Estimation of the yield strength and lava flows structure of Mt.Fuji by lava tube cave height and lava tree mold depth

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Abstract:

Many lava tube caves and lava tree molds exist in the lava flows of Mt. Fuji. Lava tube cave and lava tree mold coexists in Suyama Tainai lava flow, Ganno-Ana lava flow and Aokigahara lava flow.. Only lava tube cave exists in Subashiri-guchi lava flow located in the high altitude. Only lava tree mold exists in relatively thin lava flow such as Takamarubi lava flow, Higashisuzuka-South lava flow, Ohbuchi marubi lava flow,Kenmarubi I and Kenmarubi II lava flows. By using Bingham flow model, 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. Then, the lava flow structure of these Mt.Fuji's is also discussed based on the apparent difference of these yield strength.

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 critical(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 $f_B = Hc\ (\rho\ g \sin\alpha)/4$,for n=4, where Hc is the lava tube cave height, and from $f_B=Ht\ (\rho\ g \sin\alpha)$ for n=1, where Ht is lava thickness(depth of tree mold).

The followings are conclusions from the results, (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 of the simple flow due to inflation of lava.

1.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 , Ganno-Ana lava flow and Aokigahara lava flow.. Only lava tube cave exists in Subashiri-guchi lava flow located in the high altitude. Only lava tree mold exists in relatively thin lava flow such as Takamarubi lava flow, Higashiusuzuka-South lava flow, Ohbuchimarubi 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. A considered model for lava tree mold is shown in Fig.1, and used model for lava tube cave is shown in Fig.2.

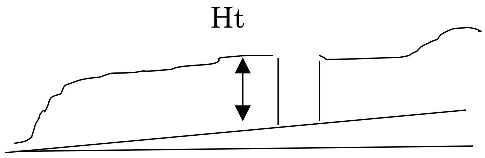

Fig.1 Lava tree mold and lava depth Ht, Apparent yield strength $f_B= H_t(\rho g \sin\alpha)$

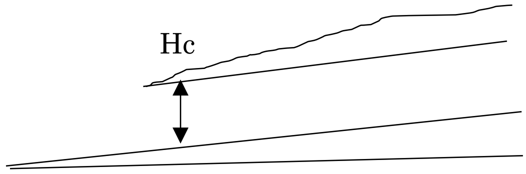

Fig2 Lava tube cave and cave height Hc, Yield strength $f_B= H_c(\rho g \sin\alpha)/4$

2.Considered hydrodynamic model

The lava flow is modeled by Bingham fluid flowing on the inclined plane or in the inclined cylindrical pipe with gravity potential(see Fig.3). 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(see Fig.4)), and the case of lava which flows through an inclined circular tube is n=4(see Fig.5). The yield strength is obtained from $f_B=H(\rho g \sin\alpha)$ for n=1, for free surface flow where H is lava thickness(depth of tree mold), from $f_B=H(\rho g \sin\alpha)/4$,for n=4, where H is the lava tube cave height, for circular tube[1].

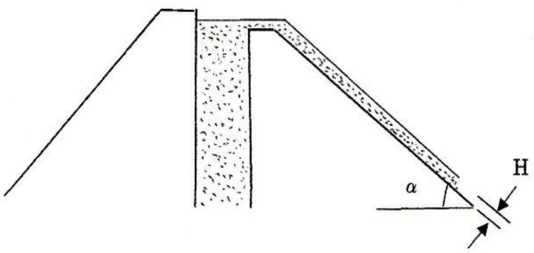

Fig.3 The lava flowing on the inclined plane or in the inclined cylindrical pipe with gravity potential

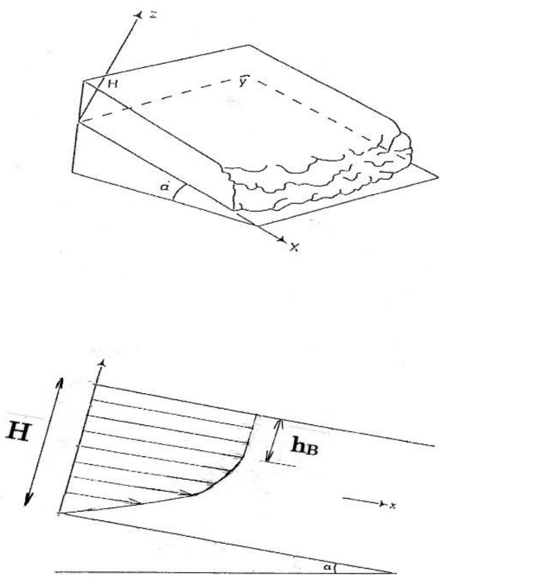

Fig.4 Lava flow on the incline plane with a free surface(n=1)

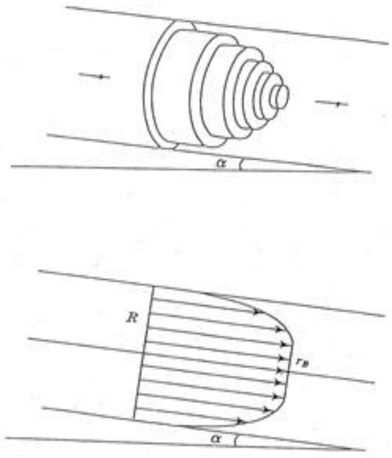

Fig.5 Lava flow through an inclined circular tube(n=4)

3.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. Some examples of lava tree mold depth and apparent yield strength together with photo and figures are shown for following several lava flows

[Suyama tainai lava flow][2]

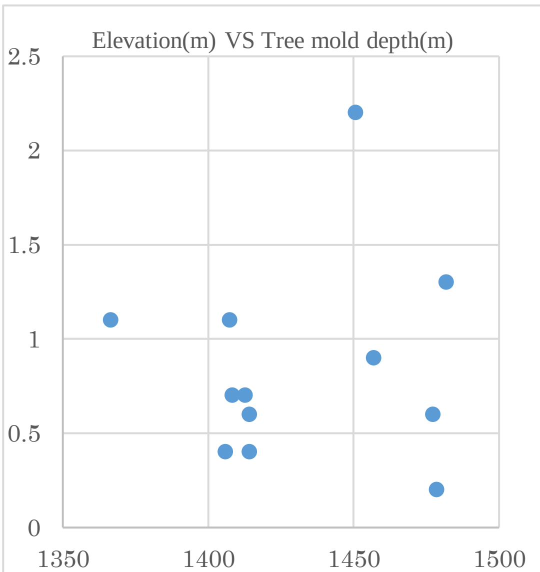

Fig.6 Lava tree mold depth of Suyama tainai

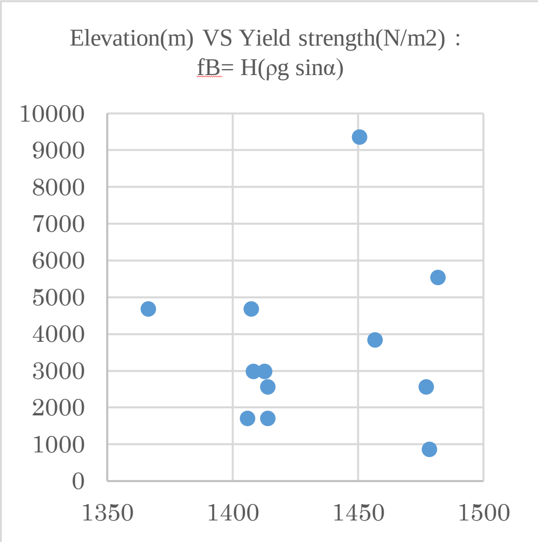

Fig.7 Yield strength of Suyama tainai lava flow

Fig.8 Lava tree mold of Suyama tainai lava flow

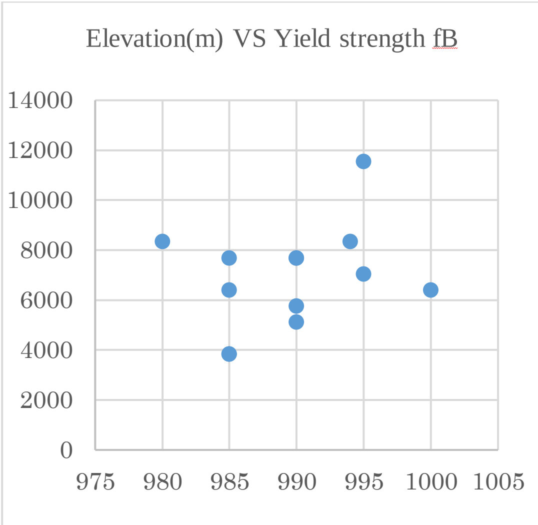

Fig.10 Yield strength of Ganno ana lava flow

Fig.11 Lava tree mold of Ganno ana lava flow

[Gannno ana lava flow][3,4]

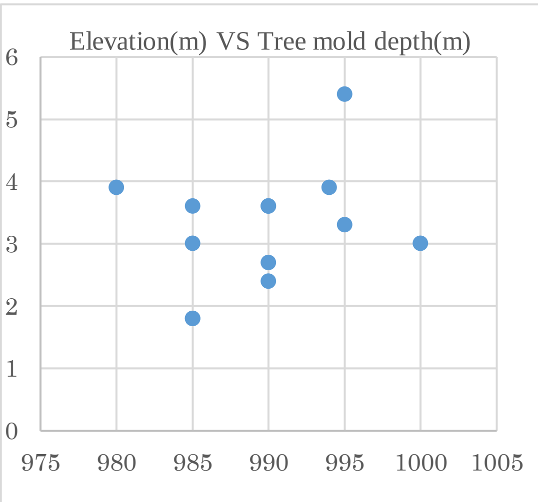

Fig.9 Lava tree mold depth of Ganno ana

[Takamarubi lava flow][5]

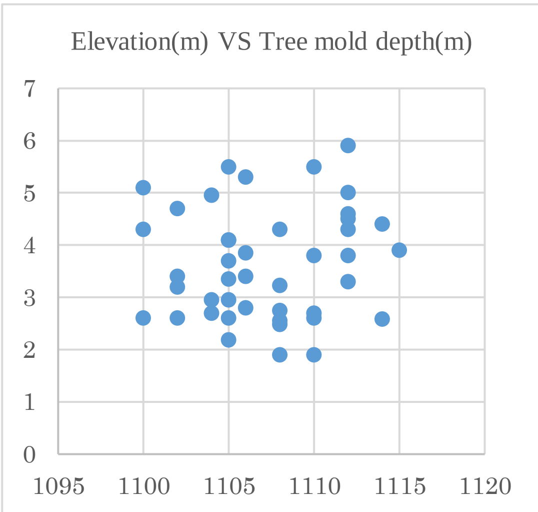

Fig.12 Lava tree mold depth of Takamarubi

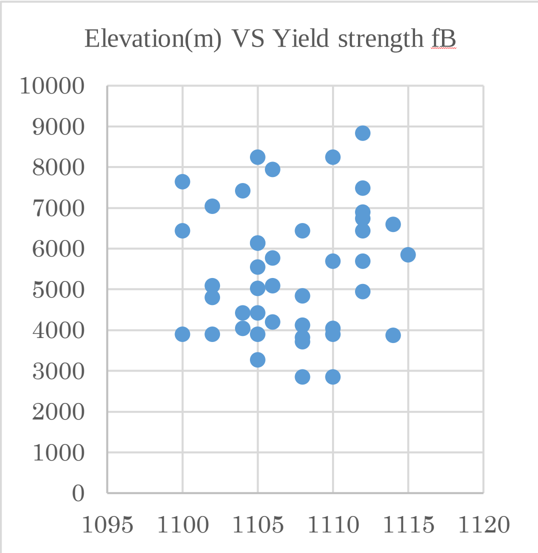

Fig.13 Yield strength of Takamarubi lava flow

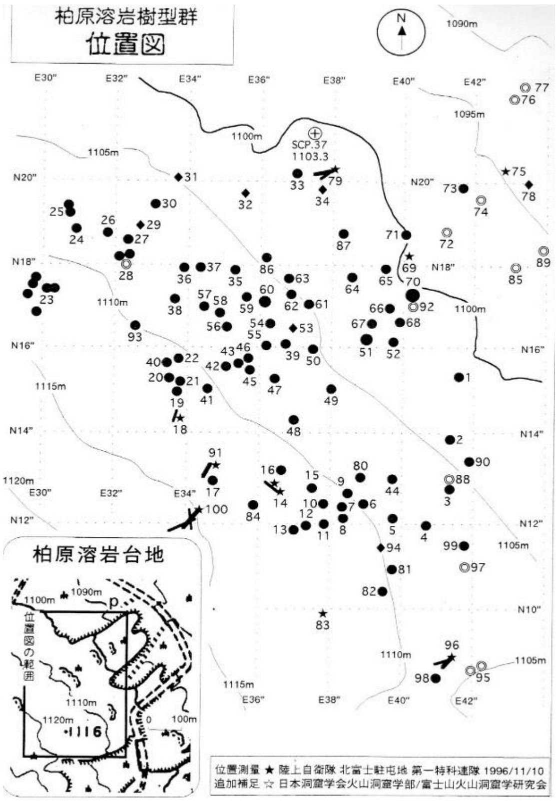

Fig.14 Lava tree mold distribution in the lower edge of Takamarubi lava flow.

[Kennmarubi-I lava flow][6,7]

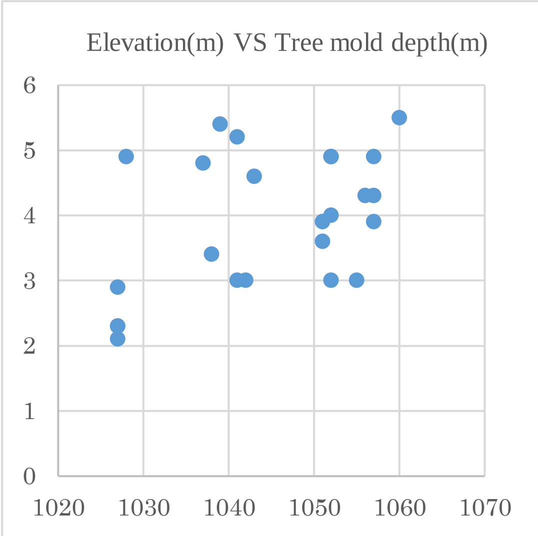

Fig.15 Lava tree mold depth of Kenmarubi-I

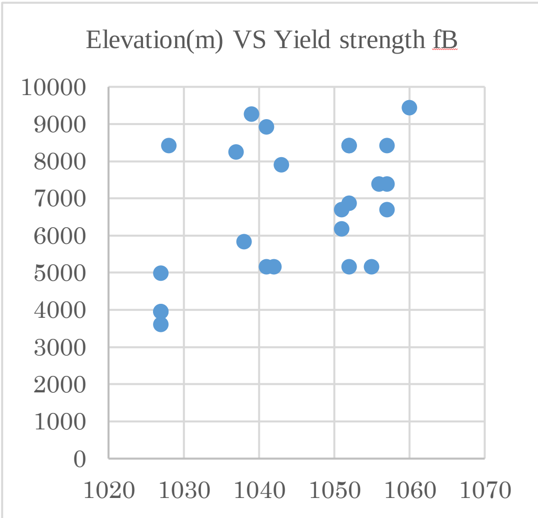

Fig.16 Yield strength of Kennmarubi-I

[Ohbuchi marubi lava flow][8)]

Fig.17 Large tree mold of Ohbunchimarubi

Fig.18 Large tree mold of Ohbunchimarubi

Fig.18 Adjuscent large tree mold

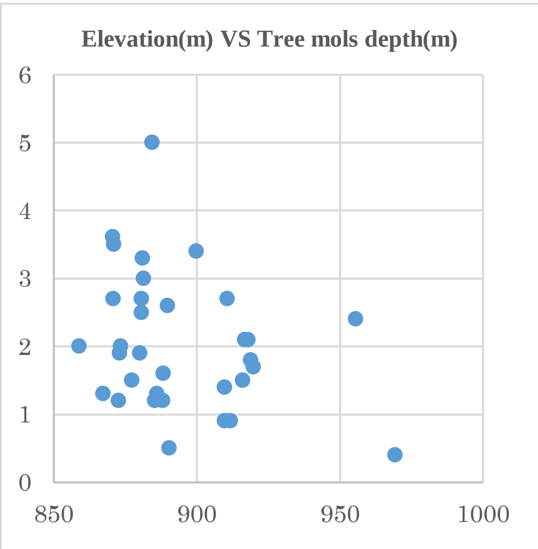

Fig.19 Tree mold depth of Ohbuchimarubi

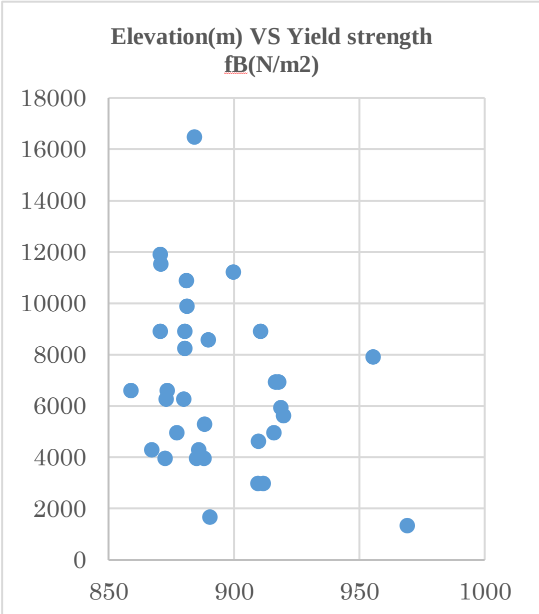

Fig.20 Yield strength of Ohbuchimarubi

The results are summarised for lava flows of Mt.Fuji 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. 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.

4.Estimation of the yield strength by the lava tube cave

When the lava tube cave hollow height is made Hc, the lava surrender value will be $f_{Bc}= H_c\ (\rho\ g\ \sin\alpha)/4$. The height of lava tube caves and slope angles for Suyama Tainai Cave (see Fig.21~Fig.23), for Subashiri Tainai Caves and for Ganno-Ana Cave are indicated in Table.1. The estimated lava yield strength are also shown in Table 1. The yield strength shows relatively low value between $0.8\text{x}10^3$ N/m^2 and $3.2\text{x}10^3$N/m^2.

Fig.21 Inside of Suyama tainai cave

Fig.22 Entrance of Suyama tainai cave

5.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.

Reference:

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Table.1 Estimation of the yield strength of Mt.Fuji lava by lava tube caves height and lava tree mold depth

Name of lava flow	SiO_2 Wt %	Slope angle: α	Height of lava tube cave：H_c	Yield strength obtained from Hc: $f_B= H_c(\rho g \sin\alpha)/4$	Depth of lava tree mold：H_t	Apparent yield strength obtained from H_t: $f_B= H_t(\rho g \sin\alpha)$
Suyamatainai	51.4	10 °	1.0m～1.8m (Subashiritainai cave)	1.1×10^3～$1.9 \times 10^3 N/m^2$	0.2m～2.2m	9.4×10^2～$9.4 \times 10^3 N/m^2$
Gannoana	51.1	5 °	1.5m~2.0m (Nagara Ana cave)	0.8×10^3～$1.1 \times 10^3 N/m^2$	1.8m～5.4m	3.8×10^3~$1.2 \times 10^4 N/m^2$
Aokigahara	51.3	3° ~10°	2m~10m(Karunizu cave,etc.,)	1.6×10^3～$3.8 \times 10^3 N/m^2$	3.3m~5.3m	8.0×10^3~$1.3 \times 10^4 N/m^2$
Subashiriguchi	50.9	20° 15°	1m 2m (Subashiritainai cave)	$2.1 \times 10^3 N/m^2$ $3.2 \times 10^3 N/m^2$	No lava tree molds	—
Takamarubi	50.9	3.5 °	No lava tube caves	—	1.9m～5.9m	2.8×10^3~$8.8 \times 10^3 N/m^2$
Higashiusuzukaminami	51	9°	No lava tube caves	—	1m~2m	3.8×10^3~$7.6 \times 10^3 N/m^2$
Kenmarubi-I	51.1	4°	No lava tube caves	—	2.1m～5.5m	3.6×10^3~$9.3 \times 10^3 N/m^2$
Kenmarubi-II	51.2	4 °	No lava tube caves	—	2m～6m	3.4×10^3~$10.1 \times 10^3 N/m^2$
Oobuchimarubi	51.2	7.7°	No lava tube caves	-	0.4m~5m	1.3×10^3~$1.65 \times 10^4 N/m^2$

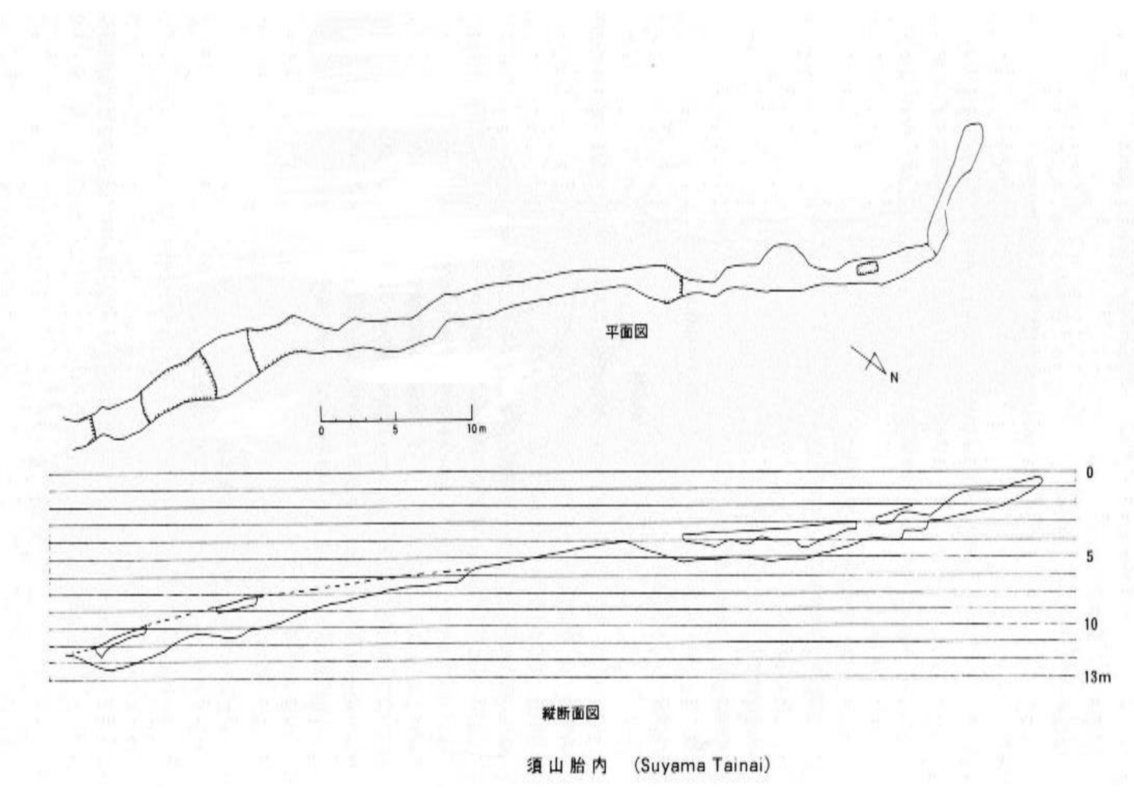

Fig.23 Lava tube cave of Suyama tainai lava flow