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Gravity variation in Akita-Komagatake volcano and thermal expansion model

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(1) In Akita-Komagatake volcano, we have monitored volcanic condition after the 1970-eruption by repeated observations at fixed points, on ground-temperature, geomagnetic total intensity, and gravity. After the end of the eruption in 1971, ground temperature rose in the surrounding area, though the crater itself cooled rapidly. The peak of this geothermal activity was about 1977-78. After then the activity decayed, and the temperature lowered to almost normal level in 1995-98. This high geothermal (HG) period is called the post-eruption HG period. Geothermal activity again revived since about 2006, and the active area is now expanding to almost east-half of Medake (the present HG period). Variation of gravity is focused in this paper, though that of geomagnetic intensity was also conformable to the above geothermal activity. Gravity remarkably increased with drop of ground temperature, and lowered with rise of it.

(2) In both HG periods (the post-eruption and the present), the ground temperature has not yet exceeded the boiling point of water and volcanic gas has not yet been detected. Hence, increase of the geothermal activity until now does not mean new magma intrusion to shallow zone. The post-eruption HG activity was probably caused by transfer of heat from the magma, which had been intruded and remained near and in the vent originally at the eruption, to the surrounding zone through convection of thermal water. The present HG activity may be caused by new upward intrusion of thermal water from deeper zone. Accumulation of aqueous vapor in the ground often behaves as effective pressure source to cause crustal deformation. This mechanism, however, seems unlikely in Medake, whose formation composed of much pyroclastic material seems to be permeable. In this condition, thermal expansion of the formation is considered to be rather appropriate mechanism to cause gravity variation, which results primarily from variation of the surface altitude (free-air effect) and secondarily from that of the formation density.

(3) As the relevant model, it is assumed that temperature of a particular zone in the semi-infinitive homogeneous isotropic elastic medium is raised uniformly by t, compared with the surrounding zone. A semi-infinitive vertical cylindrical column is assumed as the heated zone. Its upper surface is coincident with the media surface. The thermal expansion causes the surface upheaval and the density decrease. The solution is as follows: A vertical infinitive cylindrical column zone with radius r is set up in the infinitive homogeneous elastic medium, and is heated by t. Stresses and deformations in and outside the zone are estimated by application of known formulas. The horizontal surface (the O-surface) is set up across the center (O) of the column. We focus on the lower half side of the O-surface. Normal stress (p) exists on the O-surface. New stress (q) is added, to make total stress zero on the O-surface. Hence p+q=0, then q=-p. By this process the O-surface is converted to the free surface (=the ground surface). The O-surface is upheaved with q, which is tension. At the O-point the upheaval (h) and the corresponding gravity variation are estimated by application of known formulas.

(4) The above model was applied to the variation of gravity at the post-eruption HG period (1977) from the succeeding quiescent period (1998). The observed gravity variation was -0.25mGal at the top of Medake. The same value was obtained by assuming parameters conformable to the volcanic feature as the following; r=200m, t =130K, linear thermal expansion coefficient $=10^{-5}$ /K, density=2.5g/cm^3, Poisson's ratio=0.25. In this case, h was estimated as 0.65m. Direct application of the same method to the present geothermal activity is not appropriate because the geothermal area is shifted from the gravity observation points.

Keywords: Akita-Komagatake, volcanic monitoring, ground temperature, thermal expansion, elevation variation, gravity variation