Review LUSI Based On Data Taken Up To 2011

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USAKTI, Jakarta, Chairman : INAGA's Competency

Surabaya, 25 – 26 May 2011

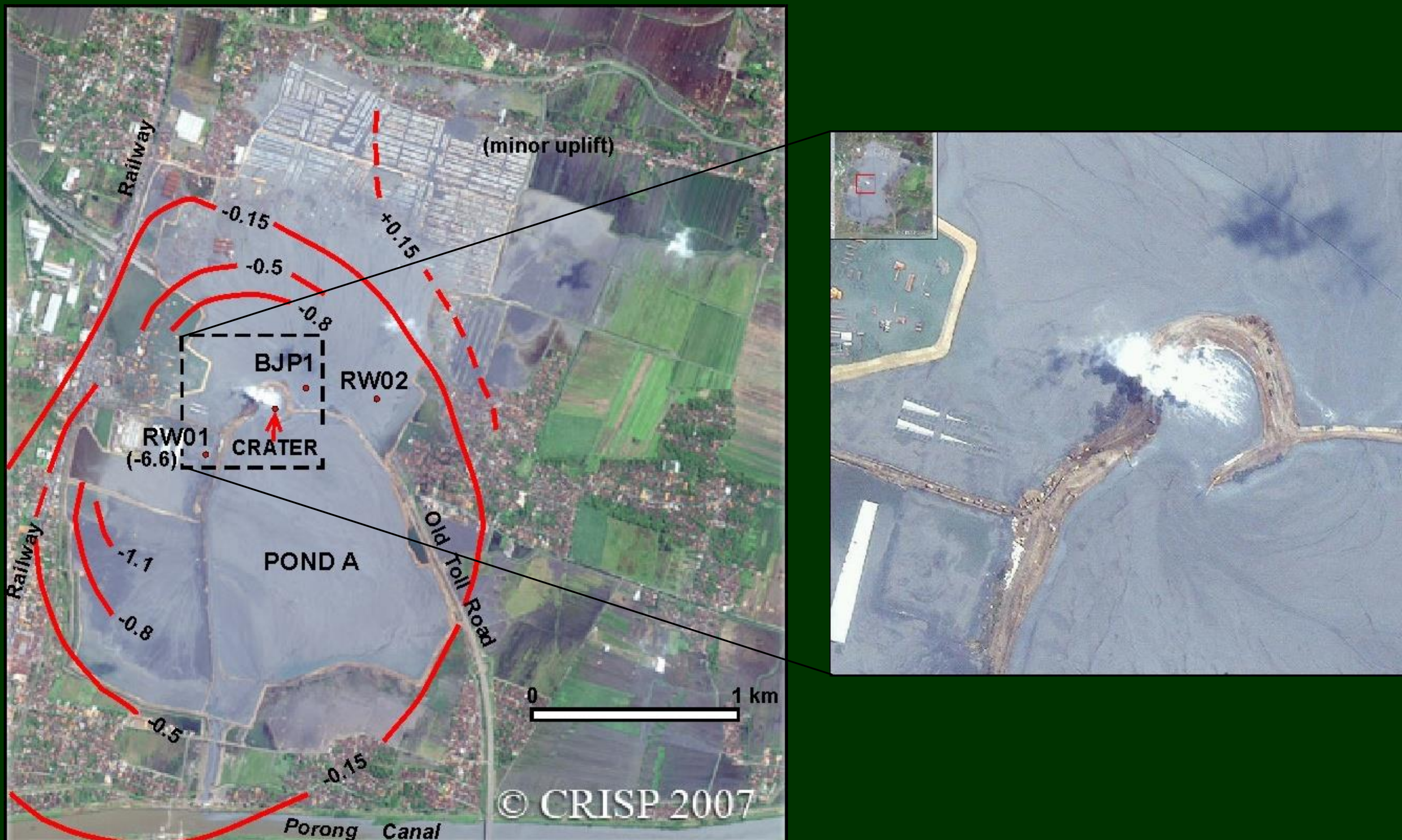
Main Data and Analysis

- **Most Important Data :**
  - Subsidence one year after the eruption (2007)
  - Hot mud flow rate and steam cloud monitoring up to 2010
  - Intensive micro gravity, micro seismics and temperature survey (BMKG, August 2008)
  - Limited MT data at Arjuno-Wellirang for geothermal prospecting (2011)

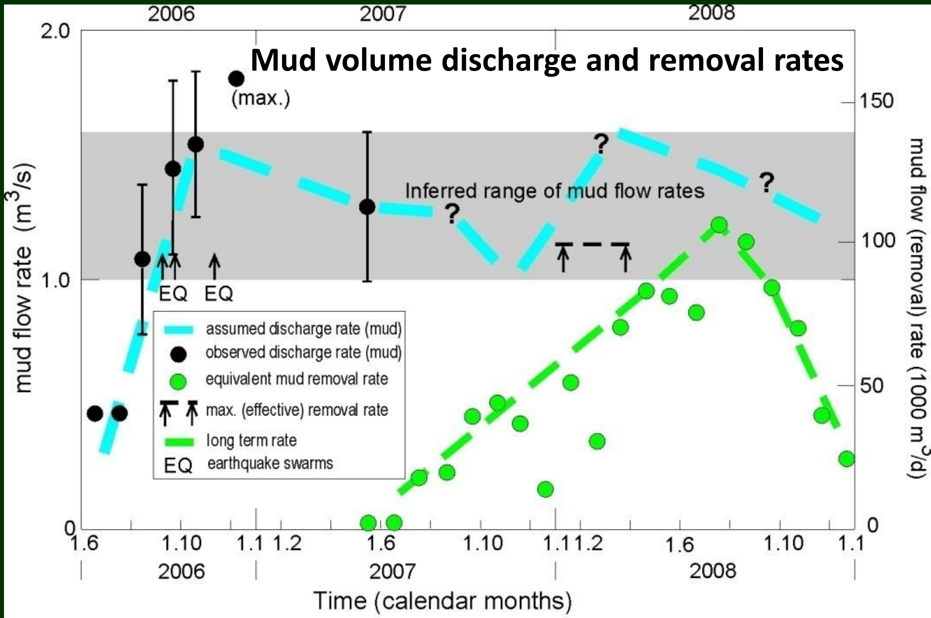
- **Analysis :**
  - Area in danger due to subsidence
  - Does LUSI relate to Arjuno-Wellirang geothermal prospect located 25 km to the S?
  - Impact to geothermal business?

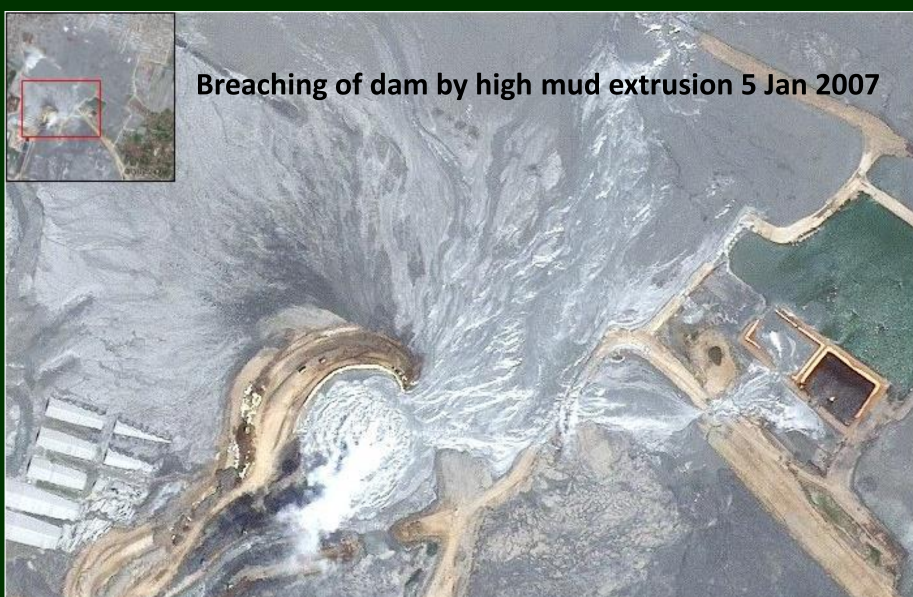
LUSI MV: the first year and first efforts to control mud flows

- The semi-circular dam around the central crater was continuously raised as the mud flow increases - both activities actually developing a continues subsidence (<2 km2 at -0.8 m contour).



Satellite photo (05.06.07) of the LUSI MV with subsidence contours (m/yr) from INSAR data one year after the eruption.





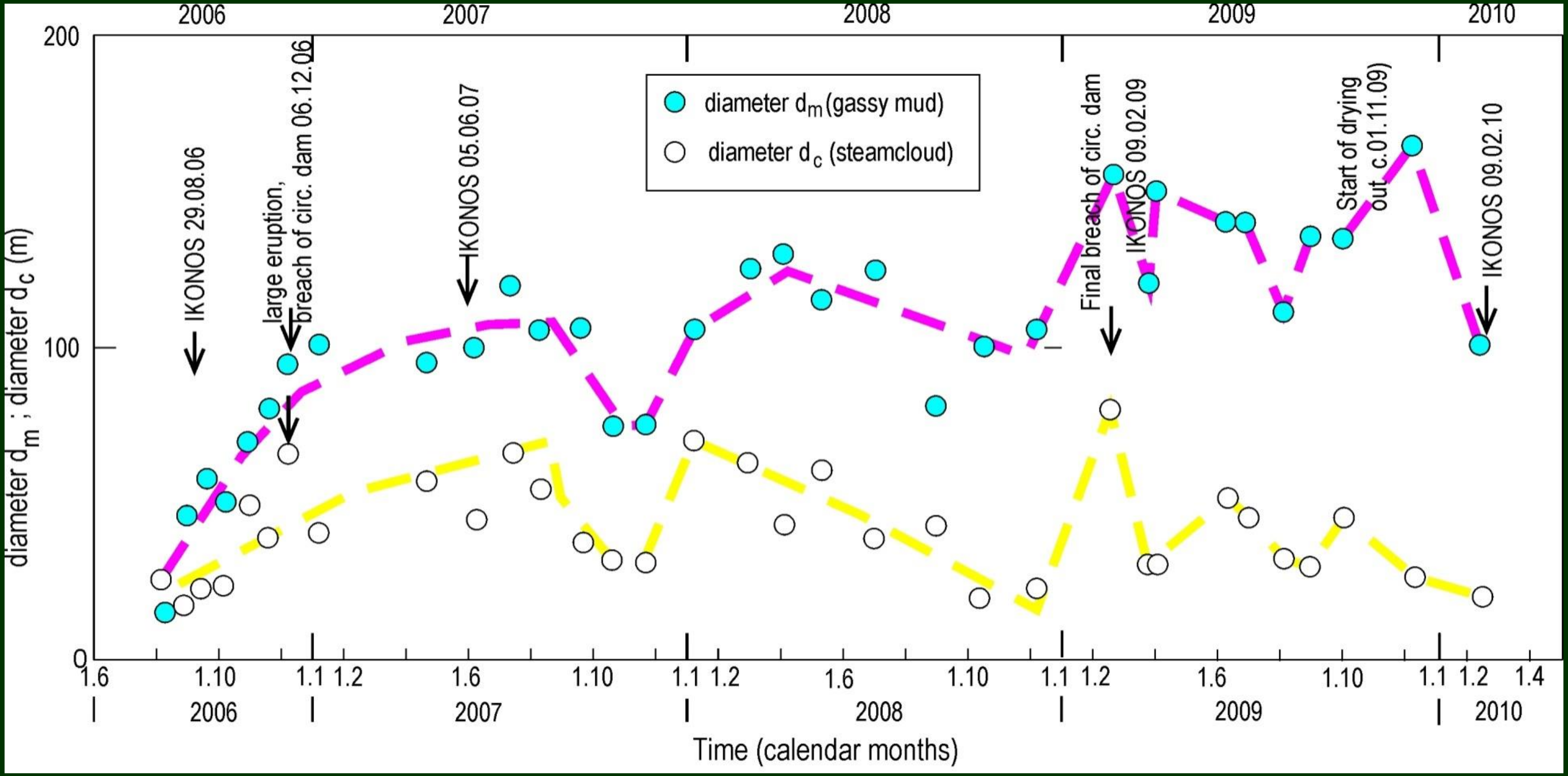
Breaching of dam by high mud extrusion 5 Jan 2007

LUSI MV: Mud discharge characteristics (Hochstein and Sudarman, WGC 2010)

- Mud discharge increase since EQ occurred from 0.5 to 1.5 m3/s and a maximum discharge 1.75 m3/s at 5 Jan 2007 led to destroy the E half size of the dam.
- Monitoring flow rate from mid 2006 up to 2008 shows in a range of 1 – 1.5 m3/s
- Near boiling heat transfer at the upwelling centre is estimated to produce 200 – 300 MWth for discharge rate 1 – 1.5 m3/s per year

Lusi MV: Temporal trends of discharges

- The diameters dm (upwelling, gas-charged mud) and dc (plume mid-height cross-sectional area), taken from IKONOS satellite photos, are plotted versus a time span of 3 ½ years
- The data sequence point to three, long-term cycles of activity with the last cycle coming to an end with reduced liquid discharges.



LUSI MV: Steam cloud characteristics

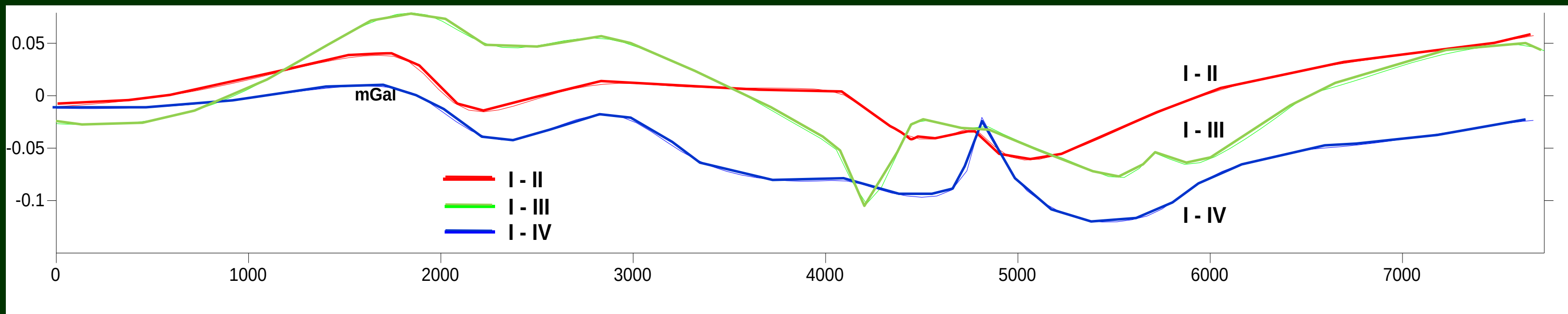
Steam cloud (height c. 200 m) over the LUSI crater

- Gas, steam, and mud discharges showed large short- and long term variations.
- This was most noticeable when comparing steam cloud volume from successive satellite photos (plume cross-sectional area 100 – 3,000m2)
- The variation of steam cloud height is between c. 10 and 250 m.
- This steam cloud is analogical to geothermal fumarole with steam heat losses ΔQc of the order of 3 and 100 MWth at the above height variation, respectively.

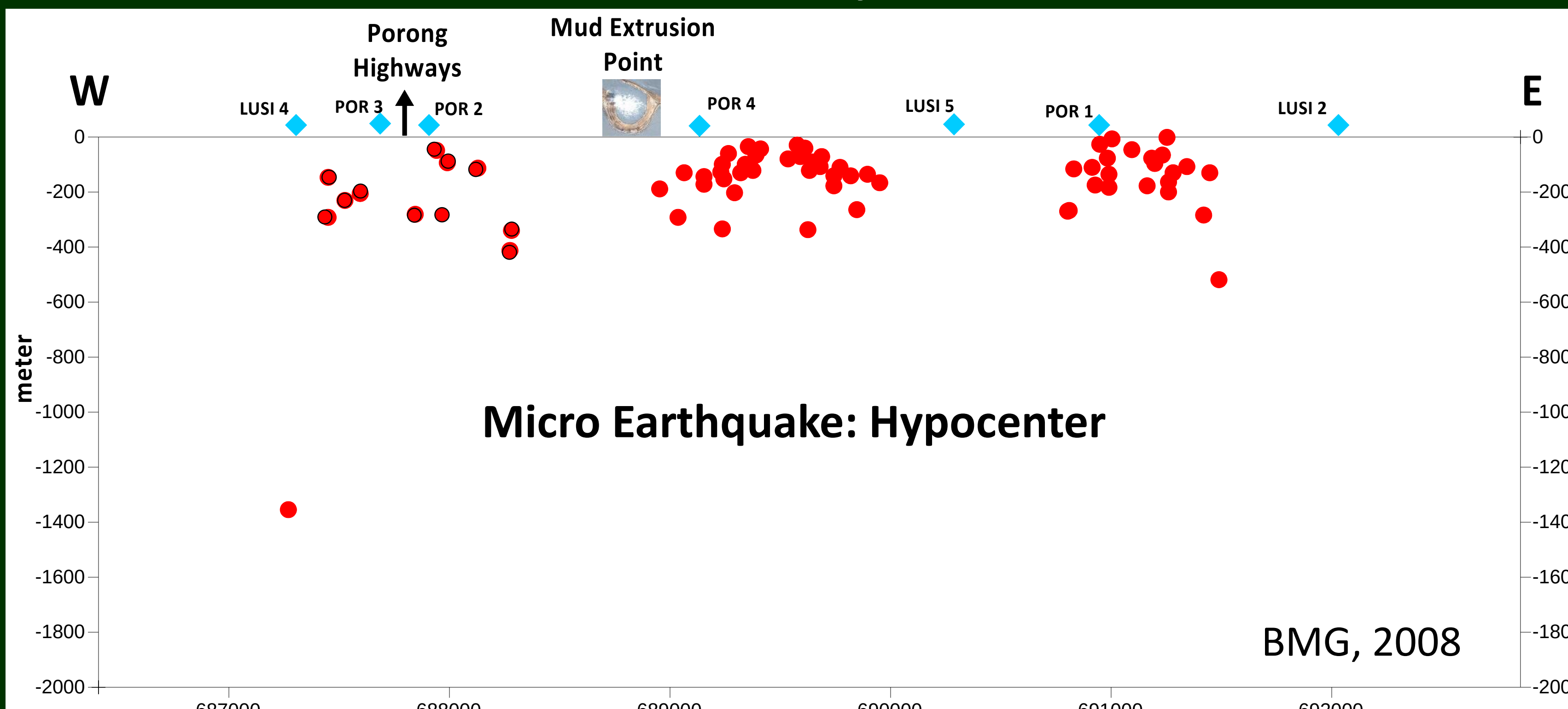
E-W Section : MEQ & Micro Gravity Monitoring

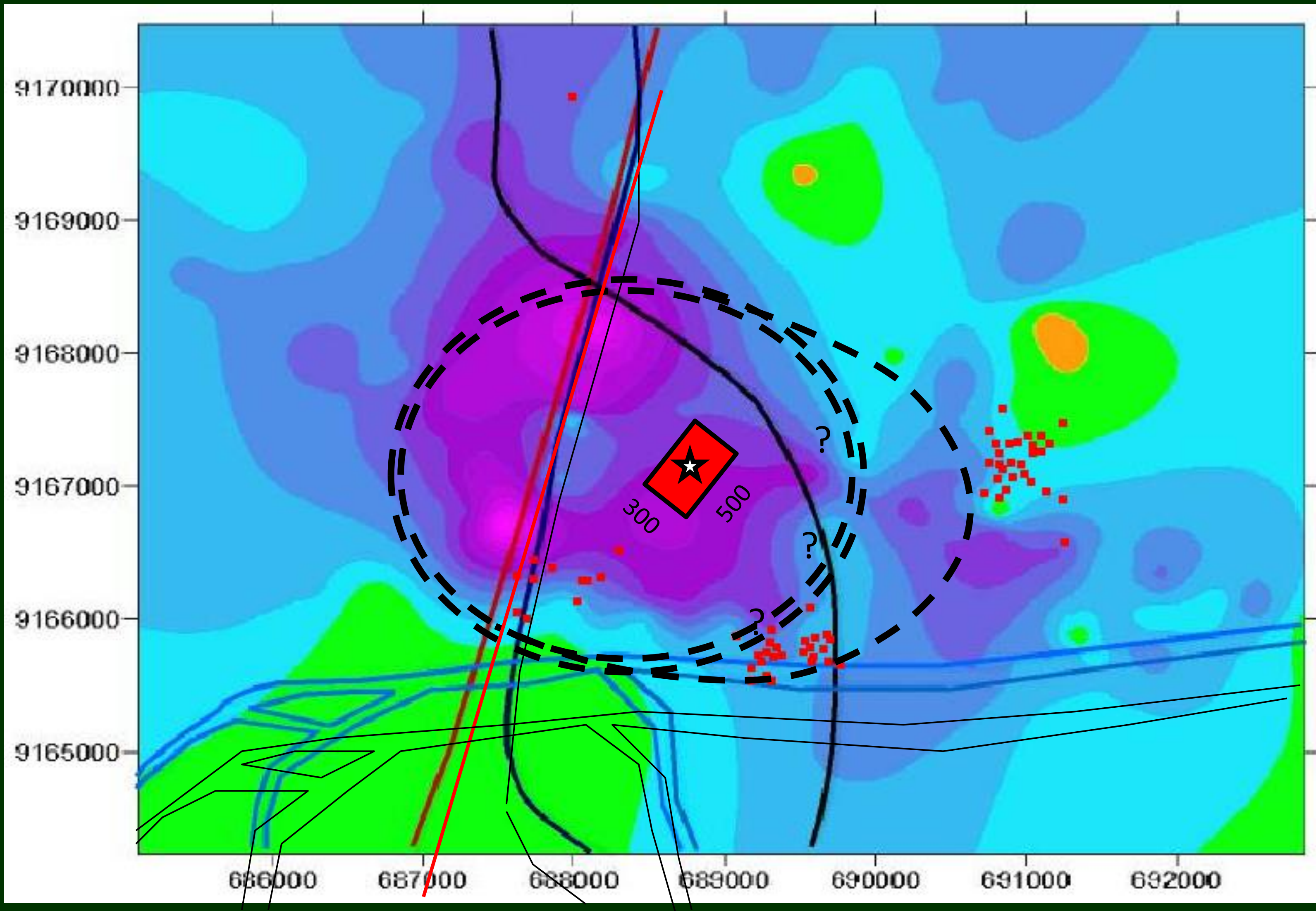
W

E

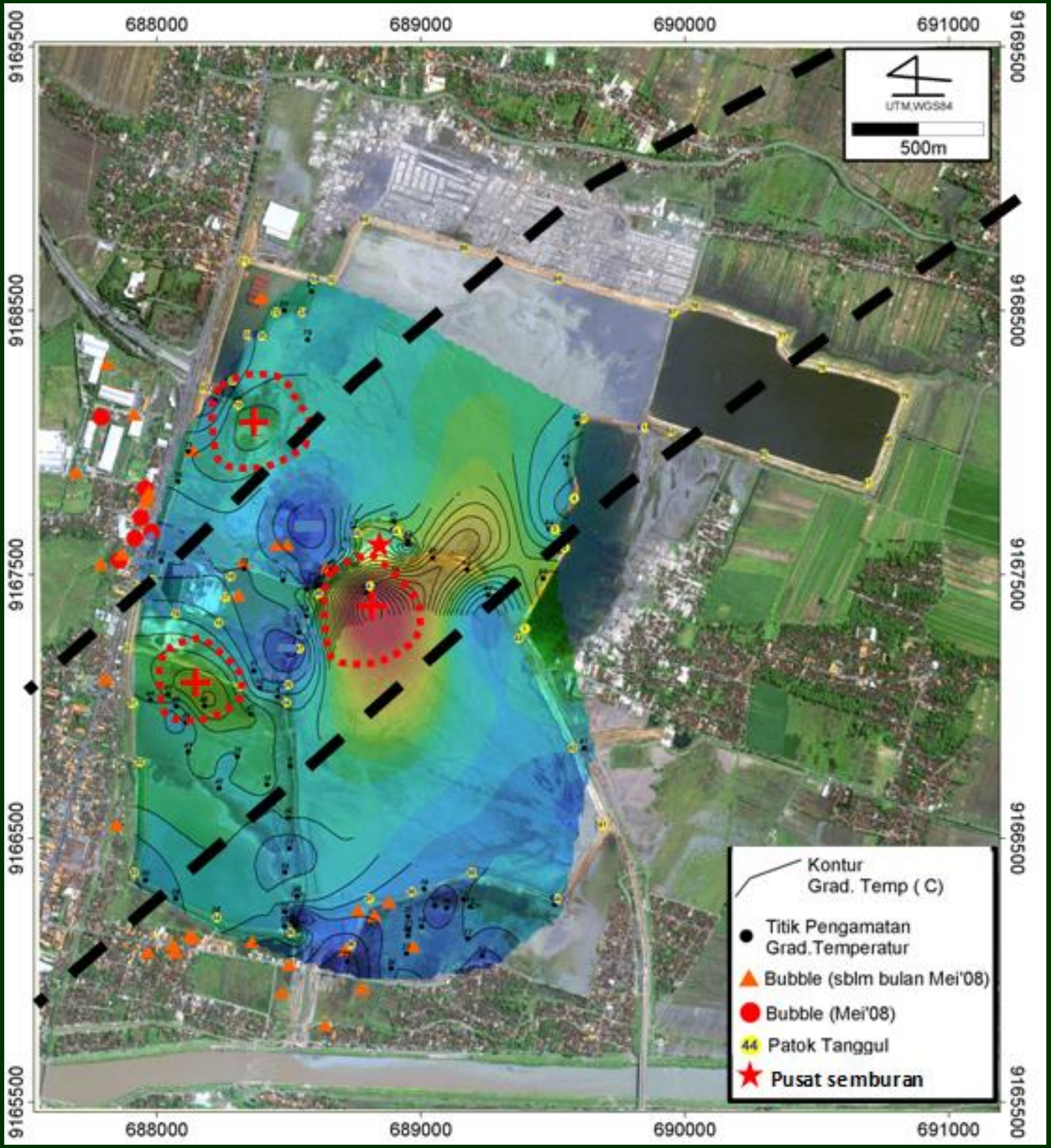


Micro Gravity Profile





Micro gravity (purple low anomaly) and 2 months micro-seismics monitoring (red dot epicenter), both data may indicate a possible collapse area 5-6 km2 (August 2008). This area is more than twice compared to subsidence in June 2007



Temperature gradient 2m map : positive gradient associated with hot upwelling zone and negative gradient associated with degassy zone.

Analysis

- Area in danger due to possible subsidence
- Related to Arjuno-Wellirang geothermal system?
- Impact to geothermal business

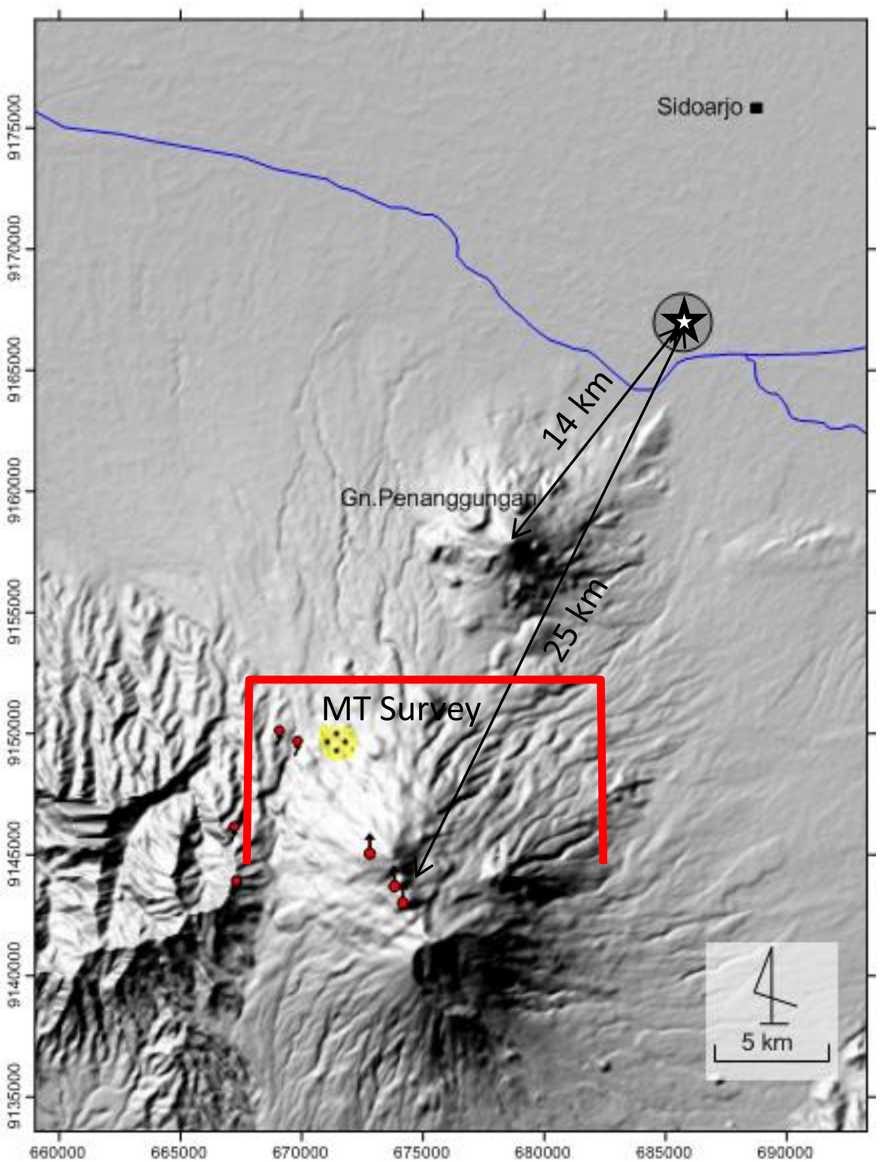
Area in danger due to possible subsidence (black circle line)

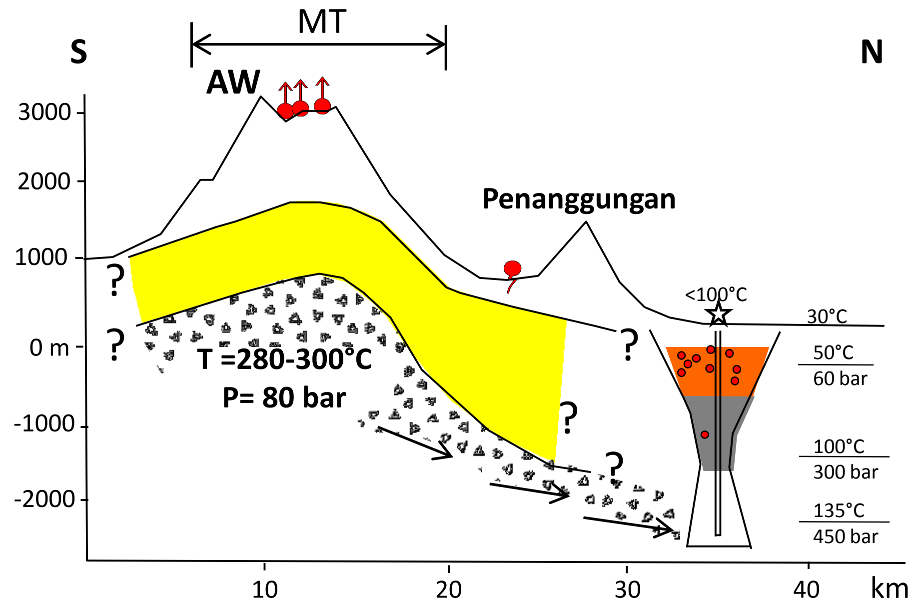
Emergence of a 'mud volcano' (IKONOS 09.02.10) with dried central base and residual brine (+ ground water?)

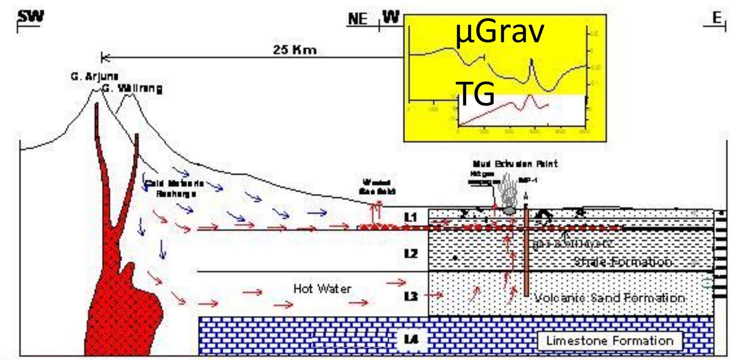
- Centre of subsidence is within the drying out of 'mud pie' area (2.5 – 3 km2).
- The drying mud pie is estimated about 100 Millions m3 in volume.
- Extension of subsidence to the Western side is possible since micro gravity low and gas bubbles recorded in this area
- The settled brine has accumulated in several pools at the fringes of the 'mud pie' (total area of pools now c. 2.7 km2).
- The flooded area has slightly increased from 6.5 km2 in mid 2007 to 7 km2 in 2010

(Modified from Hochstein and Sudarman, WGC 2010)

Does the hot mud extrusion relate to the Arjuno-Wellirang geothermal system located at about 25 km S of the extrusion centre?







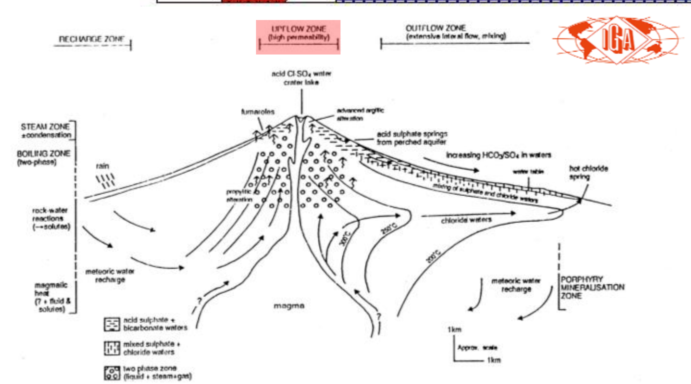
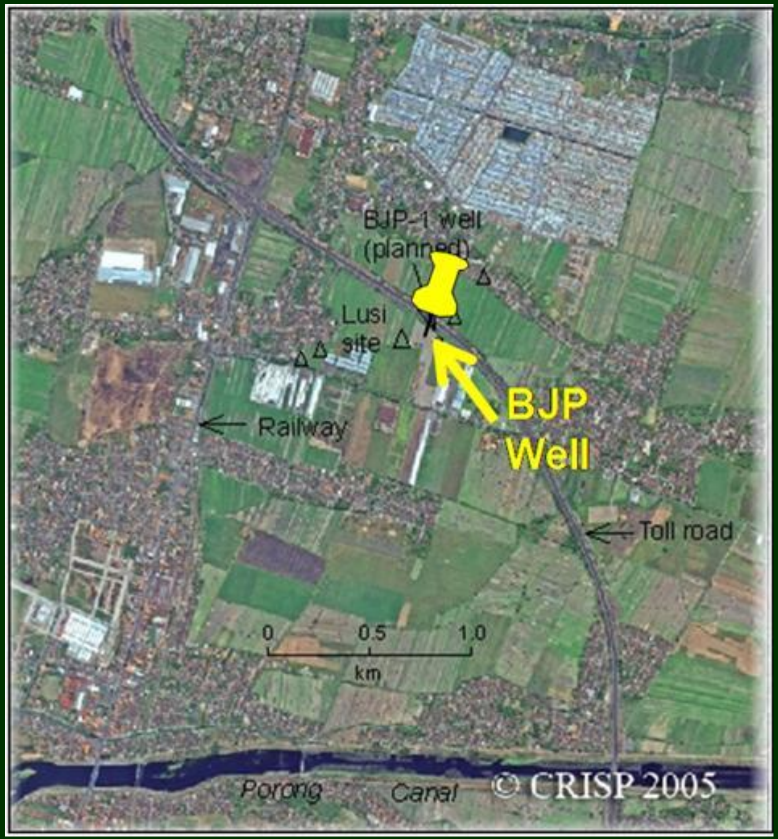


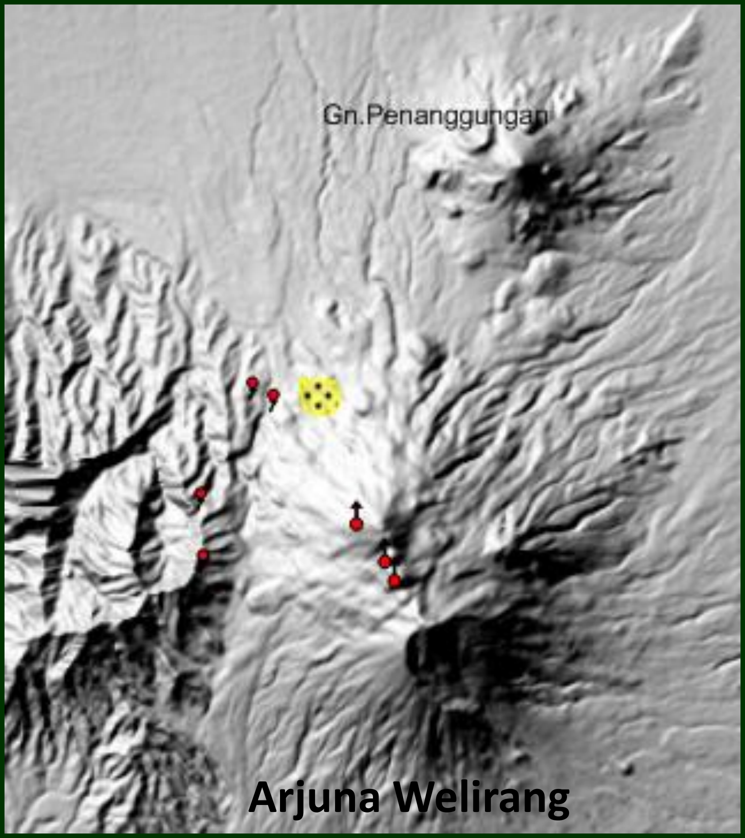
Figure 1.5. Conceptual structure of liquid-dominated geothermal systems in a high-relief setting. Note the deep two-phase zone and the extensive lateral flow compared to systems in a low-relief setting.

NZ. Geothermal Institute Lecture Note, 1993

Surface Rocks :
Arjuno-Wellirang Vs Lusi

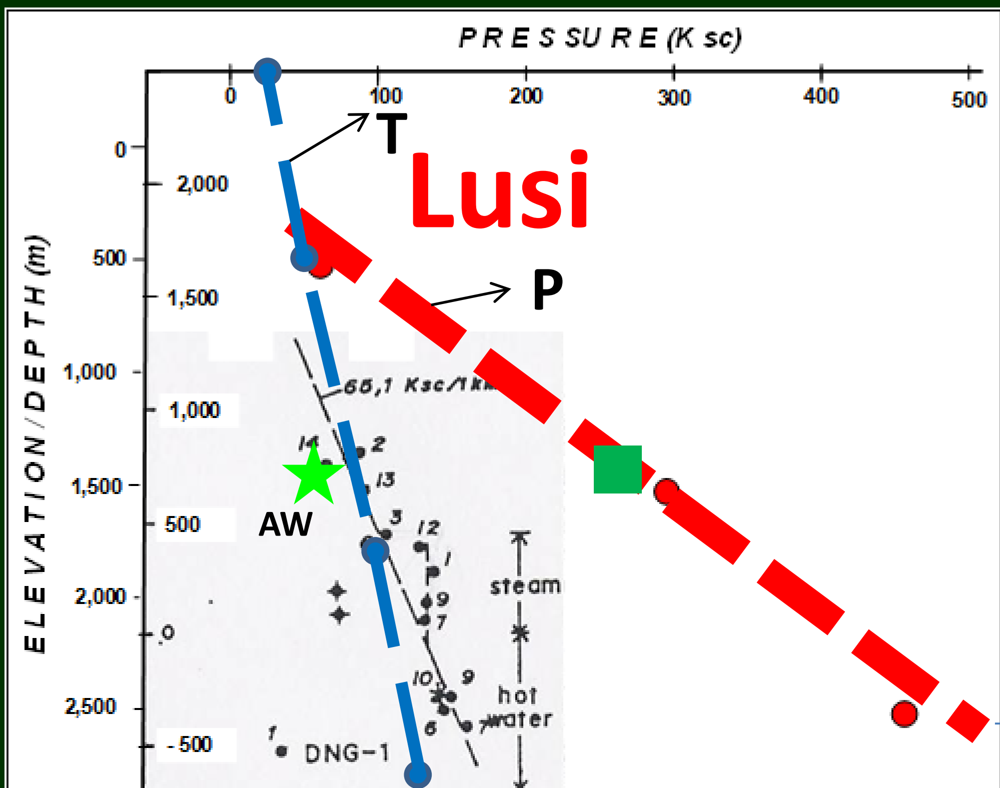
- Hard volcanic rocks Vs soft sedimentary rocks at oil and gas
- Reservoir pressure at Arjuna Welirang = 1/4-5 LUSI
- Water content in hydrothermal clay alteration = ½ clay sediment



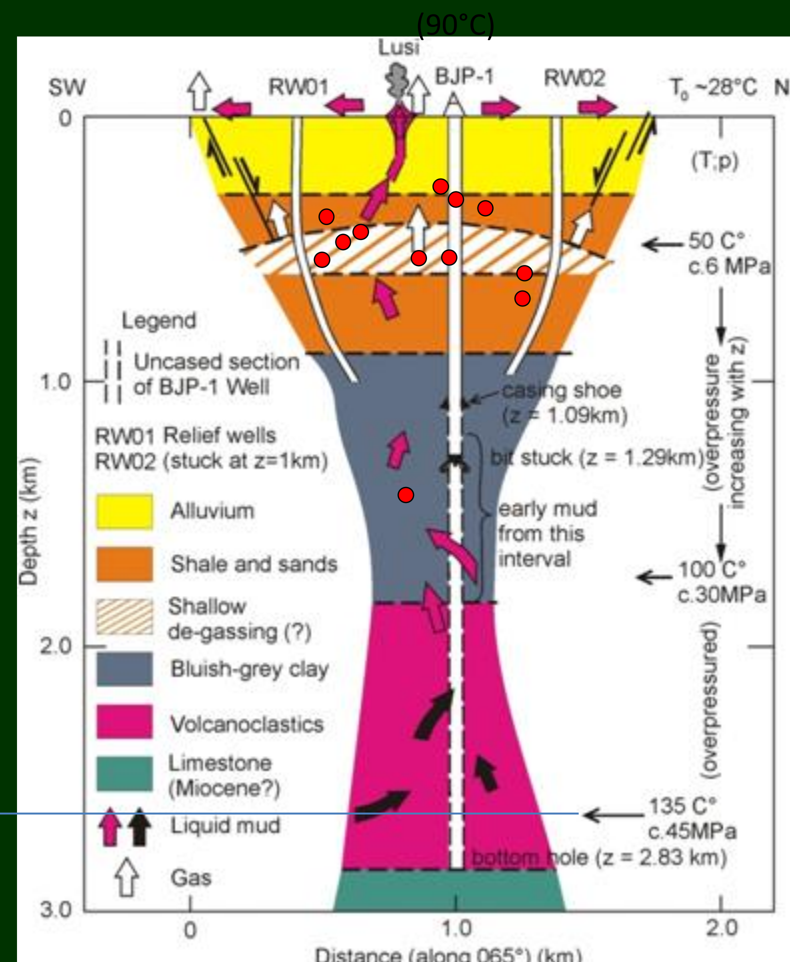


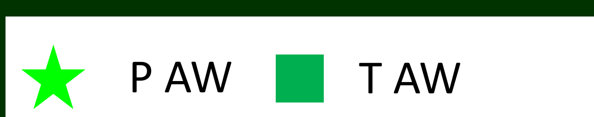
Pressure and Temperature

Geotermal Dieng/Arjuna-Wellirang and LUSI



Budihardi et al, IPA 1991, Hochstein and Sudarman, WGC 2010





Discussion and Conclusions 1/2

- Mud type and micro seismics data indicates that the origin of the mud comes from bluish-grey clay (1 – 1.8 km depth) and shale formation (0.3 – 1 km depth)
- The extrusion of near boiling hot water is predicted comes from volcano-clastics formation that filled by 25 km geothermal outflow fluids of the Gn. Arjuno-Wellirang system at 135 °C.
- Possible extension of the subsidence area to W side (~ 2 km2) of the extrusion centre has to be aware

Discussion and Conclusions 2/2

- Continuous flow rate, micro geophysical and subsidence monitoring are recommended since this time series study can give an early warning action. What happened after developing an intensive drying mud in Feb 2010?
- LUSI has make people around the geothermal prospect worry when this energy to be drilled and exploited although the case is very different. Their worry so far can be managed.

LUSI mud volcano: Acknowledgement

BMKG (August 2008) provided microgravity , micro seismics and temperature survey data

Prof (Emeritus) Hochstein from Auckland University NZ, partnership on the field discussion, in 2009

Mr. B. Istadi (P. T. Lapindo) and Dr. Prihadi (ITB) provided important data for this paper which covered earlier monitoring efforts

Mr. Soffian Hadi (BPLS) assisted with details of mud flow management data and policies.

The National University of Singapore (Centre for Remote Imaging, Sensing, and Processing) gave permission to present the IKONOS satellite photos presented during the talk.

Thank you for your interest in LUSI.