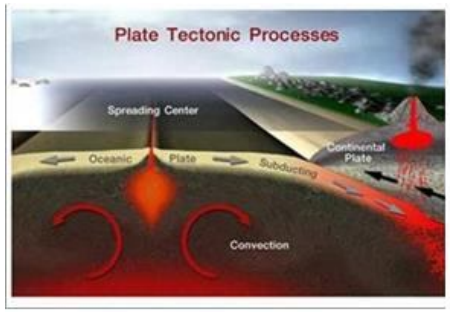
GEOCAP

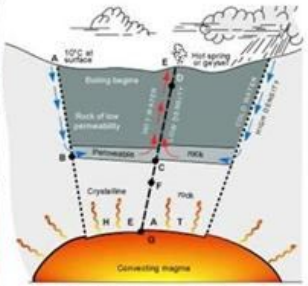
Geothermal Capacity Building Program Indonesia - Netherlands

Geothermal Reservoir and Production Engineering Knowledge And Skills

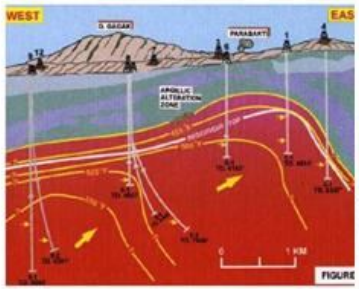
MAIN COMPONENT OF HYDROTHERMAL SYSTEM

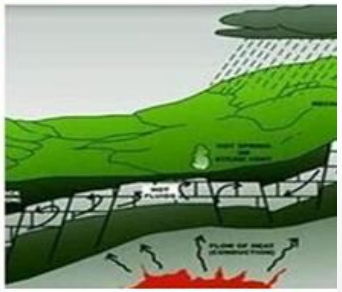
This course was developed within WP 1.04 of the GEOCAP program





Model White (1967)





Model Awibengkok-Salak (1990an)

TOPICS

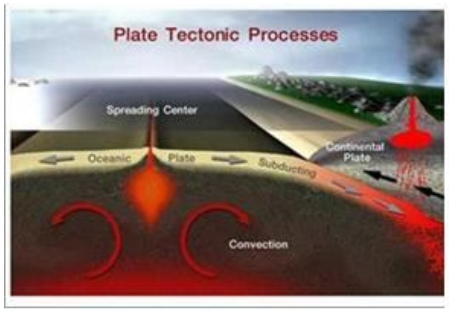
- Introduction
- Types of hydrothermal system
- Rock properties
- Conceptual model
- Key questions about reservoir
- Exercise: look at reservoir rocks

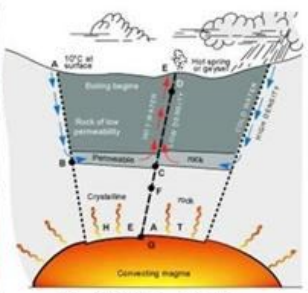
Geothermal ITB

HYDROTHERMAL SYSTEM :

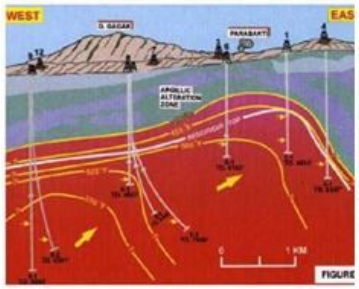
Types of hydrothermal system &
Key questions about reservoir

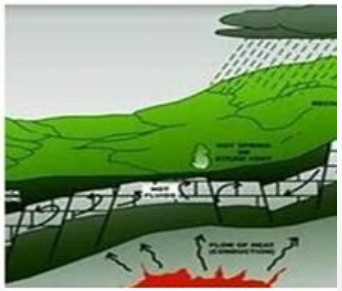
Nenny Saptadji (ITB)





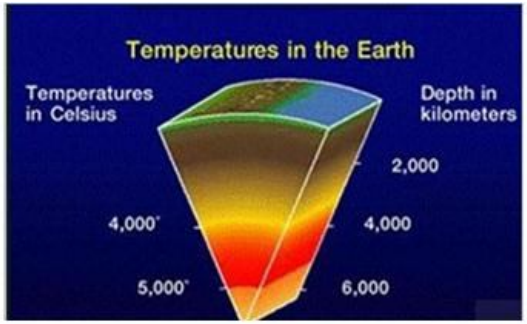
Model White (1967)

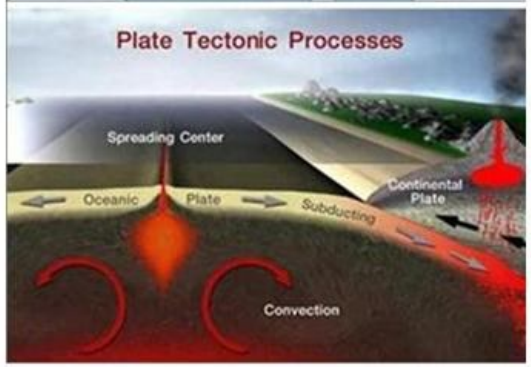


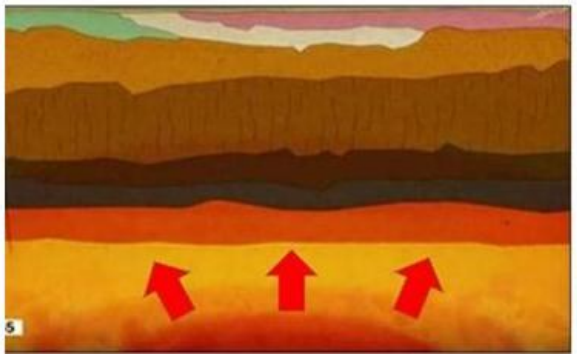


Model Awibengkok-Salak (1990an)

INTRODUCTION



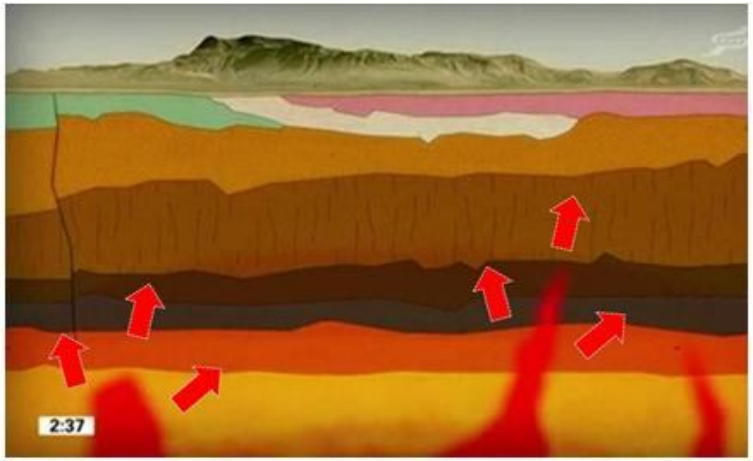


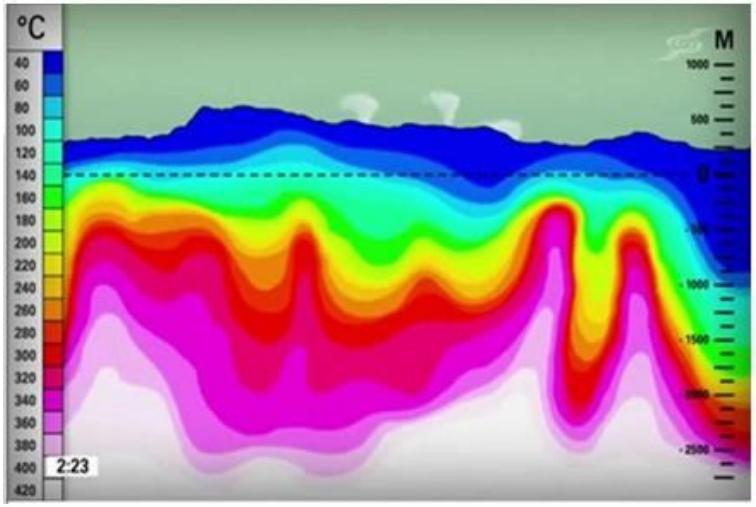


LOOK

Geothermal Energy Resources

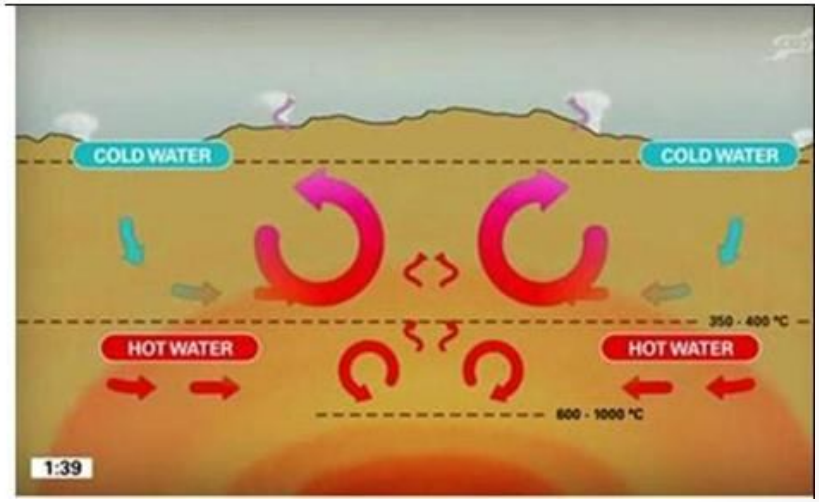
Different Types of Geothermal Reservoir



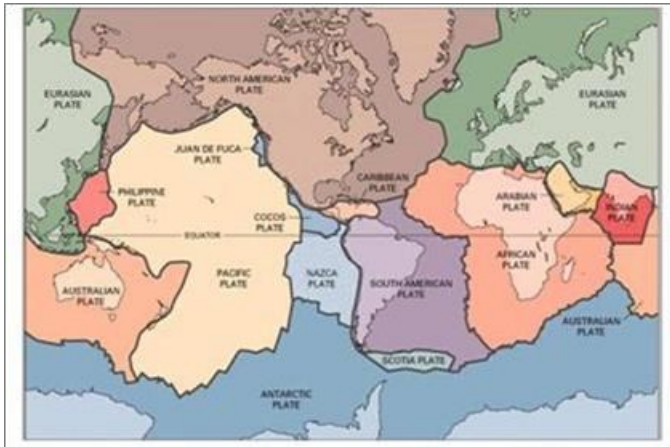


Sanyal (2005):

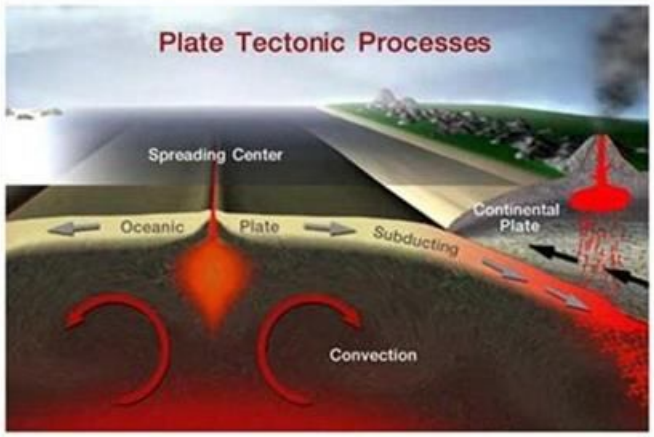
1. Hydrothermal reservoir
2. Geopressured reservoir
3. Hot dry rock reservoir
4. Magma reservoir

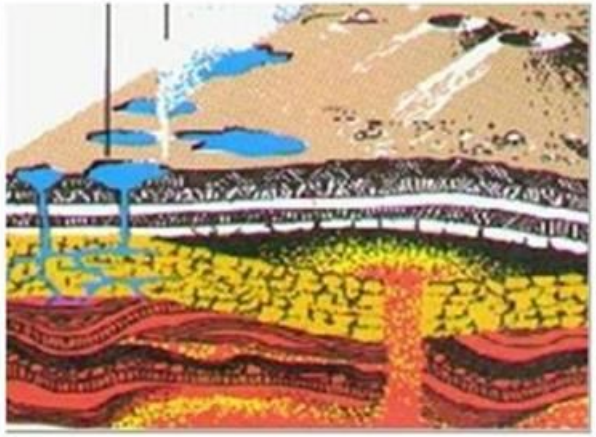


Hydrothermal Reservoirs



Hydrothermal Reservoirs: consists of heated water and/or steam stored in permeable rock at depths reachable by commercial drilling, typically less than 4 km (Subir K. Sanyal, 2005)

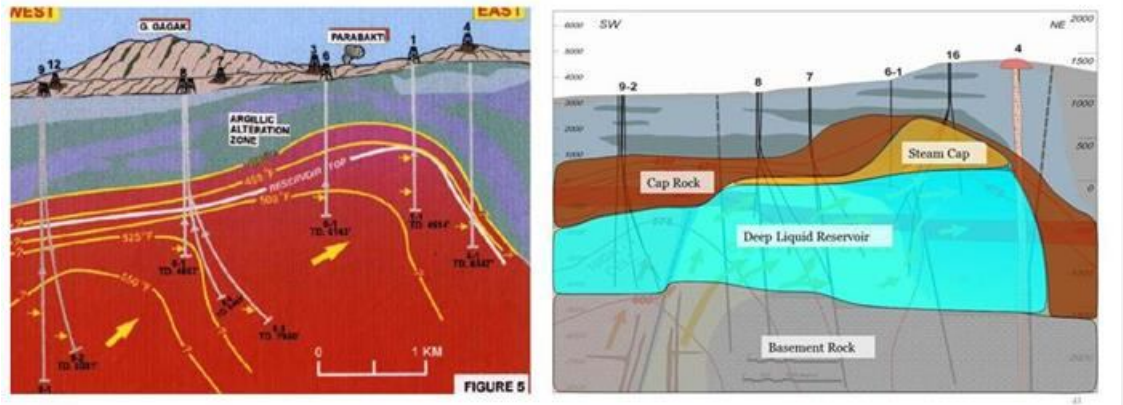




All generation of geothermal electricity to date is derived from hydrothermal system

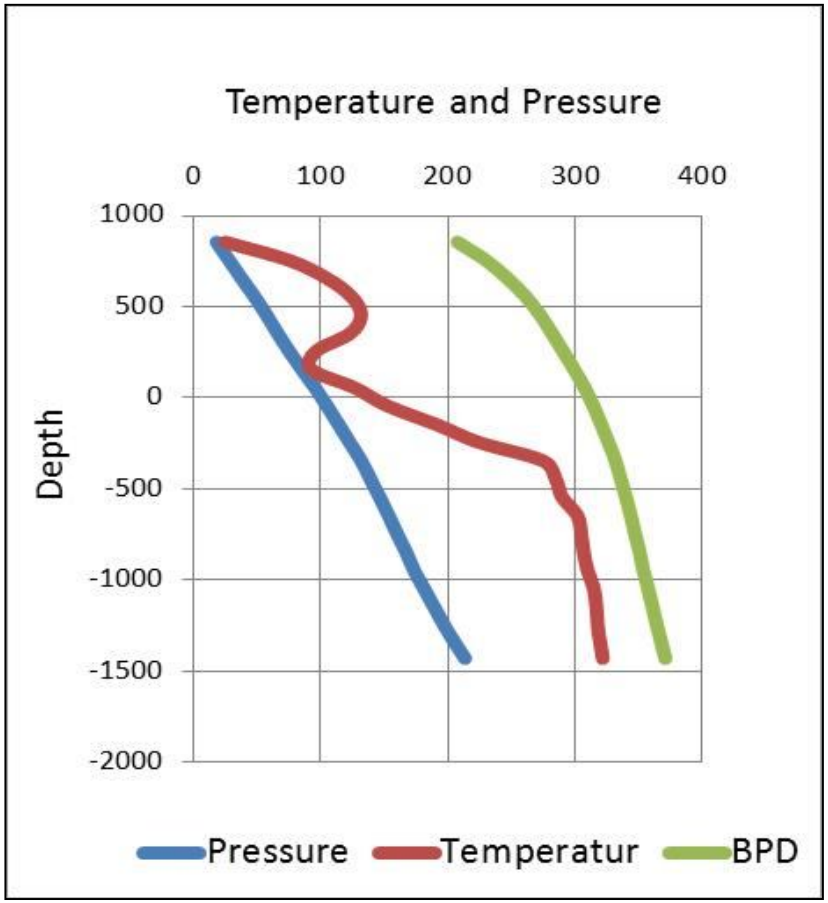
Classification of Geothermal Reservoir Based on Fluid State in the Reservoir

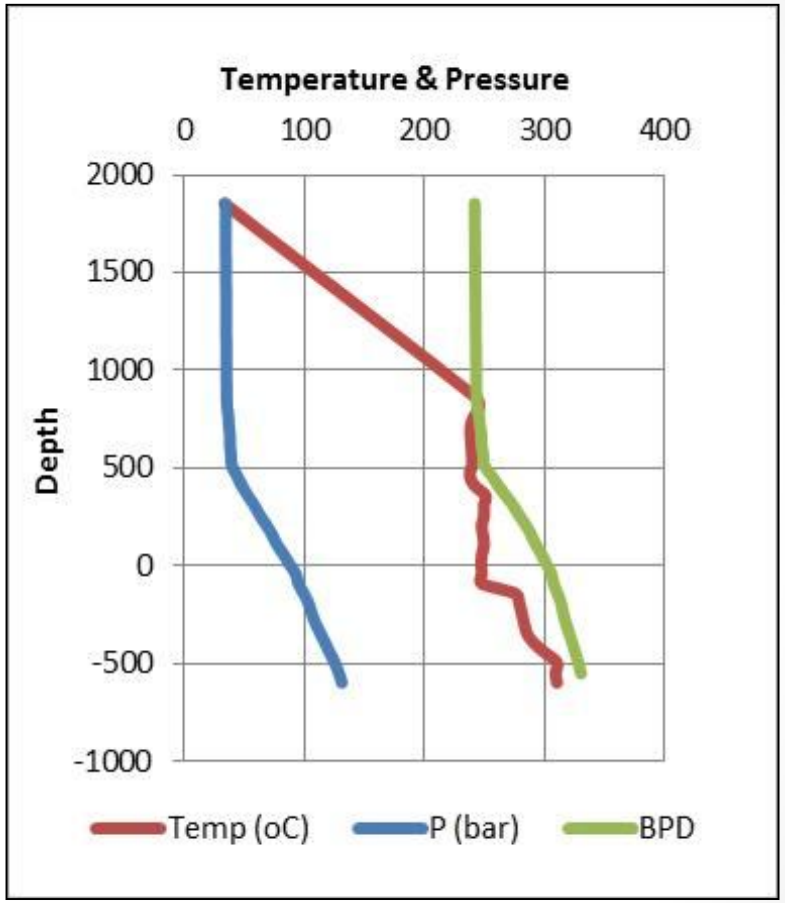
- Types of Hydrothermal Reservoir
  - Single phase reservoir
  - Two-phase reservoir
    - Water dominated reservoir
    - Vapor dominated reservoir



Conceptual Model Awibengkok Gn Salak Field, 2012

Identification of fluid state in the reservoir





BPD – Boiling Point with Depth

Resource Availability

Handbook of Geothermal Energy,Editors: Edwards, L.M., Chilingar, G.V. et al., Gulf Publishing Company, 1982, Chapter 9

Type of Geothermal System		Resource Availability
Hidrothermal Systems	Vapor-dominated	Limited
	Liquid-dominated	Limited but significant in some areas
Dry (hot-rock) formations		Potentially large
Geopressured (hot) accumulations		Limited but significant in some areas

Identified Geothermal Field in Indonesia

Field	Province	Type of Reservoir	Temp. (°C)
Kamojang	West Java	Vapor Dominated	245°C
Darajat	West Java	Vapor Dominated	245°C
Lahendong	North Sulawesi	Water Dominated	260 - 330°C
Salak	West Java	Water Dominated	240 - 310°C
Sibayak	North Sumatera	Water Dominated	240 - 275°C
Dieng	Centra java	Water Dominated	280 - 330°C
Sarulla	North Sumatera	Water Dominated	250 - 270°C
Karaha Bodas	West Java	Water Dominated	230 - 245°C
Ulubelu	Lampung (Sumatera)	Water Dominated	280°C
Lumut Balai	South Sumatera	Water Dominated	260°C

Reservoir Temperature in Two-phase Geothermal Field in Indonesia (Suryadarma et.al.. 2010)

Field	Reservoir Temperature
Salak	235-310^{o}C
Bedugul	280-320^{o}C
Dieng	240-330^{o}C
Hulu Lais	250-280^{o}C
Karaha Bodas	250-350^{o}C
Kotambagu	250-290^{o}C
Lahendong	250-350^{o}C
Lumut Balai	260-290^{o}C
Sarulla	250-310^{o}C
Sibayak	230-280^{o}C
Sungai Penuh	230-240^{o}C
Tompaso	240-260^{o}C
Ulubelu	240-260^{o}C
Wayang-Windu	240-300^{o}C

Classification of Hydrothermal Reservoir Based on Reservoir Temperature

Class	Muffer & Cataldi (!978)	Benderiter & Cormy (1990)	Haenel, Rybach & Stegna (1988)	Hochstein (1990)
Low Enthalpy	<90^{o}C	<100^{o}C	<150^{o}C	<125^{o}C
Medium Enthalpy	90-150^{o}C	100-200^{o}C	-	125-225^{o}C
High Entalpy	>150^{o}C	>200^{o}C	>150^{o}C	>225^{o}C

Classification of Hydrothermal Reservoir Based on Reservoir Temperature (cont'd)

Sanyal, K.S. (2005):

Class	Reservoir Temperature	Fluid State in the Reservoir	Fluid State in the Well Head
Very Low Temperature	100°C to < 150°C	Liquid Water	Liquid Water
Low Temperature	150°C to < 190°C	Liquid Water	Liquid Water/Steam-water Mixture
Moderate Temperature	190°C to < 230°C	Liquid Water	Liquid Water/Steam-water Mixture
High Temperature	230°C to < 300°C	Liquid Water/Liquid dominated two-phase	Steam-water Mixture
Ultra High Temperature	300°C +	Liquid dominated two-phase	Steam-water Mixture
Steam Field	230°C – 240°C	Steam Dominated (30-35 bar pressure and 2800 $\pm$10 kJ/kg entalpy)	Saturated or superheated steam

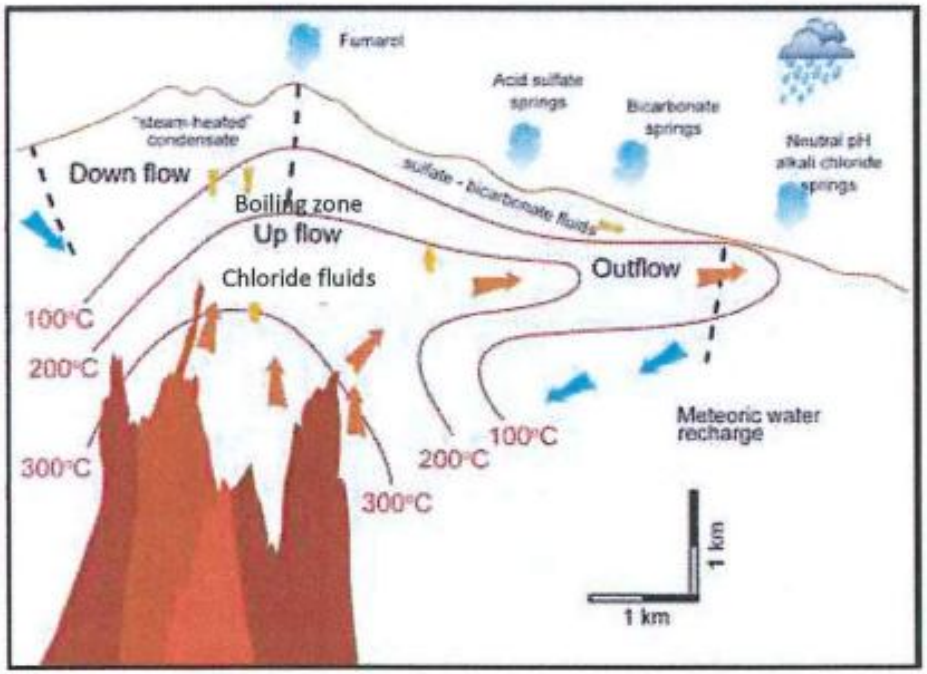
Characteristics of identified geothermal reservoirs in Indonesia

Characteristics of identified geothermal reservoirs in Indonesia:

- Reservoir fluid has high temperatures; in many cases varied from 225-350^{o}C.
- Geothermal reservoirs containing fluids is highly fractured and mostly of volcanic type.
- Most of geothermal areas are located in mountainous remote places, many of them overlapping National Park or conservation forest or protected forest.

Conceptual Model

Geothermal system in high-relief volcanic terrain

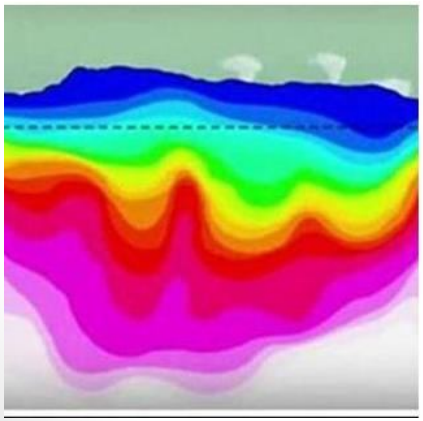


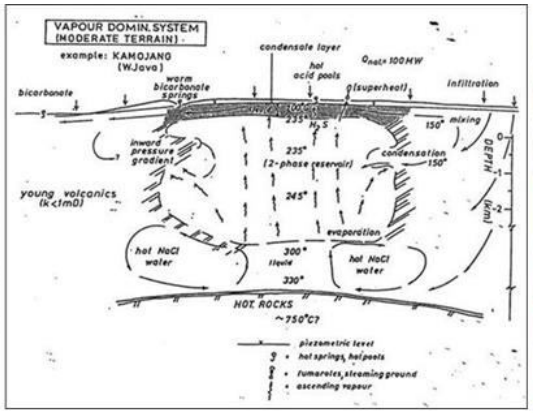
(diagram adapted from Corbett and Leach, 1994)

- Examples: Indonesia, Philippines, Japan
- Volcanic island arc setting
- Andesitic volcanism
- Shallow igneous intrusion heat source
- Vapor zones common
- Upflow is characterised by fumarolic and steam-heated type manifestations
- Reservoir fluid of moderate salinity
- Primary chloride-type reservoir fluid may not reach the surface
- Long outflow structure
- Difficult to explore

Key Questions about Geothermal Reservoir

1. Type of reservoir ?
2. Depth of reservoir?
3. Reservoir pressure and temperature ?
4. Extent of the reservoir area?
5. Rock type and properties ?
6. Fluid properties?
7. Conceptual Model?
8. Size of the resources and reserve ?
9. Electricity potential?
10. Well production potential?
11. Changes in the reservoir due to production ?





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Terimakasih