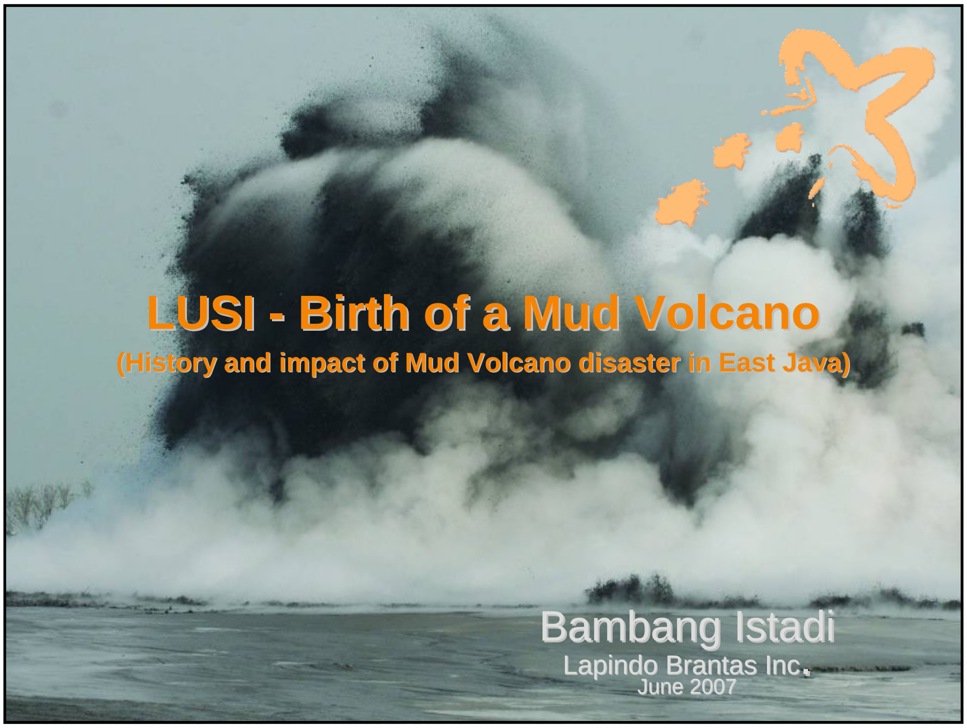
LUSI - Birth of a Mud Volcano

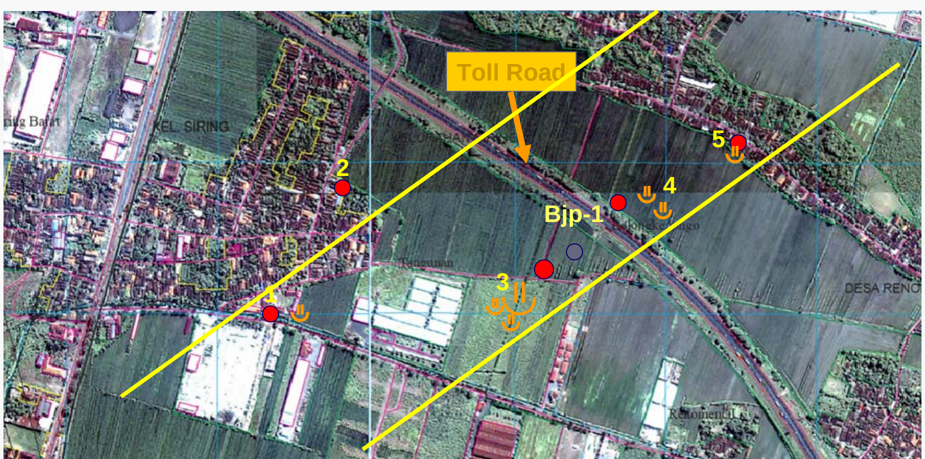
(History and impact of Mud Volcano disaster in East Java)



Bambang Istadi
Lapindo Brantas Inc.
June 2007

LUSI - Sidoarjo Mud Volcano

- **Appears approx. 200m from BJP-1 well**
- Forms a lineament
- Geyser behavior (?) (Empty chambers periodically before new burst)
- Pulsations
- Forming an upwelling or volcano like structure



Survey point   Banjar Panji 1 Well   Mud Extrusion

Gempa Jogya : 27 Mei 2006

1. Sumur bor +/- 80 m keluar air + pasir hitam.
2. Keluar air pekat dari lantai.
3. **SEMBURAN PERTAMA** 29 MEI 2006 150 M SW DARI SUMUR
4. **SEMBURAN KEDUA** 1 JUNI 2006 150 M NE DARI SUMUR (Keluar air semburan di lima titik)
5. **SEMBURAN KETIGA** 1 JUNI 2006 500 M NE DARI SUMUR

-SAAT INI HANYA DI LOKASI SEMBURAN PERTAMA YANG MASIH AKTIF

Cracks at the rig site

Cracks at location was not followed by gas or fluid coming out, suggest that it was not caused by pressure, but dislocation due to earth movement

LUSI eruption sites

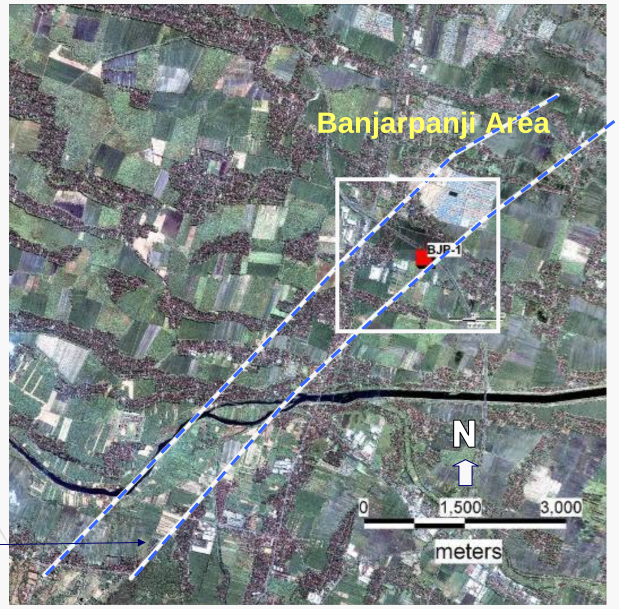
The broaches were in one straight line,

→ not typical of underground blowout.

WATUKOSEK FAULT LINEAMENT

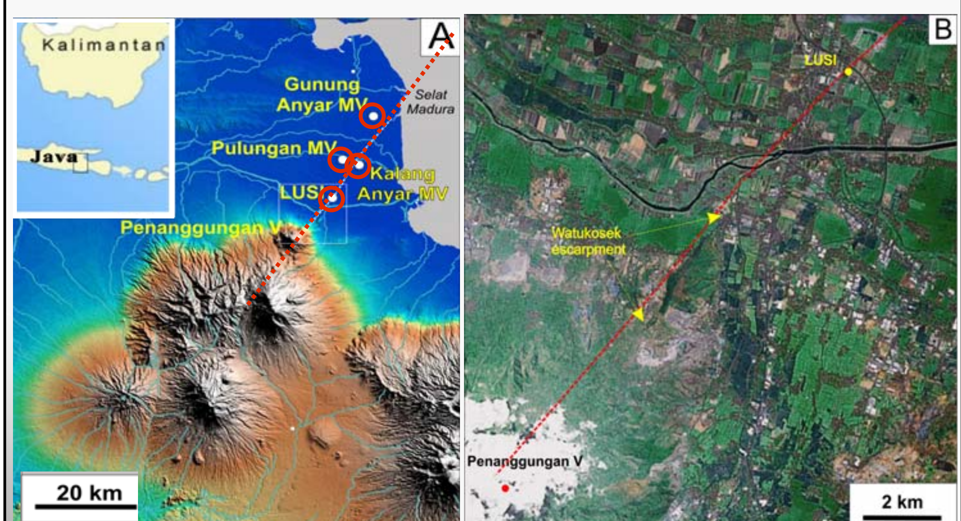
- 2 parallel faults
- River aligned along fault line
- Escapement- up thrown block of fault

- A very long propagating fracture appears due to tectonic activities / earth quakes in the region



Escarpment

LUSI and faulting

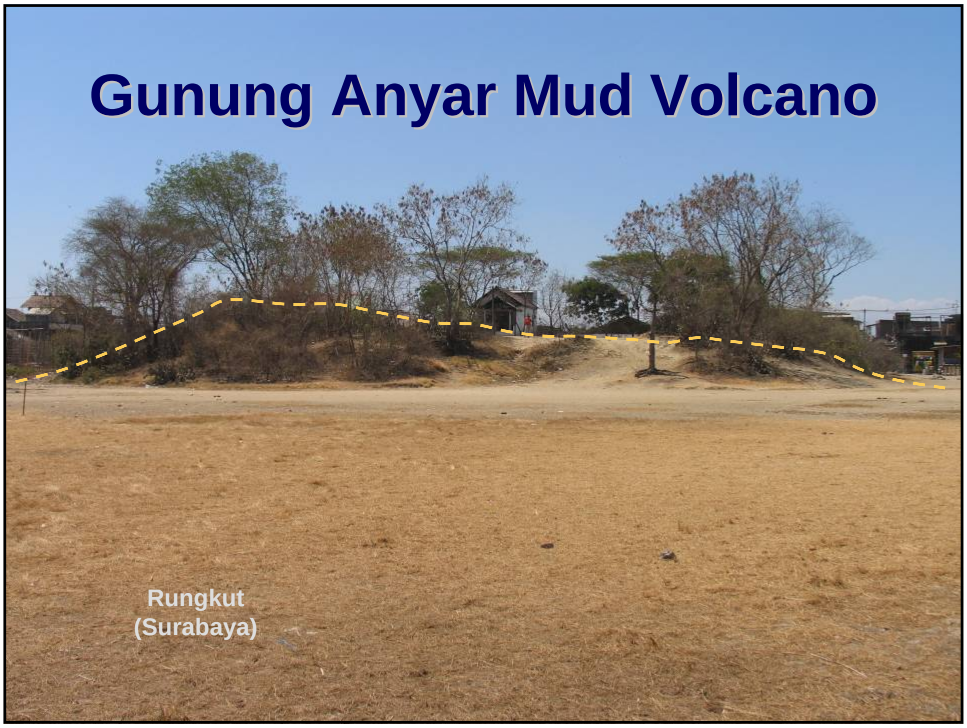


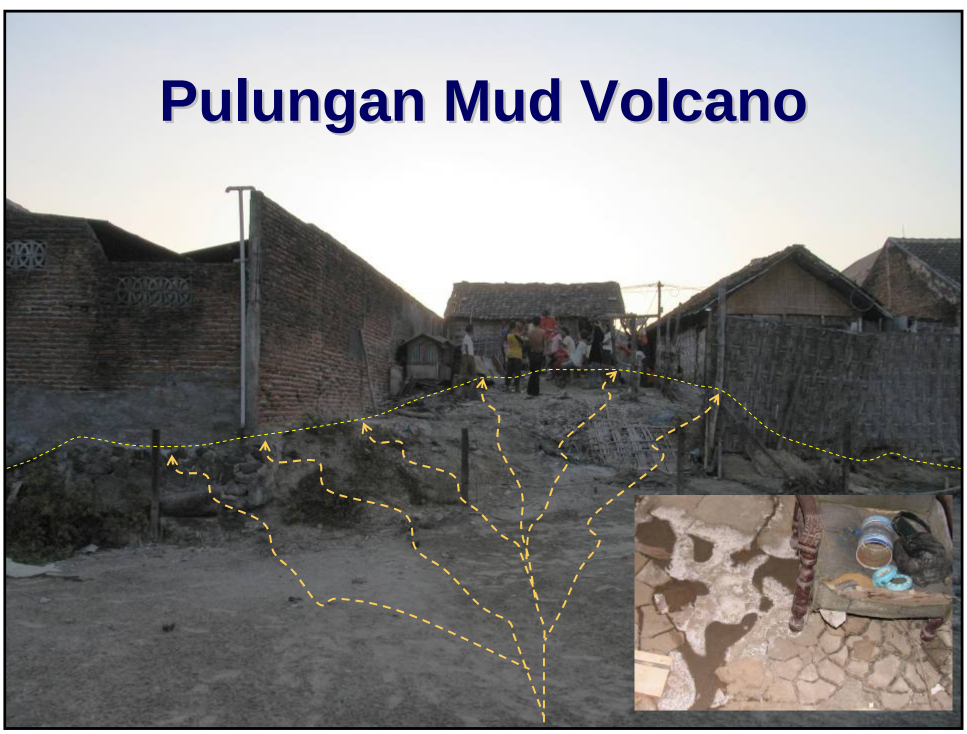
Kalang Anyar MV

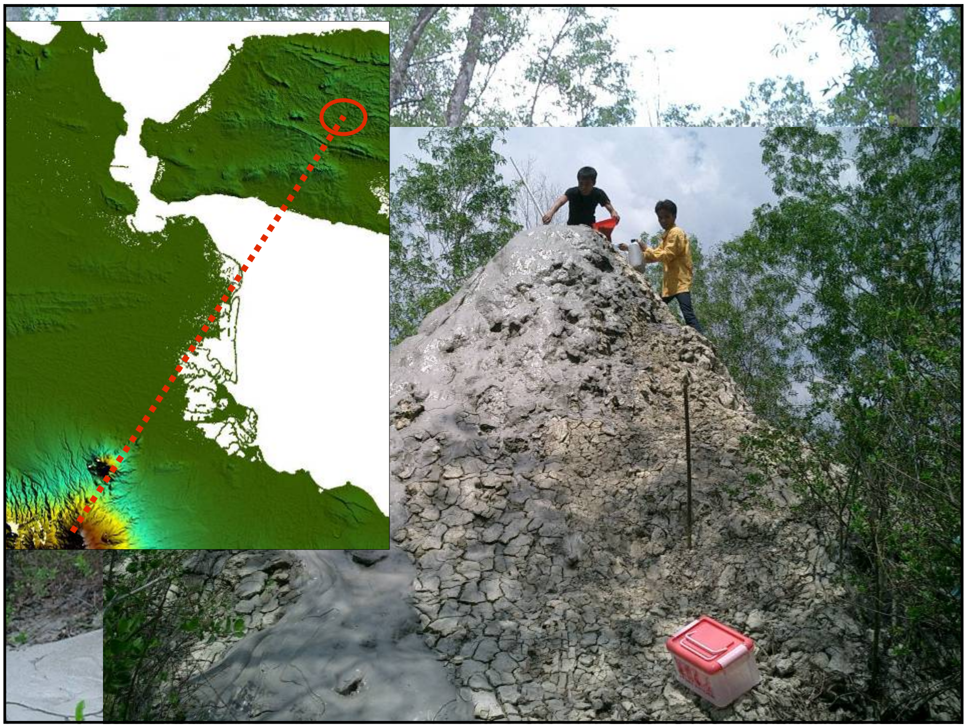
Microbial colonies

Salts/Halide

Oil Seeps

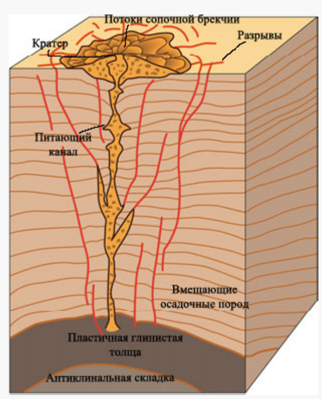

Gunung Anyar Mud Volcano
Rungkut
(Surabaya)


Pulungan Mud Volcano



Mud Volcano Processes

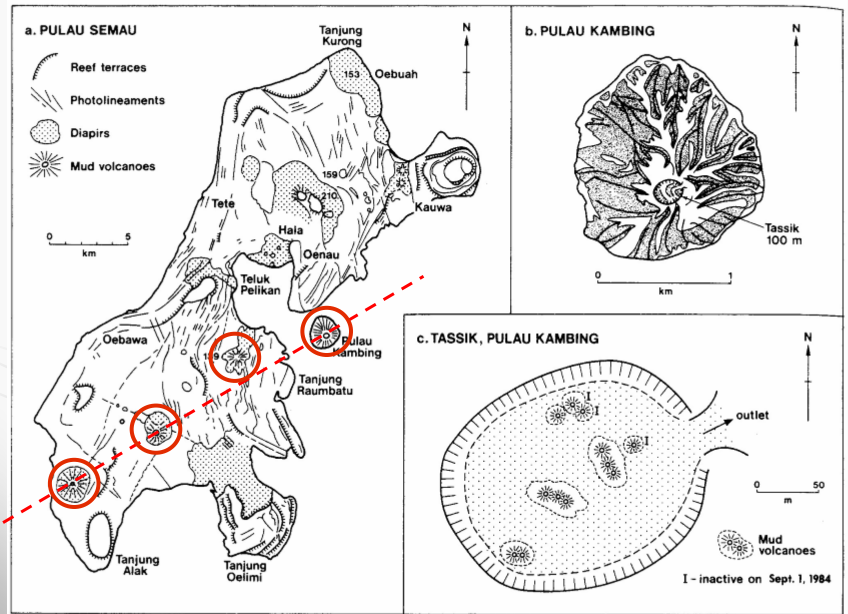
1. Rapid sedimentation and burial trapping excess water
2. Sedimentary loading resulting in abnormally high pore pressures in undercompacted shale formations
3. Mud volcanoes appear to be related to lines of fracture, faulting, or sharp folding.
4. Eruptions can occur when mud and sand are squeezed upwards by seismic forces.
5. A disturbance of the gravitational instability may trigger the beginning of flow, which may be orogenic tectonism
6. The sudden release and upward expansion of dissolved gases may also play a key role.



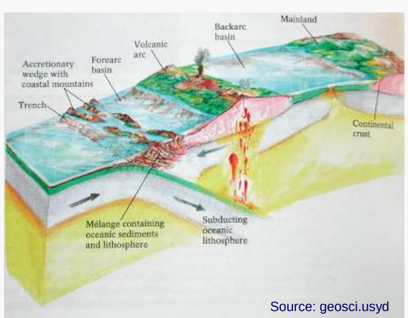

Mud Volcanoes in South Timor
Photo : Courtesy of Dr. Untung Sumotarto (BPPT)

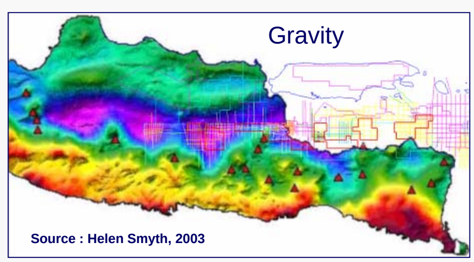

Close-Up of Mud Volcano Peak
in South Timor
Photo : Courtesy of Dr. Untung Sumotarto (BPPT)

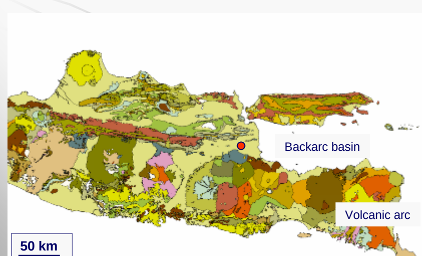
Mud Volcanoes at Semau Island, west of Timor



East Java: Geological Setting

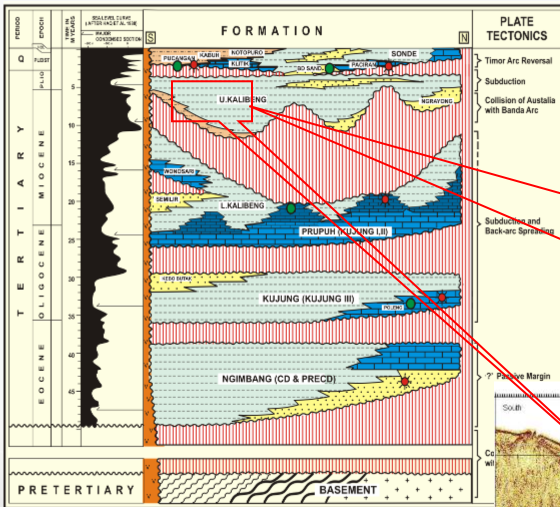






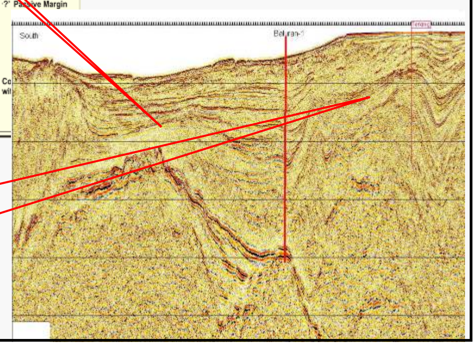
- **Convergence** of plate boundaries and the **subduction** of the oceanic plate
- Northern part of Java: **backarc** basin, Tectonically active Kendeng zone
  - **Extensional** regime → Rapid subsidence and burial
  - **High sedimentation** rate → Under-compacted unstable shales
  - Deposition of **organic-rich** sediments → production of **Hydrocarbon**

→ **ideal setting for MV**



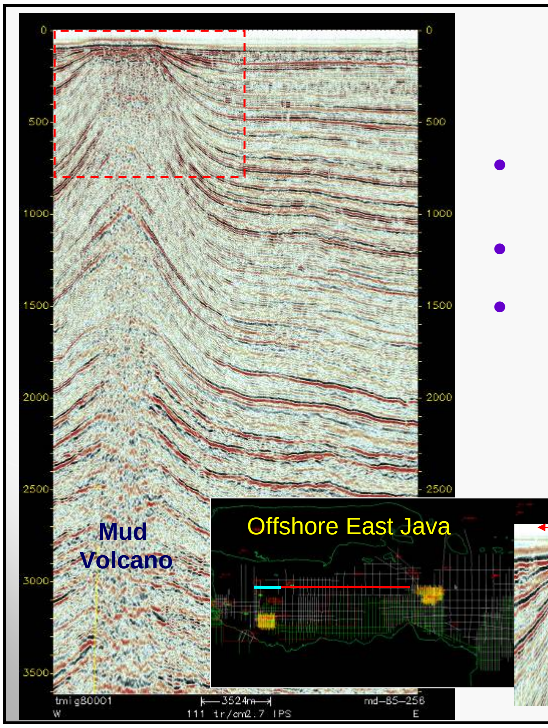
STRATIGRAPHIC SETTING OF PORONG SUB-BASIN KENDENG ZONE

the source of the mud volcano is highly plastic, undercompacted mud or shale or a mud diapir. Commonly appear related to fracture, faulting or sharp folding in the earth's crust



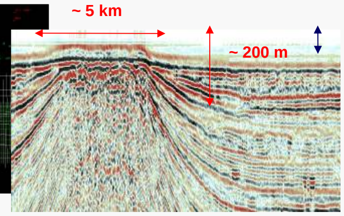
Mud volcano commonly is the result of a piercement structure created by a pressurized **mud diapir/overpressured shale**

Modified from S Asikin, 2006

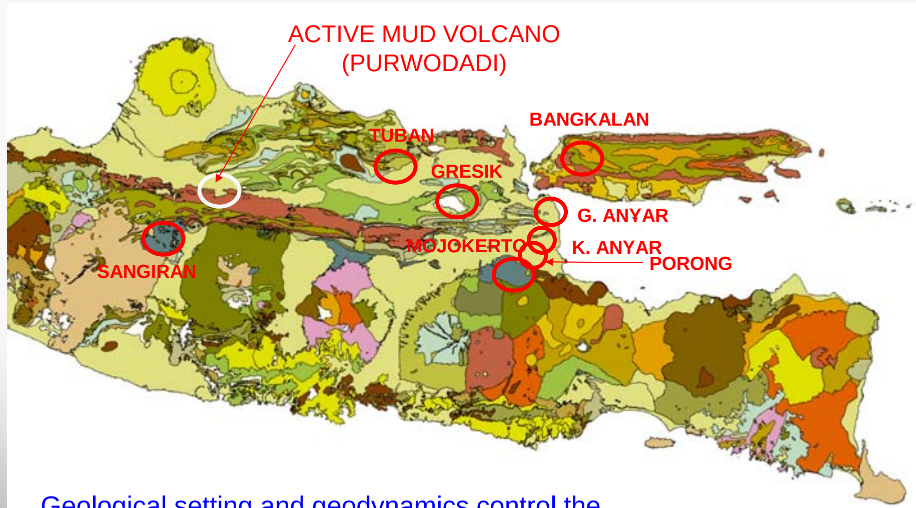


CONTROL MECHANISM

- **Presence of a layer or zone in which has a lower density than the overlying rock units.**
- **The low density material to have an ability to flow.**
- **A disturbance of the gravitational instability to trigger the beginning of flow, which may be :**
  - **Orogenic tectonism**
  - **piercement structures high pressure release**



Other Mud Extrusion/ Mud Volcano in East Java



Geological setting and geodynamics control the distribution of mud volcanoes in East Java.

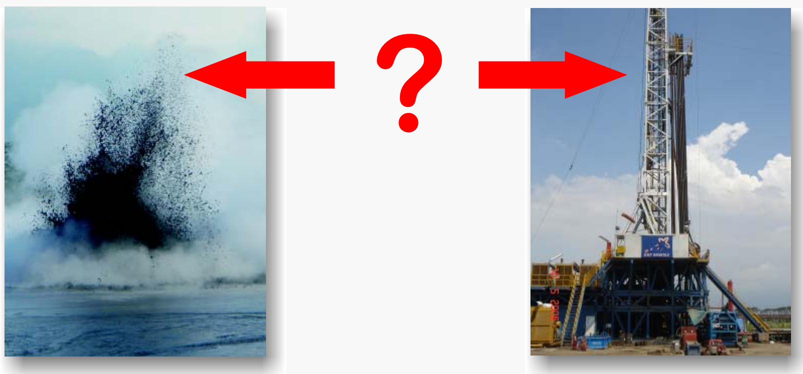
Analogues

BLEDUK KUWU

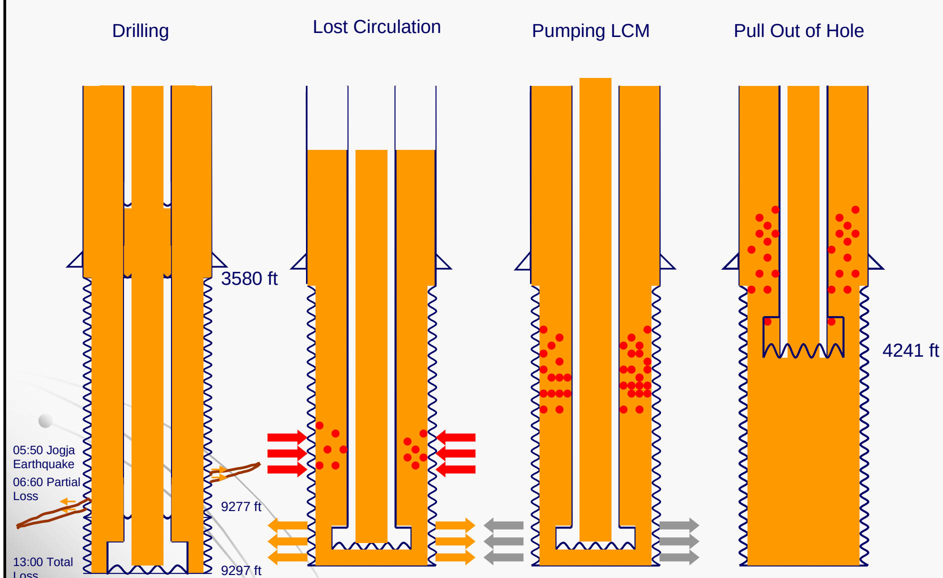
ACTIVE MUD VOLCANO (PURWODADI)

GRESIK
MUD VOLCANO

Related to the Banjarpanji-1 well ?

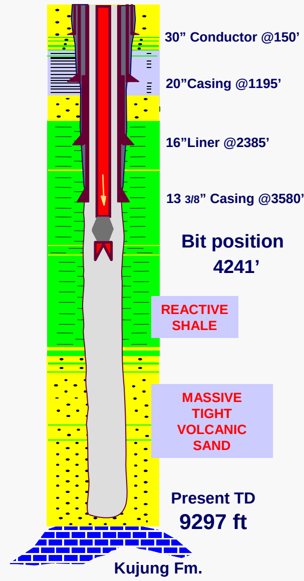


Possibilities ?



Why The Broaches Did NOT Come From The Well ?

- Partial loss of drilling mud 10 minutes after earthquake, 7 hours later complete loss circulation.
  - Suggest possible connection.
- No evidence of Kujung Formation penetration.
- Initial 320,000 bbl/day mud flow is impossible from a single 12-1/4" hole size.
- Gas+water kick entered the well bore during loss circulation, and brought up to surface while tripping and pumping out.
  - No high pressure and/or annulus evacuation by gas/water.
- Initial Shut in Pressure of 350 psi. Found gas/water (8.9 ppg) flow to surface,
  - Hydrostatic pressure in the annulus will be less than the formation strength.
  - Very unlikely could break the formation.
- Able to pump and circulate mud after broaches
  - Proves NO communication between bit and the broaches.



Did the May 27 Yogyakarta trigger the mud volcano ?

Mw 6.3

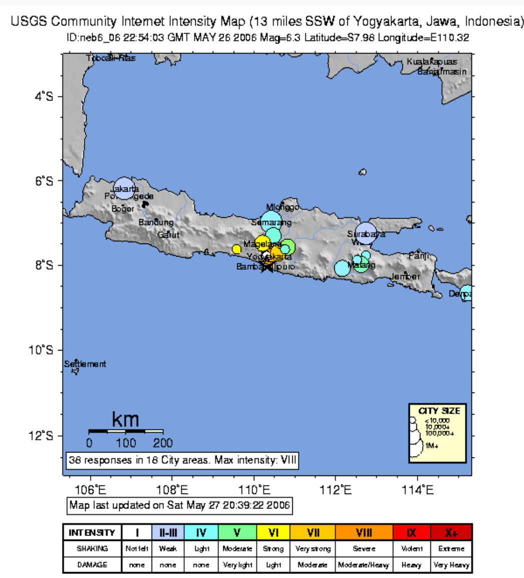
Distance ~250 km

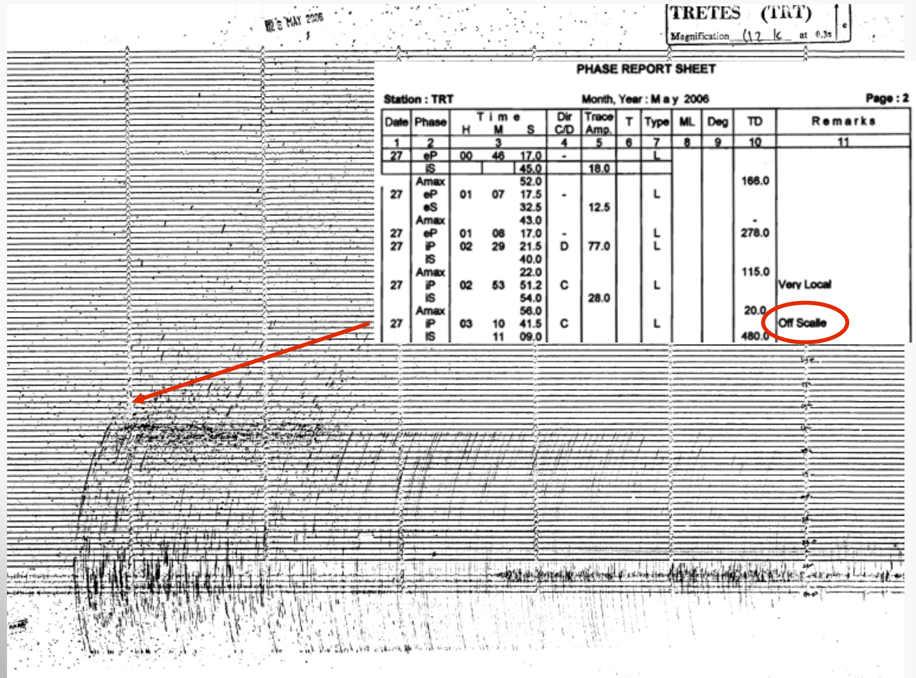
Surabaya: II-III MMI (Modified Mercalli Intensity), 3.0-3.9 Mw (Moment Magnitude)

Karang Kates: III-IV MMI, 4.0-4.9 Mw

Pasuruan II-III MMI

Tretes III-IV MMI

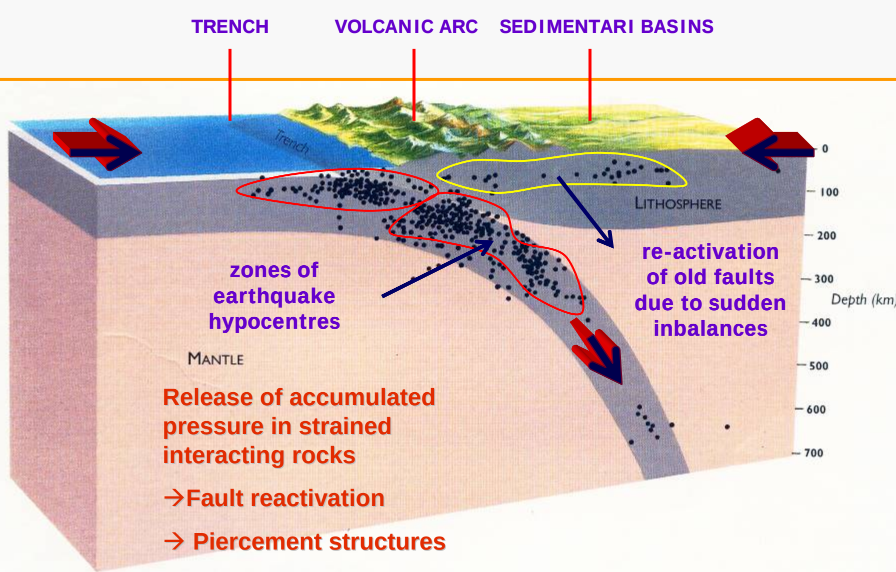




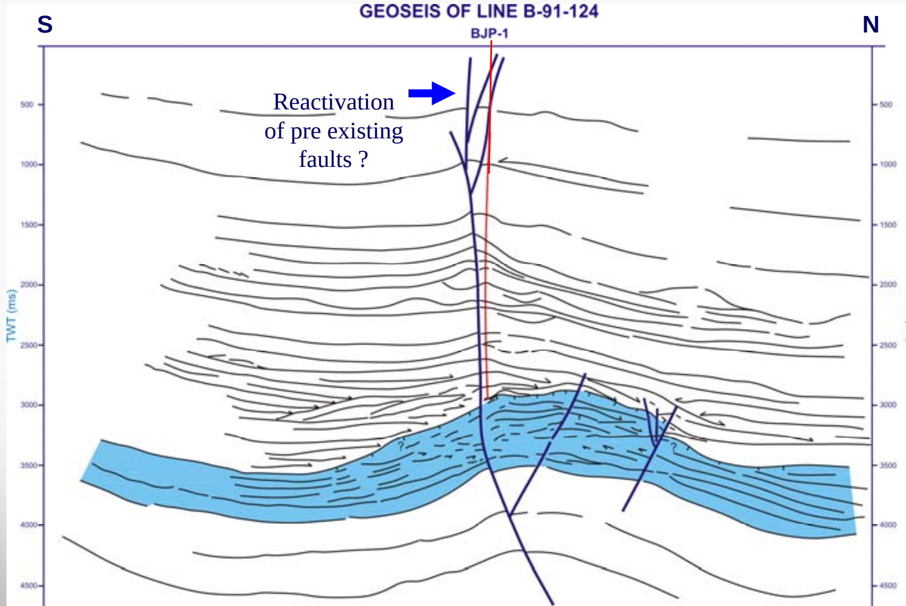
PHASE REPORT SHEET

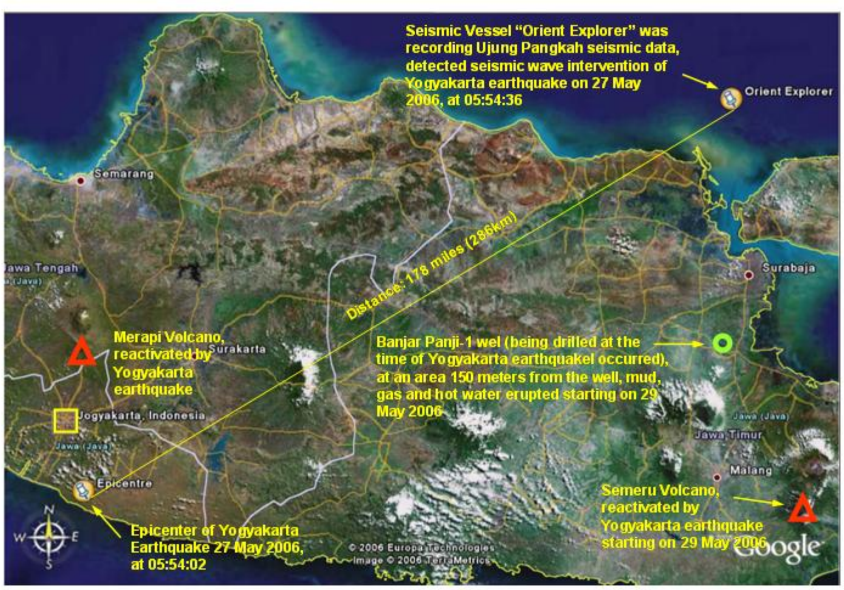
Station : TRT   Month, Year : May 2006   Page : 2

Date	Phase	Time H	Time M	Time S	Dir C/D	Trace Amp.	T	Type	ML	Deg	TD	Remarks
1	2	3			4	5	6	7	8	9	10	11
27	eP	00	46	17.0	-			L				
	IS			45.0		18.0						
	Amax			52.0							166.0	
27	eP	01	07	17.5	-			L				
	eS			32.5		12.5						
	Amax			43.0							-	
27	eP	01	08	17.0	-			L			278.0	
27	iP	02	29	21.5	D	77.0		L				
	IS			40.0								
	Amax			22.0							115.0	
27	iP	02	53	51.2	C			L				Very Local
	IS			54.0		28.0						
	Amax			56.0							20.0	
27	iP	03	10	41.5	C			L				Off Scalle
	IS		11	09.0							480.0	



RELATION BETWEEN PLATE MOVEMENT, PLATE INTERACTION AND EARTHQUAKE DISTRIBUTION

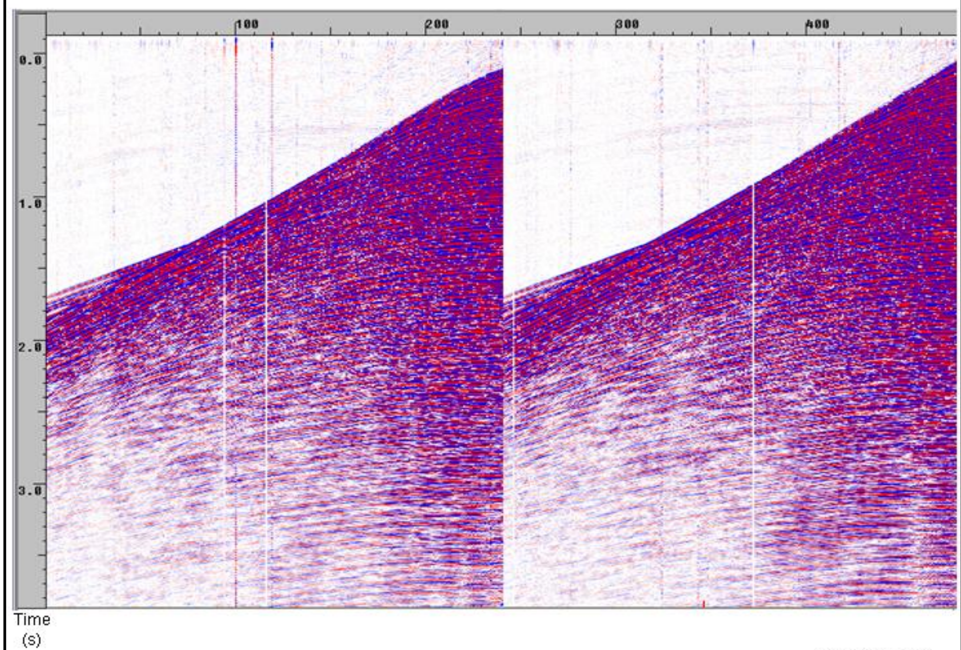




Erupsi Gunung Lumpur Banjar Panji Bisa Berhubungan dengan Gempa Yogyakarta 27 Mei 2006

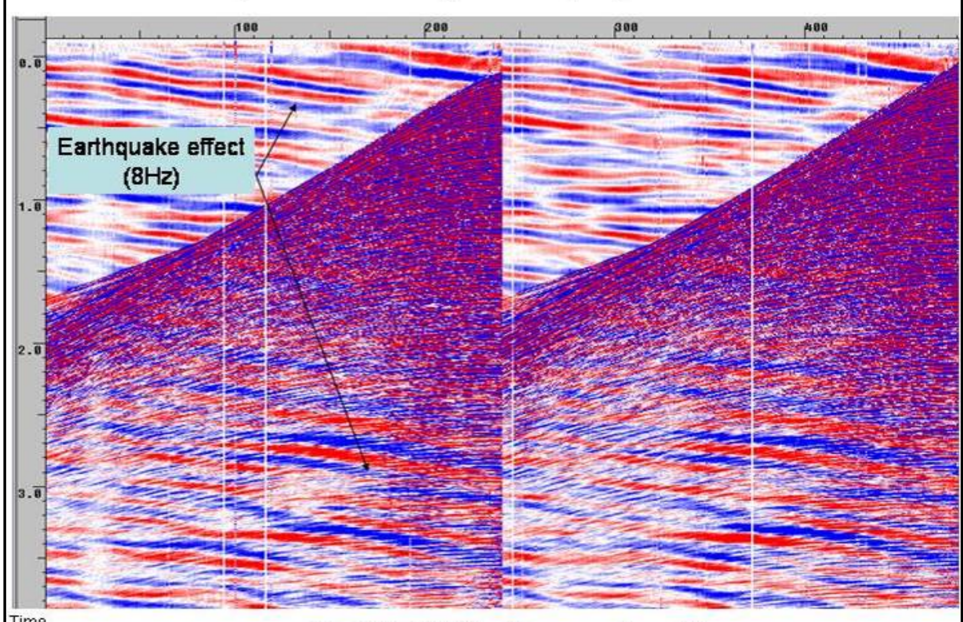
Awang H. Satyana

ShotPoint 2080 – Streamers 1 and 2 – Just before the earthquake



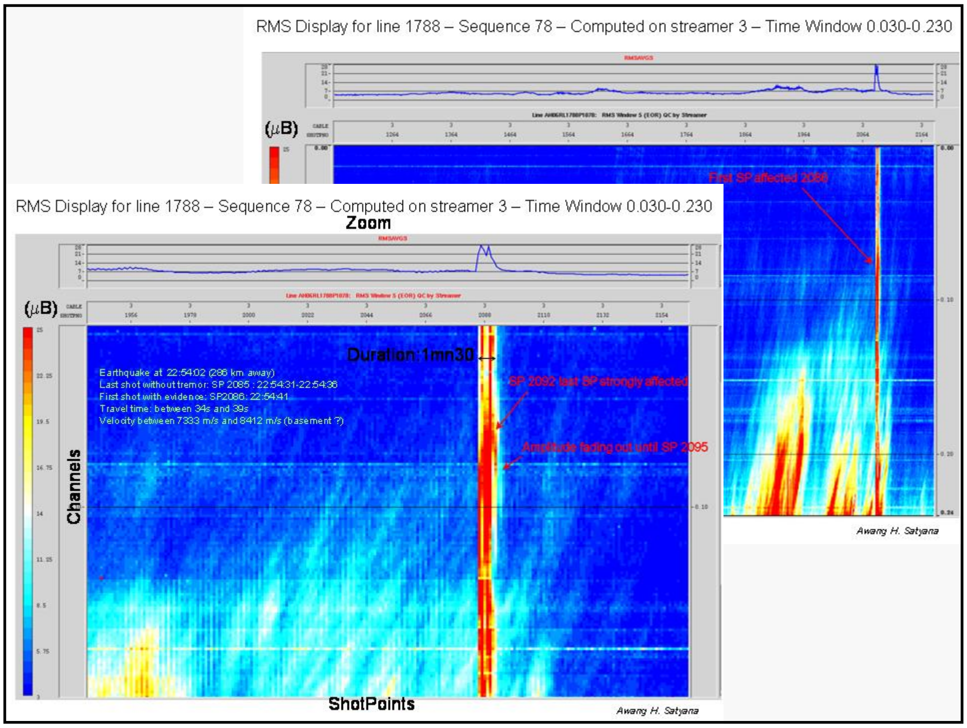
Awang H. Satyana

The Orient Explorer was recording Line 1788, Sequence 78. ShotPoint2090



ShotPoint 2090 – Streamers 1 and 2

Awang H. Satyana



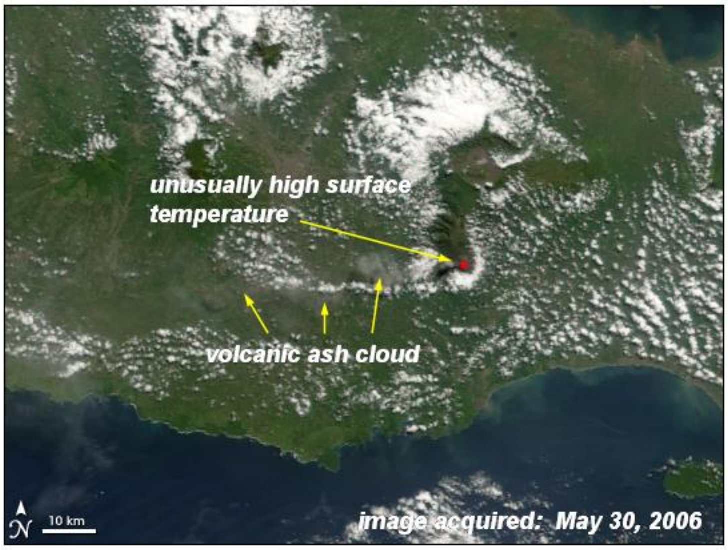
Mt. Semeru

Effective March 29, the East Java Office of Energy and Mineral Resources and Semeru Volcanic Observatory increased the danger level of Mt. Semeru to Alert Level 2 (Code Yellow – Danger). The East Java Office of Energy and Mineral Resources urged tourists and others not to climb Mt. Semeru higher than 1 kilometer from the top.

Visual observations showed increased sulferous gases 50-75 meters from the crater and numerous gas explosions rising 300-600 meters up from the crater.

http://earthobservatory.nasa.gov/NaturalHazards/Archive/May2006/semeru_tmo_2006150_lrg.jpg

Awang H. Satyana



http://earthobservatory.nasa.gov/NaturalHazards/Archive/May2006/semeru_tmo_2006150_lrg.jpg

Just three days after an earthquake struck Java, on May 27, 2006, the Semeru Volcano showed signs of heightened activity. The Moderate Resolution Imaging Spectroradiometer (MODIS) flying onboard NASA's Terra satellite took this picture on May 30, 2006. In this image, Semeru's summit is outlined in red. The outline indicates that MODIS detected unusually high surface temperatures. To the west of the summit are gray-brown clouds that dissipate as they move westward. These clouds could result from volcanic ash emitted by the Semeru Volcano.

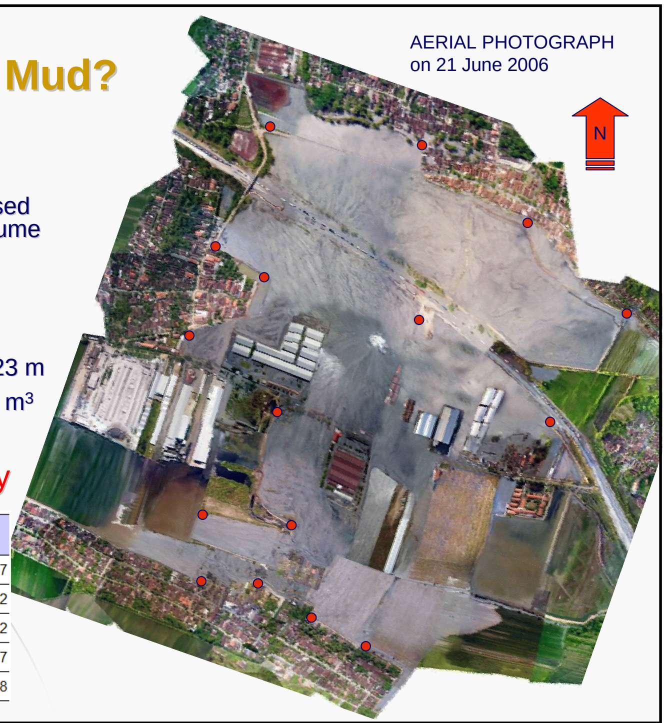
Awang H. Satyana

How Much Mud?

- Survey of height of mud on 16 points
- 3D Analysis was used to calculate the volume of the mud.
- Area of Mud : 1,108,444 m^2 or 110.84 ha
- Circumference: 6523 m
- Volume: 1.1 million m^3
- Discharge rate :
- 50,785 m^3 /day

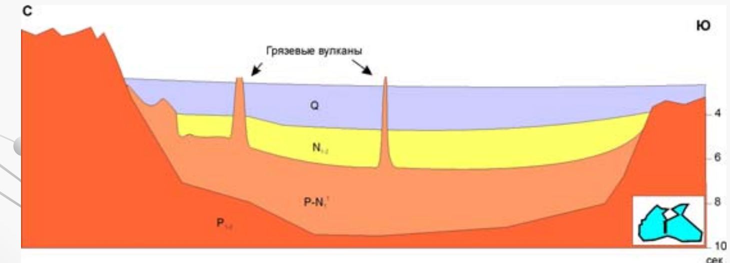
Date	Area (ha)	Volume (m^3)
Aug 29, 2006	349.78	4,438,037
Sep 29, 2006	349.78	6,012,372
Oct 29, 2006	349.78	7,535,922
Nov 29, 2006	390.09	9,110,257
Dec 24, 2006	418.30	10,249,478

AERIAL PHOTOGRAPH on 21 June 2006



Main tectonic regimes favourable for mud volcanism

Compressional regime - Active continental margin. Accretional complex

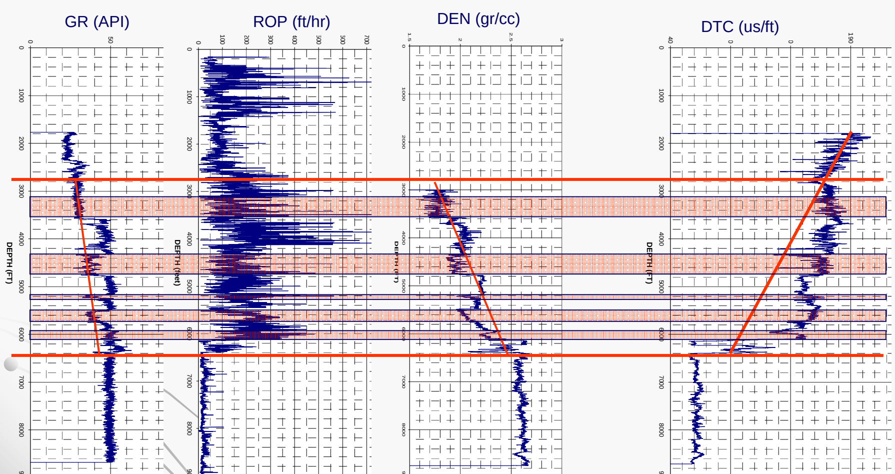


Rapid subsidence-burial Passive continental margin or back arc setting with high sedimentation rate.

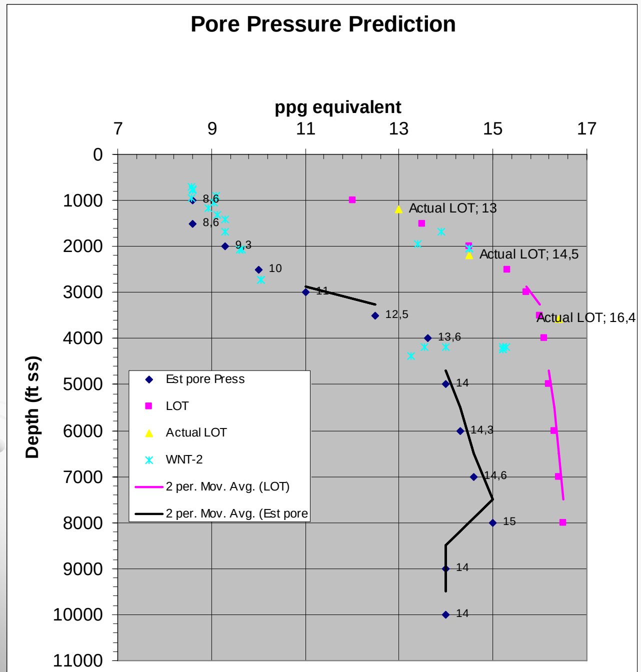
Indonesia: perfect location for MV manifestation where both regimes occur

Modified from Akhmanov (2006)

Overpressure Zones

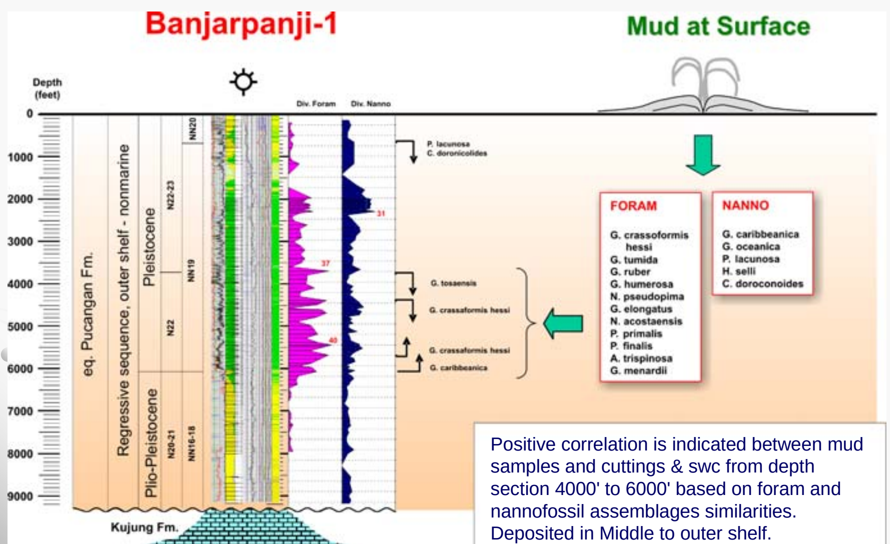


Density and shear and compressional sonic suggest the presence of overpressured zones. These are probably **highly plastic, undercompacted shale**, controlled by rapid sedimentation, trapped water results in overpressured condition.

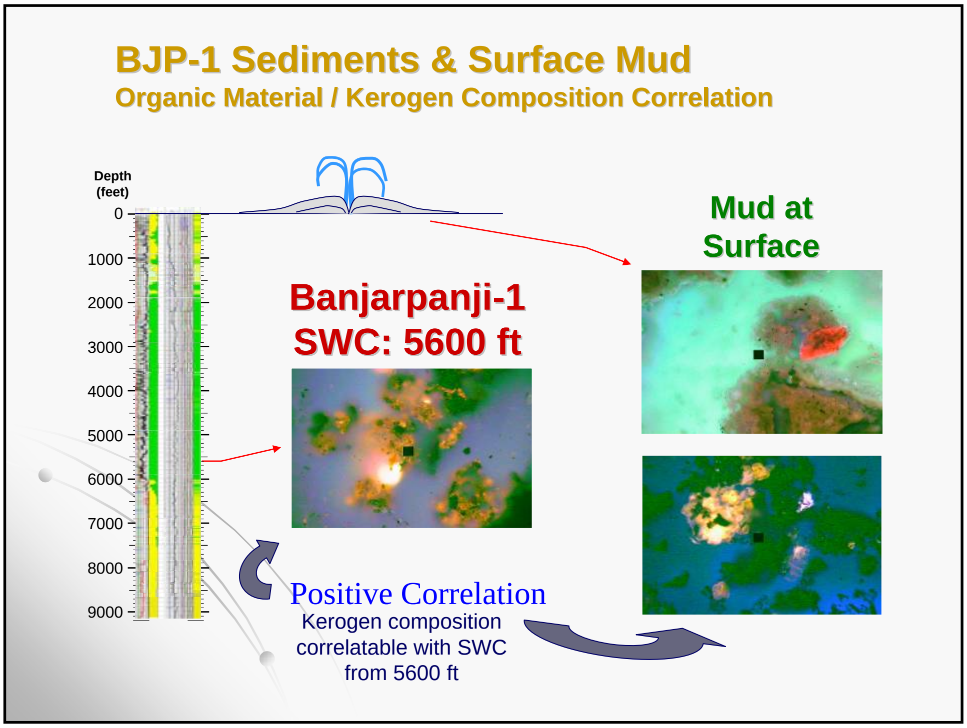


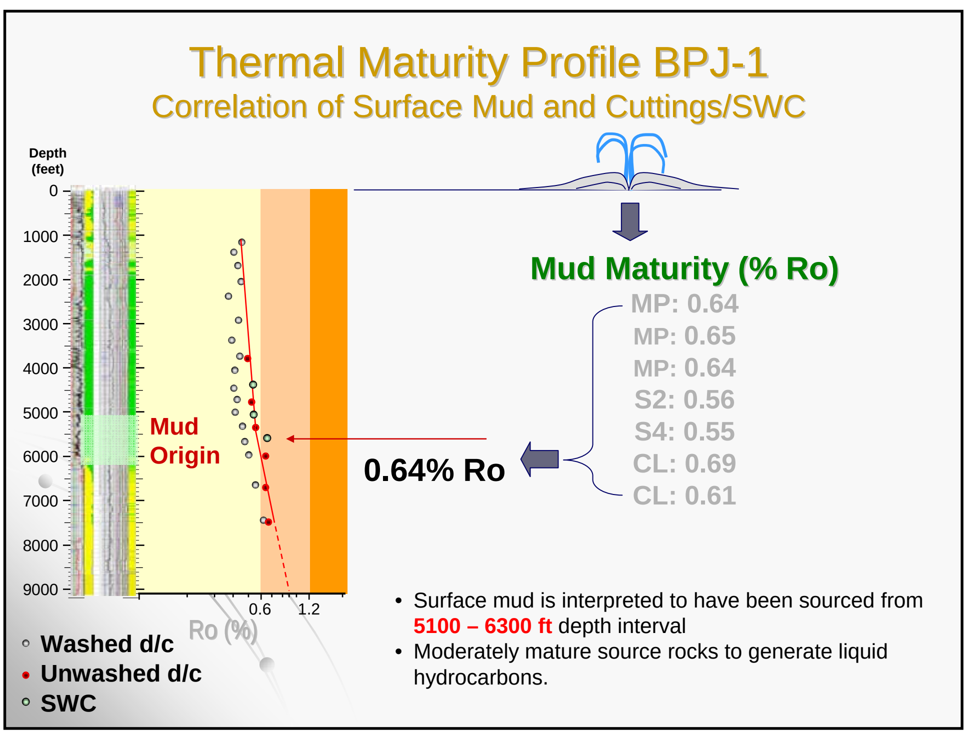
Start of Rapid Pressure transition into overpressured zone

Biostratigraphy

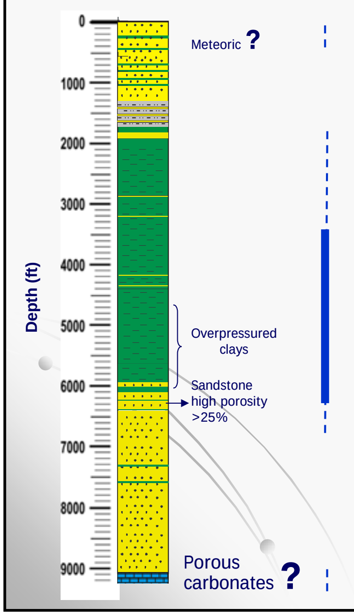


Positive correlation is indicated between mud samples and cuttings & swc from depth section 4000' to 6000' based on foram and nannofossil assemblages similarities. Deposited in Middle to outer shelf.


BJP-1 Sediments & Surface Mud
Organic Material / Kerogen Composition Correlation
Depth (feet)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Mud at Surface
Banjarpanji-1 SWC: 5600 ft
Positive Correlation
Kerogen composition correlatable with SWC from 5600 ft


Thermal Maturity Profile BPJ-1
Correlation of Surface Mud and Cuttings/SWC
Depth (feet)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Mud Origin
0.6
1.2
Ro (%)
Washed d/c
Unwashed d/c
SWC
Mud Maturity (% Ro)
MP: 0.64
MP: 0.65
MP: 0.64
S2: 0.56
S4: 0.55
CL: 0.69
CL: 0.61
0.64% Ro
• Surface mud is interpreted to have been sourced from 5100 – 6300 ft depth interval
• Moderately mature source rocks to generate liquid hydrocarbons.

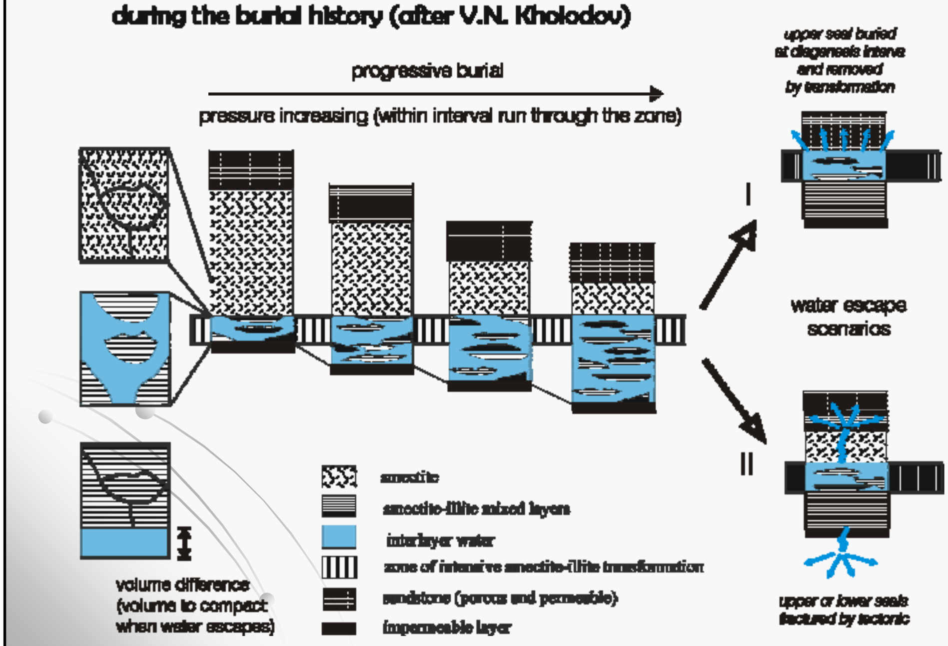
Origin of water



- **Salinity** 39% **lower** than seawater
- **Enriched** in B, Ca, Li, Na, Sr, Br
- **Depleted** in K, Mg and SO4
- **Enriched** in 18O and depleted in 2H
- LUSI fluids formed by **diagenetic modifications** and **dilution** of **seawater**
- Possible input of **meteoric water**
- Strong influence of fluids from dehydration of clays
- Possible input of fluids from **upper** porous **sandstone unit** (6360-6385 ft)
- No real evidence of fluids from **Kujung**
- Large amount of water from depth **>5700** ft (i.e. T>100 °C)

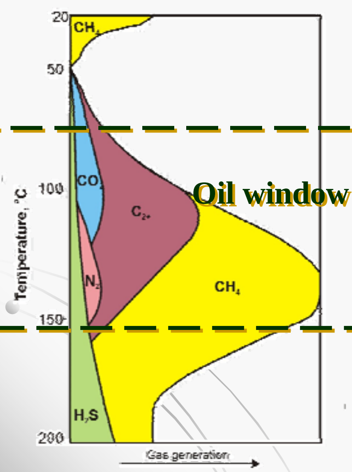
After Mazzini 2007

Principal scheme of smectite-illite transformation with water expulsion during the burial history (after V.N. Kholodov)

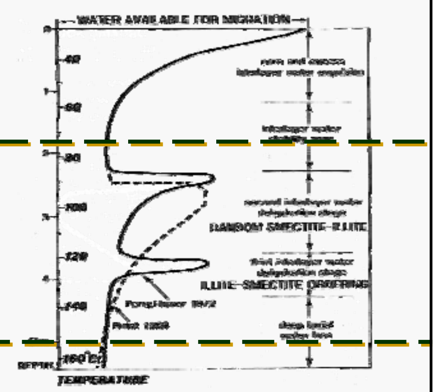


FLUIDS

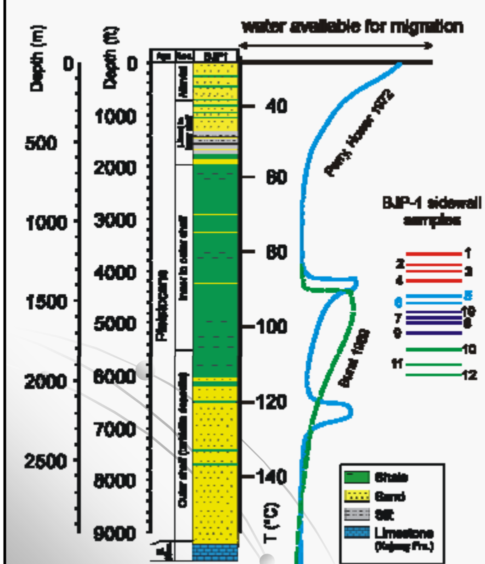
GAS



WATER



Water escape curves from smectitic rich sediments during illitization



XRD data
on
clay mineral composition

kaolinite-smectite-illite (2000-6000 ft)

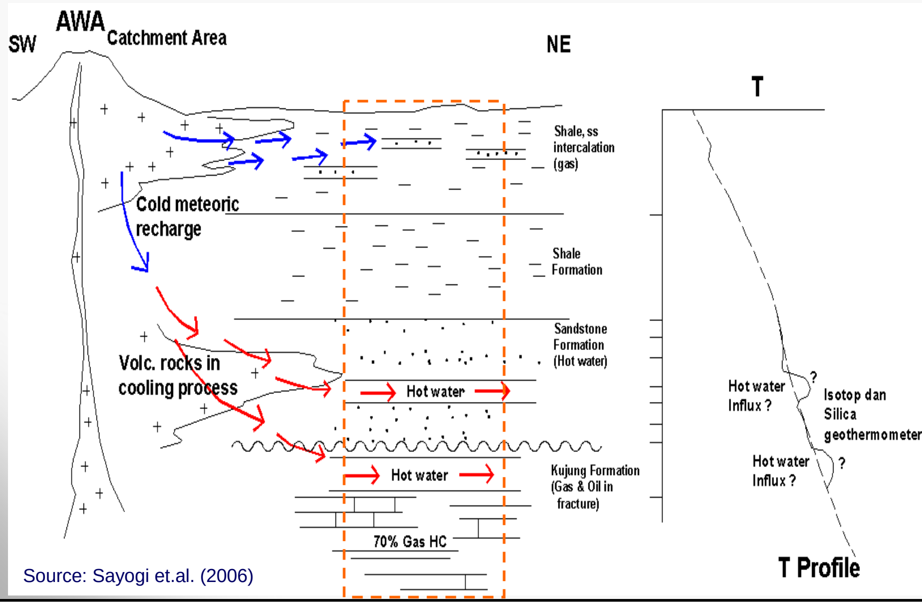
smectite (4400-4700 ft)

3640-4400 ft:
expandable smectite-illite phase
is irregular and contains 35-45% of illite layers,
illite crystallinity is low, chlorite is not detected

4700-5300 ft:
illite layers compose 45-55% of smectite-illite,
subregular and regular rectorite-like phases
are interpreted, kaolinate loses crystallinity,
chlorite signs appear

5300-6000 ft:
illite layers take up to 65% of smectite-illite,
chlorite increases in amount and crystallinity

Schematic subsurface hydrological model and temperature profile



Source: Sayogi et.al. (2006)

HOT MUD FLOW MECHANISM - HYPHOTHESIS

- Two types of pressure control the fluids flow in the rock formation – geothermal-hot water and HC-gas (+shale pore P?)
- Hot water can move vertically along 3,000 m channel due to:

(↑↑↑) Psat (hot water) + PHC-gas + Pshale >> PHydrostatic (↓)

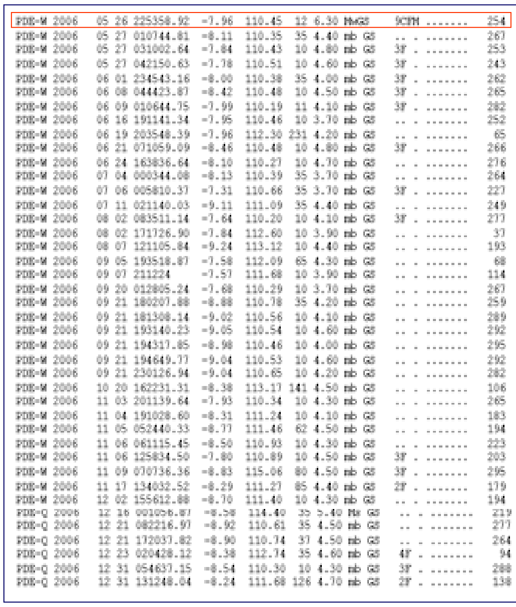
~ 40 bars + (?) + 2-3ppg equiv. 300 bars

|

depend on T reservoir

- Pressurized hot water cut and erode the shale formation at the upper level

Seismicity

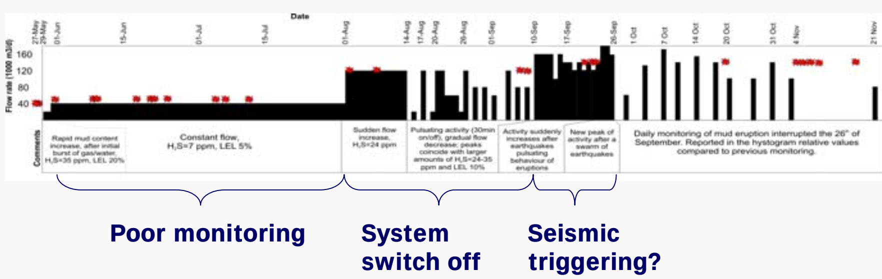


PDE-W	2006	05	26	225358.92	-7.96	110.45	12	6.30	MwGS		9CFM	....	254
PDE-W	2006	05	27	010744.81	-8.11	110.35	35	4.40	mb	GS	.. .	....	267
PDE-W	2006	05	27	031002.64	-7.84	110.43	10	4.80	mb	GS	3F .	....	253
PDE-W	2006	05	27	042150.63	-7.78	110.51	10	4.60	mb	GS	3F .	....	243
PDE-W	2006	06	01	234543.16	-8.00	110.38	35	4.00	mb	GS	3F .	....	262
PDE-W	2006	06	08	044423.87	-8.42	110.48	10	4.50	mb	GS	3F .	....	265
PDE-W	2006	06	09	010644.75	-7.99	110.19	11	4.10	mb	GS	3F .	....	282
PDE-W	2006	06	16	191141.34	-7.95	110.46	10	3.70	mb	GS	.. .	....	252
PDE-W	2006	06	19	203548.39	-7.96	112.30	231	4.20	mb	GS	.. .	....	65
PDE-W	2006	06	21	071059.09	-8.46	110.48	10	4.80	mb	GS	3F .	....	266
PDE-W	2006	06	24	163836.64	-8.10	110.27	10	4.70	mb	GS	.. .	....	276
PDE-W	2006	07	04	000344.08	-8.13	110.39	35	3.70	mb	GS	.. .	....	264
PDE-W	2006	07	06	005810.37	-7.31	110.66	35	3.70	mb	GS	3F .	....	227
PDE-W	2006	07	11	021140.03	-9.11	111.09	35	4.40	mb	GS	.. .	....	249
PDE-W	2006	08	02	083511.14	-7.64	110.20	10	4.10	mb	GS	3F .	....	277
PDE-W	2006	08	02	171726.90	-7.84	112.60	10	3.90	mb	GS	.. .	....	37
PDE-W	2006	08	07	121105.84	-9.24	113.12	10	4.40	mb	GS	.. .	....	193
PDE-W	2006	09	05	193518.87	-7.58	112.09	65	4.30	mb	GS	.. .	....	68
PDE-W	2006	09	07	211224	-7.57	111.68	10	3.90	mb	GS	.. .	....	114
PDE-W	2006	09	20	012805.24	-7.68	110.29	10	3.70	mb	GS	.. .	....	267
PDE-W	2006	09	21	180207.88	-8.88	110.78	35	4.20	mb	GS	.. .	....	259
PDE-W	2006	09	21	181308.14	-9.02	110.56	10	4.10	mb	GS	.. .	....	289
PDE-W	2006	09	21	193140.23	-9.05	110.54	10	4.60	mb	GS	.. .	....	292
PDE-W	2006	09	21	194317.85	-8.98	110.46	10	4.00	mb	GS	.. .	....	295
PDE-W	2006	09	21	194649.77	-9.04	110.53	10	4.60	mb	GS	.. .	....	292
PDE-W	2006	09	21	230126.94	-9.04	110.65	10	4.20	mb	GS	.. .	....	282
PDE-W	2006	10	20	162231.31	-8.38	113.17	141	4.50	mb	GS	.. .	....	106
PDE-W	2006	11	03	201139.64	-7.93	110.34	10	4.30	mb	GS	.. .	....	265
PDE-W	2006	11	04	191028.60	-8.31	111.24	10	4.10	mb	GS	.. .	....	183
PDE-W	2006	11	05	052440.33	-8.77	111.46	62	4.50	mb	GS	.. .	....	194
PDE-W	2006	11	06	061115.45	-8.50	110.93	10	4.30	mb	GS	.. .	....	223
PDE-W	2006	11	06	125834.50	-7.80	110.89	10	4.50	mb	GS	3F .	....	203
PDE-W	2006	11	09	070736.36	-8.83	115.06	80	4.50	mb	GS	3F .	....	295
PDE-W	2006	11	17	134032.52	-8.29	111.27	85	4.40	mb	GS	2F .	....	179
PDE-W	2006	12	02	155612.88	-8.70	111.40	10	4.30	mb	GS	.. .	....	194
PDE-Q	2006	12	16	001056.87	-8.58	114.40	35	5.40	Ms	GS	.. .	....	219
PDE-Q	2006	12	21	082216.97	-8.92	110.61	35	4.50	mb	GS	.. .	....	277
PDE-Q	2006	12	21	172037.82	-8.90	110.74	37	4.50	mb	GS	.. .	....	264
PDE-Q	2006	12	23	020428.12	-8.38	112.74	35	4.60	mb	GS	4F .	....	94
PDE-Q	2006	12	31	054637.15	-8.54	110.30	10	4.30	mb	GS	3F .	....	288
PDE-Q	2006	12	31	131248.04	-8.24	111.68	126	4.70	mb	GS	2F .	....	138

- **27-05** earthquake
- Earthquakes recorded within **300km** radius from LUSI site
- Filtered earthquakes **M>3.5**
- 27-05 to 31-12: **41 earthquakes**

Source USGS

Observed flow patterns



- **Pulsations** (approx every 30 min.) → higher amount of mud and gas released
- **Geyser** behaviour (?) (Empty chambers periodically before new burst)
- Correlation seismicity-mud flow. Periodical **reactivation of** the system?

Summary – Part 1

- Stratigraphy and tectonic activities in Sidoarjo area is potentially high in forming mud volcanoes.
- Unlikely to stop eruption permanently
- Mud extrusion could release the overpressure but difficult to predict the timing when it would stop
- Inconclusive & contradictory evidence to conclude drilling was the trigger of the mud extrusion
- ERUPTED MUD
  - LUSI fluids correspond to 5300-6000 ft
  - Foram + nannofossil section 4000-6000 ft
  - Thermal maturity suggest input from 5100 – 6300 ft
  - Kerogen composition correlates with SWC from 5600ft
  - Diagenetic transformation of clays, 4 groups defined between 3600-6000ft.

Impact of Mud Volcano Disaster

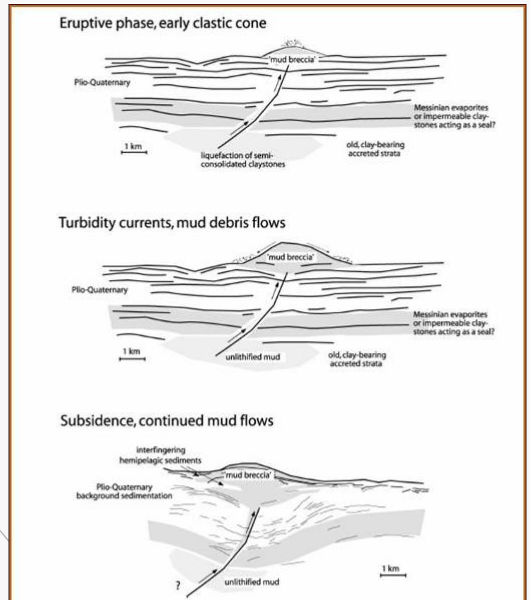


Figure 6b. Model for MV evolution proposed by *Kopf et al.* [1998] for a violent eruption with numerous debris-flow events in the Mediterranean, reprinted with permission from Springer-Verlag.

Model MV evolution dari Kopf et [1998] di daerah Mediteranean

Mud Volcanoes can not be stopped - Implications

- Initial **Transitional Phase towards Isostatic Adjustment**
- Geohazard risks vs. Mud overspill risk
- Subsiding area become:
  - Hill, if extrusion > subsidence
  - Flat, if extrusion = subsidence
- Local analogies: Bleduk Kuwu, Gn Anyar, Kalang Anyar, Paleo Porong Mud Volcano (Seismic), etc

A: Subsiding area become a Hill

Azerbaijan Giant Mud Volcanos

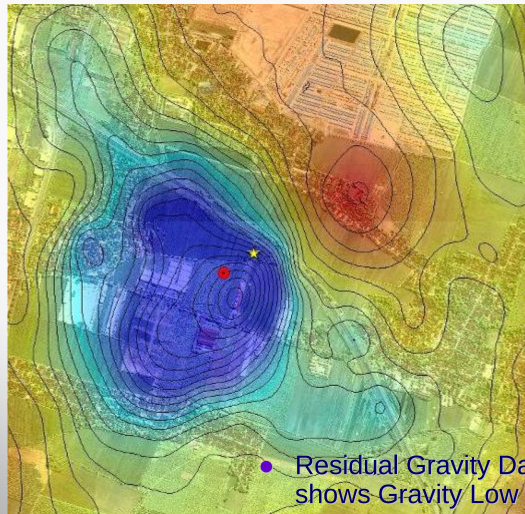
- **Size** from m to 4km (>5km offshore)
- **Height** from m up to 500 m
- **Roots** of feeder channel up to 15 km (i.e. Below Maycopian?)
- Usually situated along **anticlines**
- Associated with **HC reservoirs**

B: Subsiding area become Almost Flat

- Low relief (6m)
- Bleduk Kuwu Scenario (Active Mud Volcano, Purwodadi)

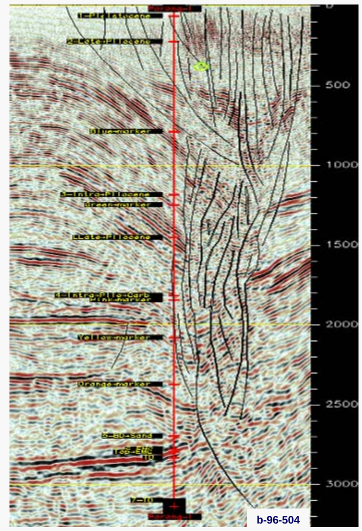
Local Analogue

Possible structure collapse near wellbore may create a lake with a radius of 1-2 km



- Residual Gravity Data shows Gravity Low

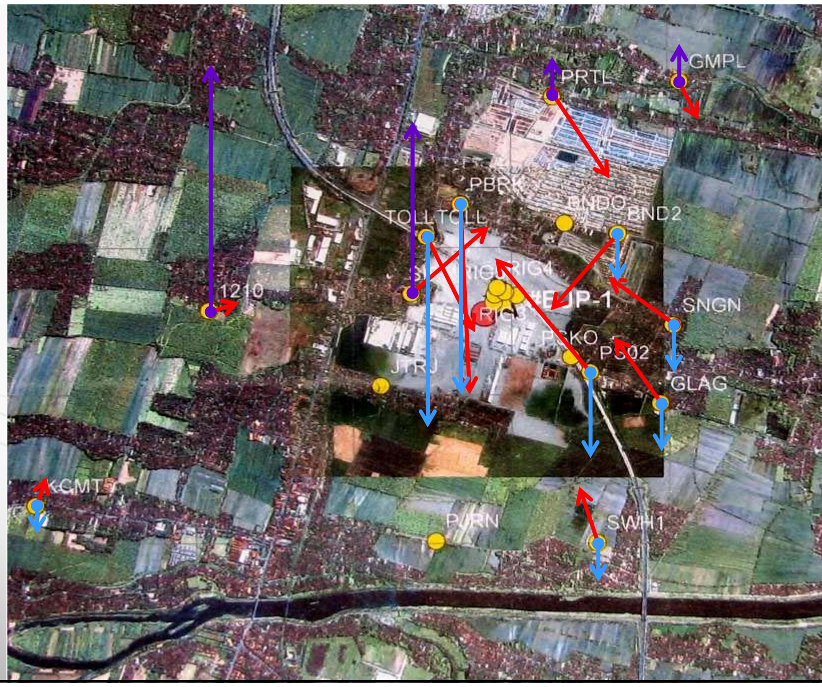
Example: Porong Collapse Structure (7 Km dari BJP -1)



Geohazard Risks

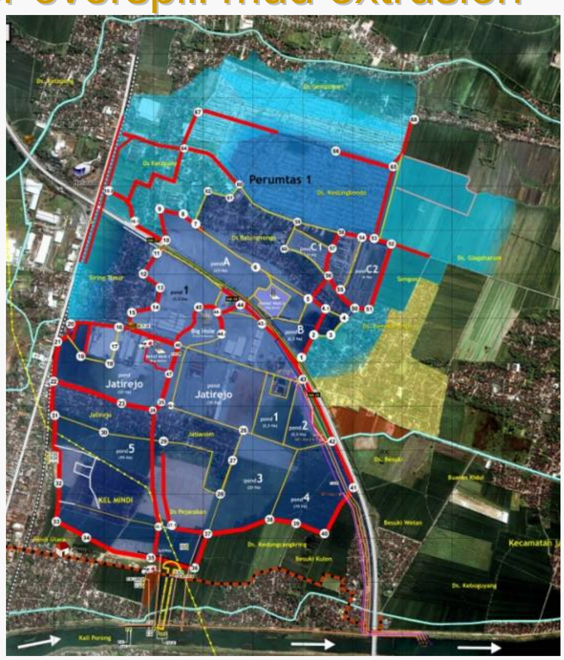
- Neo Tectonic movements along Watukosek fault lineament,
  - differential movements which trigger shear stress
  - Presence of fractures due to reactivation of pre-existing faults
- Vertical and Horizontal movements
  - Accelerated Subsidence due to unloading of overpressured shale
  - Loading, compaction of soil and land settlement due to weight of mud
- Flooding due to:
  - Bundwall Sliding and collapse
    - Unstable and critical as they were constructed in emergency situation as temporary mud containment made of soil and rock matrix
    - Bundwall exerting high hydrostatic pressure causing it to crack and collapse

Vertical and Horizontal Displacement 26–29 Aug – 17-20 Sept 2006



Need area for overspill mud extrusion

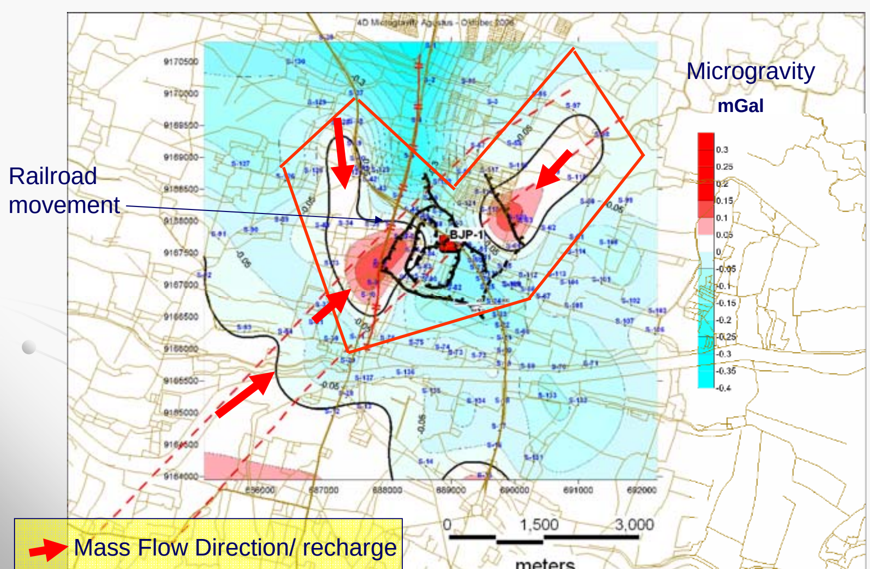
- Larger area of overspill is needed if mud cannot be managed, disposed or controlled

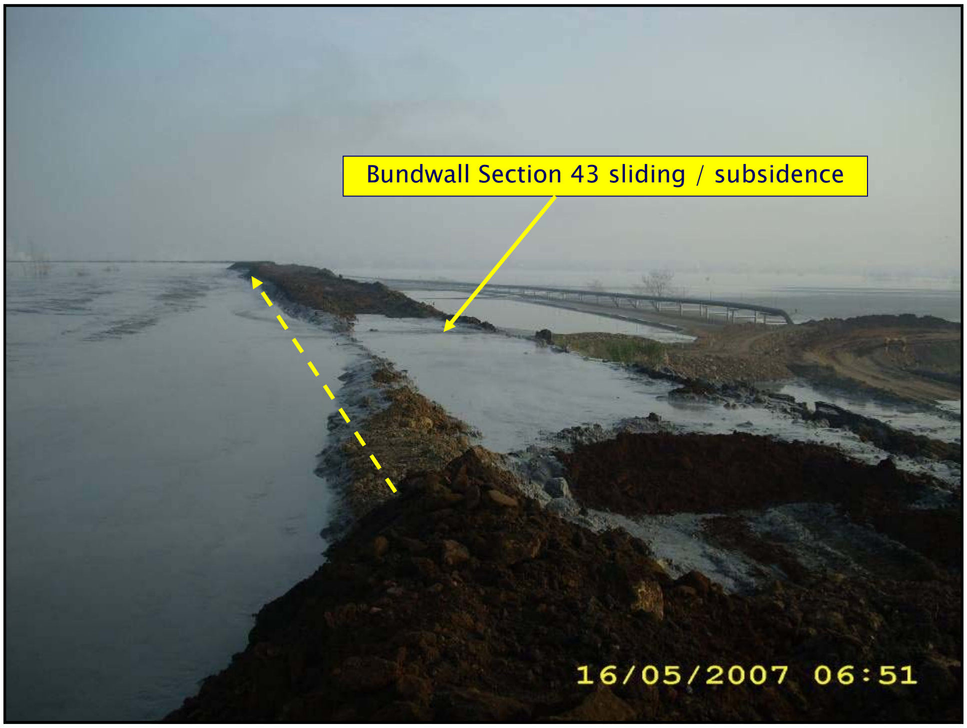


RAILROAD DEXTRAL MOVEMENT at KM 39.2

27 September 2006

GEOHAZARD RISK AREAS




Bundwall Section 43 sliding / subsidence
16/05/2007 06:51

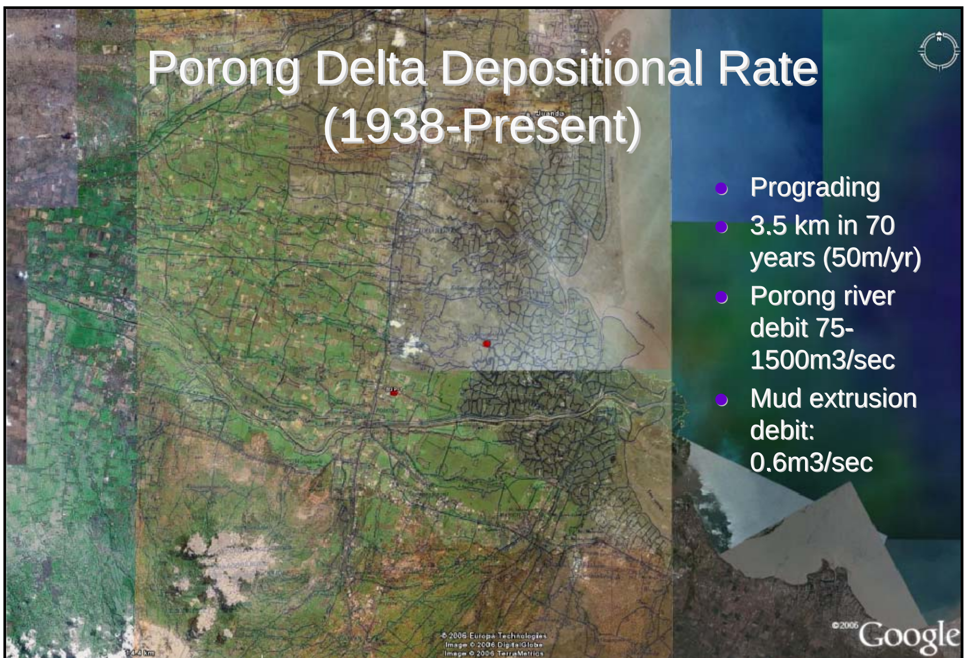

Bundwall fracture on Section 43
width 5-10 cm
16/05/2007 06:50

Summary – Part 2

- The risk of catastrophic collapse is low but the on going subsidence and lateral movement will continue. Subsidence is up to 3cm / day in parts but mostly around 1cm / day or less.
- Key risks: Gas & water pipeline (shear & subsidence); Rail road (shear/ faulting & subsidence); Toll road (subsidence); Relief wells (subsidence, shear → casing integrity)
- Current work: Simulation using current data and further set of GPS measurements, micro-seismic and micro-gravity to predict the shape and condition of the affected area in years to come, ie 5, 10, 20 or 30 years from now
- Monitoring and risk mitigation

Backup slides

Porong Delta Depositional Rate (1938-Present)



- Prograding
- 3.5 km in 70 years (50m/yr)
- Porong river debit 75-1500m3/sec
- Mud extrusion debit: 0.6m3/sec

SUMMARIES OF MUD VOLCANO ANALYSIS - BANJARPAJI-1

- Analysis of Hazardous Waste Characteristics (the characteristics are: explosive, flammable, reactive, toxic, infectious, and **corrosive**) Analysis indicates that mud volcano is reactive if it is exposed in extreme condition of PH:< 2 or pH >12, while mud pH is 6-7. Other characteristics are non hazards. So the mud **hazard level is low**.

- TCLP (Toxicity Characteristic Leaching Procedure) tests indicate that **all parameters are below threshold limit values** (TLV). So the mud is non hazardous waste.

- Toxicity test using LD-50 method indicates the mud is **non hazardous waste**.

- Toxicity test using LC-50 method indicates the mud **almost non toxic**

Note :

Mechanical Analysis of mud volcano indicates that the mud can be used as construction material such paving blocks, bricks, asphalt hotmix, and concrete blocks.

SUMMARIES OF FORMATION WATER ANALYSIS - LUSI

- Analysis with reference of Kep Men LH No. 42 Year 1996 about Threshold Limit Value (TLV) for Waste Water Resulted From Oil & Gas and Geothermal Activities. For Onshore discharge (7 parameters), 5 parameters are below TLV, while 2 parameters (COD and Phenol) are above TLV. **For Offshore discharge, all parameters are below TLV**.

- Analysis with reference of SK Gubernur Jatim No. 45 Year 2002 about TLV For Industrial Waste Water and Other Activities in East Java Province, Attachment II, Group III. There are **32 parameters measured, 27 parameter are below TLV**, while 5 parameters (TSS, TDS, BOD, COD, and Phenol) are above TLV

Note :

KLH: After treatment, the formation water can be discharged to nearby river or to sea.

SUMMARIES OF BASELINE ANALYSYS OF WATER IN KALI PORONG (± 3 KM FROM BANJARPAJI-1)

- Baseline Analysis of water in Kali Porong refer to PP RI No. 82 Year 2001 about Management of Water Quality and Control of Water Pollution, Group III. There are 33 parameters, 25 parameters are below TLV, while 8 parameters (Cu, Zn, Pb, Nitrite, BOD, COD, Detergent, and Phenol) are above TLV.

- *Conclusion : Baseline of water in Kali Porong indicates above TLV for the parameters: Cu, Zn, Pb, Nitrite, BOD, COD, Detergent, and Phenol.*

Note : There are industries along the Kali Porong