# The role of surface tension on the formation of lava stalactite and lava stalagmite

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## Abstract

The role of surface tension of lava on the formation of lava stalactite and lava stalagmite is analysed by two different physical models. A hydrodynamic instability model is used for a lava stalactite formation and a fallen droplet model is used for a lava stalagmite formation. The surface tensions estimated from two different models show a good coincidence and reasonable value as surface tension of lava.

## 1.Introduction

Inside the lava caves and lava tree mold voids formed by the basalt lava flow, lava stalactites and lava stalagmites are often observed. It is a phenomenon in which the droplet of lava falls from a ceiling and deposits on the floor. By using two simple models where the balance between gravity and surface tension acting on lava surface are taken into consideration, the estimation of surface tension of lava from the pitch of lava stalactite and size of lava stalagmite appeared in lava tube cave and tree mold void are performed and compared with various lavas.

## 2.Estimate of surface tension from lava stalactite

Fig.1 shows a genral feature of the inside of lava tree mold. Lava stalactites are positioned periodically on the surface of the ceiling wall or side wall. From the periodical pitch of the stalactites, we can obtain the surface tension of the lava[1~3]. The pitch will be the critical wave length of the occurrence of instability of thin liquid film attached on the surface of the ceiling of the lava tube cave or lava tree mold void as shown in Fig.2. The pitch P is shown as $\mathbf{P=2\pi(\gamma/g\rho_L)^{1/2}}$, where $\gamma$ is surface tension of liquid $\rho_L$ is density of liquid, g is gravity acceleration. From the pitch of lava stalactites on the roof surface, the surface tension of lava $\boldsymbol{\gamma = P^2 g\rho_L / 4\pi^2}$ is determined. If there is a superposition of the lateral and vertical surface flow, the ribbed wall will appear and keep the same pitch as that of lava stalactite. As for the surface tension calculated from the pitch of lava stalactites on the roof surface or ribbed wall (**P**=3 to 4cm) (see Fig.3 to Fig.19), the surface tension of lava was determined as 560～990 dyne/cm. The estimated surface tension matches with the experimental results by melting the lava in the Laboratory[4].

Fig.1 Void in Funatsu Tainai Lava Tree Mold

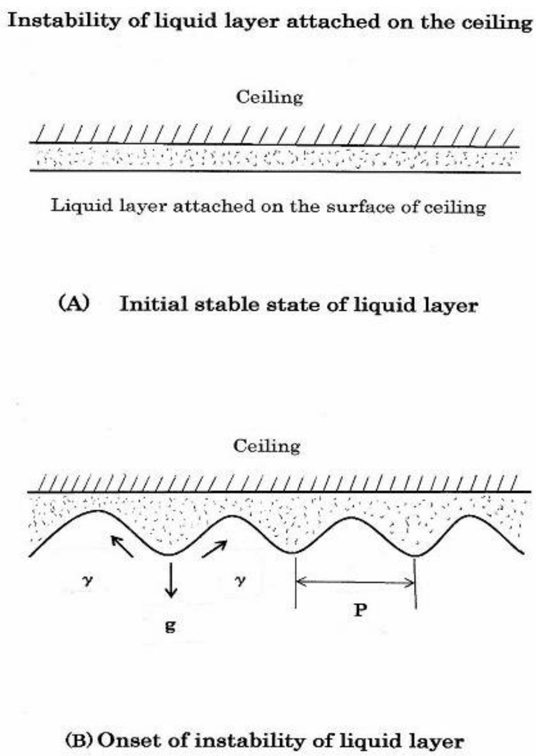


Fig.2 Instability model of liquid layer on the roof

Fig.3 Lava stalactite in Yoshida Tainai Lava Tree: P=3～4cm,γ=560～990 dyne/cm

Fig.4 Ribbed wall in Yoshida Tainai Lava Tree: P=3～4cm,γ=560～990 dyne/cm

Fig.5 Ribbed wall in Funatsu Tainai Lava Tree: P=3～4cm,γ=560～990 dyne/cm

Fig.6 Lava stalactite in Hachijojima Lava Tree: P=3～4cm,γ=560～990 dyne/cm

Fig.7 Lava stalactite in HornitoCave of Mihara-yama in Izuoshima : P=～3cm,γ=～560 dyne/cm

Fig.8 Lava stalactite in Daikon-jima,Shimane : P=～3cm,γ=～560 dyne/cm

Fig.9 Ribbed wall in Mitsuike-ana lava tube cave: P=3～4cm,$\gamma$=560～990 dyne/cm


Fig.10 Lava Stalactite on the roof in the tunnel of 2004 lava flow of Piton de la Fournaise: P=3～4cm,$\gamma$=560～990 dyne/cm


Fig.11 Ribbed wall in the tunnel of 2004 lava flow of Piton de la Fournaise: P=3～4cm,$\gamma$=560～990 dyne/cm


Fig.12 Fig.11 Ribbed wall in the tunnel of 2004 lava flow of Piton de la Fournaise: P=3～4cm,$\gamma$=560～990 dyne/cm

Fig.13 Lava stalactite on the ceiling of Mushpot Cave in Lava Bed National Monument: P=3～4cm,$\gamma$=560～990 dyne/cm

Fig.14 Ribbed wall of Catacombs Cave in Lava Bed National Monument: P=3～4cm,$\gamma$=560～990 dyne/cm

Fig.15 Lava stalactite in the lava tree mold of Newberry Volcano,Lava Cast Forest

Fig.16 Ribbed wall in the lava tree mold of Newberry Volcano,Lava Cast Forest: P=3～5cm, γ=560～1740 dyne/cm

Fig.17 Lava stalactite of ChuBluck Volcano of Vietnam,C0Cave:P=3~4cm, γ=560～990 dyne/cm

Fig.18 Ribbed wall of ChuBluck Volcano of Vietnam,B14Cave:
P=3~4cm, γ=560～990 dyne/cm

Fig.19 Ribbed wall of ChuBluck Volcano of Vietnam,C3Cave:P=3~4cm, γ=560～990 dyne/cm

**3.Estimate of surface tension from lava stalagmite**

After the droplet's falling either from the liquid layer of a ceiling or from a straw formed from a ceiling, the droplets of lava may be acumulated one after another on the floor. The cylindrical configuration of the lava droplet has a certain radius and length in such a way that the configuration of the droplets has almost the same size. It is thought that the surface tension of the droplet is playing an important role in this phenomenon. When it becomes impossible for surface tension to bear the weight of the droplet, the droplet will fall down. After that, again the liquid lava will be supplied, then, the droplet will repeat to fall down. Consequently many lava droplets will be deposited on a floor area. This phenomenon is very similar to the "weight of falling drops technique" which is the general method of measuring the surface tension of a liquid. Based on this idea, the study model for determining the surface tension $\gamma$ of lava is made[3]. When mass of the droplet is set to m, the force which pulls the droplet downward is $f_1 = mg$ (g is acceleration due to gravity), and the force of pulling up this upwards is $f_2 = 2\pi r\gamma$, where r is the radius of the lava droplet. The surface tension $\gamma$ is calculable for $f_1 = f_2$ if the weight of the lava droplet is known. As $f_1 = mg = \pi r^2 \ell \rho_L g$, where $\ell$ is length of the lava droplet, $\rho$ is the density of the lava, the surface tension $\boldsymbol{\gamma = r\ell\rho_L g/2}$ can be obtained from r and $\ell$ of the lava droplets accumulated on the floor as shown in Fig.20. If we introduce $\rho_L$= 2.5g/cm$^3$ and g= 980 cm/s$^2$, and by the fields observation of r and $\ell$, for example, the surface tension $\gamma$ = 490 dyne/cm can be obtained for r=0.2 cm, and $\ell$=2cm, and $\gamma$=980 dyne/cm can be obtained for r= 0.25 cm, and $\ell$=4cm. From the measurement of r and $\ell$ of the various stalagmites, the serface tension $\gamma$ is estimated as shown in Fig.21 to Fig.26. The surface tension of lava was in the range of 600 to 1000 dyne/cm in general.. The estimated surface tension matches with the experimental results by melting the lava in the Laboratory[4].

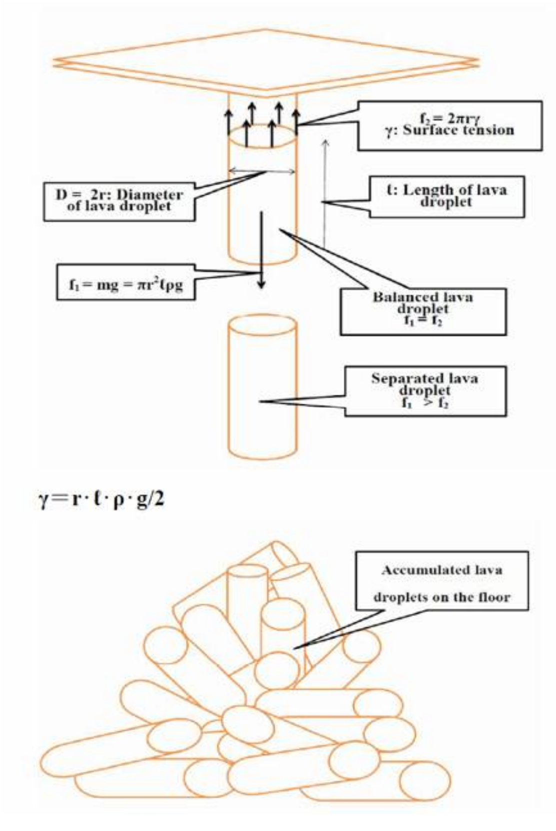


Fig.20 Fallen droplet model

Fig.21 Lava stalagmite on the floor of Mitsuike-ana lava tube cave: r=0.2~0.25cm, $\ell$=2~4cm, $\gamma$=490～980 dyne/cm

Fig.22 Lava stalagmite on the floor of Funatsu Tainai Lava Tree: r=0.25cm, $\ell$=3cm, $\gamma$=920 dyne/cm

Fig.23 Lava stalagmite on the floor of Miyakejima Lava Tree: r=0.25cm, $\ell$=5cm, $\gamma$=1530 dyne/cm

Fig.24 Lava stalagmite on the floor of Miyakejima Lava Tree:r=0.1cm, ℓ=5cm, γ=610dyne/cm

Fig.25 Stalagmite of Hachijoujima lava tree: r=0.2~0.25cm, ℓ=2~4cm, γ=490~980dyne/cm

Fig.26 Stalagmite in the tunnel of 2004 lava flow of Piton de la Fournaise: r=0.2~0.25cm, ℓ=2~4cm, γ=490~980dyne/cm

**4.Conclusions**

The value of such surface tension obtained from the lava stalagmite is in good agreement with the surface tension acquired from the pitch of the waving of the liquid layer by the simple hydrodynamic instability model of gravity/surface tension acting on the melting liquid layer attached on the inner surface of the lava cave. This value also agrees well with the extrapolated value at the temperature arround 1100 degrees Celsius obtained by I. Yokoyama and S.Iizuka[4] in the melting lava surface tension measurement experiments in Laboratory. As a conclusion, we could say that the surface tension plays a preponderant role for the lava stalactite and stalagmite formation in the lava cave and lava tree void. It seems that there is no significant difference between surface tensions of different basaltic lavas though further study for various lavas will be continued . The estimated surface tensions are summarized in the Table1 in Appendix.

**[References]**

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Appendix

**Table 1 Summary of the estimated surface tensions for various area**

| Name of Volcano, Area | $SiO_2$ weight%(Reference), Eruption year | *Cave or T-Mold | **Measured P , r and ℓ | Estimated surface tension |
|---|---|---|---|---|
| Mt Fuji, Inusuzumi-yama, Mitsuike-ana | 49.09%( H.Tsuya) , before 7000 | Cave | P=3～4cm<br>r=0.2~0.25cm,ℓ=2~4cm | 560～990dyne/cm<br>490～980 dyne/cm |
| Izu-Osima, Mihara-yama | 52~53%( T.Minakami), 1951 | Cave | P= ～3cm | ～560 dyne/cm |
| Shimane,Daikon-zima | 47%( I.Sawa), before 190000 | Cave | P= ～3cm | ～560 dyne/cm |
| France, Reunion, Le Piton de la Fournaise | 48.8~49.8% (N.Villeneuve),1998<br>48~50% (A.Peltier),2004 | Cave | P=3～4cm<br>r=0.2~0.25cm,ℓ=2~4cm | 560～990 dyne/cm<br>490～980 dyne/cm |
| Vietnam, Central Plateau, Chupluk Volcano | 48~52% (N.Hoang) | Cave | P=3～4cm | 560～990 dyne/cm |
| US,California, Medecine Lake Volcano,Lava Beds National Monument | 52.3 Average%(J.Donnelly) 36±16ka | Cave | P=3～4cm | 560～990 dyne/cm |
| Mt Fuji,Ken-marubi, Funatsu-tainai | 50.88%( H.Tsuya), 937 | T-Mold | P=3～4cm | 560～990 dyne/cm |
| Mt Fuji,Ken-marubi, Yoshida-tainai | 50.88%( H.Tsuya), 937 | T-Mold | P=3～4cm | 560～990 dyne/cm |
| Izu-Osima, Mihara-yama | 52%( S.Nakano, T.Yamamoto), 1986 | T-Mold | P=～4cm | ～990 dyne/cm |
| Miyake-zima, O-yama | 53~54%(T.Fujii et al),1983 | T-Mold | r=0.1~0.25cm, ℓ=5cm | 610～1530 dyne/cm |
| Hachijo-zima,Nishi-ya ma, | 50.4~50.5%( M.Tsukui), Before 1100 | T-Mold | P=3～4cm,<br>r=0.2~0.25cm,ℓ=2~4cm | 560～990 dyne/cm<br>490～980 dyne/cm |
| US,Oregon,Newberry Volcano, Lava cast forest | 49～50%(J.Donnelly), Before 7000 | T-Mold | P=3～5cm | 560～1740 dyne/cm |

*T-Mold=Lava Tree Mold

**P=Pitch between lava stalactites or Pitch of ribbed wall, r=Radius of lava stalagmite, ℓ=Length of lava stalagmite