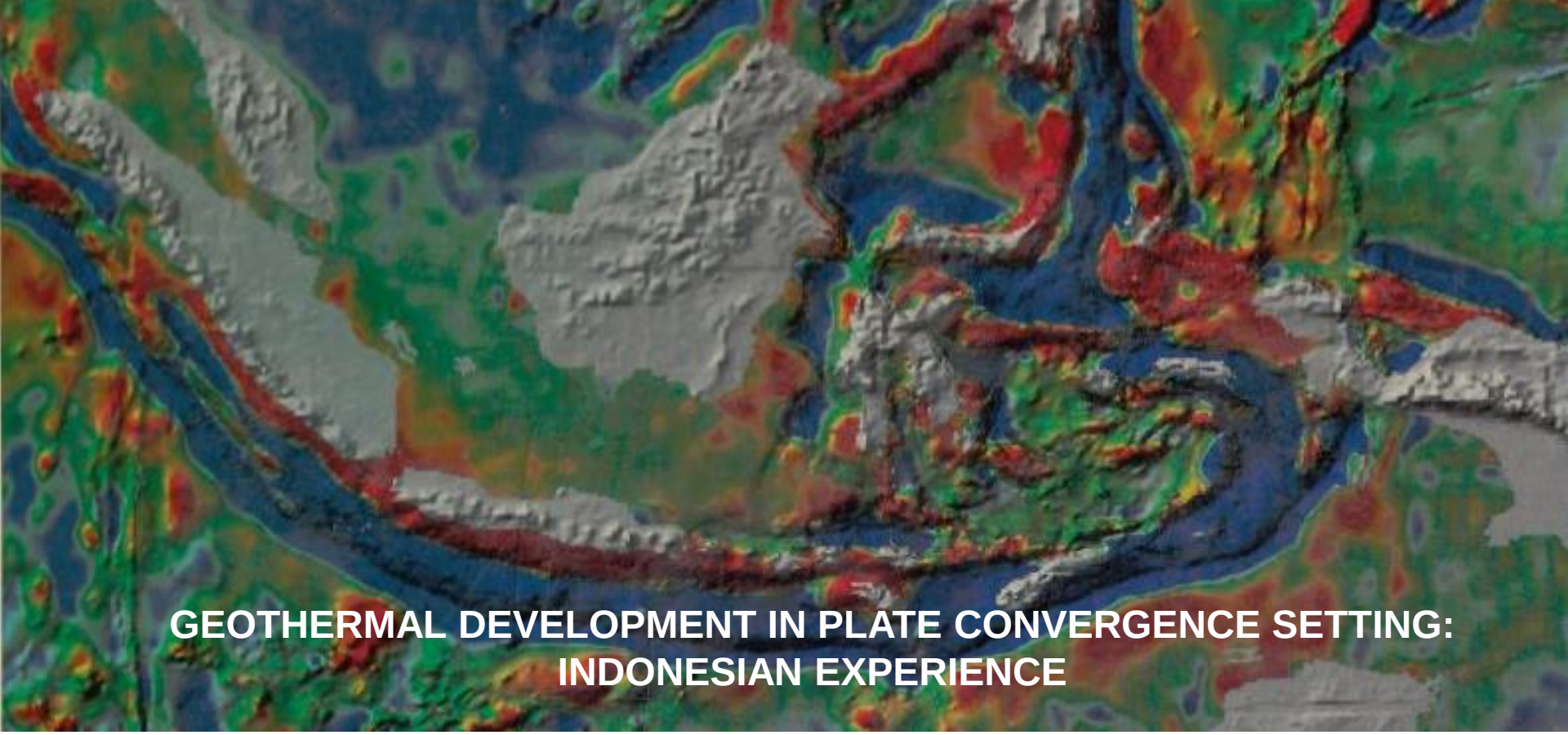
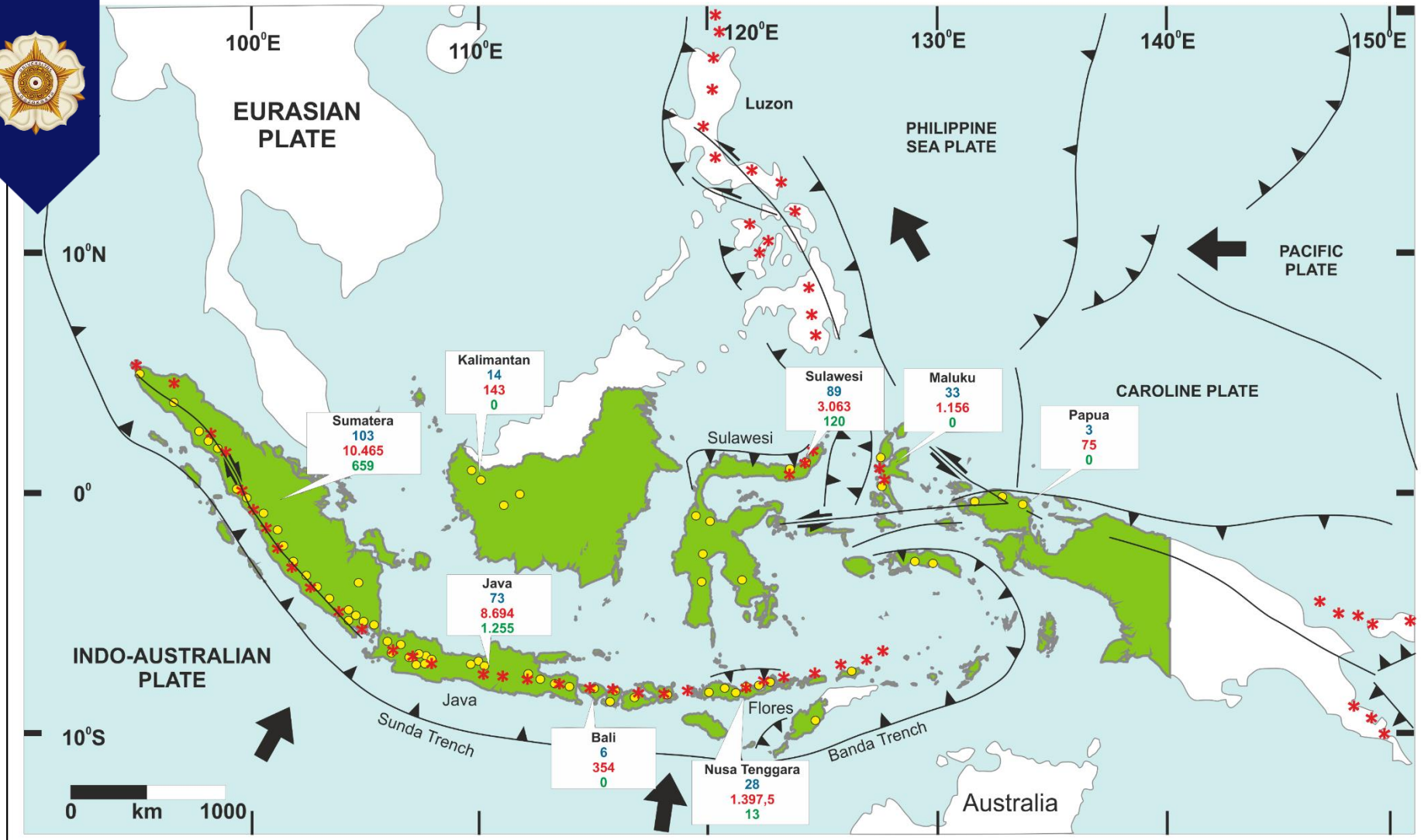


GEOTHERMAL DEVELOPMENT IN PLATE CONVERGENCE SETTING: INDONESIAN EXPERIENCE

Pri Utami
Geothermal Research Centre &
Department of Geological Engineering
Faculty of Engineering, Universitas Gadjah Mada
Jalan Grafika 2, Yogyakarta, Indonesia
p.utami@ugm.ac.id

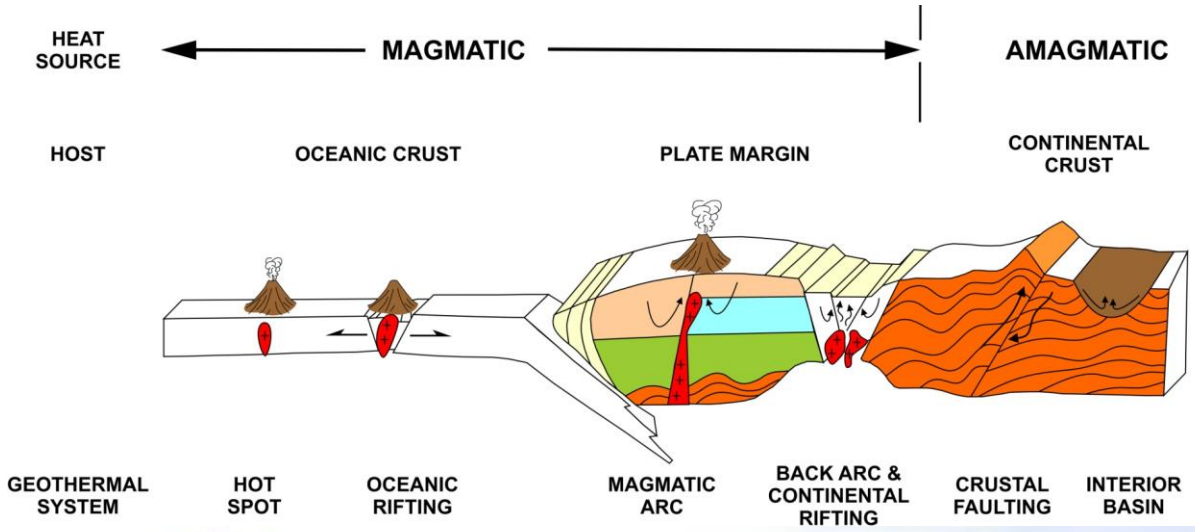
TALK COVERAGE

- Tectonic setting of the Indonesian archipelago
- Geothermal potential of Indonesia
- Some lessons learnt
- Challenges and opportunity for research



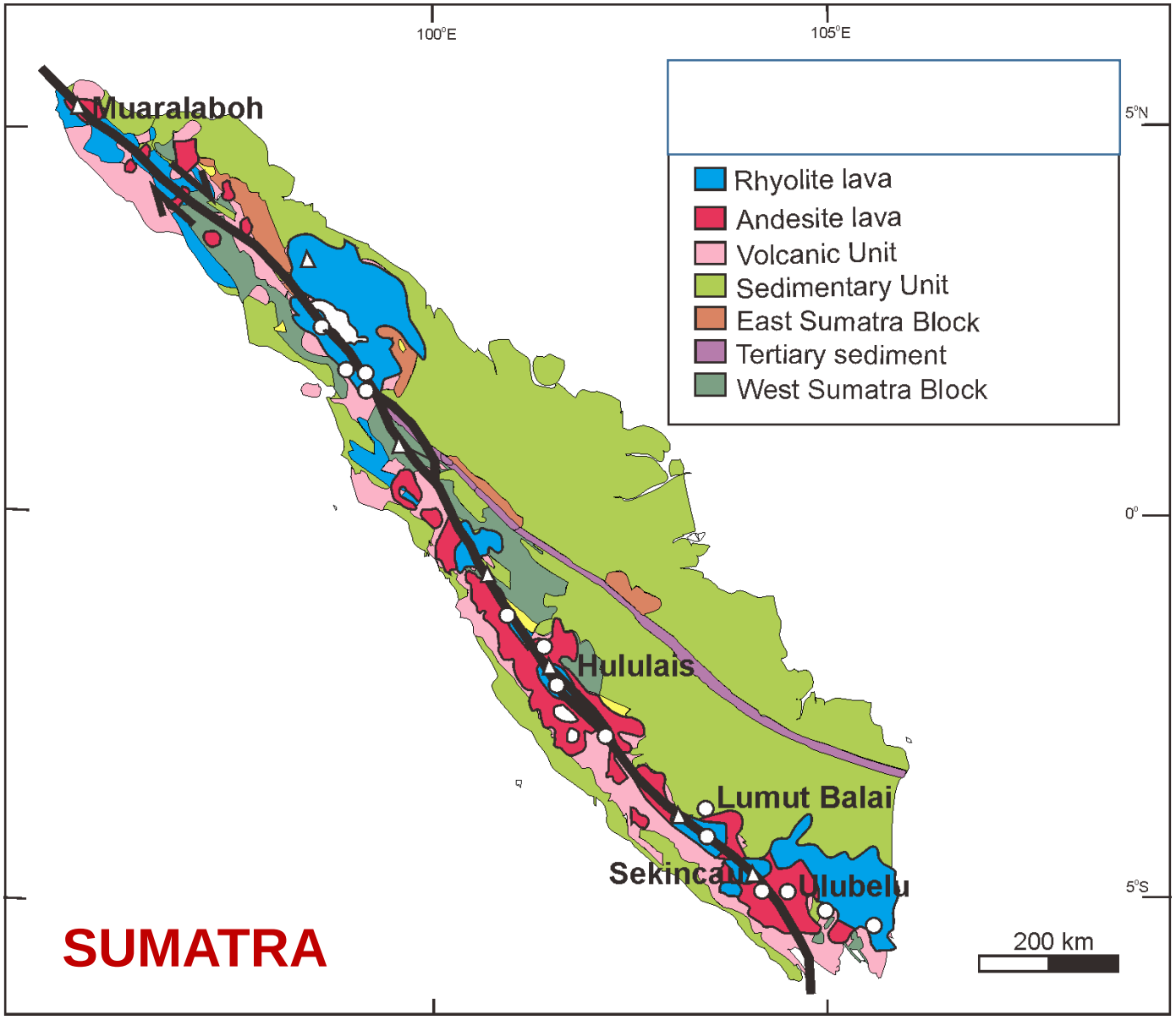
Map compiled from Hamilton (1988), Simanjuntak and Barber (1996), Macpherson and Hall (2002), MEMR (2018)

Indonesian Archipelago: 80 active and inactive strato-volcanoes • 20 volcano-hosted high-temperature geothermal systems • 2,133 MWe from 15 fields (2020) • > 20 GW total potential in > 250 locations



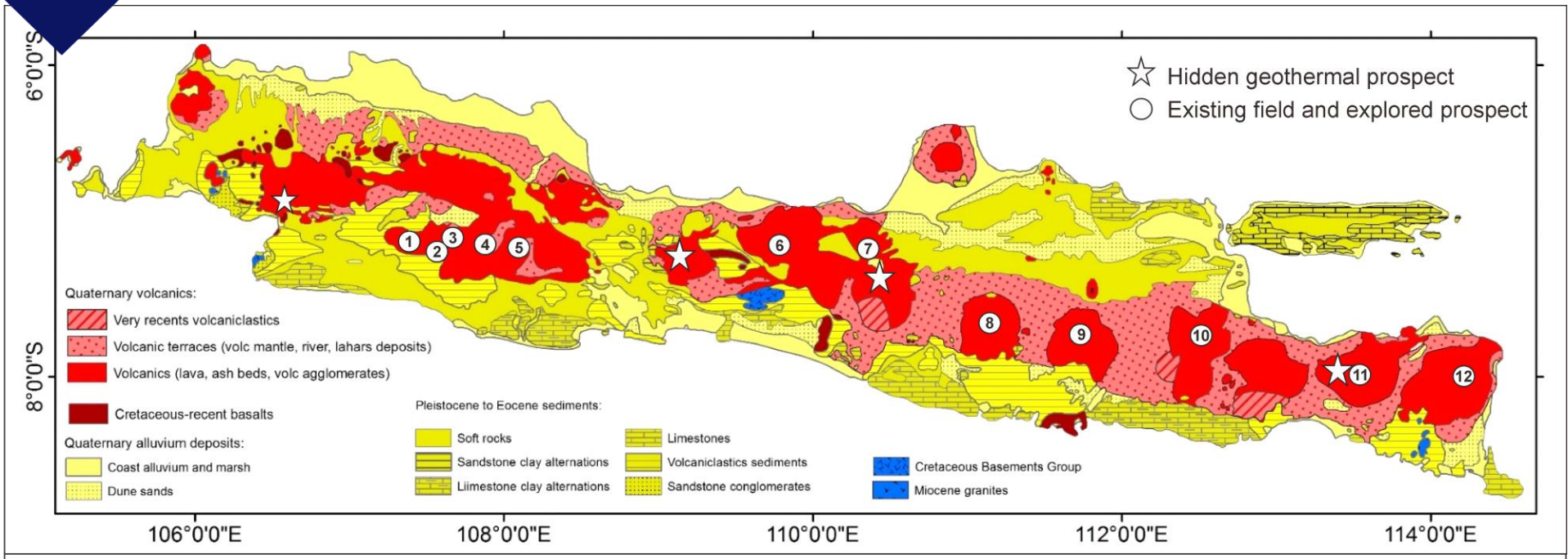
Indonesian geothermal fields

- Located at plate convergence setting
- High-temperature (225 – 300 ºC)
- Magmatic heat source
- Hosted by historically inactive volcano
- Convective geothermal systems, rain water
- Geochemically mature systems ~ 300 ka
- Expressed by hot springs, steam discharges, altered ground
- Some potential “hidden” geothermal systems



Compiled from Conoco Phillips (1993) and Hochstein and Sudarman (2008)

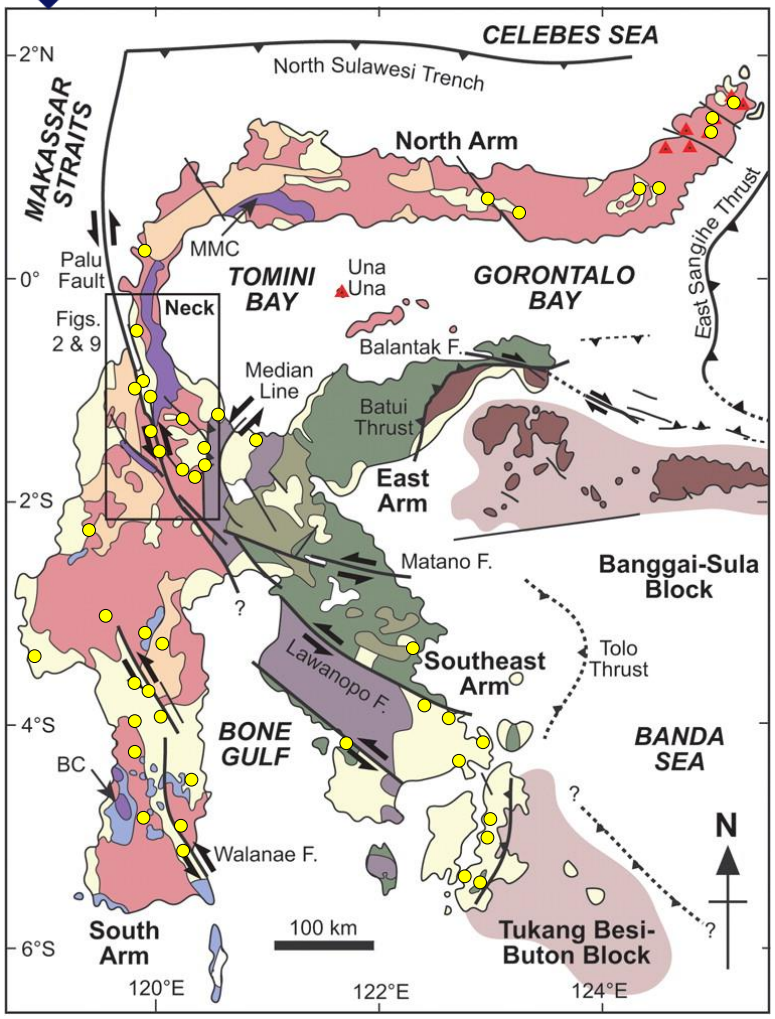
JAVA



1. Patuha; 2. Wayang-Windu; 3. Kamojang; 4.Darajat; 5. Karaha-Telaga Bodas; 6. Dieng; 7. Ungaran; 8. Lawu; 9. Wilis-Telaga Ngebel; 10. Arjuno Welirang; 11. Iyang-Argopuro; 12. Kawah Ijen.

Geology: compiled from various sources by Marliyani (2014); Geothermal field and prospect: compiled from Hochstein and Sudarman (2008); Aziz (2014); Hermawan (2011); Daud (2014);

SULAWESI



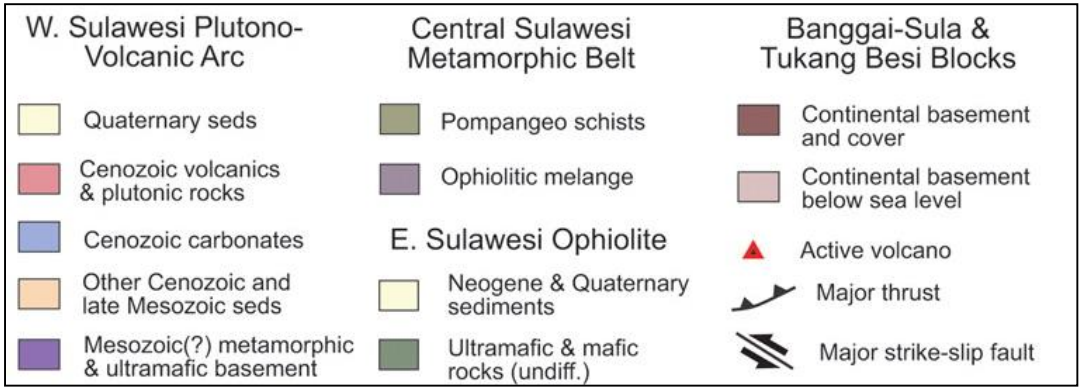
Occurrence of geothermal resources

6% → active volcanoes (Minahasa sector of the North Arm)

36% → old volcanoes (Gorontalo & South Arm)

28% → uplifted granites around the Palu fault zone

30% → faulted granite and metamorphic basement rocks and fragments of oceanic crust (Southeast Arm)



Map from Watkinson (2011)

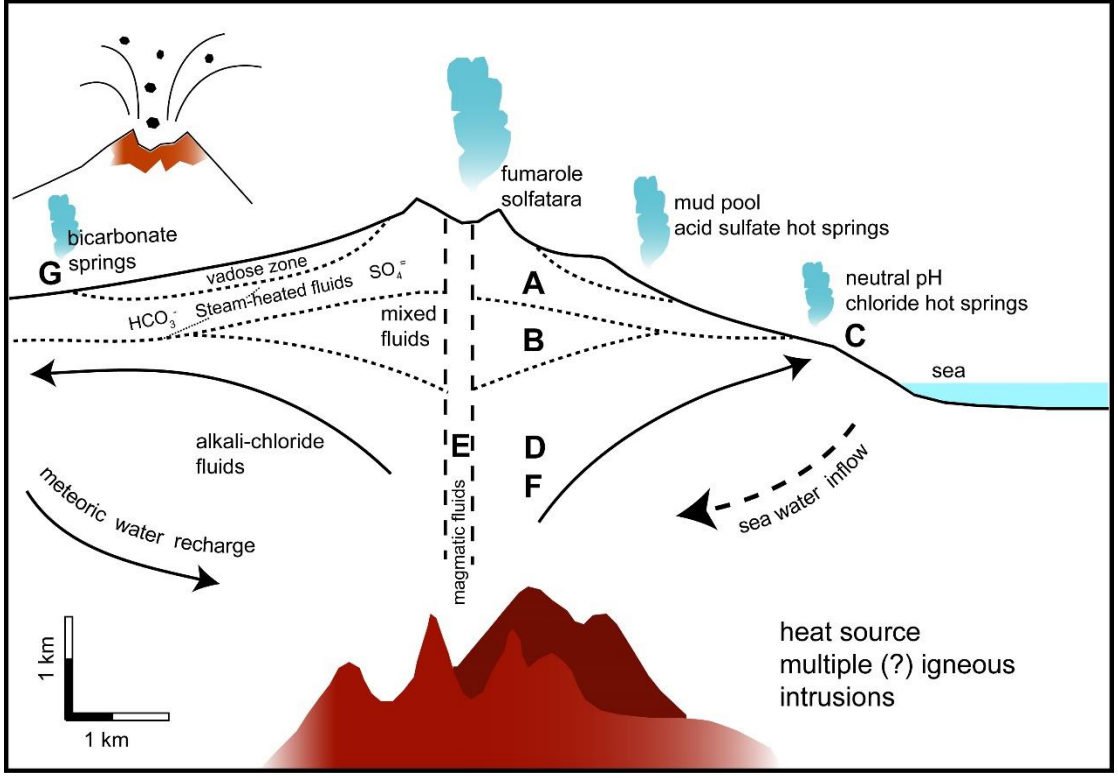
Geothermal resource locations from MEMR (2004)

Thermal manifestations

Steam-heated manifestations, boiling mud pools, acidic hot springs and fumaroles indicate upflow zone of the system in the high-relief terrain.

Thermal manifestation

New Zealand-type upflow zone indicator: neutral chloride boiling springs and geysers occur in the systems in flat terrain.

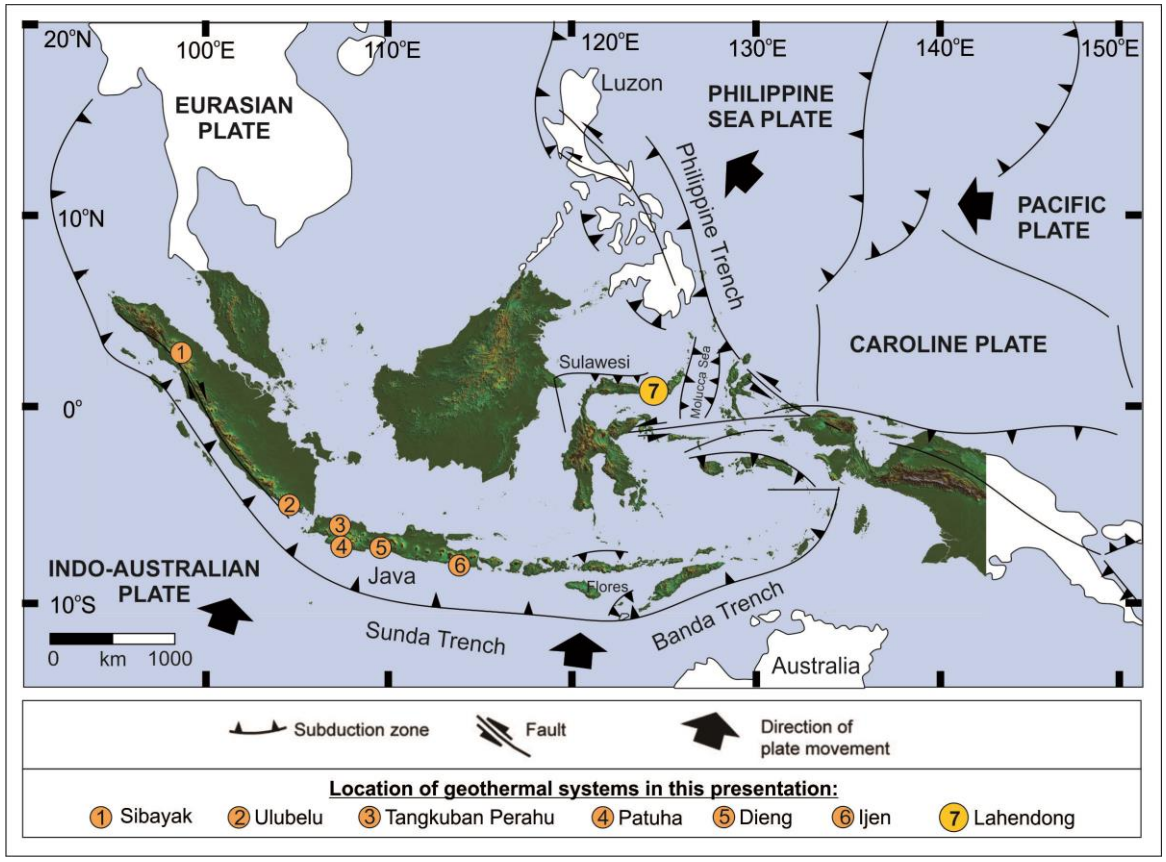


(Utami, 2011)

Idealised model of the distribution of fluid types and their corresponding mineralogy (A to G) in high-temperature geothermal systems in Indonesia (and Western Pacific in general).

A: Alunite ± kaolin ± opal-A ± cristobalite
B: Sulfates ± carbonates
C: Silica (sinter)
D: Epidote ± amphibole ± prehnite ± pumpellyite ± zeolites ± carbonates ± quartz ± adularia ± albite ± smectite ± chlorite ± illite
E: Tourmaline ± fluorite ± native sulphur
F: Fluid inclusion with sea water components
G: Carbonate (travertine)

Fields associated with magmatically derived acidic fluids.



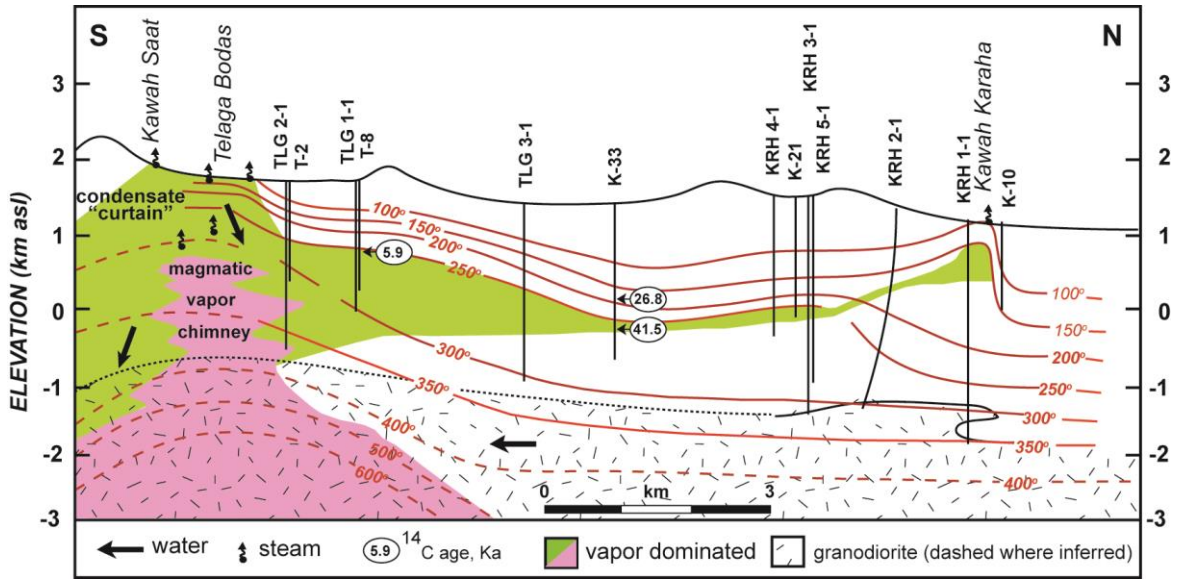
A. Geothermal systems hosted by young strato-volcanoes:

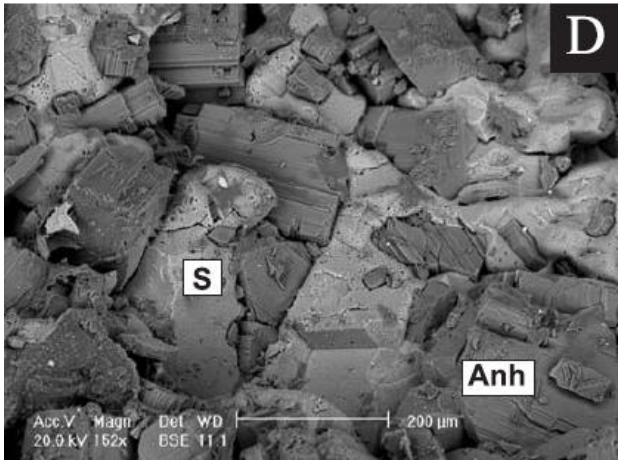
- Sibayak (North Sumatra)
- Kawah Ijen (East Java)
- Tangkuban Perahu & Karaha – Telaga Bodas (West Java)
- Ulubelu (South Sumatra)

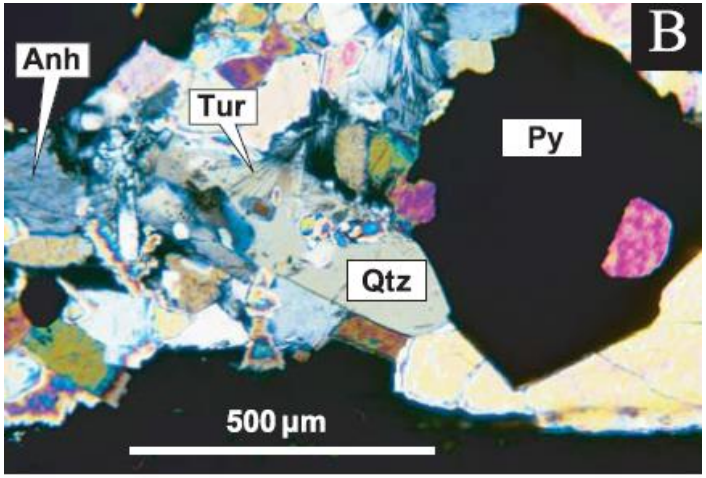
B. Geothermal systems associated with acidic fluid feeders:

- Dieng (Central Java)
- Lahendong (North Sulawesi)
- Patuha (West Java)

Karaha- Telaga Bodas, West Java



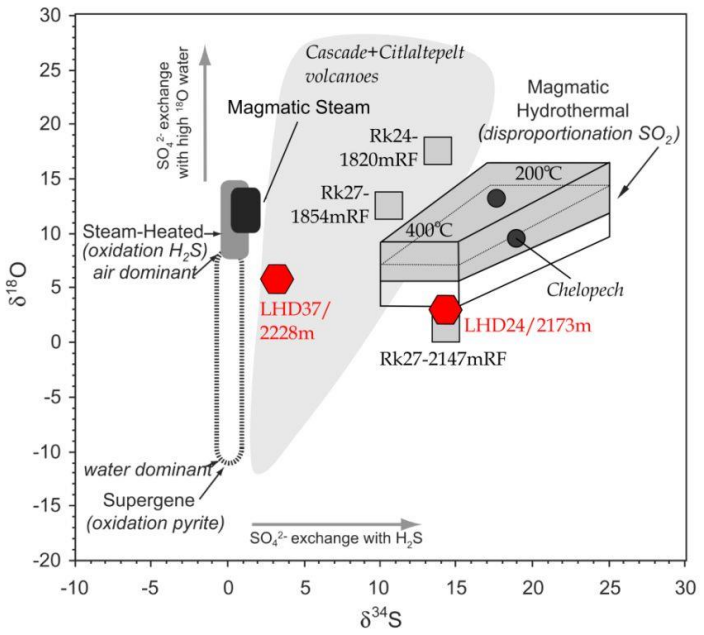


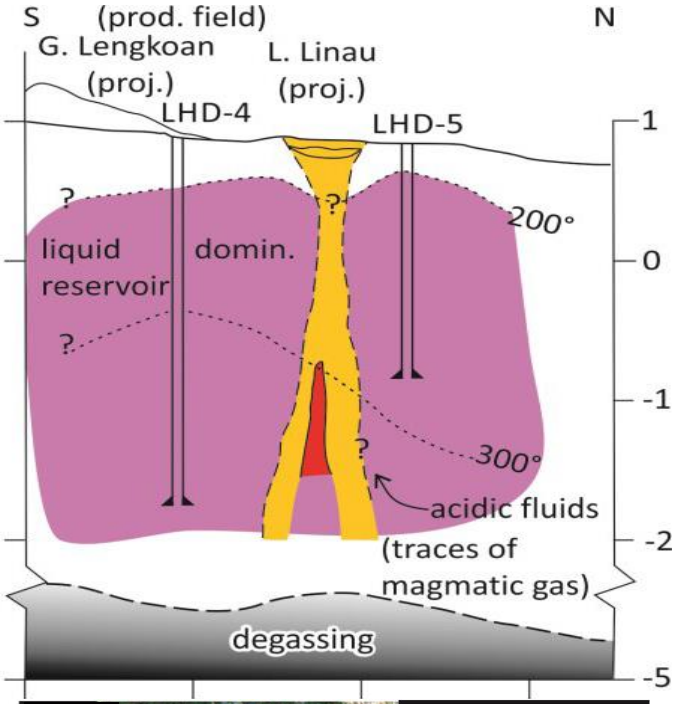


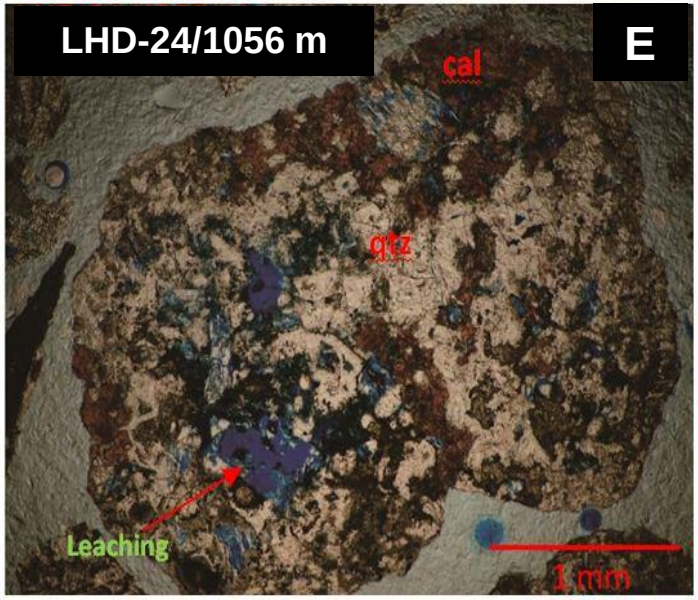
Sulfur and tourmaline in the core samples from the Telaga Bodas Sector of the Karaha – Telaga Bodas field, West Java indicating the presence of magmatic fluid input into the system (Moore et al, 2004).

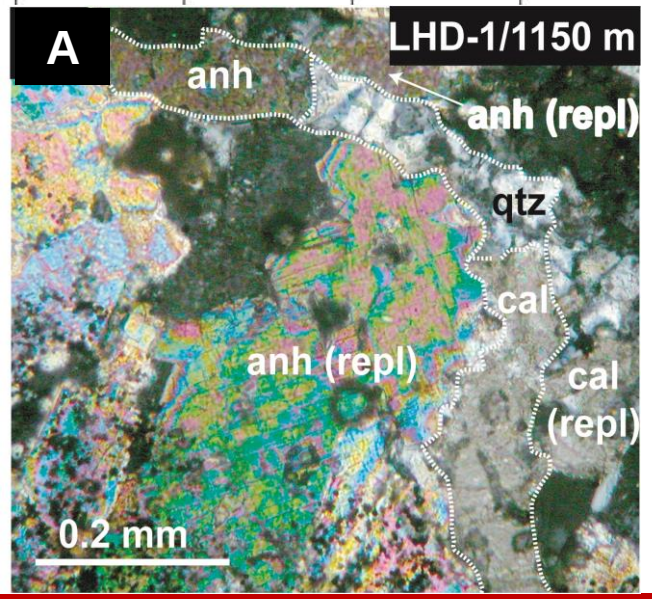
Lahendong, North Sulawesi

Utami, et al, 2015; Hochstein and Sudarman (2008)







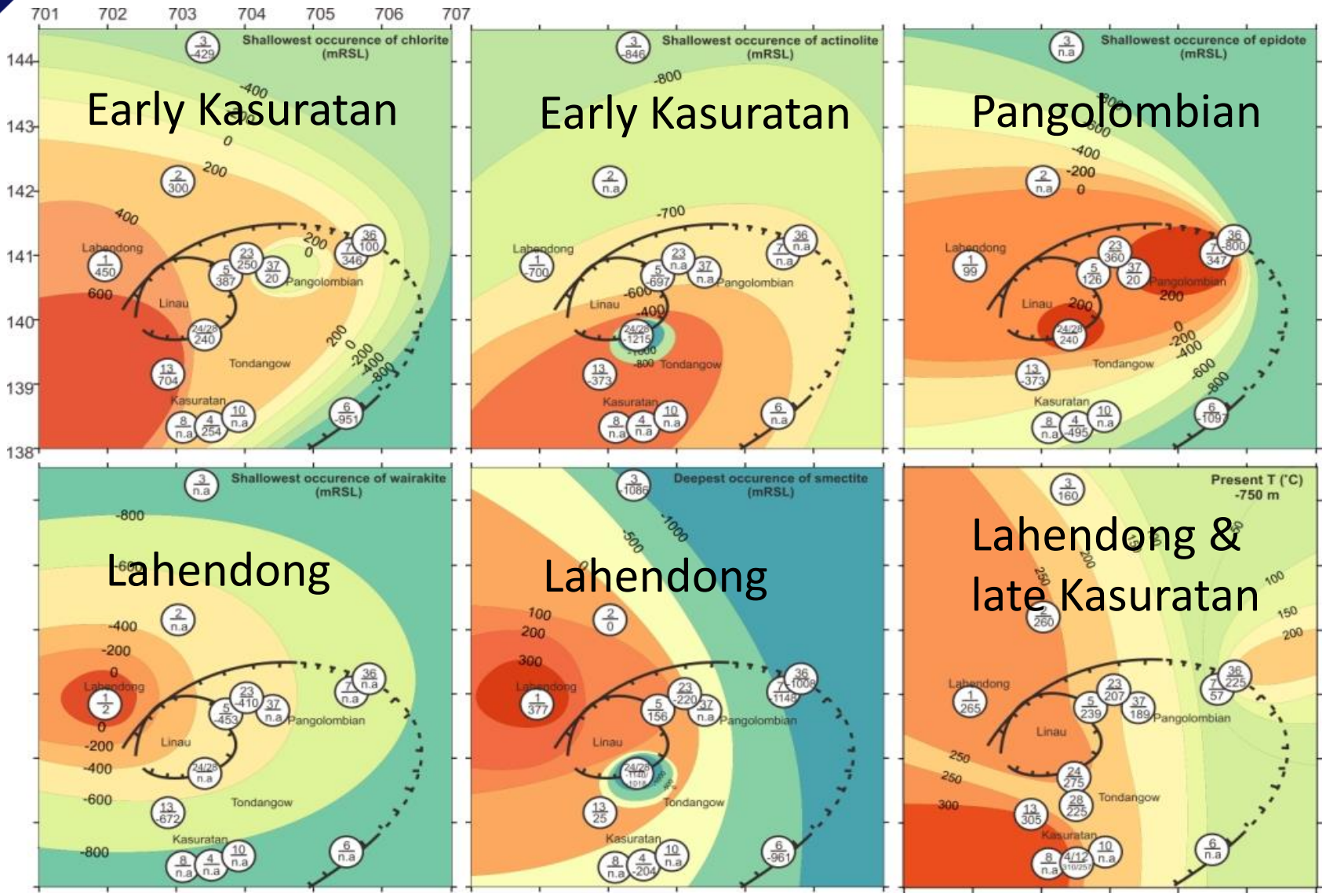


Challenges in developing potential fields with acidic fluids

- Corrosion of production facilities in the hottest sector of the field.
- Environmental management to mitigate possible damage due to the presence of deeply derived corrosive fluids.
- High NCG content from wells in the central parts of the system:
  - Lower the turbine efficiency.
  - Environmental problem.
- Anticipation of scaling problem in other parts of the system.
- Modeling the field hydrology that will help:
  - Build the development strategy to reduce risk of future problems related to deeply-derived acid fluid.
  - Find development target with high-temperature and benign fluids.

Dynamic geology: shift of thermal foci

Example from Lahendong field (Utami, 2015)



Present challenges and opportunity of geothermal research Indonesia

- High-temperature, volcano-hosted geothermal system
  - Improve the resolution of geoscientific exploration methods to accurately locate the best production zone.
  - Optimize the existing subsurface data (geoscience and reservoir measurements) to understand the character of the system.

- “Hidden” geothermal system (lack of surface manifestation):
  - Early exploration stage: Java & Eastern Indonesia
  - Heat source? Roles of faults? Fluid source and hydrology? Waning system? How hot is the resource?
  - Development of exploration technology
  - Technology to access the producible heat at the subsurface
  - Utilization scheme

Towards the future …..

DISSOLVED
PRECIOUS ELEMENTS AND COMPOUNDS
B, Li, Zn, Au, Ag
REE, SiO_2, Salts, Co_2

GEOTHERMAL AREA
BIODIVERSITY

Macro flora & fauna

Extremophilic organisms

SUBMARINE GEOTHERMAL
Energy, minerals, and bioresources

Geothermal system as natural laboratory, host of precious elements/compounds and bioresources

Thank you

Best wishes for geothermal development in Saudi Arabia