic rocks and Pliocene clastic rocks. These layers are exposed along Toya caldera rim and to the east of Usu volcano. Surface of this area is broadly covered with Quaternary volcanic rocks such as lower Pleistocene andesitic rocks and Toya pyroclastic flow deposits. Around Usu volcano, Usu deposits and alluvium covers the surface. The volcano was constructed on a southwestward deepening basement structure. The deepening Pre-Neogene basement toward Uchiura bay is detected by density, electrical resistivity and seismic velocity structures.

In 2000, eruptions occurred at northwestern foot of the volcano. Because the precursory seismic activity can be clue to clarify the pre-eruptive magma movements, we relocated the hypocenters for the three-dimensional velocity model. The precursory seismic activity is divided into three parts: a sub-vertical distribution beneath the volcano, a sub-horizontal northward migration, and a horizontal southward migration. The northward and southward migrating earthquakes are occurred along middle Miocene or Pre-Neogene layer. If we interpret the migration indicates magma movements, the magma migrated as to be constrained by the southward deepening basement structure. Because the layer becomes shallower toward north, the northward migrating magma was forced to migrate toward the ground surface and eruption occurred. On the contrary, because the basement layer deepens toward south beneath the volcano, the southward migrating magma could not move upward. Therefore, no eruptions occurred in the southern foot.

The vents and upheavals of the past eruptions in northern foot distribute from northwest to east as an arc, while no traces of past eruptions are found in southern foot. This surface distribution fairly correlates to the subsurface basement layer. Because the basement layer becomes shallower as to enclose the volcano in the northern foot, the magmas migrating to north were forced to move toward the ground surface along the basement layer. Thus, the vents and upheavals distribute as to be constrained by the subsurface structure. On the other hand, if the magma migrated along the basement toward south, it could not move upward and no eruptions occurred. Therefore, no traces of the past eruptions are found in the southern foot. The correlation indicates that the subsurface structure has controlled the magma movements and eruption locations in the past activities as well as in the 2000.