Possible existence of lava tube caves under the pits and lava yield strength of Elysium Mons,Mars

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[Introduction]

Image data of vertical pits size in the neighborhood of Elysium Mons obtained by HiRISE with Mars Reconnaissance Orbiter are listed by Y.Goto et al of JAXA[1)]. Possible existence of a lava tube cave under these vertical pits are considered by using these data and Bingham flow model. The key parameter of this model,yield strength, was estimated by the lava flow thickness of Elysium Mons obtained by J.H.Paschert et al[2)] . The smallest value among each yield strength obtained by the lava flow stop condition is used for lava tube cave height estimation[3)].

[Considered model]

The lava flow is modeled by Bingham fluid flowing on the inclined plane or in the inclined cylindrical pipe with gravity potential. For the lava flow of density ρ, and yield strength f_B, with slope angle α, under the gravity g, the lava flow stop condition is $H=nf_B/(\rho\ g \sin\alpha)$ where H is the lava thickness. The case which flows on the inclined plane with a free surface is n=1, and the case which flows through an inclined circular tube is n=4. The yield strength is obtained from $f_B=H(\rho\ g \sin\alpha)$ for n=1, then, the lava tube cave height will be obtained from $H=4f_B/(\rho\ g \sin\alpha)$,for n=4,.

[Estimation of the yield strength of lava]

As shown in Fig.1, the lava flow thickness of the neighborhood of the Elysium Mons is obtained by J.H.Paschert et al[2)] .By using this lava flow thickness H, the yield strength can be obtained from $f_B=H(\rho\ g \sin\alpha)$ as shown in Fig.2. The used value for density is $\rho=2.5g/cm^3$, for gravity is $g=373cm/s^2$. The calculated yield strength decreases from up to down from 2.63×10^5 dyne/cm^2 to 1.84×10^3 dyne/cm^2. These values are considered to be an apparent yield strength because of a deviation from simple flow structure due to lava flow inflation or lava flow multiplication[3)]. For estimation of lava tube cave height, the minimum value of 1.84×10^3 dyne/cm^2 for 0.1 degree and for 11.3 m of lava thickness is used so that the influence of inflation or multiplication is considered as minimum.

[Estimation of the lava tube cave height for the vertical pits]

The depth and diameter of the pits are listed by Y. Goto et al [1)] as shown in the left column of Table1. The slope angle at the position of the pits are estimated from a contour line of Elysium volcano in the geologic map [5)]. The limiting conditions used for estimation of the lava tube cave height is the $Hc=4f_B/(\rho\ g \sin\alpha)$ and Hc is indicated in the right column of Table1. There is a possibility that a lava tube cave exists under the vertical pit because it's H>>Hc at all vertical pits.

[Summary]

There is a possibility that a lava tube cave exists under the vertical pits of Elysium Mons, but its cave height is small compared with the vertical pit depth. Many lava tube caves may intersect in the lava layer through the vertical pit. The vertical pits would be regarded as the pit crater[6)] similar to devil's throat [7)] of Hawaii Kilauea instead of skylight of a lava tube cave.

Reference:

1) Y.Gotoh et al (2017): JAXA-RM-16-008
2)J.H.Paschert,H.Hieginger,D.Reiss(2012):Icarus 219(2012)p443-457
3) T.Honda (2017): SVC50-05,JPGU-AGU Joint Meeting2017
4)G.Hulme(1974):Geophys.J.R.Astr.Soc.vol39,p361

5)USGS (1999):GEOLOGIC MAP OF THE GALAXIAS QUADRANGLE (MTM 35217) OF MARS
6) G.E. Cushing(2012): Journal of Cave and Karst Studies, v. 74, no. 1, p. 33--47. DOI: 10.4311/2010EX0167R
7)C. H. Okubo, S. J. Martel (1998): Journal of Volcanology and Geothermal Research 86,1998 p1-18

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Fig. 1　横軸：傾斜角度（度）vs 縦軸：溶岩厚さ（m）

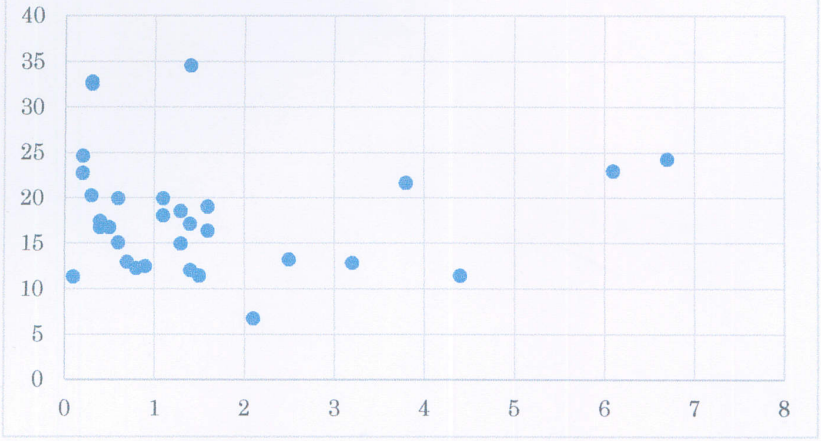

Fig. 2　横軸：傾斜角度（度）vs 縦軸：降伏値(dyne/cm²)

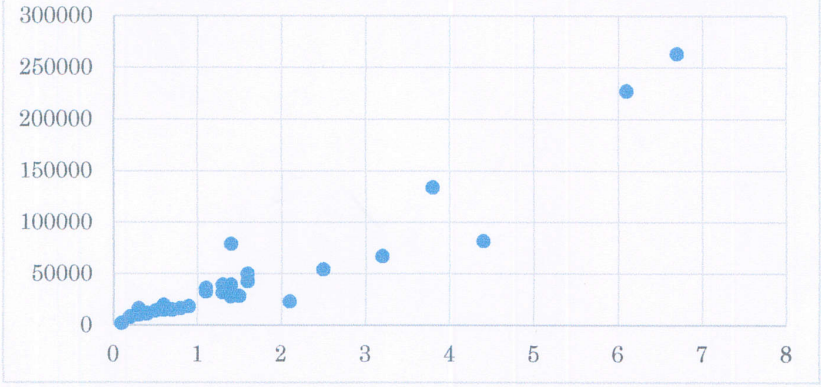

Table 1 エリシウム火山の縦穴深さ H と推定溶岩チューブ洞窟高さ Hc の比較

縦穴番号*	直径*	深さ H*	*斜度 本多が等高線より推定*	*円形断面チューブ空洞高さ $Hc=4f_B/(\rho g \sin\alpha)$ (f_B は 1.84x10³ dyne/cm² を使用)*	*備考*
1	358.8m	98.7m	*0.6°*	*7.5m*	*H>>Hc*
2	88.0m	12.5m	*1.0°*	*4.5m*	*H>>Hc*
3	121.5m	42.0m	*0.6°*	*7.5m*	*H>>Hc*
4	140.5m	63.2m	*1.0°*	*4.5m*	*H>>Hc*
5	243.8m	61.1m	*0.6°*	*7.5m*	*H>>Hc*
6	143.5m	29.2m	*0.6°*	*7.5m*	*H>>Hc*
7	17.1m	-	*0.6°*	*7.5m*	-
8	192.0m	42.1m	*1.0°*	*4.5m*	*H>>Hc*
9	254.8m	84.8m	*0.6°*	*7.5m*	*H>>Hc*
10	94.5m	69.9m	*6°*	*0.76m*	*H>>Hc*
11	110.3m	17.7m	*6°*	*0.76m*	*H>>Hc*
12	115.2m	25.2m	*6°*	*0.76m*	*H>>Hc*

*後藤祐紀他(2017): 火星エリシウム山麓における縦孔陥没地形リスト,JAXA-RM-16-008

