Yield strength and lava tube cave height estimated from pits and lava flows of the Moon and Mars

*Tsutomu Honda[1]

1. Vulcano-speleological Society

[Introduction] The vertical pit, Marius Hills Hole (MHH) of the Moon, found by Haruyama et al[1~3] has several lava layers in it's cross-section as reported by Robinson et al[4] through LRO observation. The cross sectional thickness is also reported from Cushing[5] on the vertical pit in Martian Arsia Mons. On the other hand, the lava flow thickness of the Moon and Mars have been observed from the surface appearance of the lava flow from which lava yield strength were estimated, though these yield strengths had widely spread values. Here, the yields strengths are estimated from the thickness of the lava layers in a vertical pit and compared with those estimated from the lava flow surface appearance thickness. The height of lava cave tube possibly located under the vertical pit of the Moon and the Mars will be estimated by using the proper value from the comparison.

[The yield strength estimated from lava layer in the cross section of the vertical pit] Marius Hills Hole (MHH) consists of 4m-12m thickness of stratified lava layer in a vertical pit section(an average of 6m thickness)(Robinson[4]). When average thickness of H=6m and slope angle α=0.31 deg in Rille-A area(Greeley [6]) are used for the lava flow stop condition of Simple flow, the yield strength is given as f_B= ρ gsin α H=131 Pa (Honda[7])where the lava density is ρ =2.5g/cm^3 and surface gravity is g=162 cm/s^2. On the other hand, the thickness of the stratified lava layer of the ceiling section of vertical pit-I at the foot of north area in Arsia Mons is found to be H=3m (Cushing [5]). The stop condition of Simple flow of lava where slope angle of pit-I area is 0.28 deg gives the yield strength f_B=136 Pa. For this estimation, the lava density ρ =2.5g/cm3 and surface gravity g=371 cm/s^2 are used.

[The yield strength obtained from the surface appearance thickness of the lava flow and comparison] Lots of yield strength of lava were obtained for lava flows of the Moon and Mars by using Simple flow stop condition (Hulme [8]), though these values are widely scattered. The Table 1 and Table 2 show the minimum and maximum value for the Moon and the Mars ever obtained. The minimum value 100 Pa in the Moon is near the yield strength 131 Pa obtained from cross sectional layer thickness of the pit. When the yield strength shows a bigger values, it seems that a lava flow manifests Multiple flow or Inflation of lava instead of Simple flow, then, the yield strength is considered as an apparent yield strength. An example of lava thickness and yield strength as a function of slope angle of Arsia Mons of the Mars obtained byMoore et al[9]is shown in Fig1 and Fig.2. The yield strength indicates the smaller value for the lower slope angle. The minimum value 120 Pa is near 136 Pa which is obtained from cross sectional layer thickness of the pit. For the lower slope angle, it seems probably to converge into the true yield strength.

[Estimation of the lava tube cave height under the pit] The lava tube cave height Hc under the MMH and Pit-I of Martian Arsia Mons will be estimated by the lava flow model on the inclined surface with slope angle α.The flow critical condition of the lava is expressed as $Hc=nf_B/(\rho\ g \sin\alpha)$, where ρ is density, g is gravity, For the case of n=2, cave height between infinite width parallel plates and for the case of n=4, cave height in the circular tube (Hulme [8]). The used yield strengths as proper value would be those obtained from the lava layer in the pit hole. For the MHH, for n=2 and n=4, Hc=12m and 24m respectively. As the observed Hc is 17m, n will be about 3. This possibly shows the cross section of the lava tube cave under MHH is rectangular (Honda[7]). For the pit-I of Martian Arsia Mons, for n=2 and n=4, Hc=6m and 12m respectively.

[Summary] The cross sectional observation of the lava flow layer is very important (Hasenaka et al[10]) to obtain the true yield strength. Because it seems difficult to judge whether the lava flow is Simple flow,or

Multiple flow or Inflated flow from the remote surface appearance of the lava flow for the Moon and Mars. If the yield strength obtained from cross sectional observation contains still an influence of lava inflation, on site sampling and examination is necessary to obtain the true yield strength. With true yield strength, the lava tube cave height can be estimated.
References:(1)~(10),see japanese version

Keywords: Moon, Mars, vertical pit, lava flow, yield strength, lava tube

Table.1 外観観察による月の溶岩降伏値

月、溶岩地域	最小降伏値	最大降伏値	参考文献
Mare Imbrium	100 Pa	400 Pa	Moore et al(1975),Hulme et al(1977)

Table.2 外観観察による火星の溶岩降伏値

火星・火山名	最小降伏値	最大降伏値	参考文献
Arsia Mons	120 Pa	5.19 x10⁴ Pa	Moore et al(1978),Warner et al(2003), Hiesinger et al(2015)
Ascraeus Mons	199 Pa	1.3 x 10⁵ Pa	Zimbelman(1985),Hiesinger et al(2007), Hiesinger et al(2008)
Pavonis Mons	93 Pa	1.3 x 10⁴ Pa	Baloga et al(2003), Hiesinger et al(2008) , Hiesinger et al(2015)
Elysium Mons	184 Pa	2.63 x10⁴ Pa	Pasckert et al(2012), Hiesinger et al(2015)
Elysium Planitia	100 Pa	500Pa	Vaucher et al (2009)

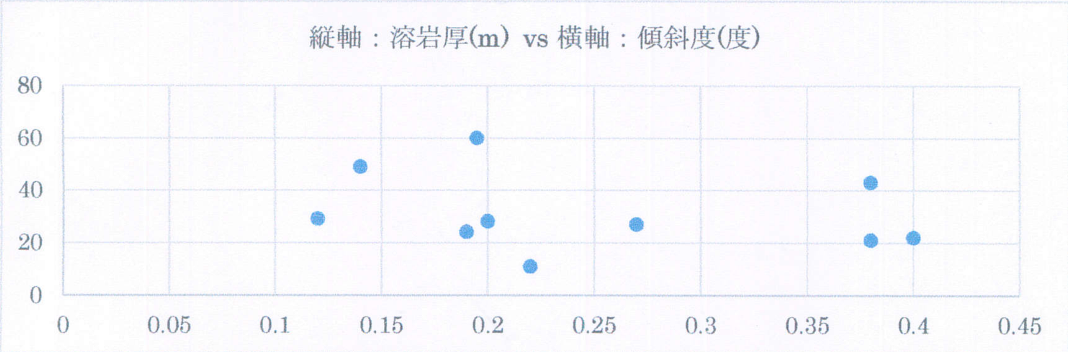

Fig.1 Arsia Mons 南麓の溶岩流厚さ H(Moore et al(1978))

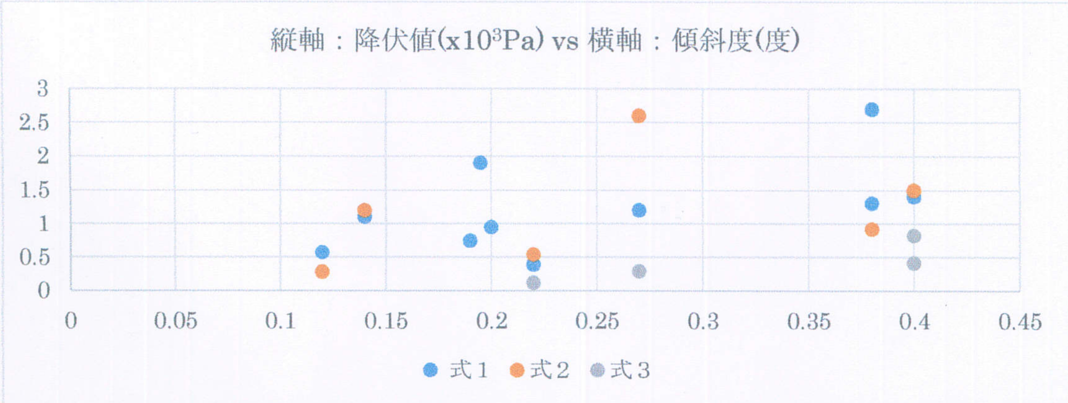

Fig.2 Arsia Mons 南麓の溶岩流降伏値 f_B (Moore et al(1978)):最小値 120Pa 最大値 270Pa, 式 1:$f_B=H(\rho g \sin\alpha)$, 式 2: $f_B = H^2\rho g/W_f$, 式 3: $f_B = 2W_b(\rho g \sin^2\alpha)$,ここで H は溶岩流の厚さ,$W_f$ は溶岩流の幅,W_b は溶岩堤防の幅。