# Conceptual Models

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# Conceptual Models

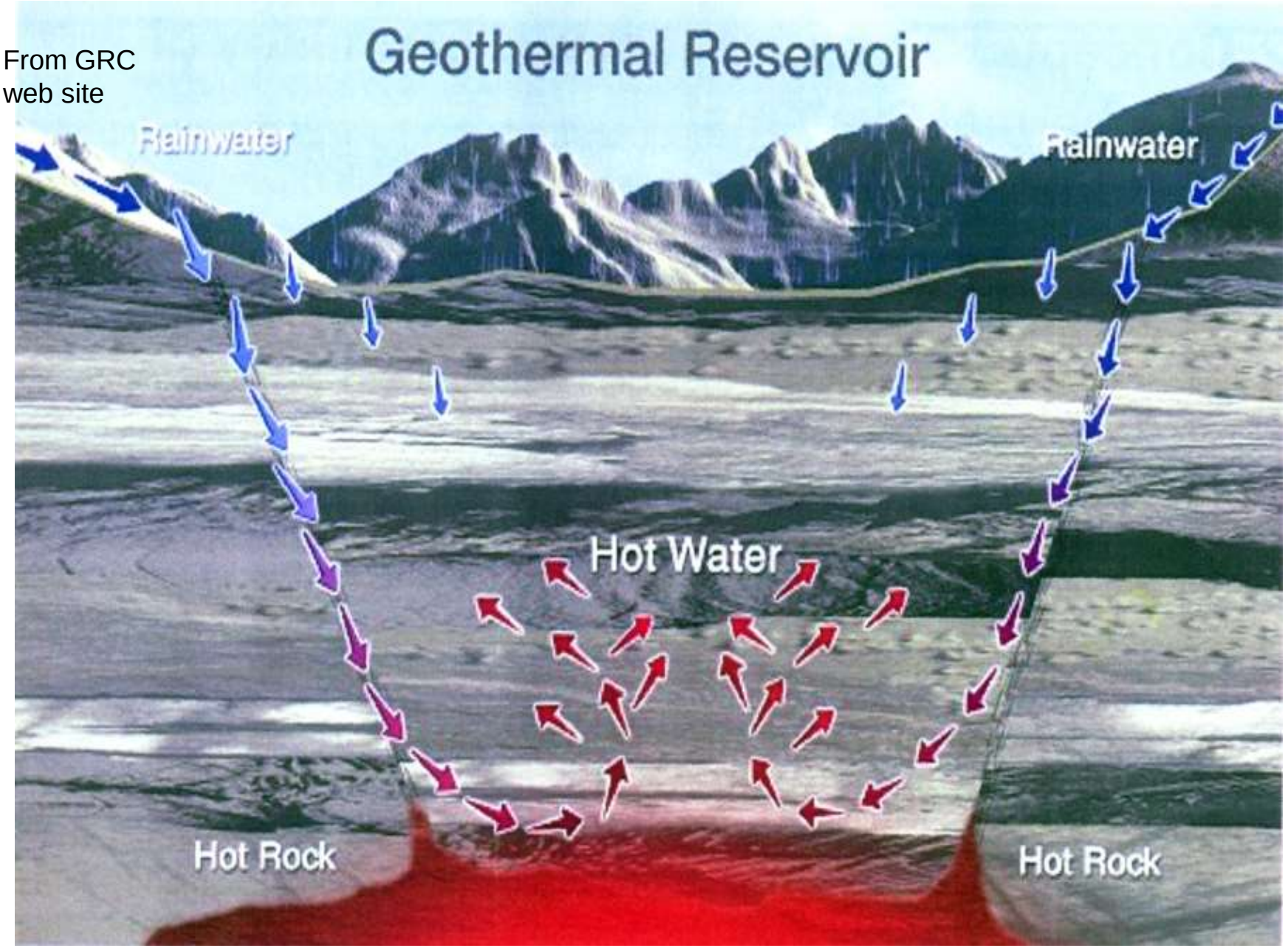
# Different conceptual models for different geothermal systems

Generalisations can be made about geothermal systems



But each system is unique

From GRC web site




Basic Conceptual Model

# Typical geothermal system

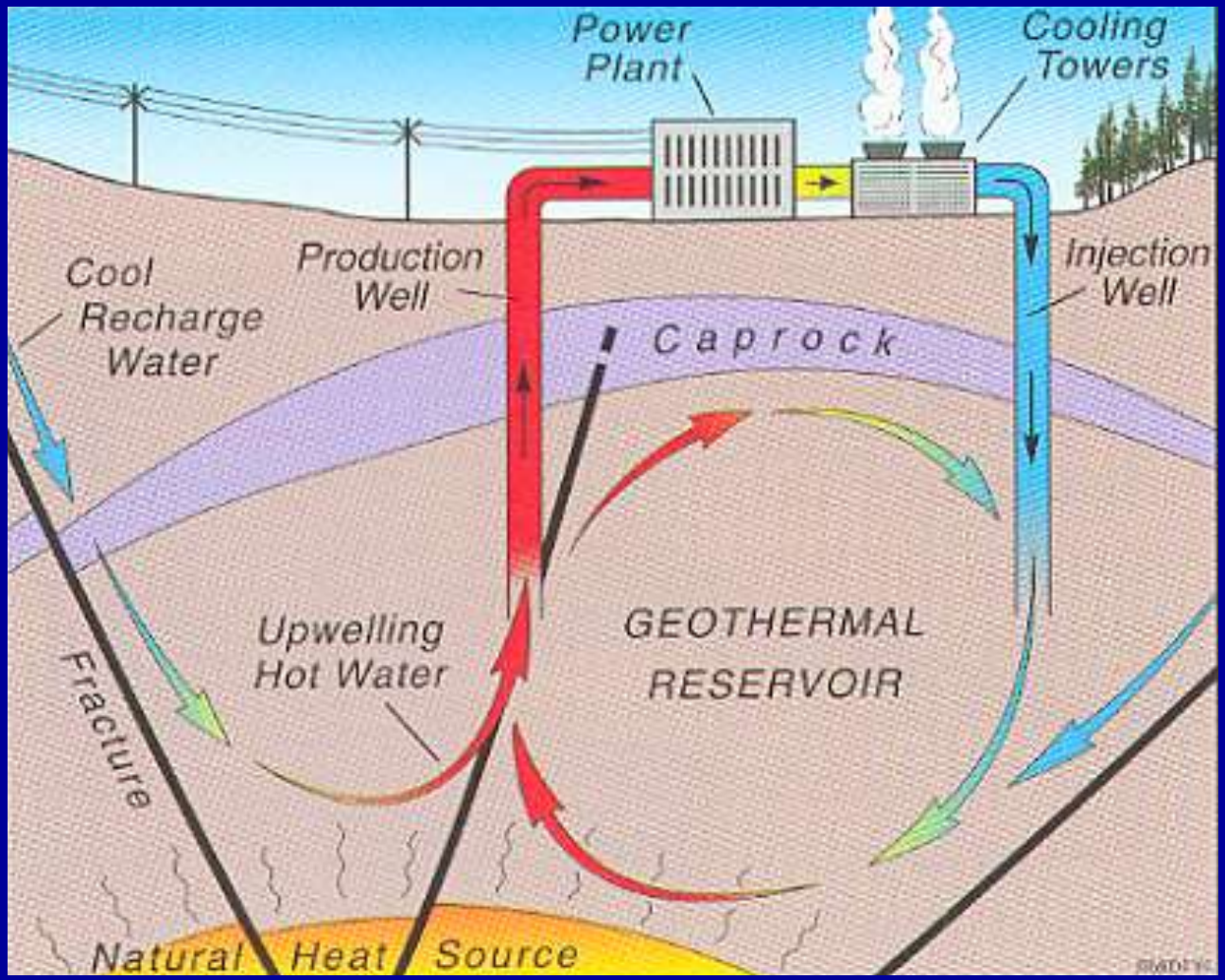



Diagram by Utah University

# Temperature with Depth gradient

Normal gradient 10 - 40 100 ˚C/km

Anomalous heat flow (higher than normal) = >100 ˚C/km
Due to magmatic processes

# Let’s look at different conceptual models

High temperature systems

Low temperature systems

Heat Sweep systems

Hot dry rock systems

Submarine systems

Volcanic systems

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**High temperature systems**

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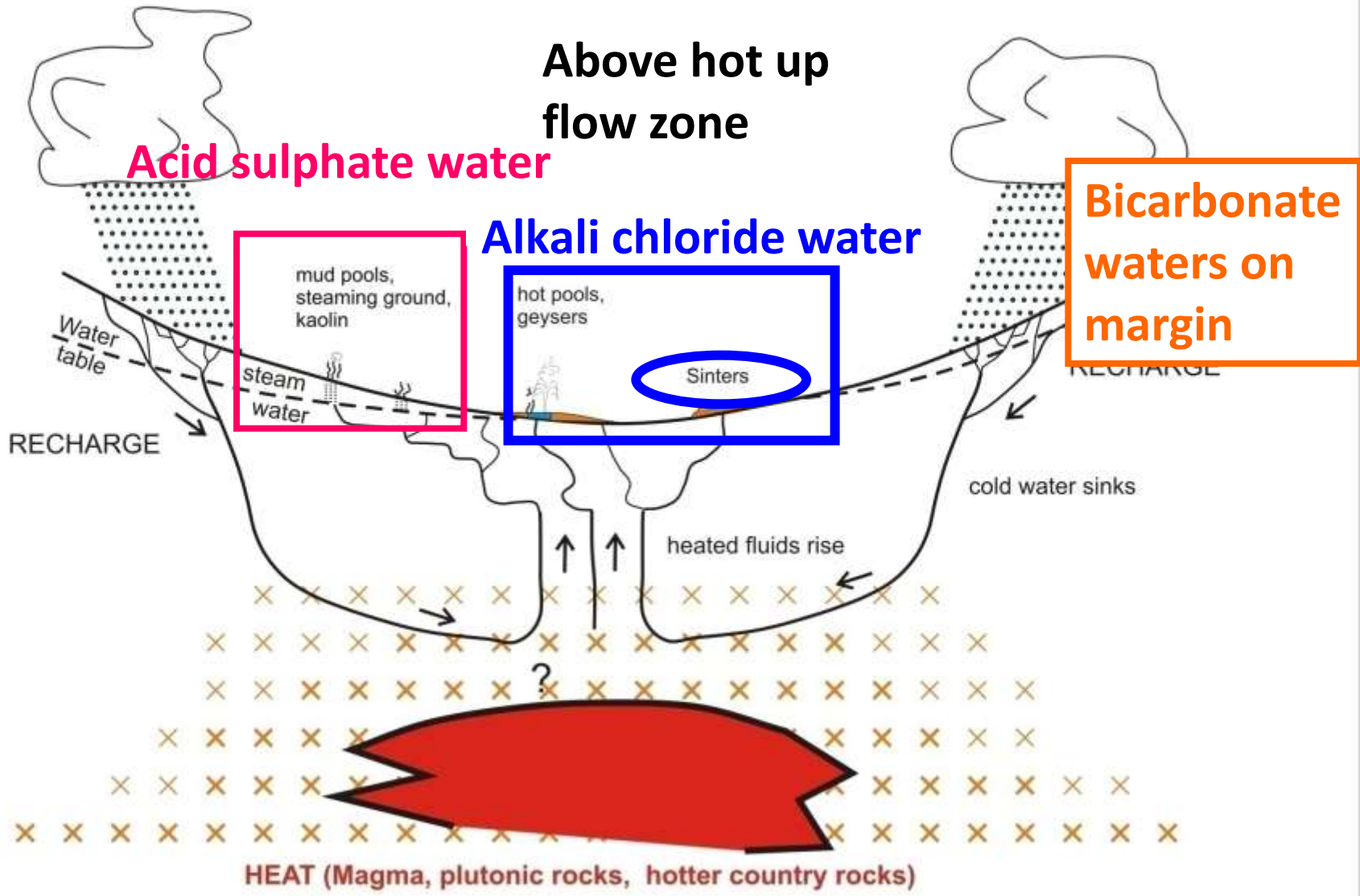



General concept of a geothermal system

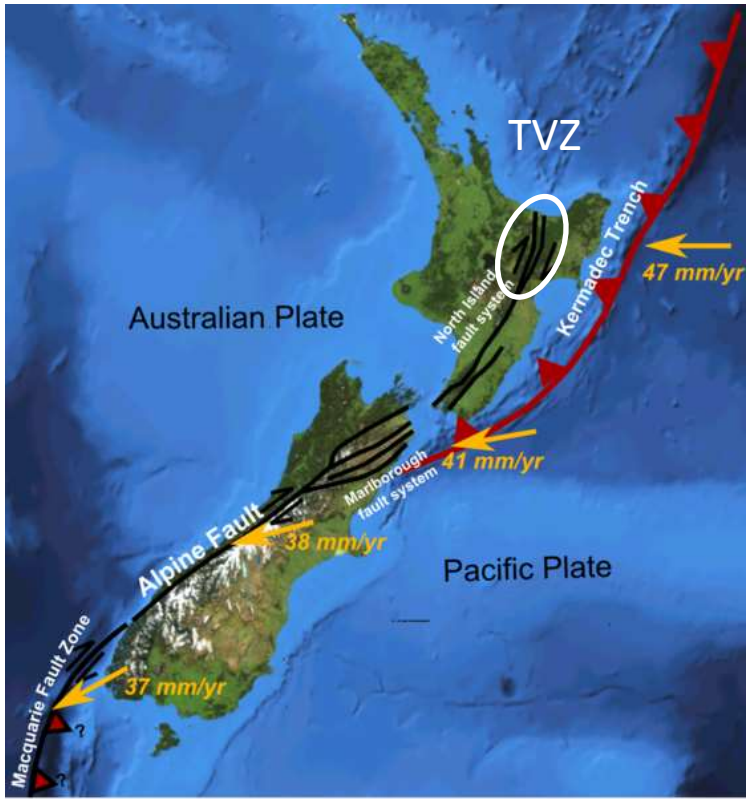
## High temperature geothermal systems:

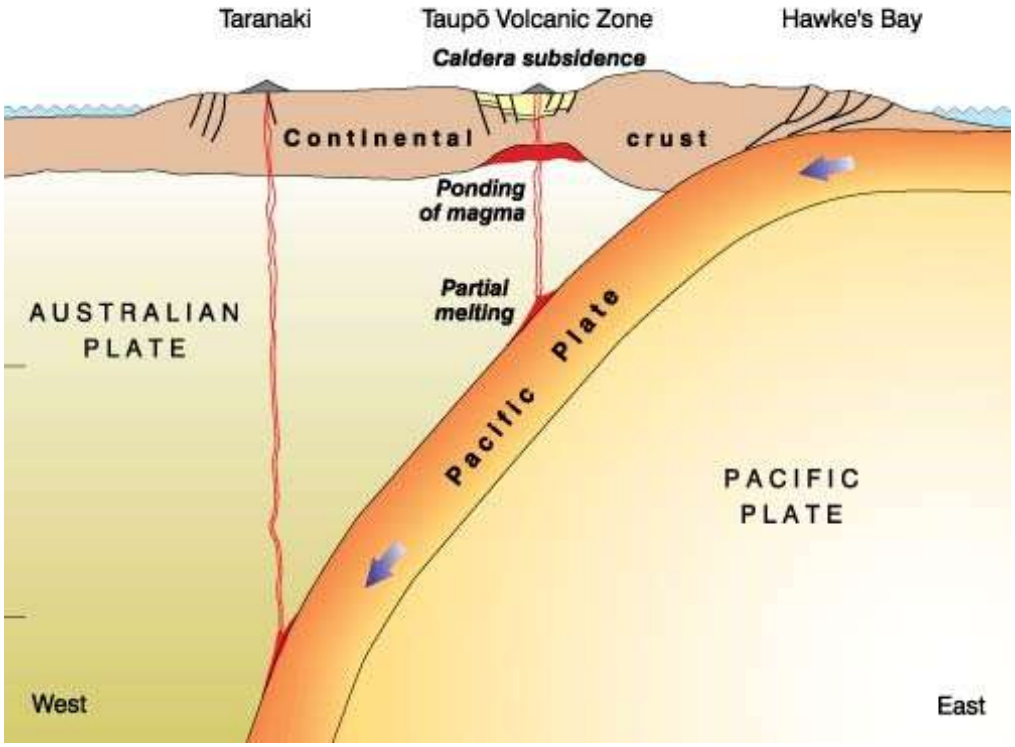
- reservoir temperatures >125° C
- boiling or two phase conditions exist
- able to generate electricity
- anomalous temperature gradient (magmatism)

Cyclic:

- water circulates advecting thermal energy
- open system
- flow driven by magmas, gravity, structures
- hydro-pressured (hydrostatic gradient)

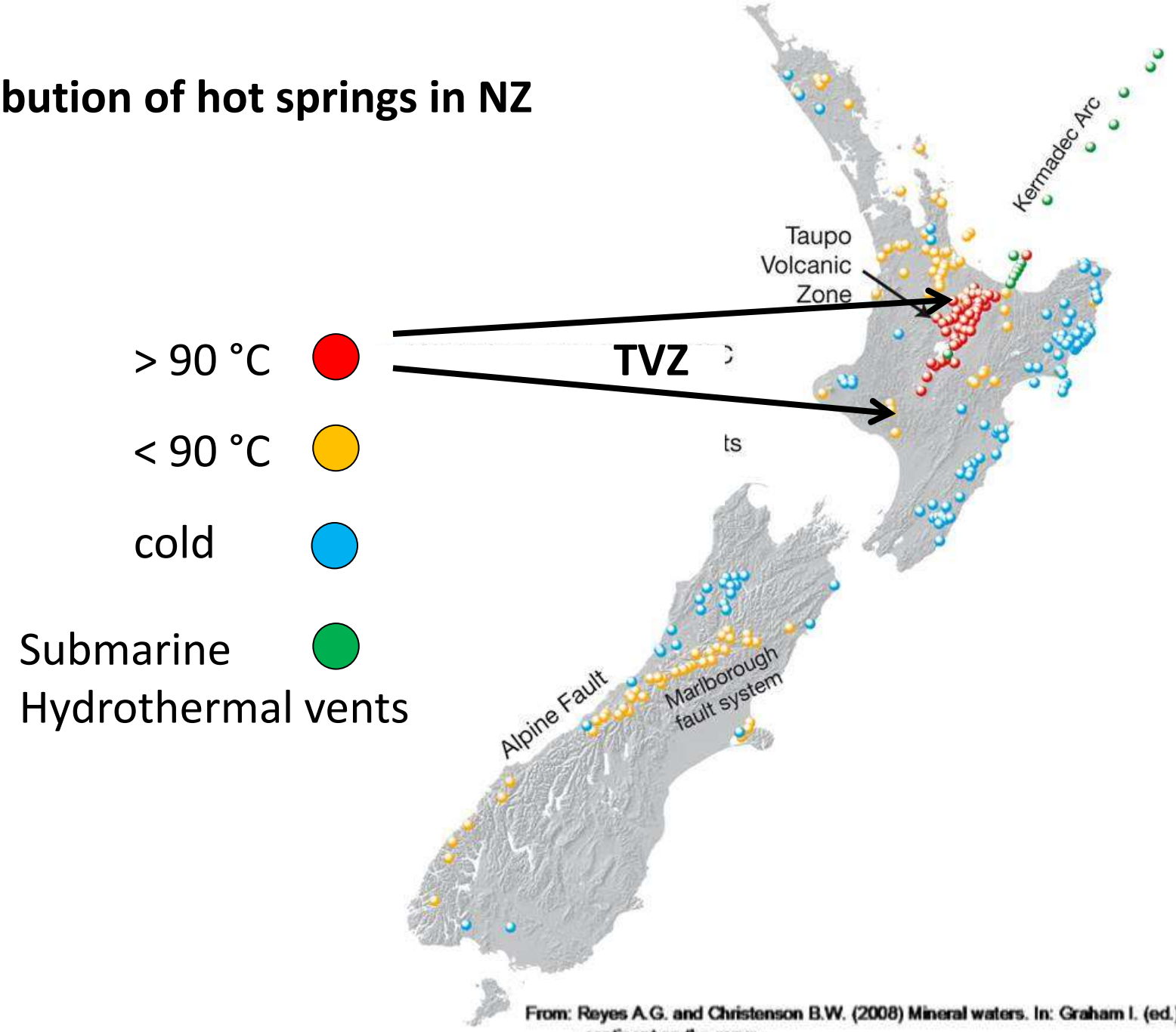
New Zealand situated on plate boundary
= subduction → high heat flow areas
active volcanism
active faulting
HIGH TEMPERATURE GEOTHERMAL SYSTEMS




http://www.teara.govt.nz/en/volcanoes/2/2

# Distribution of hot springs in NZ



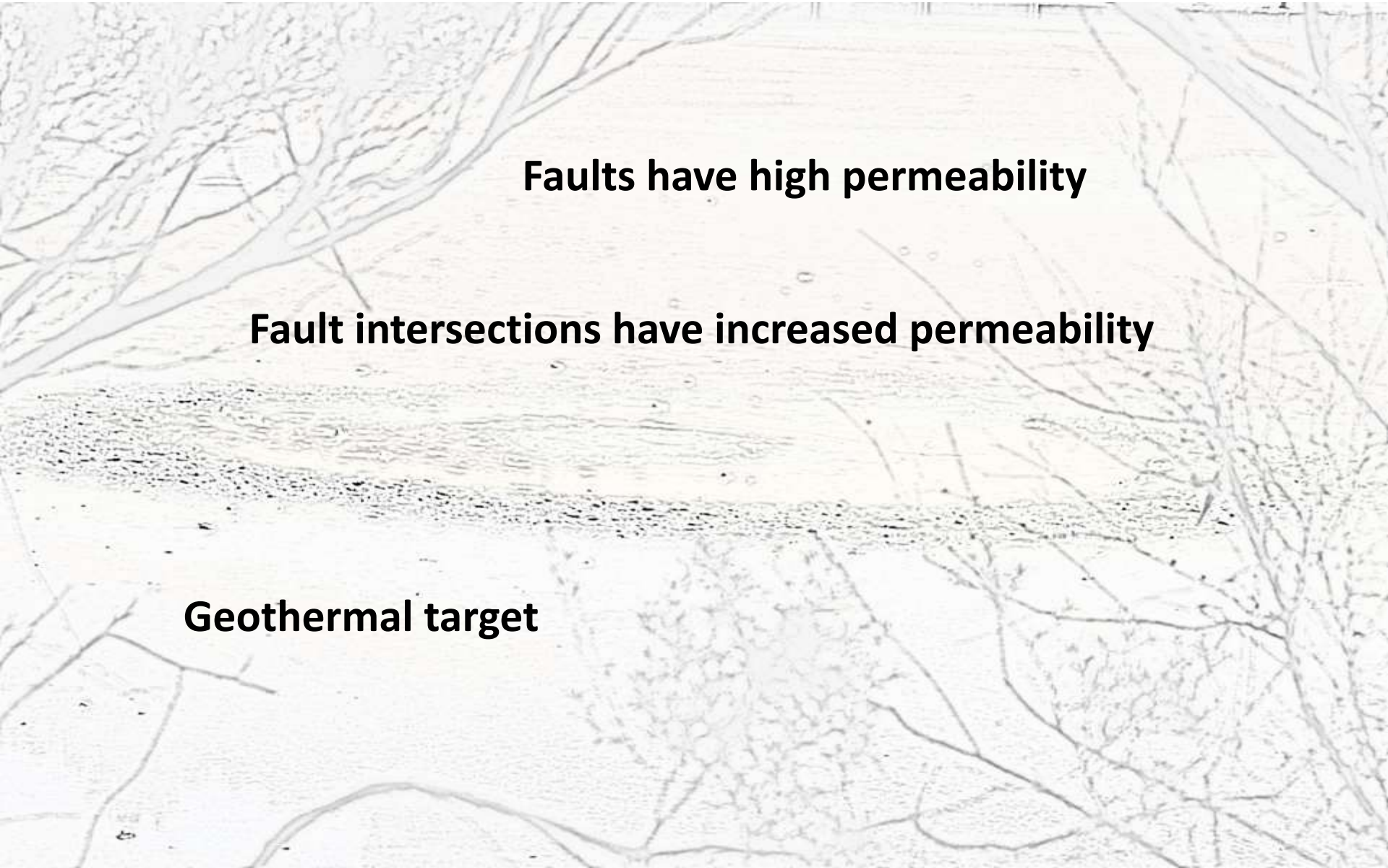
# Controls of high temperature geothermal systems

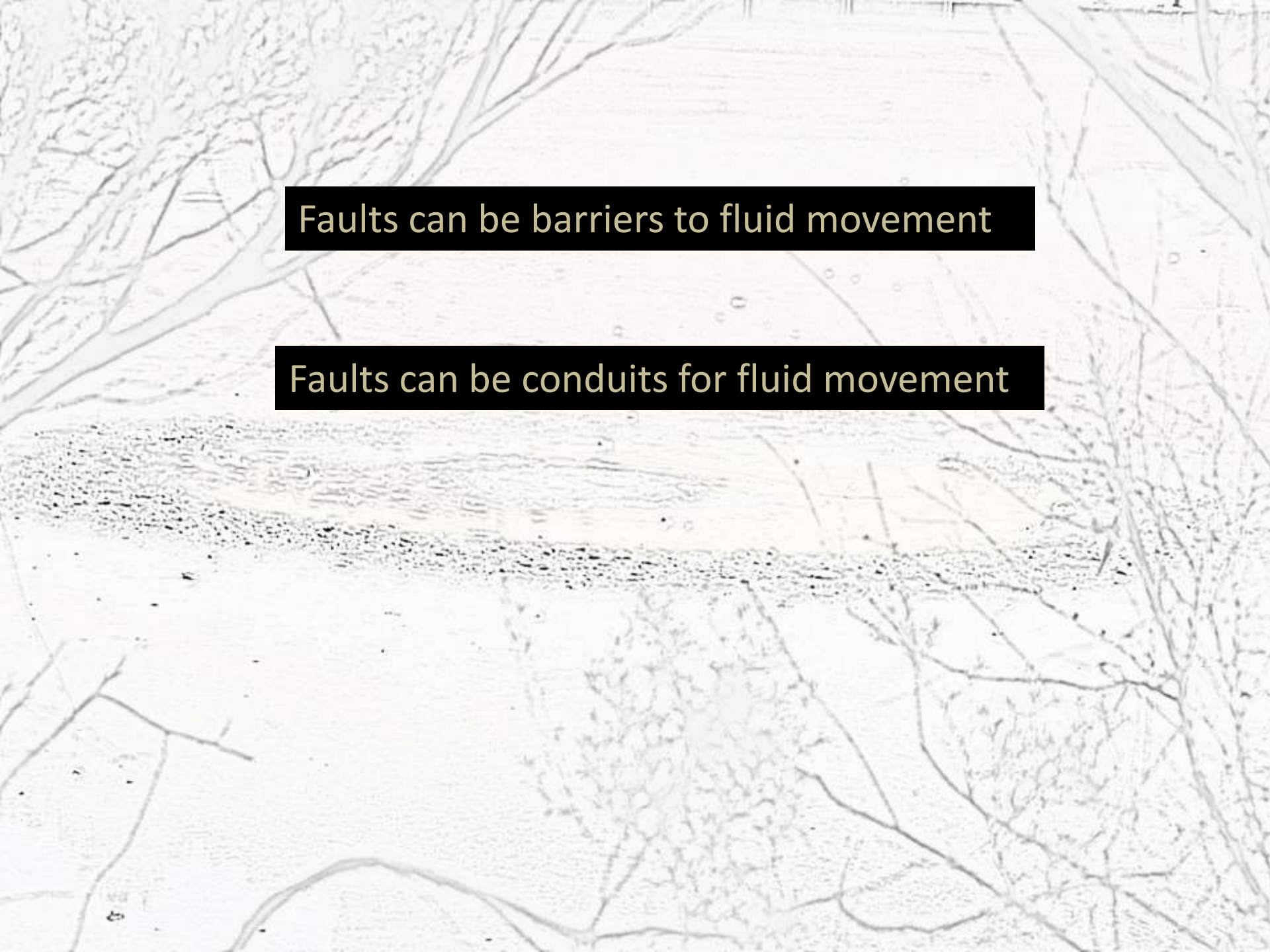
Let’s look first at volcanism and tectonism

**Strong relationship between faults = permeability**

**Volcanism = heat source**

# Different conceptual models for different geothermal systems

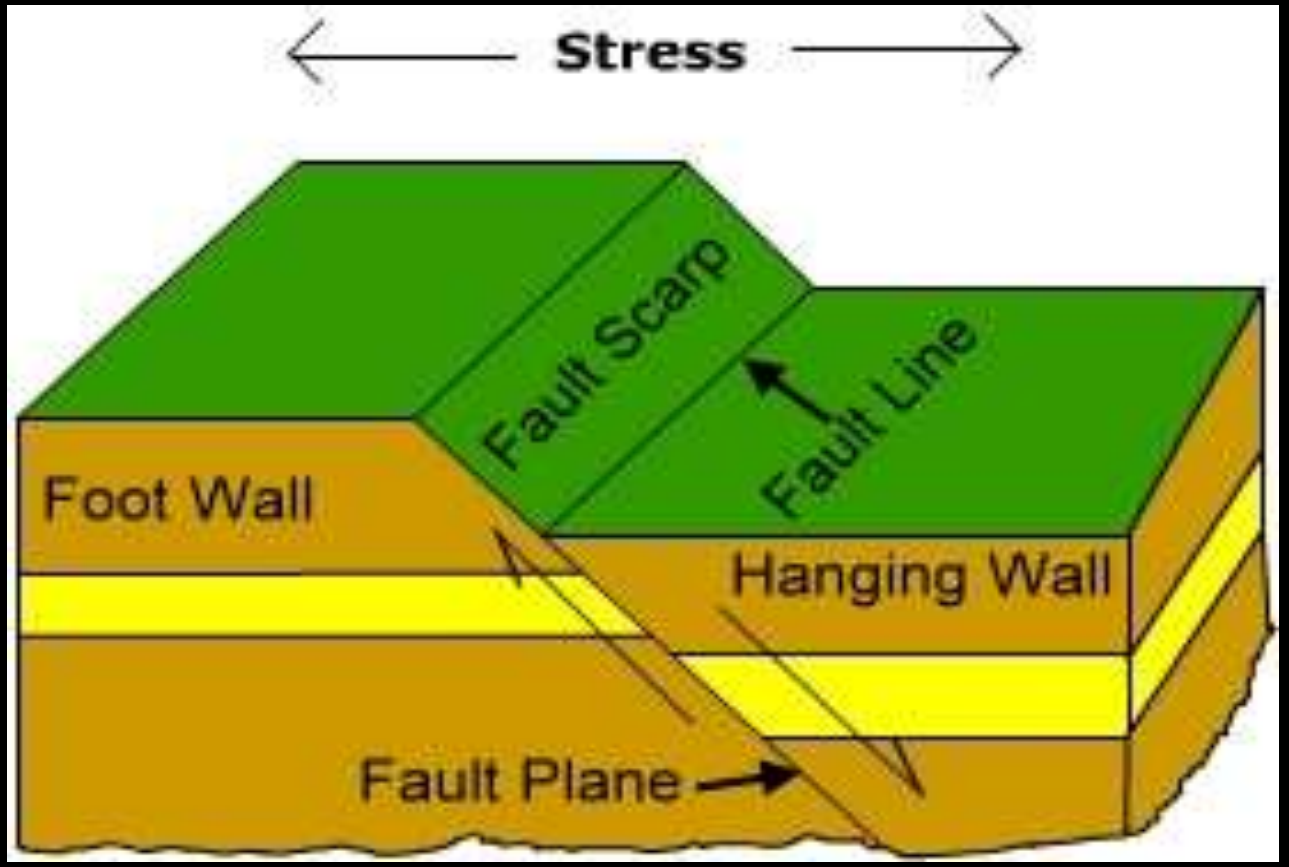



Faults can be barriers to fluid movement
Faults can be conduits for fluid movement

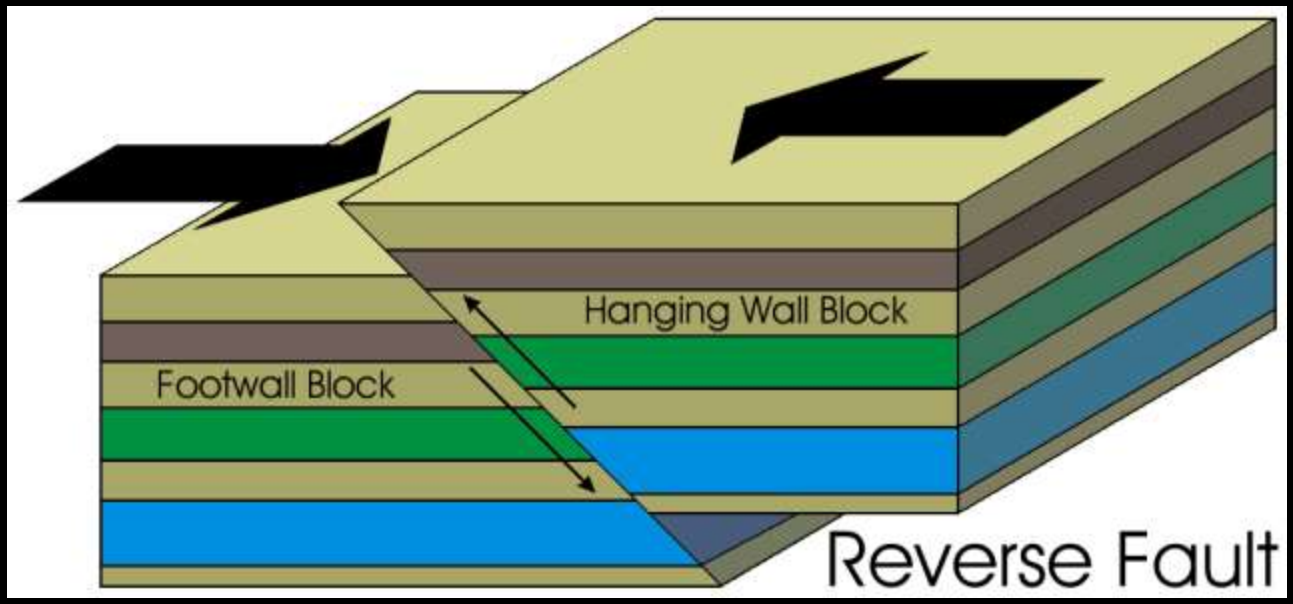
# Normal Faulting

Space creating

Permeable



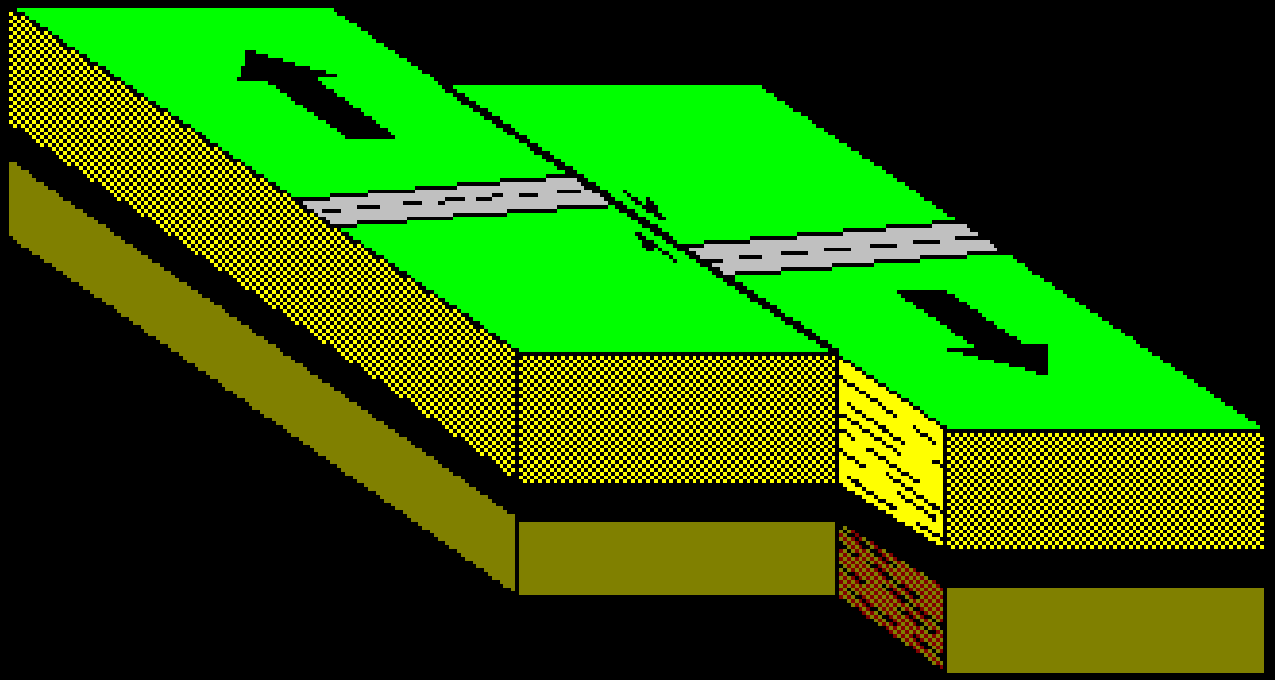
# Reverse Faulting




Not permeable (tight)

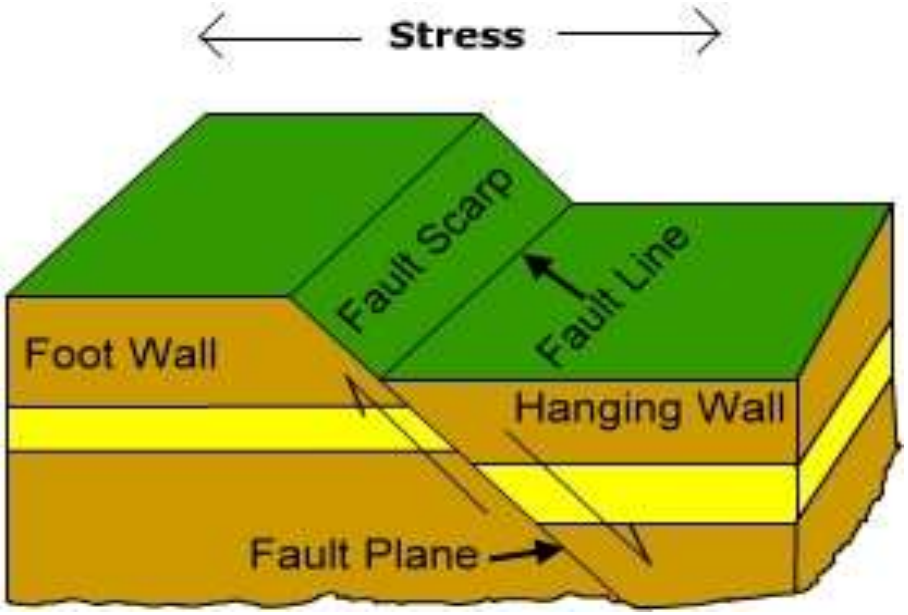
http://www.artinaid.com/2013/04/components-and-types-of-geological-faults/

# Strike-slip Faulting



http://www.artinaid.com/2013/04/components-and-types-of-geological-faults/

In geothermal exploration we look for <u>normal faults</u>

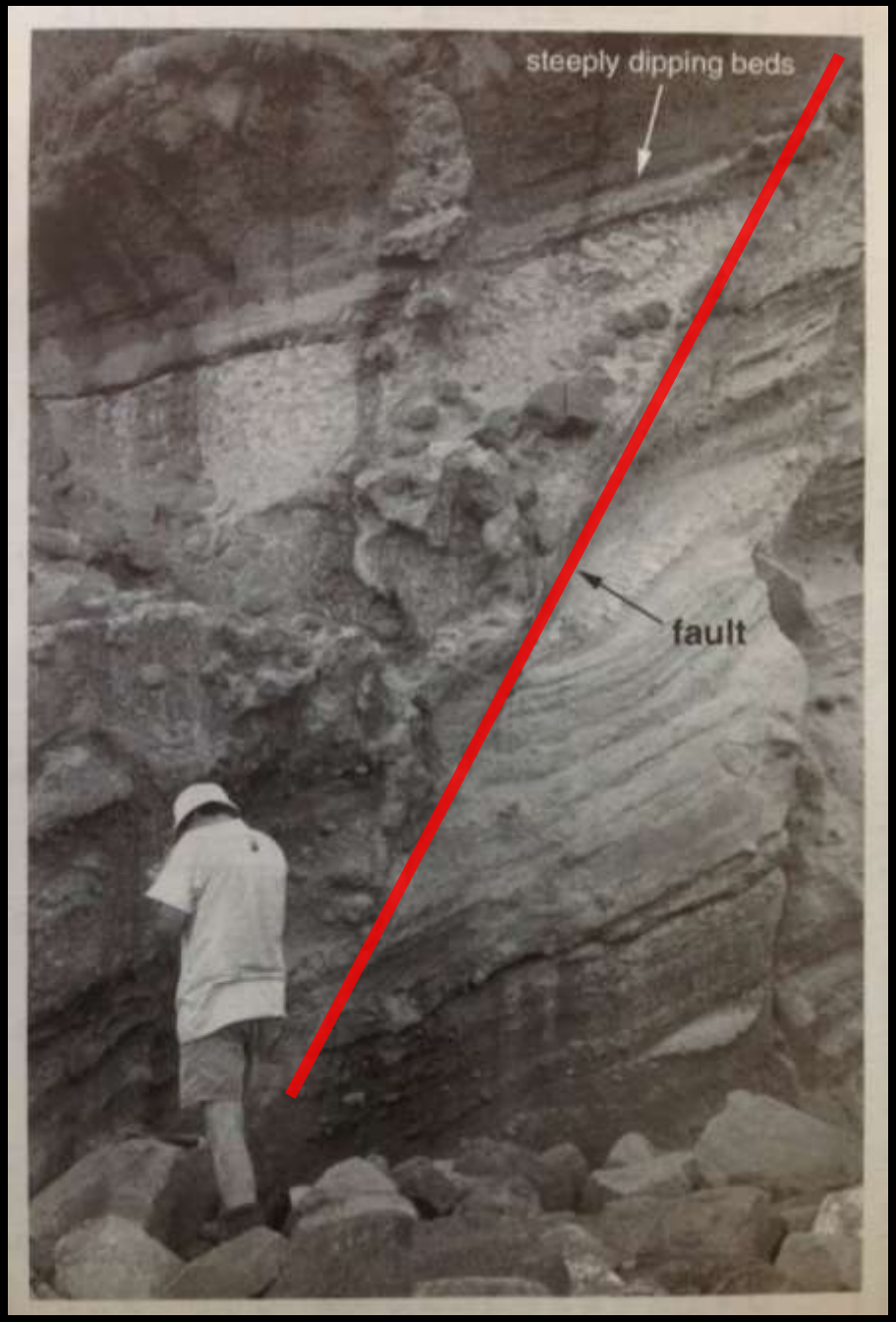



These provide open pathways for large quantities of fluids to move through rocks

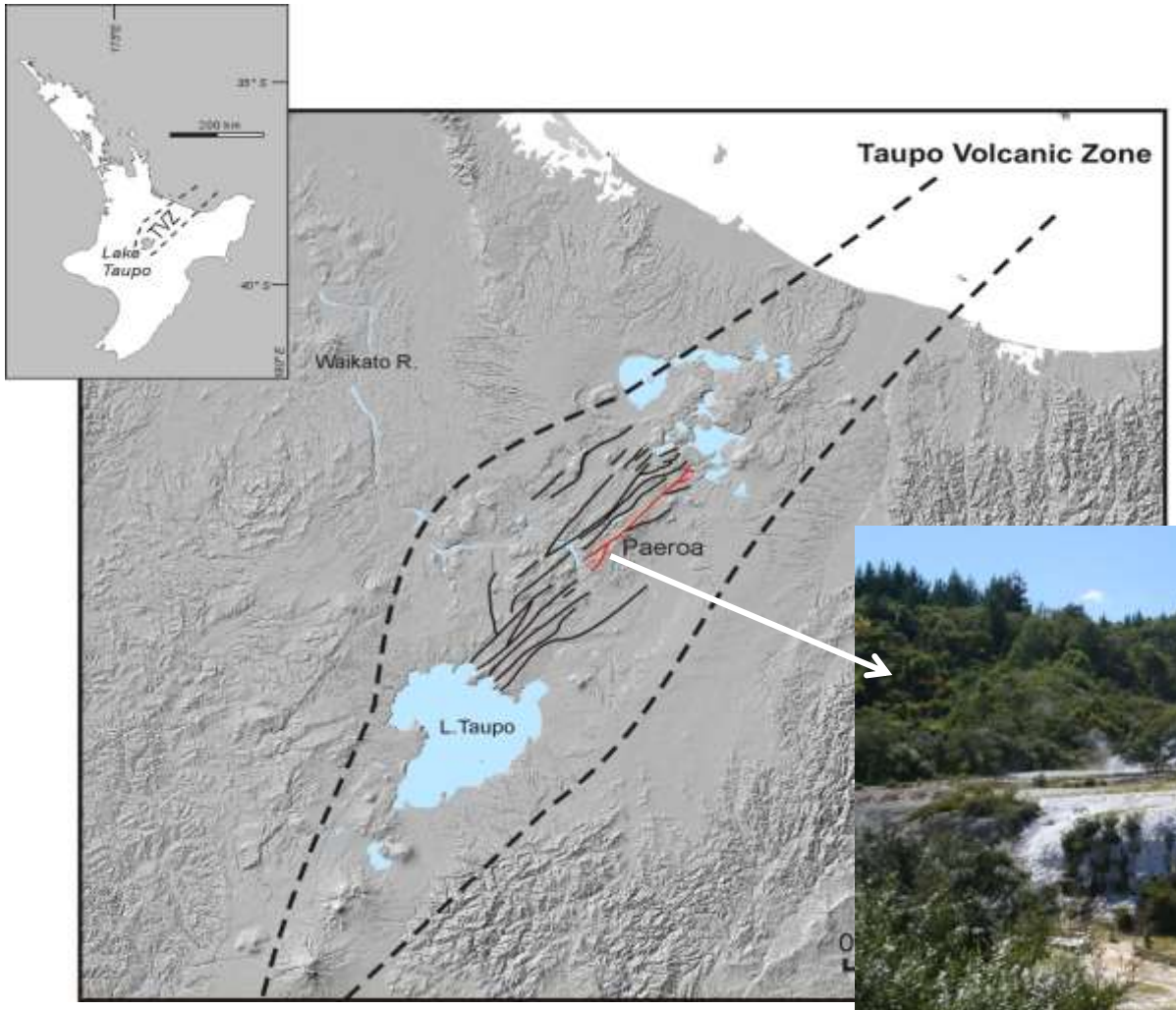
# Normal faults on Montserrat

EGS (2010)

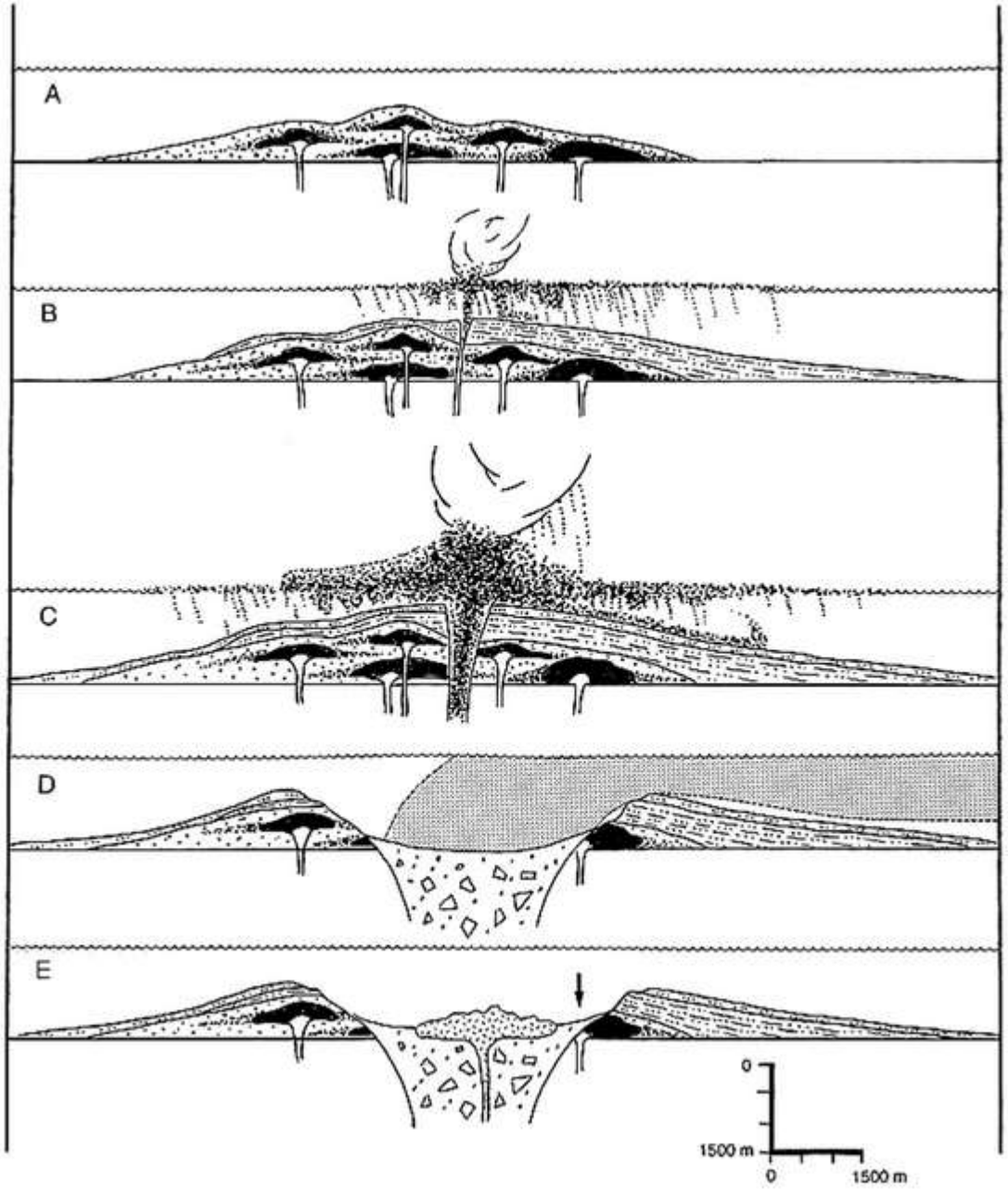
**Garibaldi Hill**




Montserrat

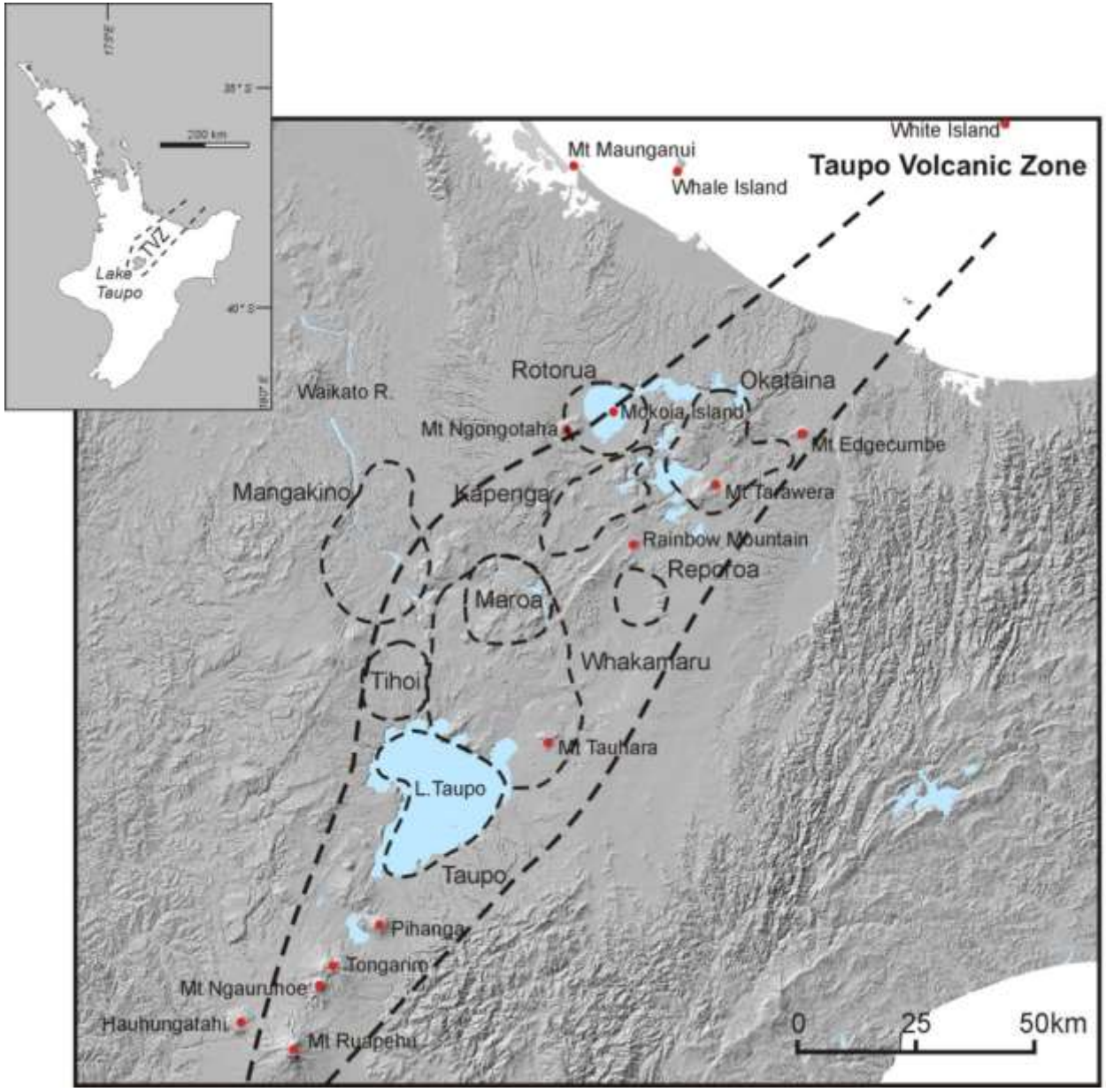



# Normal faults



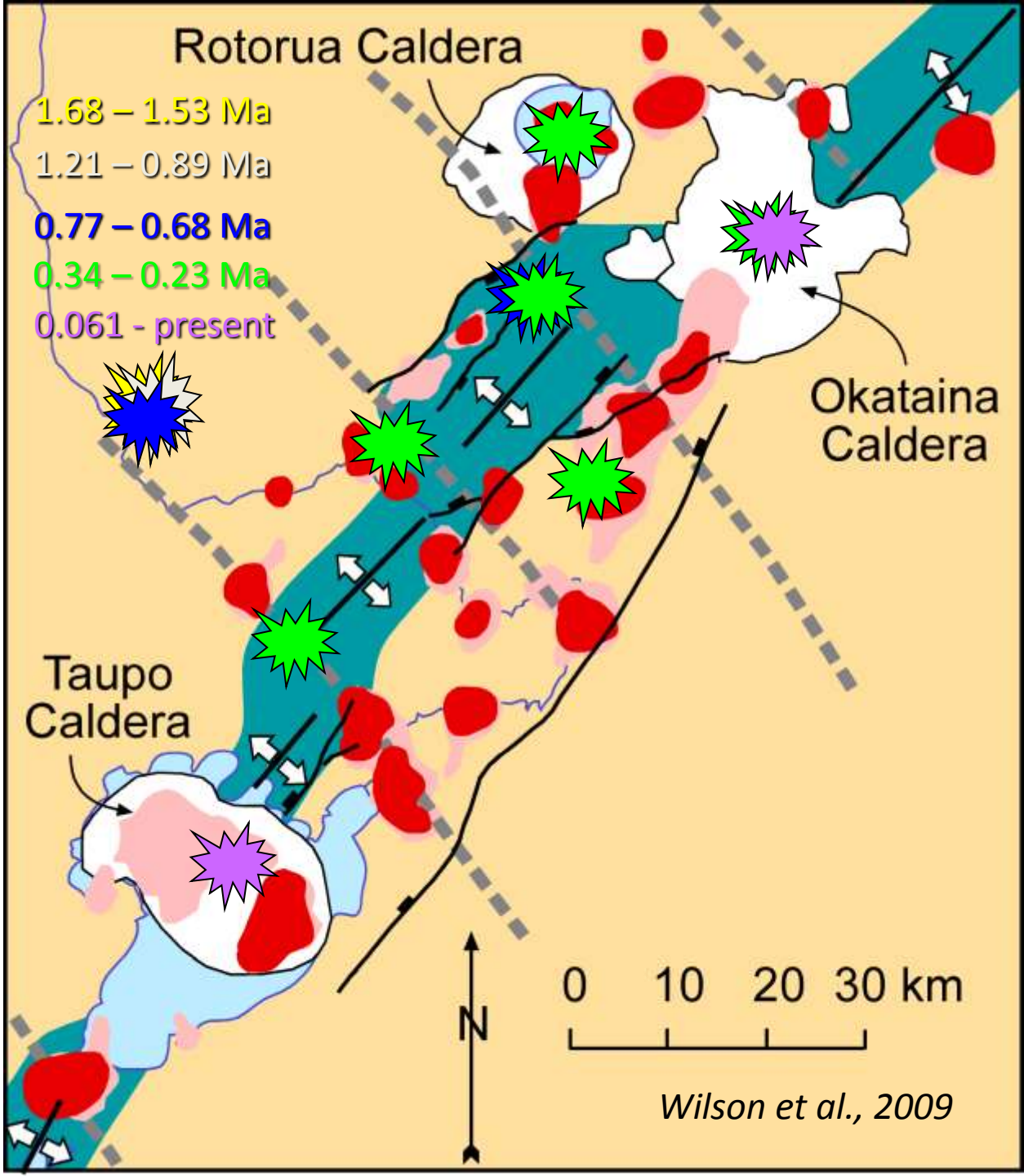

Calderas
– related to volcanism

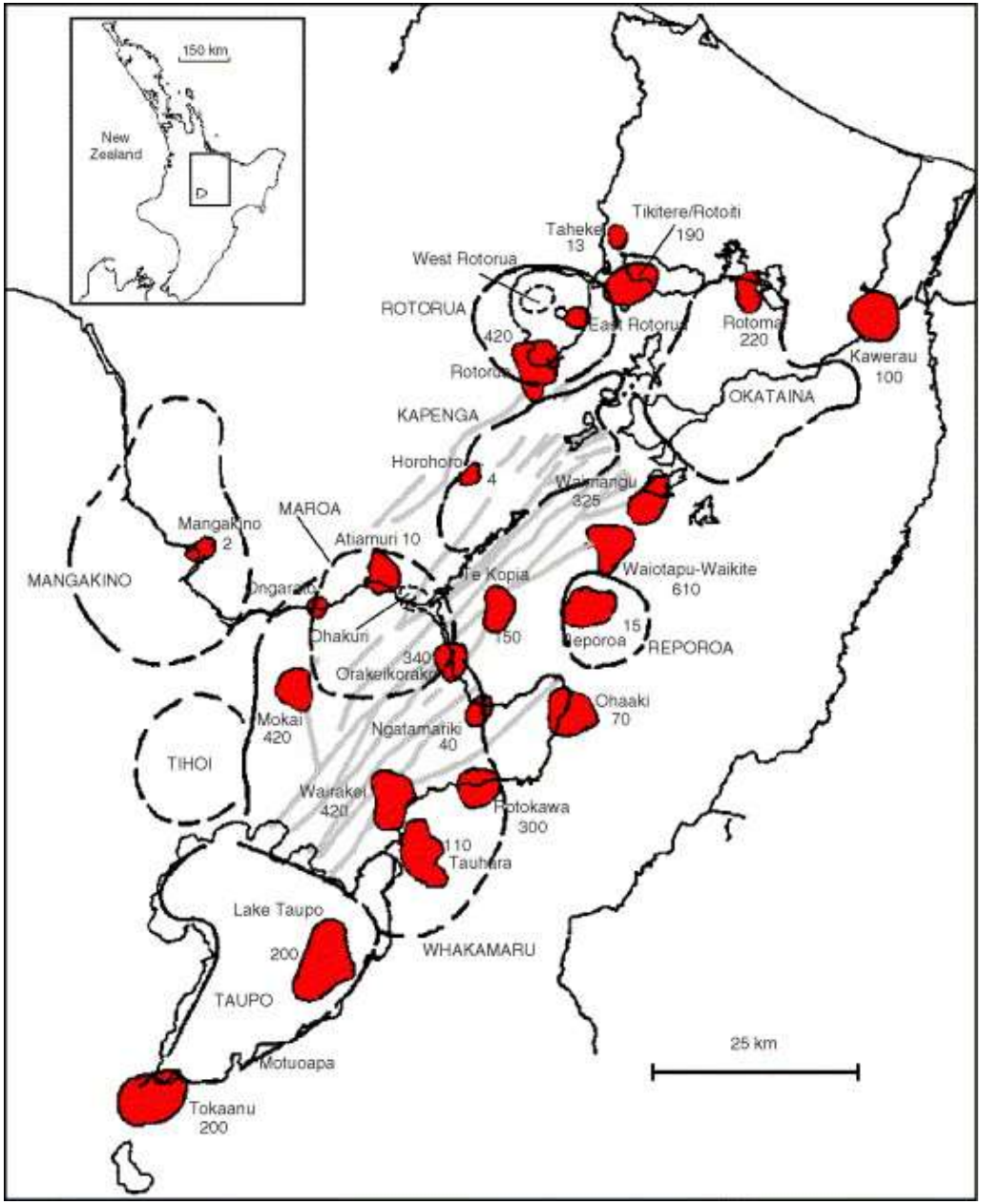
How do they form?


Taupo Volcanic Zone
White Island
Mt Maunganui
Whale Island
Rotorua
Okataina
Waikato R.
Mokoia Island
Mt Ngongotaha
Mt Edgecumbe
Mangakino
Kapenga
Mt Tarawera
Rainbow Mountain
Reporoa
Maroa
Whakamaru
Tihoi
Mt Tauhara
L.Taupo
Taupo
Pihanga
Tongariro
Mt Ngauruhoe
Hauhungatahi
Mt Ruapehu
0
25
50km
TVZ
Lake Taupo
200 km

Pattern of large caldera eruptions

Flare-ups






- Volcanism (calderas)
- Tectonism (faults)
- Geothermal systems (hot spots)

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**Low temperature systems**

Heat Sweep systems

Hot dry rock systems

Submarine systems

Volcanic systems

## Low temperature geothermal systems:

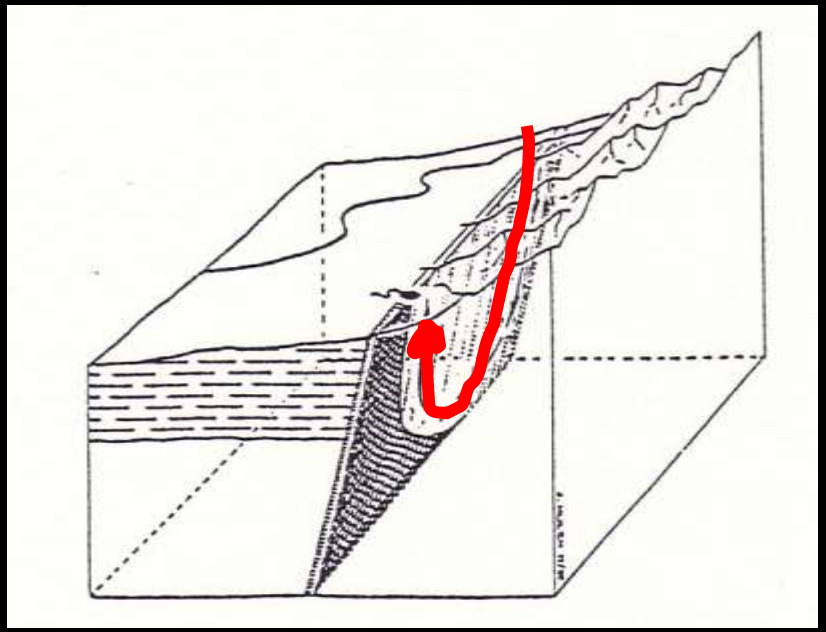
- reservoir temperatures <125° C
- no boiling
- used for direct heating only
- average temp gradient
- deep penetrating faults = permeability

Storage:

•water locked in rocks (e.g. pore space)
•commonly hosted in sedimentary rocks
•pressures exceed hydrostatic, up to lithostatic in some cases
•flow occurs when the rock formation is intersected by drill hole
•geo-pressured

## Simple Low Temperature Model (1)

Fault bounded sedimentary basin, e.g. Hauraki Plains, NZ



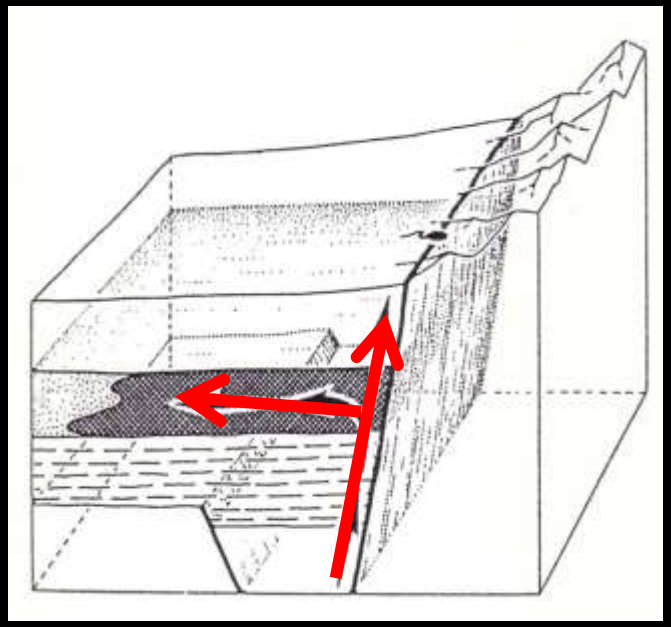
permeable fault-
penetrates 2-4 km depth

heating lowers water density
making it buoyant

convective circulation confined
to fault plane

## Simple Low Temperature Model (2)

Fault bounded sedimentary basin, e.g. Hauraki Plains



Horizontal fluid movement influenced by permeable strata

Hot water can be accessed by shallow wells

# Hot spring 60° C : Low Temp example

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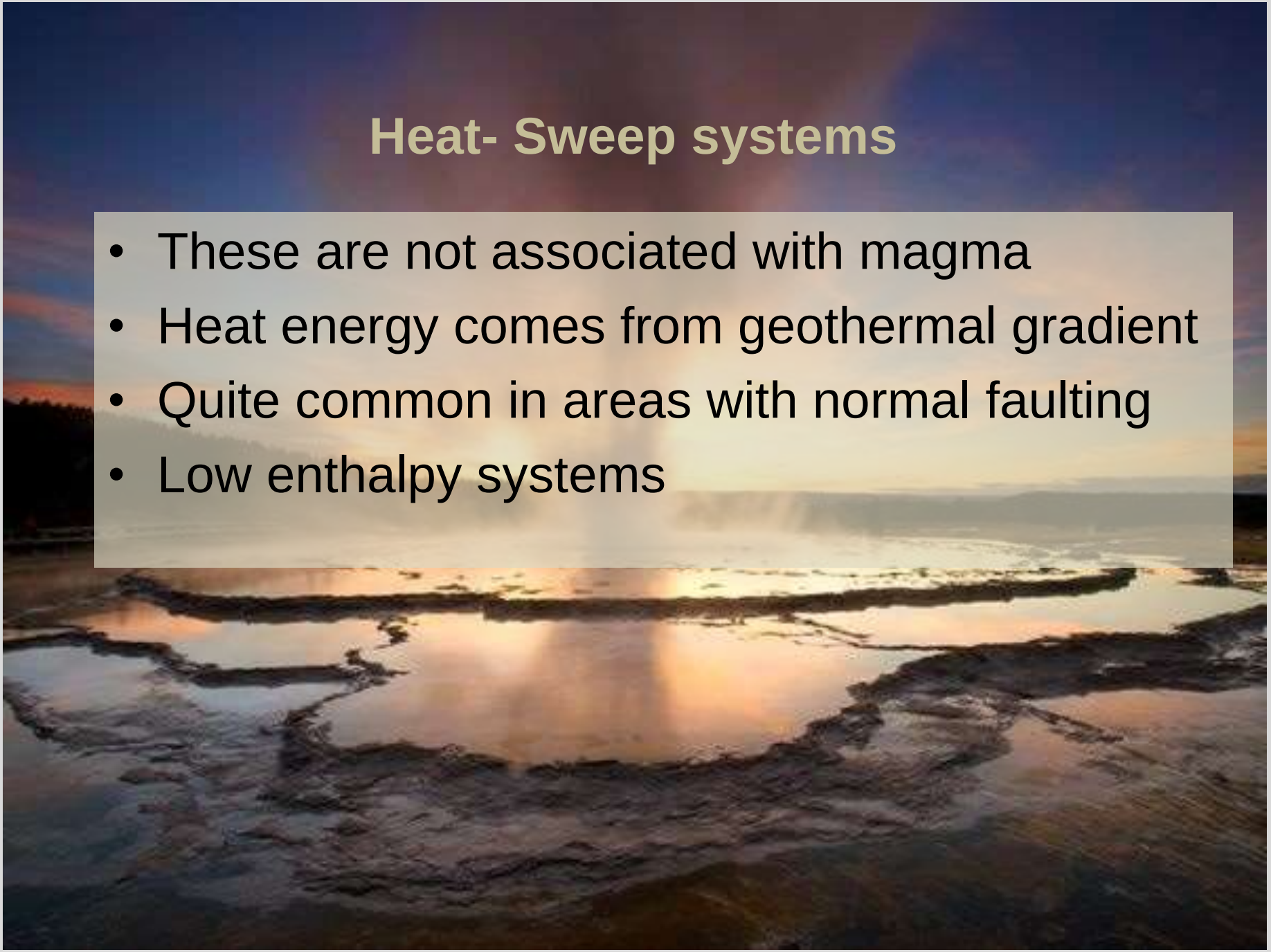

## Heat- Sweep systems

- These are not associated with magma
- Heat energy comes from geothermal gradient
- Quite common in areas with normal faulting
- Low enthalpy systems

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## Hot Dry Rock-Enhanced Geothermal Systems (EGS):

- Thermal energy locked in rocks lacking fracture networks or interconnected pore space
- Permeability structure is engineered (hydrofracturing)
- Thermal energy transferred by circulating fluid down one well and up a second well.
- High risk…little success.

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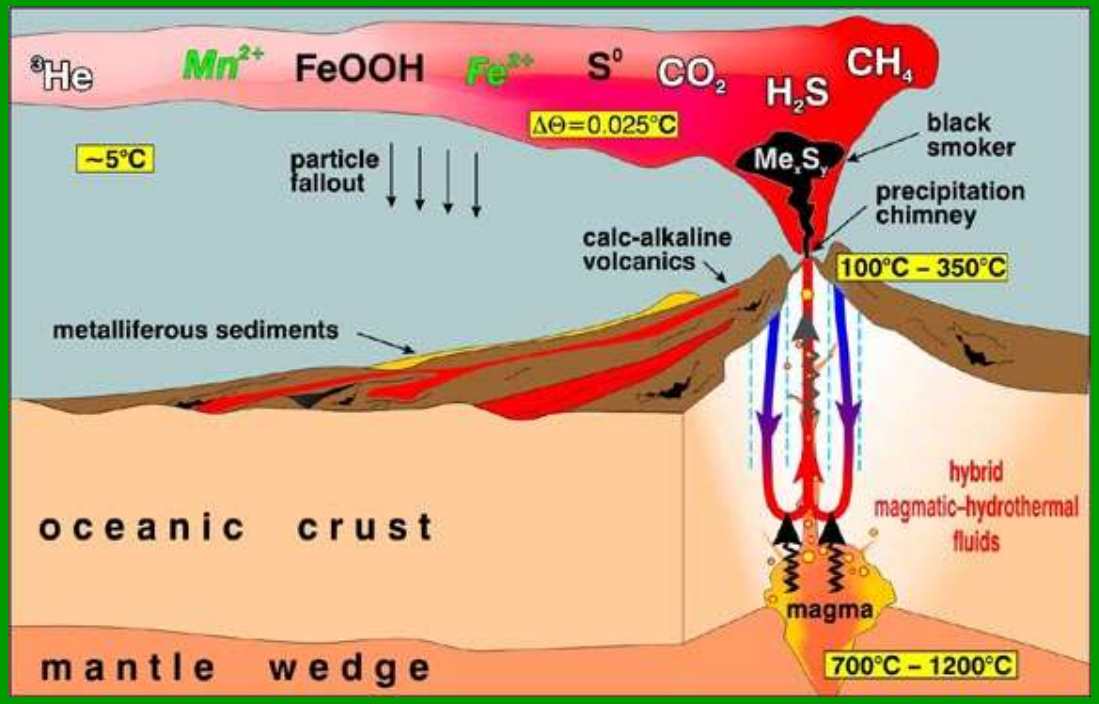


Kermadec arc volcanoes: classic sites for submarine geothermal systems

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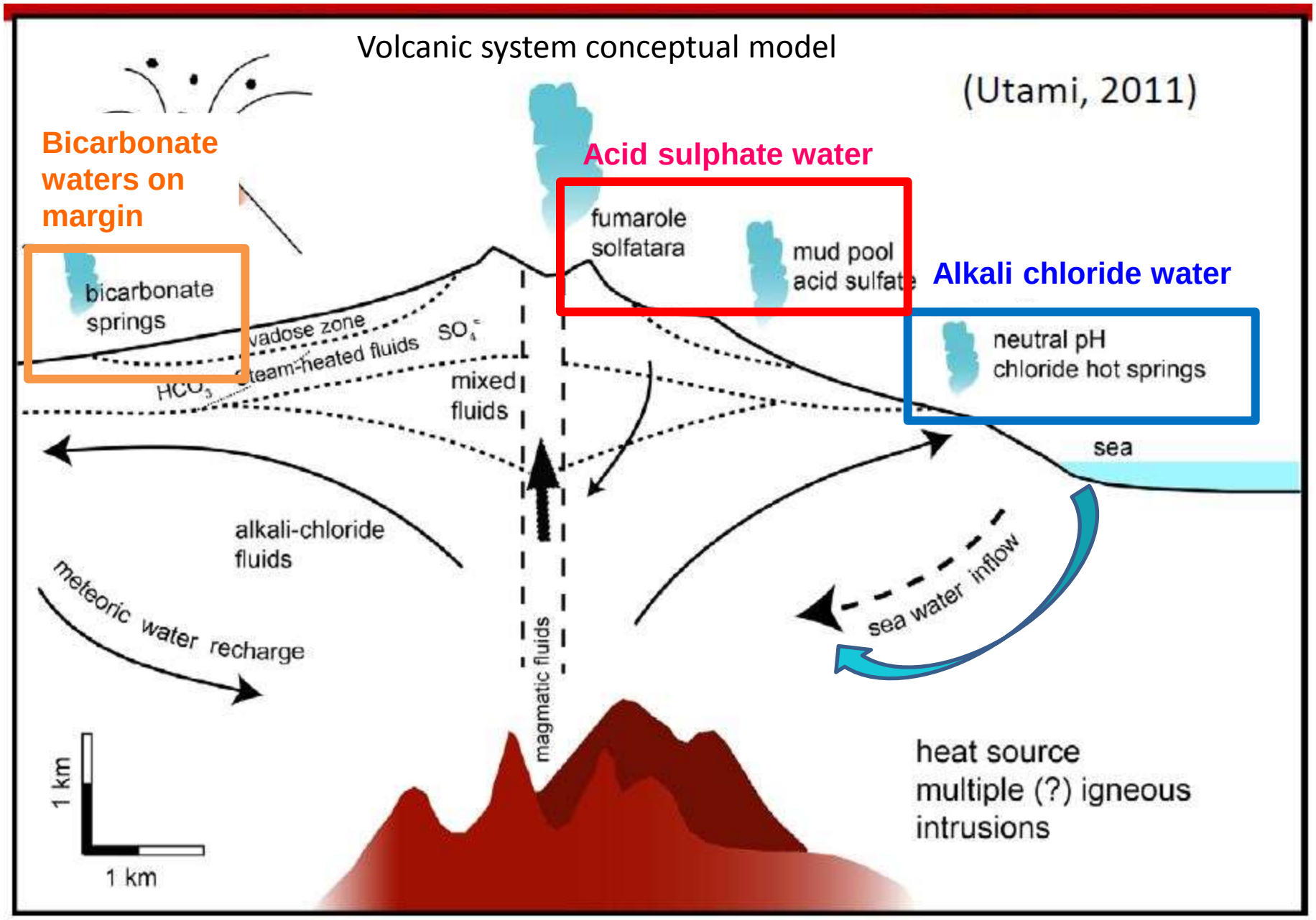
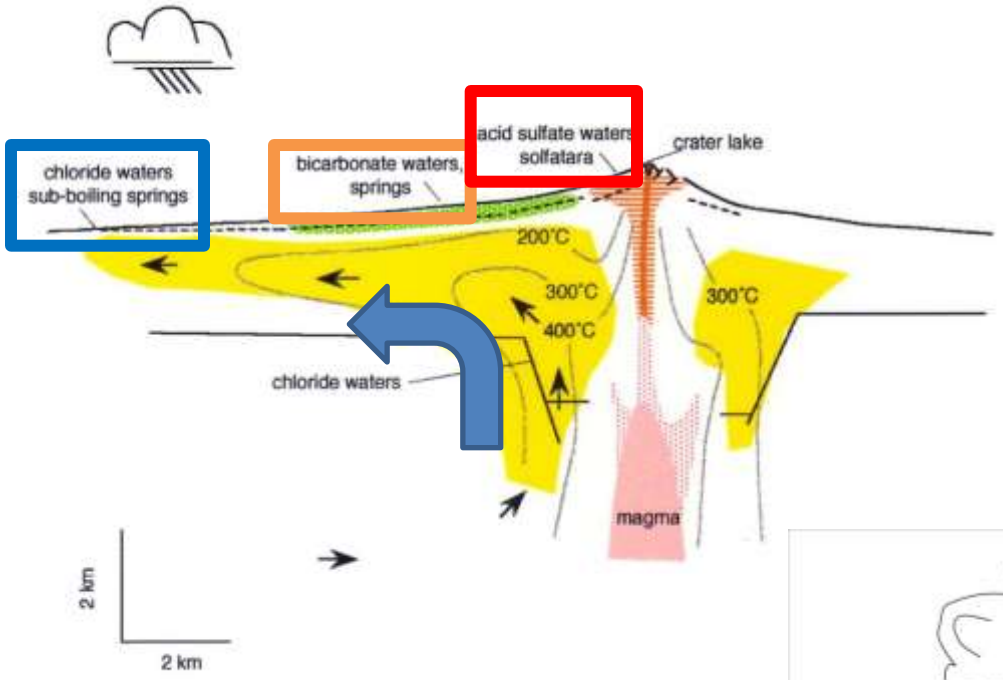
Volcanic – geothermal models
White Island, NZ

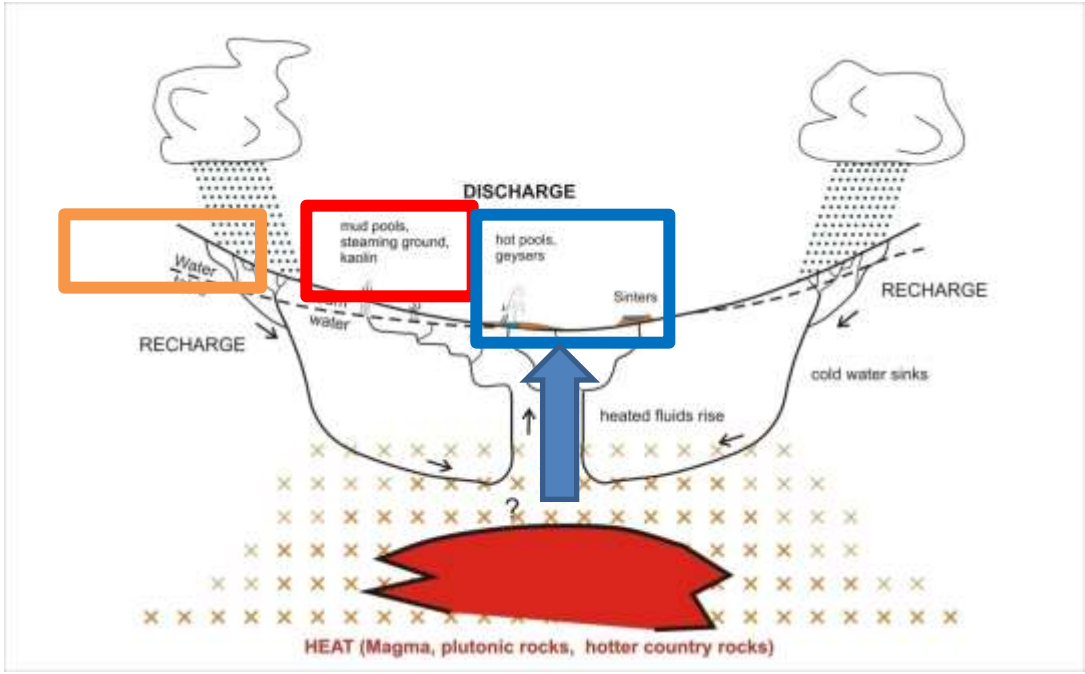
# Active volcanism in NZ

# Active volcanism in Montserrat

Volcanic system conceptual model





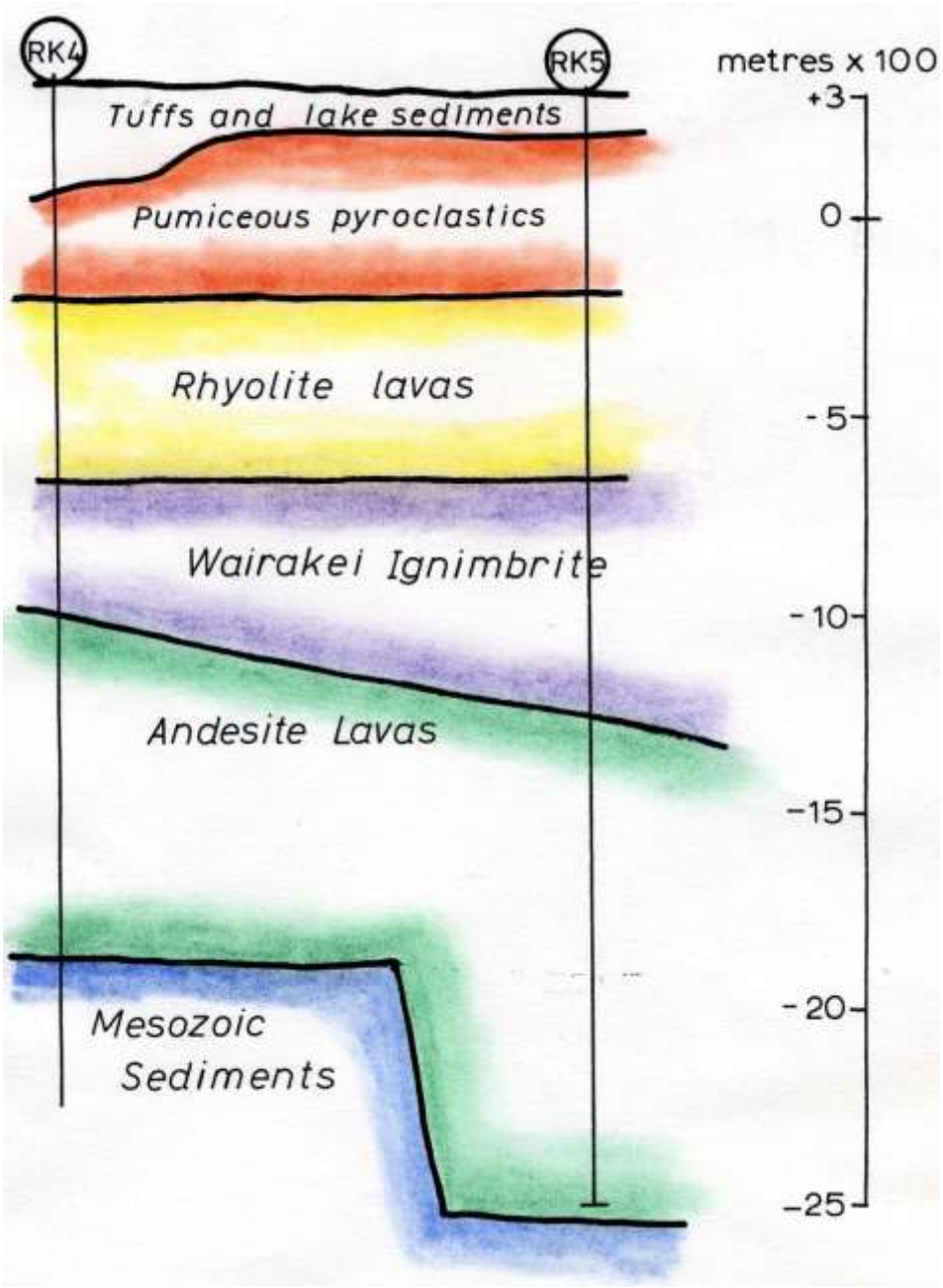



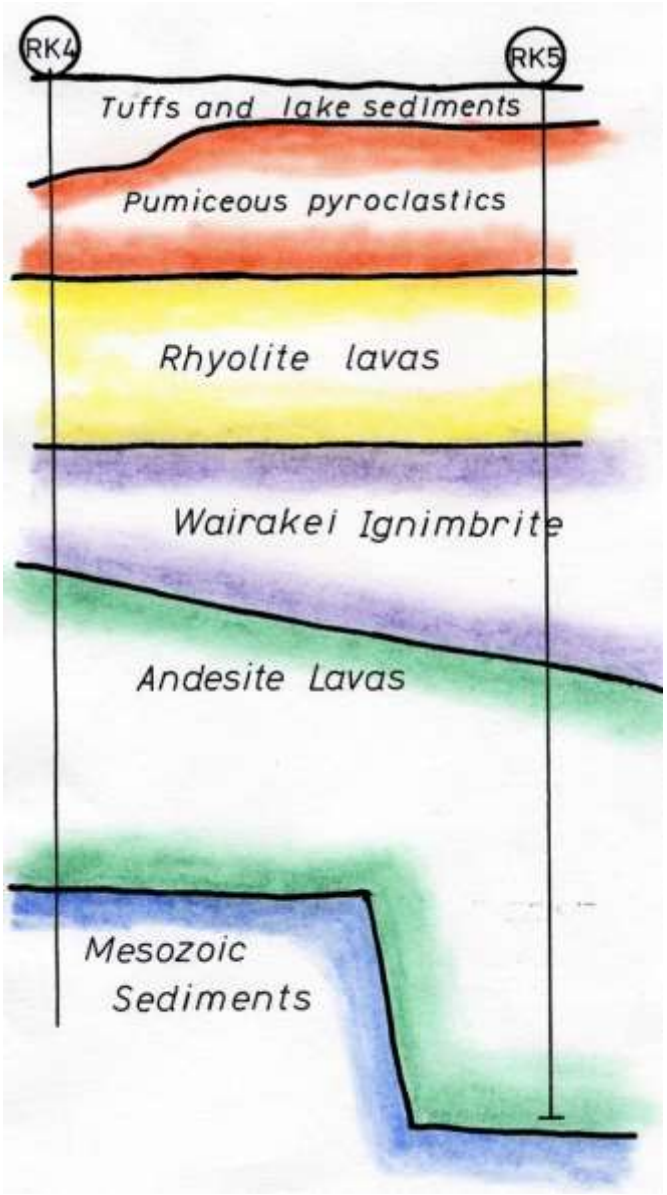

Each setting is unique – multi-disciplines approach required

# How do you build your conceptual model?

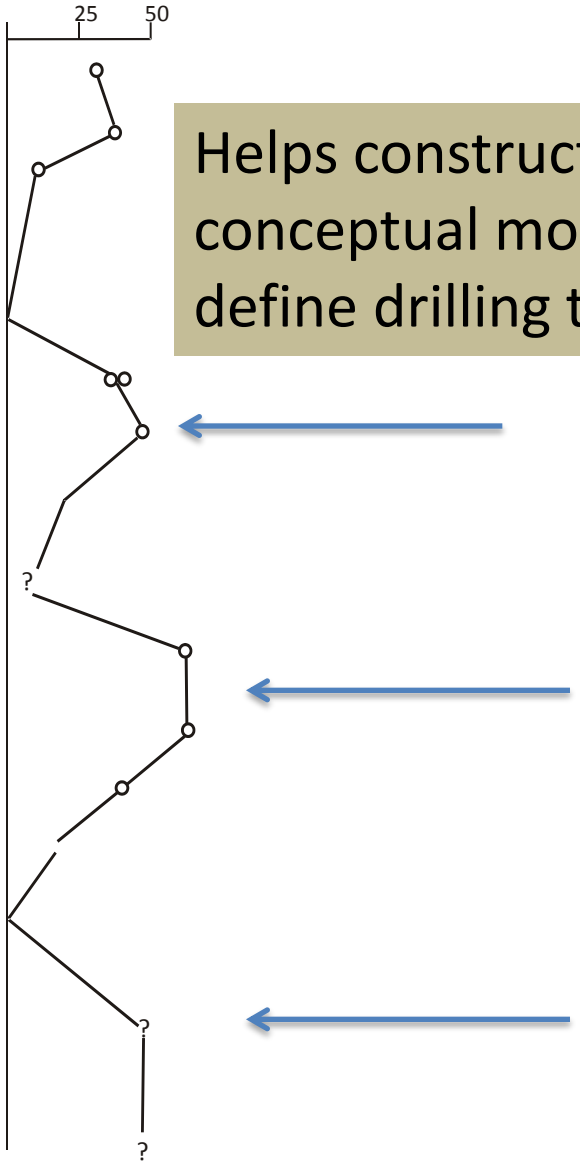
Team of scientists from different disciplines

How a geologist sees things



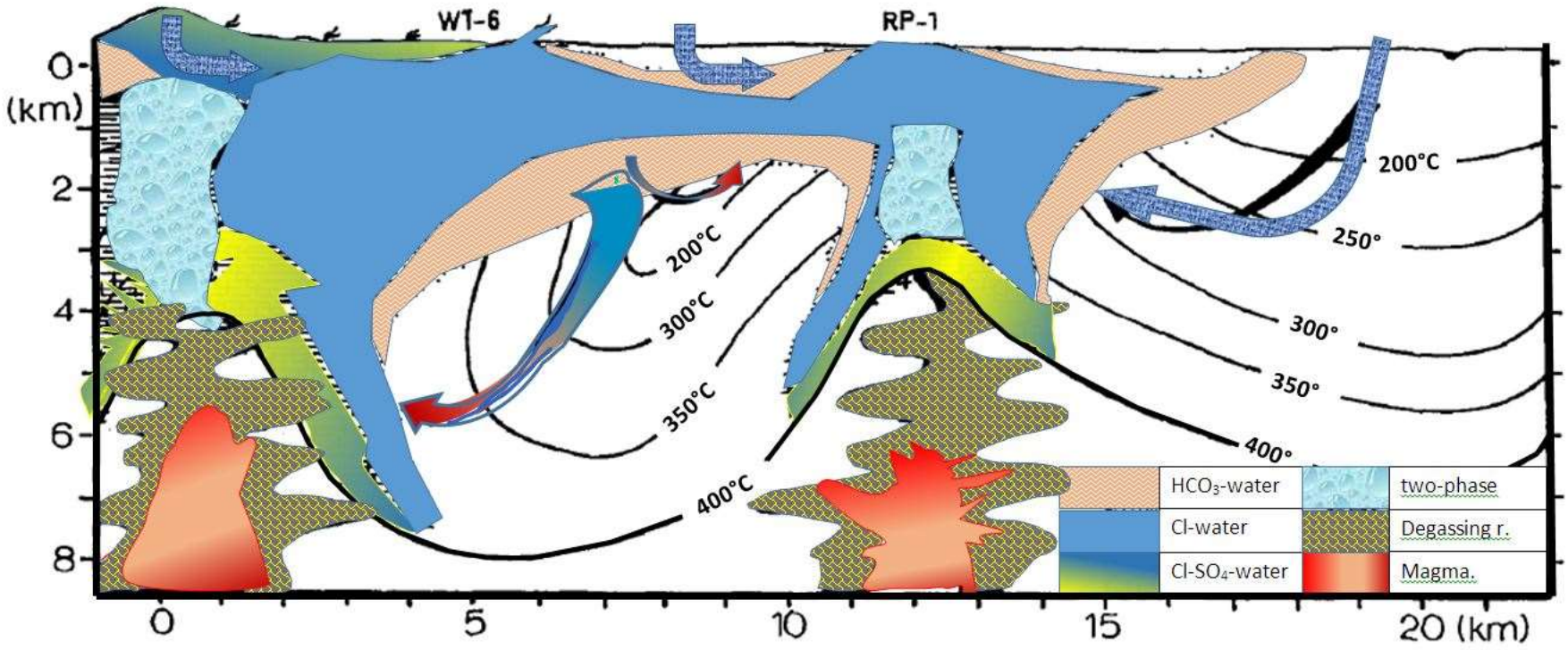



Adularia = mineral = permeability



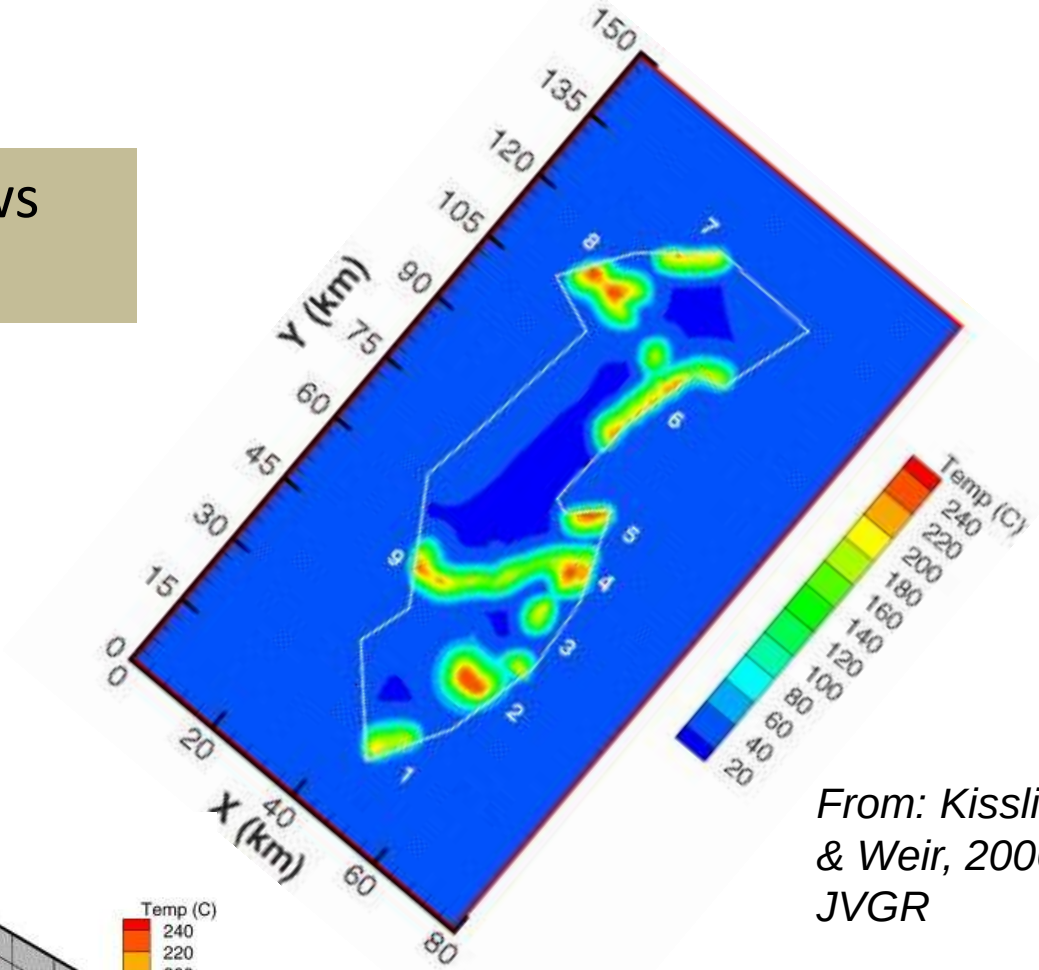

Helps construct conceptual model and define drilling targets

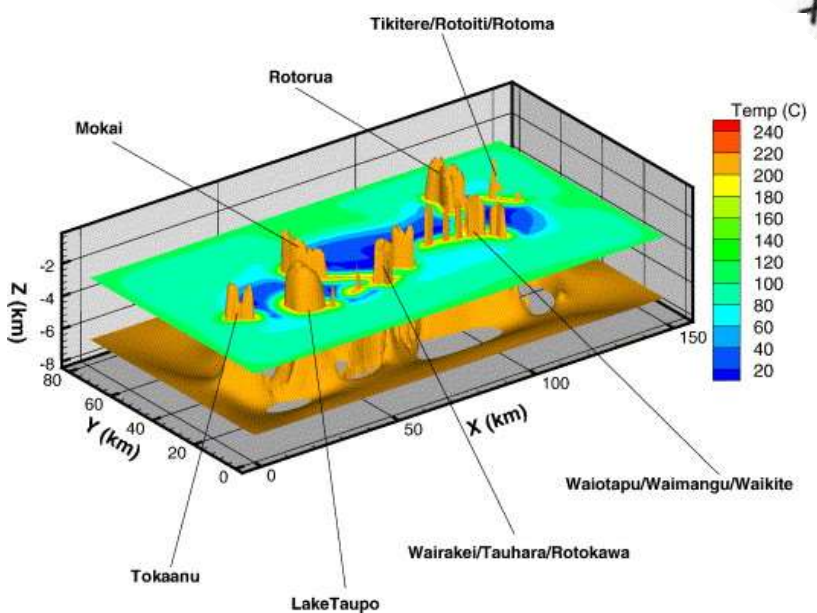
# How a geochemist sees the model




*From: Giggenbach et al., 1994, Geothermics*

# How a geophysicist views the conceptual model




*From: Kissling & Weir, 2006, JVGR*

How does our understanding of conceptual models help guide development and monitoring?

The type of geothermal system will determine how it is developed and/or monitored

For example

Volcanic system has a different set of issues to a high temperature flat terrain system

Development and Monitoring of a Volcanic system

Terrain limitations
Safety limitations – toxic gases, lava flows
Casing corrosion – acidic environment
People live a long way from source increased pipeline costs

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# Conclusions

- Conceptual models involve the intergration of many data sets from different disciplines
- Constantly refining conceptual model even throughout production
- Constantly refining monitoring program (how often and what to monitor) as systems change over time

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Research works *wonders*