A possible method of lava flow temperature estimation by lava tube cave of Earth,Moon and Mars

*Tsutomu Honda[1]

1. Vulcano-speleological Society

[Introduction]In the lava flow of Miharayama of Izu Oshima eruption in 1951, the lava temperature,the lava flow thickness and the flow velocity were directly measured on the site[(1)]. Then, the temperature dependent viscosity coefficient and the yield strength were calculated [(1,2)]. In addition, the temperature dependent surface tension was measured in the laboratory by re-melting the collected sample[(3)]. In 2005, a lava tube cave called Hornito Cave was discovered under the hornito located at the crater edge. The inner and outer structure of the Hornito cave was investigated and lava yield strength and surface tension have been also identified [(4, 5, 6)]. Miharayama Hornito Cave is a representative example where lava temperature, viscosity coefficient, yield value and surface tension are identified. On the other hand, in the universe, vertical holes/pits are found in the lava zone of Moon and Mars and lava tube caves are thought to be present under the vertical hole/pit [(7, 8, 9)]. Based on the example of Mihara yama of Izu Oshima in the Earth, it seems to be possible to identify the lava temperature and viscosity coefficient from lava yield strength and surface tension obtained from lava tube shape and internal structure on the Moon and Mars. It should be considered as an important purpose of future vertical hole/pit exploration.

[Data obtained from Izu Oshima Mihara yama Hornito Cave]For Mihara yama Hornito Cave ,internal observation and the preparation of the survey map of horizontal section and longitudinal section were made [(4)]. Based on the cavity height of the lava tube cave and its slope angle, the lava yield strength f_B is estimated from $f_B = H(\rho g \sin \alpha) / 4$, the flow limitation condition of the Bingham fluid flowing in the inclined circular tube. The obtained lava yield strength was 5000 Pa[(5,6)]. This value is consistent with 4300Pa obtained by field observation of actual lava flow of 1951 of temperature ranging from 1125 to 1038[(2).] From the pitch P of the lava stalactite descending from the ceiling of the cave, the surface tension $\gamma = P^2 g \rho / 4 \pi^2$ is obtained. As the measured pitch is roughly P = 3 to 4 cm, then the surface tension is 600 to 1000 mN / m[(5,6)]. This value is consistent with extrapolated value from the temperature dependent surface tension of Izu Oshima 1951 lava measured by Yokoyama et al.,in his laboratory with the remelted sample[(3)]. This indicates that, if lava tube cave is present. it is possible to estimate the lava temperature of the eruption time, even if lava flow temperature at the past eruption is unknown.

[Application to the Moon,Mars and Future Exploration]

In the vertical hole/pit cross section images of the Moon shown by LRO, the traces such as lava flow layer thickness,lava tube cave height can be seen, so, it seems possible to identify the lava flow temperature using these traces.

For Marius Hills Hole located in the Rille-A, the yield strength can be obtained as 131 Pa from the slope angle with an average lava layer thickness of 6 m and tube cavity height of 18 m[(10)]. If the temperature dependent data of the yield strength is acquired separately, the temperature of the lava flowing through the rill-A can be estimated. Further, if we can find lava stalactite inside of the cave by future moon exploration, the temperature can be identified also by comparing the surface tension obtained from the pitch of the lava stalactite with the temperature dependent surface tension data. The viscosity coefficient can also be fixed by the temperature dependent viscosity coefficient data. Fig.1 shows a concept of estimation.

At the stage where sampling on the Moon and Mars can not be done immediately, the synthetic samples based on the chemical composition will be used to acquire the temperature dependent yield strength and surface tension data.

References:
(1)T. Minakami:Bulltin of the Earthquake Research Institute, University of Tokyo,Vol.29, pp. 487-493, 1951, (2) G. Hulme: Geophys. J. R. astr. Soc. (1974) 39, 361-383, (3) I.Yokoyama et al: Geophysical bulletin of the Hokkaido University, 24: 57-61, 1970, (4) H.Tachihara et al: Volcanic cave survey and observation report of Oshima, Tokyo, Volcanic Cave Society, 2006, (5) T.Honda: V102-001, Japan Earth and Planetary Science Joint Meeting, 2006, (6) T.Honda, et al: AMCS Bulletin 19 / SMES Boletin 7-2006, pp 185-187, Proc.X, XI, XII Internat. Symposia on Vulcanospeleology, 2008, (7) J. Haruyama, et al: Geophysical Research Letters, Vol. 36, L2 1206, 2009,
(8) M.S. Robinson et al:Planetary and Space Science 69, pp 18-27, 2012,
(9) G.E.Cushing, et al: Geophys. Res. Lett., 34, L 17201, 2007,(10) T.Honda: SVC 50-05, Japan Earth and Planetary Science Joint Meeting, 2017

Keywords: lava tube cave, Miharayama hornitocave, lava flow temperature