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SUB CRUCE LUMEN
Anatomy of the 'LuSi' Mud Volcano, East Java
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Trees
~ 8 m high
Photo courtesy BPLS

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Anatomy of Lusi Mud Volcano, East Java

- CURRENT THEORIES ON SUBSURFACE GEOLOGY
- NEW INFORMATION ON SUBSURFACE GEOLOGY
- SO, WHAT DO AND DON'T WE KNOW?

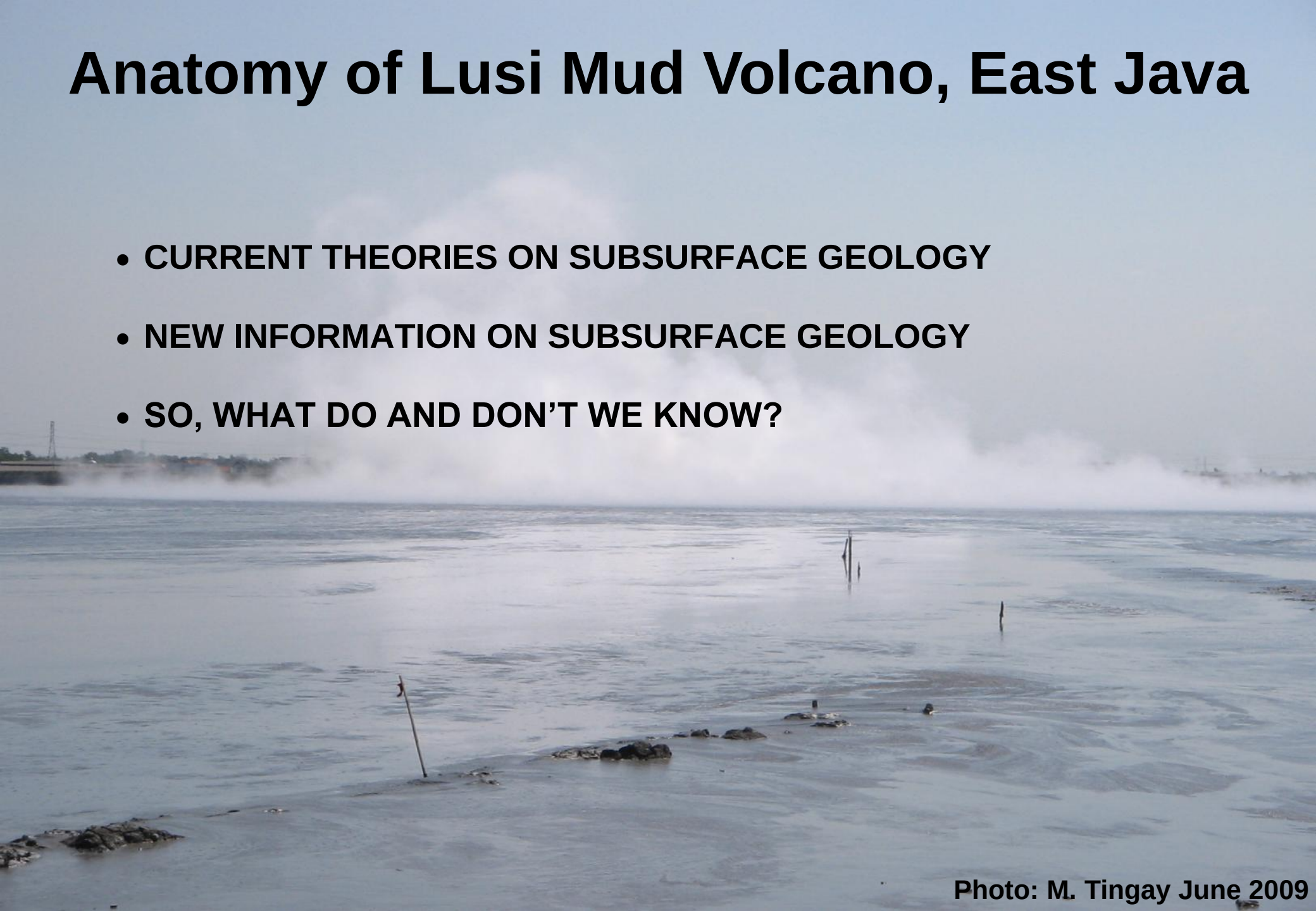


Photo: M. Tingay June 2009

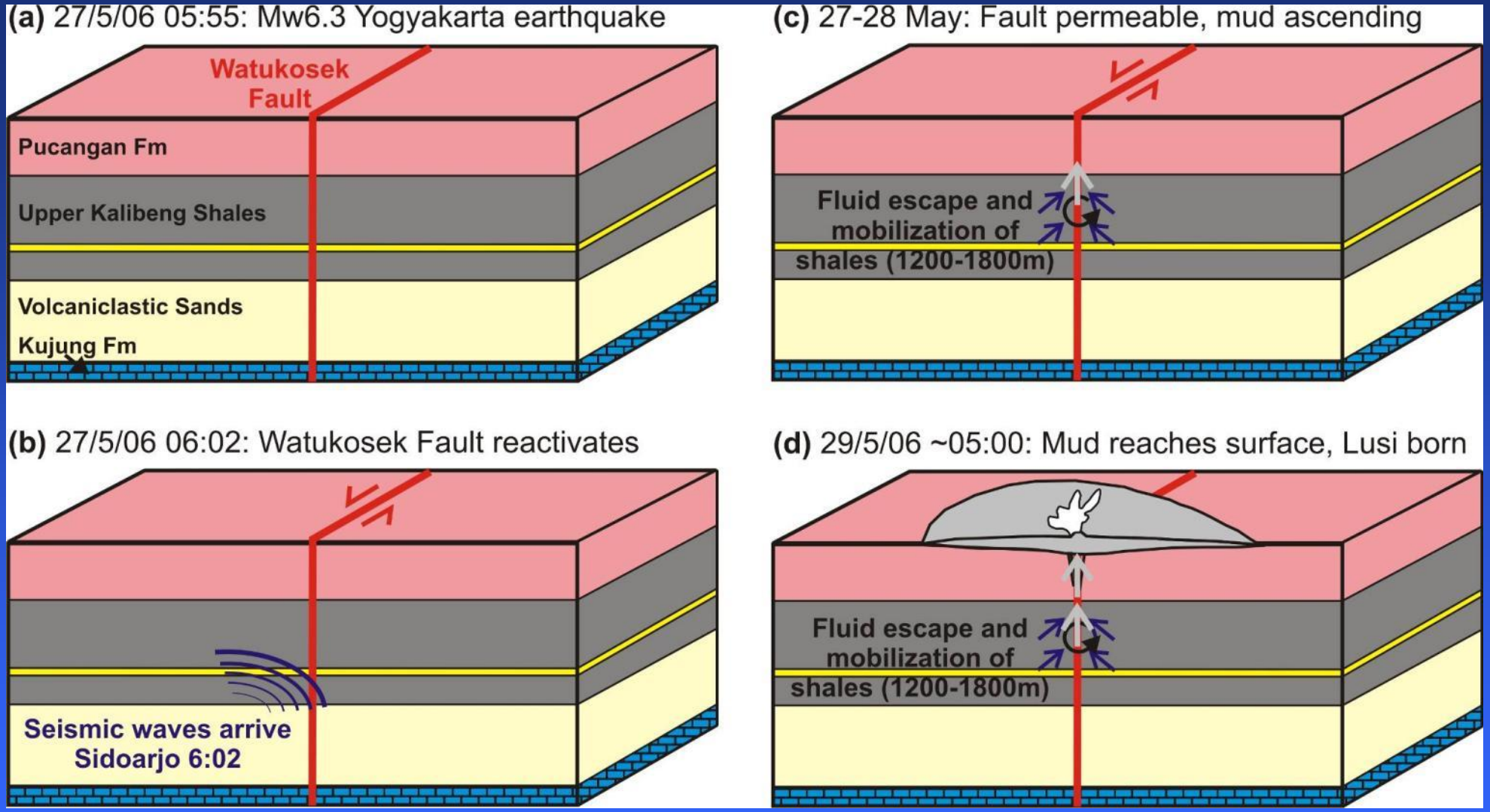
WHAT DO WE CURRENTLY THINK ABOUT LUSI?

- **Solid fraction (clay) is principally from Pleistocene Upper Kalibeng shales (1200-1800m).**
- ***Water origin unknown*, temp/chem suggest >1700m?**
- **Migration originally along NE-SW fault (Watukosek?), later reactivation of ~NW-SE (& other) faults.**
- **Some limited geology from Banjar Panji-1 well.**
- **Pre-existing and subsequent structure poorly understood (poor seismic, difficult geophysics).**

Uncertainty in water origin and subsurface geology leads to two models for Lusi based on different triggering theories.

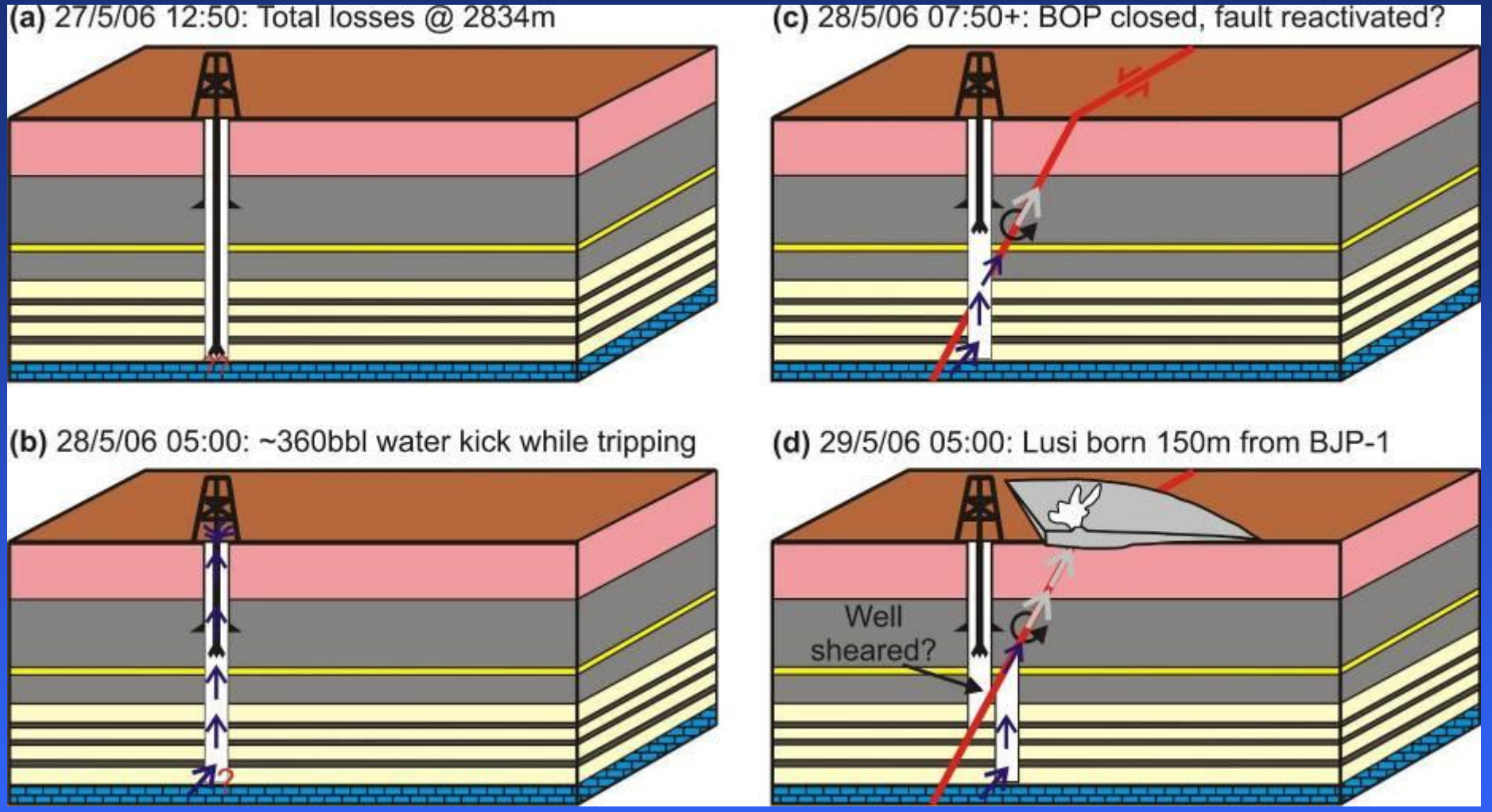
Sources: Mazzini et al., 2007; Davies et al., 2008; Photo: © Greenpeace, reproduced with permission

Schematic Model for Earthquake Triggering of Lusi



Earthquake trigger theory suggests Lusi result of **remote reactivation** of Watukosek fault. Seismic shaking caused reactivation, mobilization (& liquefaction?) of Kalibeng Shales.

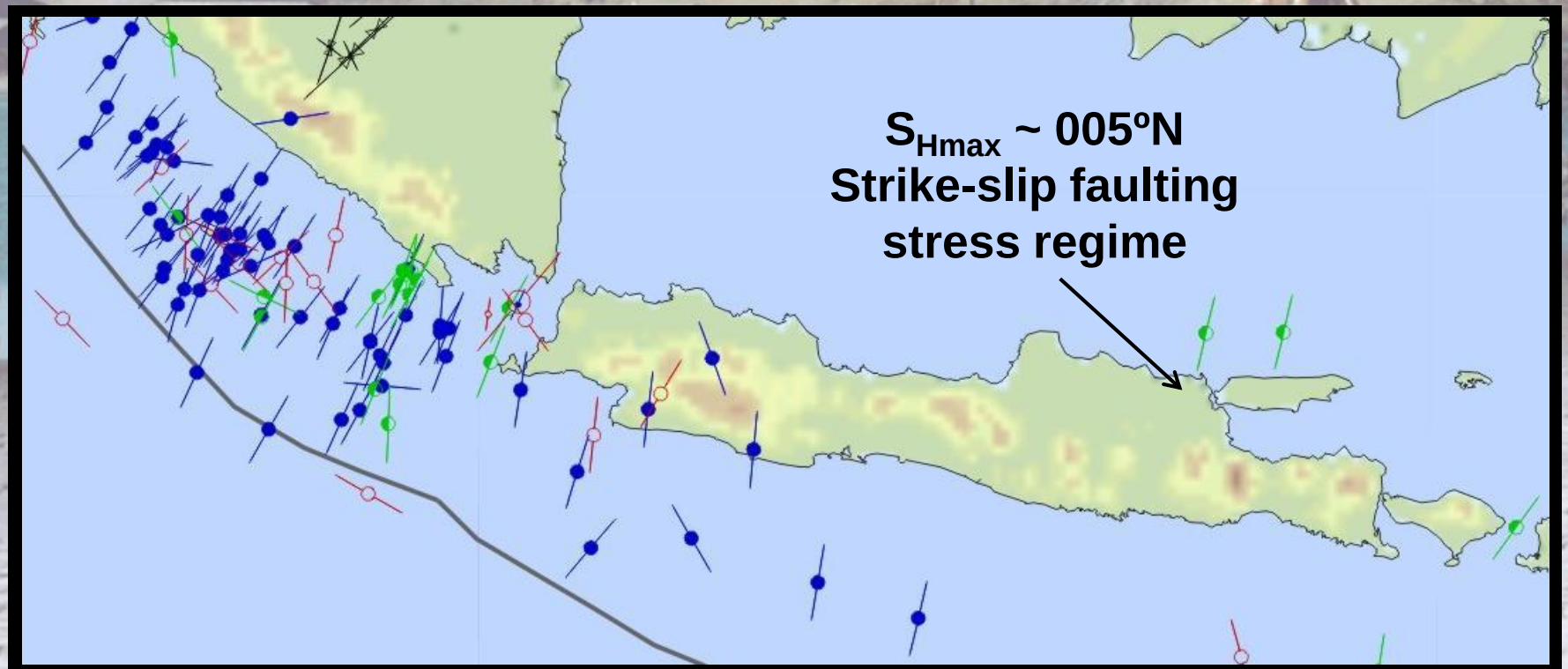
Schematic Model for Drilling-Induced Triggering of Lusi



Drilling-induced trigger theory suggests mud eruption from **fault reactivation following an 'internal blowout'.** Water primarily from carbonates, mixes with clay/water from Kalibeng en route to surface.

SIMILARITIES BETWEEN MODELS?

- **Models often considered very different, but both examine the strike-slip reactivation of NW-SE fault due to pore pressure increase (or effective stress decrease).**
- **Consistent with in-situ stress state.**
- **Faulting mechanically easier than tensile fracturing.**



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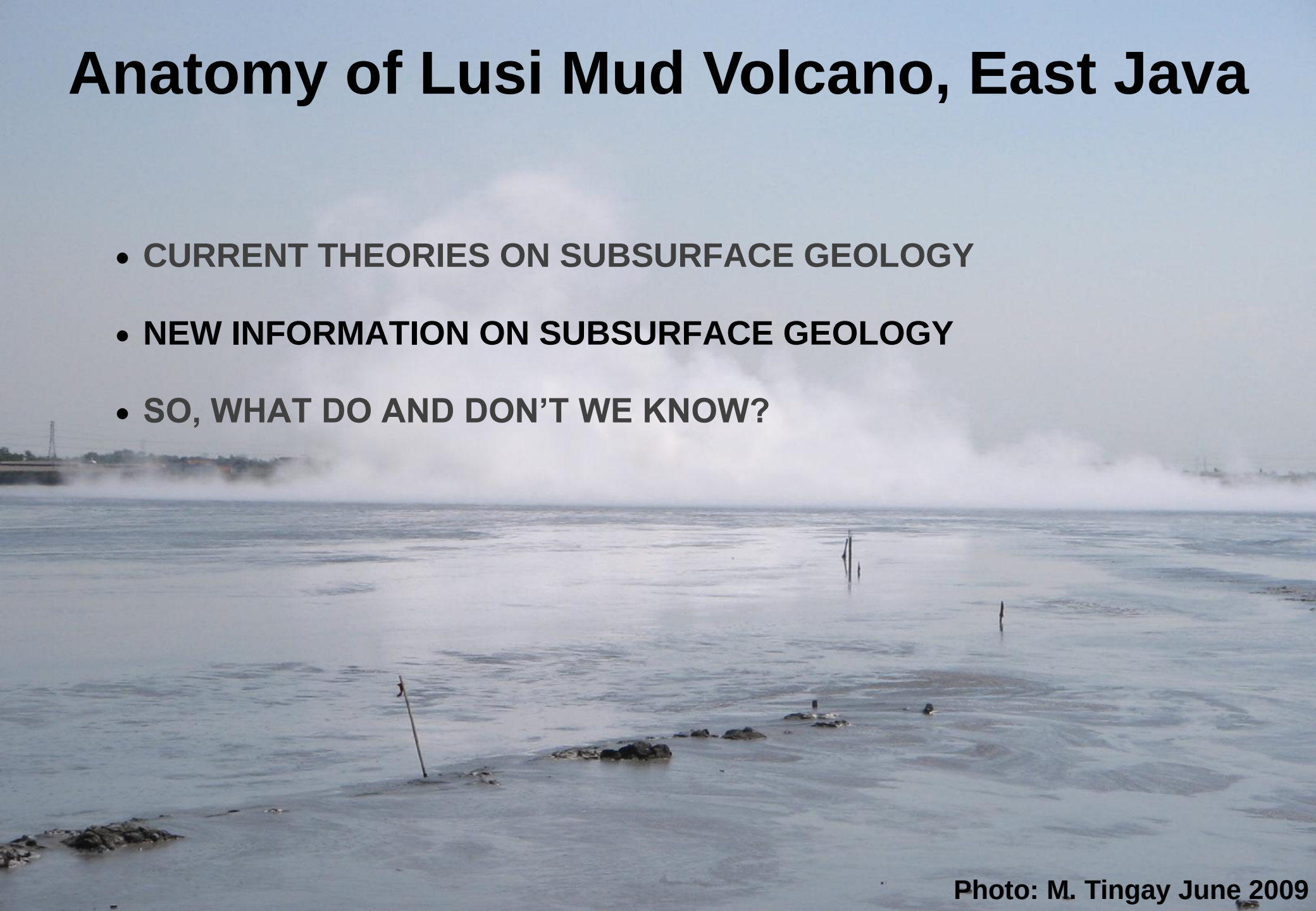
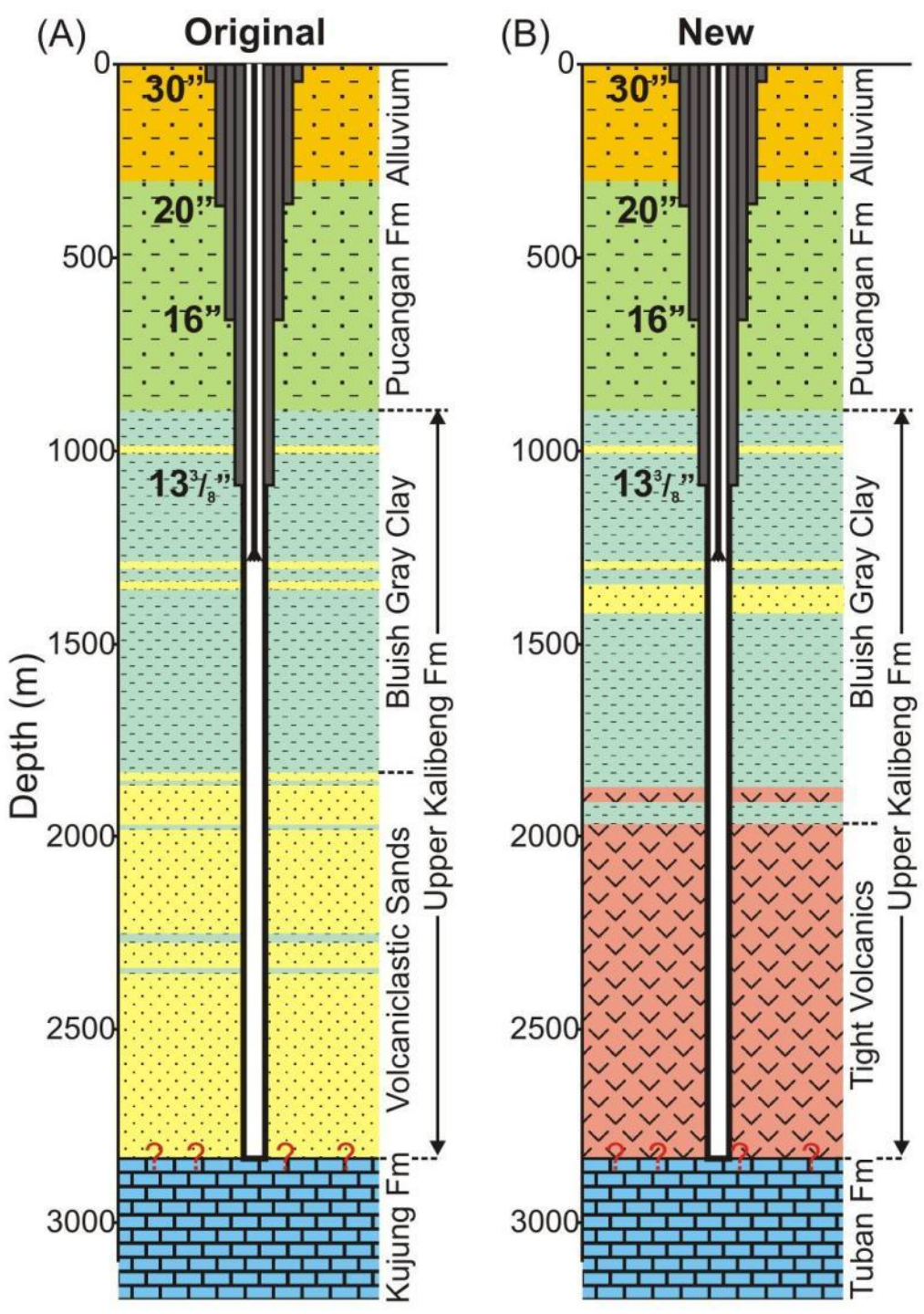


Photo: M. Tingay June 2009

New Interpretation of Lithologies Under Lusi

1) Volcaniclastic sands reinterpreted as tight volcanics.

2) Deep Kujung carbonates reinterpreted as Miocene Tuban or Prupuh Fm reefal carbonates.



Why Volcanics and Not Volcaniclastic Sands?

• Inspection of cuttings indicates error in original mud logger interpretation.

• Cuttings comprised of andesite, dacite, welded tuffs - lava flows, ash and maybe lahars.

• Ground down fragments easily misinterpreted as volcaniclastics (very low ROP, high WOB).

•Major differences between volcanics and volcaniclastics.

• Likely source: Pleistocene-Recent Penanggungan volcanic complex 15km SW of Lusi

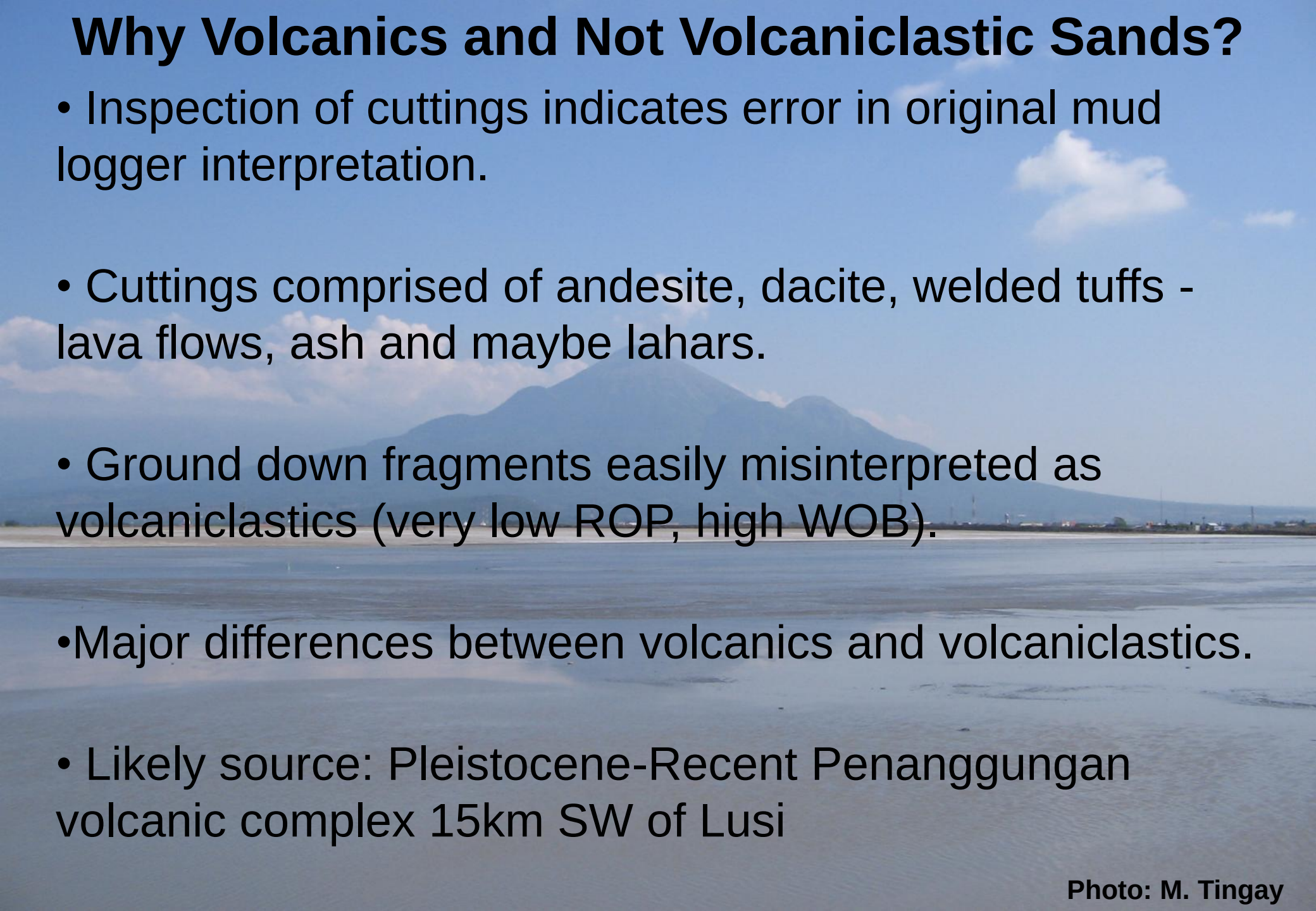
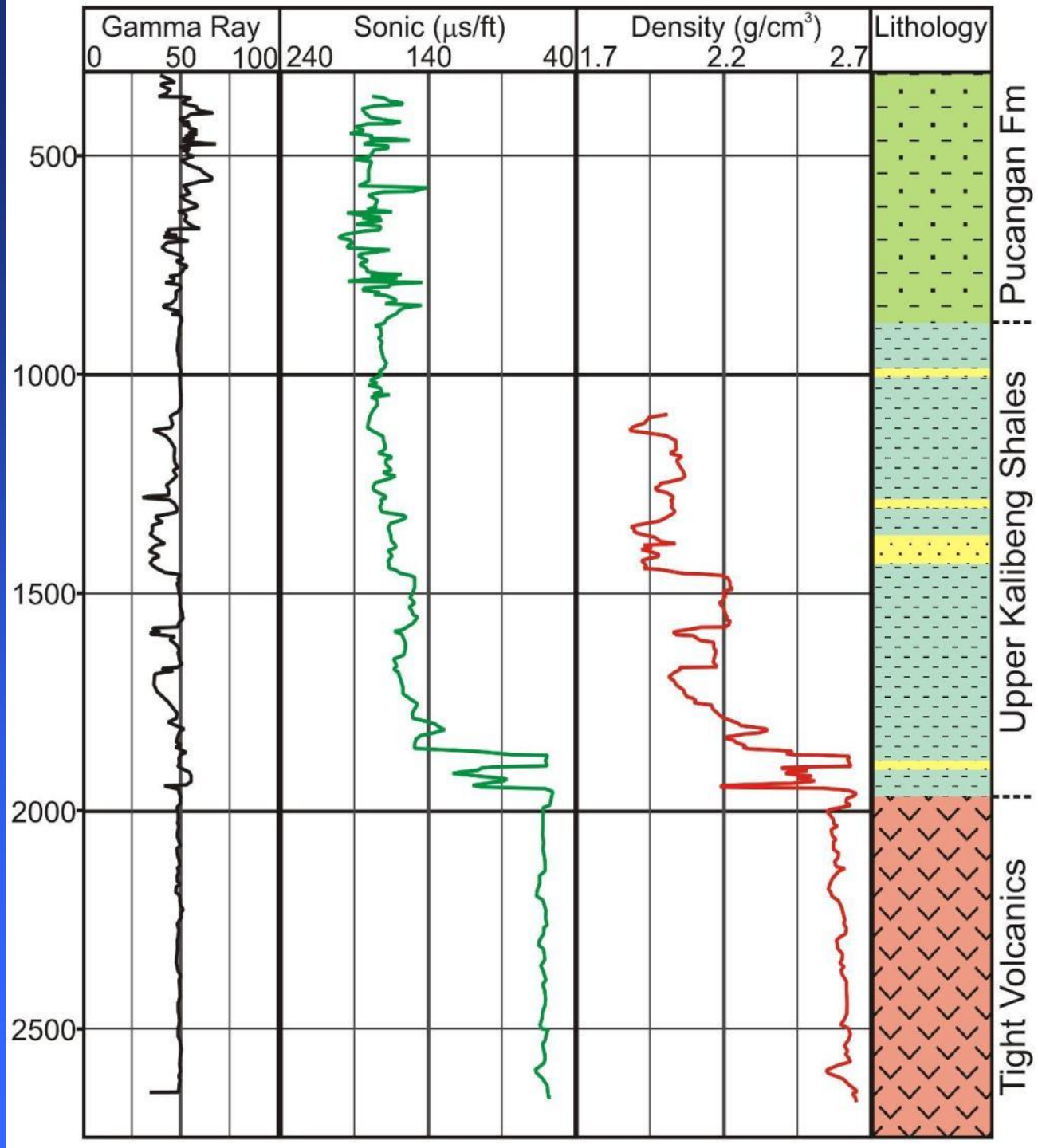


Photo: M. Tingay

Petrophysical logs also suggest volcanics

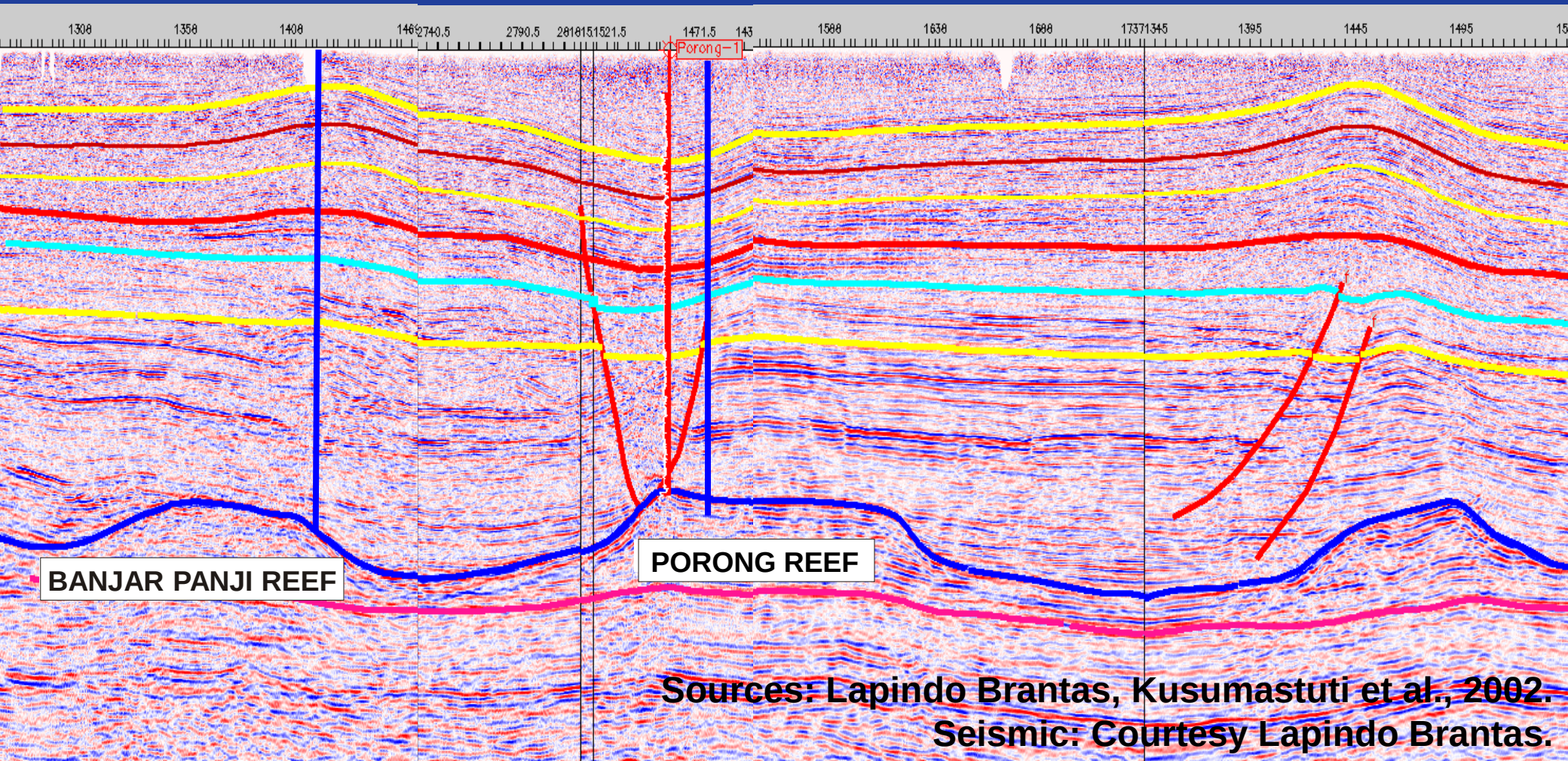
- Uniform log responses
- High density (~2.6 g/cm^3)
- Fast sonic (~65 μs/ft)
- Indicates porosity <9%

Likely very low matrix permeability (high fracture permeability?).



NOT THE KUJUNG CARBONATES?

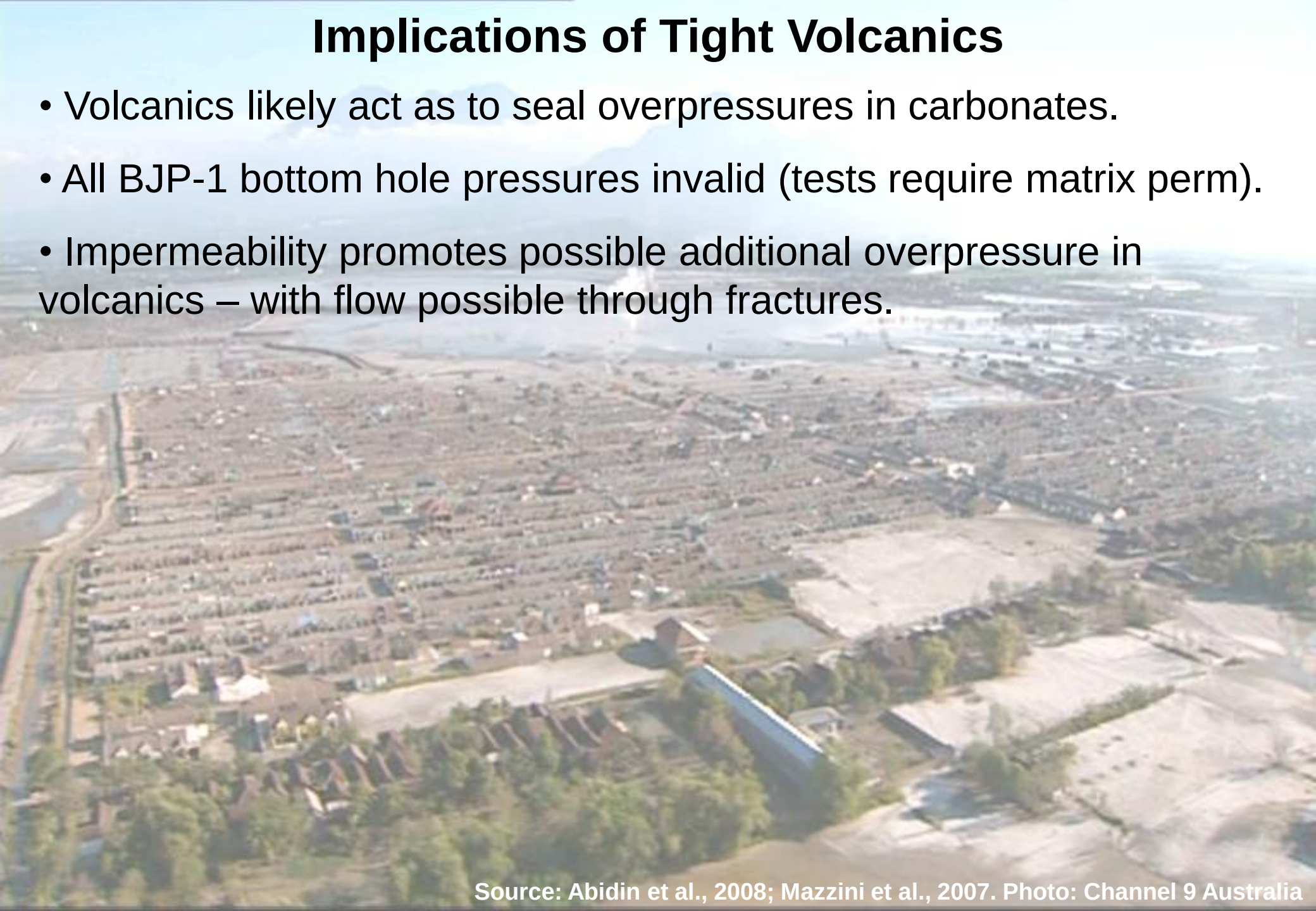
- Oligocene Kujung Fm is primary reservoir unit in East Java Basin.
- Sr ratios from Porong-1 (7 km away) show carbonates 16Ma.
- Suggests carbonates Mid Miocene Tuban or Prupuh Formations.



Sources: Lapindo Brantas, Kusumastuti et al., 2002.
Seismic: Courtesy Lapindo Brantas.

Implications of Tight Volcanics

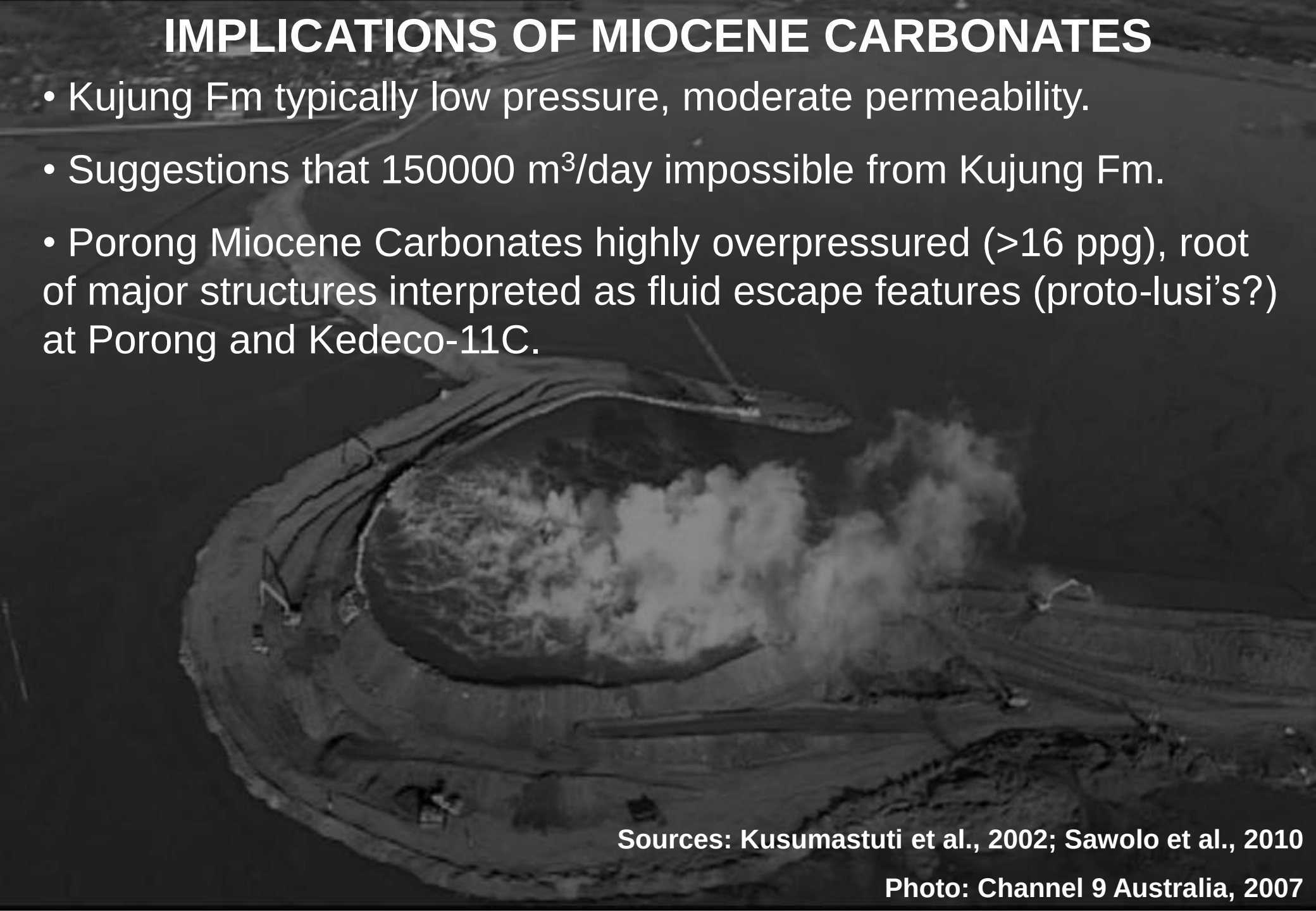
- Volcanics likely act as to seal overpressures in carbonates.
- All BJP-1 bottom hole pressures invalid (tests require matrix perm).
- Impermeability promotes possible additional overpressure in volcanics – with flow possible through fractures.



Source: Abidin et al., 2008; Mazzini et al., 2007. Photo: Channel 9 Australia

IMPLICATIONS OF MIOCENE CARBONATES

- Kujung Fm typically low pressure, moderate permeability.
- Suggestions that 150000 m^3/day impossible from Kujung Fm.
- Porong Miocene Carbonates highly overpressured (>16 ppg), root of major structures interpreted as fluid escape features (proto-lusi's?) at Porong and Kedeco-11C.



Sources: Kusumastuti et al., 2002; Sawolo et al., 2010

Photo: Channel 9 Australia, 2007

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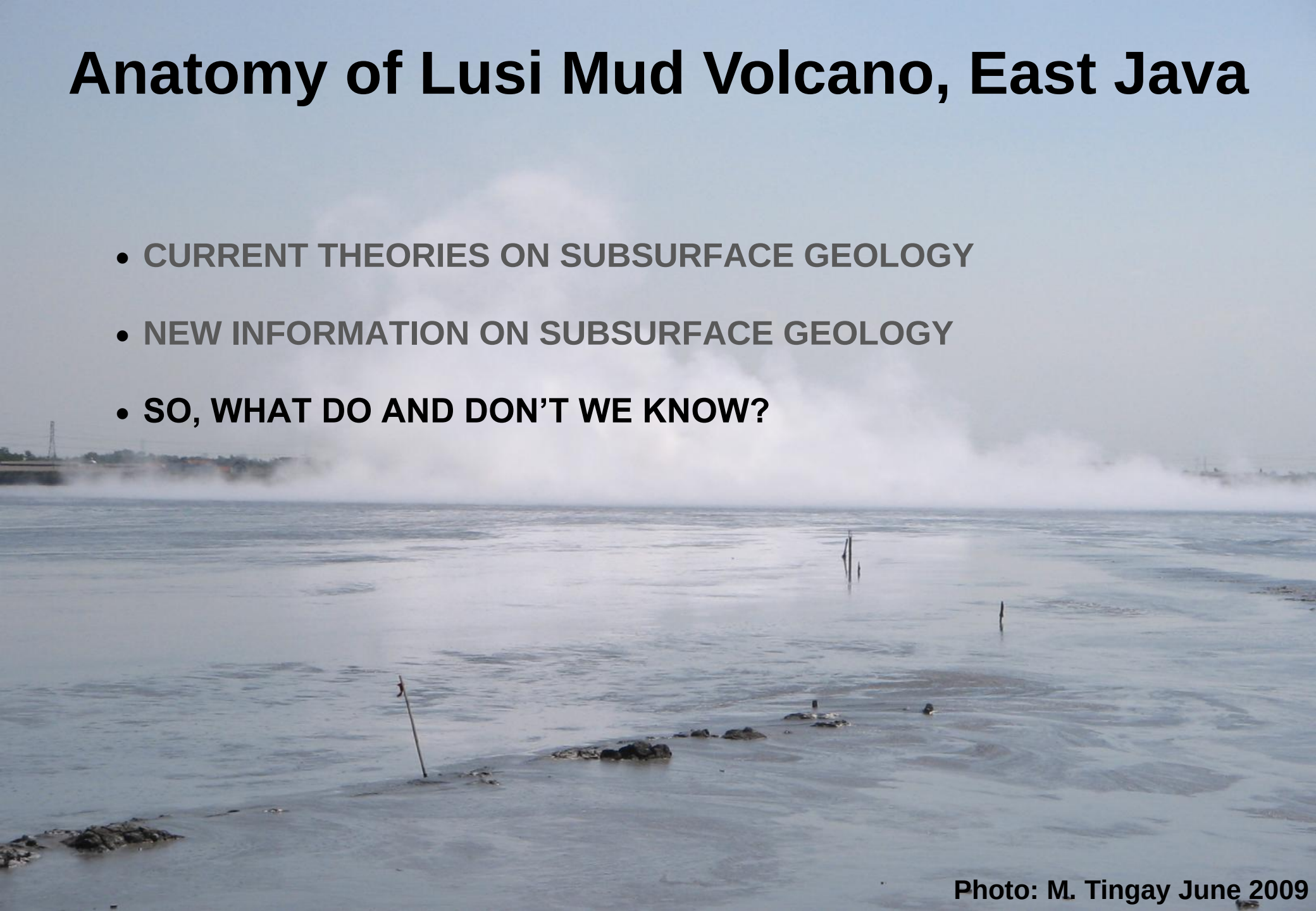


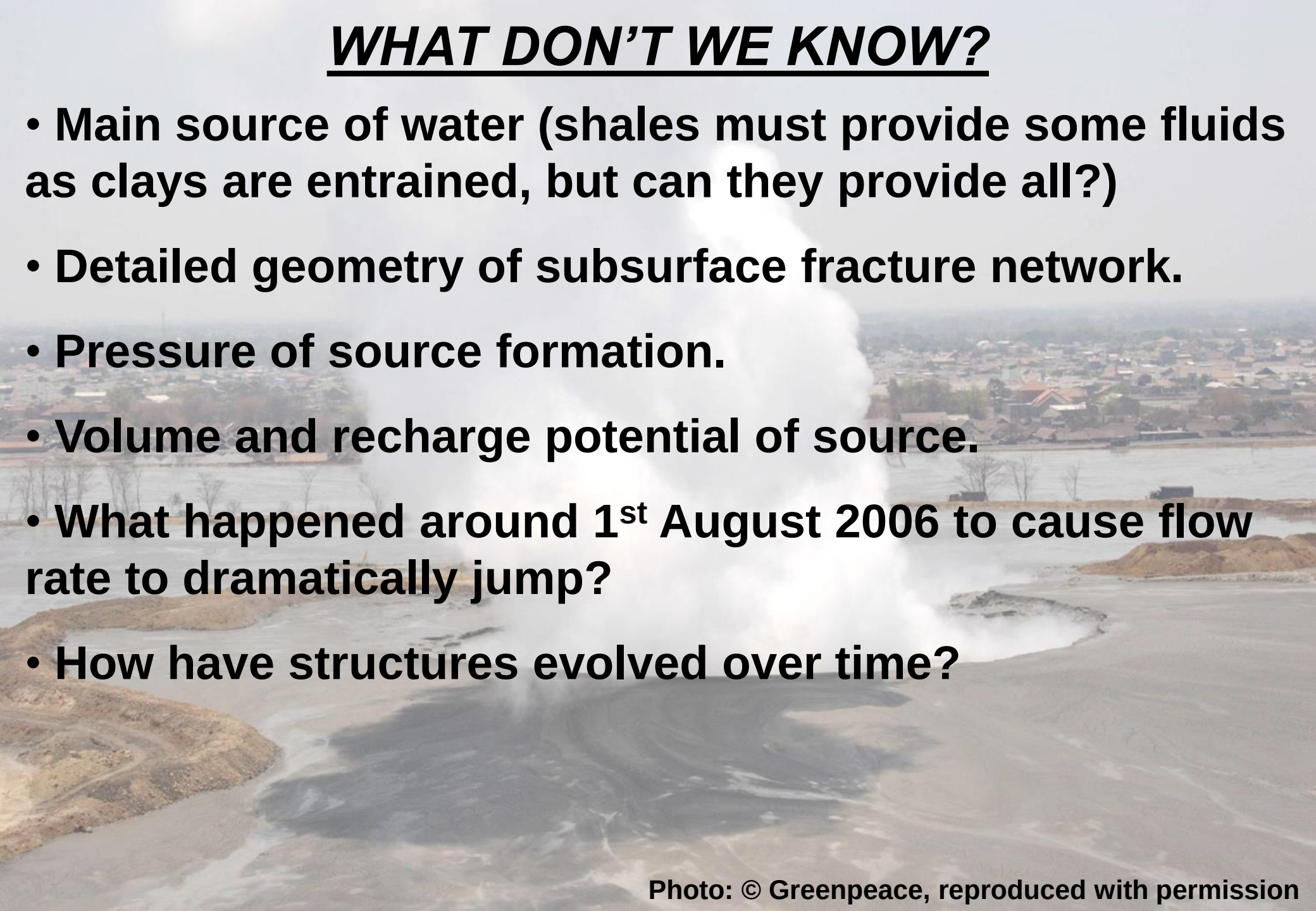
Photo: M. Tingay June 2009

WHAT DO WE KNOW?

- **Primary source of clays Kalibeng Fm.**
- **Originally NE-SW fault (Watukosek?) reactivated.**
- **Large fault network since developed, consistent with present-day stress state.**
- **Pucangan Fm, Upper Kalibeng Fm, Volcanics? (not volcaniclastics?), Miocene carbonates (not Kujung).**
- **Fluid source must have high pressure and high bulk permeability (shales?? carbonates?).**

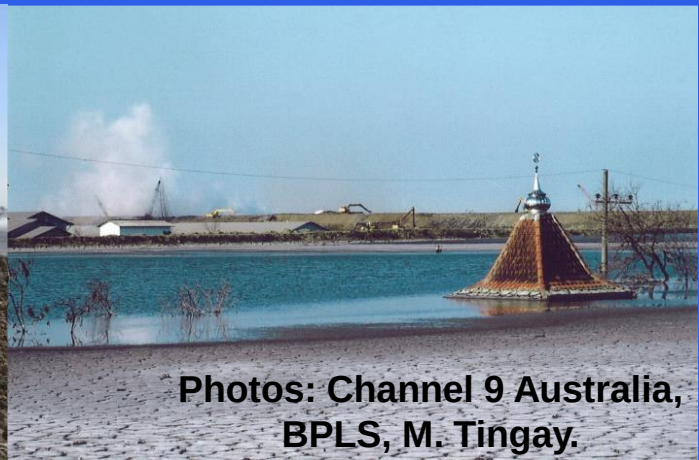
WHAT DON'T WE KNOW?

- **Main source of water (shales must provide some fluids as clays are entrained, but can they provide all?)**
- **Detailed geometry of subsurface fracture network.**
- **Pressure of source formation.**
- **Volume and recharge potential of source.**
- **What happened around 1st August 2006 to cause flow rate to dramatically jump?**
- **How have structures evolved over time?**



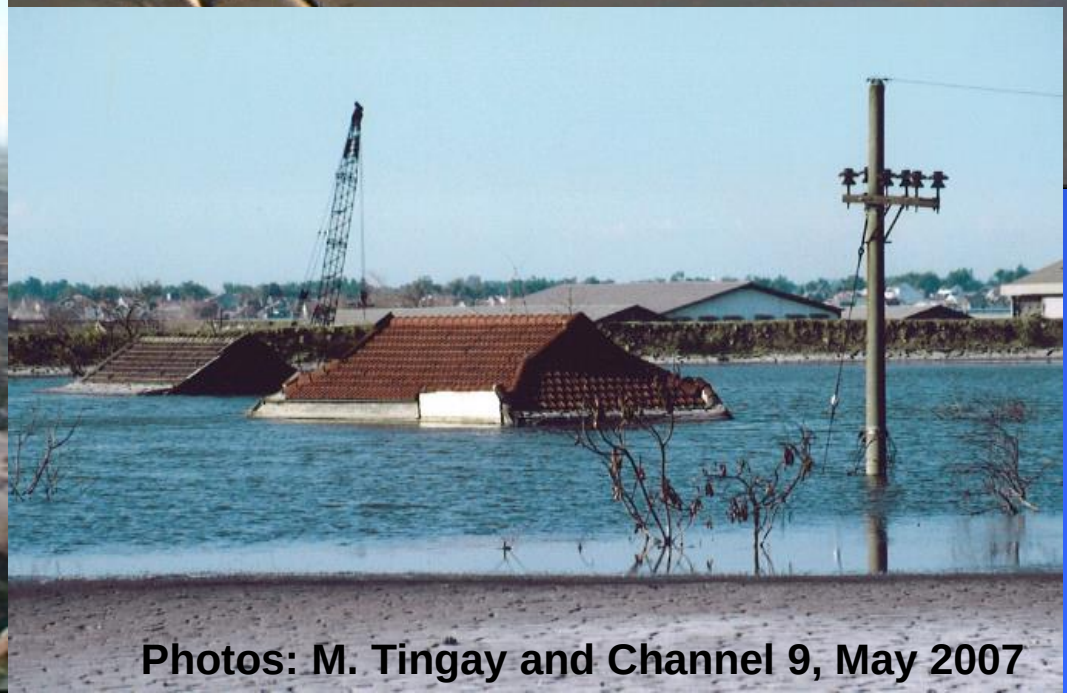
Future Possible Data Collection?

- High quality seismic (3D/4D) – for subsurface structure/evolution.
- Magnetotellurics – for delineation of fluid flow depths.
- More geochemistry of gases and fluids.
- Monitoring wells? ($$$, risk) – pressure monitoring, core (k, ϕ).
- Tiltmeters – surface strains.



Photos: Channel 9 Australia, BPLS, M. Tingay.

Thank You!!



Photos: M. Tingay and Channel 9, May 2007