

Yield strength obtained from tree molds and lava tube caves of Medicine Lake Volcano

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1.Introduction: Medicine Lake Volcano in northern California is the largest volcano in the Cascade Range that has erupted nine times over the past 5200 years. On the northeastern flank of this shield volcano, many lava tree molds formed on the lava flow that flowed about 10,000 years ago and many lava caves formed 30,000 to 40,000 years ago are preserved in the Lava-Beds National Monument ^{1,2,3)}. We measured the depth of these tree molds and the height of the lava tube cave, then, estimated the yield strength of the lava flow. The slope angle was roughly estimated by reading the map contour.

2.Lava tree molds: Lava tree molds are abundant in the btm (basaltic tree mold) lava flow of SiO₂: 51.9wt%, 12,330 yr B.P at an altitude of 2000m, with their diameter range from 15cm to 90cm. Since it is an old lava flow, deposits are accumulated at the bottom of most vertical tree molds, though for the btm-TM-4.2m vertical tree mold, it has been removed for C14 dating⁴⁾. The position of the tree mold at N41.63854, W121.60744, with diameter: 0.79mx0.91m, depth: 4.2m as shown in Fig.1. . As the tree mold depth is the lava flow thickness H , the critical limit thickness of lava flow $f_b = H (\rho g \sin \alpha)$ was used to determine the apparent lava yield strength f_b where the gravity acceleration was $g = 980 \text{ cm} / \text{s}^2$, and density was $\rho = 2.5 \text{ g} / \text{cm}^3$. As shown in Table.1, the apparent yield strength: $1.8 \times 10^4 \text{ Pa}$ is obtained from the slope angle α of 9.5° . This apparent yield strength shows a relatively high value for a lava flow of SiO₂: 51.9wt%, which may be due to lava inflation.

3.Lava tube caves: The heights H of Valentine Cave located in bvc lava flow (SiO₂: 53.0 wt%, 12,260 yr B.P.) and Sentinel Cave located in bmc lava flow (SiO₂: 52.3 wt%, 40Ar / 39Ar age / $36 \pm 16 \text{ ka}$) are measured. Fig.2 and Fig.3 show photographs of inside of each cave. The lava yield strength f_b was obtained from the flow critical limit condition of the gravity flow in an inclined pipe of slope angle: α , $f_b = H (\rho g \sin \alpha) / 4$. Table 2 shows the lava yield strength obtained from these lava tube caves. The obtained yield strength is in the range of 1.54×10^3 to $2.8 \times 10^3 \text{ Pa}$ which is a reasonable yield strength as a basaltic lava of SiO₂: 52.0-53.0 wt%.

4.Conclusions: The apparent yield strength obtained from the tree mold depth (lava thickness) is 6 to 12 times higher the yield strength obtained from the lava tube cave height. Even though the btm lava flow is different from the bmc lava flow, this indicates that the lava flow caused lava inflation in general and transitioned from simple flow to inflated flow. This also shows that the lava tube cave is formed through lava inflation.

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References:

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3)<http://geotripper.blogspot.com/2010/01/other-california-if-tree-falls-in.html>

4)Private communication with Donnelly–Nolan, J.M.,:Jul 16, 2018, on the locations of the carbon-14 samples collected from large tree molds in map units btm, bvc, and bbr.

5)Donnelly–Nolan, J.M (2010):Geologic Map of Medicine Lake Volcano, Northern California:Pamphlet to accompany Scientific Investigations Map 2927,USGS

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



Fig.1 4.2m lava tree mold(btm lava flow)



Fig.2 Valentine cave(bvc lava flow)

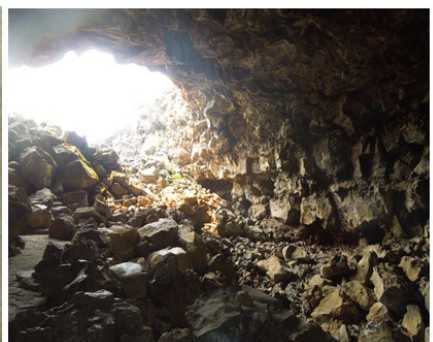


Fig.3 Sentinel cave(bmc lava flow)

Table.1 Apparent yield strength obtained from lava tree mold depth of btm lava flow(*from ref 5))

btm-TM No. (12,330 yr B.P, SiO ₂ :51.9wt% *)	Depth:H(lava thickness)	Lava density: ρ	Gravity:g	Slope angle: α (by map contour)	Apparent yield strength: $f_b = H(\rho g \sin \alpha)$
btm-TM-4.2m	4.20m	2500kg/m ³	9.8m/sec ²	9.5°	1.8x10 ⁴ Pa

Table.2 Yield strength obtained from lava tube cave height of bvc and bmc lava flows(*from ref 5))

Lava flow name and eruption time *	SiO ₂ wt%*	Slope angle α from contour	Lava tube cave name and height:H	Yield strength $f_b = H(\rho g \sin \alpha) / 4$
Valentine Cave (bvc) 12,260 yr B.P	52.9, 52.9, 53.4% avg of 3 samples= 53.0%	6 °	Valentine cave: H= 8-10ft=2.4m~3m	1.54 x10 ³ Pa ~1.93 x10 ³ Pa
Mammoth Crater(bmc) 40Ar/39Ar age is 36 ± 16 ka	48.4–55.9%; avg of 45 samples= 52.3%	3.5°	Sentinel cave : H= 25 ft high=7.5m	2.8x10 ³ Pa