UNDERSTANDING THE ORIGIN OF SIDOARJO MUD VOLCANO IN RELATION TO LONGEVITY ESTIMATION BASED ON REGIONAL STUDY AND SEISMIC INTERPRETATION

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MAY 26, 2011

TALK STRUCTURES

I. INTRODUCTION

II. MUD VOLCANO: DEFINITION, ORIGIN AND CHARACTERISTICS

III. SIDOARJO MUD VOLCANO: DATA AND FACTS

IV. REGIONAL TECTONICS

V. GEOPHYSICAL INTERPRETATION

VI. MODEL OF SIDOARJO MUD EXTRUSION

VII. CONCLUSIONS

Extraordinary explosive !!!

INTRODUCTION

THE ERUPTION OF MUD SIDOARJO OCCURRED IN MAY 29, 2006 HAS BECOME THE MOST SUBJECT TO DEBATE IN RECENT GEOLOGICAL PHENOMENON AMONG EARTH SCIENTISTS

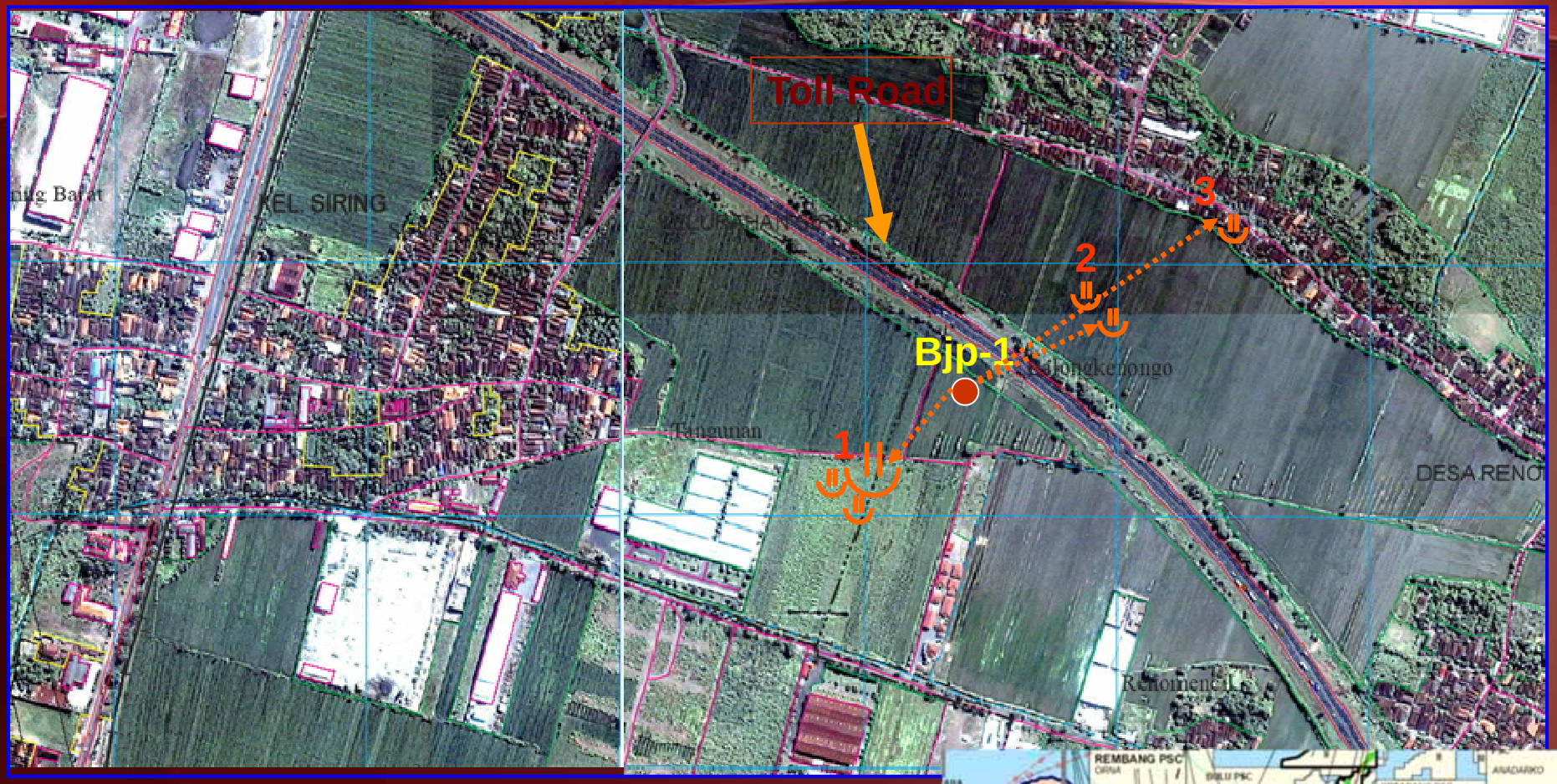
THE MOST PART OF DEBATE IS ON THE CAUSE OF THE ERUPTION WHETHER IT IS DUE TO DRILLING ERRORSOF WELL BANJAR PANJI -1 OR IT RELATES TO EARTQUAKE OCCURED ON MAY 26 2006 (JOGJAKARTA EARTHQUAKE)

THE PERSISTENT ERUPTION SINCE THEN HAS CREATED “VOLCANO” AND THEN TERMINOLOGY OF MUD VOLCANO HAS BEEN USED TO DESCRIBED THE PHENOMENON OF MUD SIDOARJO EXTRUSION

WHAT KINDS OF MUD EXTRUSION THAT SIDOARJO HAS ???

Location map of Sidoarjo Mud Extrution and Well Banjar Panji-1

LOCATION MAP OF SIDOARJO MUD ERUPTION AND WELL BANJAR PANJI -1



SumurBanjar Panji 1 Semburan Lumpur Panas

(CRONOLOGY OF ERUPTION (Report Lapindo Brantas))

- 1st Erution: May 29, 2006. 150 m SW of Well BP-1
- 2nd Erution: June 01, 2006 150 m NE of Well BP-1
- 3rd Eruption:June 02, 2006 500 m NE of Well BP-1
- Present eruption is still in location 1

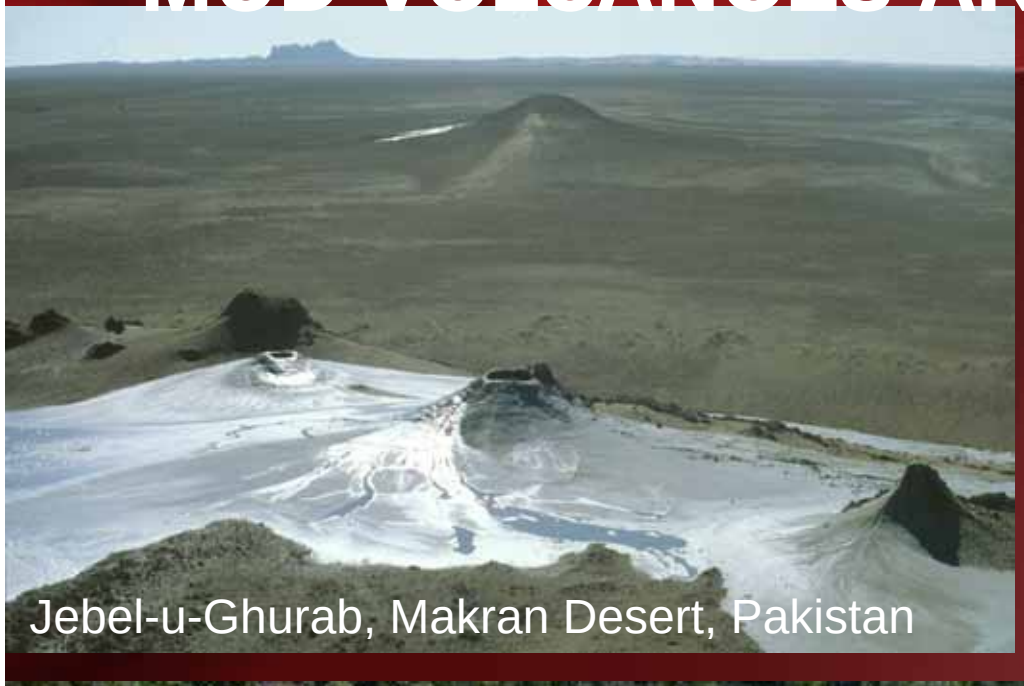
II. MUD VOLCANO: DEFINITION, ORIGIN AND CHARACTERISTICS

- ***Mud volcano*** is common terminology in geology that has genetic meaning.
-Terminology of mud volcano, in general, is used to describe an appearance that more or less similar to eruption or surface extrusion of mud and water or clay that associated with gas methane (CH4).
- Composition of mud material indicated the origin that is possibly from shale or mud diapiric.
-Mud volcano is not necessary in the shape of dome or conical, the appearance of this result can be from incompetent masses and if squeezed will go up along weak zone such as fault or fracture.

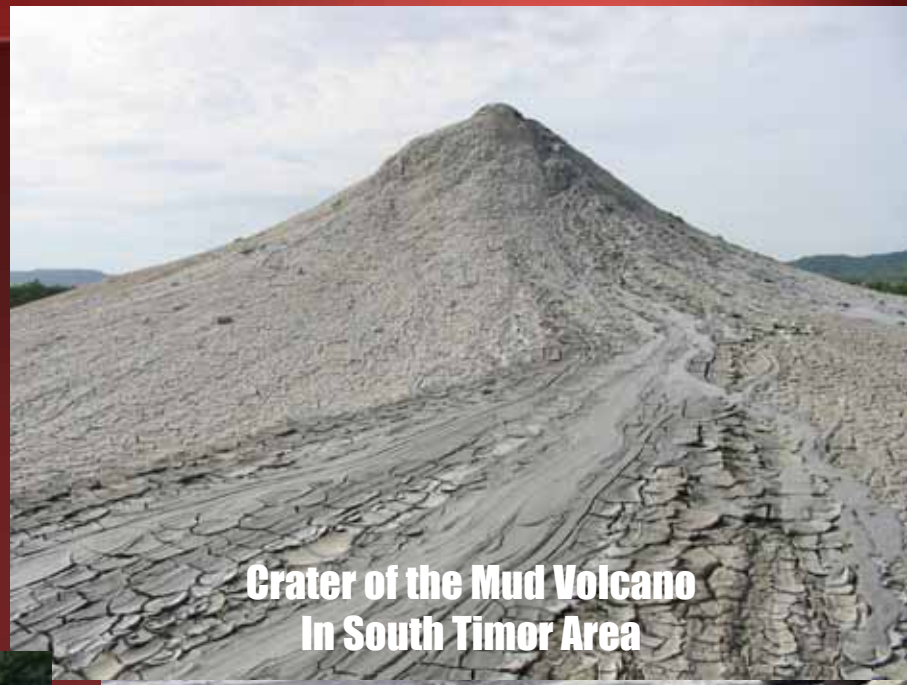
PROFILE OF MUD VOLCANO INTRUSION

Mud volcano raise from a fracture or fault from a deep that has layer with high pressure and in the plastic condition and easy to move

MUD VOLCANOES AROUND THE WORLD



Jebel-u-Ghurab, Makran Desert, Pakistan

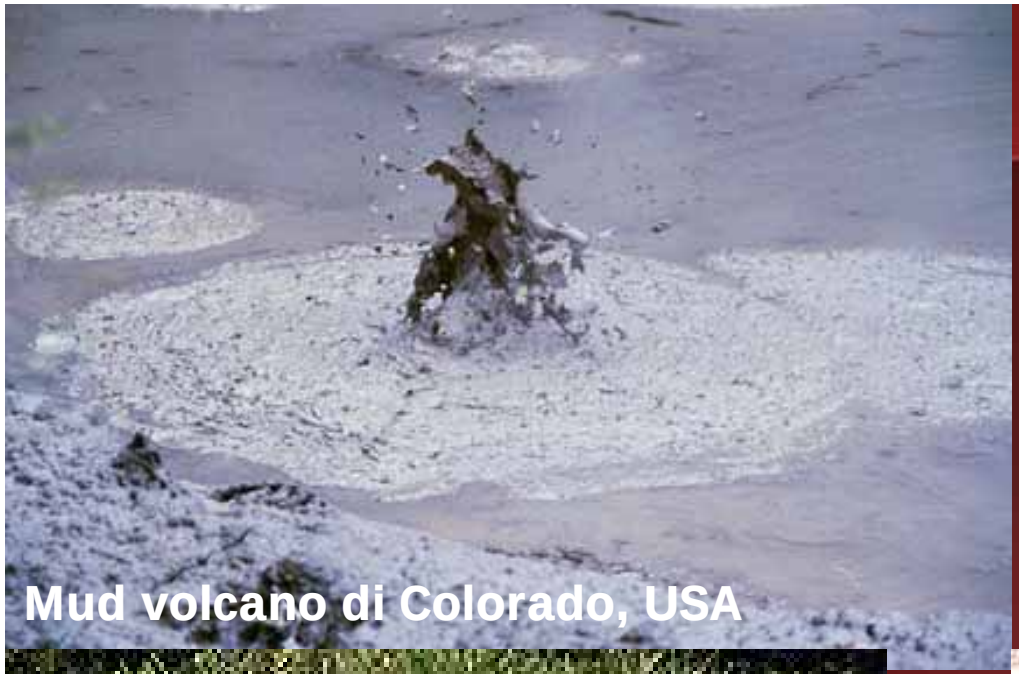


Crater of the Mud Volcano
In South Timor Area

Mud volcano di Columbia

Close-Up of Mud Volcano Peak
in South Timor

Viscous, low temperature with cone



Mud volcano di Colorado, USA

Mud volcano di Azerbaizan

Mud volcano di Taiwan

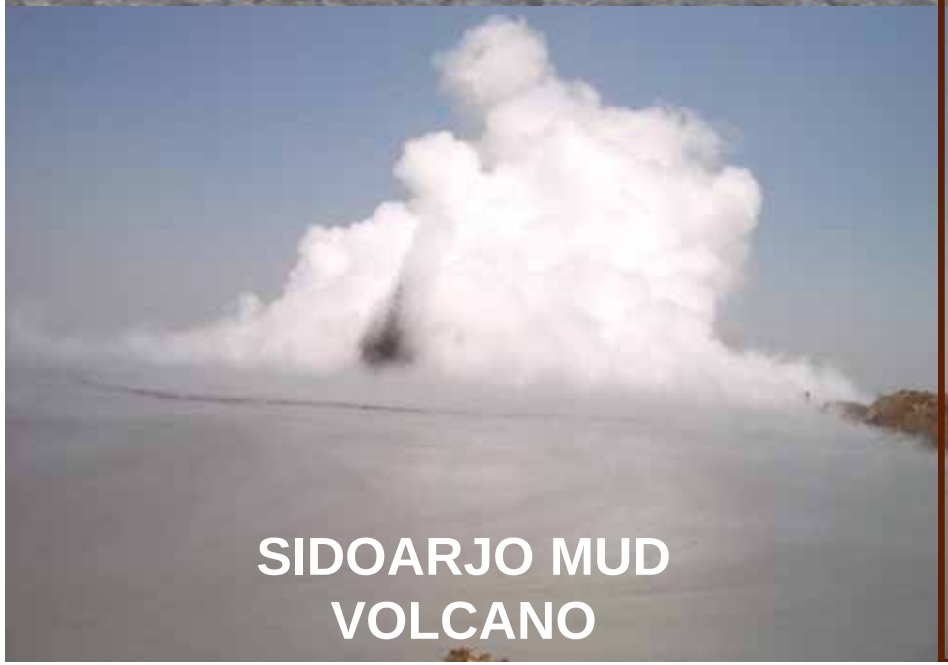
Mud Volcano in Sarawak Malaysia

Viscous, low temperature with cone

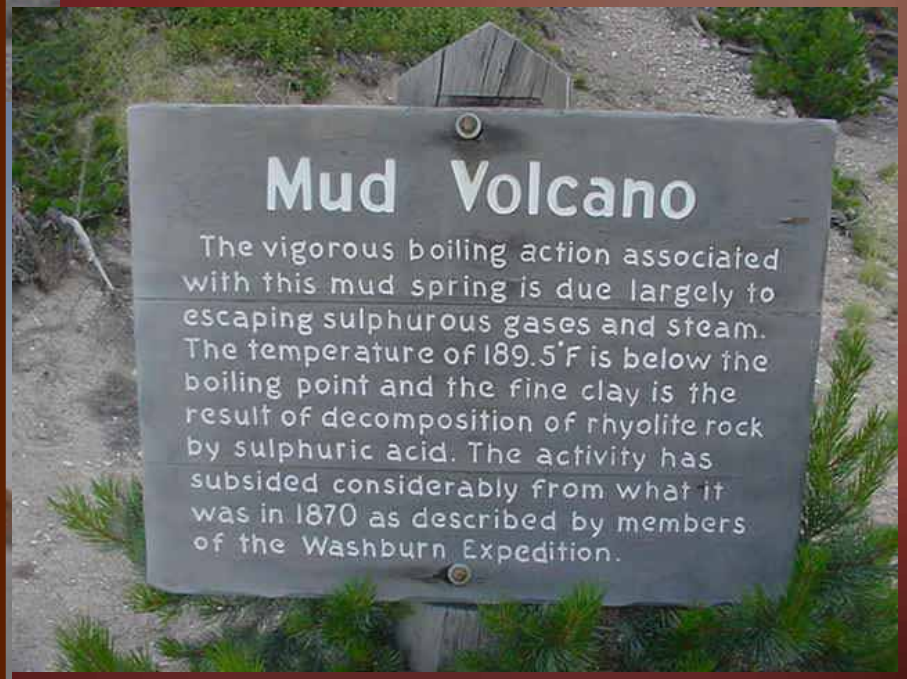
How About Sidoarjo Mud Volcano ??

BLEDUK KUWU - ACTIVE MUD VOLCANO
(Purwodadi, Central Java, Indonesia)

LIQUID DOMINANT, HOT, NO CONE AND HUGE RATES



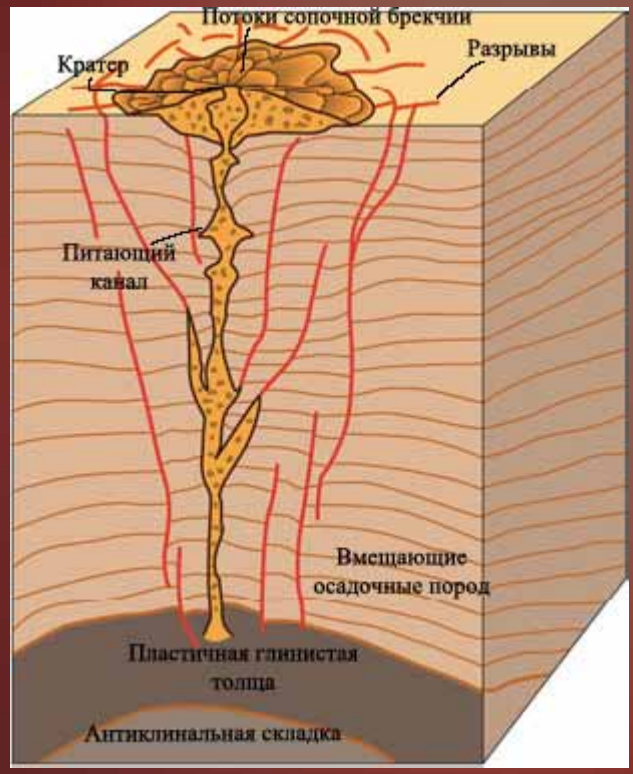
SIDOARJO MUD VOLCANO



Reference

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.



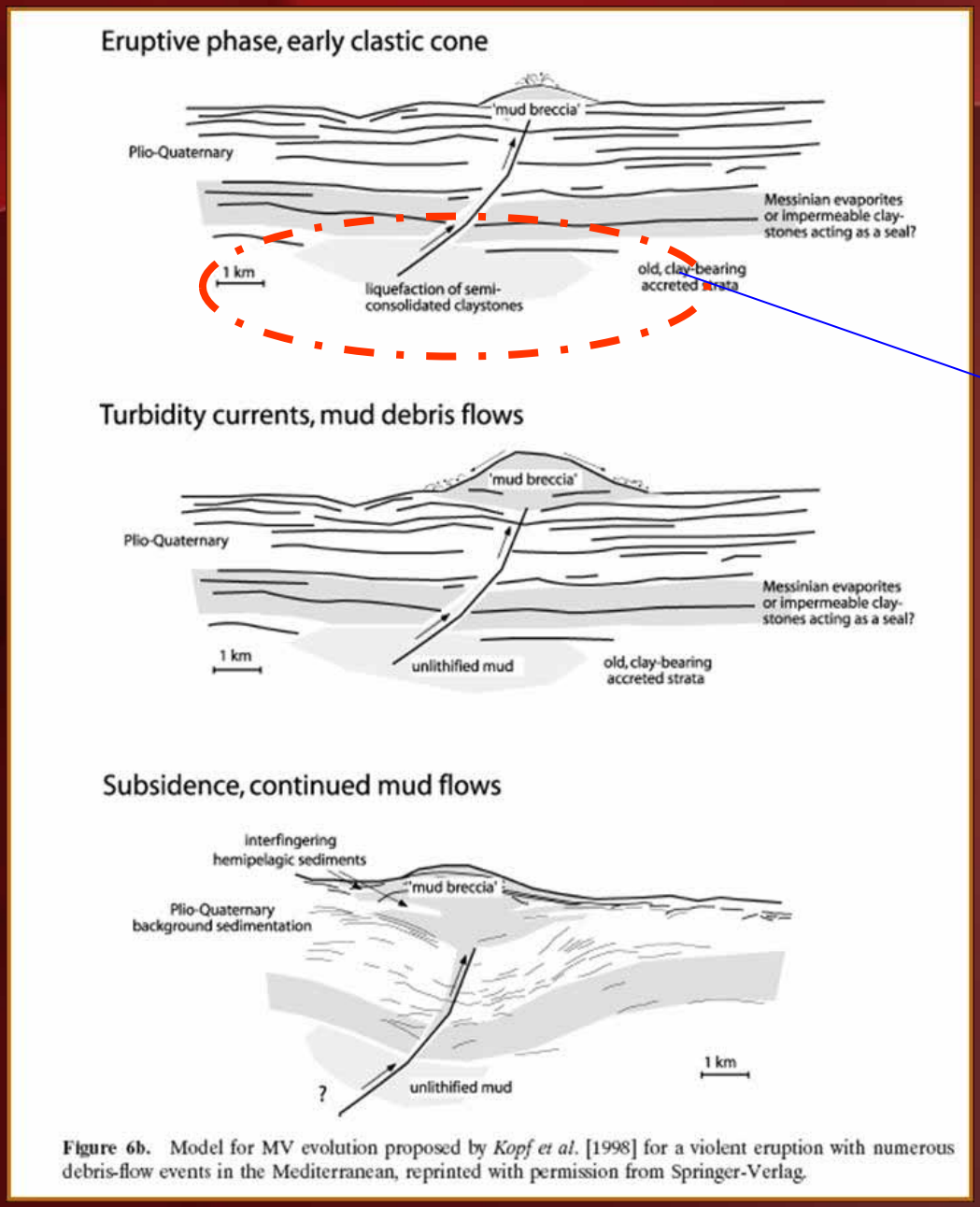
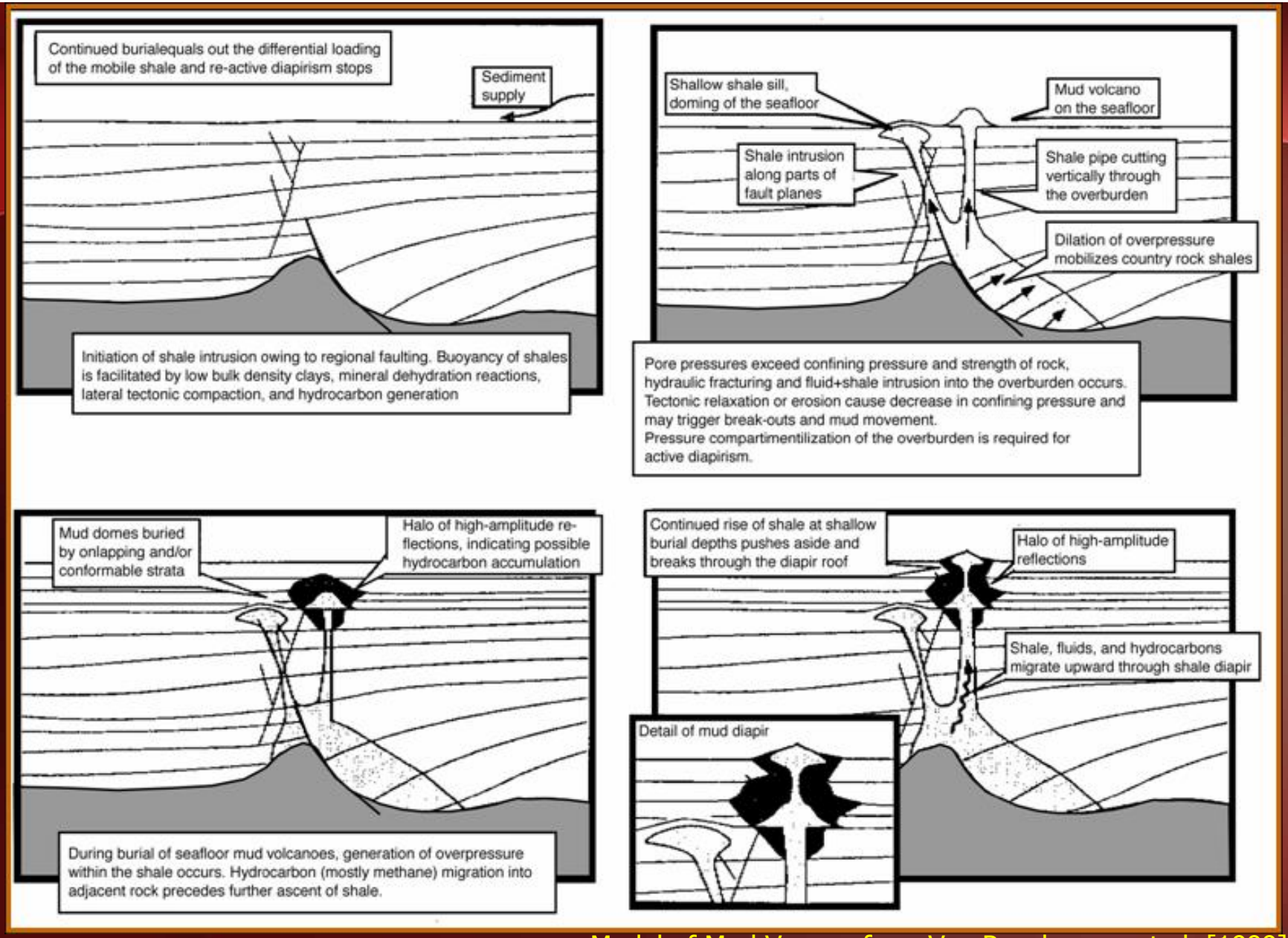


Figure 6b. Model for MV evolution proposed by *Kopf et al.* [1998] for a violent eruption with numerous debris-flow events in the Mediterranean, reprinted with permission from Springer-Verlag.

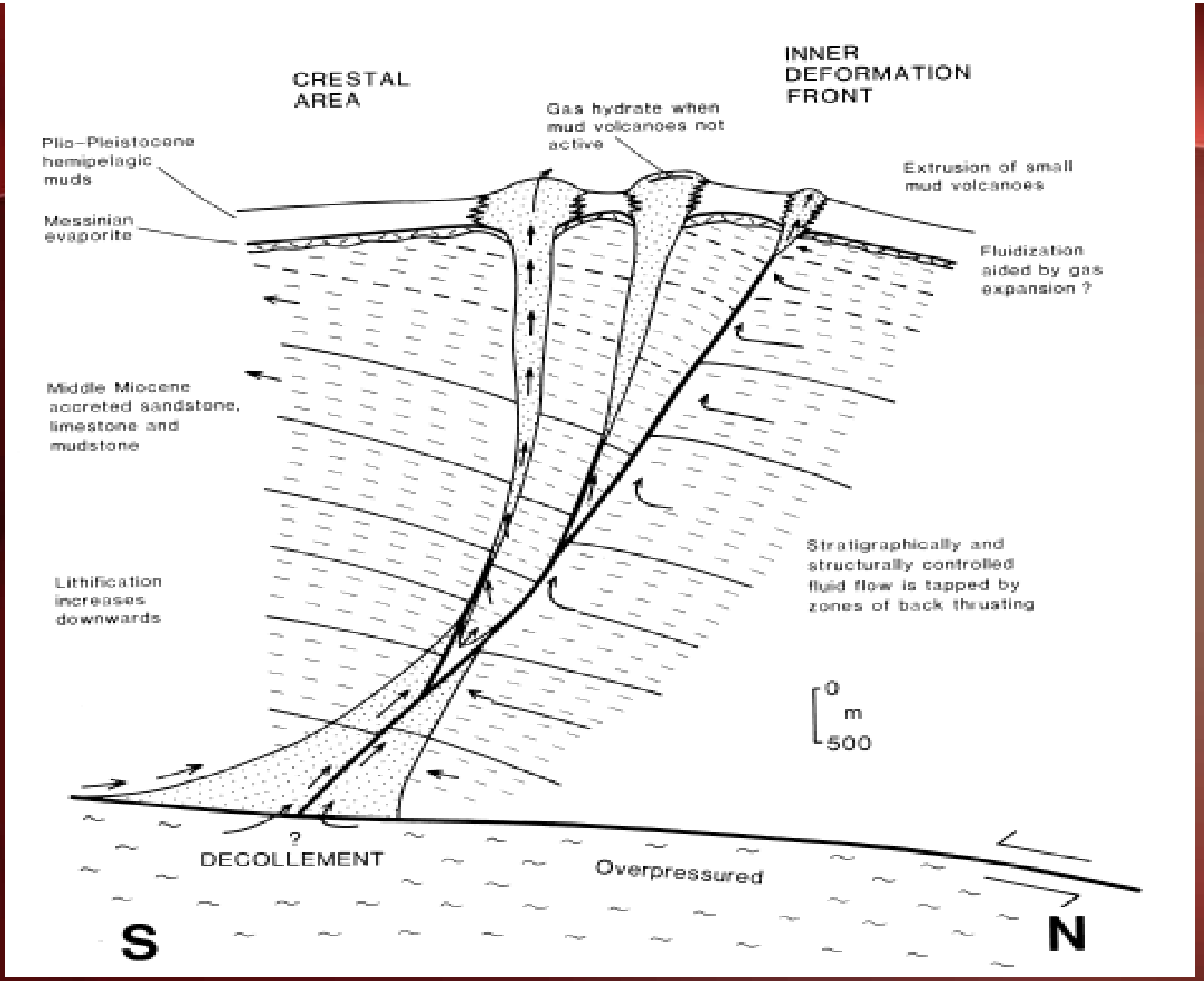
Source of mud derived from semi-consolidated material that can erupted through Fault reactivation

Model MV evolution dari Kopf et [1998] at the Mediteranean

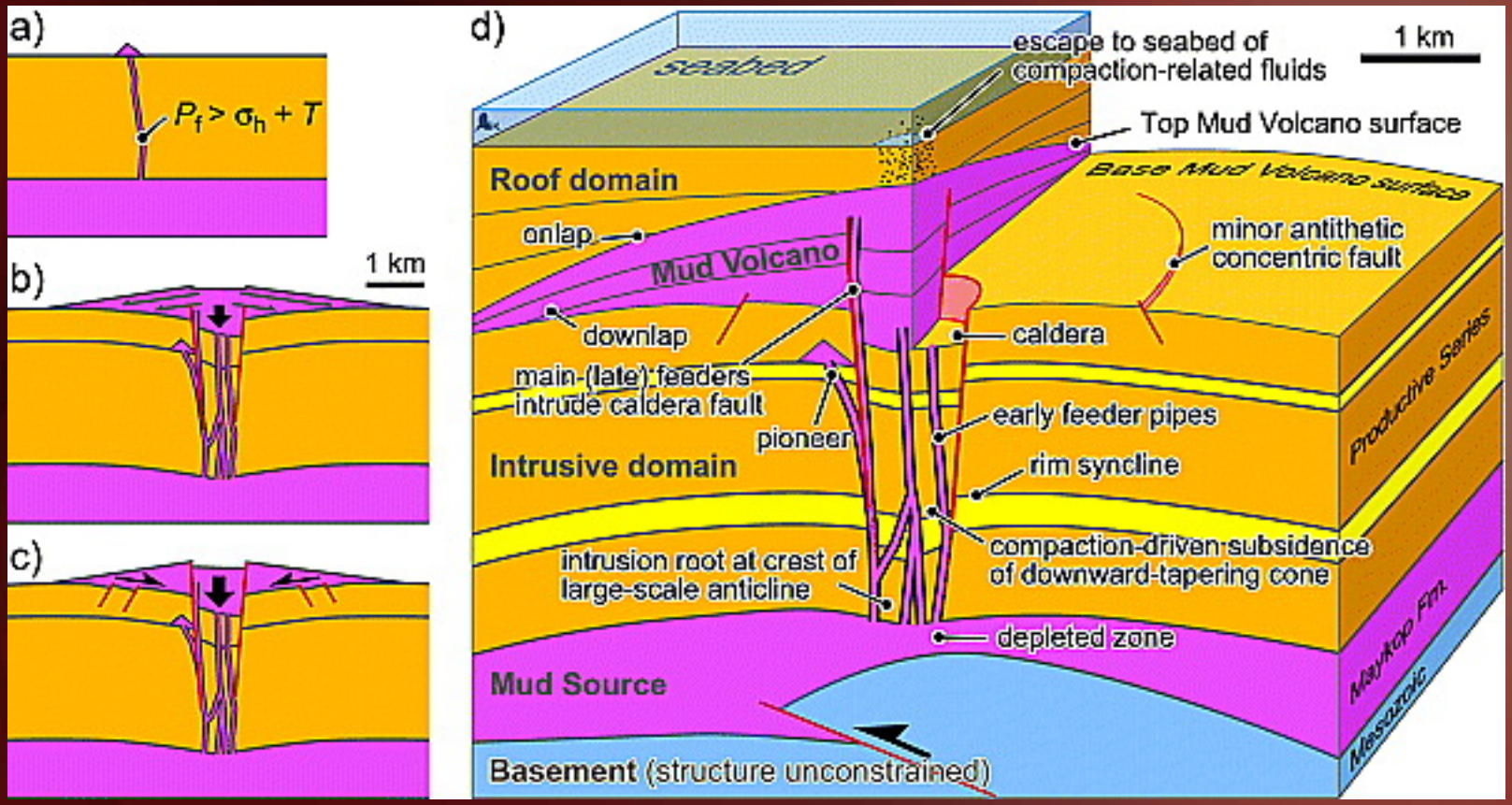


Model of Mud Vocano from Van Rensbergen et al. [1999]

THE MOST TYPICAL MODEL OF MUD VOLCANO WHERE MOBIL SHALE MOVEMENT RELATED ALSO WITH HYDROCARBON GENEATION AS PRIME MOVER OF SHALE DIAPIRIC IN WHICH MUD AND LIQUID DERIVED FROM THE SAME SYSTEMS



DIAPIRIC MODEL RELATED WITH TECTONIC LOADING OVERTHRUSTIN



MODEL OF MUD VOLCANO DEVELOPMENT WITH MULTIPLE FEEDER PIPE

WHAT KIND OF MUD VOLCANO IN SIDOARJO ???

THE SIDOARJO MUD VOLCANO IS CERTAINLY HAS UNIQUE EXPLANATION IN TERMS OF THE ORIGIN AND DO NOT REFER TO THOSE KNOWN AS GENETIC MUD VOLCANO

III. DATA AND FACTS: EXTRUSION OF SIDOARJO MUD VOLCANO

What kinds of mud ????

Ratio between Water and Mud : 70 : 30

MUD COMPOSITION (volumetric):

GRAVEL : ~30%

FINE PARTICLE & WATER : ~70%

40 – 50 m

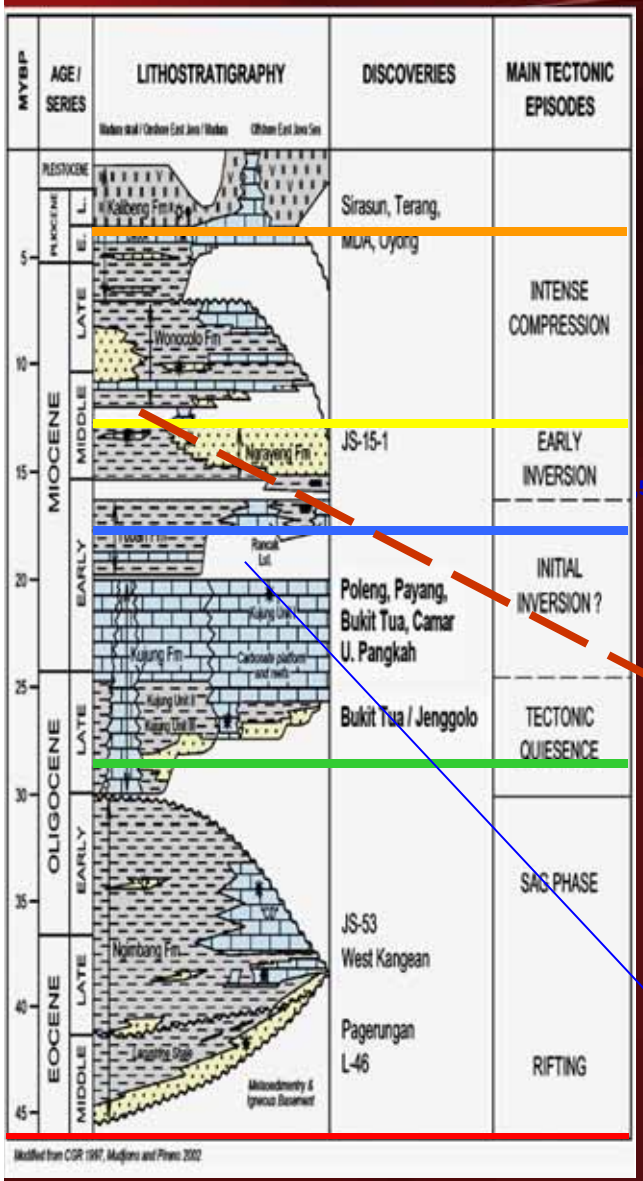
Hot Mud Sidoarjo as mix of fluid and solid in salty water, mud, sand, and gas as well as vapour reaching 100^0 Celcius

EXPLORATION WELL OBJECTIVE

- **Early Miocene Limestone**
- **Pliocene Limestone**

SUMMARY WELL LOG BANJARPANJI-1

Spud Date : March 08,2006
Completed :
Well Status : Drilling in progress
Operator : EMP Brantas



580' TVD

LOWER PLIOCENE - PLEISTOCENE

KABUH FM
700 ft
PUCANGAN FM.
3220 ft
UPPER KALIBENG FM.

0
500
1000
2000
3000
4000
4440 ft
5000
6000
7000
8000

Volcanic sandstone, med to coarse grained, with clay intercalation.

Interbedded fine grained sandstone, siltone and shale contain Elphidium. Litoral to inner shelf depositional environment.

Gray slightly calc. shale with minor fine grained sandstone ,with lithic fragment, intercalations.

Shale contains forams, nanno and shell frag *ment* Benthonic forams: *A. Trispinosa* and index nannofossils *Gephyrocapsa* common. Inner sublitoral depositional environment.

High abundance nanno and foram
Mid to outer sublitoral depositional environment.

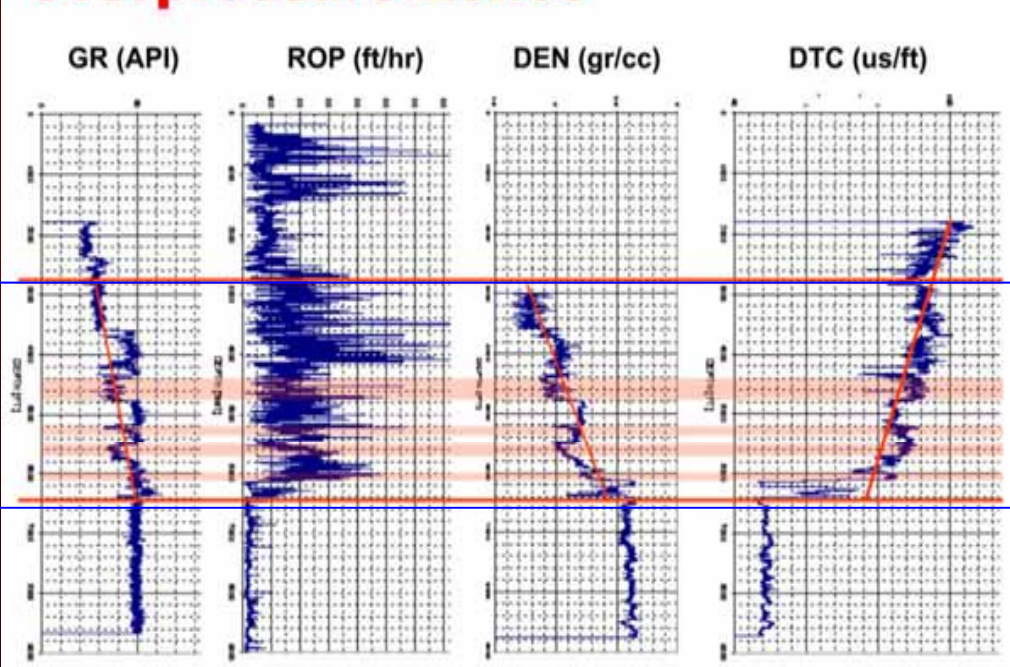
Volcanik sandstone with minor shale intercalation in the upper part.

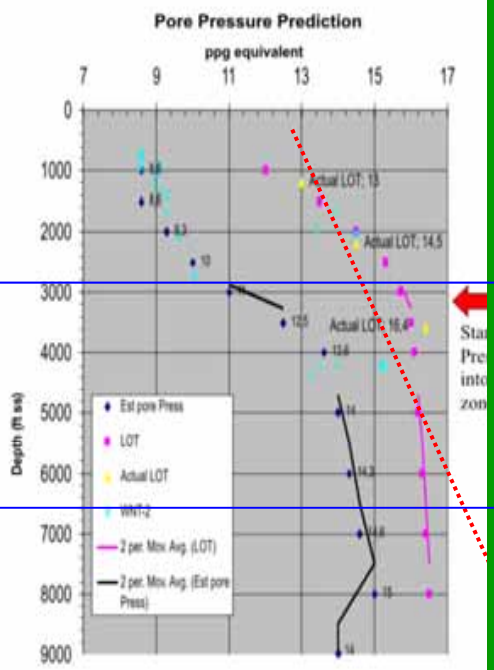
Volc. sandstone, dark gray, med to coarse grained, sub angular, feldspar andesitic rock fragment. Shale contain rare nanno of Plio-Pleistocene age. Inner shelf depositional environment

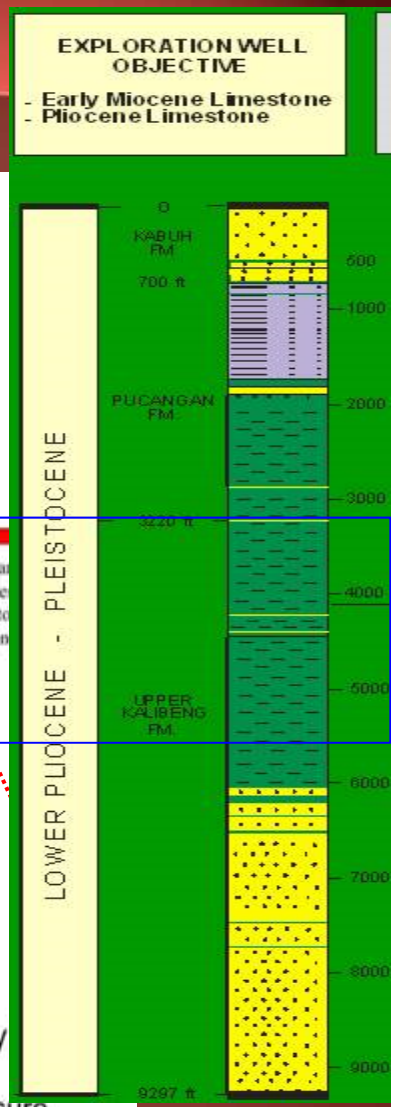
KUJUNG FORMATION IS NOT YET PENETRATED!!!

Lithology data of Well Banjar Panji #1 showing rigid lithology from top to bottom

Overpressure Zones







Overpressured Zone

Interpreted Overpressured Zones

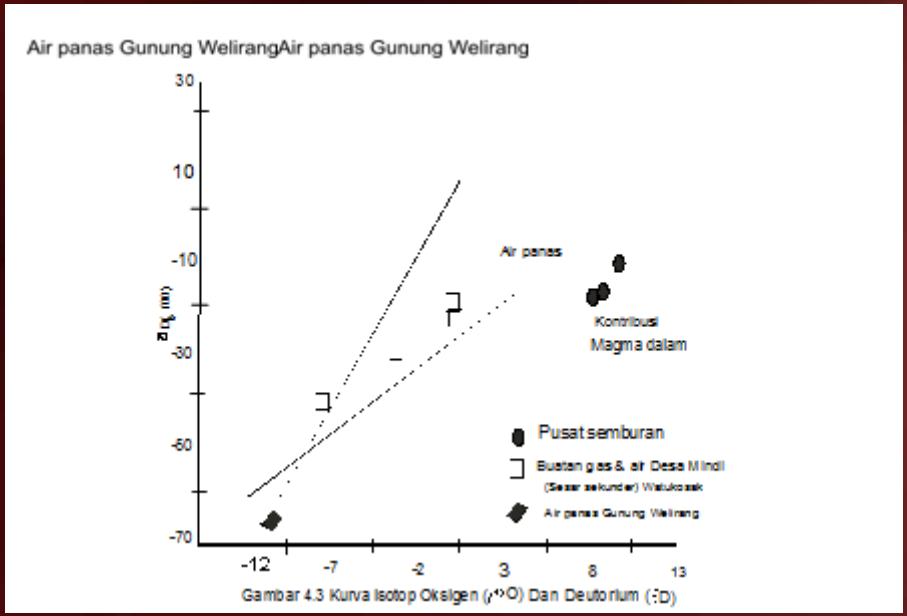
- Density and shear and compressional sonic suggest the presence of overpressured zones. These are probably plastic, and undercompacted shale, controlled by rapid sedimentation. The rapid burial of shale with low sand/shale ratio results in low permeability zone which expels water at a very low rate causing an overpressure condition.

Density and shear and compressional sonic suggest the presence of overpressured zones. Zone at interval 4000 – 6000 feet.

MUD , WATER AND GAS ANALYSES OF SMV: FROM BIOLOGY, CHEMICAL, AND PHYSICS

- The age of mud based on foraminifera and nano fossil suggests as Early Piocene (not older than 4.9 Ma), and this is derived from Kalibeng Formation. In Well BP-1 loacted at depth from 2000 feet – 6-000 feet (See Figure 2.1)
- Result of Xray analyses suggests that mud consists of minerals: pyrite, albite, kaolinite, paragonite, and halit. It suggest that the rocks has experienced hydrothermal alteration, AND water associated with mud is salty, and it has been considered THAT the salty water is not derived from MUD. The analyses of water in facts, is dominated by Natrium (Na), Magnesium (Mg) dan Calsium (K), containing above 8 mg/l and Cloride (Cl) above 1.8 mg/l.
- The chlorite contents is about 14000 ppm, whereas from the surrounding wells; Kujung Formation or Kalibeng Formation has chlorite contents smaller than <10000 ppm, or Kujung Formation at Well Porong #1 has chloride content Cl 11000 ppm.
- The presence of Gas H2S, indicated that the gas is derived from from deep structure (probvably Kujung Formation as commonly found in East Java Basin>
- Gas Eruption Analyses at spillway besides H2S, there are other gases such as; C1: 96%, C2 :4.1%, C3: 2.6%, C44% nC4:1.0%, C5:1.4%
- The gas isotopic composition supports the hypothesis of a mixed biogenic and thermogenic origin of the gases erupted at LUSI (e.g. cfr. Bernard et al., 1978; Whiticar, 1999; Quoted from Mazzini et al 2007)
- Correlation with seismic data shows that mud was derived from overpressure zone located at depth 4000 – 6100 feet.
- Water analyses done by Badan Geologi suggested the presence of Deuterium as it indicated from deep magma source

Isotop Oksigen (δ ^{18}O) dan Deutorium (δ D)



Gambar 4.3 Kurva Isotop Oksigen ($\delta^{18}O$) Dan Deutorium (δD)

Badan Geologi Departement Energi dan Sumber Daya Mineral Juni 2007

Sidoarjo Mud Extrusion based on Oxygen isotope (δ ^{18}0) and Deuterium (δ D) is influenced by deep magmatic

Magmatic heat emitted from deep structure through fault reactivation penetrated Kujung Formation and erupted to the surface as vapour hot water and known as Sidoarjo Mud Volcano

The prime mover of the extrusion is the transformation of hot magmatic process to the formation of vapor hot water

The water age analyses suggested the age is older than 50,000 years old, and suggested no influence of meteroic water nor sea water at the present day

May 29th 2006, 9 am

Extrusion in grass field NOT in the drilling site or the BJP exploration well

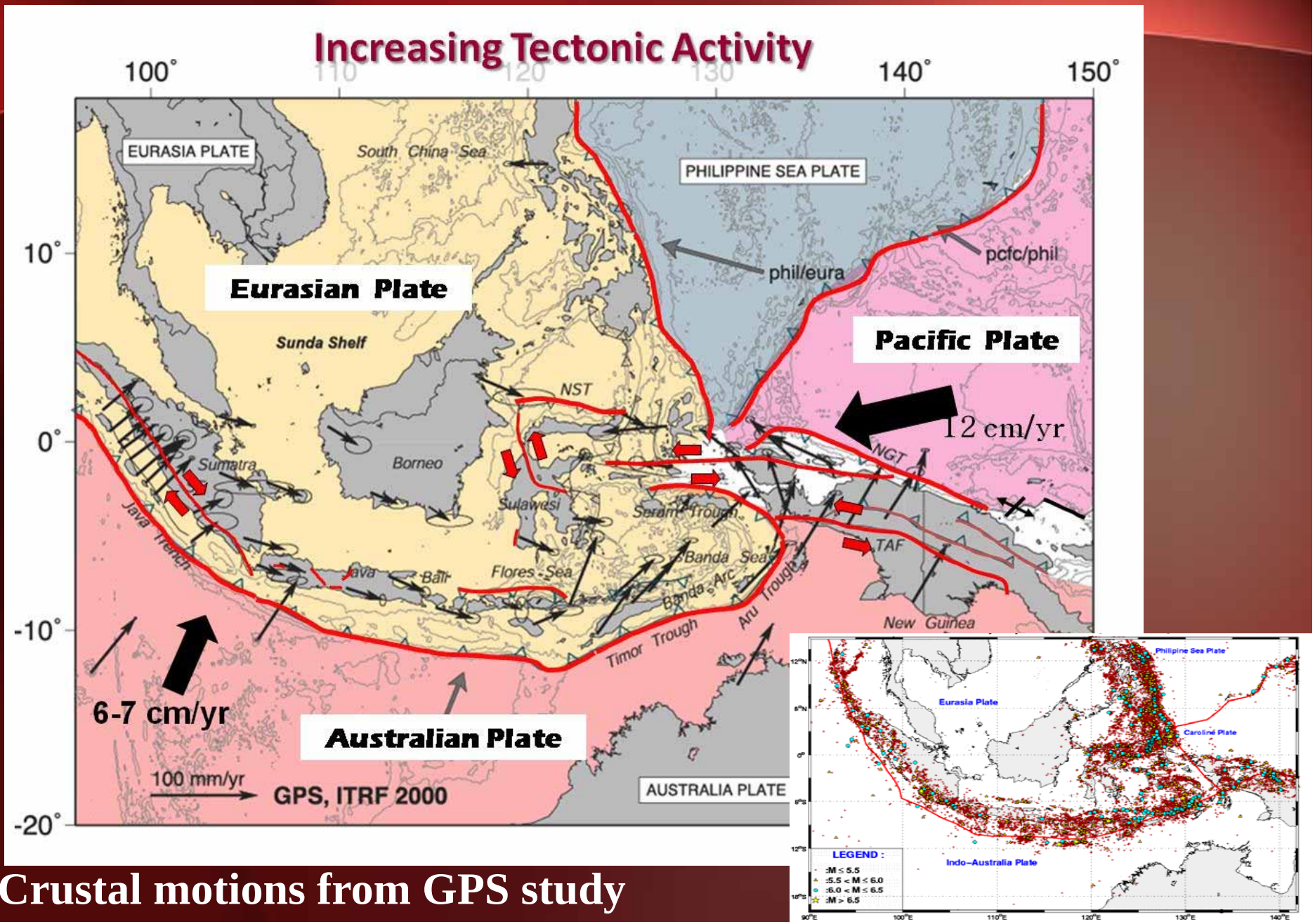
What makes those such big flow rates ????

The history of mud extrusion flow rates started at ~ 5000 m^3/day, and sharply increased to 50,000 m^3/day and have reached the peak ~150,000 m^3/day, averaging at ~100,000 m^3/day, and after 5 years at the present day is around 10,000 m^3/day

ISSUES ???

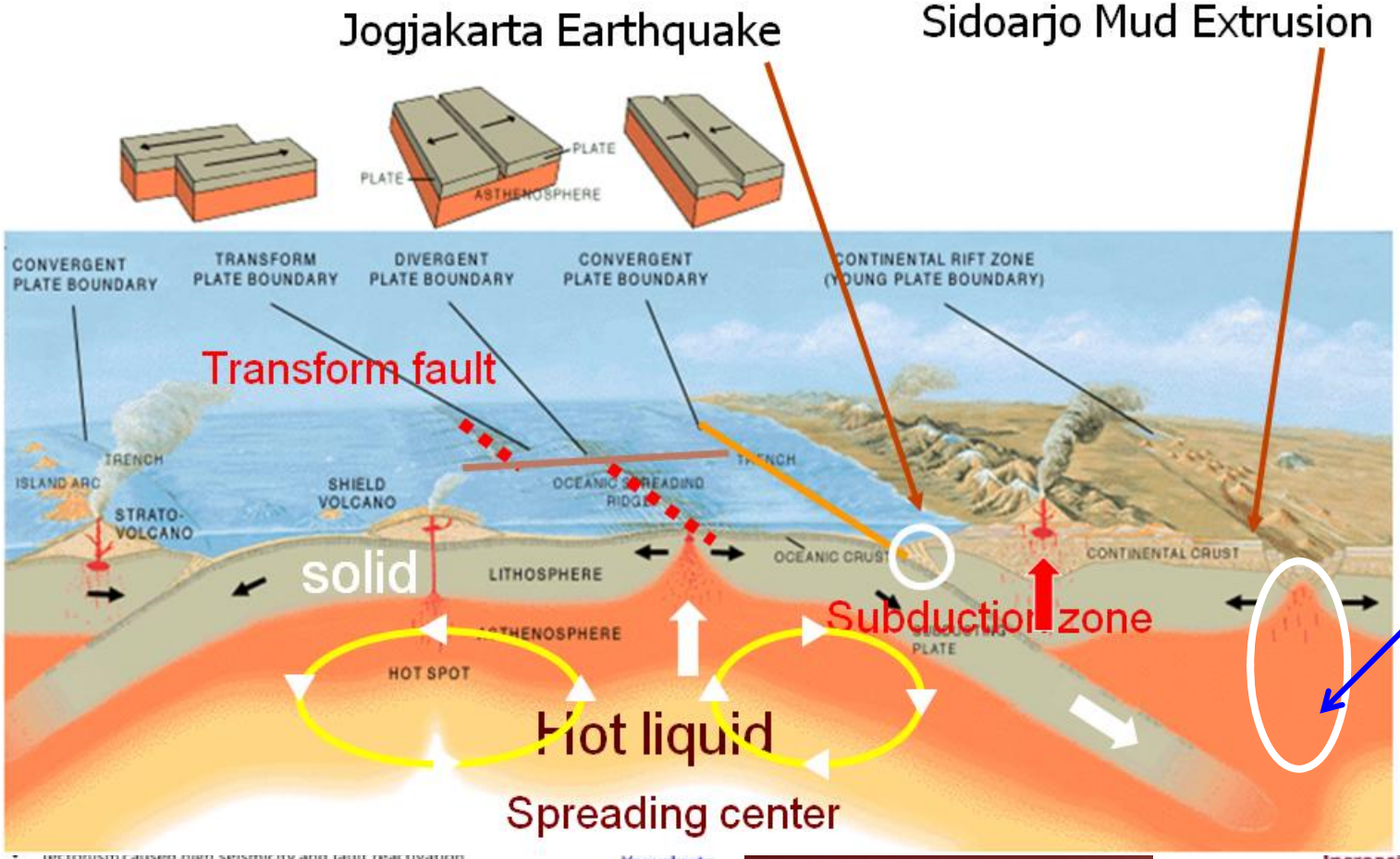
- THE COMPOSITION OF MUD 30% AND HOT WATER 70% WITH TEMPERATURE ABOVE 100^0 C, AS WELL AS HUGE FLOW RATE (PEAK 150,000 M3/DAY eq 1,000,000 BWPD), DO NOT INDICATE AS NORMAL CONVENTIONAL MUD VOLCANO
- THE PRESENCE OF GAS H2S IS PROBABLY DERIVED FROM KUJUNG FORMATION, WHEREAS KUJUNG FORMATION ITSELF IS NOT YET PENETRATED BY THE WELL BP-1. THE PRESENCE OF THERMOGENIC GAS IS ALSO SUPPORT DEEP ORIGIN. IN ADDITION THE PRESENCE OF DEUTERIUM AS SHOWN FROM WATER ANALYSES DONE BY BADAN GEOLOGY SUGGESTED THE SOURCE RELATED TO MAGMATIC PROCESSES
- THE DEBIT OF ERUTION STARTED FROM 5000 M3/DAY DURING EARLY ERUTION, WITH THE PEAK UP TO 150,000 M3/DAY AND PLATEAU AT 100,000 M3/DAY INDICATED AS NATURAL PROCESSES. AND THE MOST QUESTION IS WHAT MAINTAIN THE FORCE OF THOSE ERUPTION UP TO PRESENT DAY AFTER 5 YEARS NON-STOPPING ERUPTION. THE MOST PLAUSABLE ANSWER IS THAT THE PRESSURE MAINTENANCE IS DERIVED FROM MAGMATIC PROCESSES IN DEEP DEPTH
- IT IS ALSO NOTED THAT THERE IS NO SIGNIFICANT AND CLEAR SHALE DIAPIRIC STRUCTURE IN THE KALIBENG FORMATION INTERVAL (2000 FEET – 6000 FEET)
- IT IS CLEAR THAT MUD AND WATER ARE TWO DIFFERENT SYSTEMS, IN OTHER WORDS MUD AND WATER ARE FROM DIFFERENT SOURCE OF DEPTH.

IV. REGIONAL TECTONICS

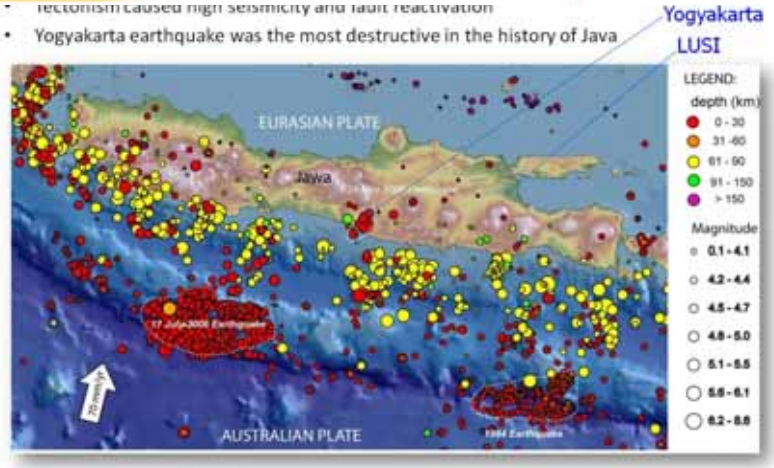


Crustal motions from GPS study

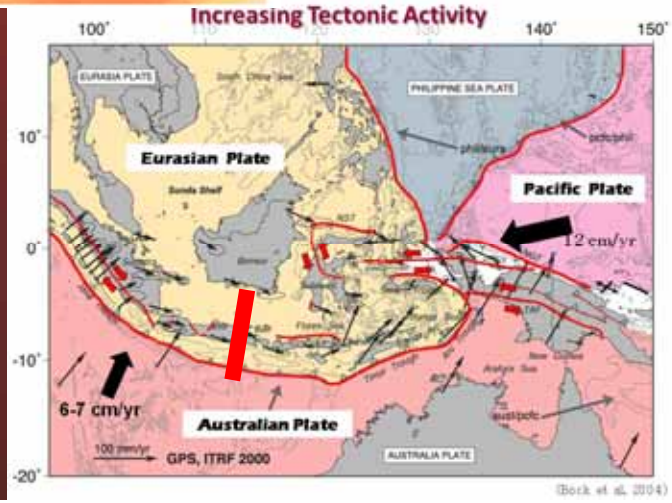
PROFILE OF SUBDUCTION-BACK ARC BASIN IN RELATION TO MANTLE UPWELLING



- Tectonism caused high seismicity and fault reactivation
- Yogyakarta earthquake was the most destructive in the history of Java

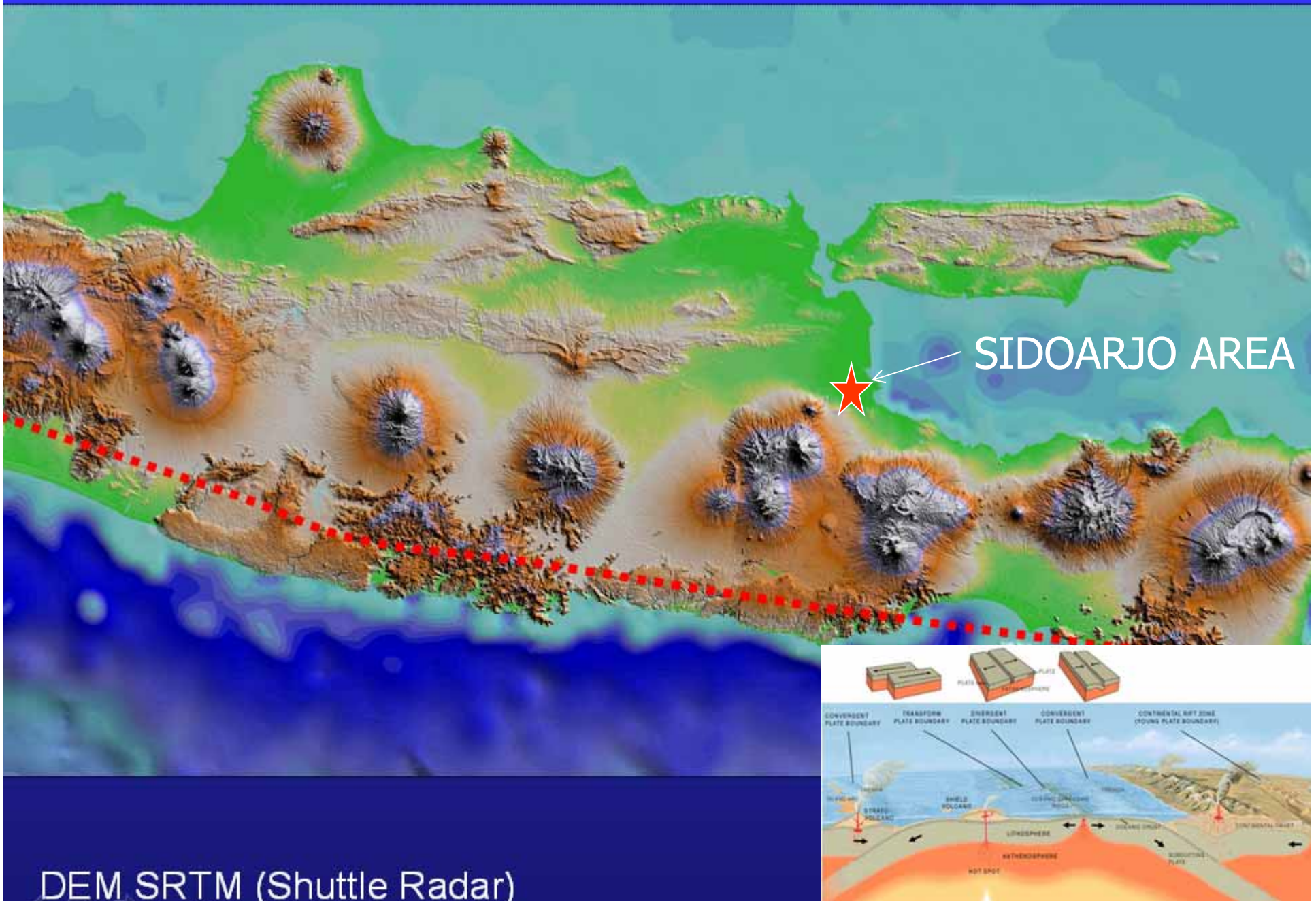


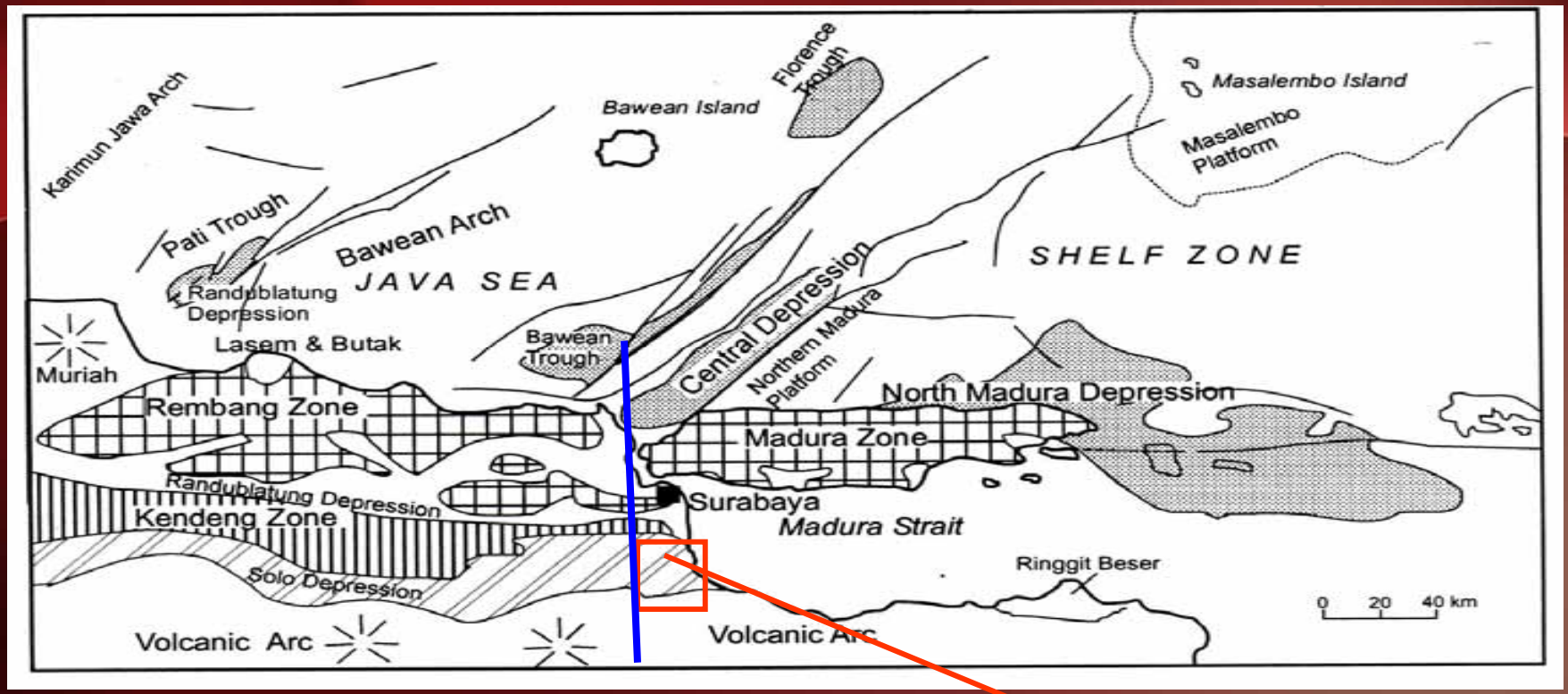
SEISMICITY OF JAVA NEIC- USGS (1973-2006)

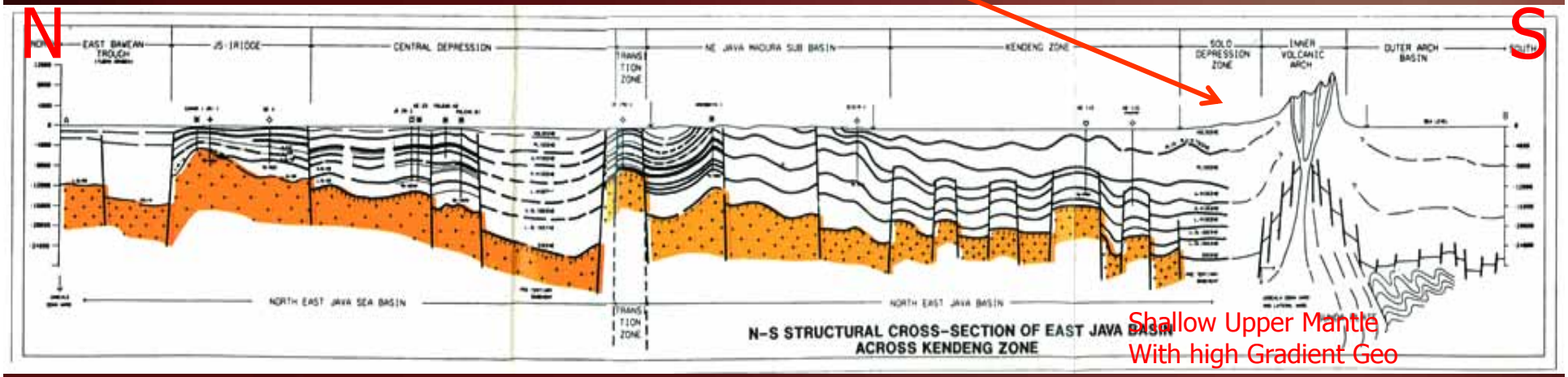


(Bock et al. 2004)

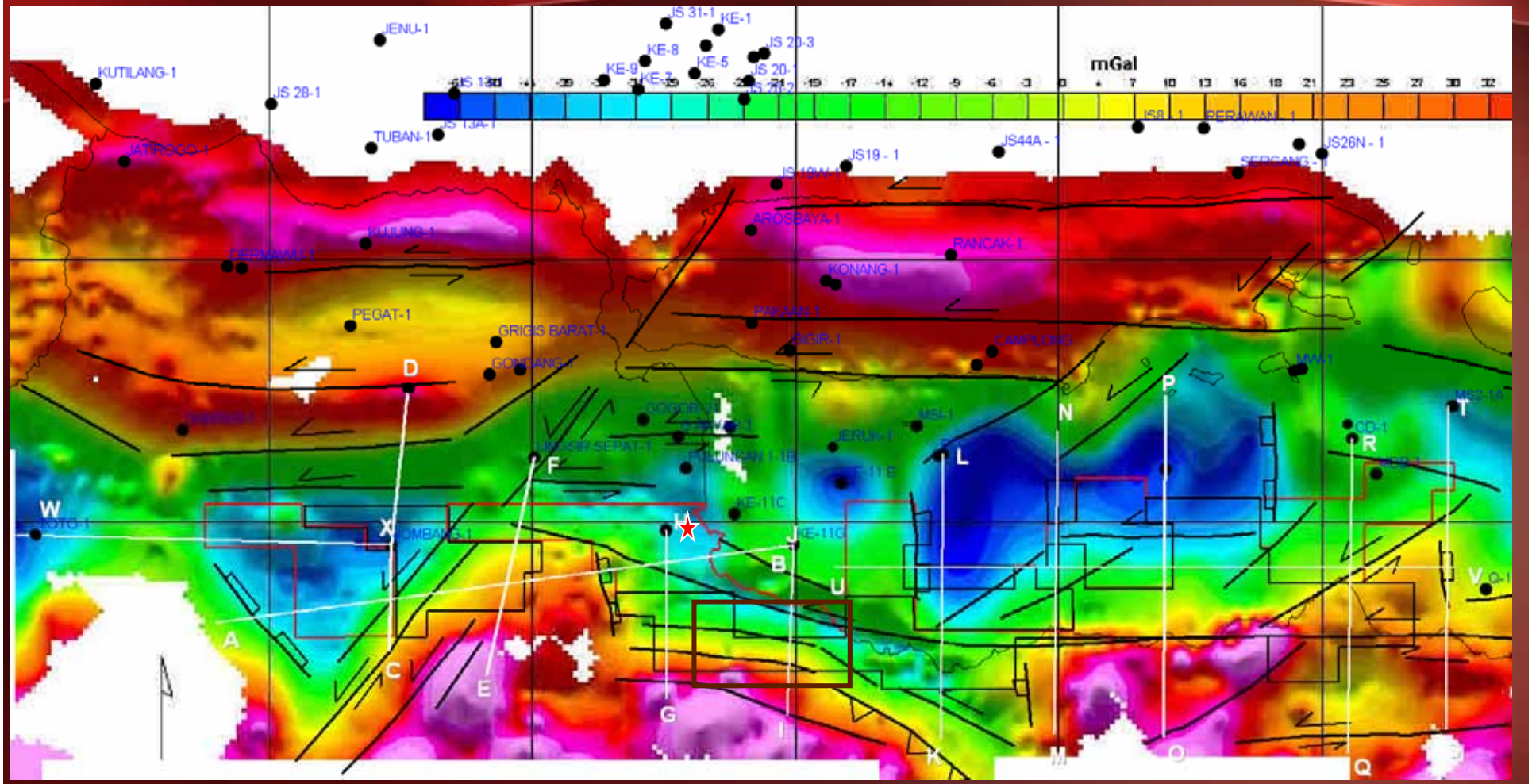
III. REGIONAL EAST JAVA TECTONICS





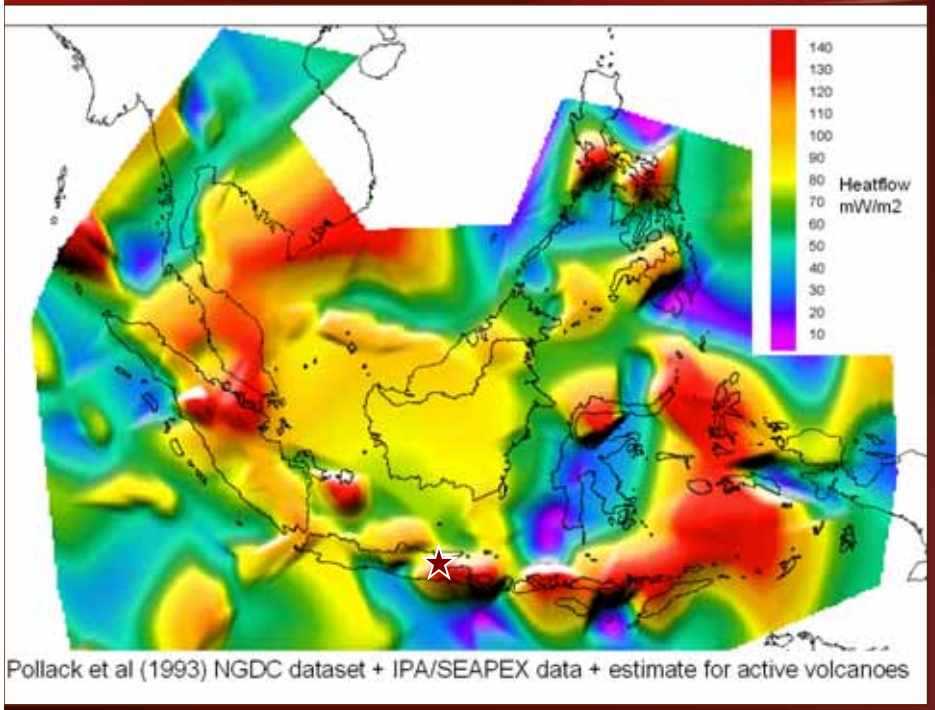


REGIONAL STRUCTURE MAP AND PHYSIOGRAPHY OF EAST JAVA
(Latief et al. 1990)



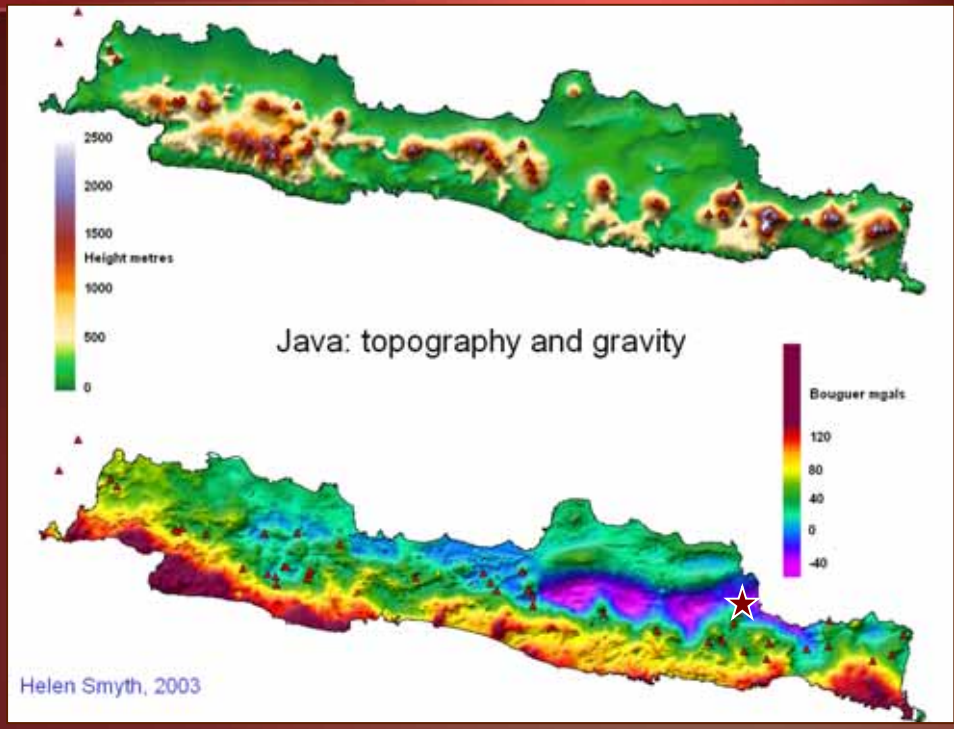
Gravity data of East Java showing E-W Deep structure which is the same with Surface expression (Coutessy of Lapindo)

HEAT FLOW MAP OF INDONESIAN REGION



Pollack et al (1993) NGDC dataset + IPA/SEAPEX data + estimate for active volcanoes

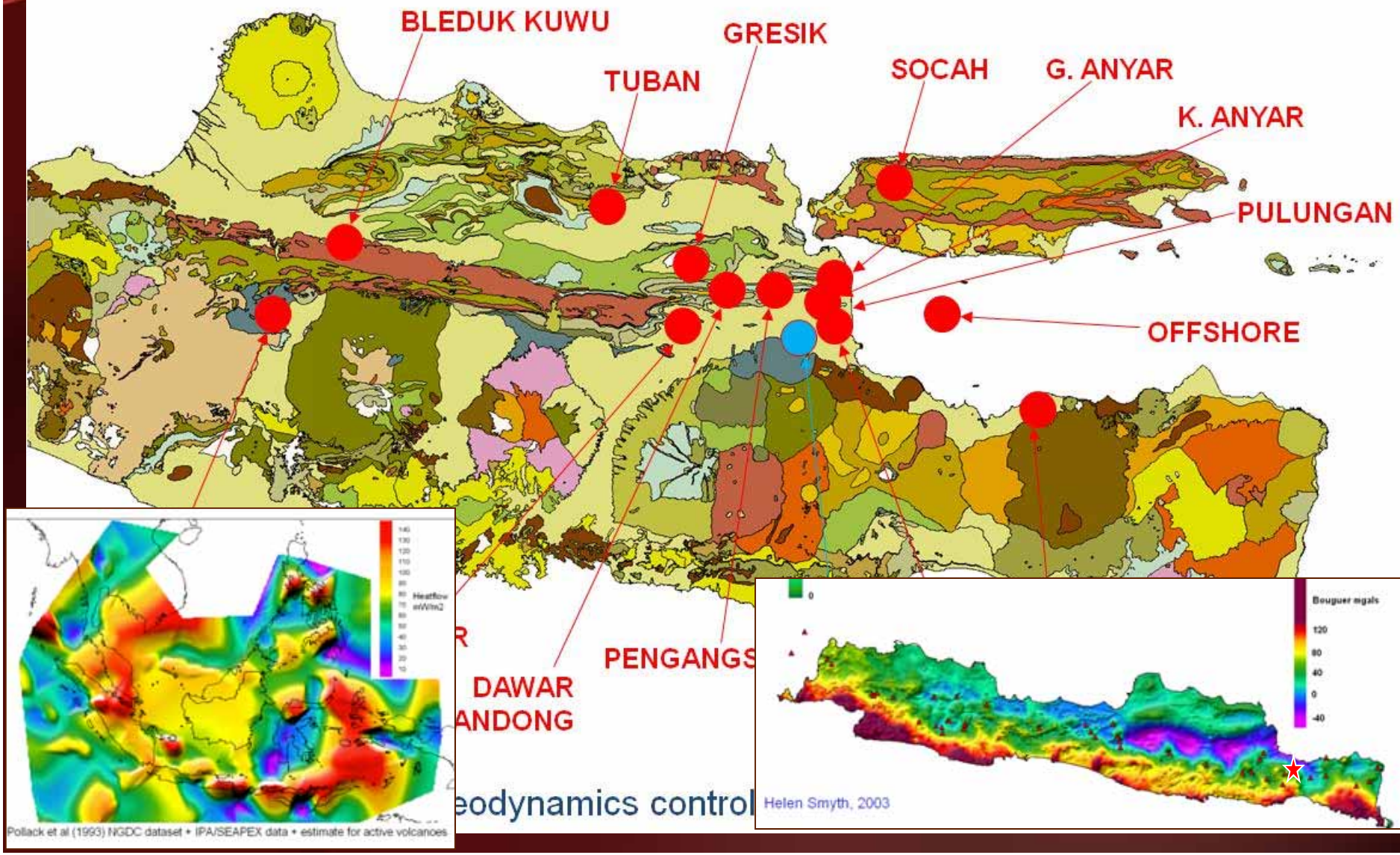
TOPOGRAPHY AND GRAVITY DATA OF JAVA ISLAND



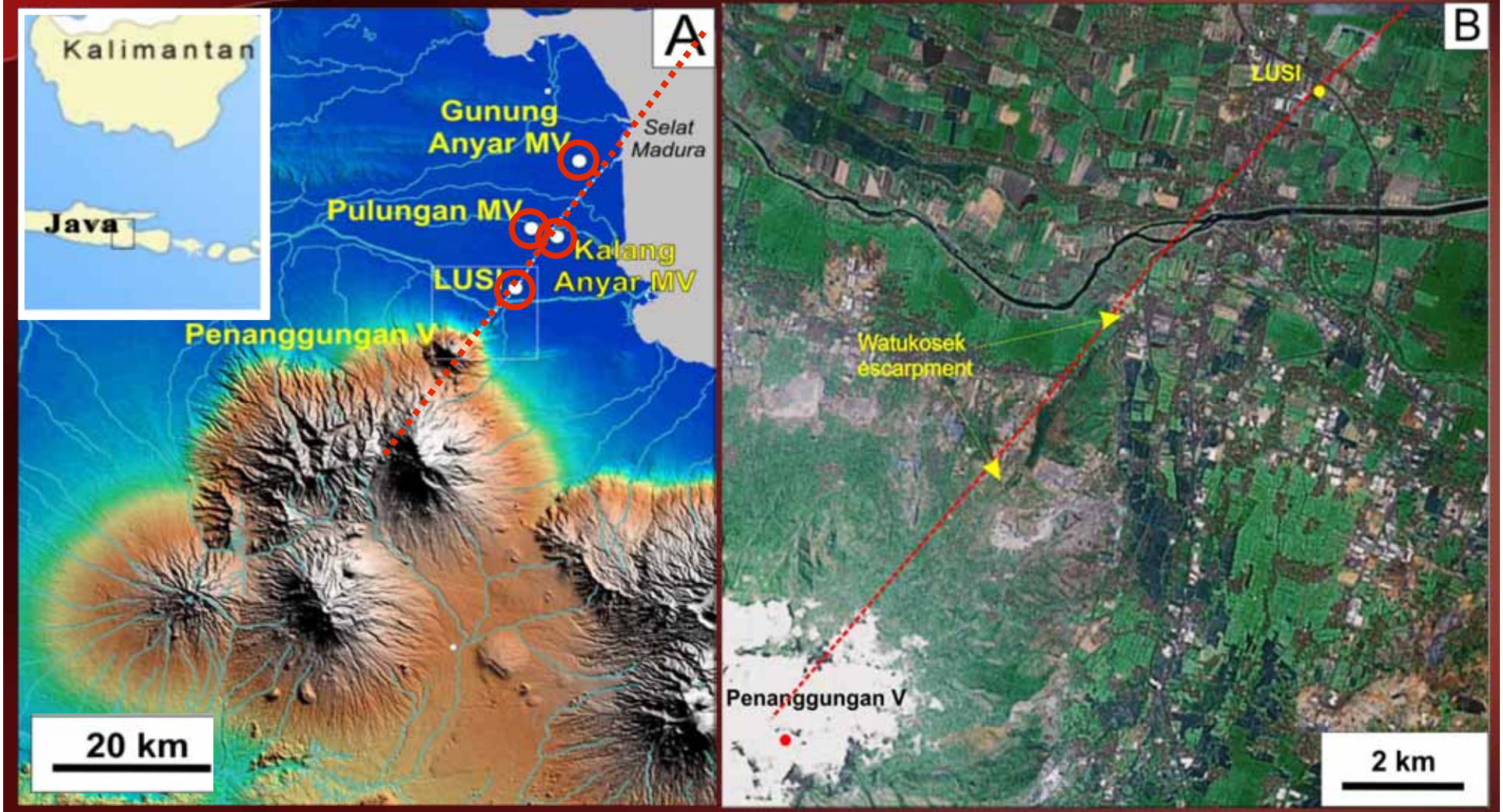
HEAT FLOW AND GRAVITY VALUES ARE WELL CORRELATED WITH THE PRESENCE OF DEEP BASIN (MORE THAN 6 KM) FOLLOWED BY CRUSTAL

THINNING AND THERMAL UPDOOMING

GEOLOGICAL SETTING AND GEODINAMIC CONTROL OF THE DISTRIBUTION OF MUD VOLCANO IN EAST JAVA THAT WELL CORRELATED WITH GRAVITY AND HEAT FLOW

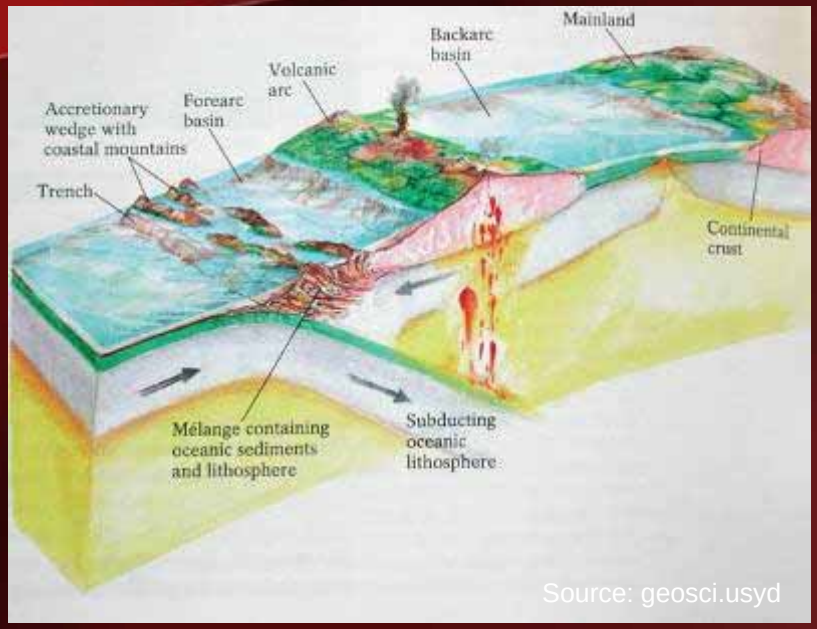


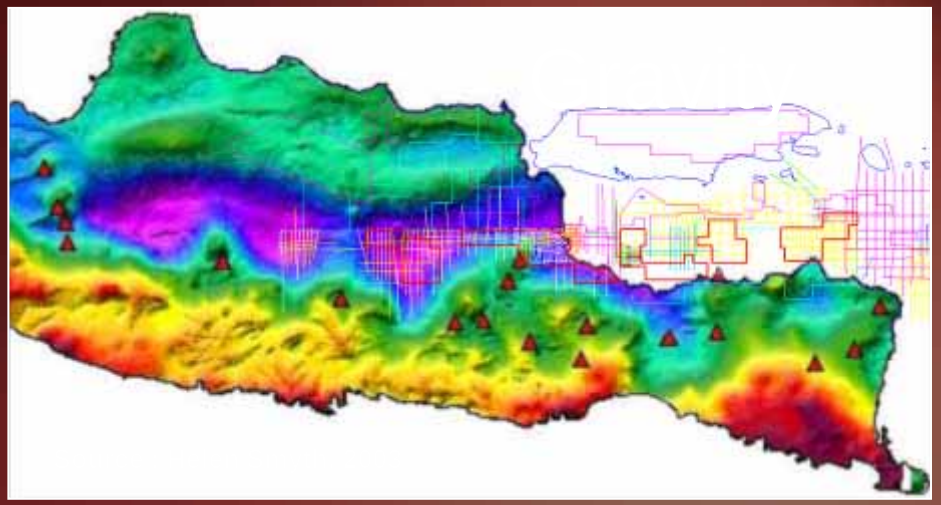
LUSI and faulting

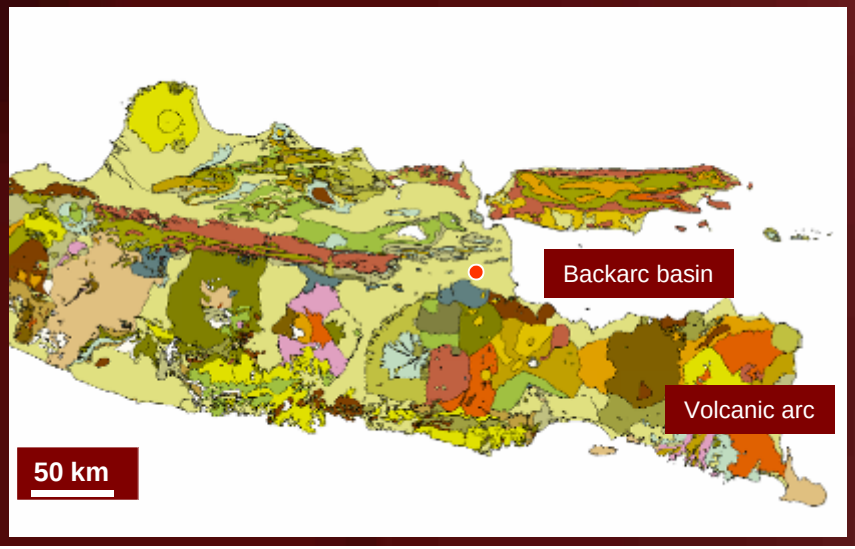


Mud Volcanoes, River and Escarpment- aligned along fault lines. A very long propagating fracture appears due to tectonic activities / earth quakes in the region

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**

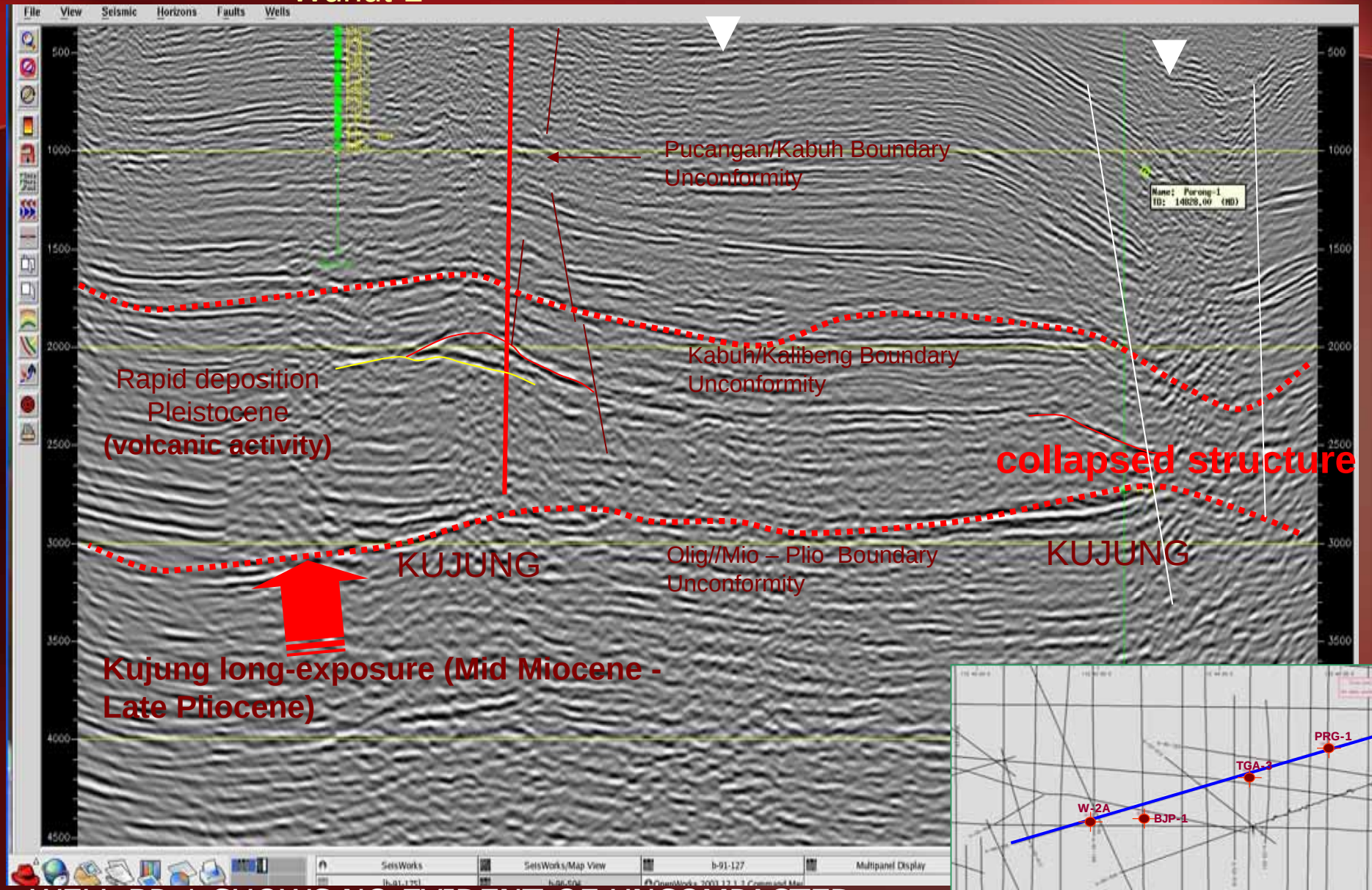
→ **ideal setting for MV**

V. SEISMIC INTERPRETATION

BJP-1

Wunut-2

PRG-1



WELL BP-1 SHOWS NO EVIDENT OF UNCOMPACTED SHALE AND NO SIGNIFICANT DIAPIRIC STR

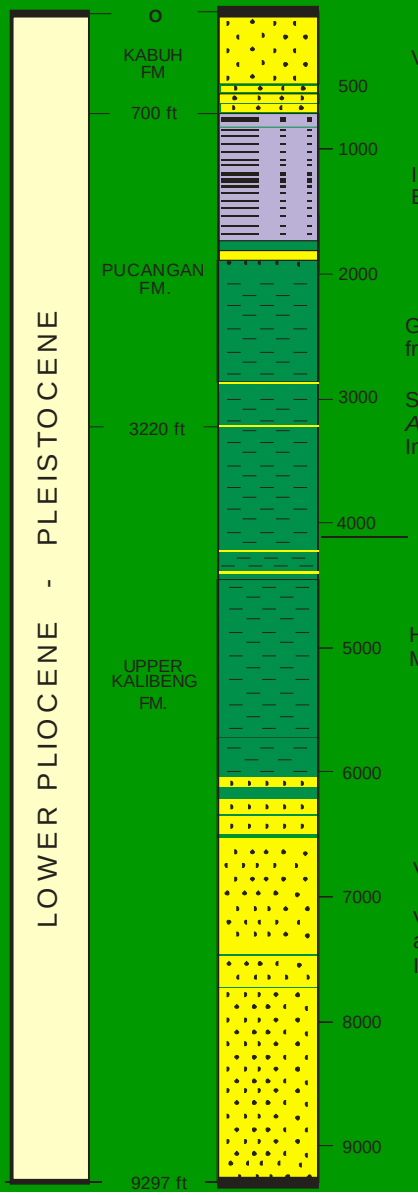
WELL RESULT OF BANJAR PANJI -1

EXPLORATION WELL OBJECTIVE

- **Early Miocene Limestone**
- **Pliocene Limestone**

SUMMARY WELL LOG BANJARPANJI-1

Spud Date : March 08,2006
Completed :
Well Status : Drilling in progress
Operator : EMP Brantas



Volcanic sandstone, med to coarse grained, with clay intercalation.

Interbedded fine grained sandstone, siltone and shale contain Elphidium. Litoral to inner shelf depositional environment.

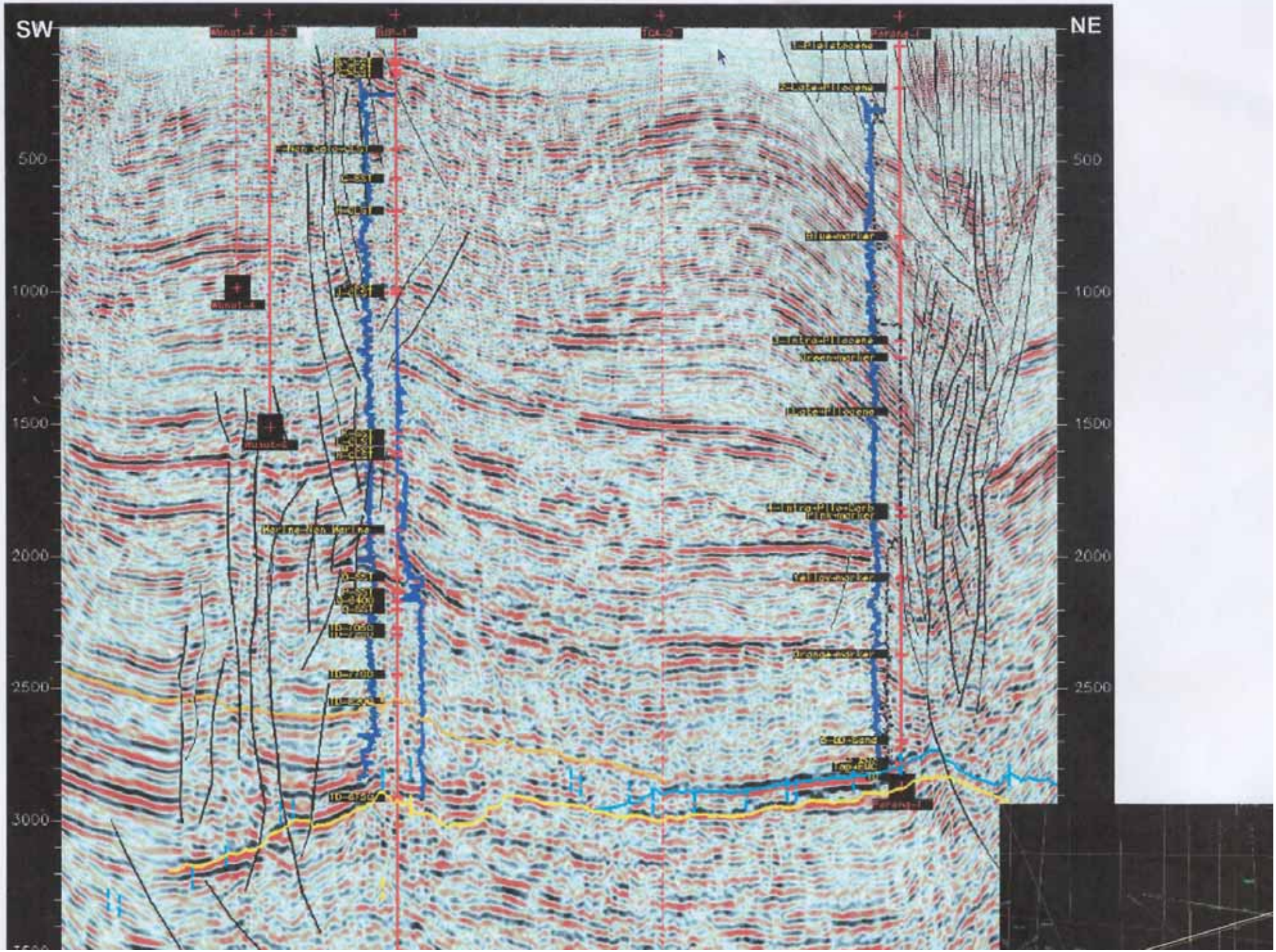
Gray slightly calc. shale with minor fine grained sandstone ,with lithic fragment, intercalations.

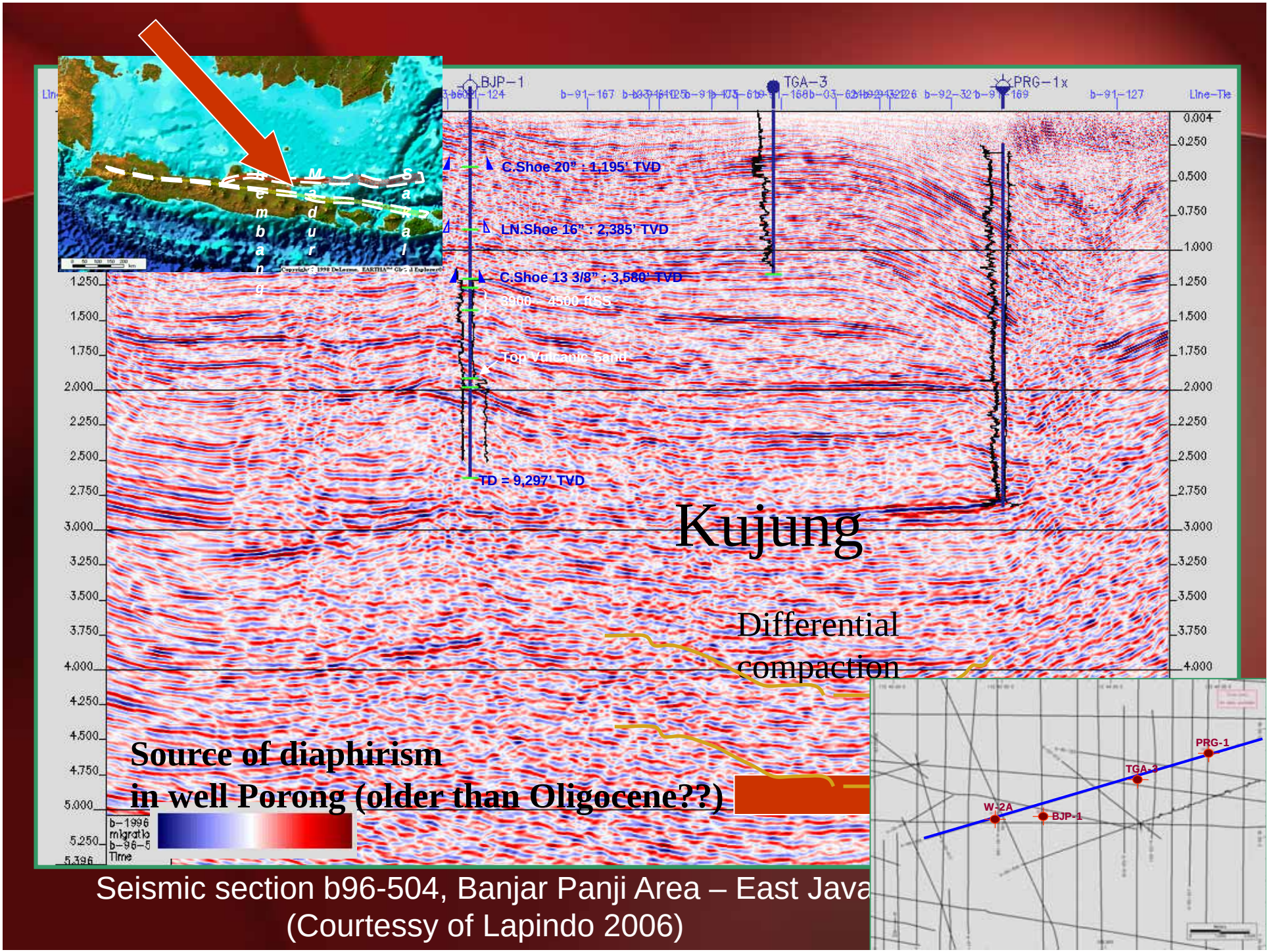
Shale contains forams, nanno and shell frag *ment* Benthonic forams: *A. Trispinosa* and index nannofossils *Gephyrocapsa* common. Inner sublitoral depositional environment.

High abundance nanno and foram
Mid to outer sublitoral depositional environment.

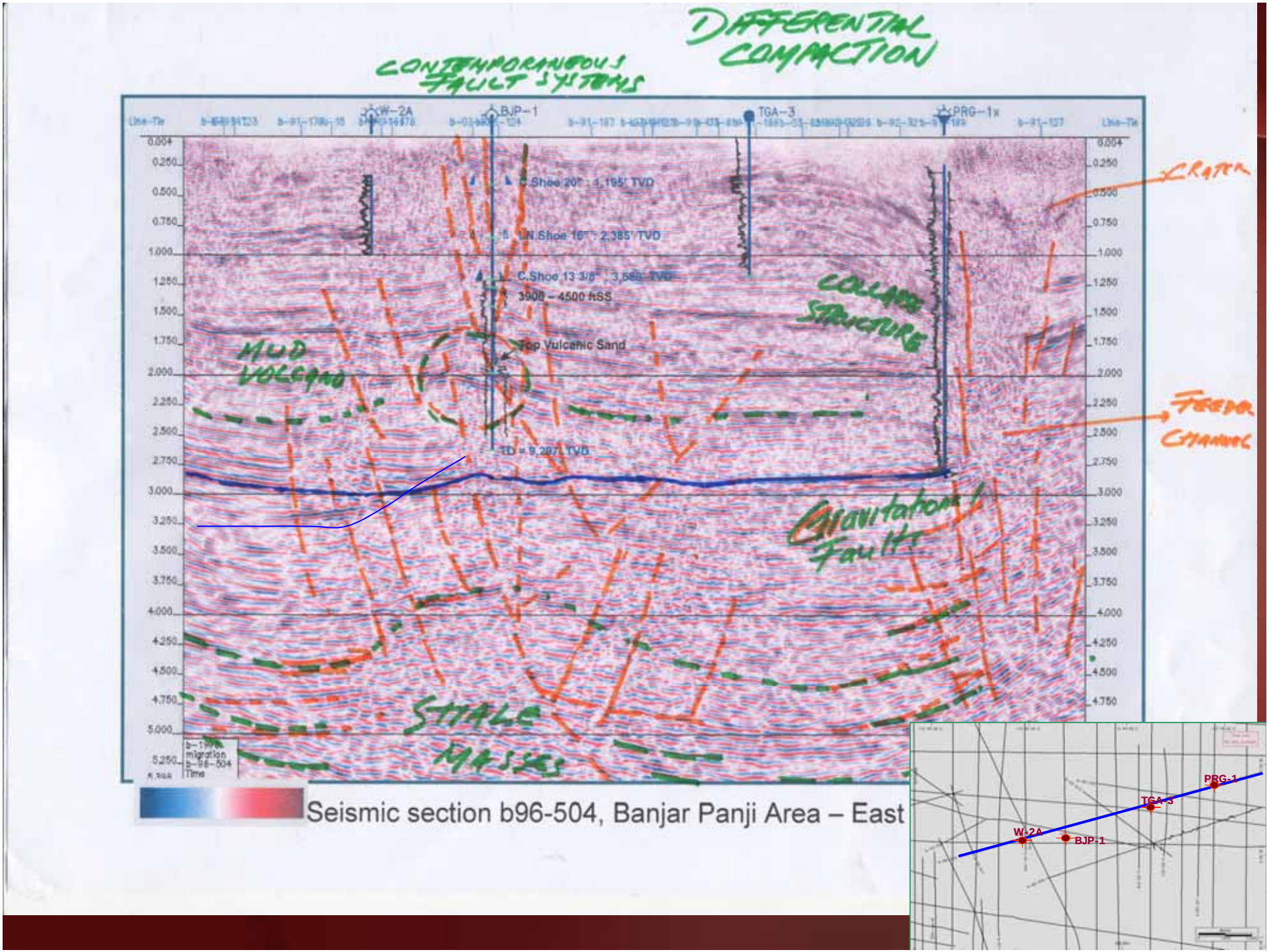
Volcanik sandstone with minor shale intercalation in the upper part.

Volc. sandstone, dark gray, med to coarse grained, sub angular, feldspar andesitic rock fragment. Shale contain rare nanno of Plio-Pleistocene age. Inner shelf depositional environment


SW
NE
500
1000
1500
2000
2500
3000



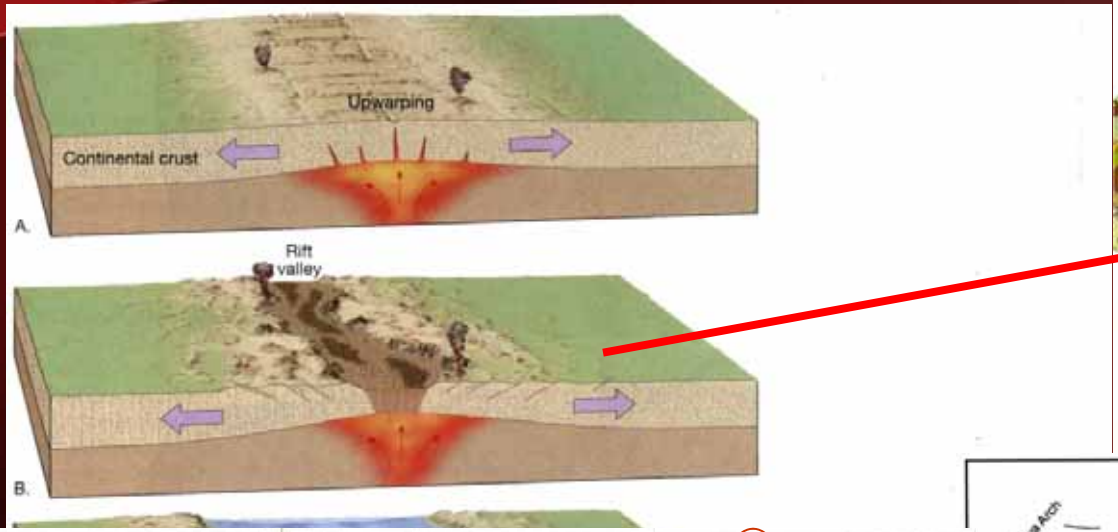
Seismic section b96-504, Banjar Panji Area – East Java
(Courtessy of Lapindo 2006)

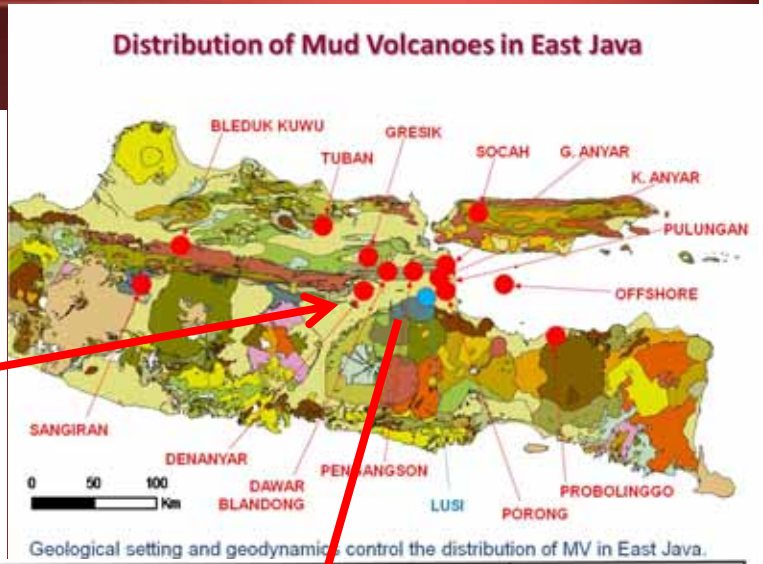


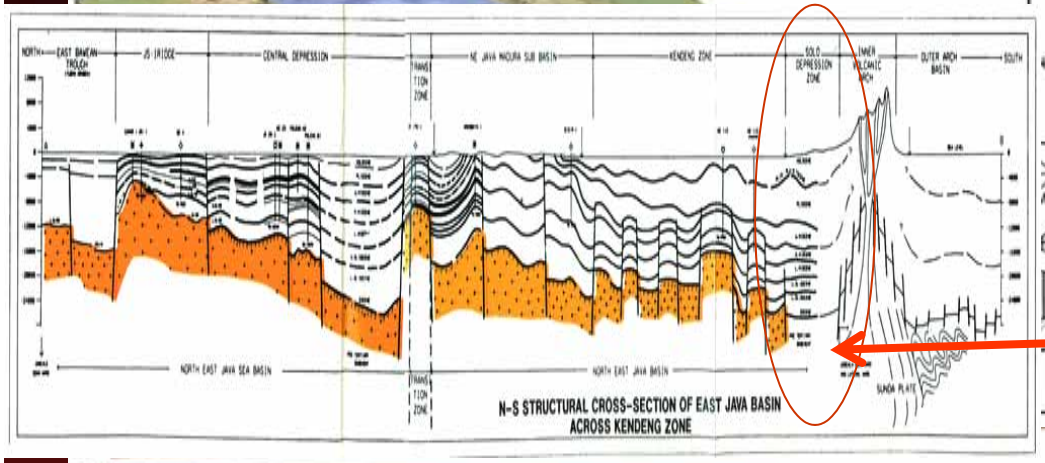
Seismic section b96-504, Banjar Panji Area – East

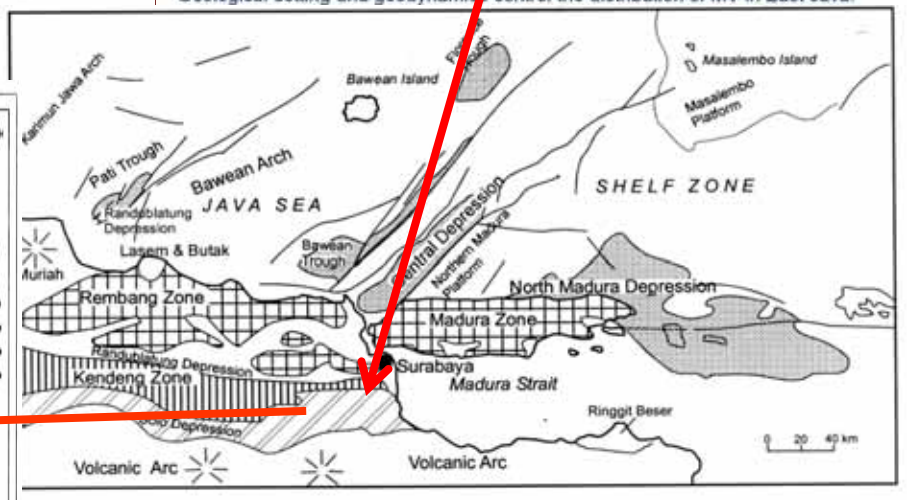
HYPOTHESIS and MODEL FOR MUD EXTRUSION

RIFT TO SUBDUCTION ZONE RELATED

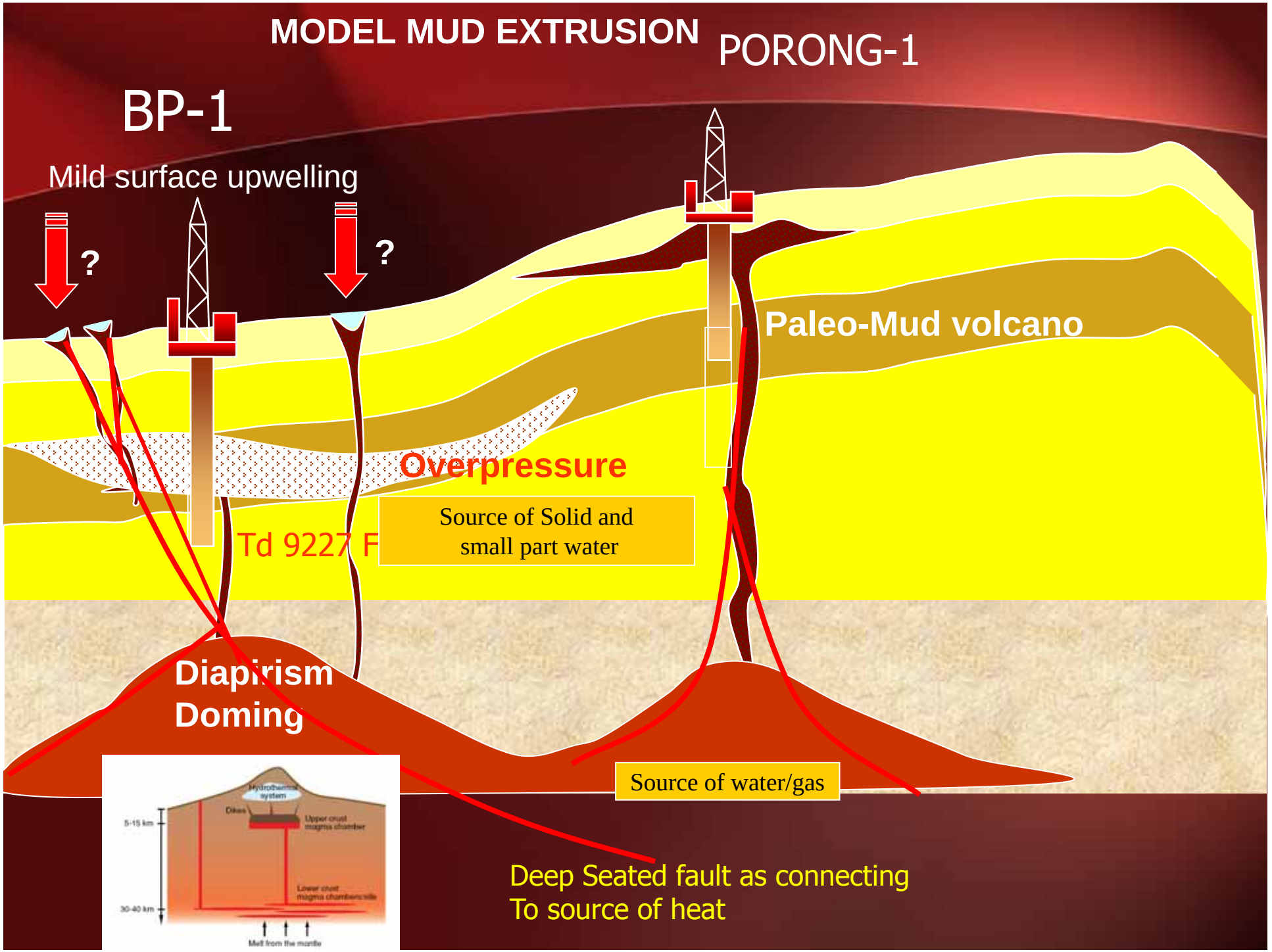








THE OPENING OF BACKARC BASIN IN RELATION TO SUBDUCTION PROCESSES HAS CREATED MANTLE UPDOOMING IN PROVIDING MAGMATIC PROCESSES


MODEL MUD EXTRUSION
PORONG-1
BP-1
Mild surface upwelling
?
?
Paleo-Mud volcano
Overpressure
Source of Solid and
small part water
Td 9227 F
Diapirism
Doming
Source of water/gas
Deep Seated fault as connecting
To source of heat

CONCLUSIONS

- Mud Volcanoes are common phenomena in the East Java and even Porong Area has many scattered mud volcanoes and some are still active.
- Well BP-1 conform not to penetrate Kujung Formation.
- Well Analyses of BP-1 suggested that no significant reservoar was found up to TD, even the volcanic sand is very tight, and the reservoir must come from much deeper than TD of Well BP-1
- Laboratory analyses suggested that that MUD and WATER are two different source of depth
- The pressure maintenance of those unstop extrusion is derived from magmatic processes creating hot vapour water and emitted through the fault up to surface
- The source of water and associated gas from deep structure are supported from gas and water analyses
- The longevity of SMV will last long with the intermittent period as the activity will be influenced by pressure build ups derived from heat transformation from magmatic and can be accelarated by fault reactivation due to tectonic processes. IT MEANS UNPREDICTABLE BEHAVIOUR

THANK YOU