



# EKSPLORASI DAN EKSPLOITASI GEO THERMAL

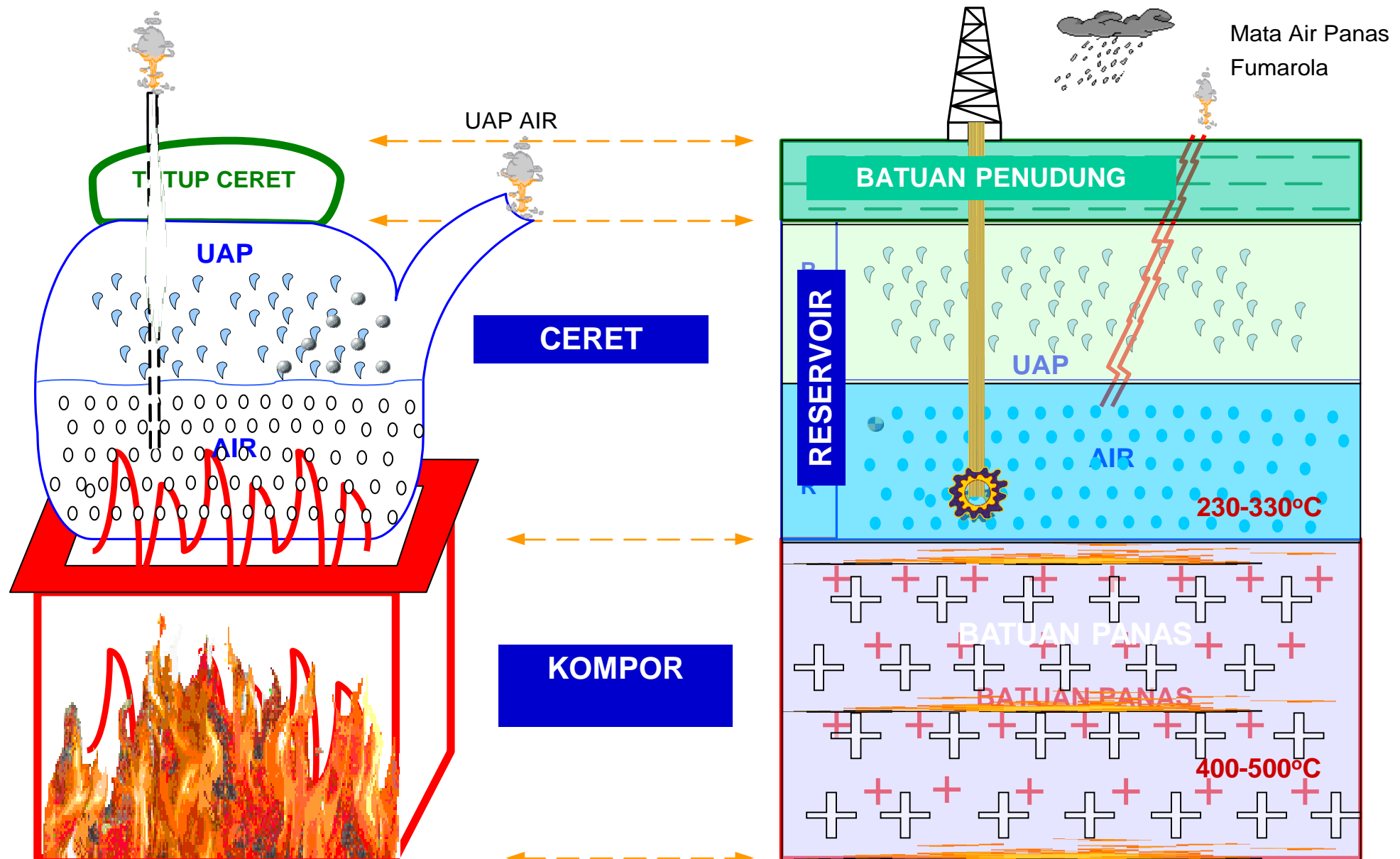


OKTOBER 2023

PT PERTAMINA GEOTHERMAL ENERGY



# Ilustrasi Sistem Energi Panasbumi



# Bukti-bukti keberadaan geothermal

## Manifestasi geothermal



Mata air panas



Fumarol dan steam vent



Kolam lumpur panas



Altered ground dan Warm Ground

# Klasifikasi Sistem Geothermal



# Klasifikasi Sistem Geothermal berdasarkan Temperatur / Enthalphy-nya :

---

	(a)	(b)	(c)	(d)	(e)
Low enthalpy resources	< 90	<125	<100	≤150	≤190
Intermediate enthalpy resources	90-150	125-225	100-200	-	-
High enthalpy resources	>150	>225	>200	>150	>190

*Source: (a) Muffler and Cataldi (1978).  
(b) Hochstein (1990).  
(c) Benderitter and Cormy (1990).  
(d) Nicholson (1993).  
(e) Axelsson and Gumlaugsson (2000)*

# Klasifikasi Sistem Geothermal berdasarkan Tipe Fluida

## 1. Tipe dominasi air (Liquid Dominated)

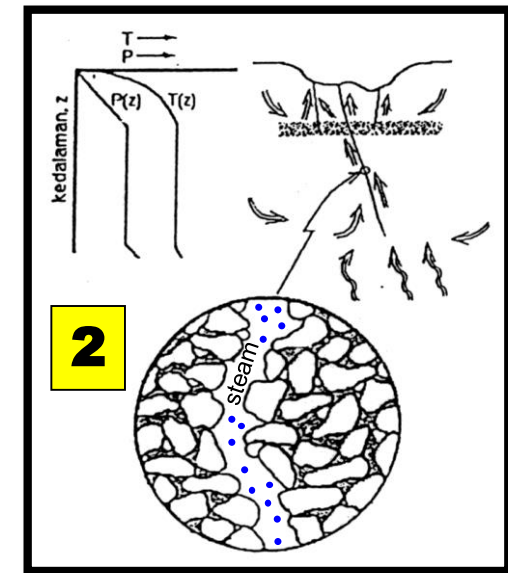
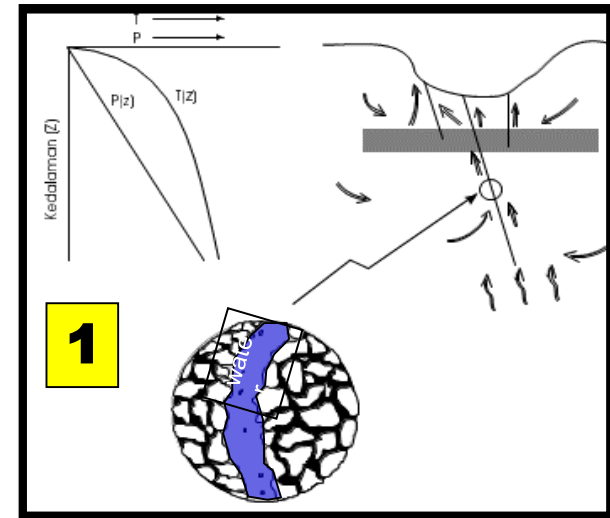
Permeabilitas reservoir terisi oleh fasa air  
contoh sistem geothermal :  
Sumatera, G. Salak

## 2. Tipe dominasi uap

Permeabilitas Reservoir terisi oleh fasa uap  
contoh sistem geothermal :  
Kamojang, Darajat

## 3. Tipe 2 (dua) Fasa

Permeabilitas Reservoir terisi oleh air dan uap  
contoh sistem geothermal :  
Wayang Windu, Lahendong



# Eksplorasi & Eksploitasi Geothermal





## EXPLORATION

Permit, Clearance, Reserve confirmation

2 tahun



## DEVELOPMENT

Drilling, Production & Construction

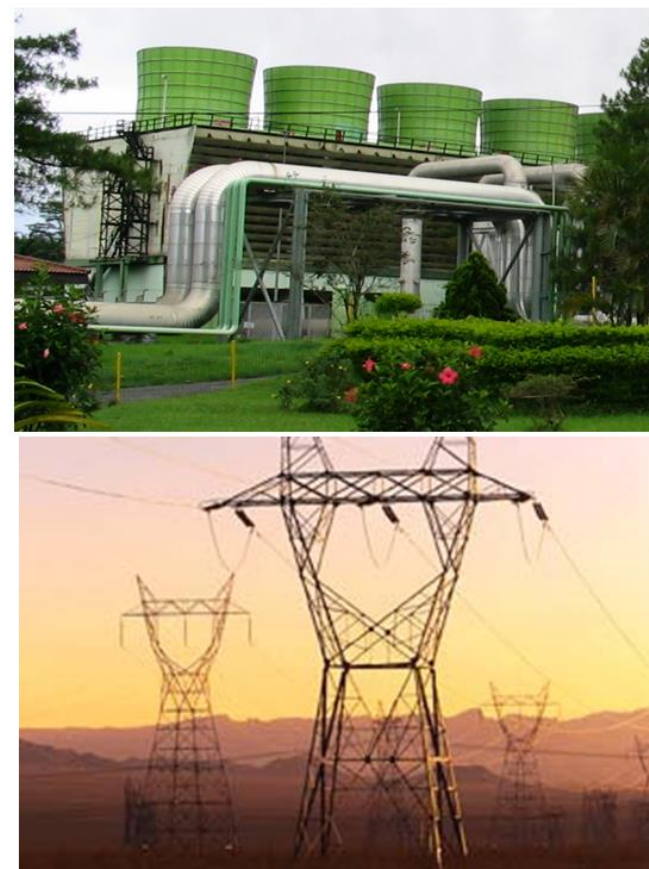
2-3 tahun



## COMMERCIAL

Commissioning, Commercial Operation

25-30 tahun



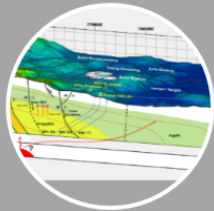


# Exploration Scope of Works



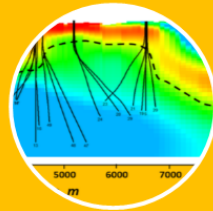
## Geoscience Studies :

- Regional geology
- Volcanostratigraphy
  - Geological structures
- Geomechanics
- Magnetotellurics
  - Gravity
- Microearthquake
- Water and gas geochemistry
- Isotope analysis
  - Recharge
- Petrophysics



## Resource Assessment

- Reservoir geometry delineation: clay cap distribution, bottom clay cap, reservoir boundary from MT
- Defining geothermal system: upflow-outflow, hydrology, temperatures, fluid type, fluid conduits, possible heat source
- Building conceptual model
- Reserve estimation



## Well Targeting

- Permeability targeting
- Temperatures prediction
- Fluid type, including possibility acidic zone



## Drilling Program and Monitoring

- Depth of formation markers
- Depths to fault targets
- Casing design
  - High temp loggings: borehole imaging, sonic, resistivity, production
- Coring program: convent. & side wall
- Wellsite geology



## Reservoir Monitoring Support

- Time-lapse gravity to estimate reservoir mass changes and possible recharge area
- MEQ monitoring related to production-reinjection

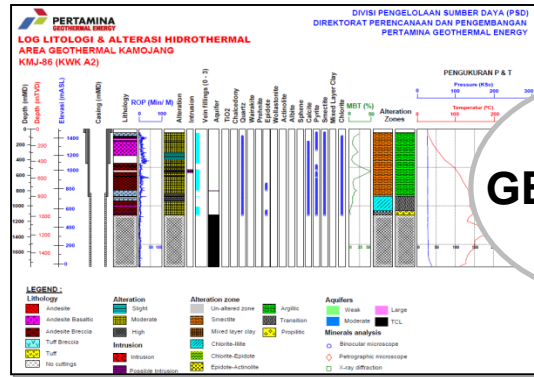


## Geohazard Studies

- Comprehensive geohazard potential study: landslide, volcanism hazard, flood, earthquakes
- Geoelectrical study



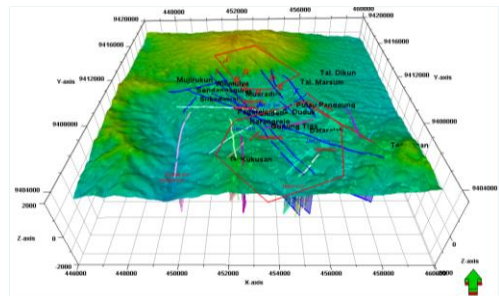
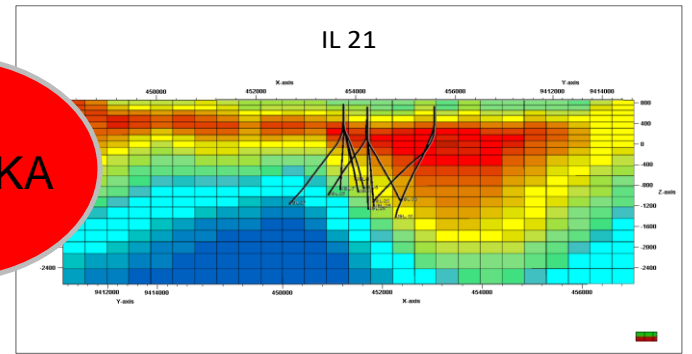
# Flowchart Pekerjaan Tim Geosains



GEOLOGI

GEOKIMIA

GEOFISIKA



GEOTHERMAL MODEL

WELLS TARGETING

DRILLING



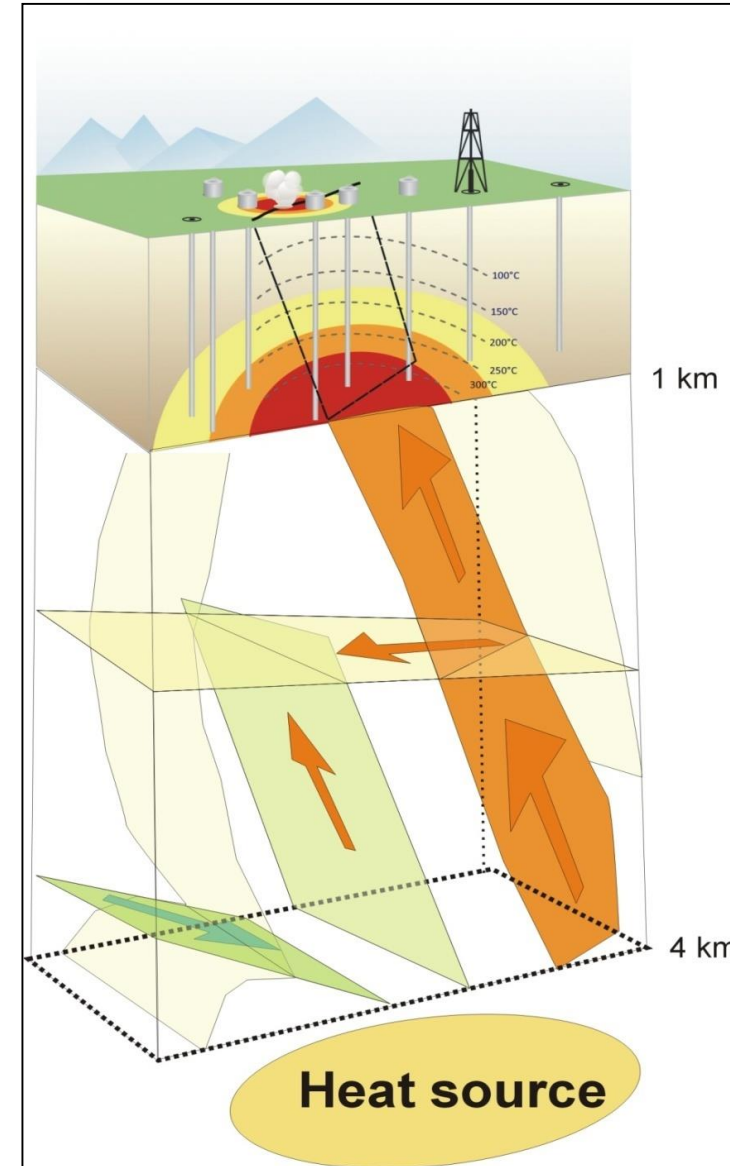
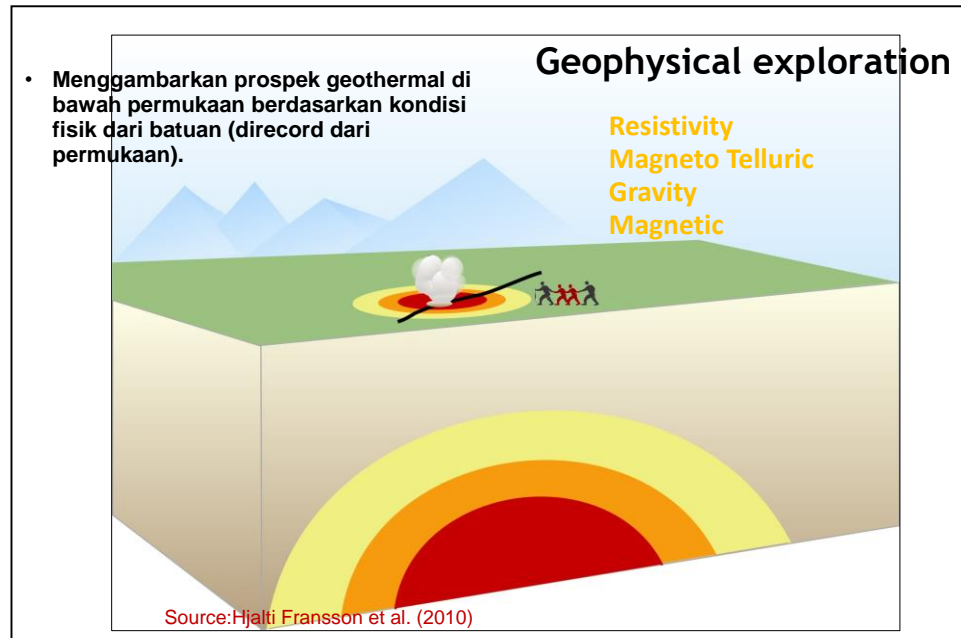
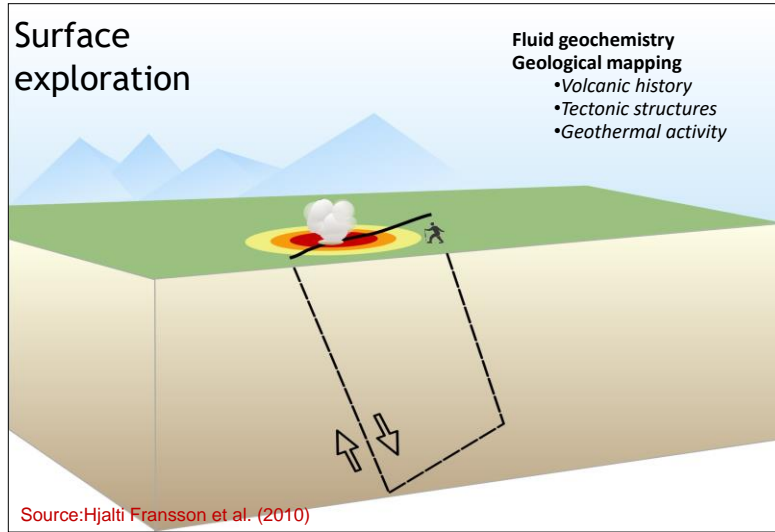
Pada tahap eksplorasi sumber daya geothermal, tim geosains berperan sangat penting dalam melokalisir prospek geothermal dan memperkirakan cadangan geothermal yang ada

# Eksplorasi Geothermal

Geothermal geoscience team mirip dengan team ahli kedokteran.

	Tugas	Major
Dokter ahli 1	<b>Mengamati gejala pada tubuh pasien, kondisi fisik, analisa medical record, dll</b> menyelidiki sistem vulkanis, struktur geologi, umur batuan, jenis dan tipe batuan ubahan dalam kaitannya dengan sistem panas bumi.	Geologi
Dokter ahli 2	<b>Menganalisa parameter kimiawi pasien dari sampel darah, urine, dll</b> menyelidiki tipe dan tingkat maturasi air, estimasi temperatur reservoir, asal mula air panas, model hidrologi dan sistem fluidanya.	Geokimia
Dokter ahli 3	<b>Melakukan perekaman kardiologi, CT Scan, USG, tomography, X-Ray radiologi dll</b> Menyelidiki struktur bawah permukaan sistem panas bumi menggunakan parameter fisik batuan (resistivity, gravity, magnetic, seismic)	Geofisika

# Model Konseptual Sistem Geothermal



# Tahapan Kegiatan Eksplorasi Geothermal

---

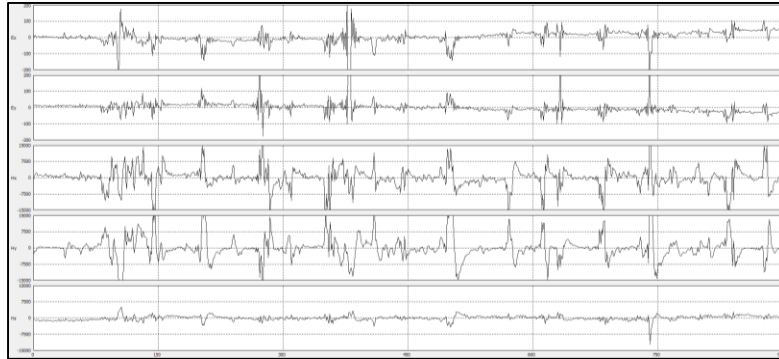
1. Reconnaissance (**speculative/hypothetical resource**)
2. Pemetaan Geologi & Manifestasi geothermal
3. Survey Geokimia
4. Survey Geofisika
5. Penyusunan conceptual model (**possible reserve**)
6. Pemboran eksplorasi (**probable reserve**)
7. Pre feasibility study
8. Uji sumur (**proven reserve**)
9. Feasibility Report
10. Pemboran pengembangan



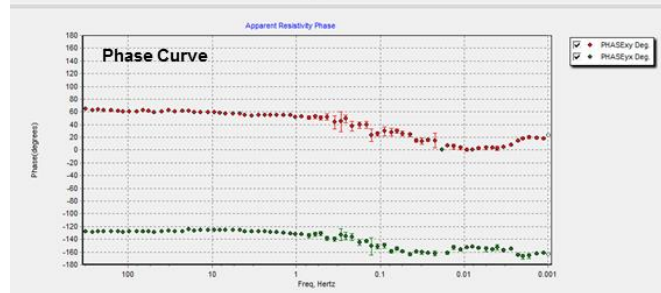
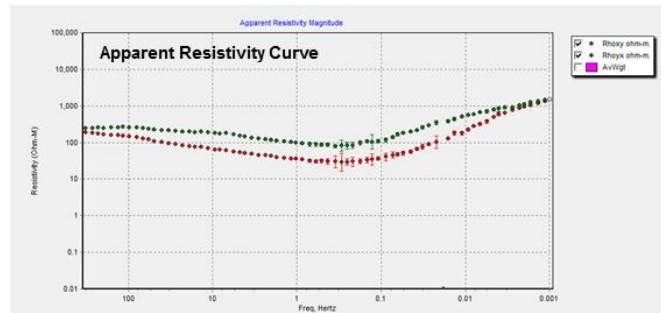
## MT Field Campaign



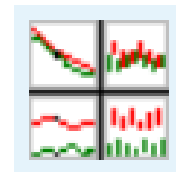
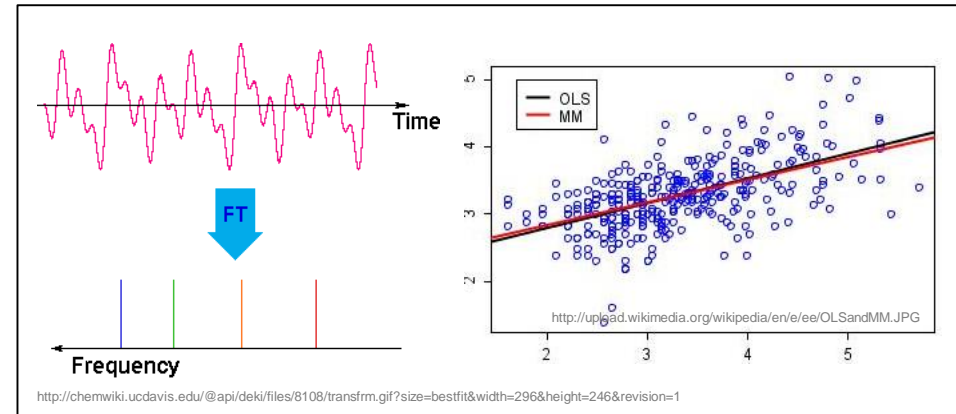
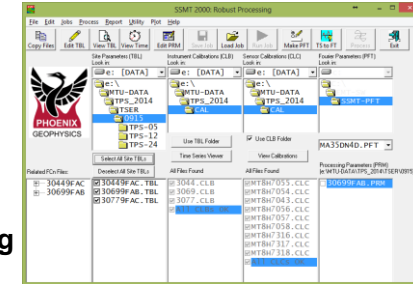
## MT Data Processing



Raw MT Time Series Data  
(Sync Time Series Viewer)

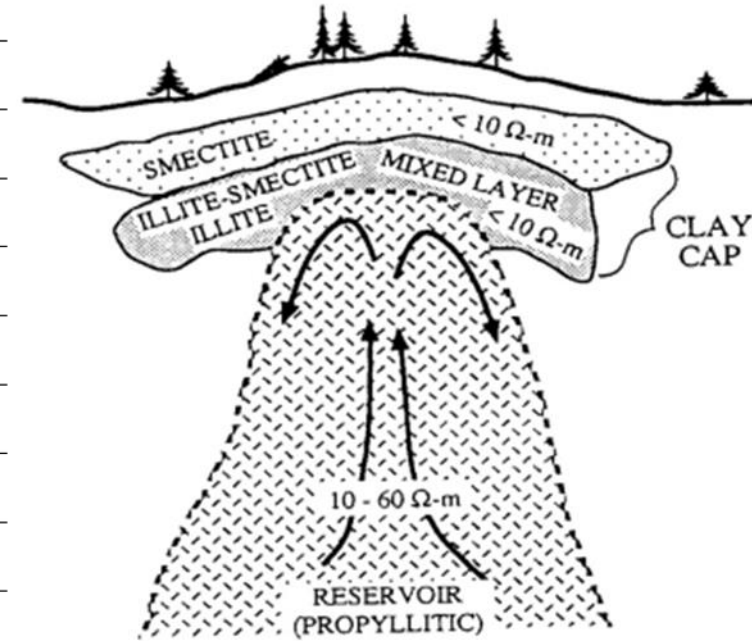
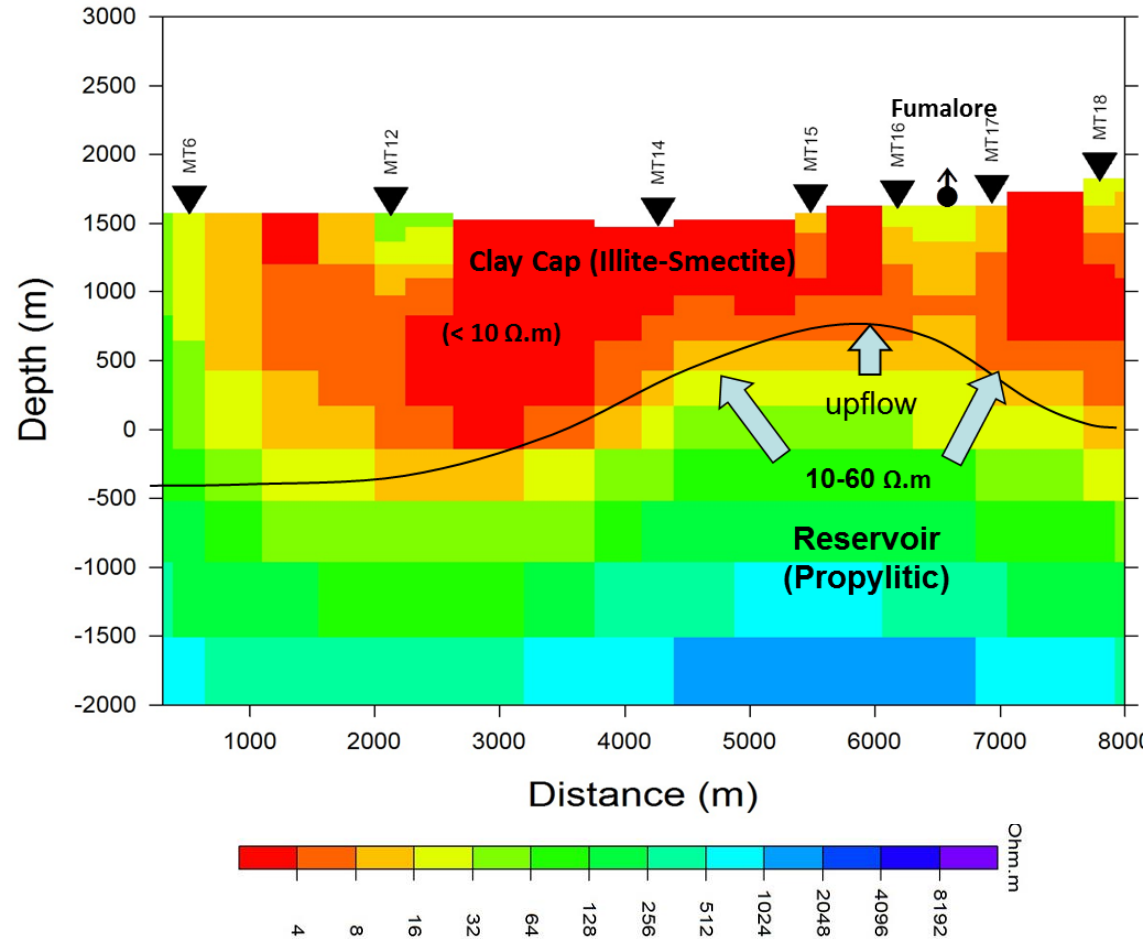


Fourier Transform & Robust Processing  
(SSMT2000)



Selecting Crosspower MT Curve  
(MTEditor)

2D Inversion Model

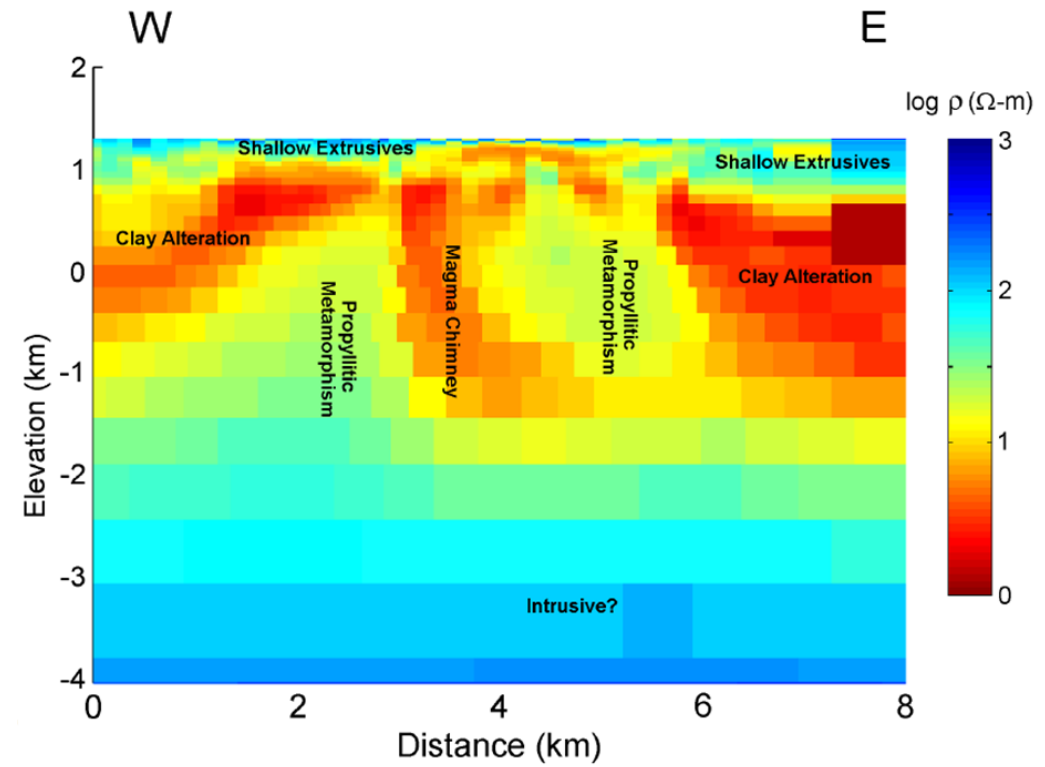
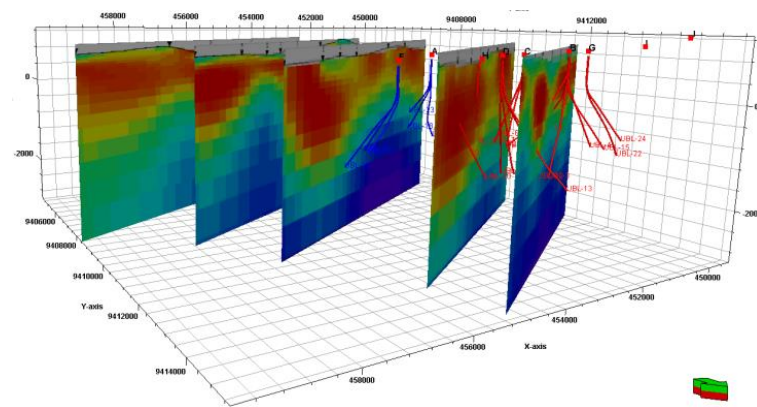
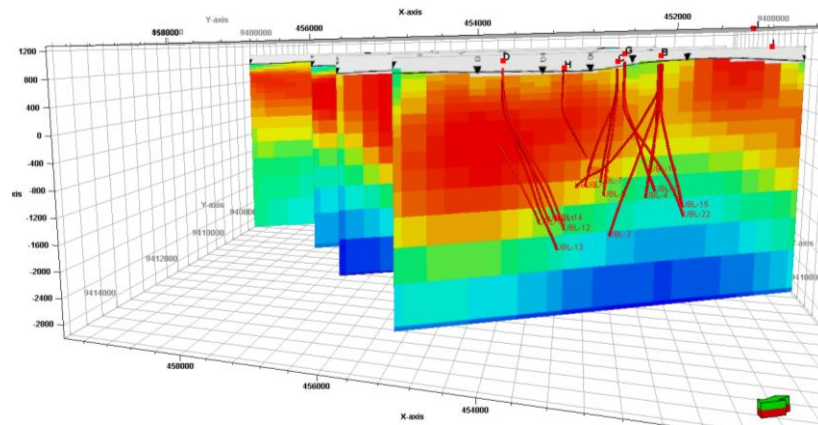


Generalized Resistivity Structure

Taken from: Johnston et.al., 1992

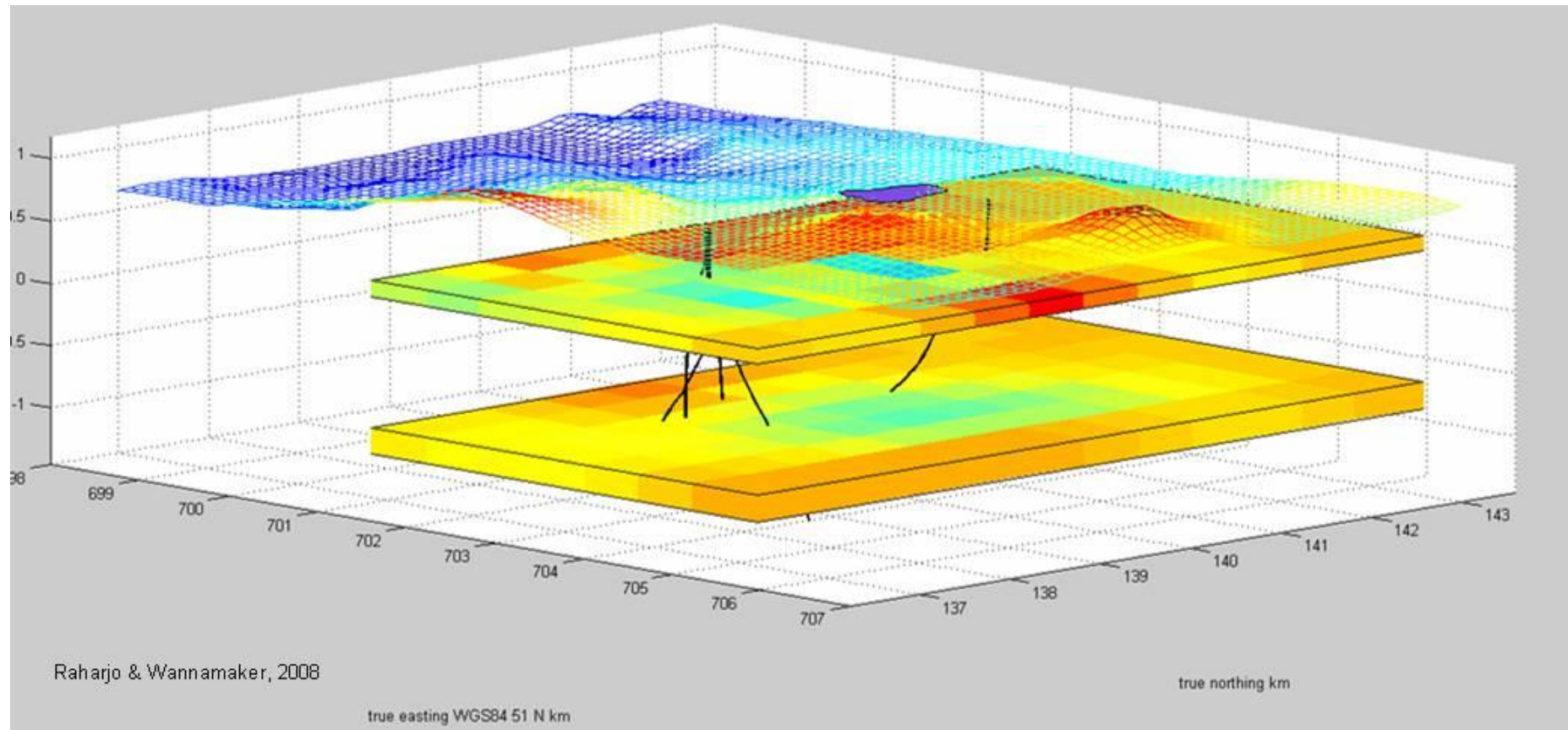


## 2D Inversion Model



Raharjo, et al, 2002

## 3D Inversion Model



**red : clay cap conductor**

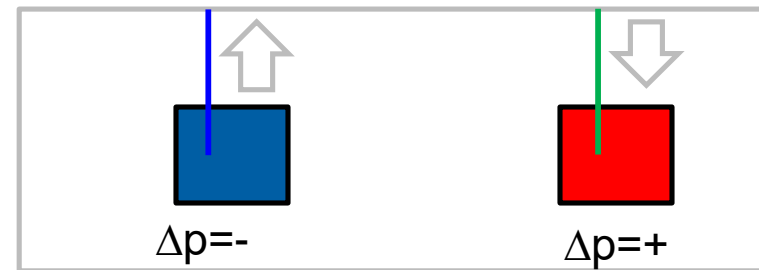
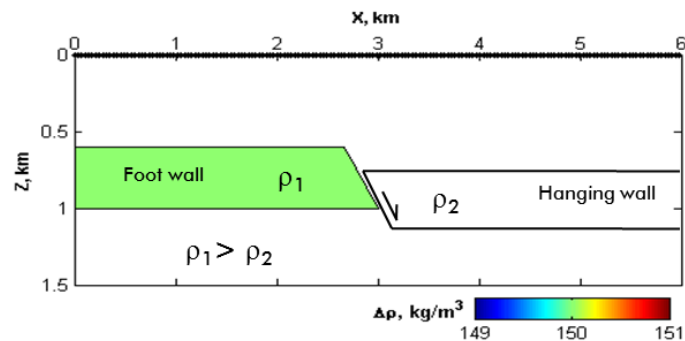
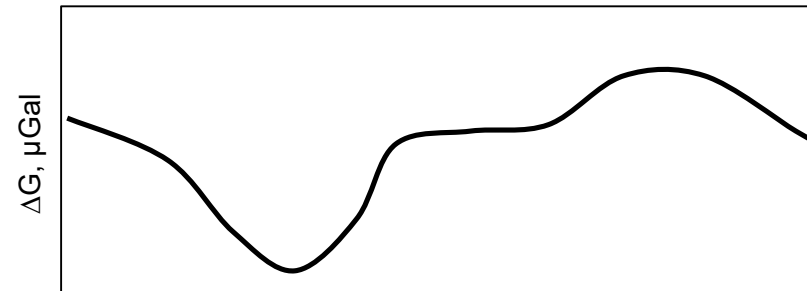
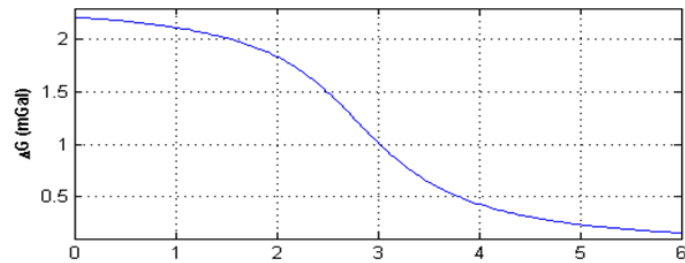
**Blueish slightly resistive: propylitic reservoir**

The gravity method is one of the geophysical methods used to measure the variation of the gravitational field at the surface caused by density contrasts within the subsurface rocks.

**Objective :** to map regional structure, density changes time lapse caused by production & injection activity

Newton's Law

$$F = \frac{G m_1 m_2}{r^2}$$



## Gravity Field Campaign

Gravity Station



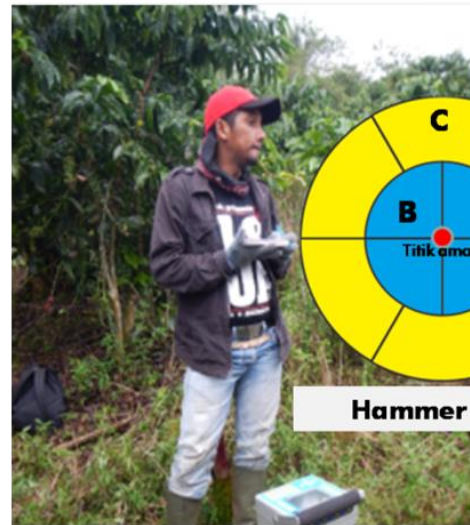
Gravity Measurement



Elevation Measurement



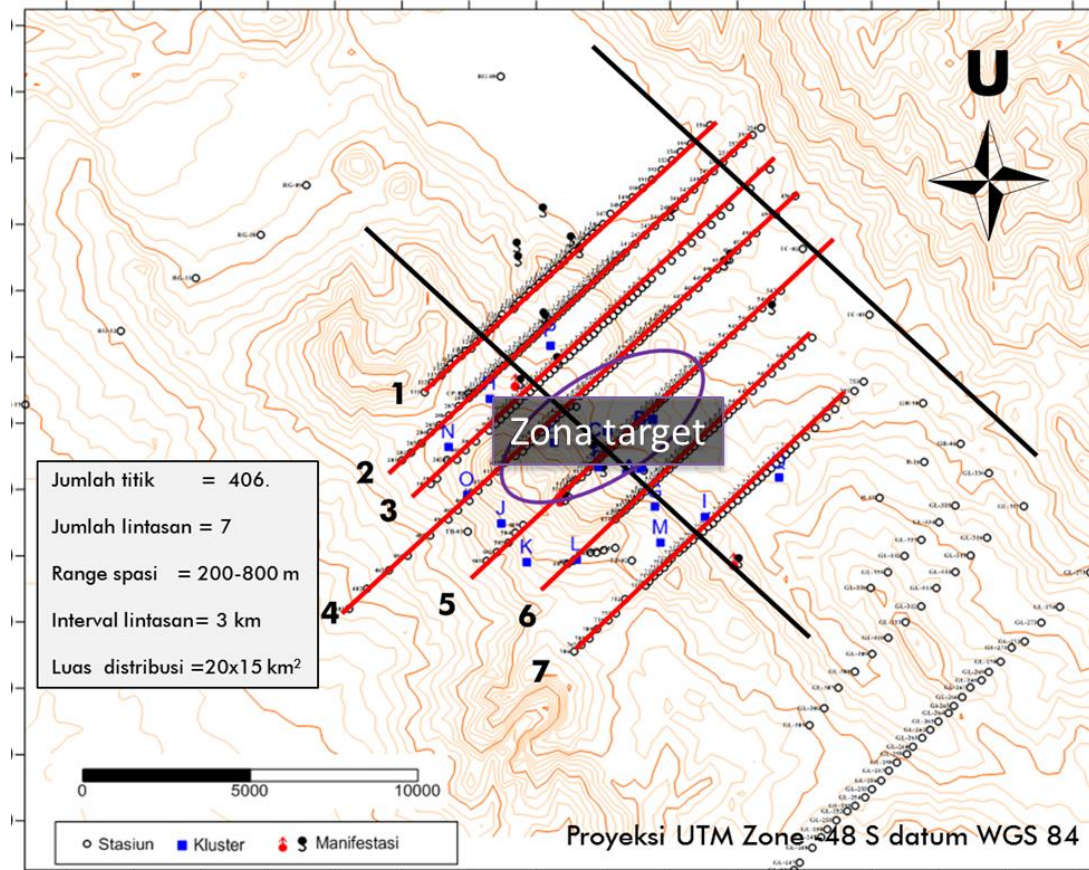
Terrain Observation



Hammer Zone

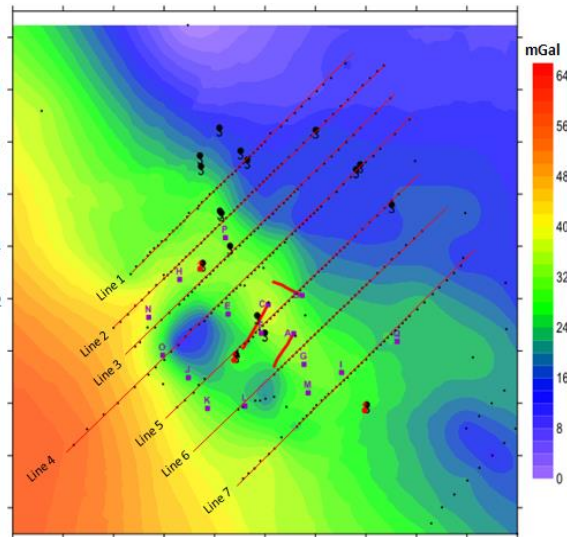
B

## Gravity Data Acquisition

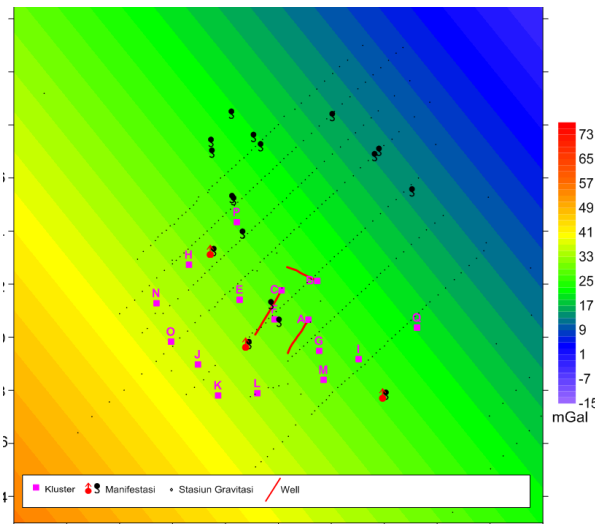


- The distribution should covers target and background (dynamic design tailored to progress in the field)
- Lines perpendicular with regional geoelectrical trend.
- Station's distribution should cover the target and the background
- The spacing between station at least 250 – 500 meter.

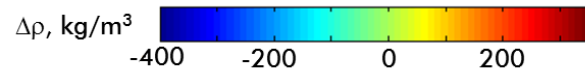
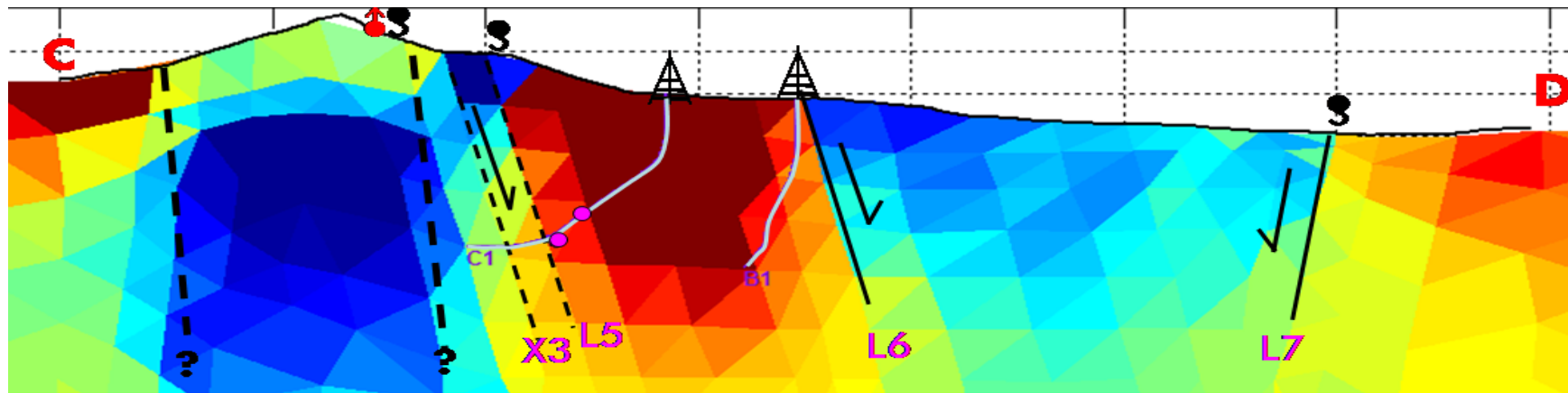
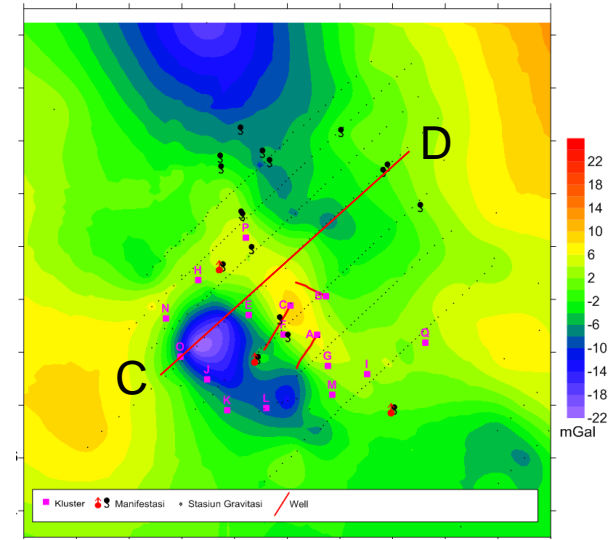
### CBA



### REGIONAL ANOMALY

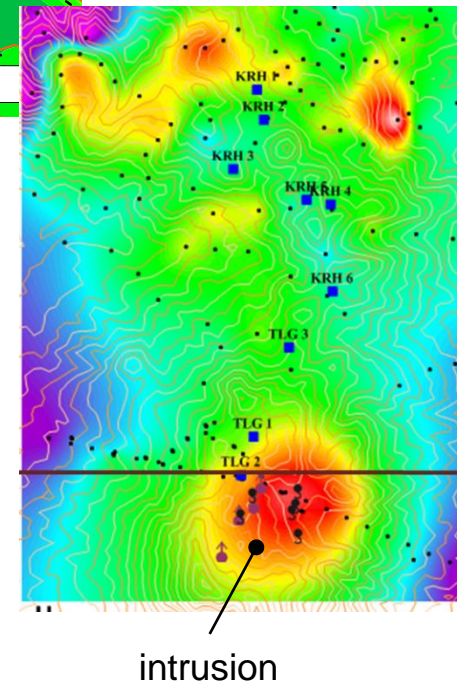
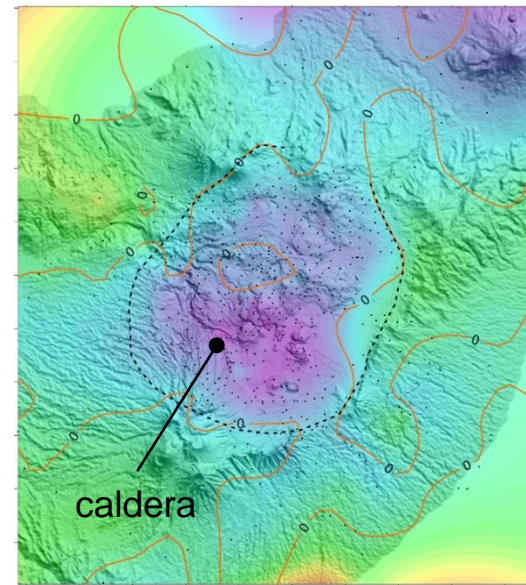
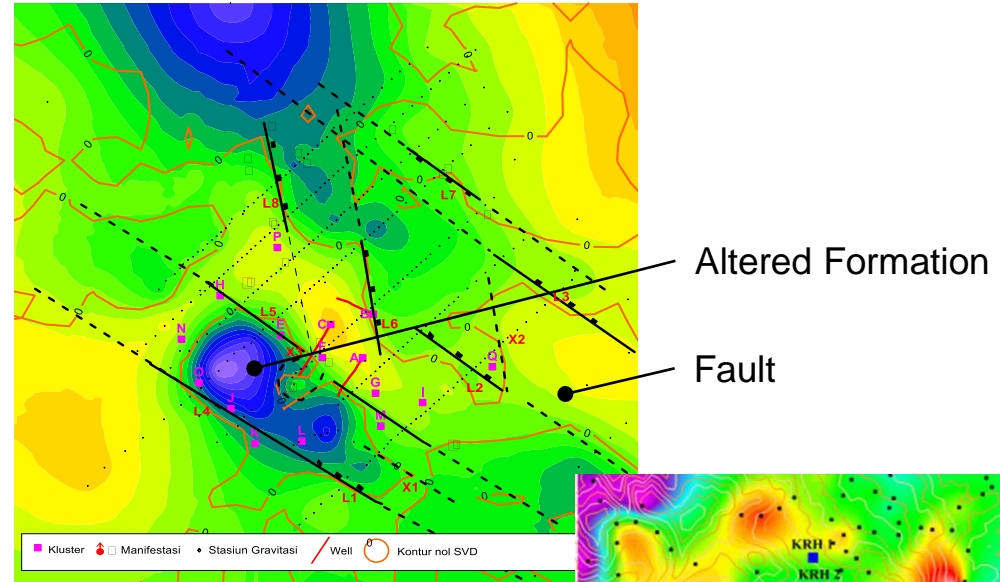
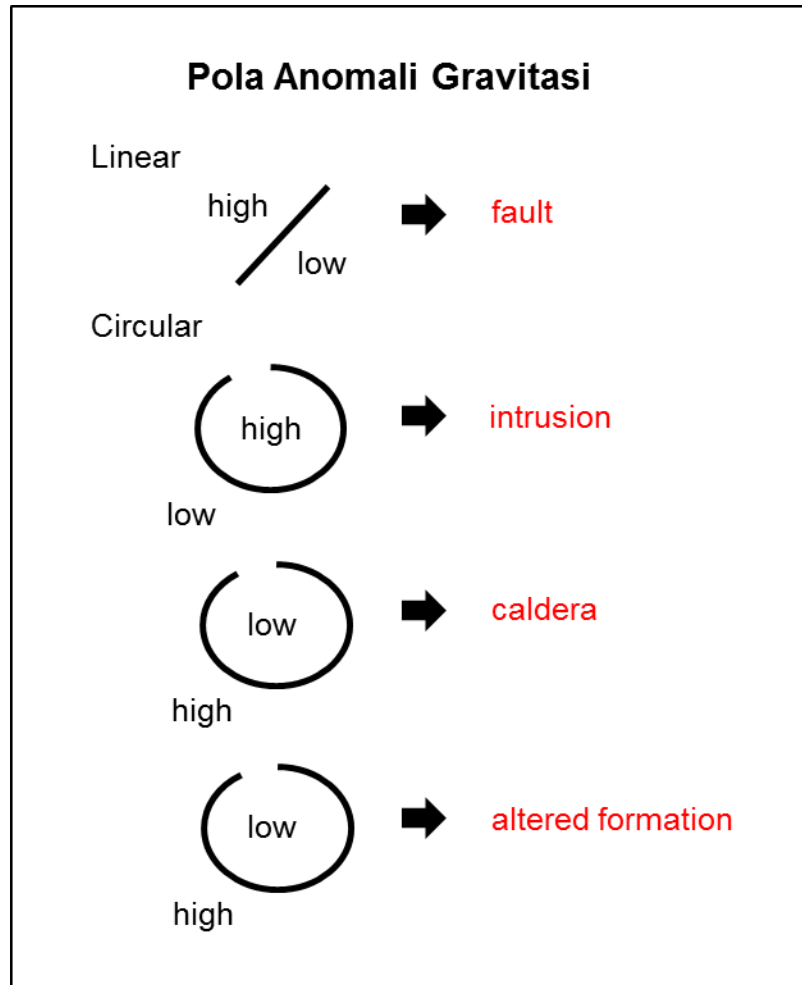


### RESIDUAL ANOMALY



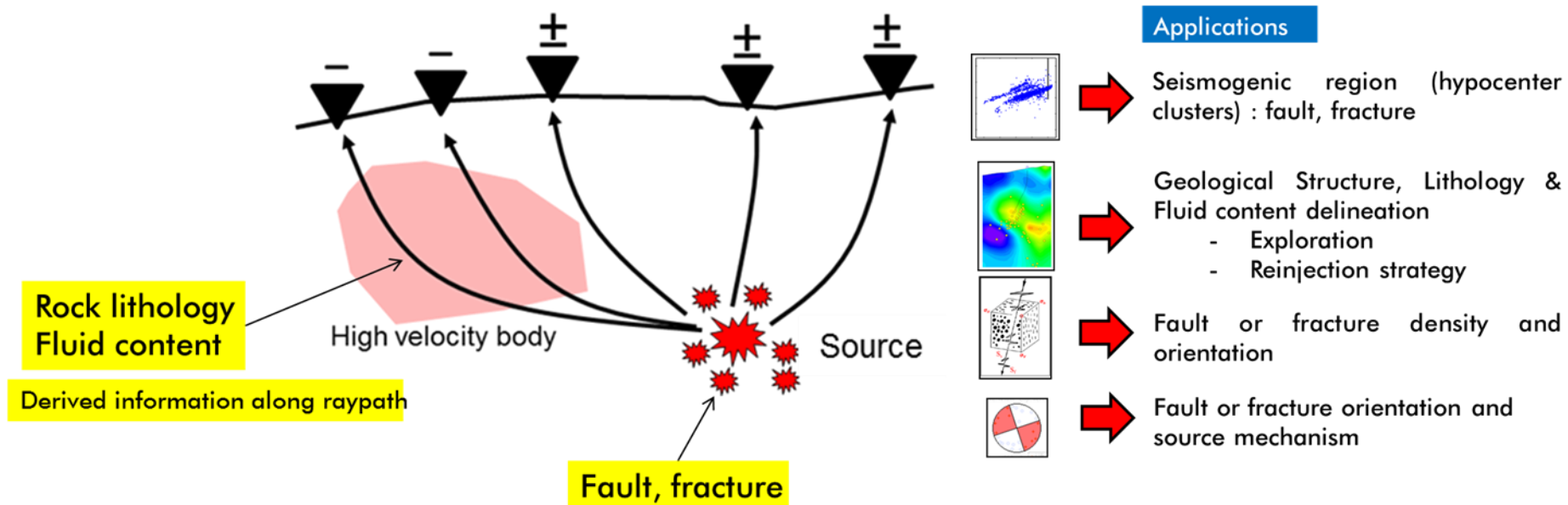
Sastranegara, et al. 2014

## Gravity anomaly shape

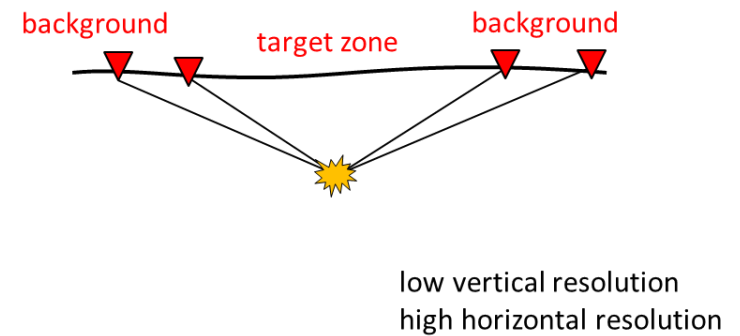
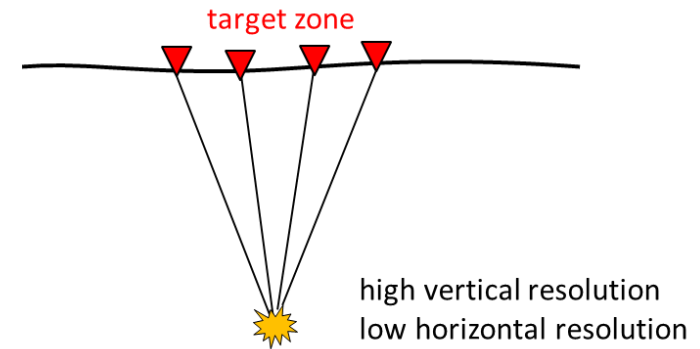
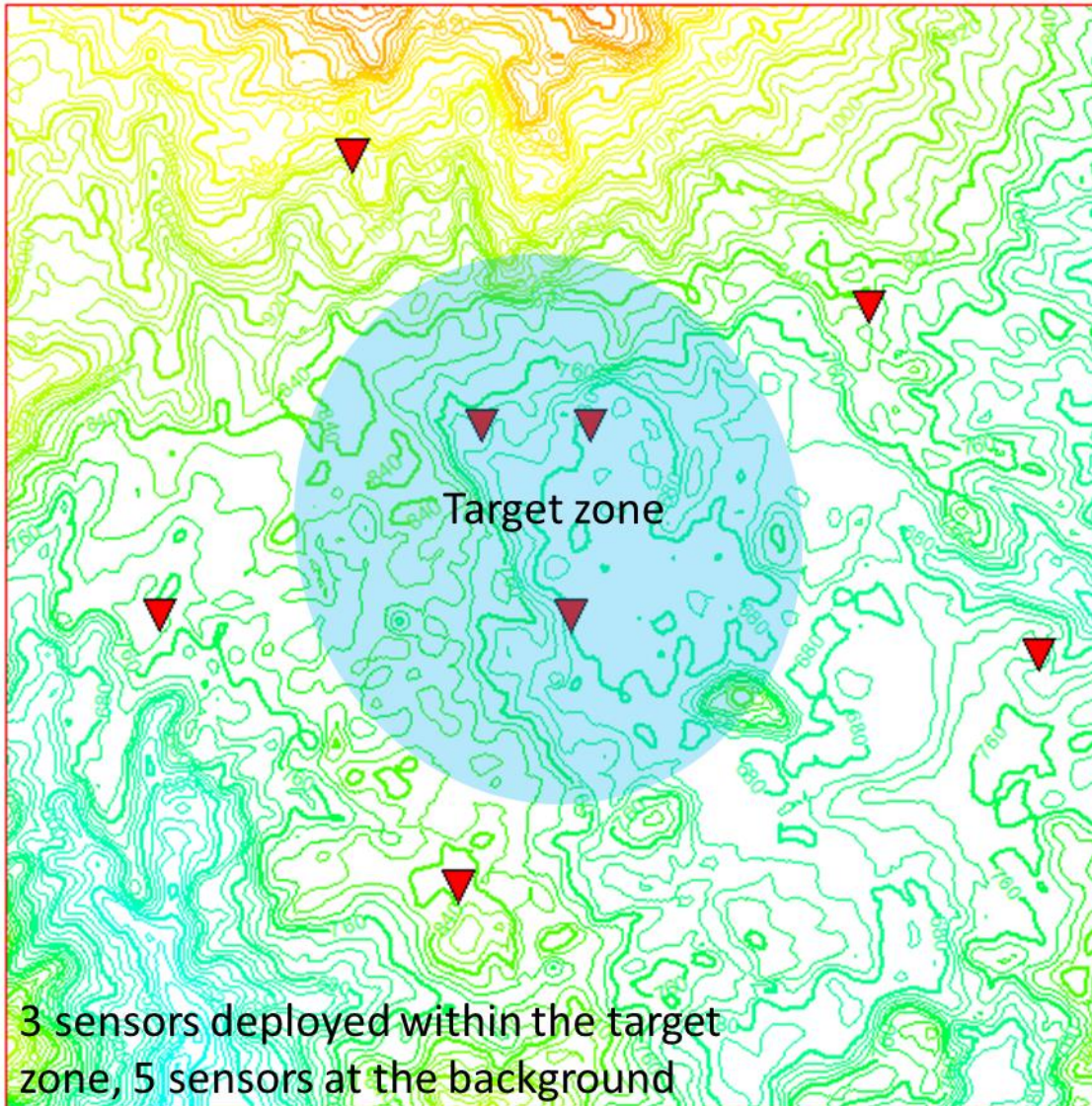


Microearthquake (MEQ) method utilized microearthquakes event to delineate active fault or fracture

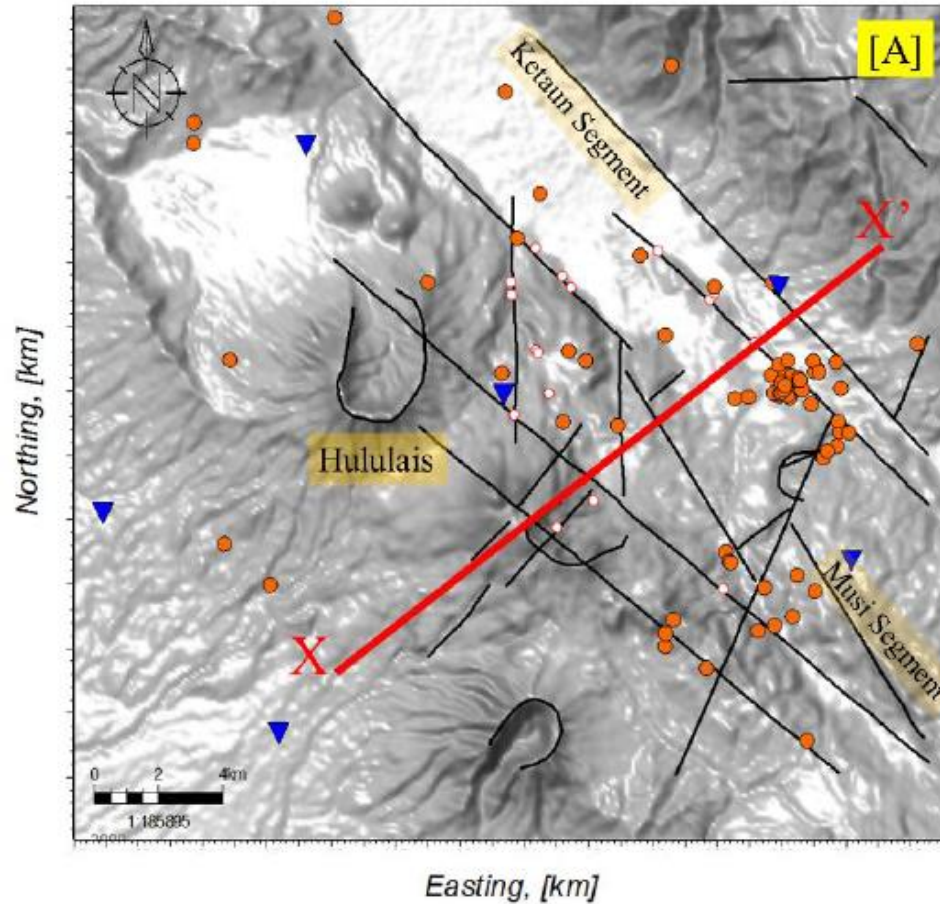
**Objective :** to delineate seismogenic region, geological structure, rock lithology, fluid content



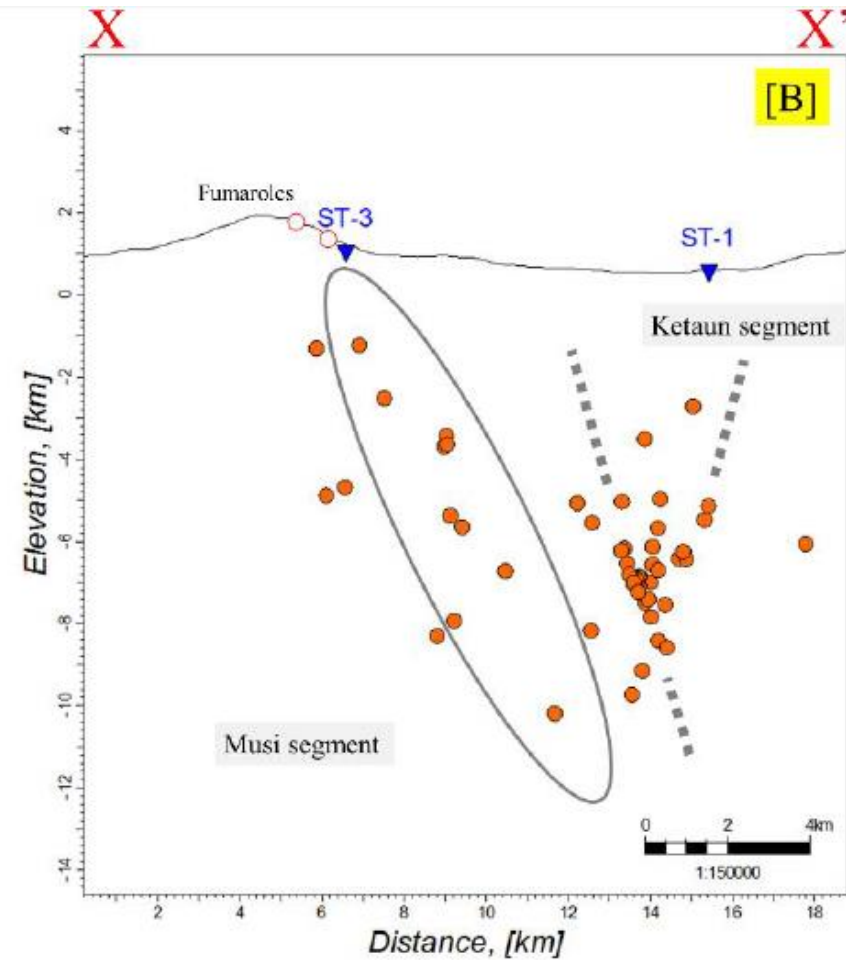




## Epicenter Map

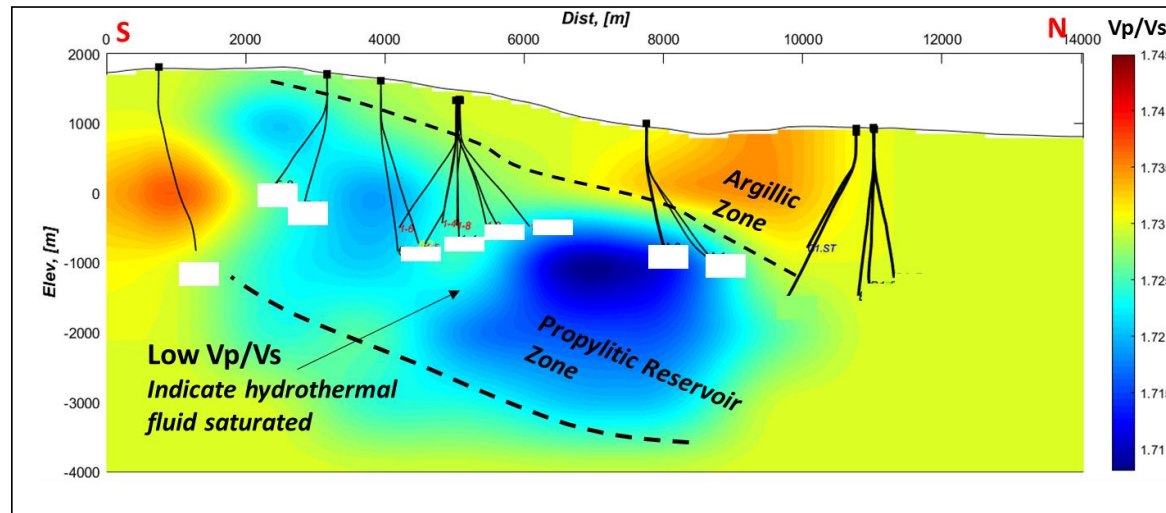
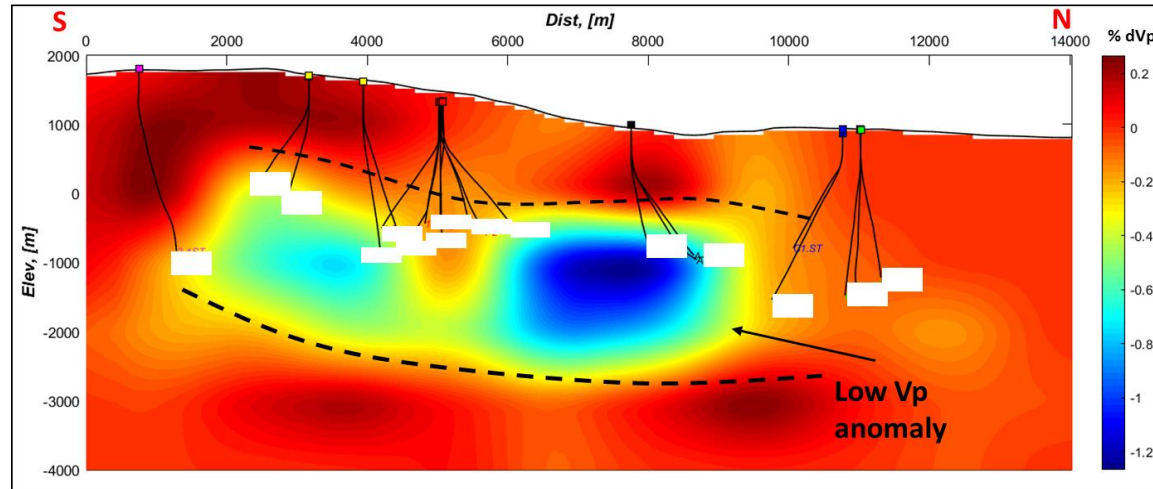


## Section showing hypocenters



- ▼ Stations
- Thermal Manifestation
- MEQ from JHD
- Fault Plane

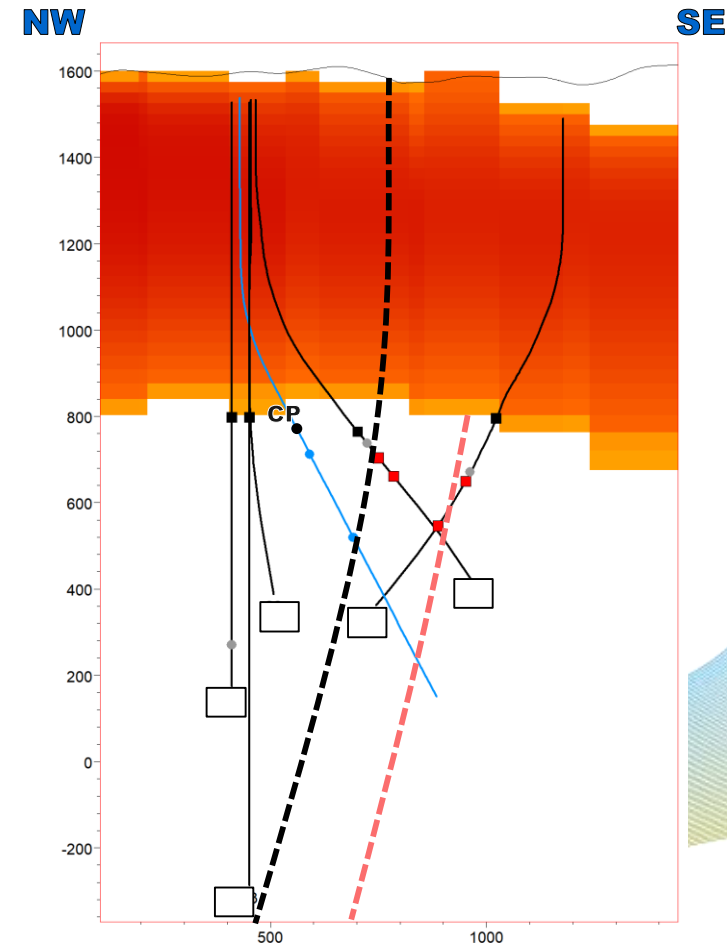
Juanda et al, 2015



Low anomaly of Vp and Vp/Vs interpreted as hydrothermal fluid saturation zone

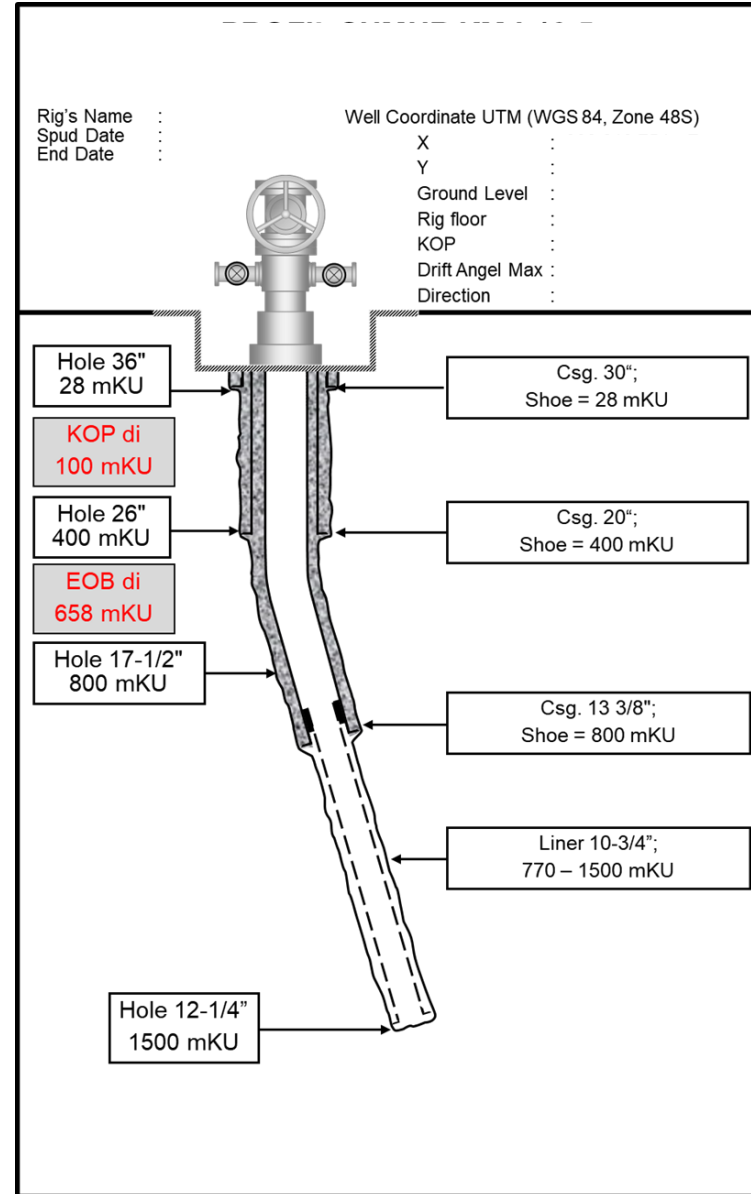
Tommy et al, 2019

# PEMBORAN PANAS BUMI



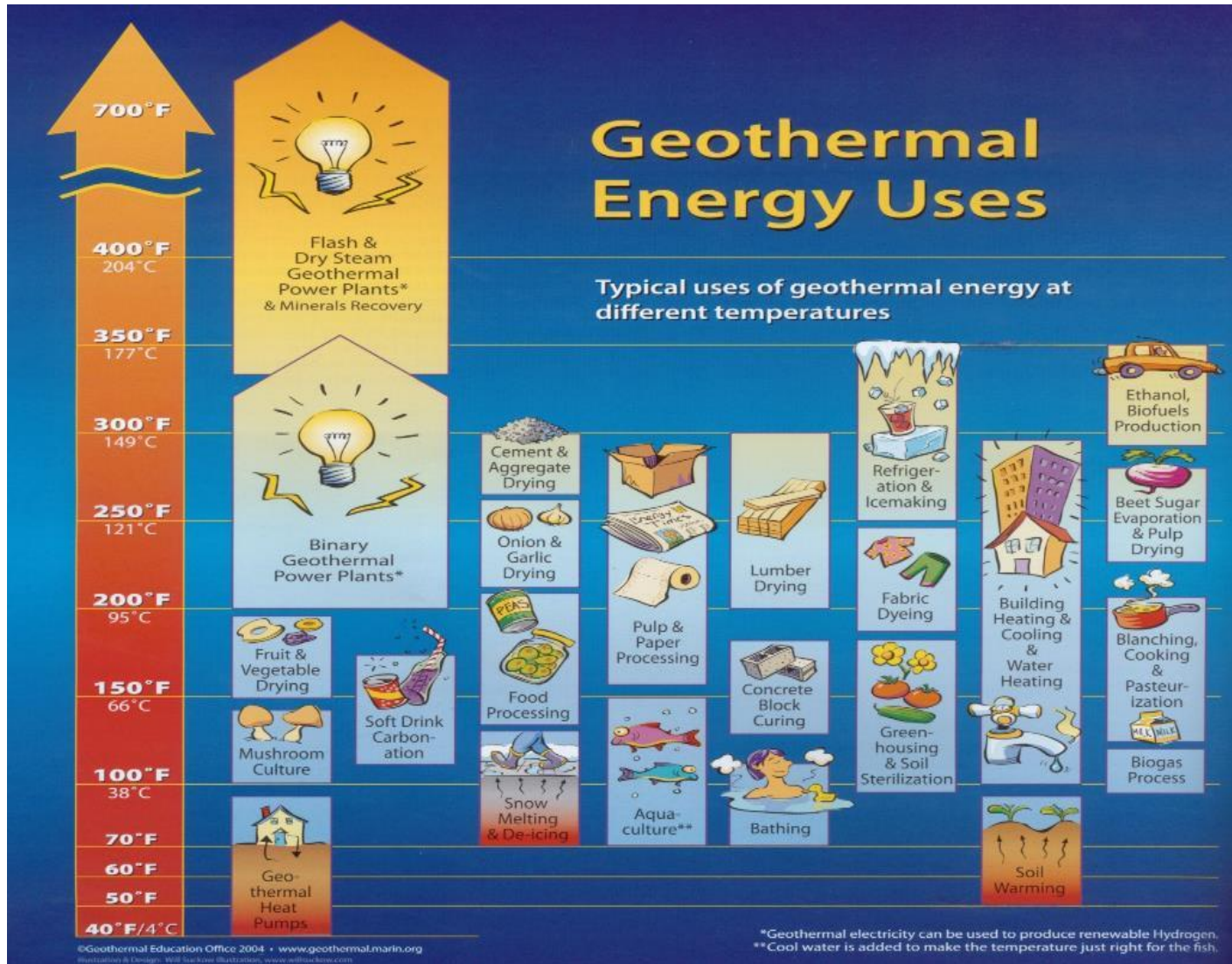
# WELL OVERVIEW & CASING DESIGN

Trayek	Interval	Panjang Trayek	Selubung	Interval Selubung
36"	0 – 28 mKU	28 m	<b>30"</b> <i>Stove Pipe</i>	0 – 28 mKU
26"	28 – 400 mKU	372 m	<b>20"</b> <i>Intermediate Casing</i>	0 – 400 mKU
17-1/2"	400 – 800 mKU	400 m	<b>13-3/8"</b> <i>Production Casing</i>	0 – 800 mKU*
12-1/4"	800 – 1500 mKU	700 m	<b>10-3/4"</b> <i>Perforated Liner</i>	770 – 1500 mKU



# Pemanfaatan Energi Geothermal



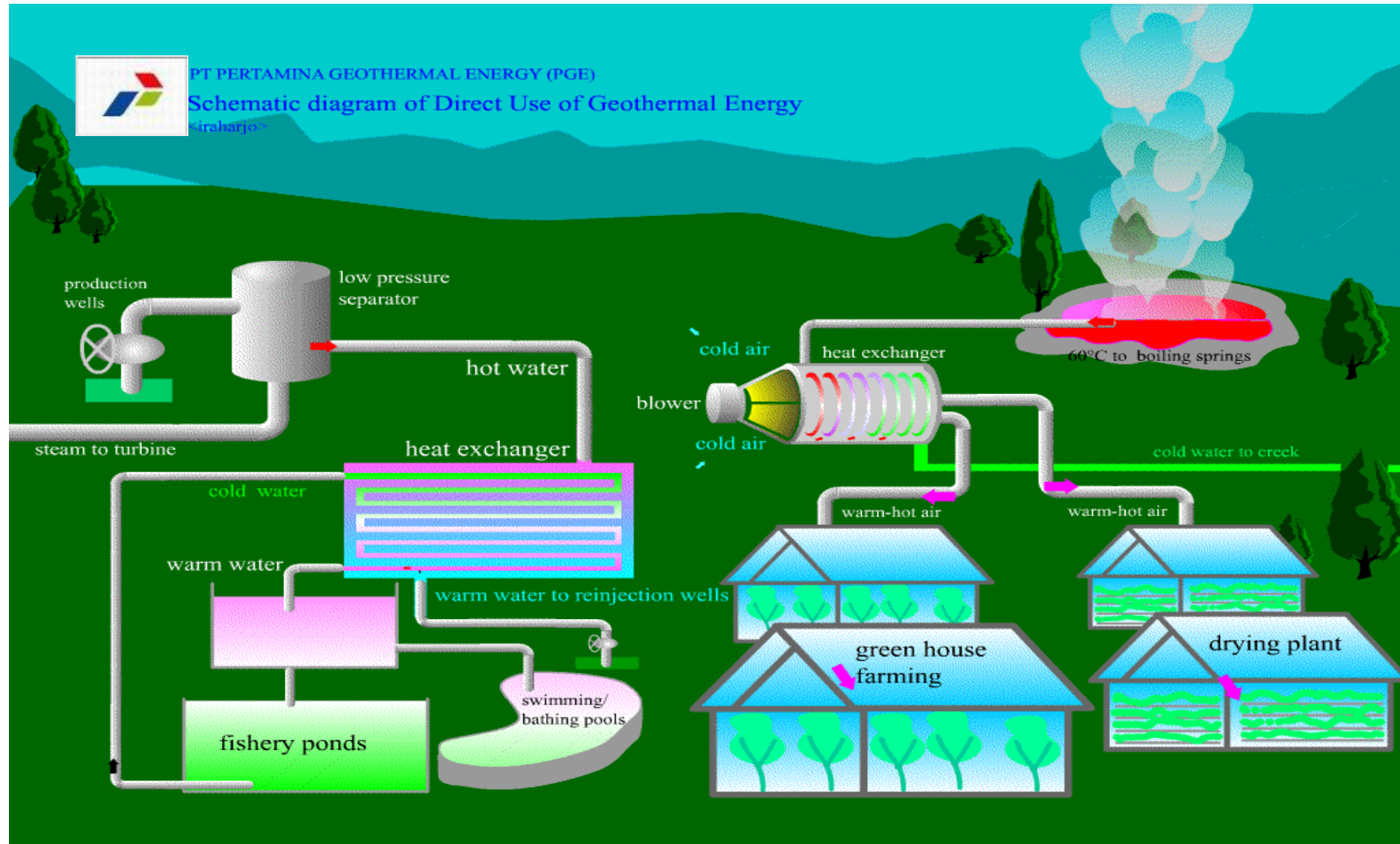


## TIPE PEMANFAATAN ENERGI GEOTHERMAL

**1. PEMANFAATAN LANGSUNG (DIRECT USE)**

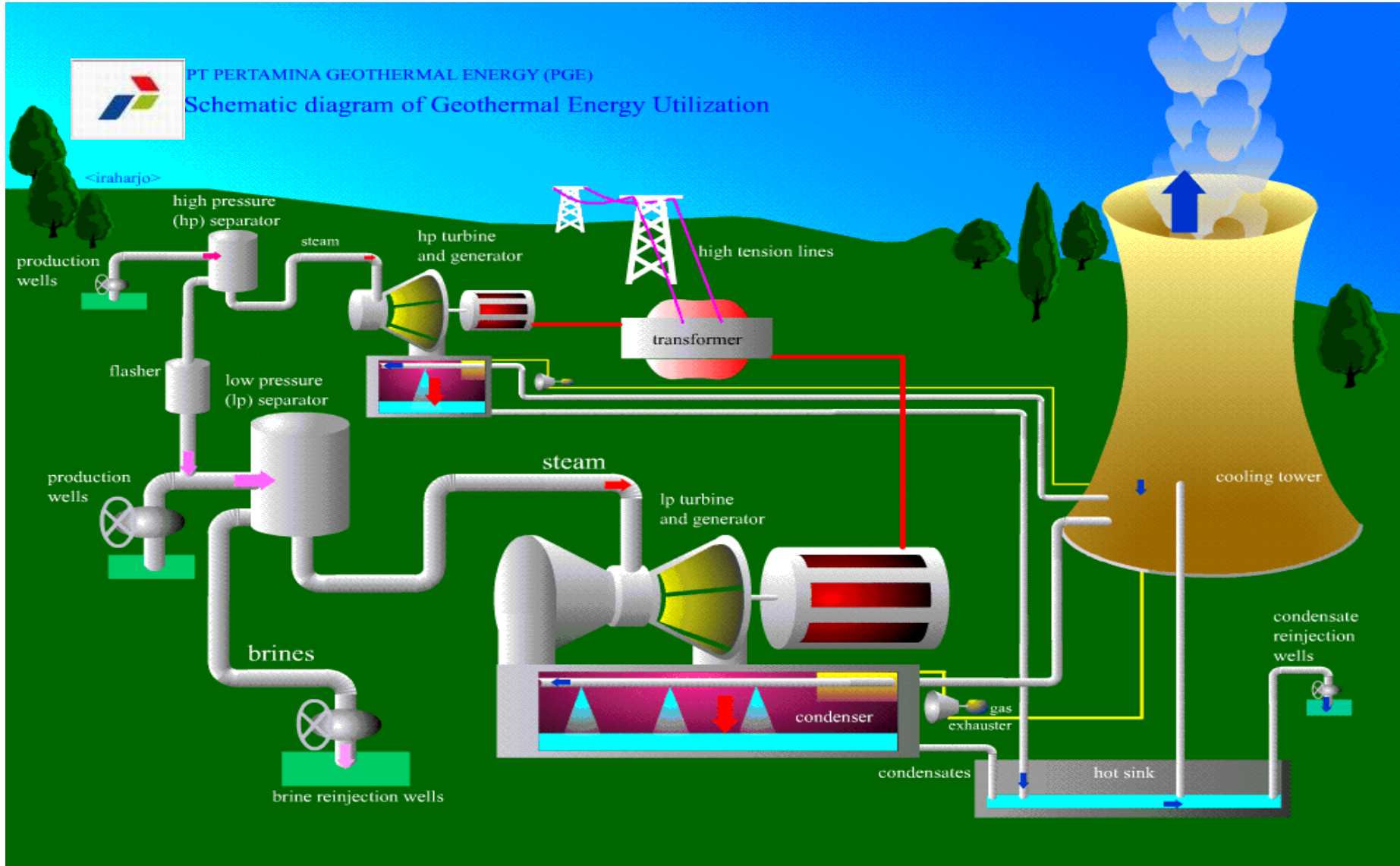
**2. PEMANFAATAN TIDAK LANGSUNG (INDIRECT USE)**

# Schematic Diagram of Direct Use of Geothermal Energy

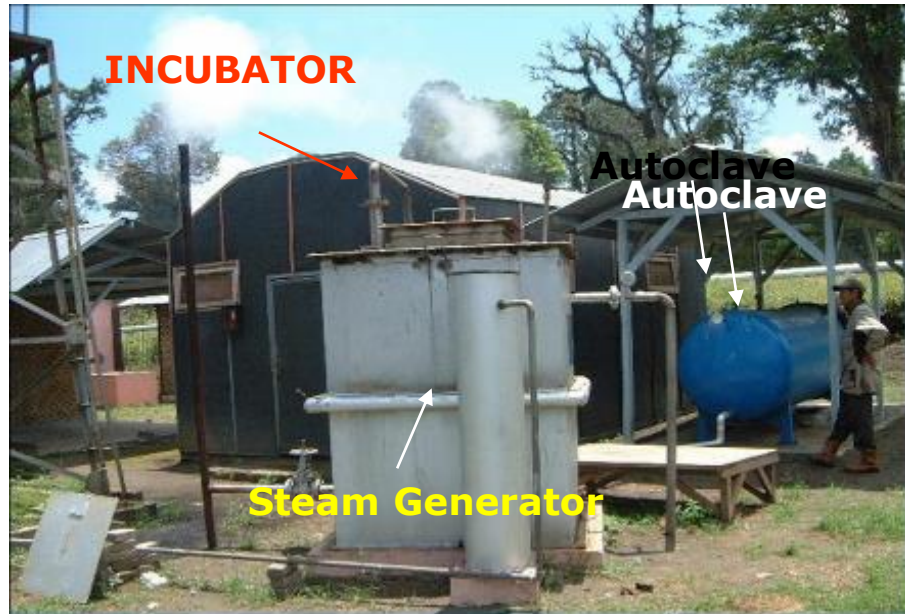




# Schematic Diagram of Geothermal Energy Utilization



# Direct Use of Geothermal Energy at PGE



# BATHING

# CISOLOK



# GREEN HOUSE & AGRIKULTUR



# Pengeringan Cengkeh dan Vanili



# GEO THERMAL TOURISM

REKREASI & KESEHATAN MASYARAKAT



Clean energy  
Ramah lingkungan



# TERIMA KASIH



**GEOHERMAL  
GREEN ENERGY FOR THE FUTURE**