Lava tubes and lava tube caves are formed in the lava flow of Nishinoshima volcano in Ogasawara islands?

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[Introduction] Nishinoshima which consists of andesite lava continues an eruption since November 20,2013. Various reports [1),2)] on the previous 1973 year eruption and on this 2013 eruption are referring about existence of "lava tunnel" (lava tube or lava tube cave). Here, the possible formation of "lava tunnel" was considered based on hydrodynamic model as Bingham fluid. Because a lava tube cave (lava tunnel) exists clearly in a basalt lava flow, however, any lava tube caves have not been found hitherto in an andesite lava flow [3),4)] .

[Hydrodynamic model of a lava tube and hollow (lava tube cave) formation] A considered model is indicated on figure 1 where M is head height by magma pressure, L is length of lava tube and R are the lava tube radius, and αis slope angle of a lava tube. Case(A) shows the lava spouted from a crater goes down a slope and forms a lava tube. The flow in the lava tube is controlled by the magma pressure and gravity (forced flow). After the termination of eruption, two cases (B) and (C) are considered. Case(B) shows a “filled lava tube” in which lava is stayed in the tube without drained out from the tube. Case (C) shows a “lava tube cave” in which the lava in the tube can be drained out by the gravity (free flow), a hollow is formed in the tube. For Case (A), M/L>0 and τ_W = (ρ gsin α+ ρgM/L) R/2>f_B, for Case(B), or Case(B), M/L=0 and τ_W= (ρ gsin α) R/2B, for Case(C), M/L=0 and τ_W= (ρ gsin α) R/2>f_B, where
τ_w is shear stress on the tube wall, f_B is Bingham yield strength of lava, g is the gravity force and ρis lava density.

[Estimate of a presence of a lava tube and a lava tube cave] From the correlation line between SiO_2wt% and Bingham yield strength of Hulme [5)], the Bingham yield strength for 58~60 % is $5x10^4$~10^5 N/m2. The slope angle of lava flow is estimated as 6 degree from “Cross section of Nishinoshima for 2013.12.4.~2015.7.28”of Japanese Geological Survey. The estimated limiting lava tube height(H=2R) calculated for M/L= 1.0 and 0.5 and also M/L= 0 is shown in table 1. In case of M/L=0, the formation of a lava tube cave is impossible. On the other hand, in case of M/L>0 where pressurization by a magma is existing in the tube, there is a possibility of the lava tube formation depending on lava flow thickness. The followings are summary from the estimation based on the model:

(1) The magma pressure enough to overcome the high Bingham yield strength of andesite lava should be acting in the lava tube to make flow the lava in a lava tube.

(2) Even if a lava tube is formed, and when magma pressure is deleted, the lava will not be drained out from the lava tube. Then, lava tube cave will not be formed, only filled lava tube will be found.

[Conclusions] For the Nishinoshima lava flow of andesite, a lava tube cave will not be able to be found. Instead, there is a possibility to find a filled lava tube. The inspection of the lava flow thickness, the lava tube length/the height, the degree of the slope in Nishinoshima after landing is expected[6)]. A clear definition as a technical term of the lava tunnel or the lava tube is necessary. Use of active lava tube, filled(plugged) lava tube and drained lava tube(lava tube cave) is proposed.

[References]

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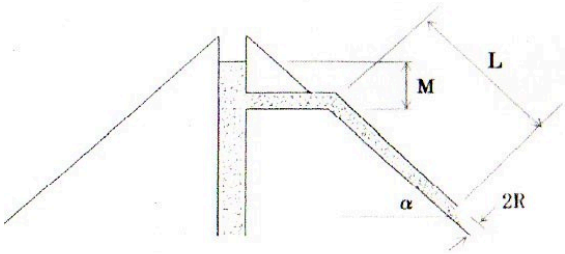
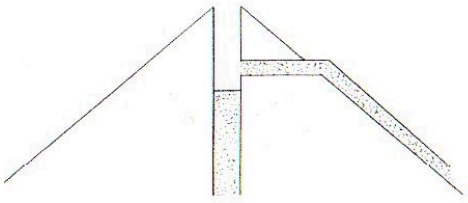
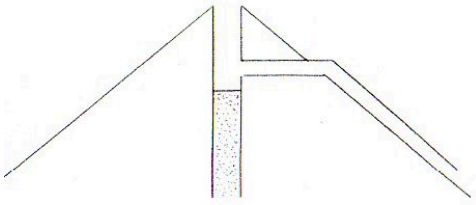
Fig.1 Hydrodynamic Model of Bingham Fluid



(A) Active lava tube: $(\rho g \sin\alpha + \rho g M/L)R/2 > f_B$



(B) Filled lava tube: $(\rho g \sin\alpha)R/2 < f_B$



(C) Drained lava tube: $(\rho g \sin\alpha)R/2 > f_B$

Table1 SiO_2wt% and Lava tube/cave height(Slope angle=6°)

SiO_2wt%, Yield strength	Acting pressure : M/L= 1.0,0.5,0	Required tube height:H	Comparison with lava thickness:h(<50m)
SiO_2 58%: *$5x10^4$ N/m^2	1.0 (Magma+Gravity)	7m	<h?(Tube formation?)
	0.5 (Magma+Gravity)	13m	<h?(Tube formation?)
	0 (Gravity)	80m	>h(No cave formation)
$SiO_2$61%: *$1x10^5$N/m^2	1.0 (Magma+Gravity)	15m	<h?(Tube formation?)
	0.5(Magma+Gravity)	26m	<h?(Tube formation?)
	0 (Gravity)	120m	>h(No cave formation)

*G.Hulme(1974):Geophys.J.R.Astr.Soc.,vol39,p361

