

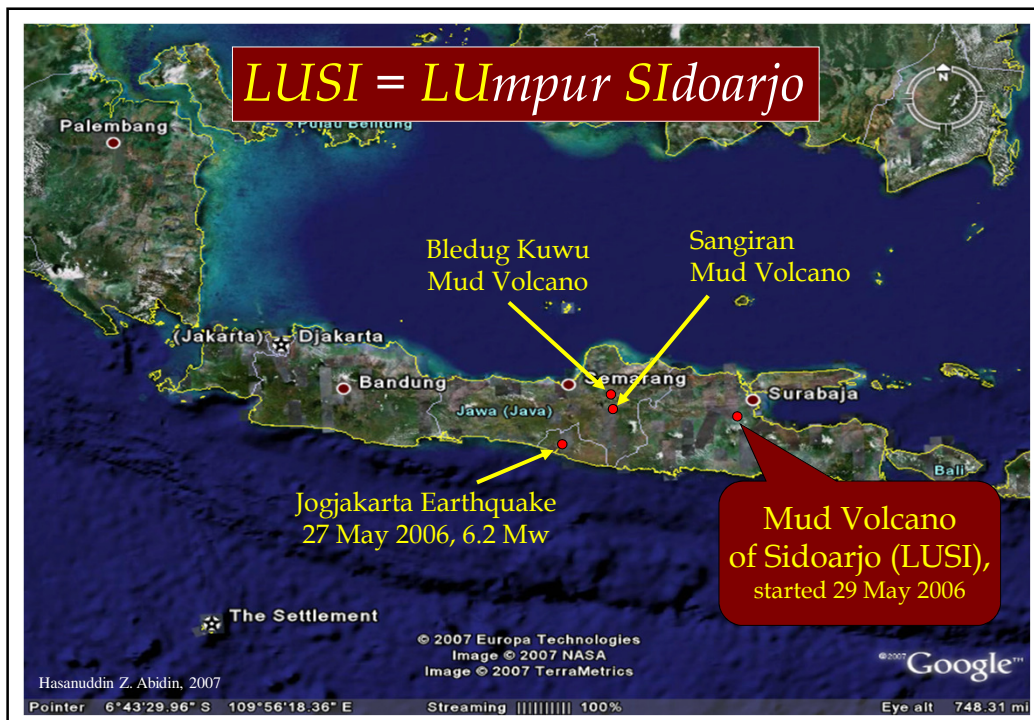
After four years of Ground Displacement  
following LUSI Mud Volcano eruption :  
Sign of its ending eruption

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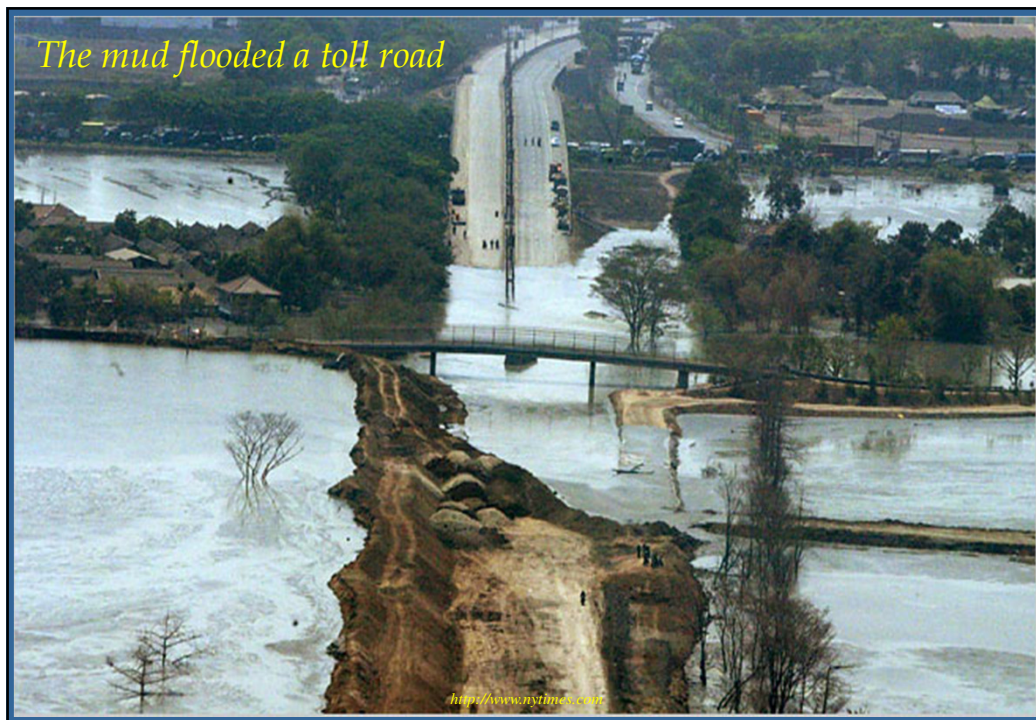
FIG 2011  
Marrakech, Morocco











## **Mud volcano eruption triggers the ground displacements**

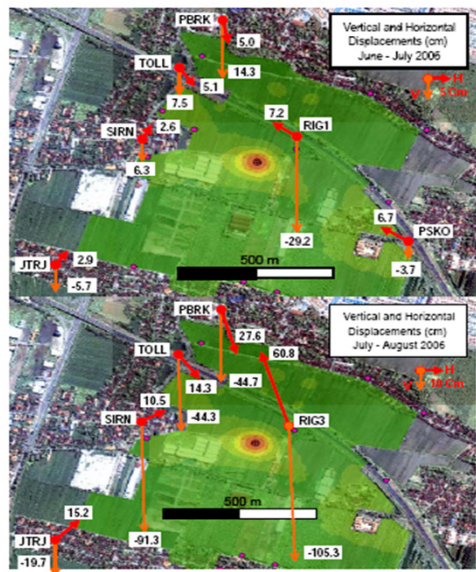
The eruption of the LUSI mud volcano has triggered vertical (subsidence) and horizontal ground displacements.

In the early development of mud volcano, GPS surveys results show that ground displacement around the eruption area was occurring at rates up to

**1 cm/day (horizontal displacements)**

**4 cm/day (vertical displacements)**

Hasanuddin Z. Abidin, 2008



Period	Vertical Displacement	Horizontal Displacement
June-July 2006	Rate < 1.1 cm/day; Subsidence (all stations)	Rate < 0.3 cm/day; Directions: all to north-west of the main vent
July-Aug 2006	Rate < 3.6 cm/day; Subsidence (all stations)	Rate < 0.9 cm/day; Directions: all to north-west of the main vent
Aug-Sep 2006	Rate < 2.1 cm/day; Subsidence and Uplift	Rate < 0.7 cm/day; Directions: mostly to north-west of the main vent
Sep-Oct 2006	Rate < 2.4 cm/day; Mostly subsidence	Rate < 0.9 cm/day; Directions: mostly to north-west of the main vent
Oct 2006-Feb 2007	Rate < 0.3 cm/day; Subsidence (all stations)	Rate < 0.3 cm/day; Directions: all to north-west of the main vent
Feb-March 2007	Rate < 0.3 cm/day; Mostly subsidence	Rate < 0.3 cm/day; Directions: some to north-west of the main vent
March-May 2007	Rate < 0.2 cm/day; Subsidence and Uplift	Rate < 0.1 cm/day; Directions: some to north-west of the main vent
May-June 2007	Rate < 0.2 cm/day; Subsidence and Uplift	Rate < 0.1 cm/day; Directions: no specific pattern of direction

Figure 4 Figure and table showing vertical and horizontal displacement around LUSI mud volcano on periode June 2006 up to june 2007 (Abidin, 2008)

Hasanuddin Z. Abidin, 2008

*Ground displacements generated infrastructural damages in the area*

## Dextral Movement of Railway (km 39.2)



## Movement of Toll Bridge

*KK Geodesi (2006)*



## Cracking of buildings and houses



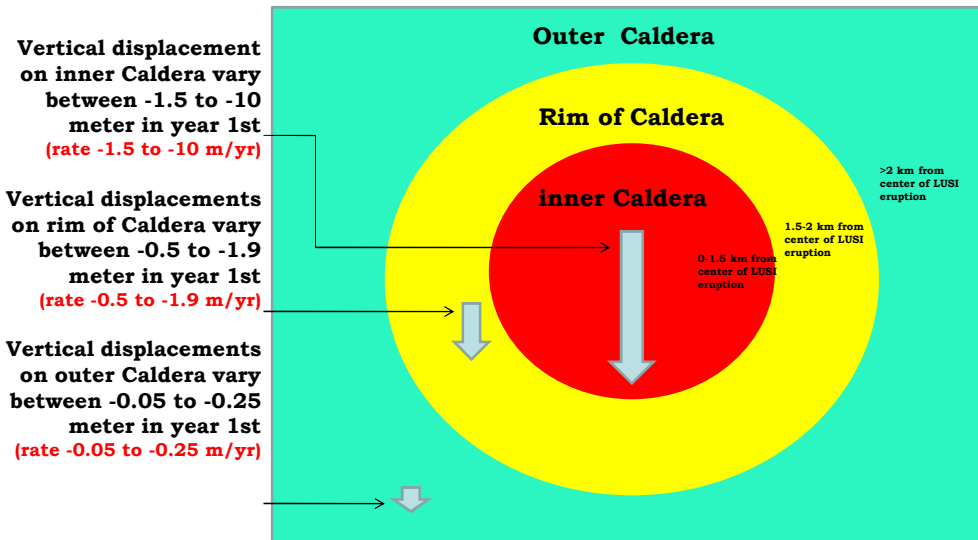
## INVESTIGATION OF GROUND DISPLACEMENT OF LUSI MUD VOLCANO



Documentation of GPS Survey around LUSI Mud Volcano

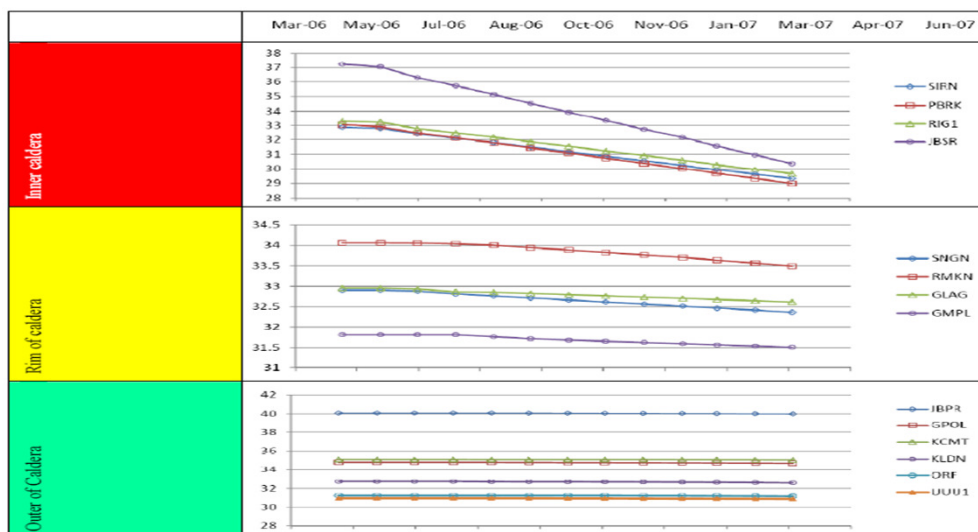


## 1<sup>st</sup> YEAR OF GROUND DISPLACEMENT AROUND LUSI



**Figure** Conceptual model on first year of ground displacement around LUSI Mud Volcano

## 1<sup>st</sup> YEAR OF GROUND DISPLACEMENT AROUND LUSI



**Figure 3** Graphic trend after several month from eruption up to a year time, on the series of vertical displacement component (in meter) on several GPS points investigation in LUSI area.

## THE MODEL OF CFP ON LUSI MUD VOLCANO

CFT : Caldera Formation Processes

A very much interesting to see from the first year of ground displacement observation result, the pattern of horizontal displacement showed concentrate outlook toward the center of subsidence, meanwhile the vertical displacement given the model of cone subsidence.

These GPS derived information together with field surface representation of displacement (cracks), and also occurred bubble plotting, micro seismic, etc has shown the good fact that **caldera formation processes** is being developed in LUSI mud volcano

## THE MODEL OF CFP ON LUSI MUD VOLCANO

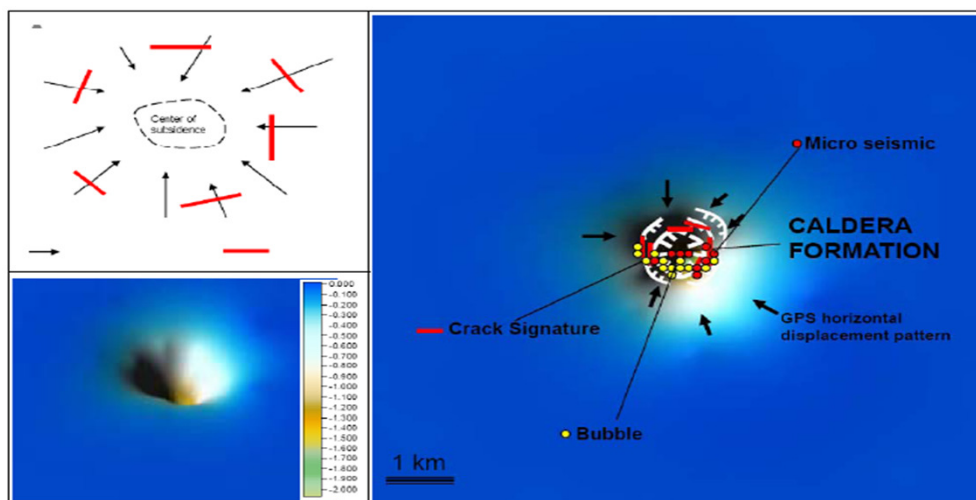
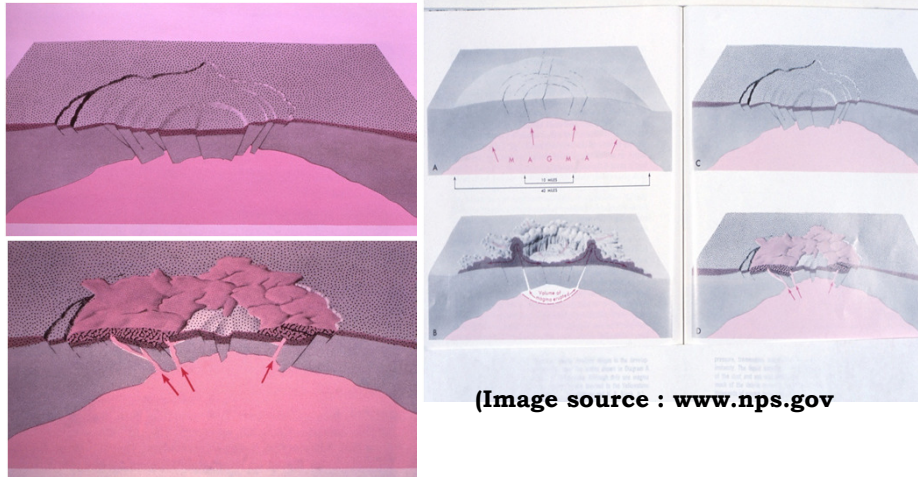


Figure. 4 (a) GPS model derived horizontal displacements (b) the vertical displacement given the model of cone subsidence, (c) Illustration of caldera formation processes on recently birth LUSI Mud Volcano

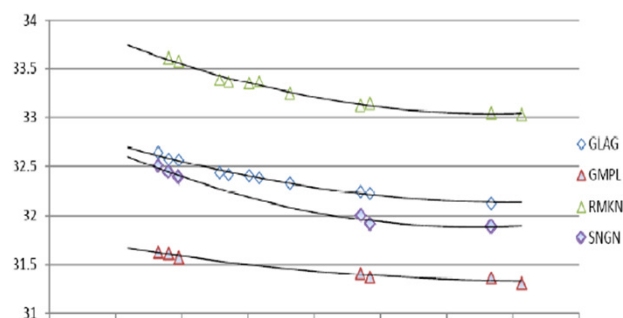
## THE MODEL OF CFP ON LUSI MUD VOLCANO

CFT : Caldera Formation Processes

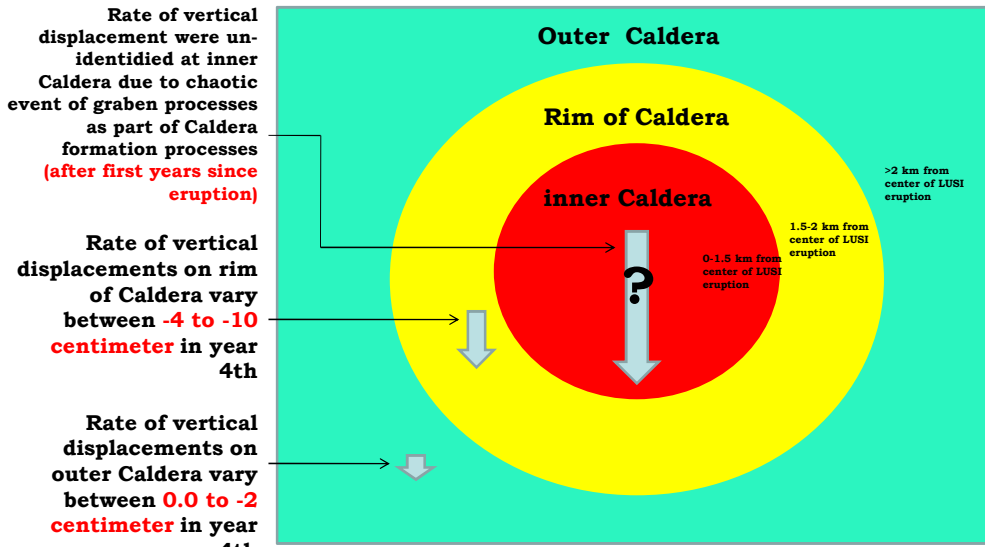


## AFTER 4<sup>th</sup> YEAR OF GROUND DISPLACEMENT AROUND LUSI

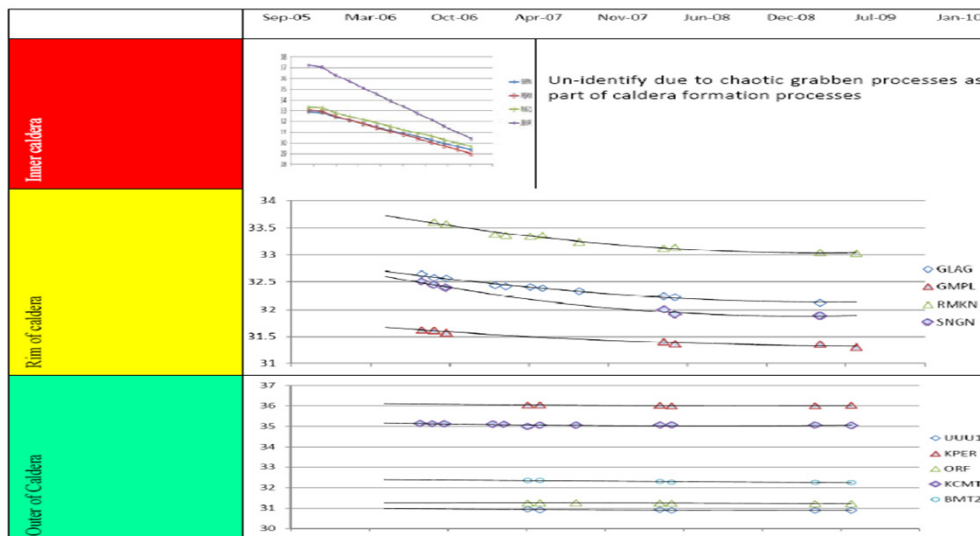
What happen after four years of the eruption turn out that the ground displacement has slowing at rates. Its not 2-4 cm/day anymore but only **several centimeter up to desimeter in a years time**. A linier trend were replaced by exponential decay instead.



## AFTER 4<sup>th</sup> YEAR OF GROUND DISPLACEMENT AROUND LUSI



## AFTER 4<sup>th</sup> YEAR OF GROUND DISPLACEMENT AROUND LUSI



## **SIGN OF LUSI ENDING ERUPTION ??**

Exponential decay of displacement might be indicating or signing the ending of LUSI Mud volcano eruption. From the displacement projection result, after **10 year** period we will see rate generally **1-2 cm/years** surrounding the eruption area which we can simply conclude that eruption may be ignored, and within **20 years** we will see the rates generally **less then cm/year** which can be state that the eruption generally ended.

Seeing other research (Davies et.al, 2010) which made prediction of 26 years probabilistic longevity estimate for the LUSI mud volcano eruption, a very much similarity in the eruption time prediction found with our result (~20 years).

## **CLOSING REMARKS (1)**

The first 4 months of mud extrusion showed the rates of displacements (from data compilation and interpolation) are in the order of 0,4 to 2,5 cm/day and increasing on the next 8 to 12 month later into 0,6 to 3,8 cm/day for vertical component surrounding the eruption site.

After four years of the eruption turn out that **the ground displacements have slowing down**. The rates not 2-4 cm/day anymore but only several centimeter up to decimeter/year. A linier trend were replaced by exponential decay.

## CLOSING REMARKS (2)

The clear analysis showed that ground displacement divide into two stage which is **rapid ground displacement** (that explained to be associate with Caldera formation processes) and **normal ground displacement** representing adjustment from the effects of mud loading, ground relaxation due to mud outflow, etc.

Since the displacement associate with the eruption, **the exponential decay might be indicating or signing the ending of LUSI Mud volcano eruption**. From the displacement projection result, after ten years period we can simply conclude that eruption may be ignored, and within twenty years from the first eruption we may state that the eruption is generally ended.

# THANK YOU