Estimation of the yield strength of lava flows of Mt.Fuji by lava tube caves and lava tree molds

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[Introduction]
Many lava tube caves and lava tree molds exist in lava flows of Mt. Fuji. Lava tube cave and lava tree mold coexists in Suyama Tainai lava flow and Ganno-Ana lava flow. Only lava tube cave exists in Subashiri-guchi lava flow located in the hight altitude. Only lava tree mold exists in relatively thin lava flow such as Takamarubi lava flow, Higashisuzuka-South lava flow, Kenmarubi I and Kenmarubi II lava flows. The yield strength of the Mt. Fuji lava flows was estimated from the hollow height of the lava tube cave and the depth of the lava tree mold and compared each other by using Bingham flow model. The lava flow structure of these Mt.Fuji is also discussed based on the difference of these yield strength.
[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 of lava which flows on the incline plane with a free surface is n=1, and the case of lava which flows through an inclined circular tube is n=4. The yield strength is obtained from $f_B = H(\rho g \sin \alpha)/4$,for n=4, where H is the lava tube cave height(see Fig.1)and from $f_B=H(\rho g \sin \alpha)$ for n=1, where H is lava thickness(depth of tree mold)(see Fig.2).
[Estimation of the yield strength by the lava tube cave]
When the lava tube cave hollow height is Hc, the lava yield strength will be $f_{Bc}= H_c(\rho g \sin \alpha)/4$. The height of lava tube caves and slope angles for Suyama Tainai Cave [2], for Subashiri Tainai Caves [3,4] and for Ganno-Ana Cave [5] are indicated in Table.1. The estimated lava yield strength are also shown in Table 1. The yield strength shows relatively low value between 0.8×10^3 N/m^2 and 3.2×10^3N/m^2.
[Estimation of the apparent yield strength by the lava flow thickness (the tree mold depth)]
The yield strength $f_{Bt}= H_t(\rho g \sin \alpha)$ is estimated from the lava flow stop condition of the free surface of lava flow of lava depth Ht which is equivalent of the depth of lava tree mold. Slope angle α is estimated from a contour line of the map. The results of lava flows for Suyama Tainai [2], Ganno-Ana[3,4], Takamarubi[6], Higashisuzuka South[7,8], Kenmarubi I[9,10], Kenmarubi II[9],are shown in Table.1. The apparent yield strength obtained from the lava depth shows higher value than those obtained from the lava tube cave hollow height.The highest value is $f_{Bt}=10.1\times10^3$N/m^2 for Kenmarubi II. It seems that the lava flow caused a deviation from simple flow due to inflation and repeated accumulation of lava, consequently, indicates higher value of apparent yield strength.
[Summary]
(1) The yield strength obtained from the lava flow thickness (the depth of the tree mold) is an apparent yield strength, because the lava flow has caused inflation and repeated accumulation of lava. (2) The minimum yield strength can be obtained from the thickness of the toe or the lobe in the front edge of lava flow. (3) The true yield strength of lava can be obtained from the hollow height of the lava tube cave. (4) The lava tube cave can be formed when a lava flow caused an increase of the thickness more than 4 times due to inflation of lava.

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Keywords: Fuji, lava flow, yield strength, lava tube cave, tree mold

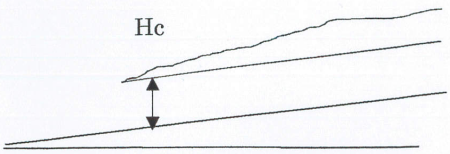

Fig 1 溶岩チューブ洞窟と空洞高さ Hc
溶岩降伏値 $f_B= H_c(\rho g \sin\alpha)/4$

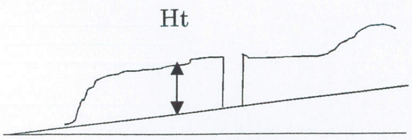

Fig 2 溶岩縦樹型とその深さ Ht
みかけの溶岩降伏値 $f_B= H_t(\rho g \sin\alpha)$

Table 1 富士山・溶岩チューブ洞窟と溶岩樹型から推定される溶岩降伏値

溶岩流名	珪酸重量分率 :%	傾斜度 :α	溶岩チューブ洞窟高さ：H_c	溶岩チューブ洞窟高さから得られる降伏値：$f_B= H_c(\rho g \sin\alpha)/4$	縦樹型深さ(溶岩流厚さ)：H_t	溶岩流厚さから得られるみかけの降伏値：$f_B= H_t(\rho g \sin\alpha)$
須山胎内[2)]	51.4	10 度	1.0m～1.8m (須山胎内洞窟)	$1.1 x10^3$～ $1.9 x10^3 N/m^2$	0.2m～2.2m (須山胎内樹型群)	$9.4x10^2$～$9.4x10^3 N/m^2$
雁の穴[3,4)]	51.1	5 度	1.5m~2.0m (ながれ穴)	$0.8x10^3$～ $1.1x10^3 N/m^2$	1.8m～5.4m (雁の穴樹型群)	$3.8x10^3$~$1.2x10^4 N/m^2$
須走口 I[5)]	50.9	20 度 15 度	1m(須走胎内洞窟) 2m(須走胎内洞窟)	$2.1x10^3 N/m^2$ $3.2 x10^3 N/m^2$	樹型無し	—
鷹丸尾[6)]	50.9	3.5 度	チューブ洞窟無し	—	1.9m～5.9m (柏原樹型群)	$2.8 x10^3$~$8.8 x10^3 N/m^2$
東臼塚南[7,8)]	51%	9 度	チューブ洞窟無し	—	1m~2m (東臼塚樹型群)	$3.8x10^3$~$7.6x10^3 N/m^2$
剣丸尾 I[9,10)]	51.1	4 度	チューブ洞窟無し	—	2.1m～5.5m (船津胎内樹型群)	$3.6x10^3$~$9.3x10^3 N/m^2$
剣丸尾 II[9)]	51.2	4 度	チューブ洞窟無し	—	2m～6m (吉田胎内樹型群)	$3.4x10^3$~$10.1x10^3 N/m^2$