The mechanism of overpressure generation in the LUSI mud volcano

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a. Mud rheology of LUSI
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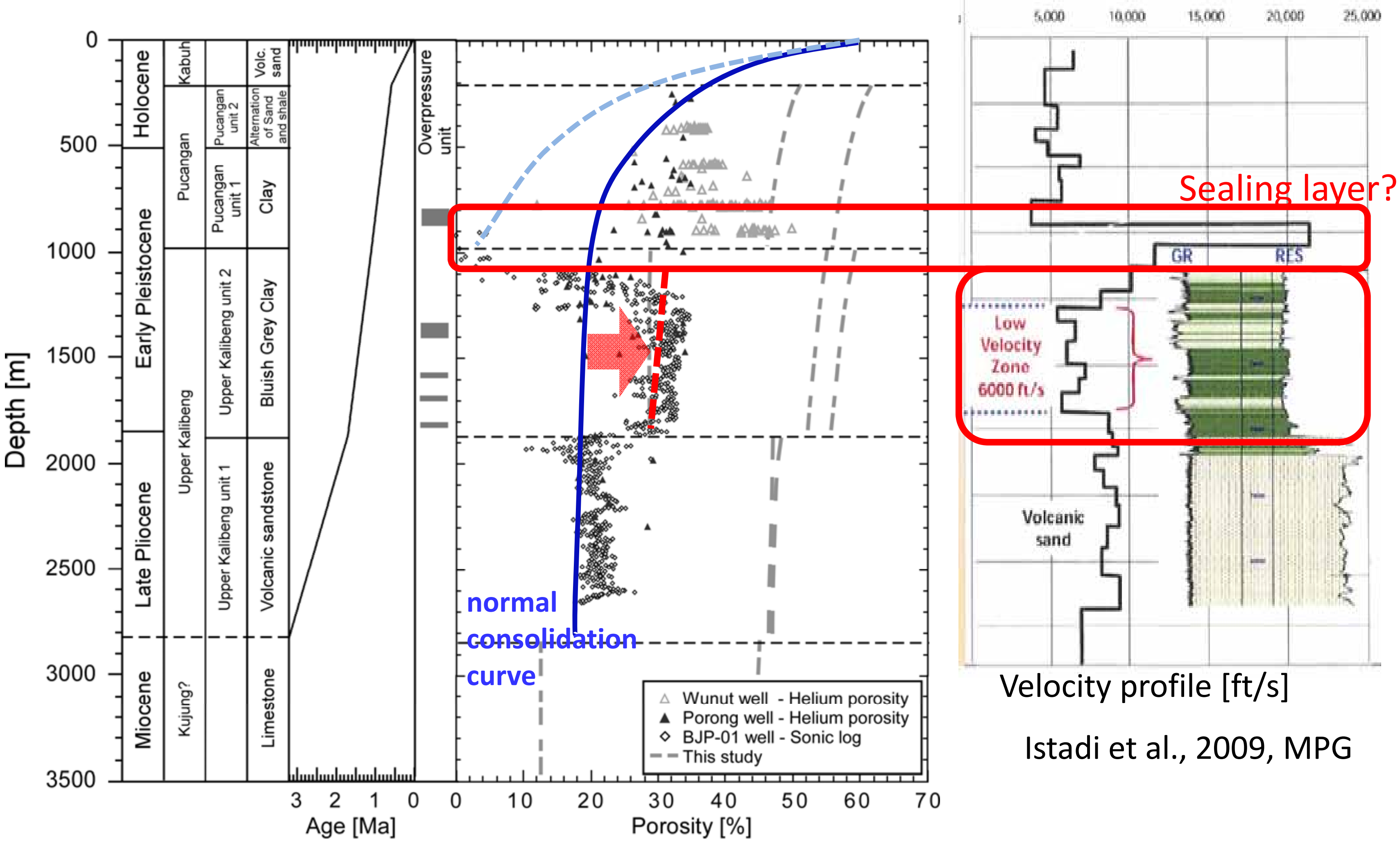
Target - Porosity gap at Banjarpanji1 well



Porosity gap at Upper Kaliberng unit2 - Source of LUSI mud

→Overpressure? →Undercompaction?

Abnormal pressure

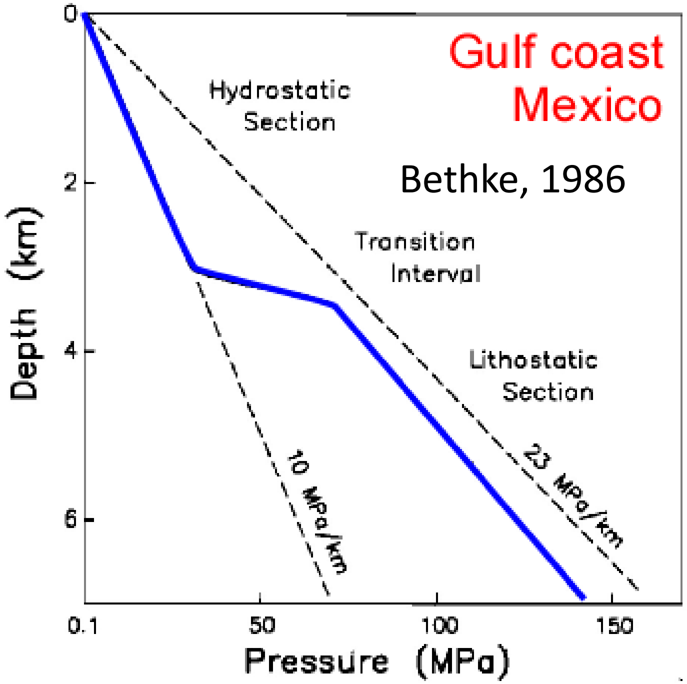
Mud volcanoes are often found where overpressure was developed (Kopf, 2002).

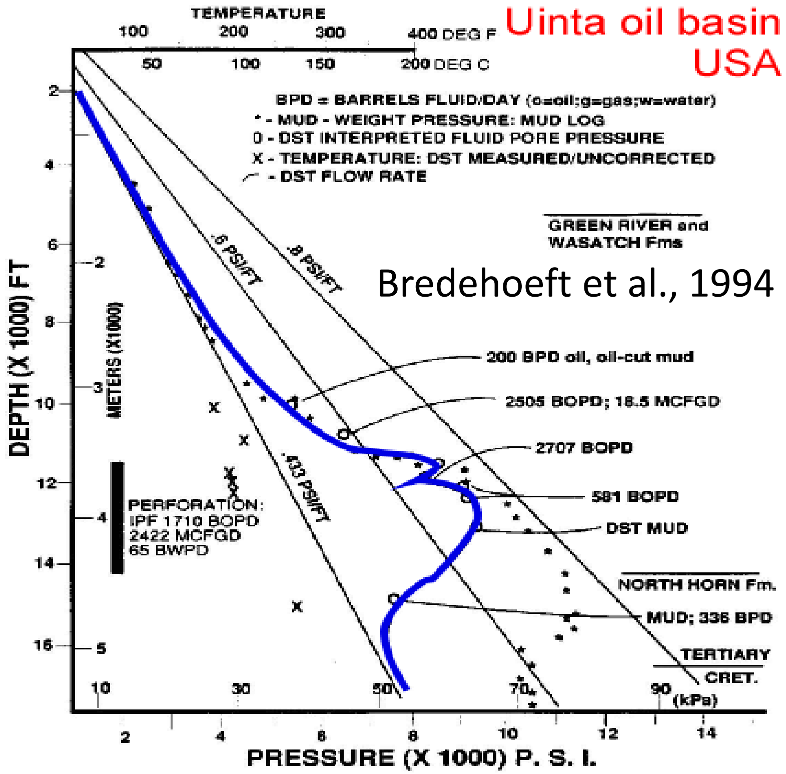
・Hydrostatic at shallow depth

・Transition zone from hydtostatic to overpressured

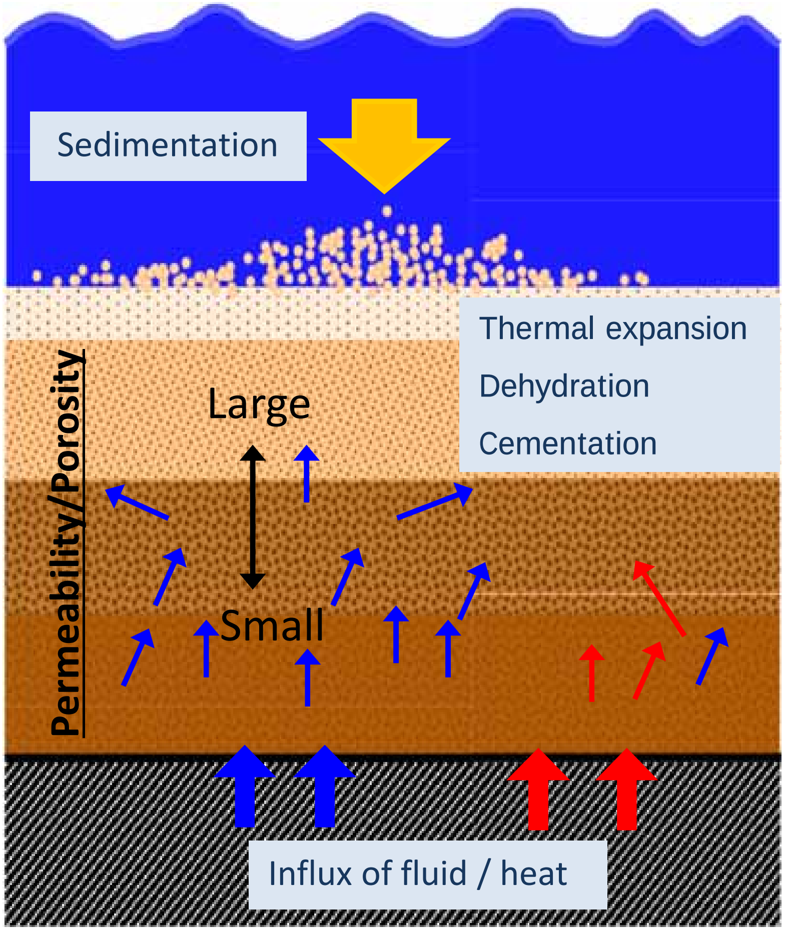
・(Approaching to lithostatic)

・LUSI – if so, develop at very shallow horizon





Mechanism of overpressure generation



(eg. Bredehoeft and Hanshaw, 1968; Lou and Vasseure, 1996; Wangen 2001)

Key process for thick sedimentary basin

1. Sedimentation (Vertical compression)

Sedimentation rate, Sediment thickness

Mechanical compaction

2. Thermal expansion of fluid

Geothermal gradient, heat source

3. Chemical reaction

a. Dehydration ; smectite → illite ＋ water

b. Oil , gas hydrate production

c. Cementation of carbonate

4. Influx from deep source

5. Tectonic compression (Lateral compression)

Hydrological property –Key of overpressure

- Porosity
- Permeability
- Pore compressibility (storage capacity)

Equation for evaluation of overpressure generation

$$\frac{\partial Pp}{\partial t} = \frac{1}{Ss}\frac{\partial}{\partial z}\left(\frac{k}{\mu}\frac{\partial}{\partial z}Pp\right) + B\frac{\partial Pc}{\partial t} + \frac{\varphi\alpha_f}{Ss}\frac{\partial T}{\partial t} + \frac{q_f}{Ss}$$

Diffusion term　Sedimentation　Thermal expansion　Dehydration/Oil generation

（Gibson 1958,Bethke and Corbet 1988,Luo and Vasseur 1992, Wang 2000, Wangeng 2001）

Pp: pore pressure	μ: fluid viscosity	T: Temperature
Pc: confining pressure	α_f: fluid expansibility	q_f: fluid production rate

Darcy's law
Effective pressure law
Linear-poroelasticity

Horizontal distribution of Pp, ϕ
Temporal change of Pp, ϕ

Unknown parameters

k: Permeability (m^2)

φ: Porosity (%)

Ss: Specific storage (Pa^{-1}) = $(\delta m/\delta Pp)_{\Delta Pc=0}$

B: Skempton coefficient = $(\delta Pp/\delta Pc)_{\Delta m=0}$

Complicated in sedimentary basin

1. Lithological variation

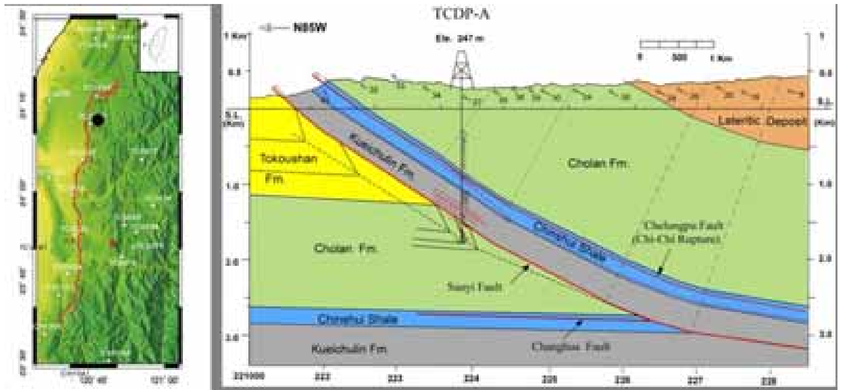
2. Stress dependence

Estimation by laboratory scale experiment

Example of the overpressure analysis

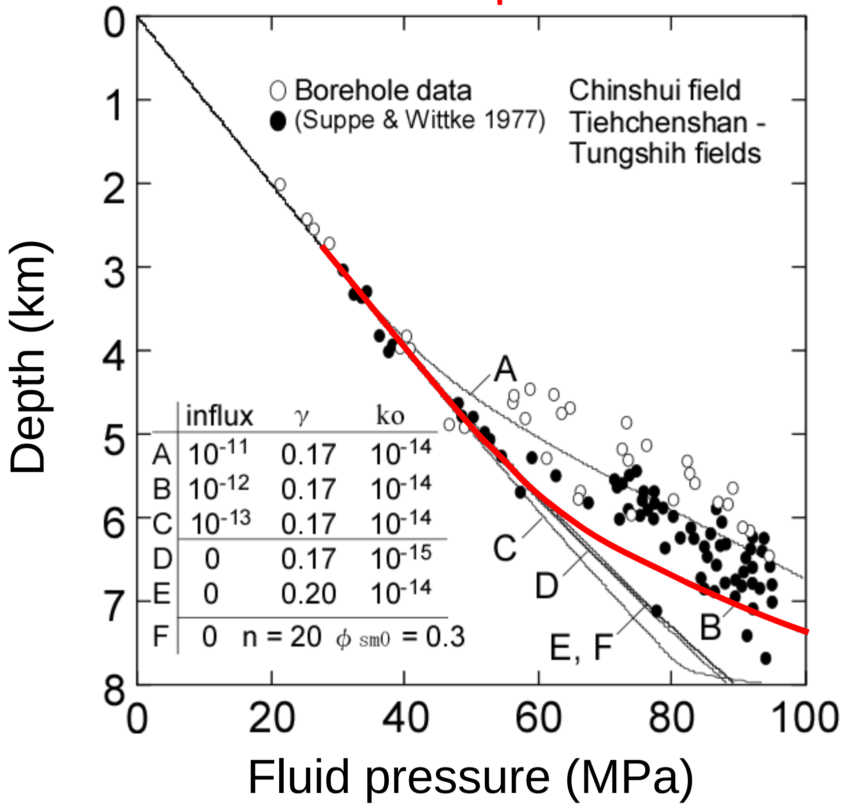
1999Taiwan Chi-Chi earthquake

http://www.zisin.jp/modules/pico/index.php?content_id=1475



After Ma et al.,2003; Yeh et al.,2007

Source of overpressure



Importance of overpressure for EQ

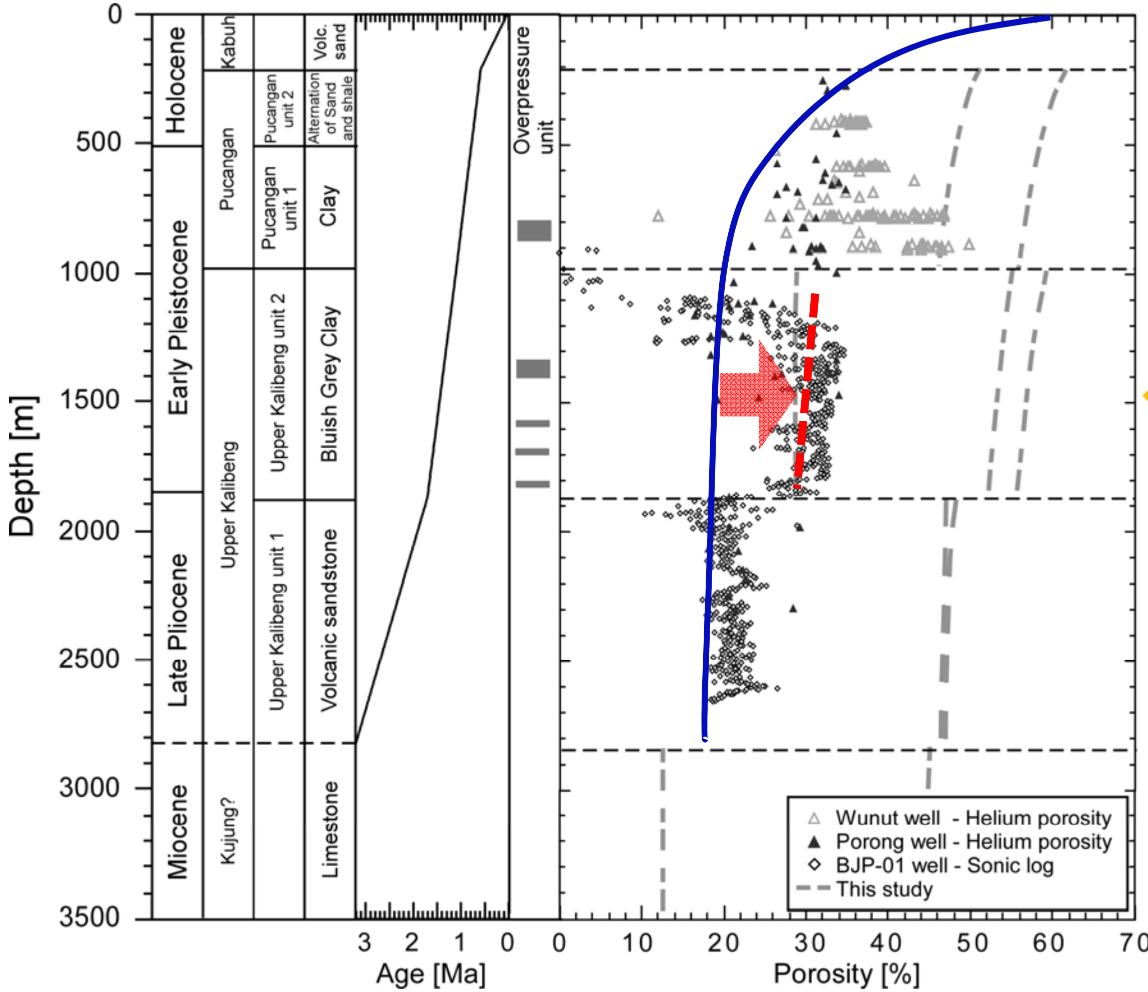
- Reduce of shear stress
- Trigger to earthquake

1.Influx of large fluid from depth (muscovite and biotite of metamorphic dehydration)

2. Permeability reduction of sediment due to consolidation

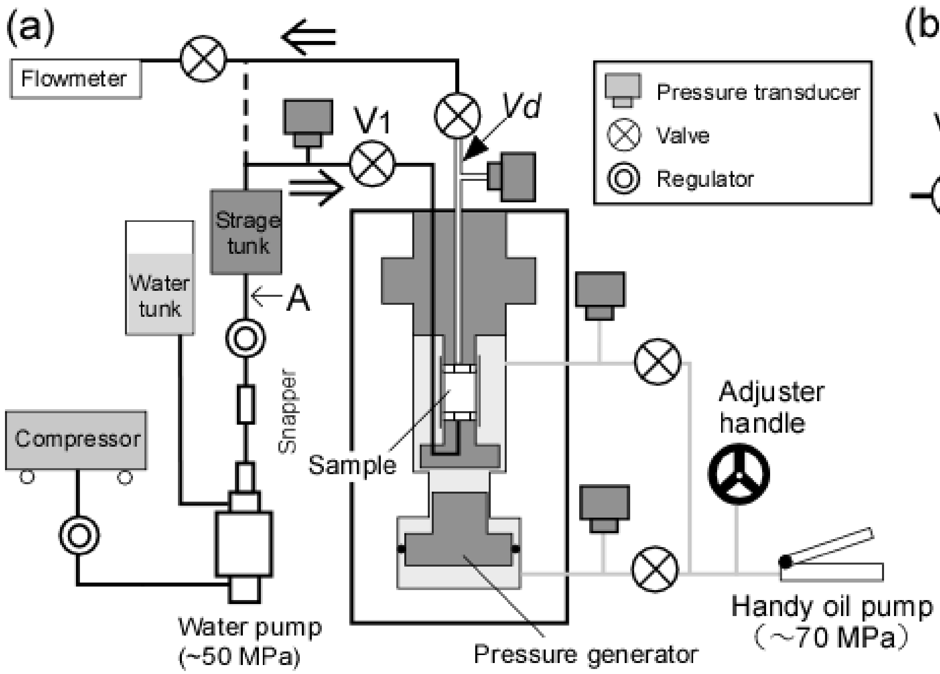
→ Process is controlled by geological setting

Porosity distribution at Banjarpanji1 well



To analyze LUSI, we used outcropped samples to cover the lithological variation of Banjarpanji1 well

Methodology



Condition – not unique ,standard test

Size：Cylinder, ϕ25mm*L20mm

Confining pressure：～150 MPa

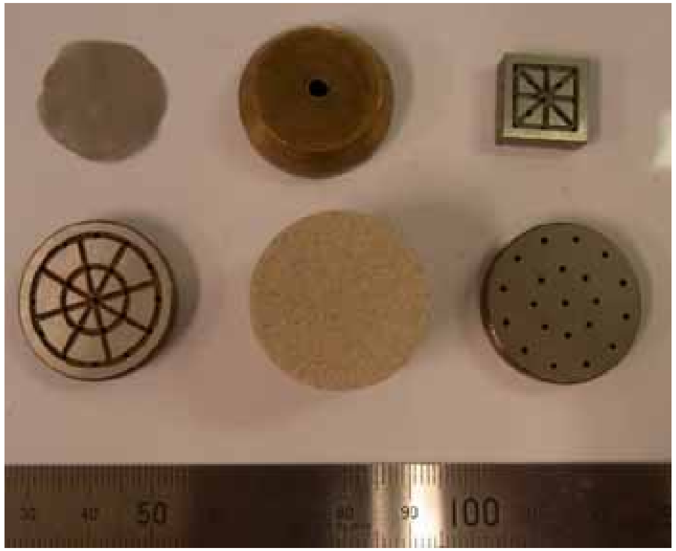
Permeability: (ΔP=<2 MPa)

Steady state flow method

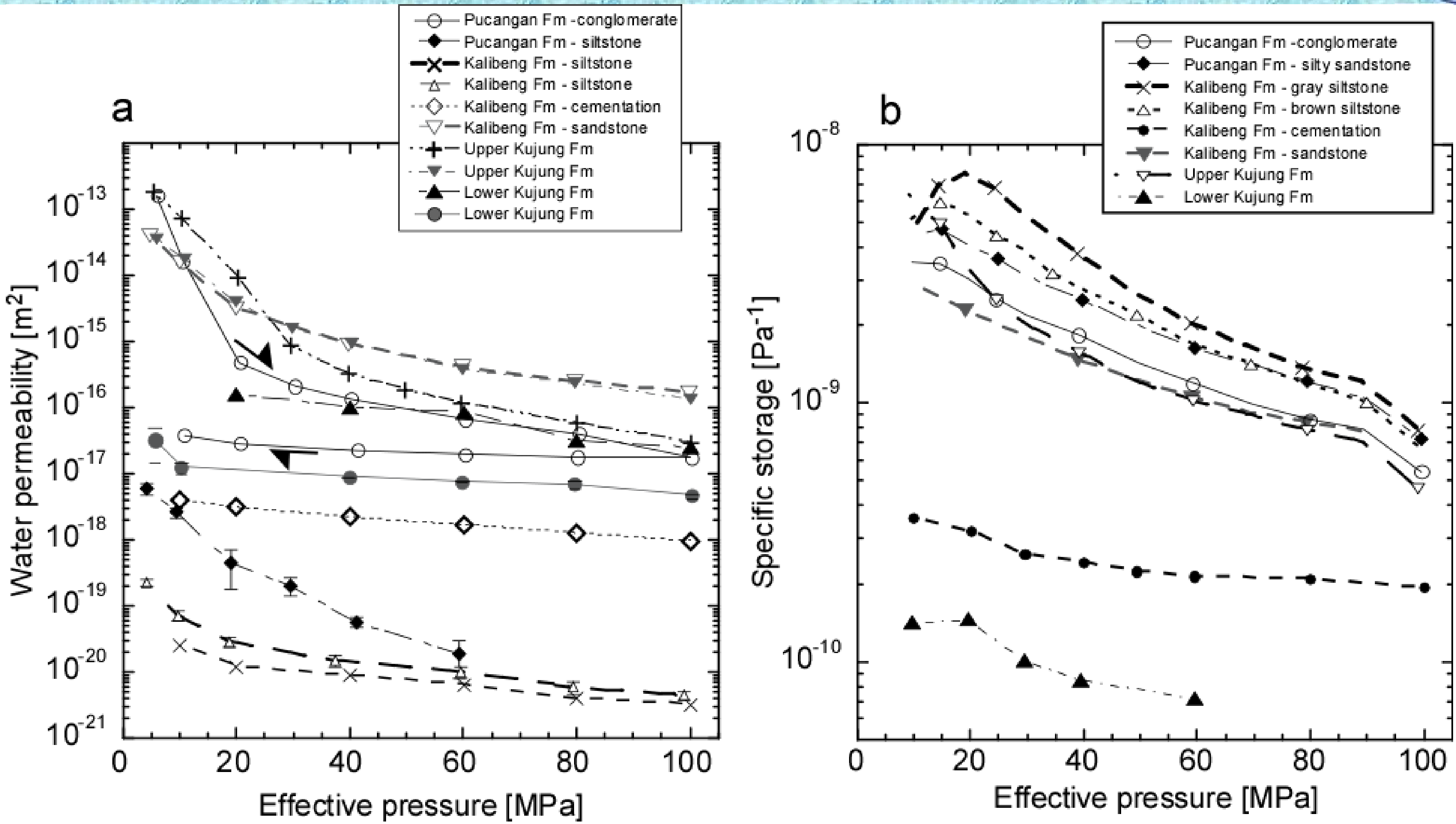
Transient pulse method

Porosity：

Ideal gas equation (PV=constant)



Result: pressure dependence

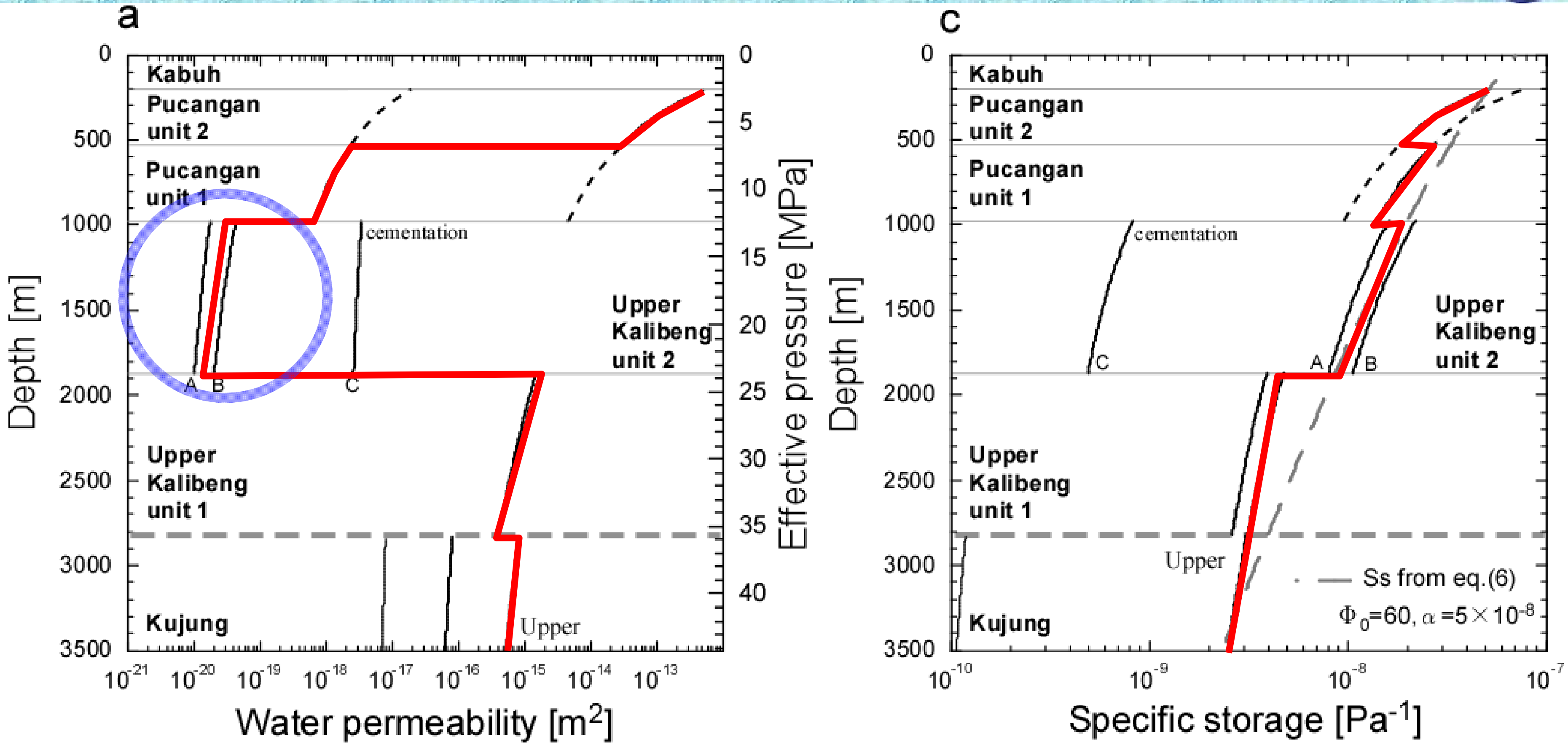


Effective pressure dependence

Permeability – Large variation (10^{-13} to 10^{-20} m^2)

Specific storage – Small fluctuation (around 10^{-8} to 10^{-9} Pa^{-1})

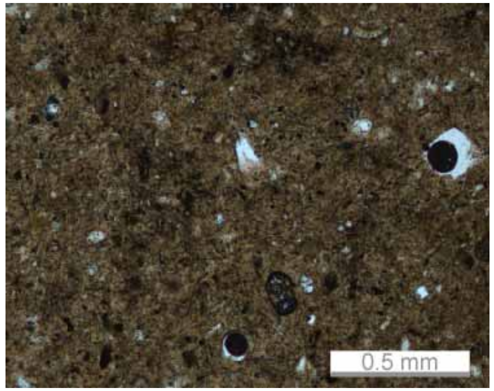
Stratigraphic variation



Permeability - Large fluctuation

Low permeability layer - U. Kalibeng Fm

Specific storage –Decrease with depth



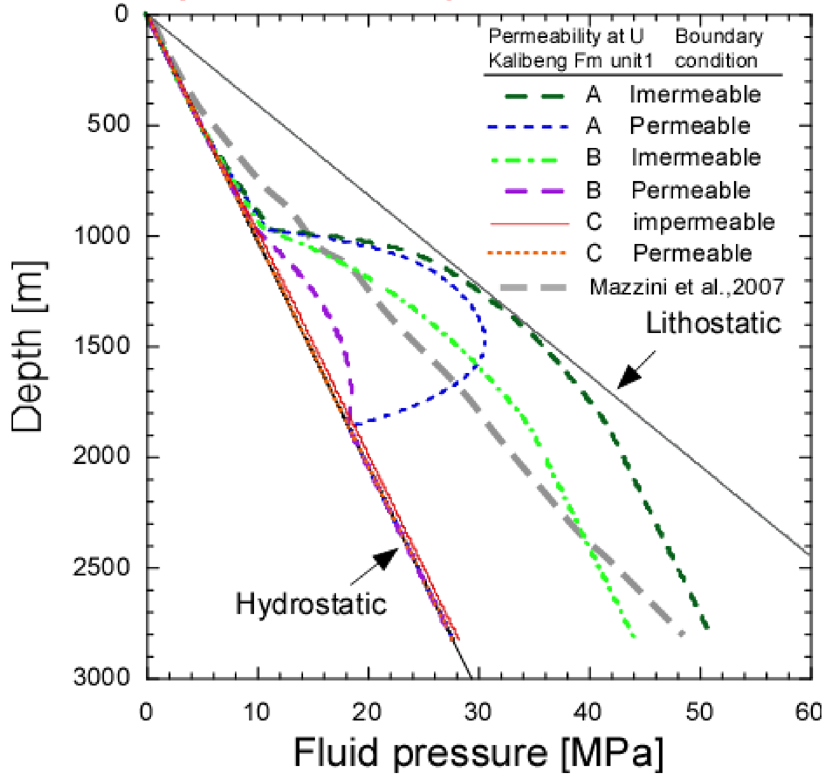
Numerical modeling result

Two specific boundary condition at the bottom (lack of information)

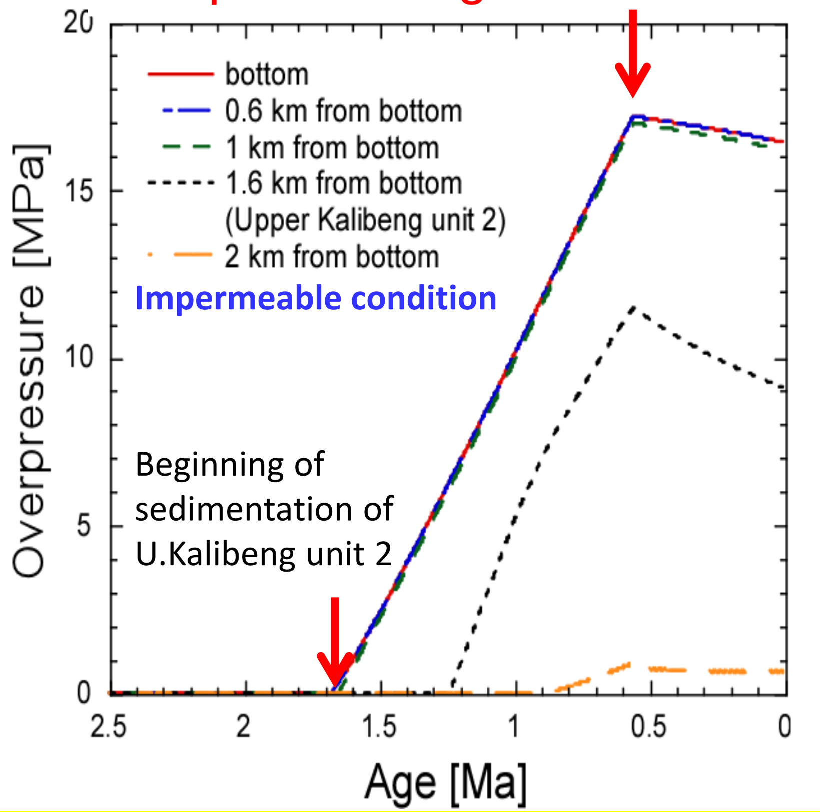
1. Permeable – hydrostatic at the boundary (possible?)
2. Impermeable – no downstream flow (often used in basin analysis)

*Constant influx might be more reasonable?

Spatial change



Temporal change



Main reason for overpressure

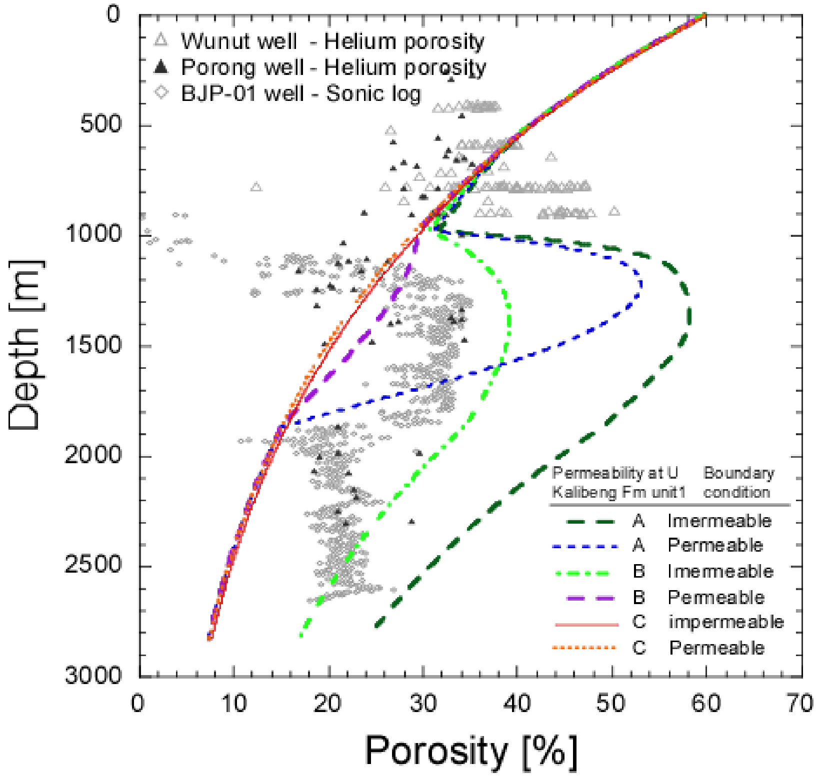
1. Thick low permeability layer 2. Rapid sedimentation rate（~1.5km/Ma）

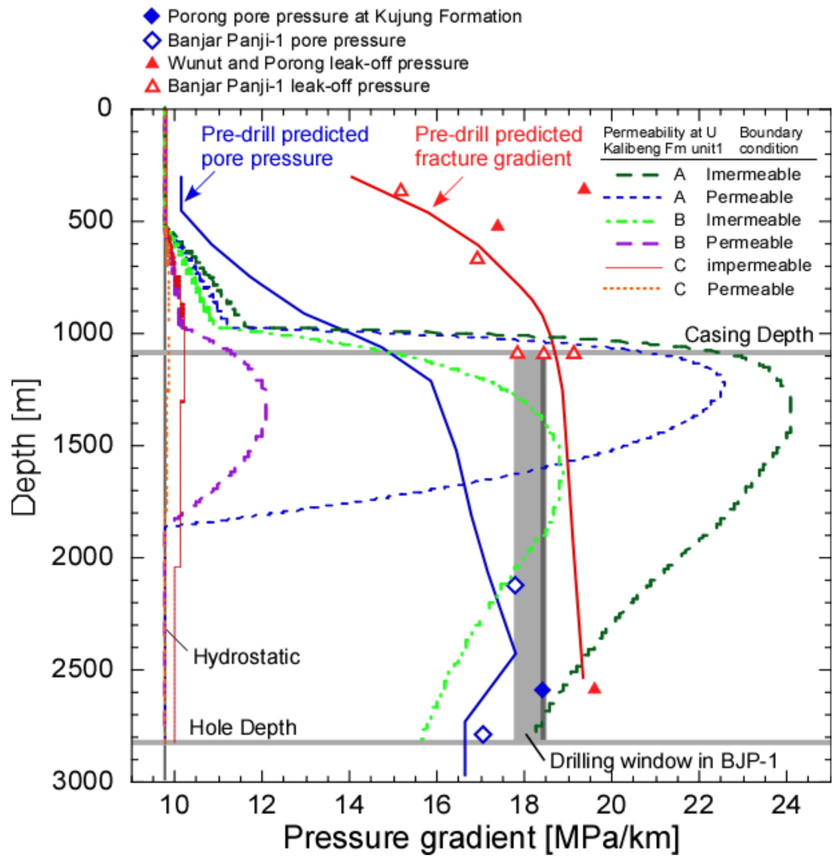
LUSI : potential to overpressure maintenance for long period

Role of overpressure in LUSI

1. Rock strength had been weak before LUSI eruption
2. Potential to cause fracturing or fluidization induced by small impulse
3. Help for reactivation of fault that generates flow path

borehole data vs. numerical results



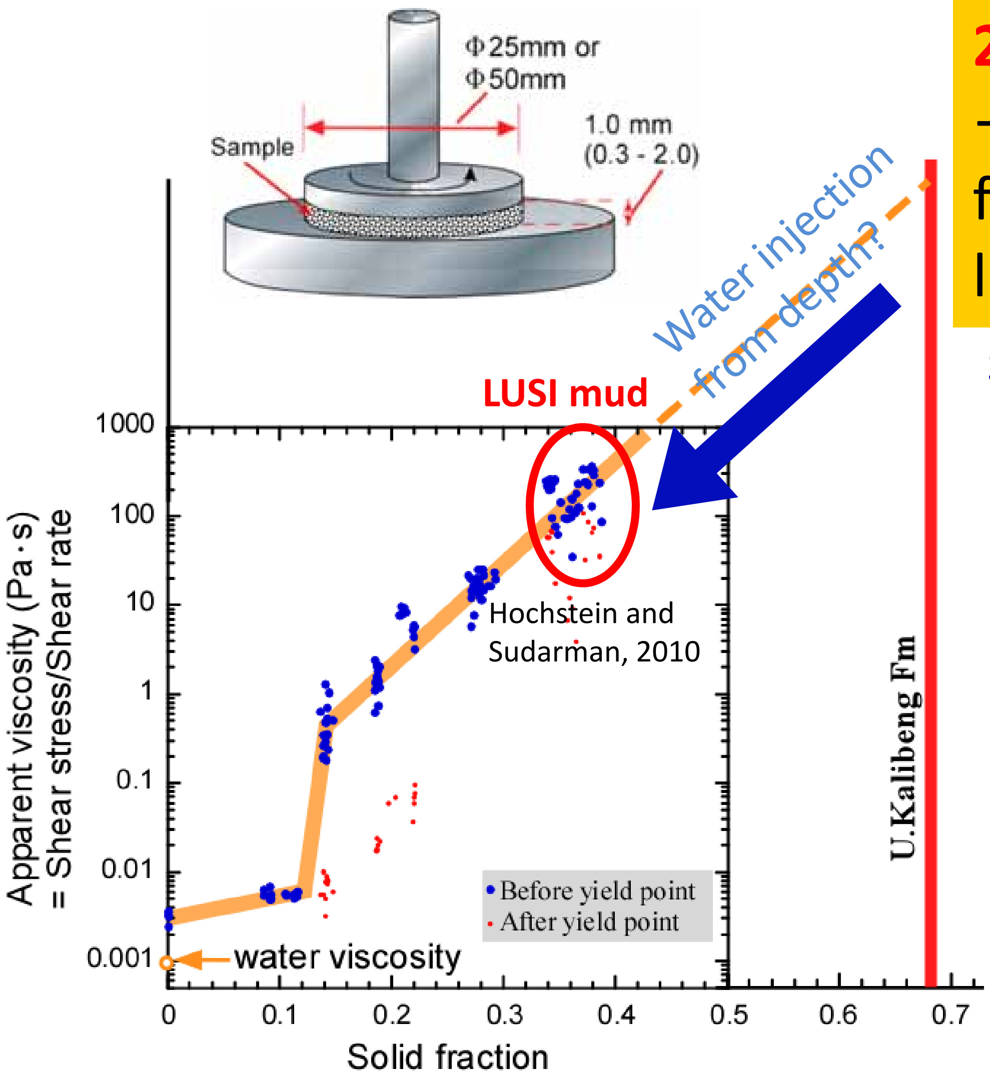


*Simplification of the numerical modeling, parameter setting, boundary condition caused errors.

Rheology of mud

Viscosity measurement

RC30 (Rheotec Ltd.), shear velocity: 10-3 ~ 1.0 m/s

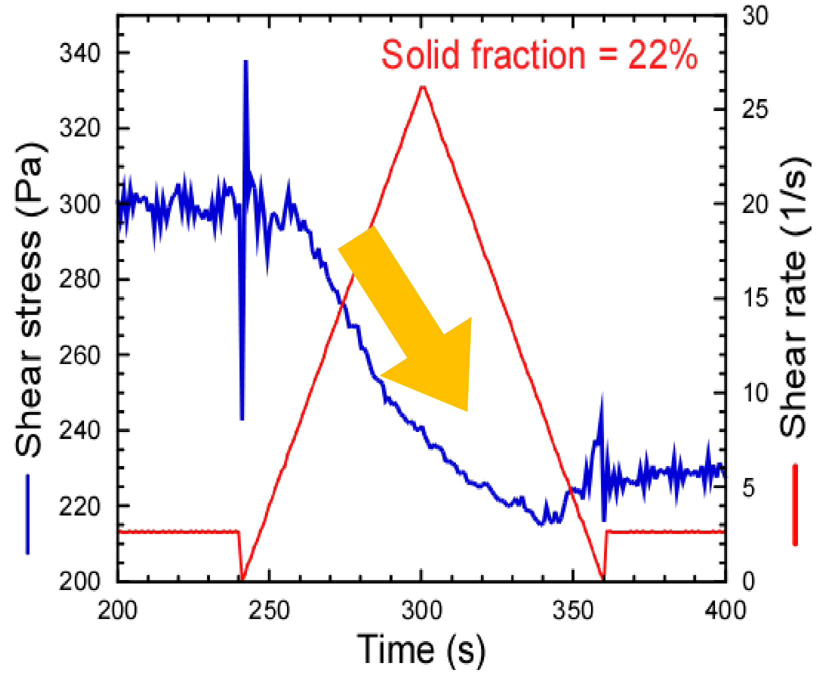


LUSI mud can loose strength by

1. **Increase in liquid fraction**
2. **Increase in strain**

→ Fluid injection and Watukosek fault activity promoted liquefaction?

Shear deformation test of MV by rheometer



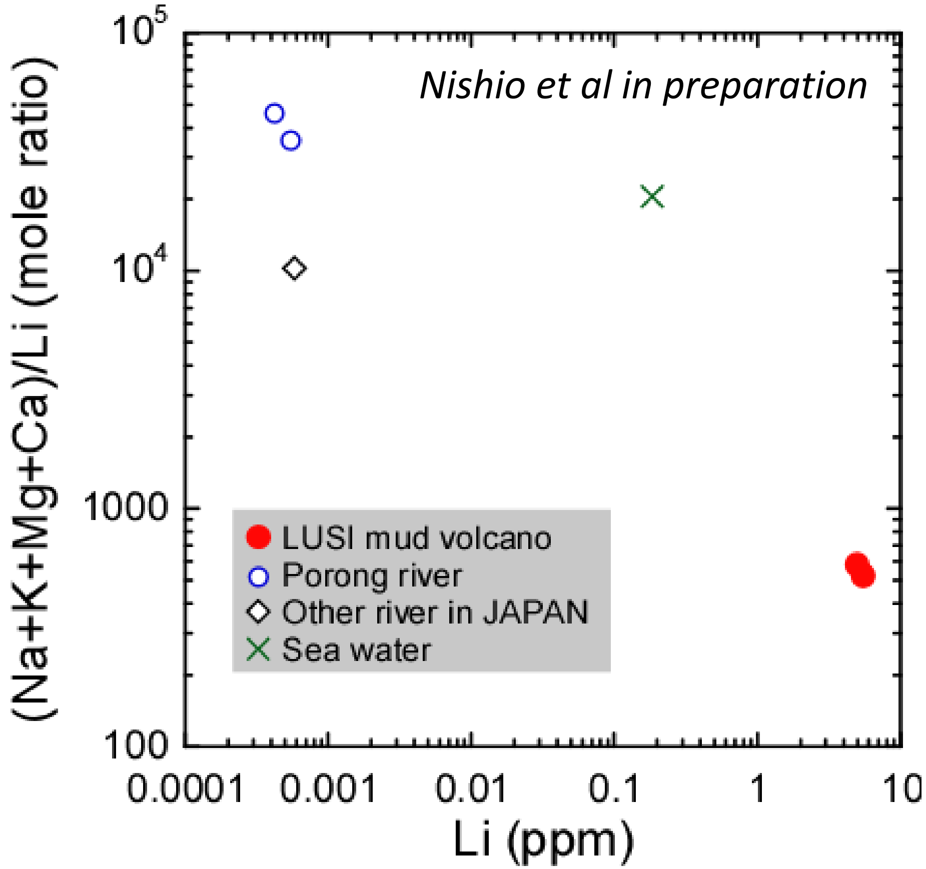
Lithium enriched geofluid in LUSI

The global demand for lithium used to make high-powered batteries for camera and hybrid cars is expected to triple in the next 15 years.

Bolivia's Uyuni Salt Flats

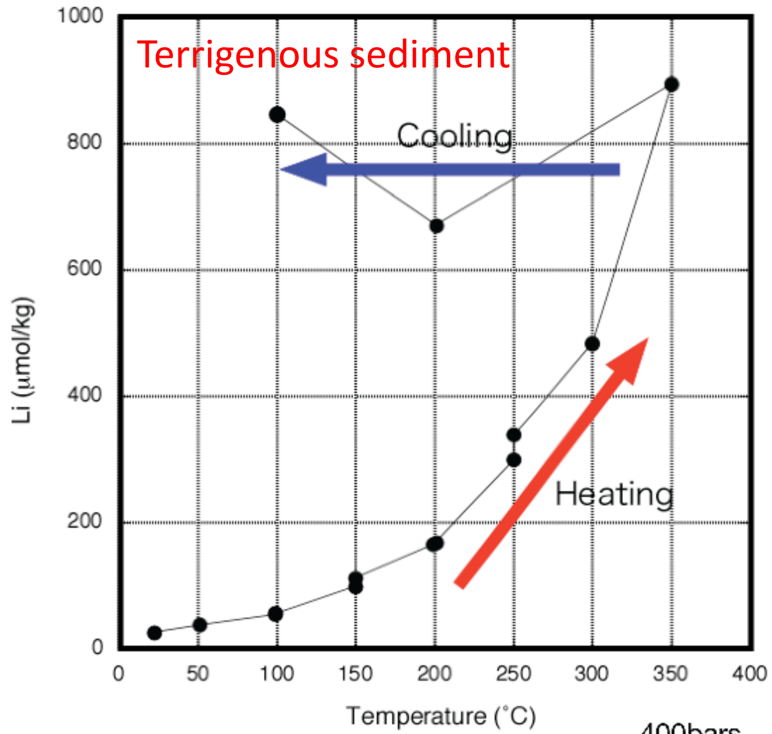
50 to 70% of the world's lithium reserves

Relatively high concentration in LUSI

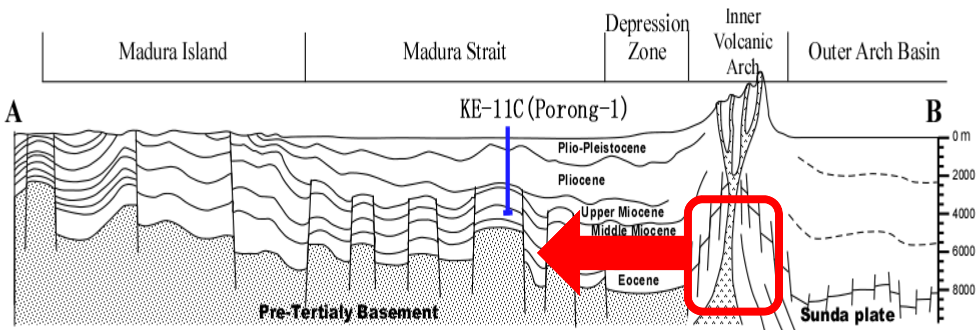


Lithium enriched geofluid in LUSI

Hydrothermal reaction test



James et al., GCA 67 (2003) 681-691

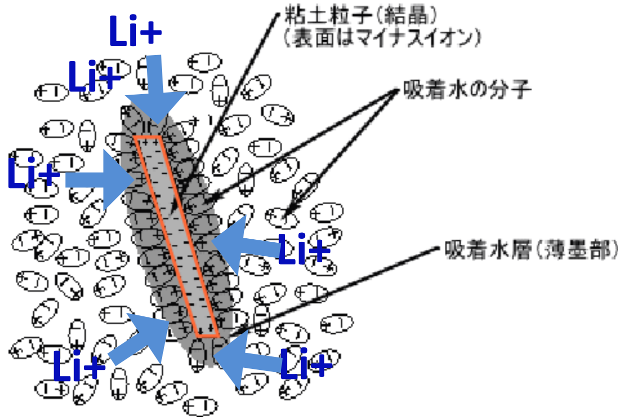


LUSI as large thermal gradient

Magmatic heat source

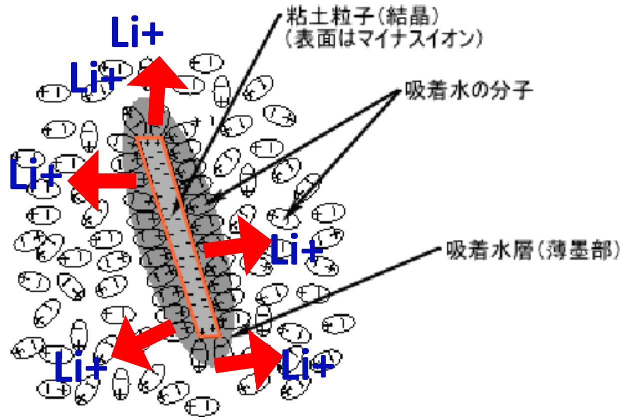
Early stage sedimentation - Low T

Rich clay mineral causes absorption of Lithium from sea water



Late stage, burial to deep - High T

Thermal desorption from clay mineral is occurred in hydrothremal condition.



Summary

Fluid overpressure had long been maintained at depth of East Java basin and at LUSI as well

・Rapid sedimentation rate
・Thick impermeable layer

Strong potential to generate natural MV and eruption

・Overpressure generated at shallow depth
・Strike slip fault (Watukosek Fault) - flow path?

Future plan and my Interest

・Rheology and strength of sediment.
・Drilling to fault zone to understand fault zone process.