Science and Technology Research Partnership for Sustainable Development Program

Integrated Study on Mitigation of Multimodal Disasters Caused by Ejection of Volcanic Products

Recent two distinct eruptions in Indonesia: Kelud 2014 and Sinabung 2013-15

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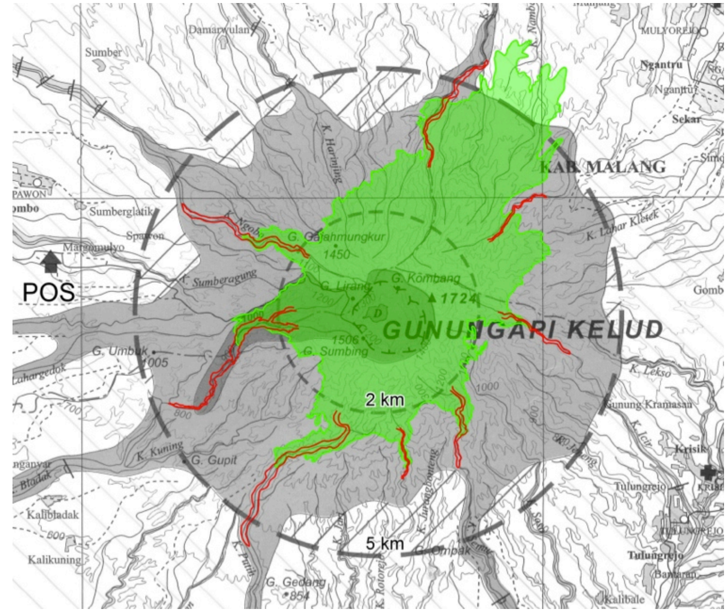
Result on Kelud

- We clarified the sequence of the 2014 Plinian event at Kelud based on eruptive deposits, and estimated some key physical parameters controlling eruption dynamics.
- The plinian phase was **preceded by partial disruption of lava dome and generation of energetic pyroclastic density currents** directed to NNE.
- Lava dome was completely disrupted during the climactic phase.



Distribution of pyroclastic density current deposits.
Hazard map by (Mulyana et al., 2004).
Shaded area: potentially affected by pyroclastic flows, lava flows, eruption lahar and rain lahars.

Lava dome acted as a plug, and significantly affected the eruption processes.

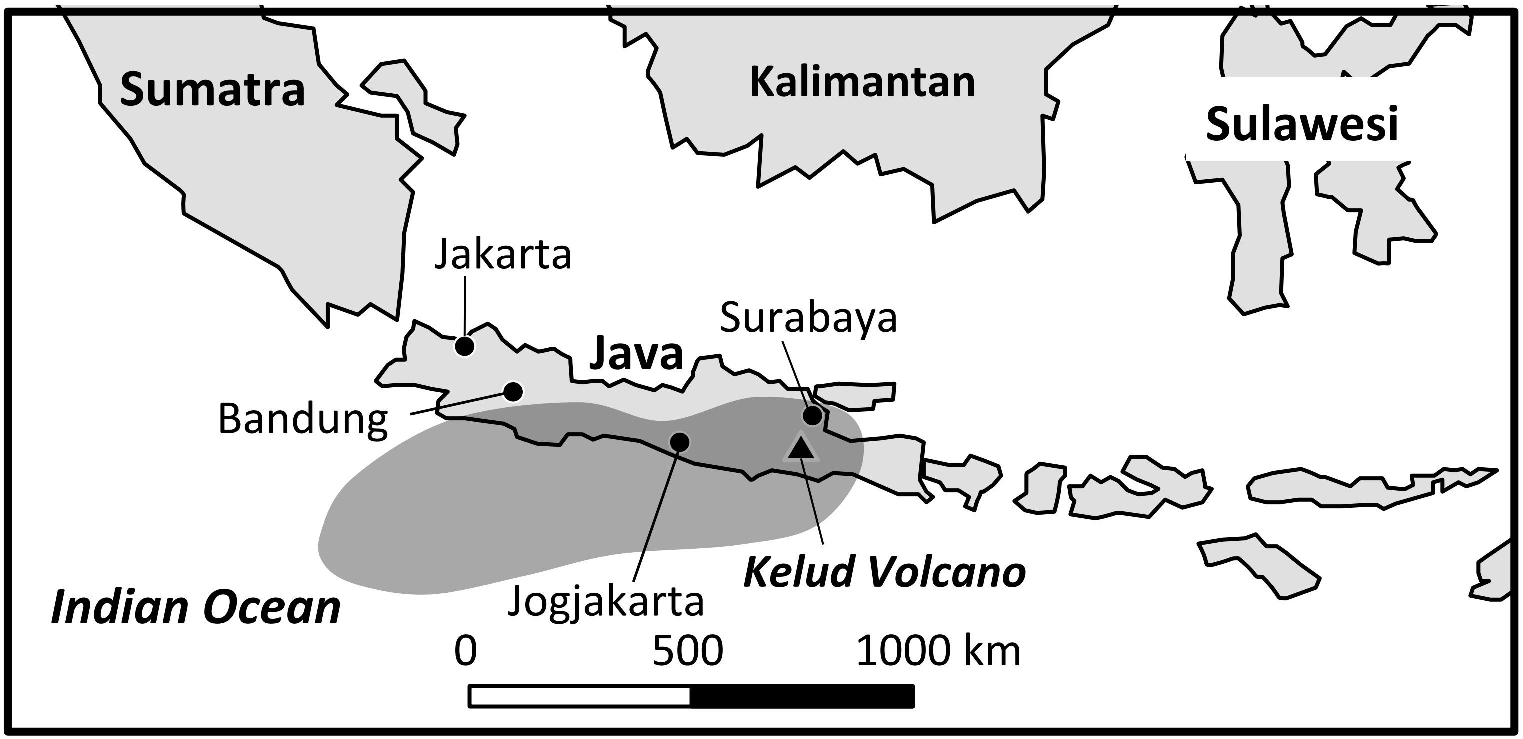


Fig. 1
Nakada et al.

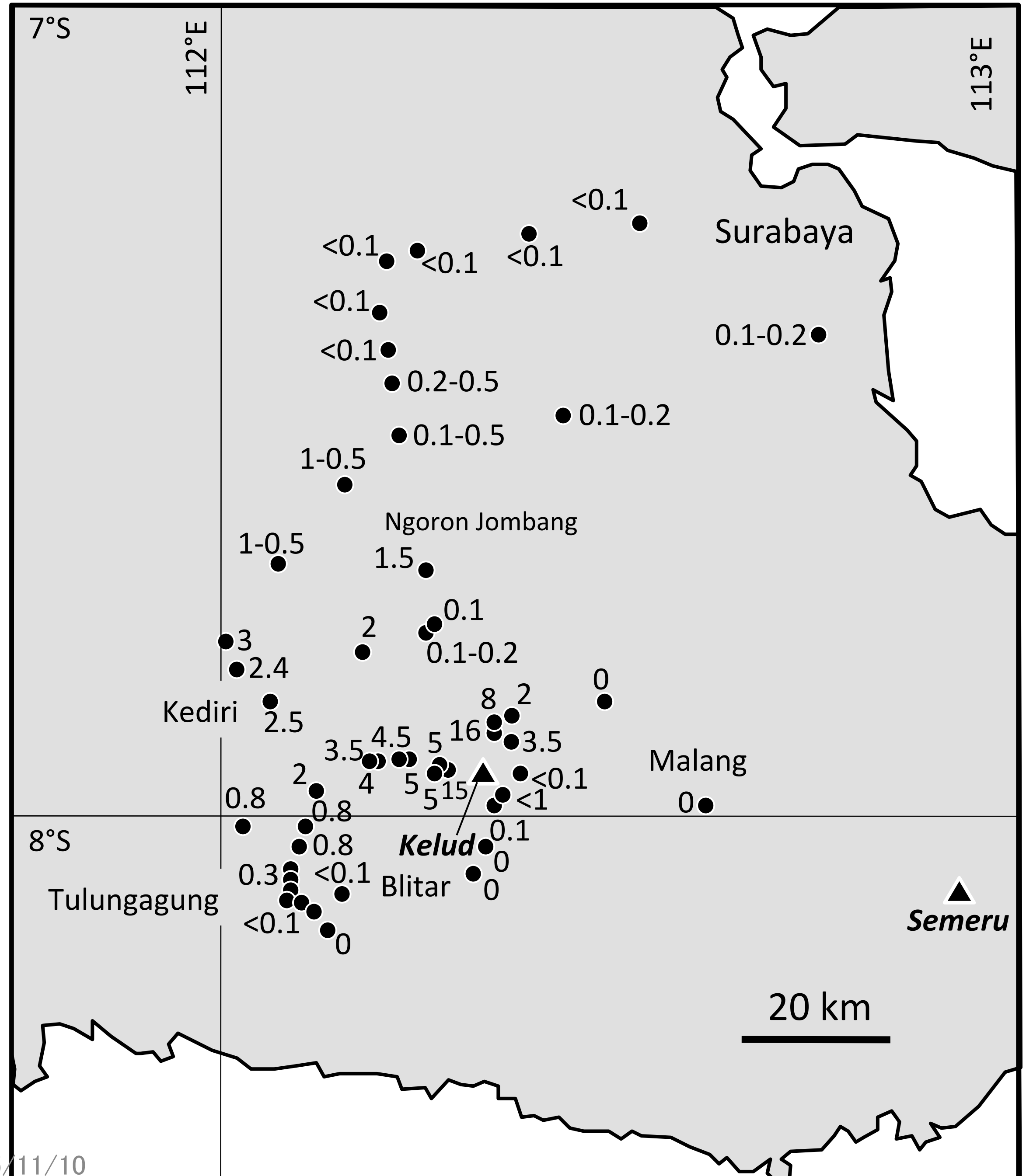
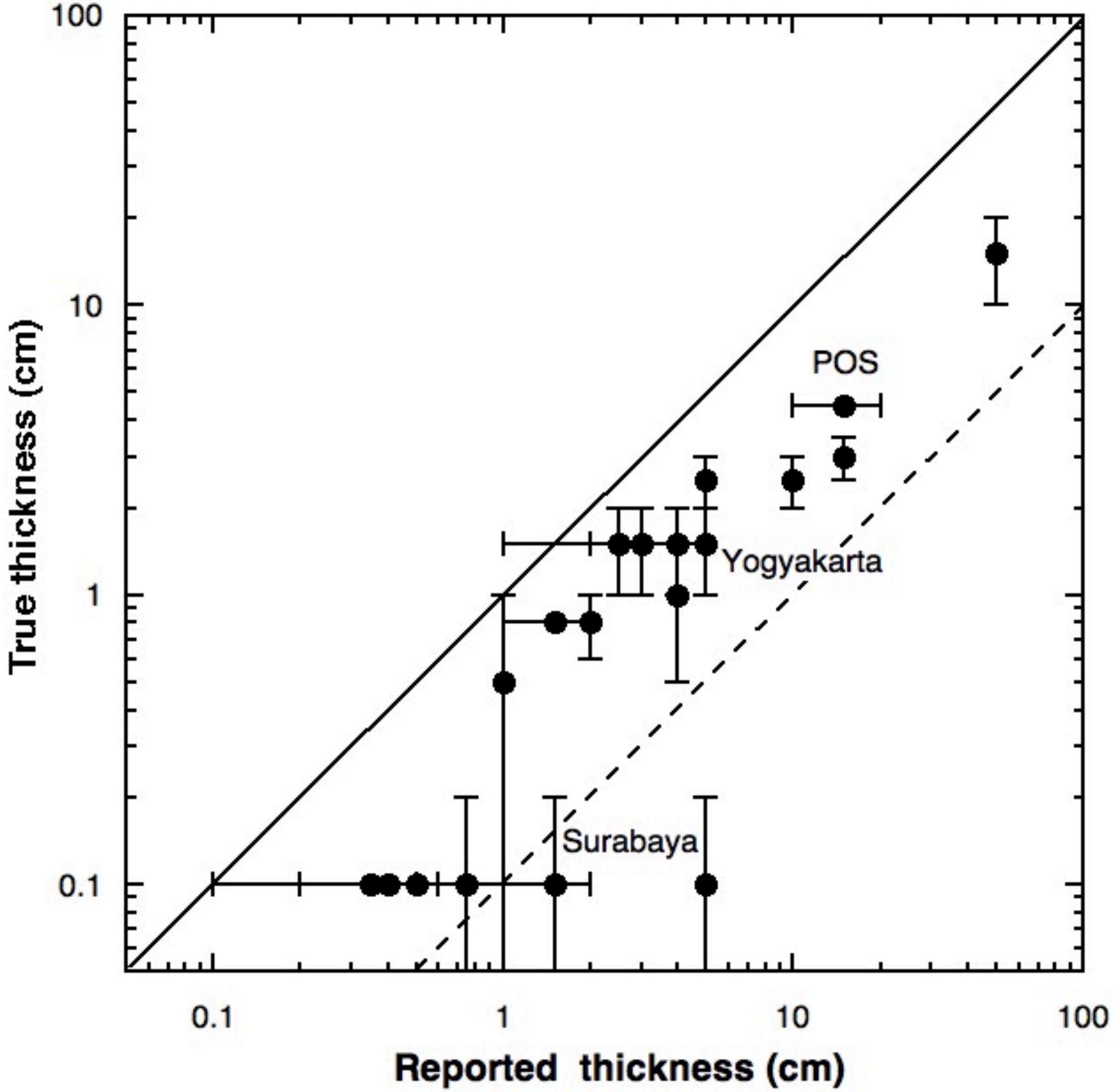
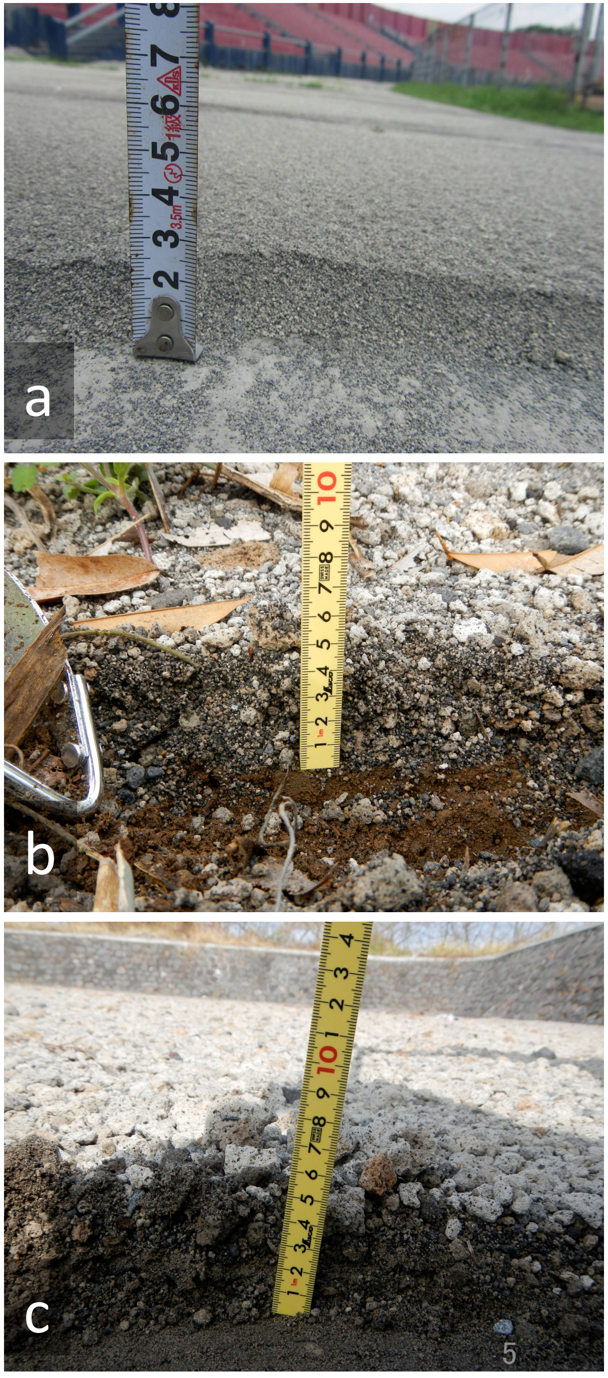


Fig. 2 Nakada et al.



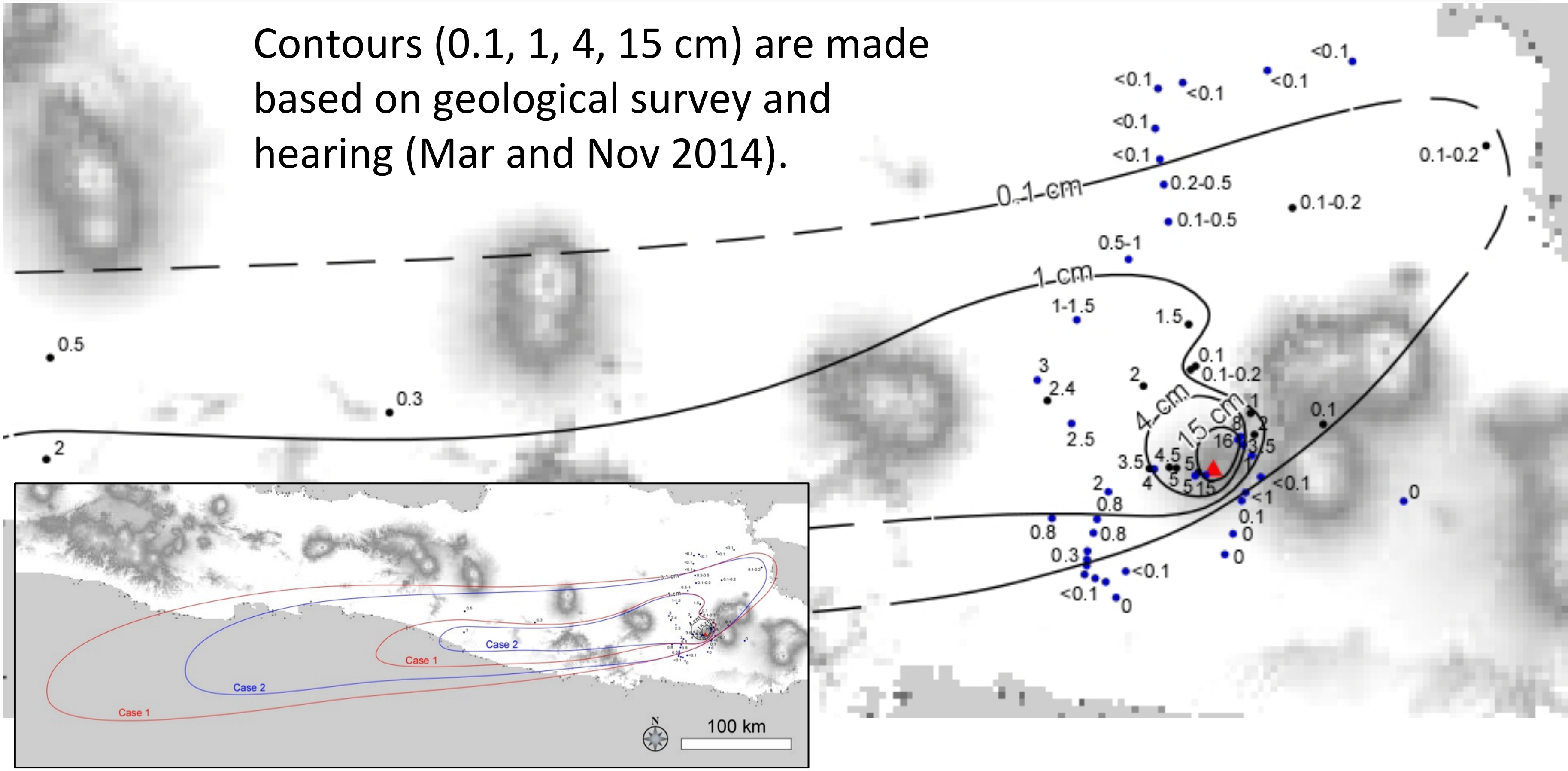
True thickness (cm)
Reported thickness (cm)
100
10
1
0.1
0.1
1
10
100
POS
Yogyakarta
Surabaya

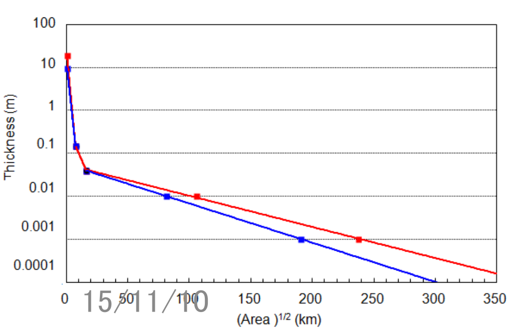


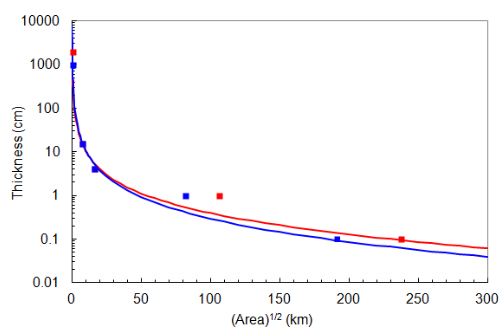
a
b
c

Isopach map of fallout tephra and volume estimation

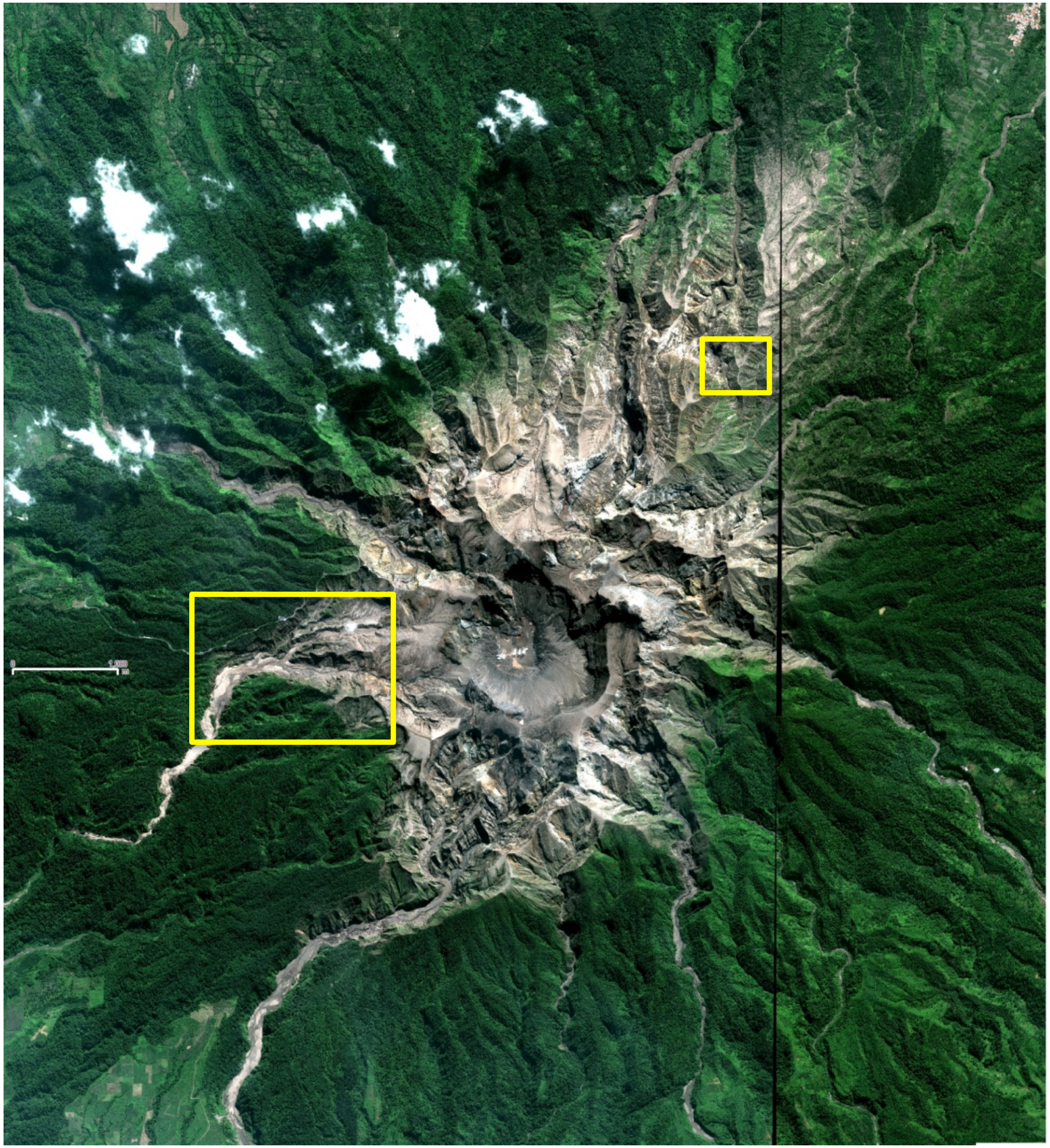
Contours (0.1, 1, 4, 15 cm) are made based on geological survey and hearing (Mar and Nov 2014).





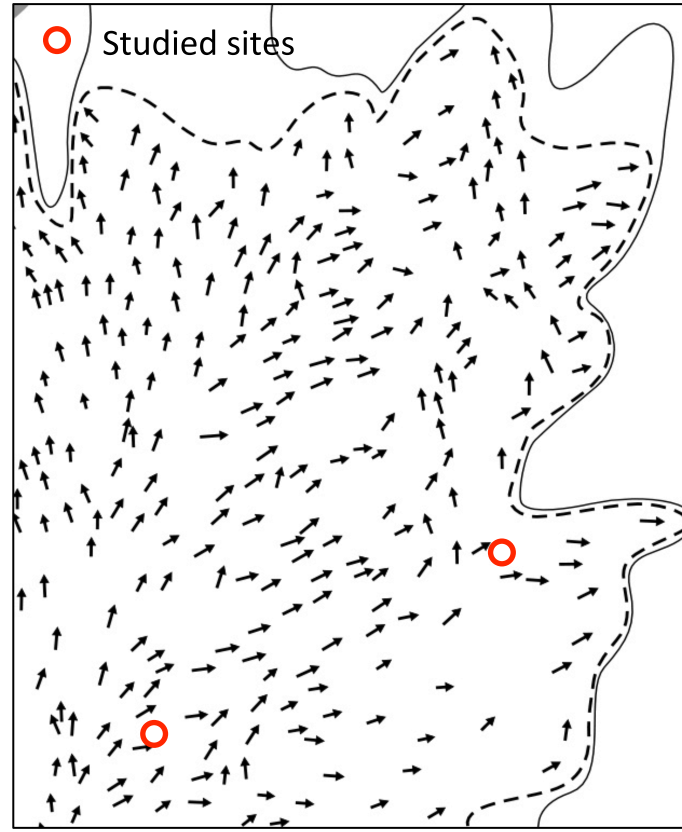


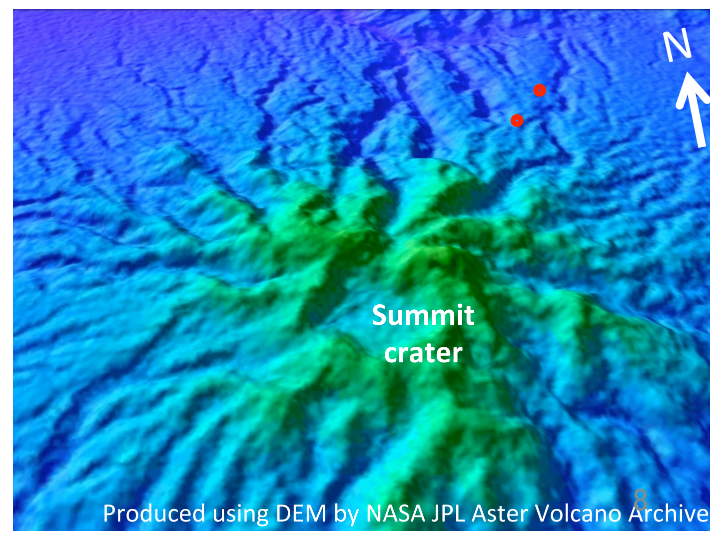
- Fierstein and Nanthenson (1992)'s method produces 0.46 km^3 for case 1 and 0.29 km^3 for case 2.
- Bonadonna and Costa (1992)'s method produces 0.43 km^3 for case 1 and 0.32 km^3 for case 2.



WorldView-2 image
19 May 2014

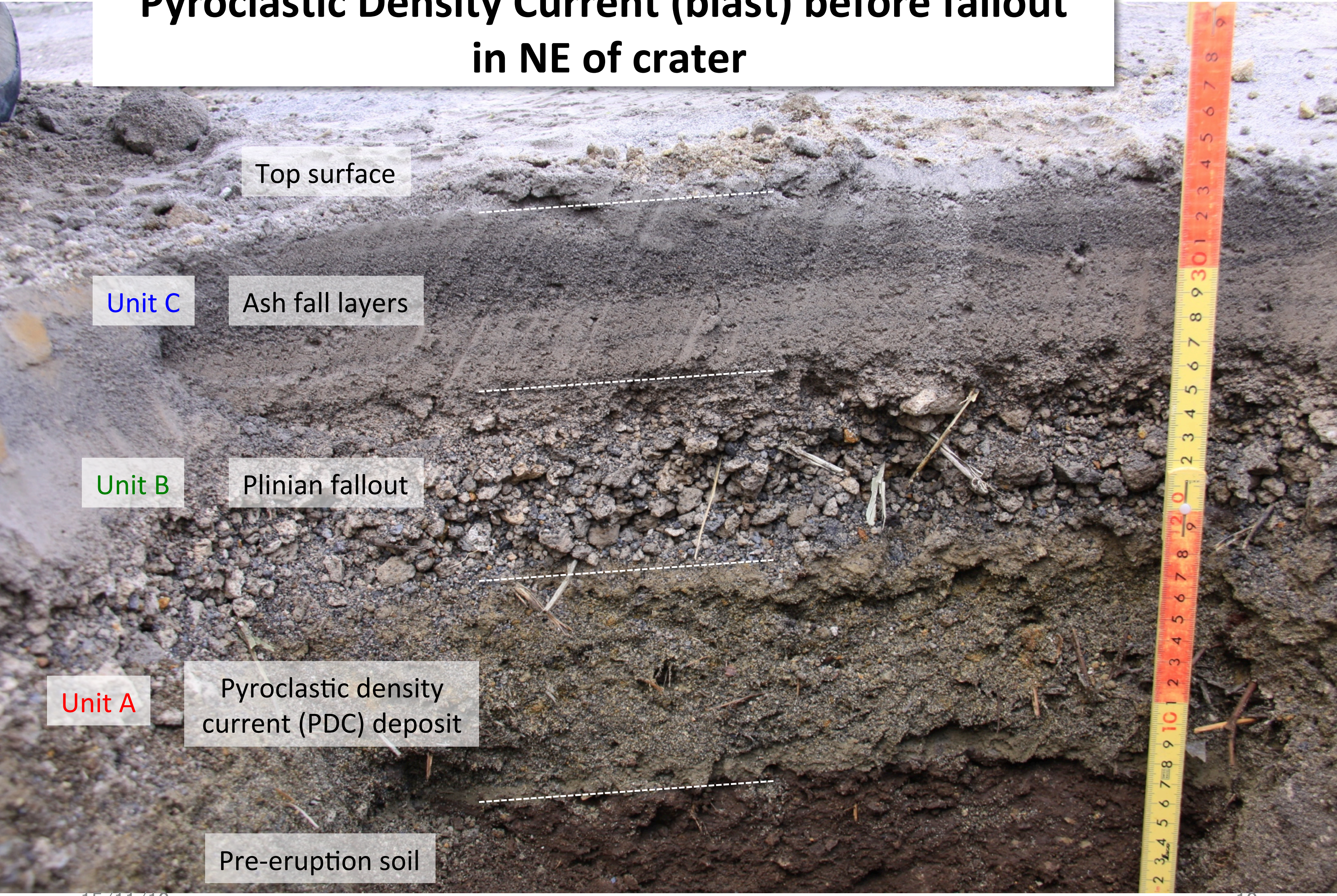
Area affected by PDCs



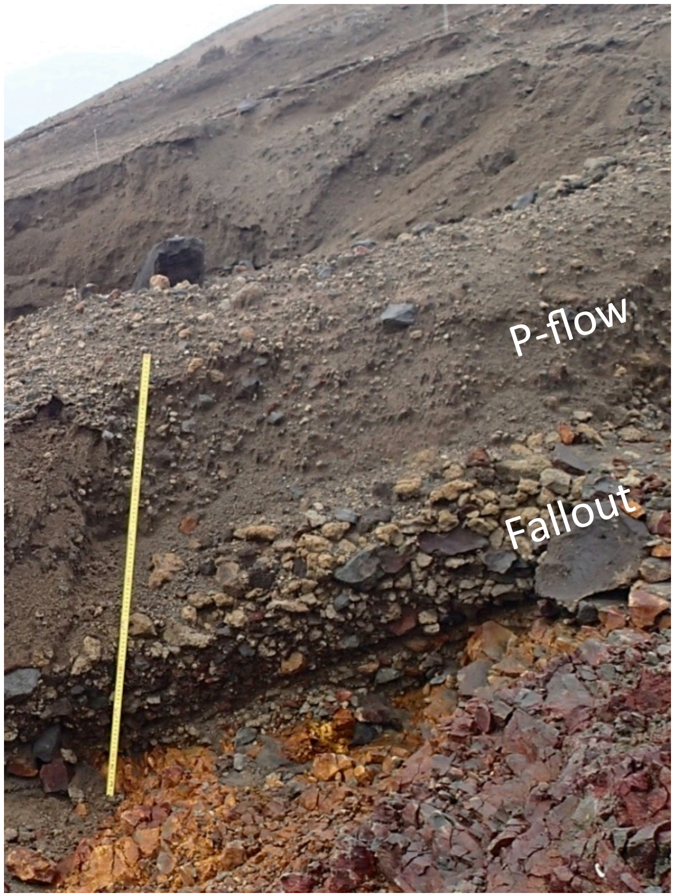


Uprooted and fallen trees and the Plinian pumice fall deposited on them

Pyroclastic Density Current (blast) before fallout in NE of crater



Fallout and pumice-rich pyroclastic flow deposits



Deposits on the western slope of Kelud volcano

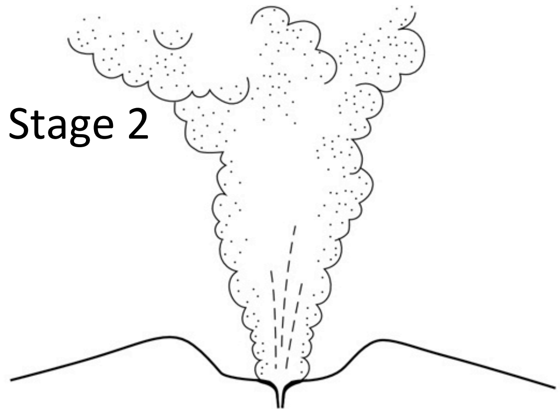
Valley-filling pumiceous pyroclastic density current with flow lobes in W of Kelud.

Chronology of the 2014 Kelud eruption

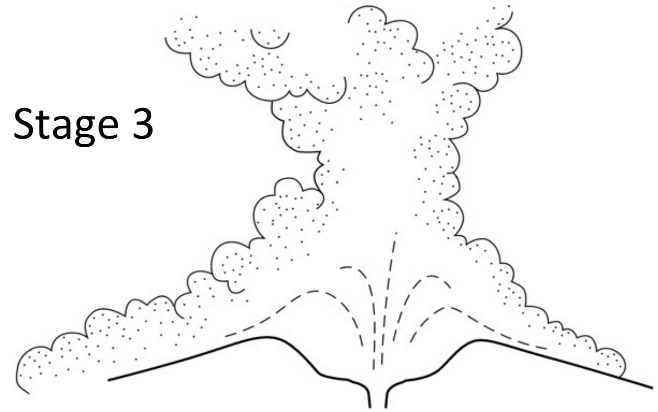
Geological and witness observations

Stage 1

Stage 2



Stage 3



Crater camera and seismometers were destroyed at 10:40-45 pm.

Pyroclastic density currents directed to NNE, blowing off lava dome and down numerous trees.

Plinian column rose up > 20 km (~11:15 pm), and began to spread umbrella could.

Lava dome completely destroyed.

Valley-filled pumice-rich pyroclastic density currents generated by column-collapse.

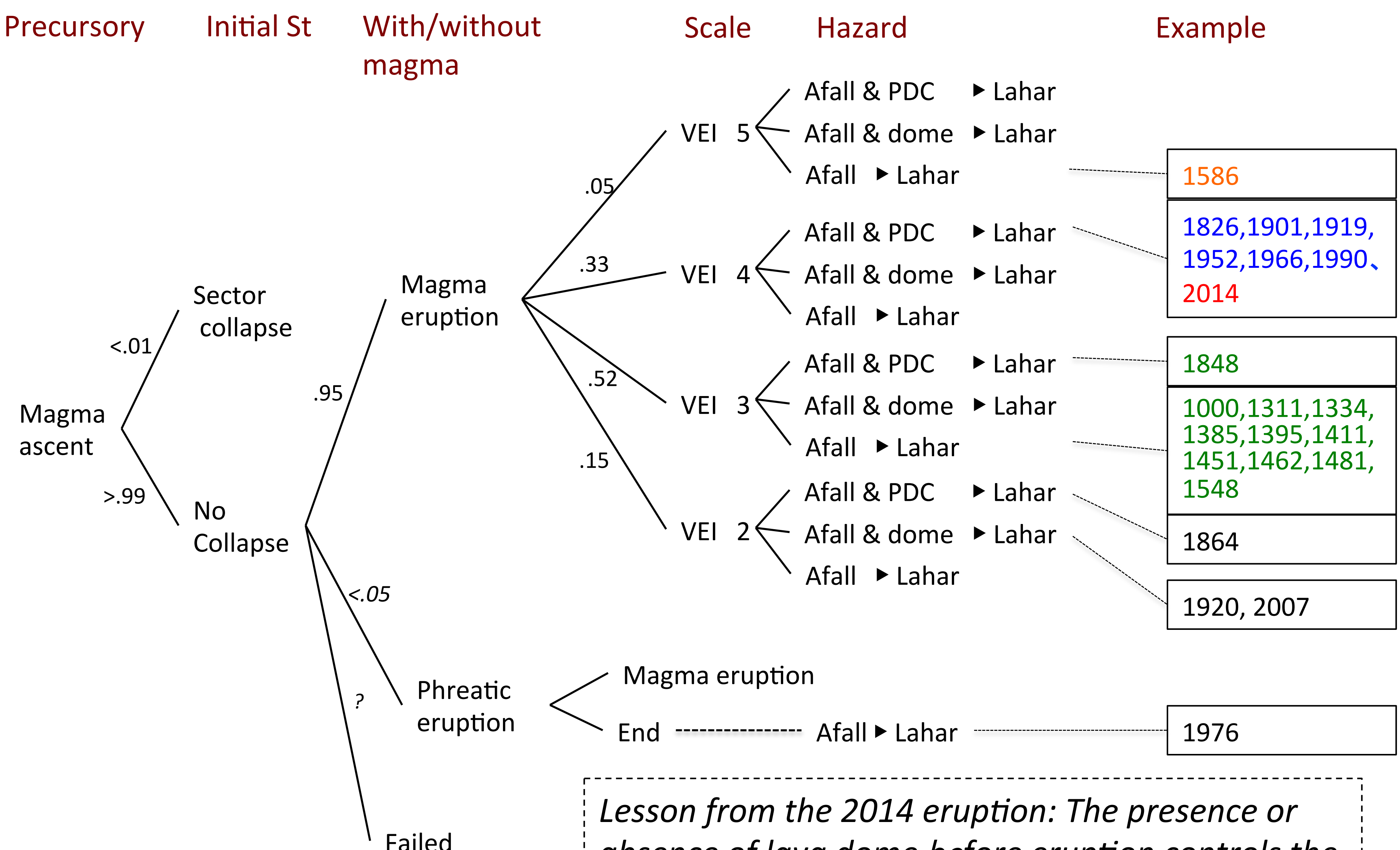
The eruption ended around ~1:00 am (?).

Observation from broadband seismometers (GEOFON) (Takeo A. et al., 2014)

Generation of acoustic wave at 10:46 pm.

2 hours event with acoustic waves from 11:02 pm.
Rayleigh wave generation from 11:15 pm.

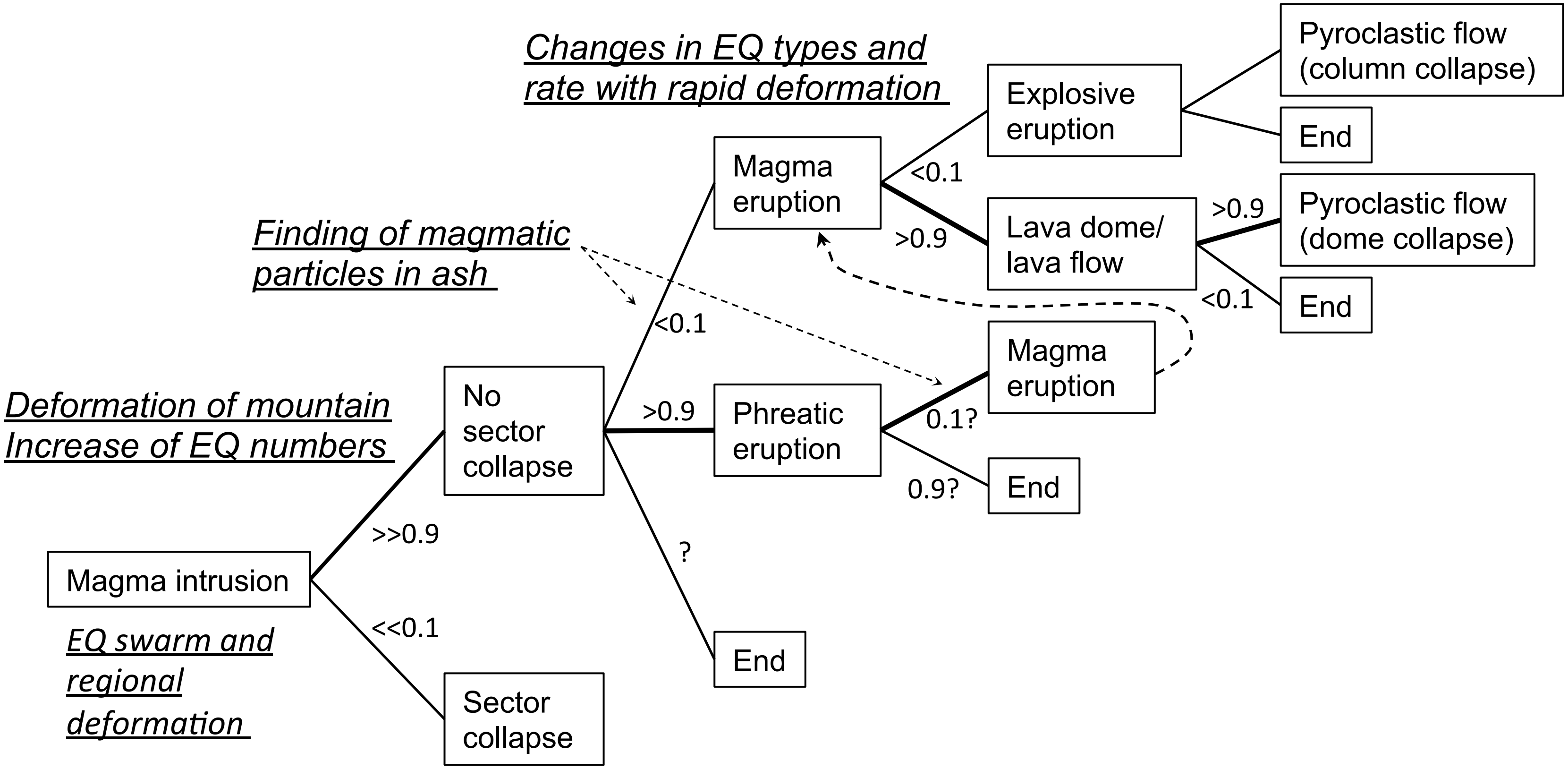
Event tree at Kelud



Lesson from the 2014 eruption: The presence or absence of lava dome before eruption controls the initial condition of eruption process!

Event tree of Sinabung

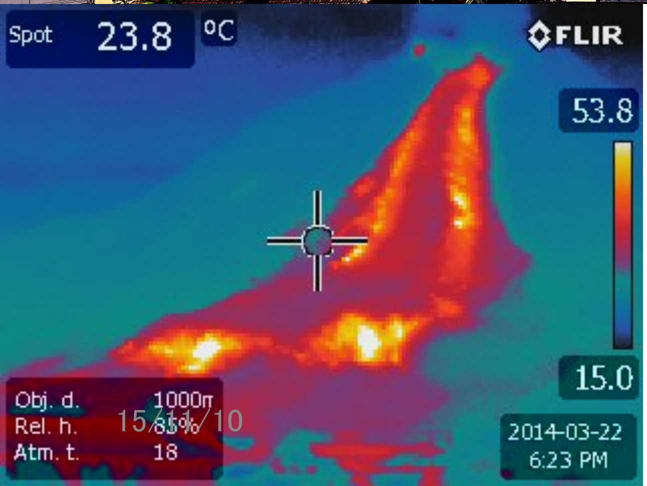
The basic model was shown in 2011.



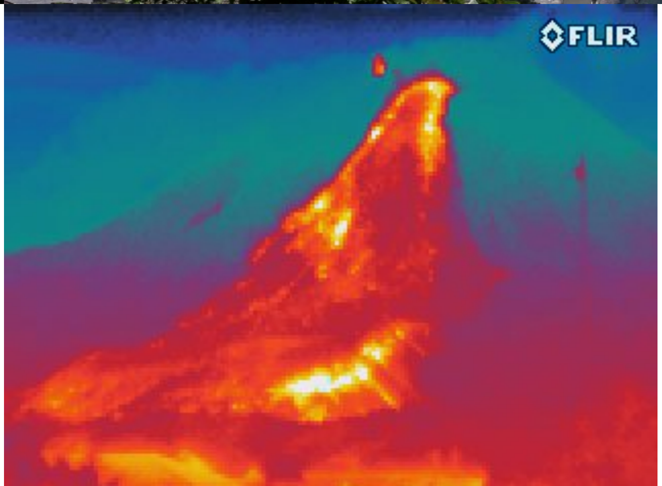
Every eruptive phenomenon is accompanies by cinder/ash fall and lahar.


Aug 30, 2010
Phreatic event
Vulcanian event
Courtesy by PVMBG
Nov. 23, 2013
Jan. 5, 2014
Jan. 18, 2014
Jan. 24, 2014
Feb.26, 2014
Jun. 6, 2014
Growing part
Eroded scarp
Oct. 19, 2014

Lava complex extending on SE slope



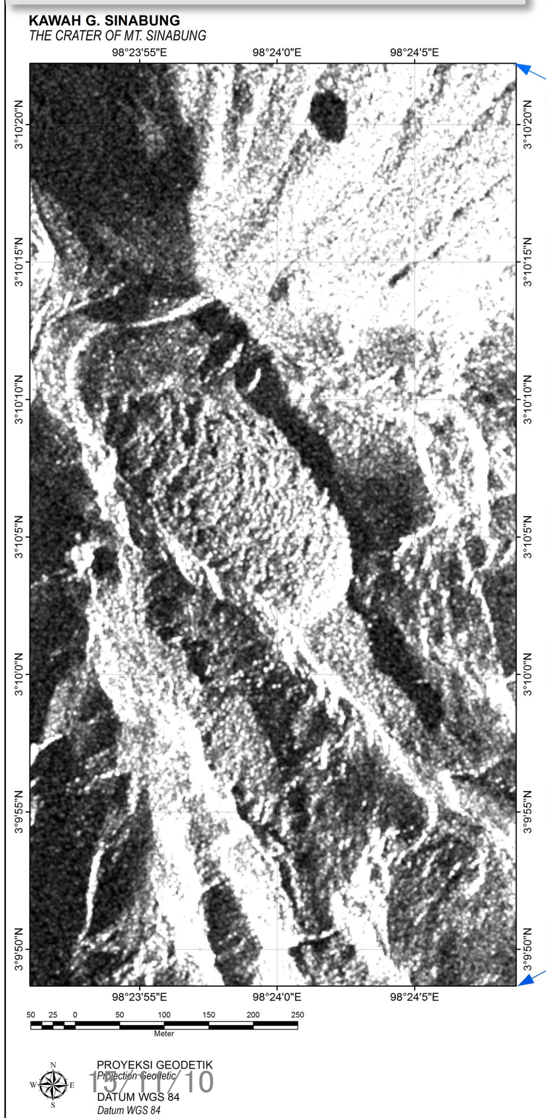
March 22, 2014

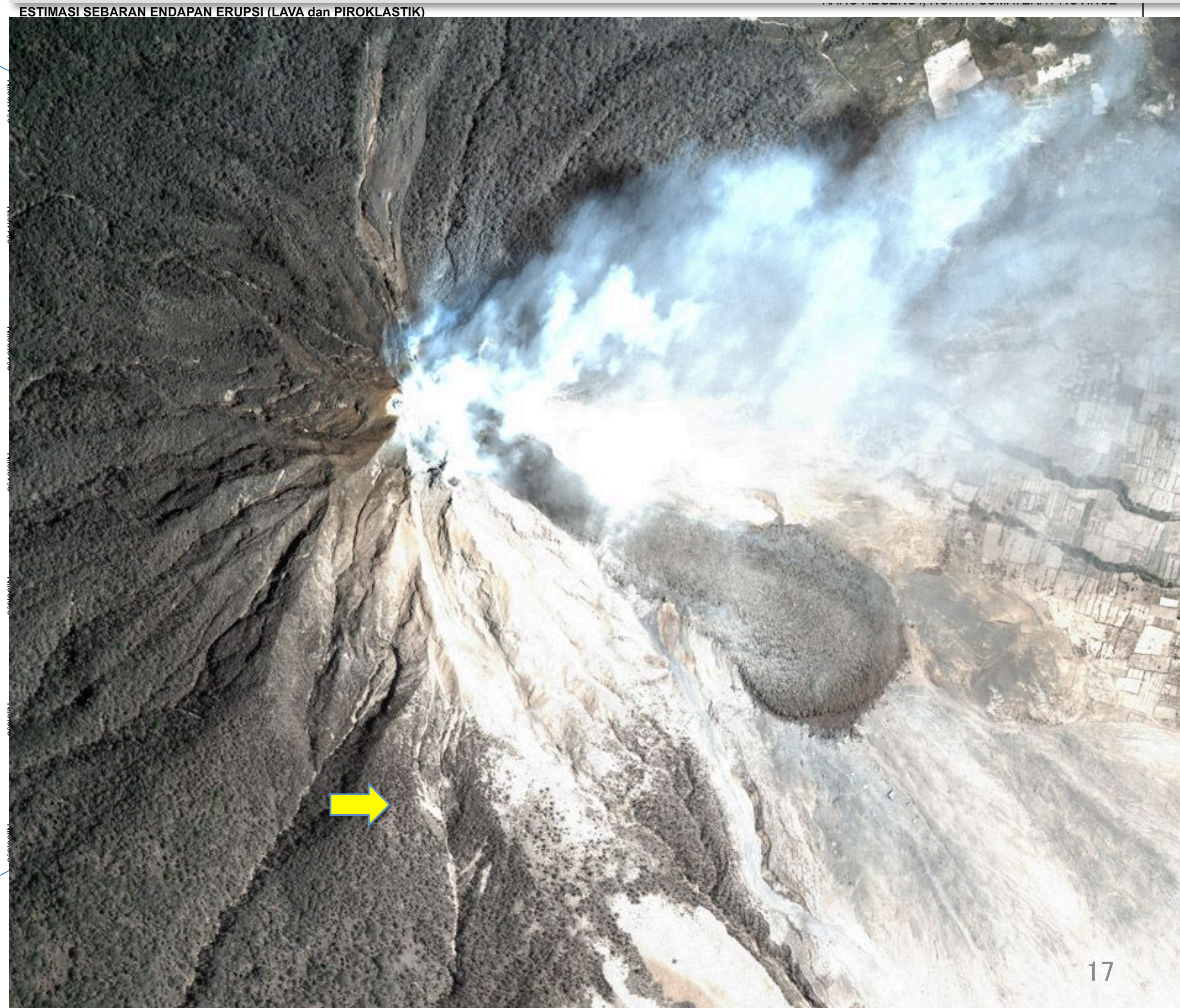


June 6, 2014

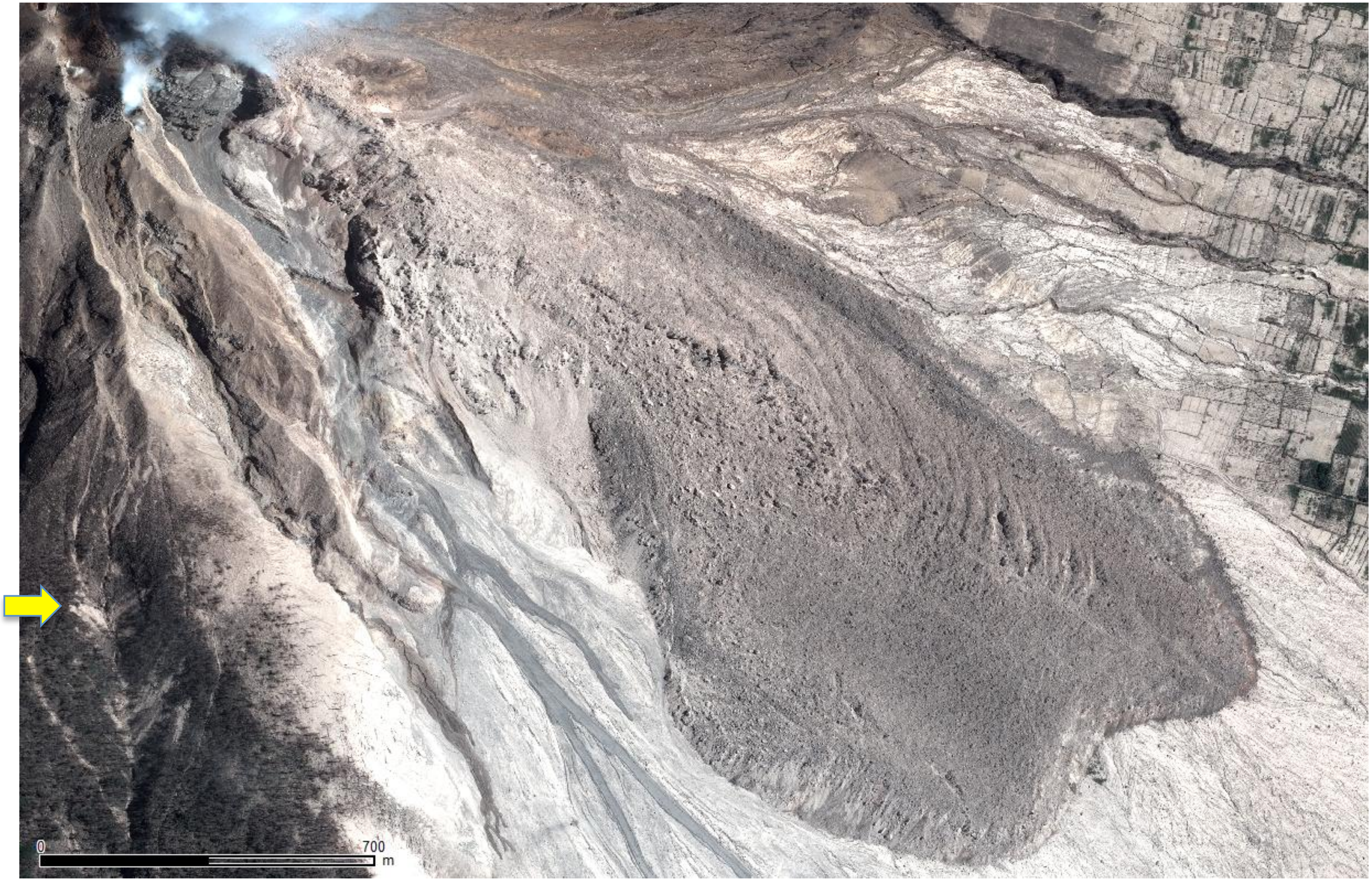
TERRASAR-X (Jan 18, 2014)

Centre for Remote Imaging, Sensing and Processing (CRISP) (Feb. 18, 2014)





Pleiades image (March 14, 2015)



Still active

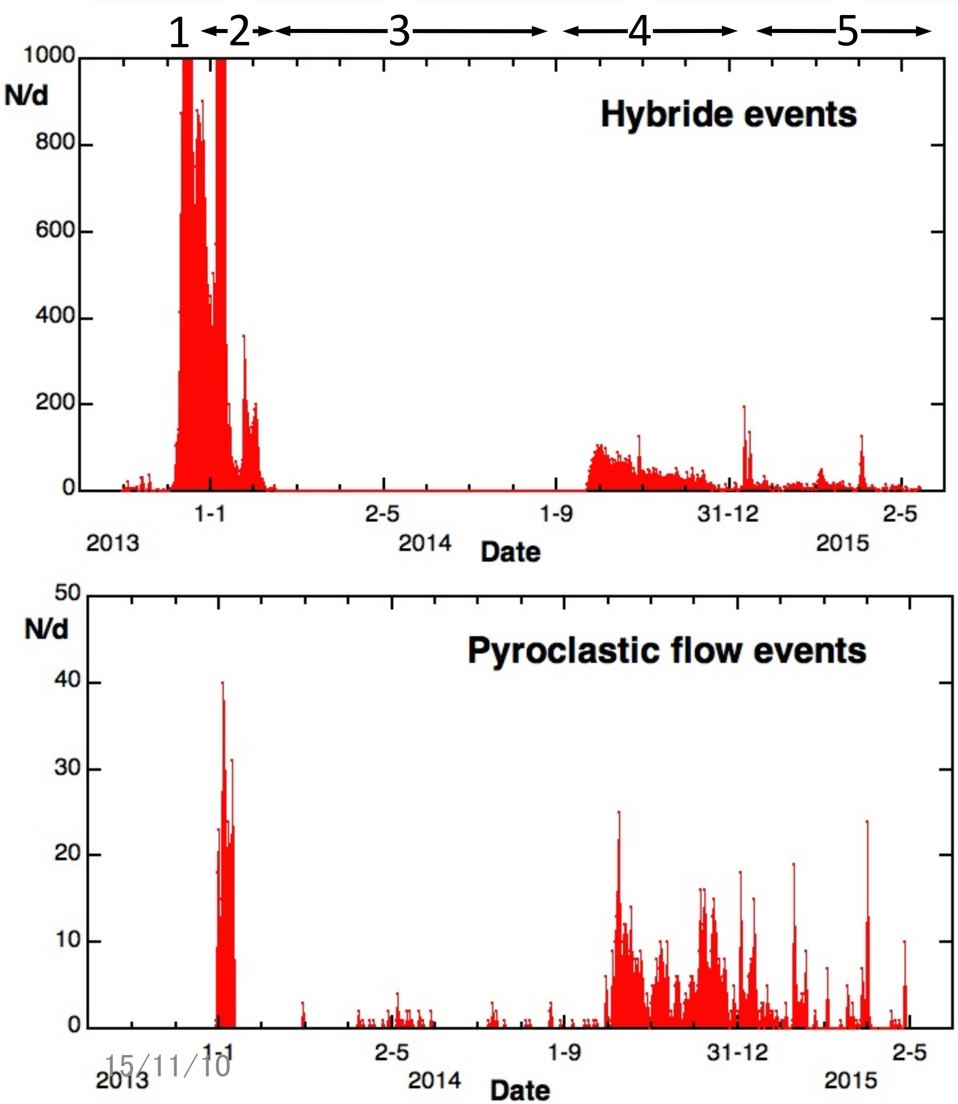
Status Gunung Api di Indonesia

Level 4 (AWAS)

since June 2, 2015

Oct 31, 2015

Temporal change in growth pattern of lava complex



Eruption sequence

1. Intrusion of lava at the summit

2. Lava dome/flow growth with frequent partial collapse (PDCs).

3. Lava flow growth in gentle slope

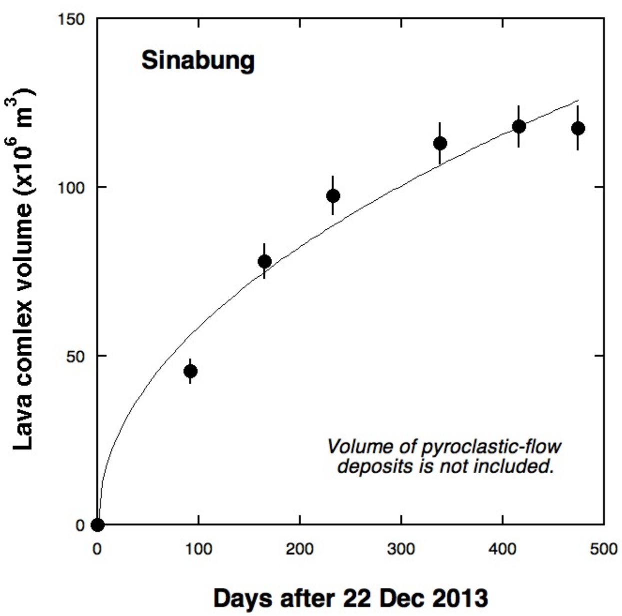
4. Endogenous growth (swelling of lava in the upper part) with partial collapse (PDCs).

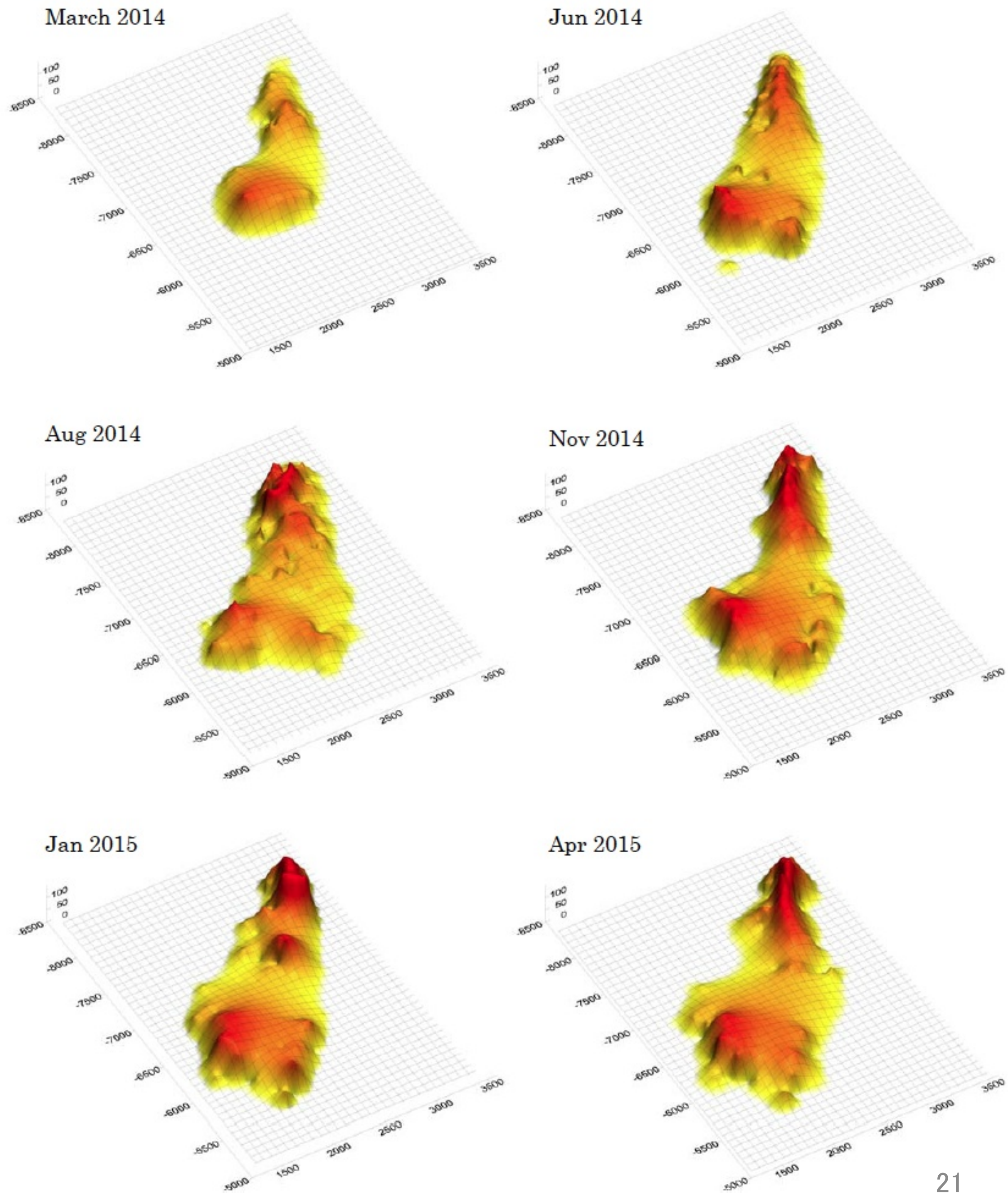
5. Dome growth to the south with partial collapse to generate largest PDCs, though low discharge rate.

All data left are from CVGHM

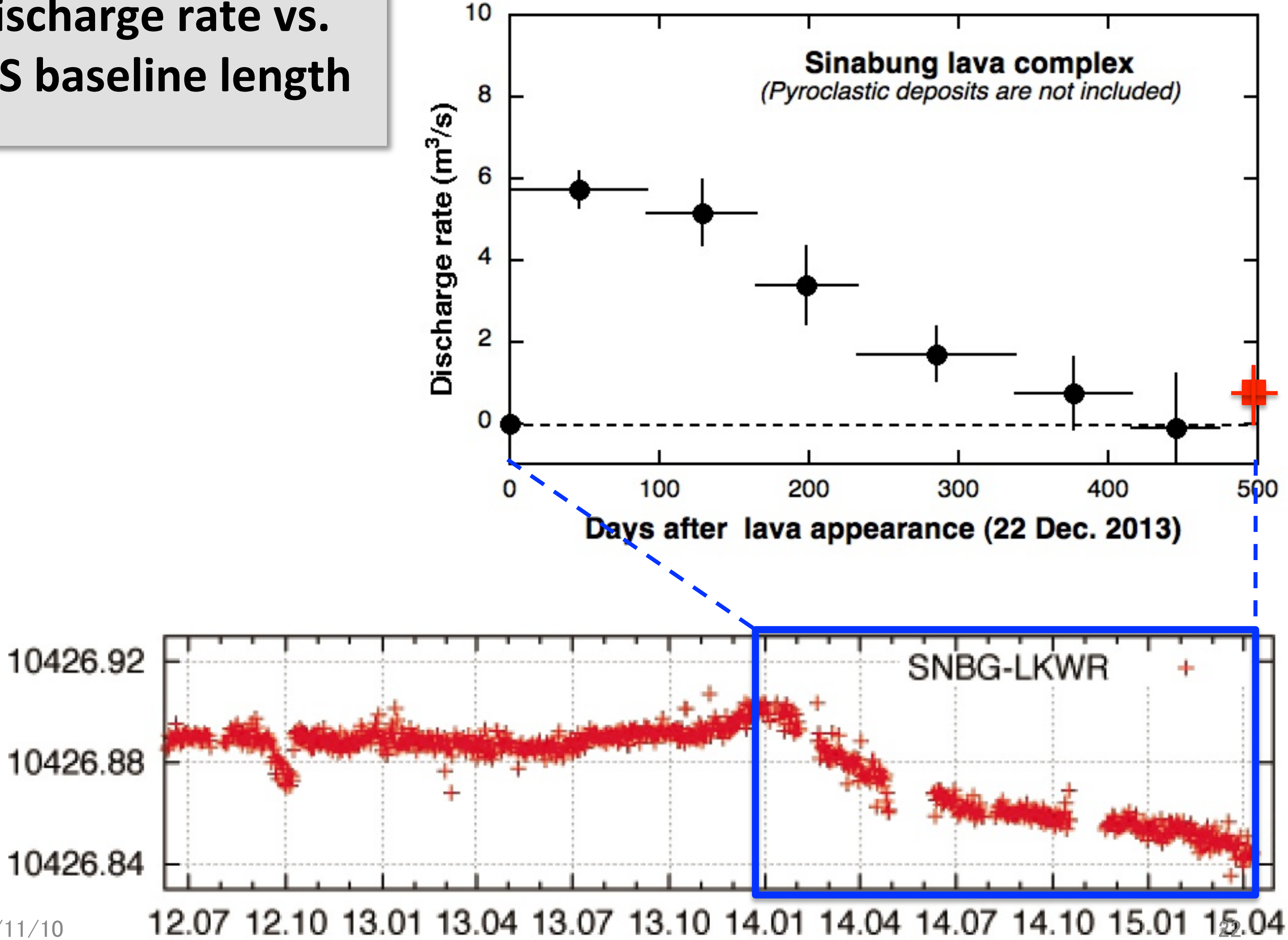
Measurement of lava complex at Sinabung

Laser distance meter was very useful to catch the volume change of the growing lava complex.





Discharge rate vs. GPS baseline length



Devastation by pyroclastic density currents

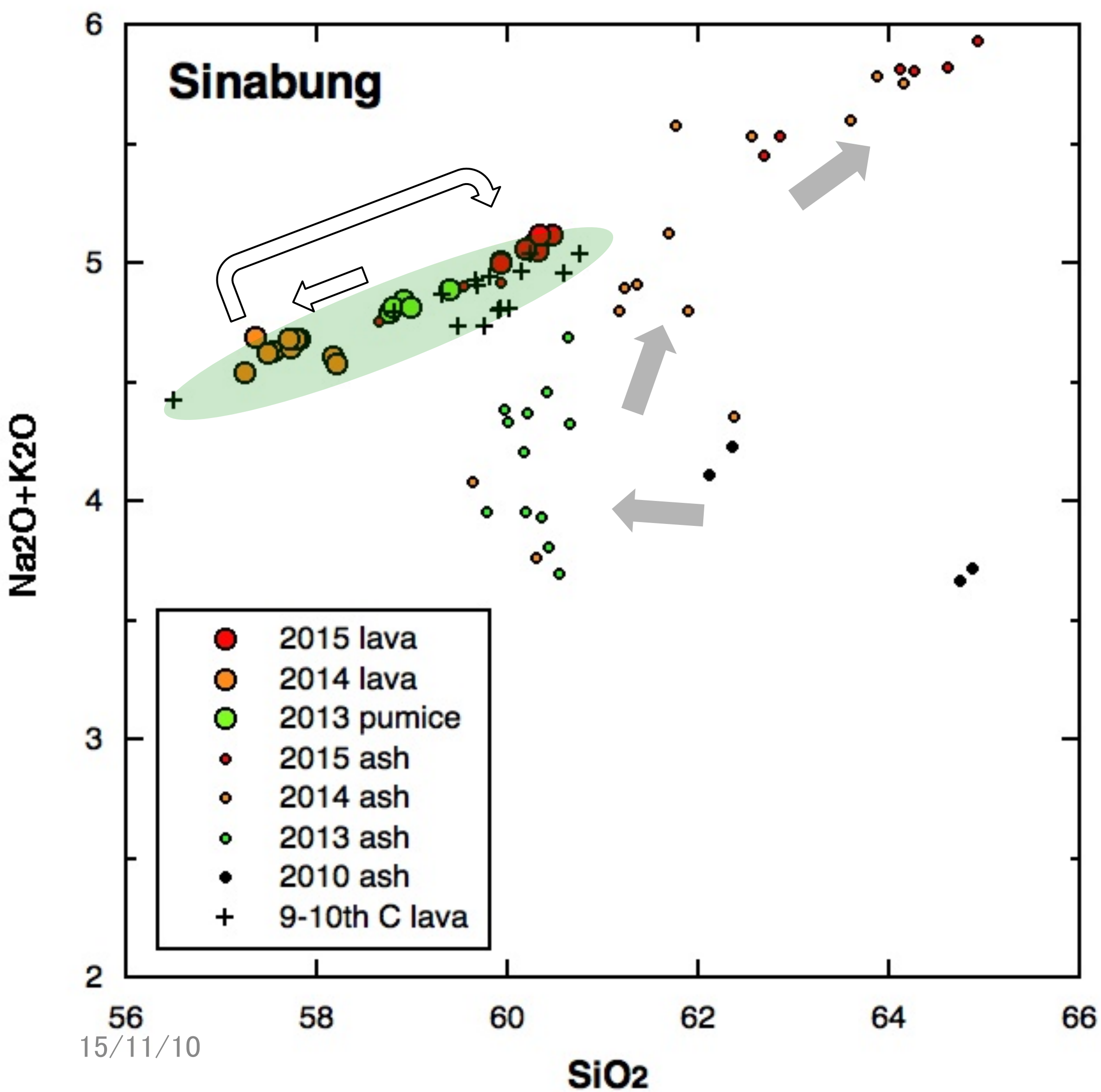
Jan 11, 2014 deposit

April 2, 2015 surge

April 2, 2015 PDC dep

PDC deposit of 28 April 2015

Chemical monitoring of eruption products



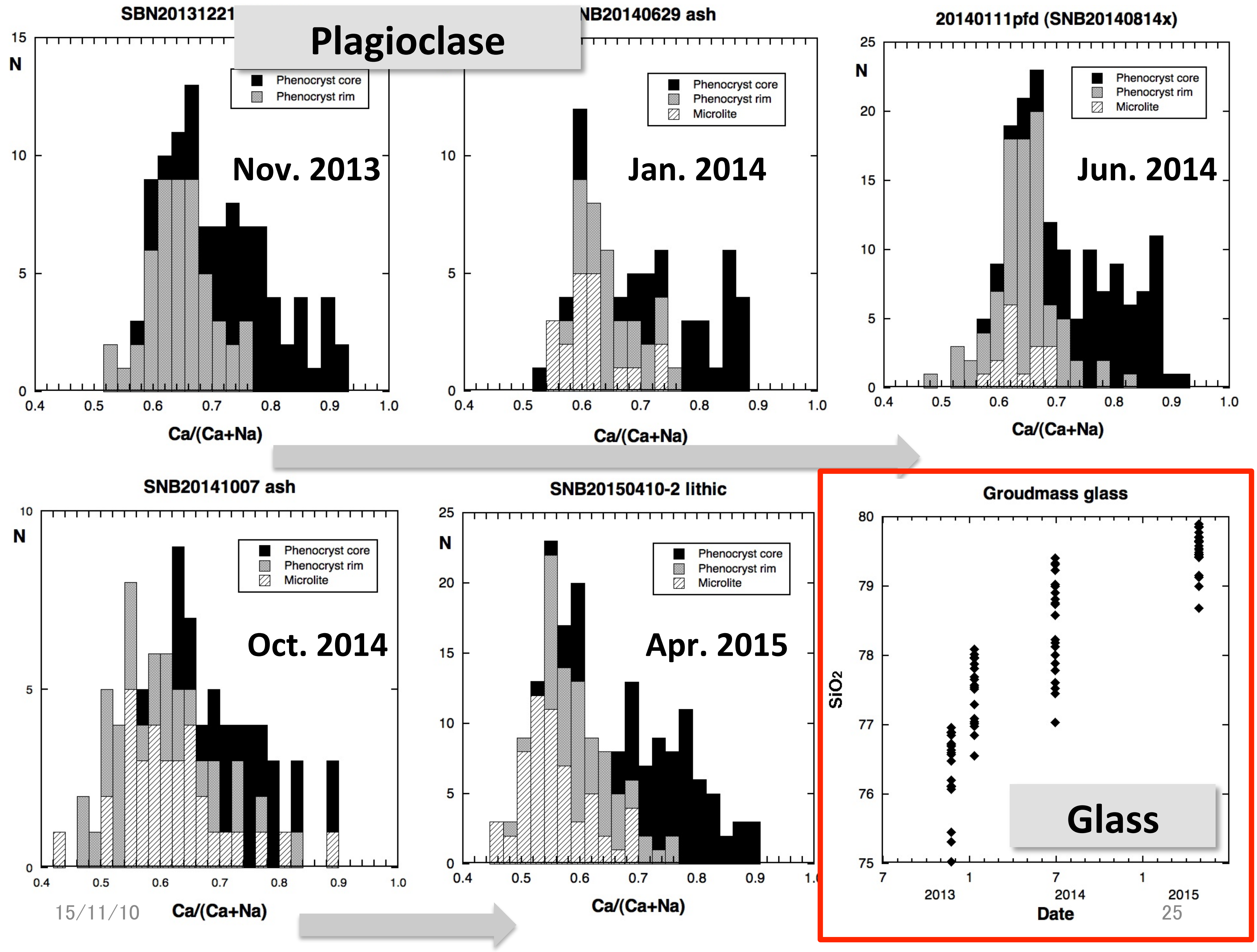
<u>Magma chemistry</u>
(SiO_2 in weight)

59% pumice
58% lava
60% lava

<u>Volcanic ash chemistry</u>

low-Na 62-64% phreatic
low-Na 60% phr/phr-magma
61-63% magmatic (PDC)
64% magmatic (PDC)

Point: The change in magma chemistry and the nature of eruption can be also known by volcanic ash which can be collected easily and safely.

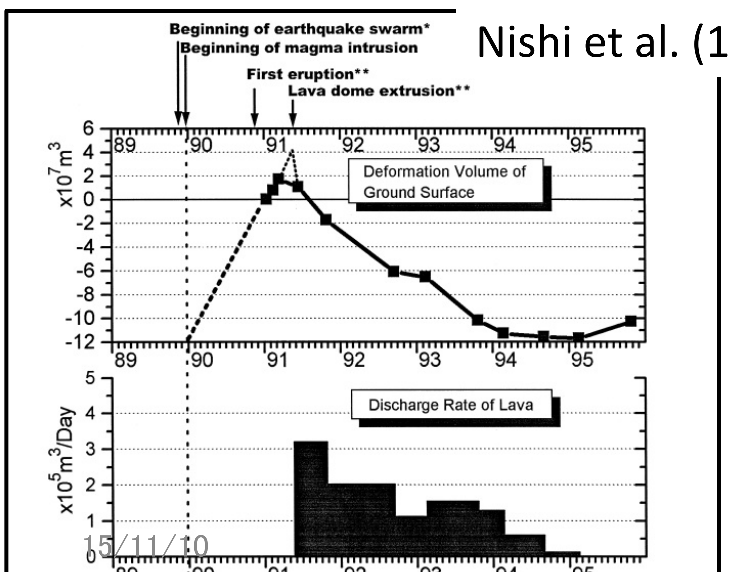


Plagioclase
SBN20131221
NB20140629 ash
20140111pfd (SNB20140814x)
Nov. 2013
Jan. 2014
Jun. 2014
Phenocryst core
Phenocryst rim
Microlite
N
Ca/(Ca+Na)
SNB20141007 ash
SNB20150410-2 lithic
Oct. 2014
Apr. 2015
Groudmass glass
SiO2
Date
2013
2014
2015
Glass

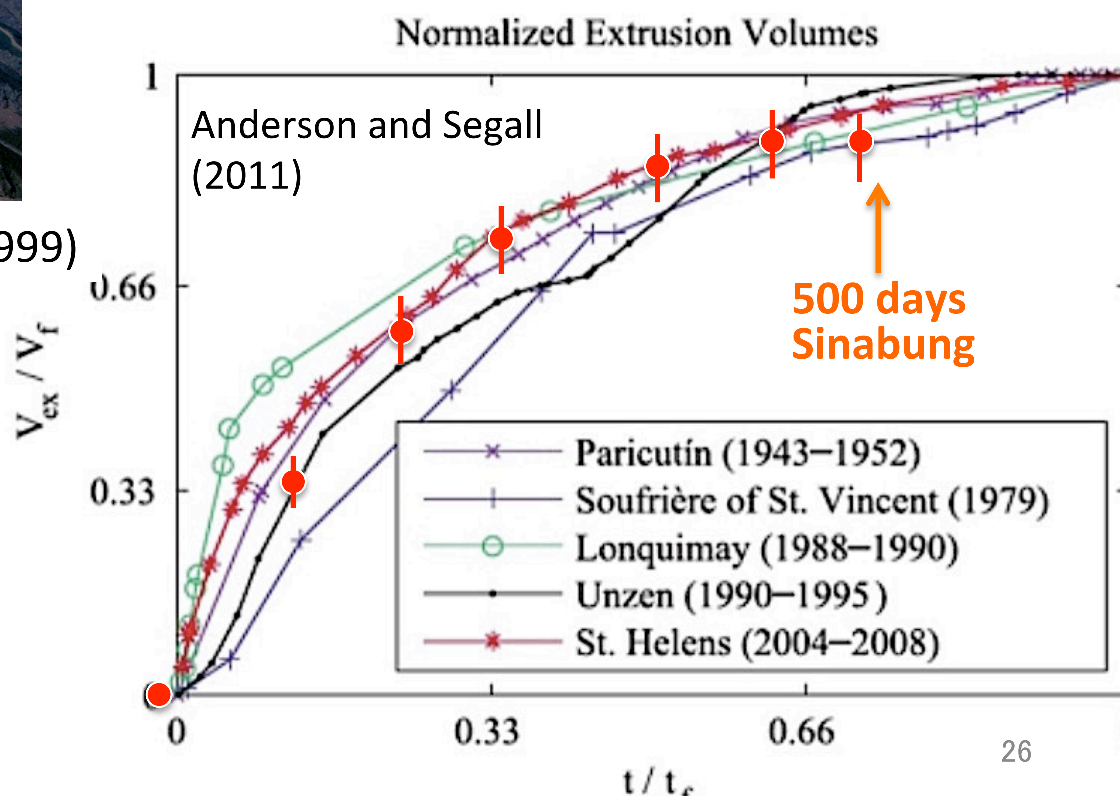
Sinabung (2013-15+) vs. Unzen (1991-95)

Sinabung vs. Unzen

1. Exogenous/endogenous growth at the discharge rate (1.5~2.0 m^3/s).
2. The groundmass glass ranges from 75% to 80% with time.

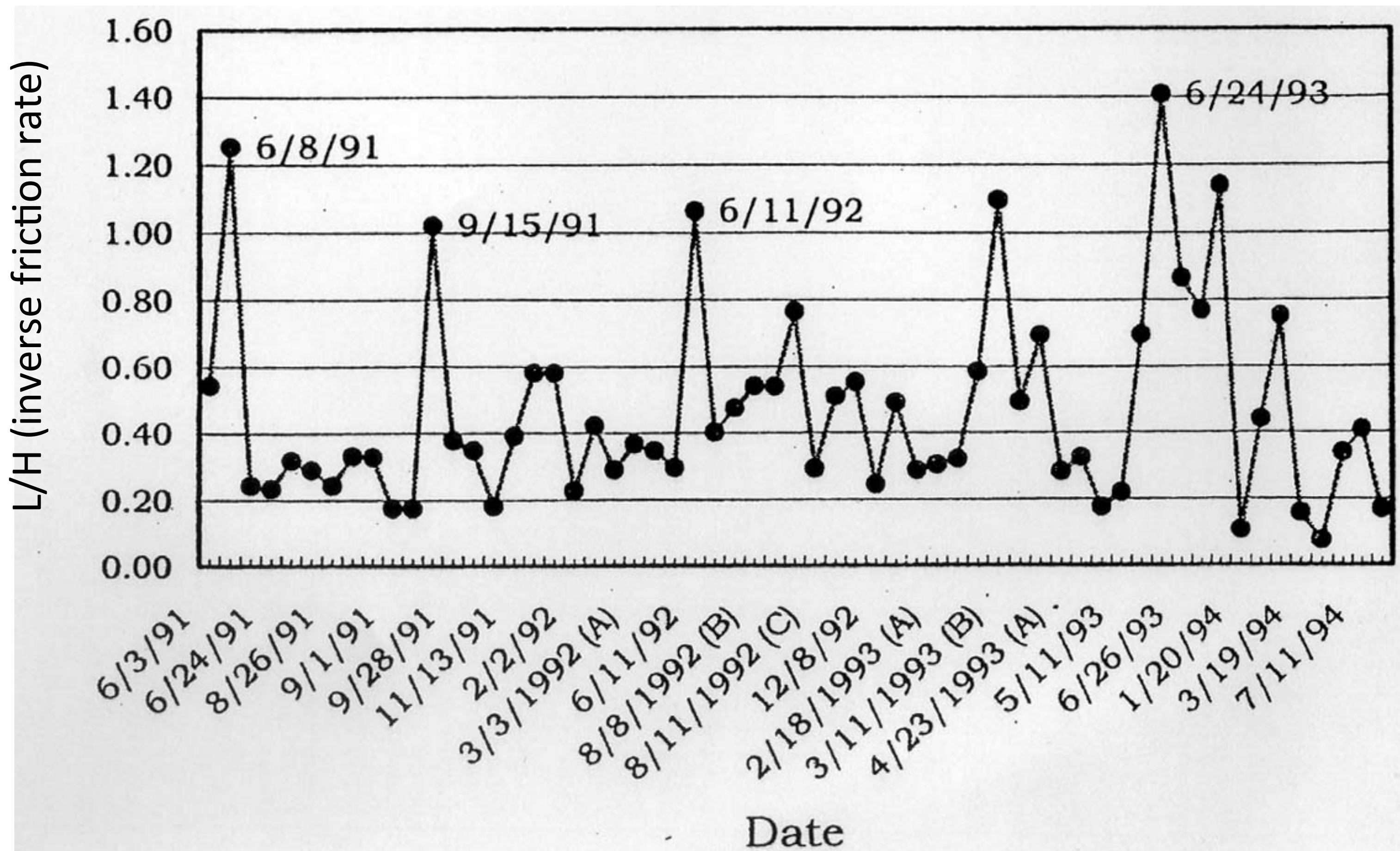


Nishi et al. (1999)



Length/height (L/H) of major pyroclastic flows at Unzen

W.Fernadez (1999MS) JICA training course report



Summary of Sinabung

- The present eruption is very close to the 9-10th Century eruption in terms of lava dome/flow growth, the area of eruption, and magma chemistry.
- Magma discharge rate decreased with time, which is in harmony with the decreasing deflation monitored with GPS.
- Pyroclastic density currents frequently occurred in the earliest stage and the later-half, endogenous stage, when hybrid events increased.
- Though the discharge rate had declined in the latest stage, pyroclastic density currents traveled in longer distances due to the elevated starting point, compared with in the earliest stage.
- Chemical monitoring of volcanic ash is useful to catch the eruption style and magma chemistry changes.
- Many similarity with the Unzen 1991-95 eruption.

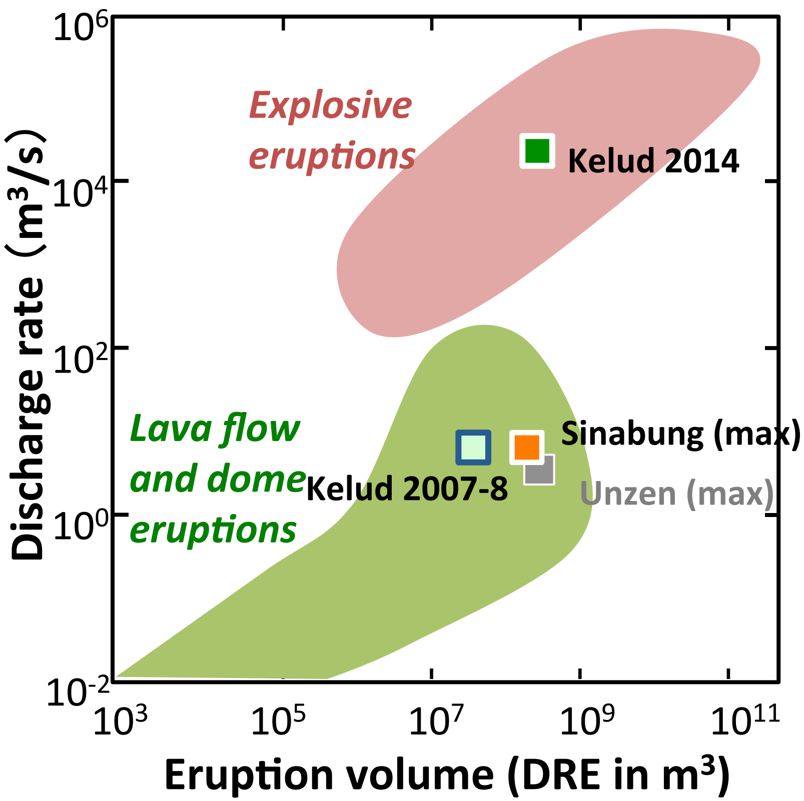
Summary of eruptions in two volcanoes

	Kelud 2014	Kelud 2007-8	Sinabung
Eruption style	Plinian event	Lava dome	Lava flow complex
Magma chemistry	Basaltic andesite (56% SiO2)	Basaltic andesite (56% SiO2)	Andesite (57-59% SiO2)
Precursory phreatic event	Non	Yes?	Yes
Total erupted volume (DRE)	~0.2 km^3	0.027 km^3*	>0.12 km^3
Discharge rate	2~4x10^4 m^3/s	~5 m^3/s**	6 to 0 m^3/s
Magma ascent speed prior-to-eruption	~2 km/d	0.1 km/d***	~0.04 km/d

* According to M. Hendrasto. ** Assuming 2 months for dome growth.
*** Siebert et al. (2011).

-Magma ascent speeds prior to eruption and discharge rates are clearly different between explosive and effusive eruptions.

Summary at Kelud and Sinabung



Background based on Kozono et al. (2013)

- Two eruptions were volcanic events contrasting each other, that is, explosive vs. less-explosive, short vs. long-lasting at repeating vs. long-dormant volcanoes, respectively.
- We tried to do real-time estimation of eruption volumes for both eruptions in order to get the discharge rates, which is important to link to the warning system.
- Eruption scenarios for these volcanoes were made. Historical eruption records are important to forecast the future eruption volume, eruption scenario and disasters.

Terimakasih

End of my talk