

Role of a Geoscientist

**The Geothermal Institute
University of Auckland**

Bridget Lynne

Santiago de Chile, 26-29 May 2014



**GEOHERMAL
INSTITUTE**



**THE UNIVERSITY
OF AUCKLAND**

NEW ZEALAND

Te Whare Wānanga o Tāmaki Makaurau

A photograph of a geothermal geyser erupting from a rocky landscape. The water is white and foamy, spraying upwards. The surrounding rocks are brown and covered in green moss and lichen. The background is a blurred view of the geyser's pool and surrounding terrain.

Presentation outline

**Role of a geoscientist in geothermal
exploration
development
production**

**Role of geologist
 geophysicist
 geochemist**

**Geothermal Energy Development involves
geoscientists and is multi-disciplinary**

**Geology
Geochemistry
Geophysics**

Geoscientist has a role at the Exploration Phase

Geoscientist has a role during Development

Geoscientist has a role during Production



Role of a geothermal geoscientist during EXPLORATION

Literature Review

Map geology, surface activity, hydrological characteristics

Sample and characterise thermal features

Map surface alteration

Determine equilibration temperatures



Role of a geothermal geoscientist during DEVELOPMENT

Site wells

Examine and log cores and cuttings

**Establish mineral zones and alteration
mineralogy and its significance**

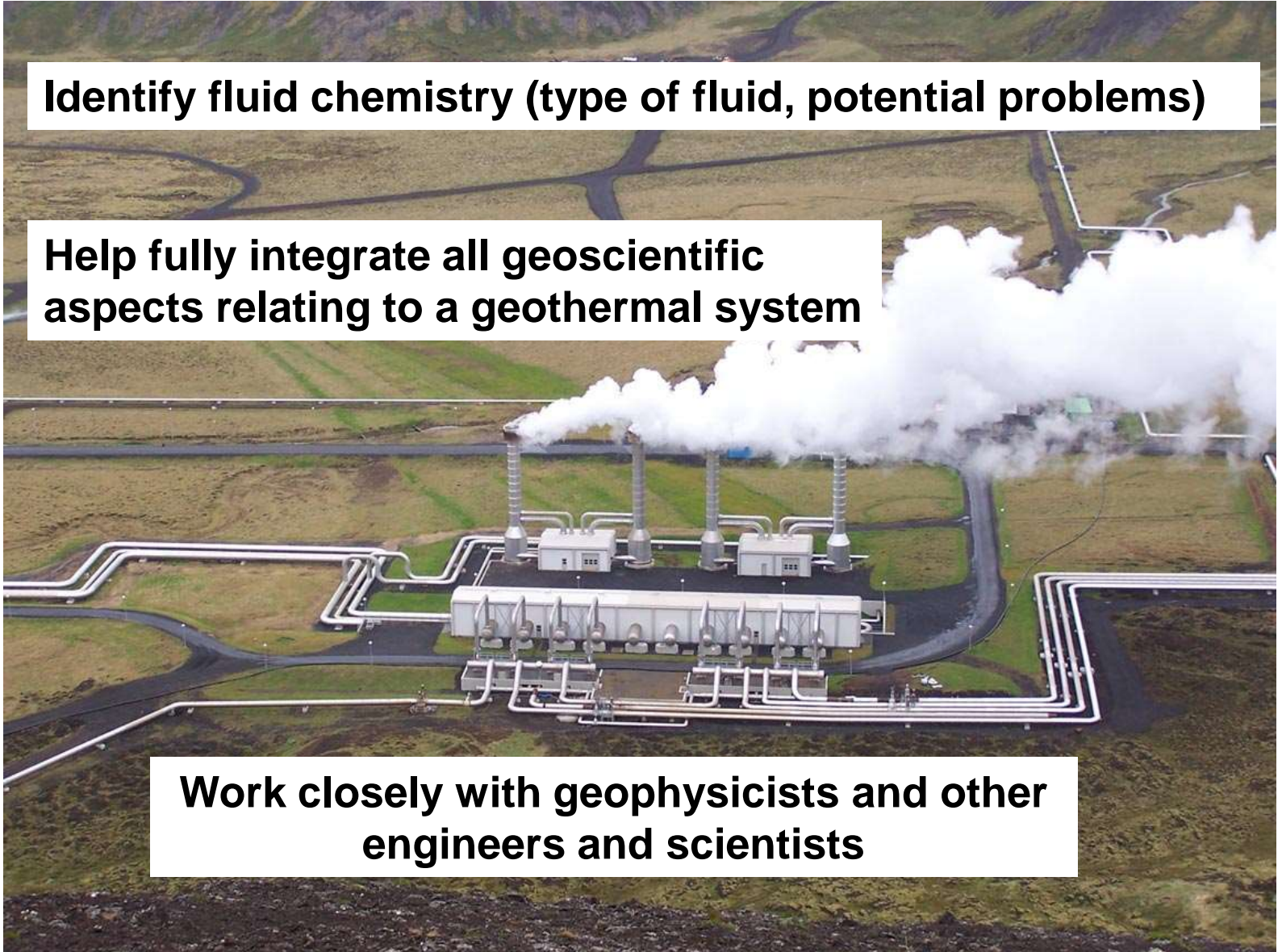
**Identify lithological and structural controls
on permeability**

Role of a geothermal geoscientist during DEVELOPMENT

Identify fluid chemistry (type of fluid, potential problems)

Help fully integrate all geoscientific aspects relating to a geothermal system

Work closely with geophysicists and other engineers and scientists



Role of a geothermal geoscientist during PRODUCTION

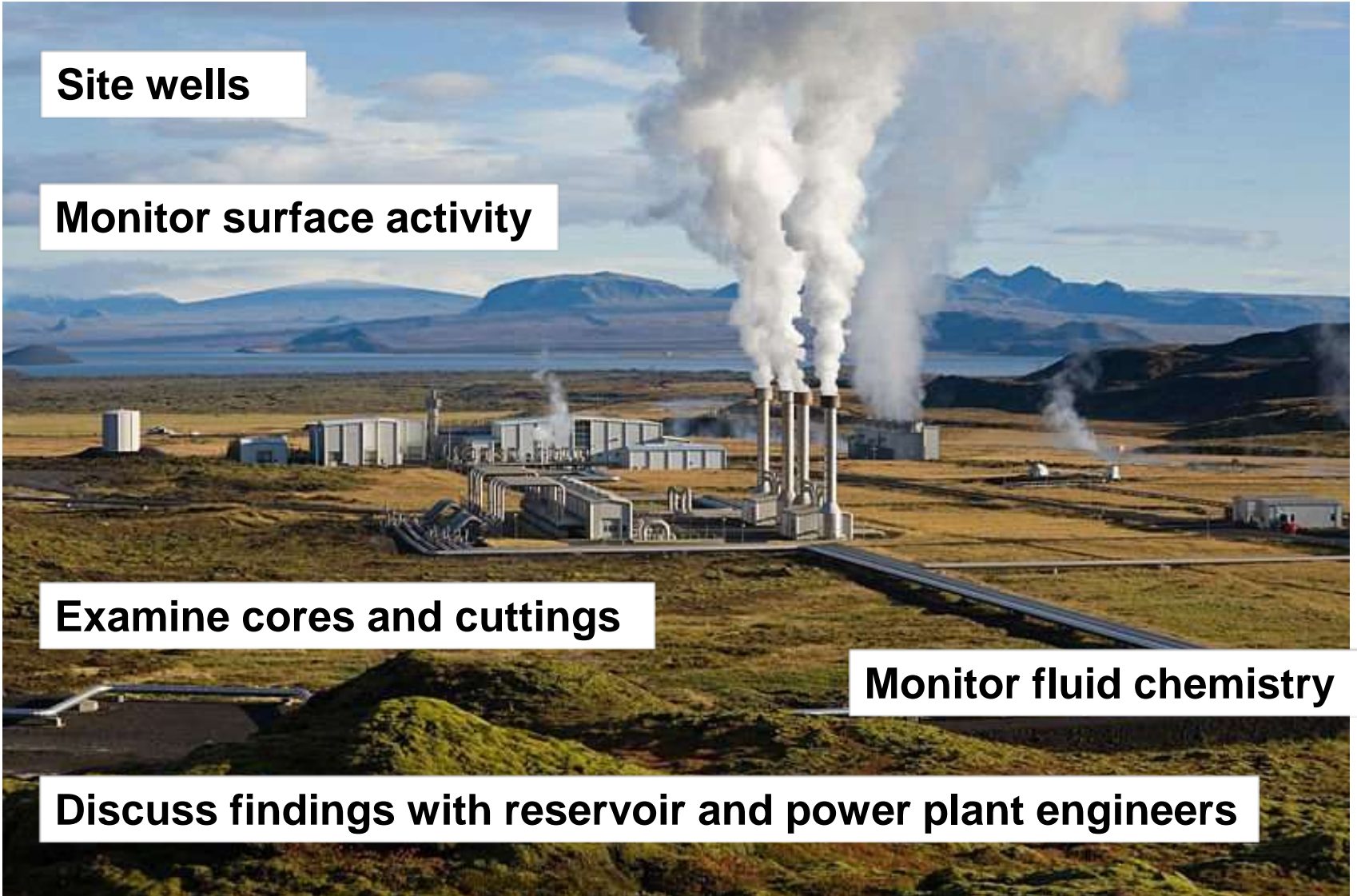
Site wells

Monitor surface activity

Examine cores and cuttings

Monitor fluid chemistry

Discuss findings with reservoir and power plant engineers

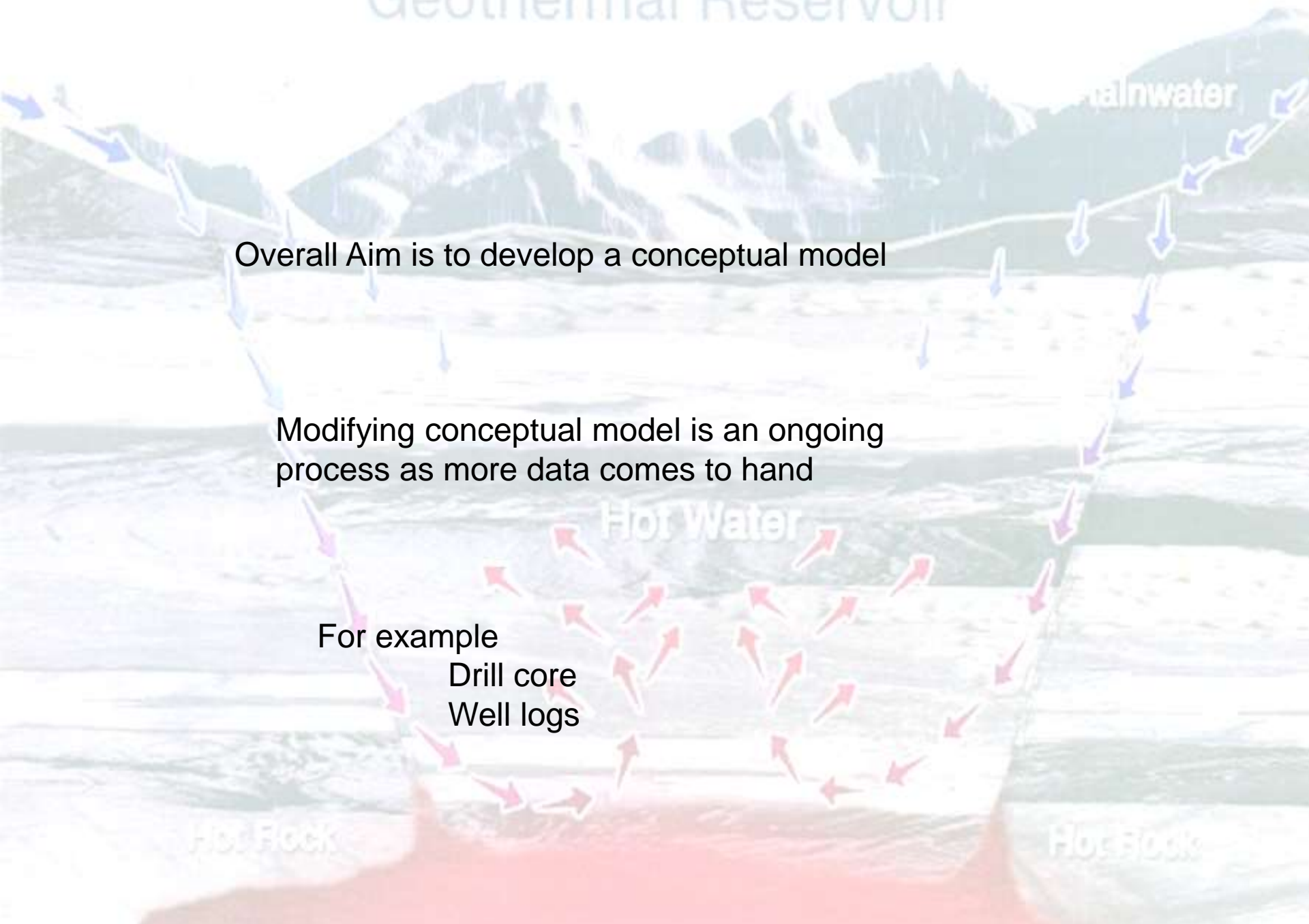


Geothermal Reservoir

Overall Aim is to develop a conceptual model

Modifying conceptual model is an ongoing process as more data comes to hand

For example
Drill core
Well logs



Role of a geologist



Let's look at the tasks of a **geologist**



Team
Approach

Map geology and surface manifestations
(hot springs, fumaroles etc)

Map surface features

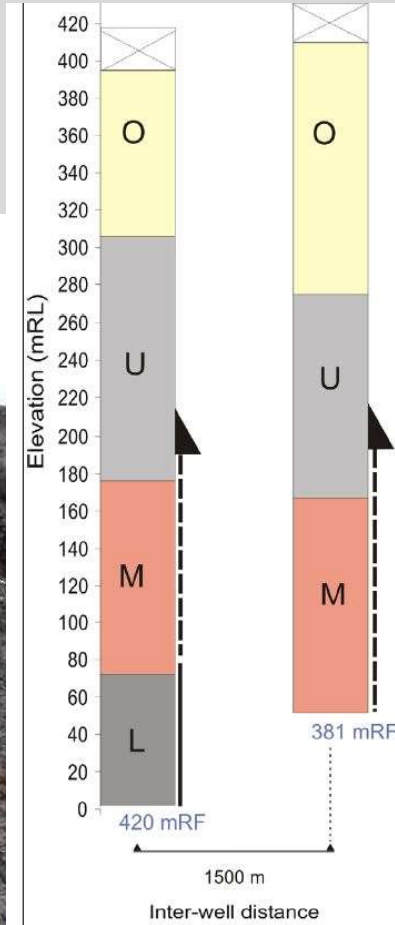
- water temperature
- flow rate
- feature size
- analyse water chemistry
- measure velocity of steam from fumaroles



- **Determines hydrology**
- **Heat & mass flow**
- **Provides pre-exploration data base**
- **Determines fluid chemistry etc**

Another task of a geologist

Stratigraphy



Determine lithologic vs structural controls

We need permeable rocks

Surface rocks tell us what we can expect in the subsurface

Impermeable rocks are not good host rocks for geothermal energy as they can't move fluid

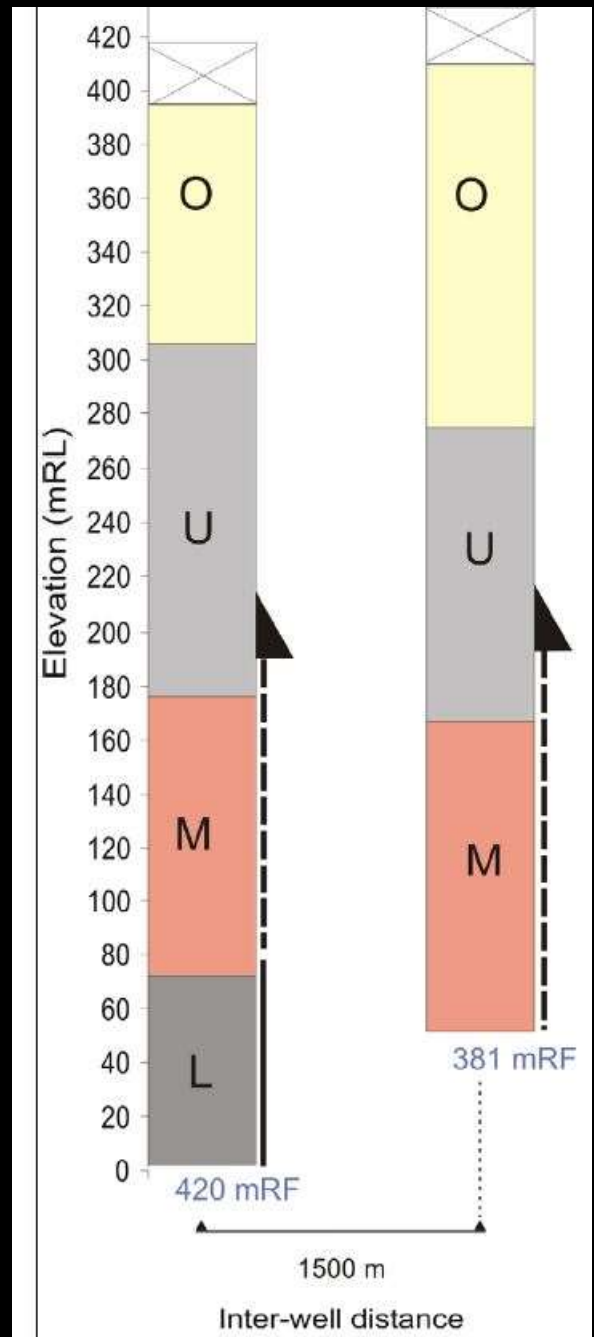


**Look for evidence of fractures and fluid flow
Can the rock hold a fracture?**



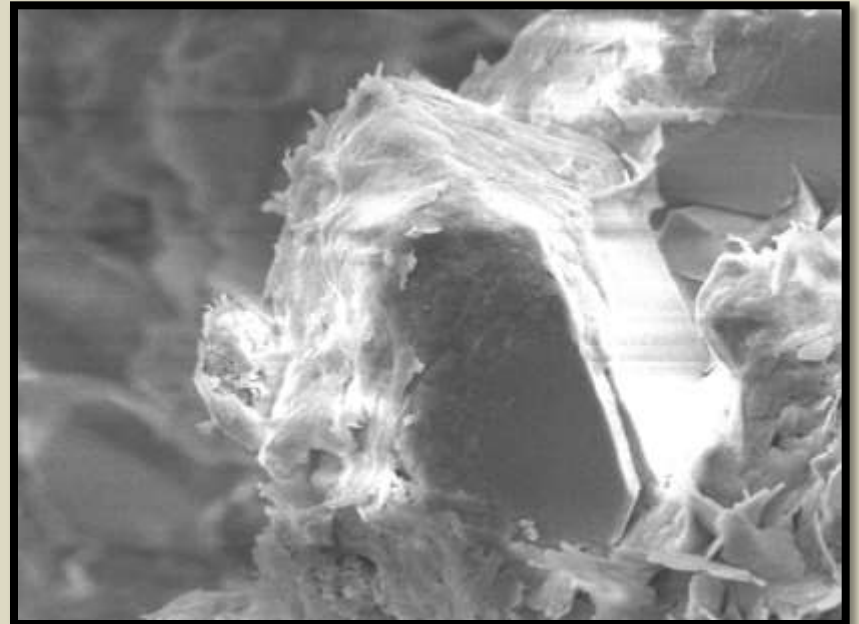
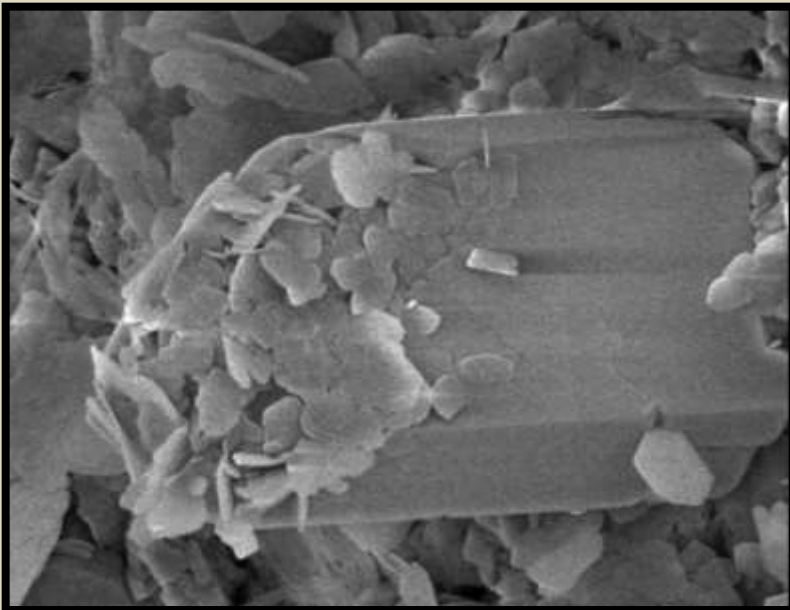
Examine core

Map subsurface rock units
(stratigraphy)



Examine hydrothermal alteration of rocks

Tells us about fluid-rock interaction and reservoir conditions such as temperature and permeability



What do the minerals tell us about the reservoir?

Fluid type e.g. pH, relative gas content

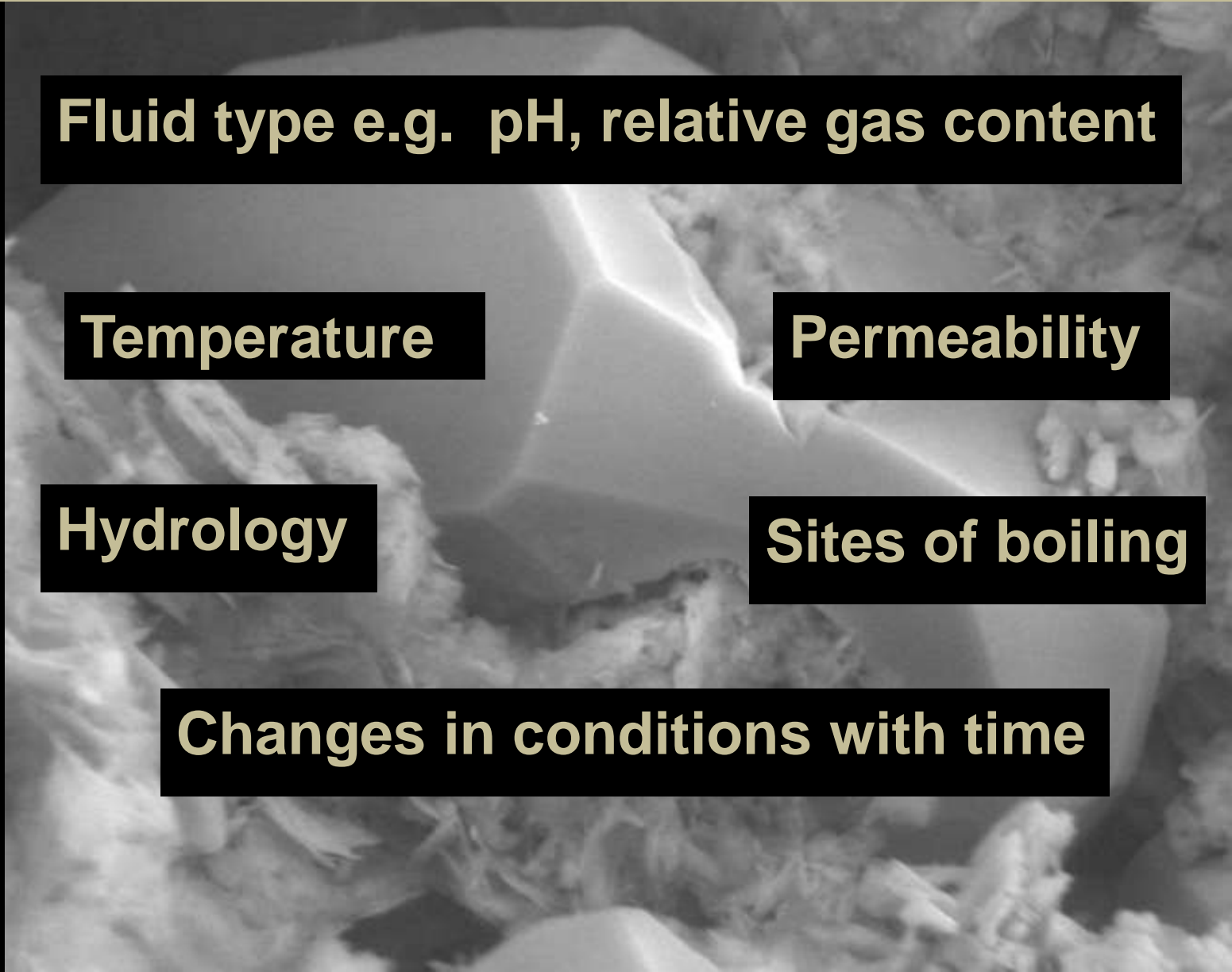
Temperature

Permeability

Hydrology

Sites of boiling

Changes in conditions with time



Temperature indicating minerals

A photograph of a geothermal landscape, likely a hot spring or geyser area. The terrain is covered in various mineral deposits, including white, yellow, and brownish structures. Steam is visible rising from several points, indicating high temperatures. The background shows a clear blue sky and some sparse vegetation.

We want to find heat

Epidote > 240 °C

Illite ~210 °C

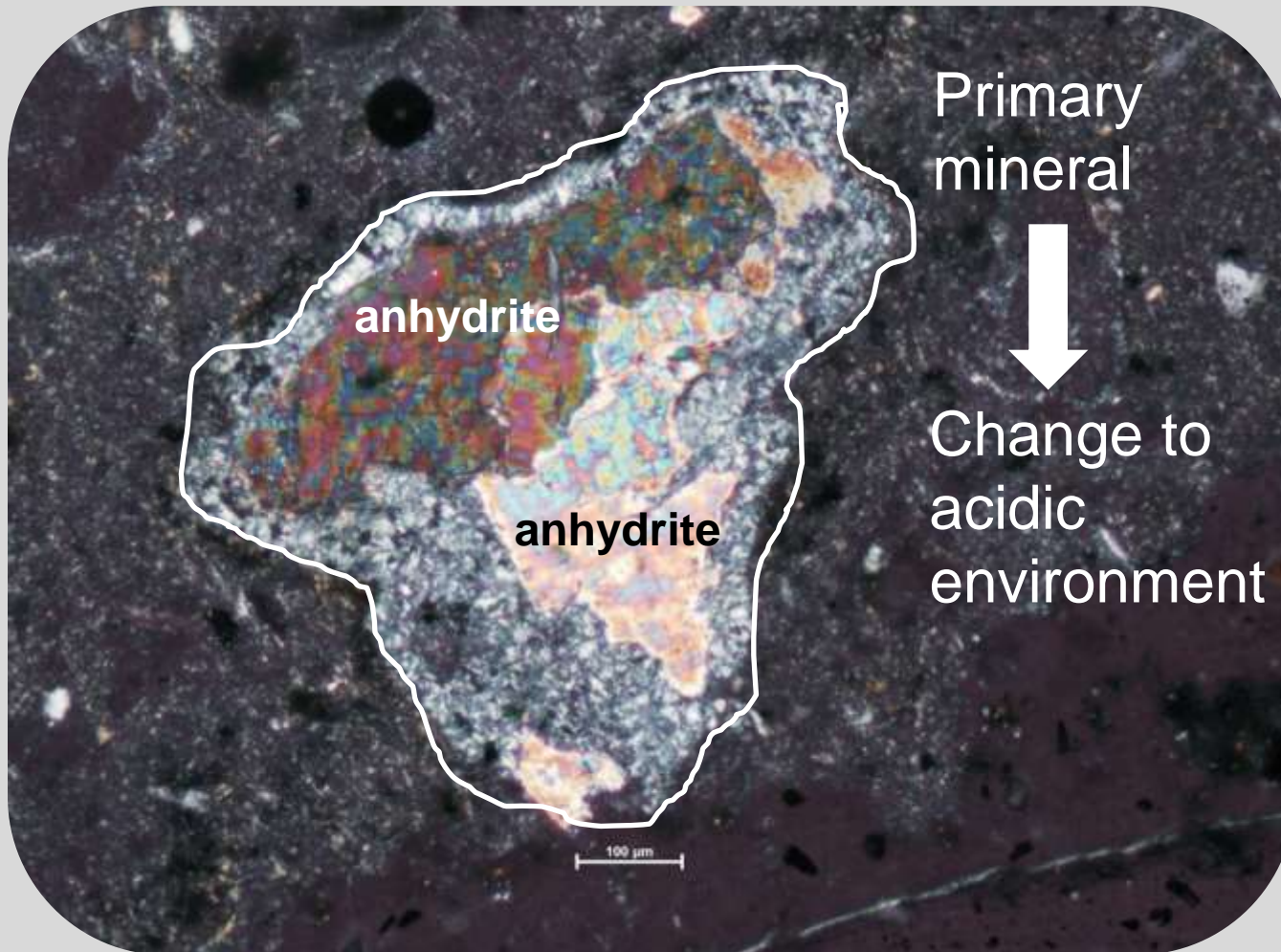
Montmorillonite ~ 140 °C

Many others

and permeability

Adularia = permeability

Reservoir conditions change – geologists track them by examining the minerals



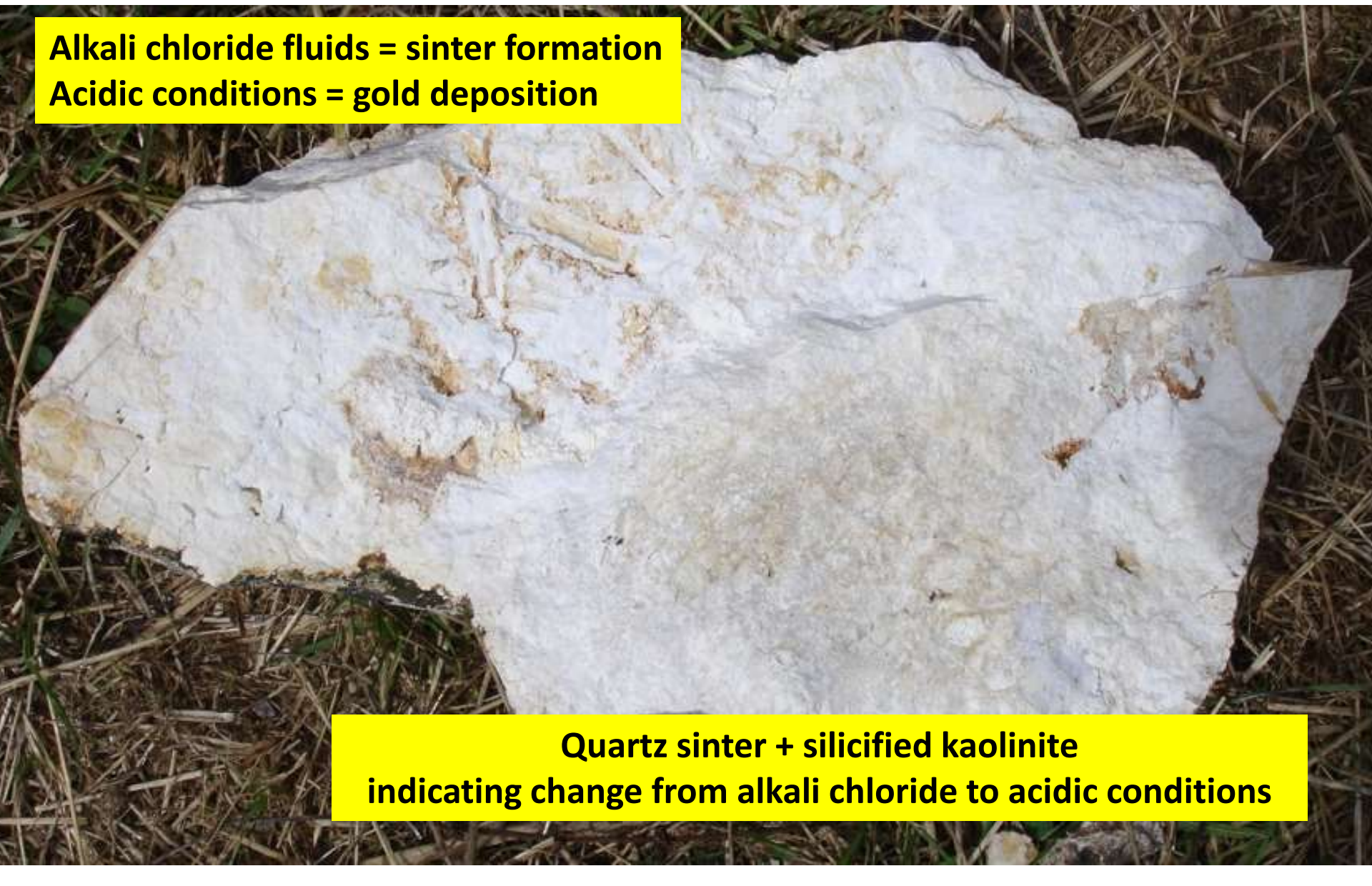
Acidic conditions are not ideal

Casing corrosion

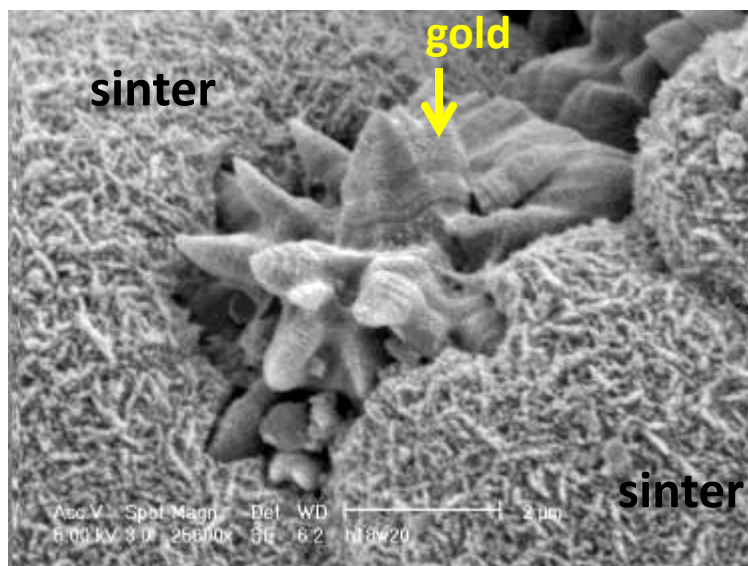
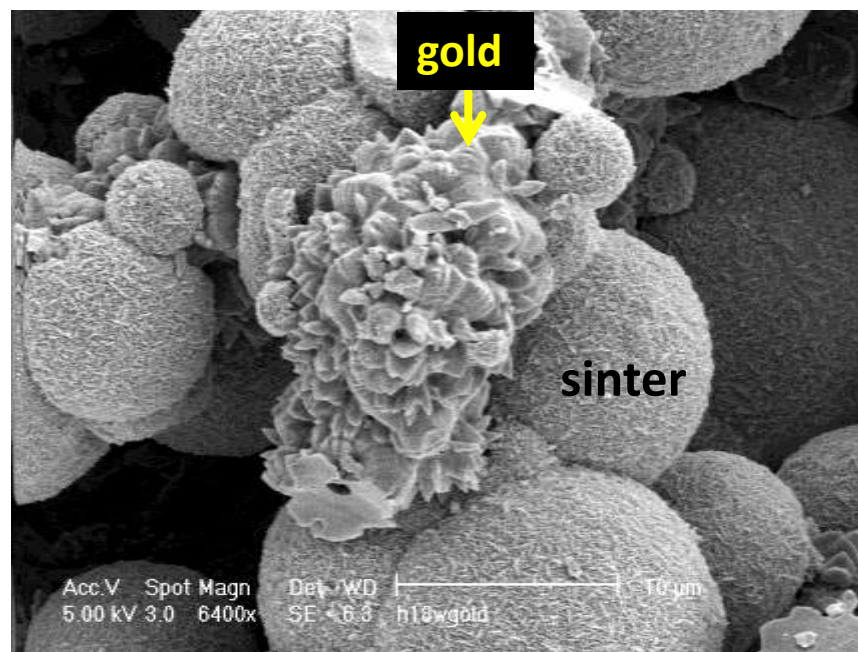
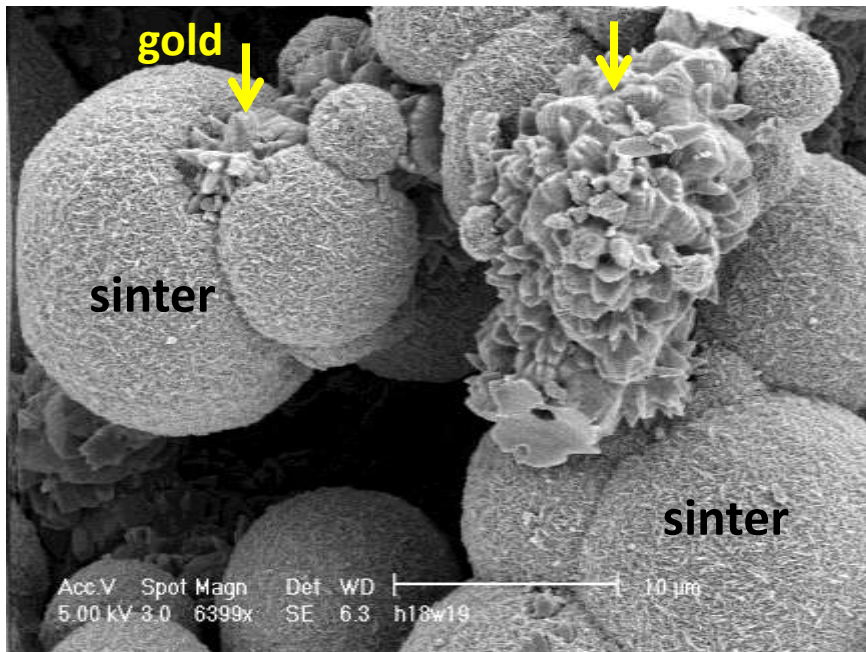
Sinter located directly above NZ gold mine

**Alkali chloride fluids = sinter formation
Acidic conditions = gold deposition**

**Quartz sinter + silicified kaolinite
indicating change from alkali chloride to acidic conditions**



Scanning electron microscope images of sinter within a gold mining area in USA



An aerial photograph of a geothermal field, likely a hot spring or geyser area. The ground is covered in various mineral deposits, creating a mosaic of colors including white, yellow, orange, red, and green. The terrain appears rugged and volcanic. The text is overlaid on this background.

In summary, geologists

Decide depths of production casing and well depth

Determines if reservoir is heating up or cooling down

Helps determine if the well will be a good producer

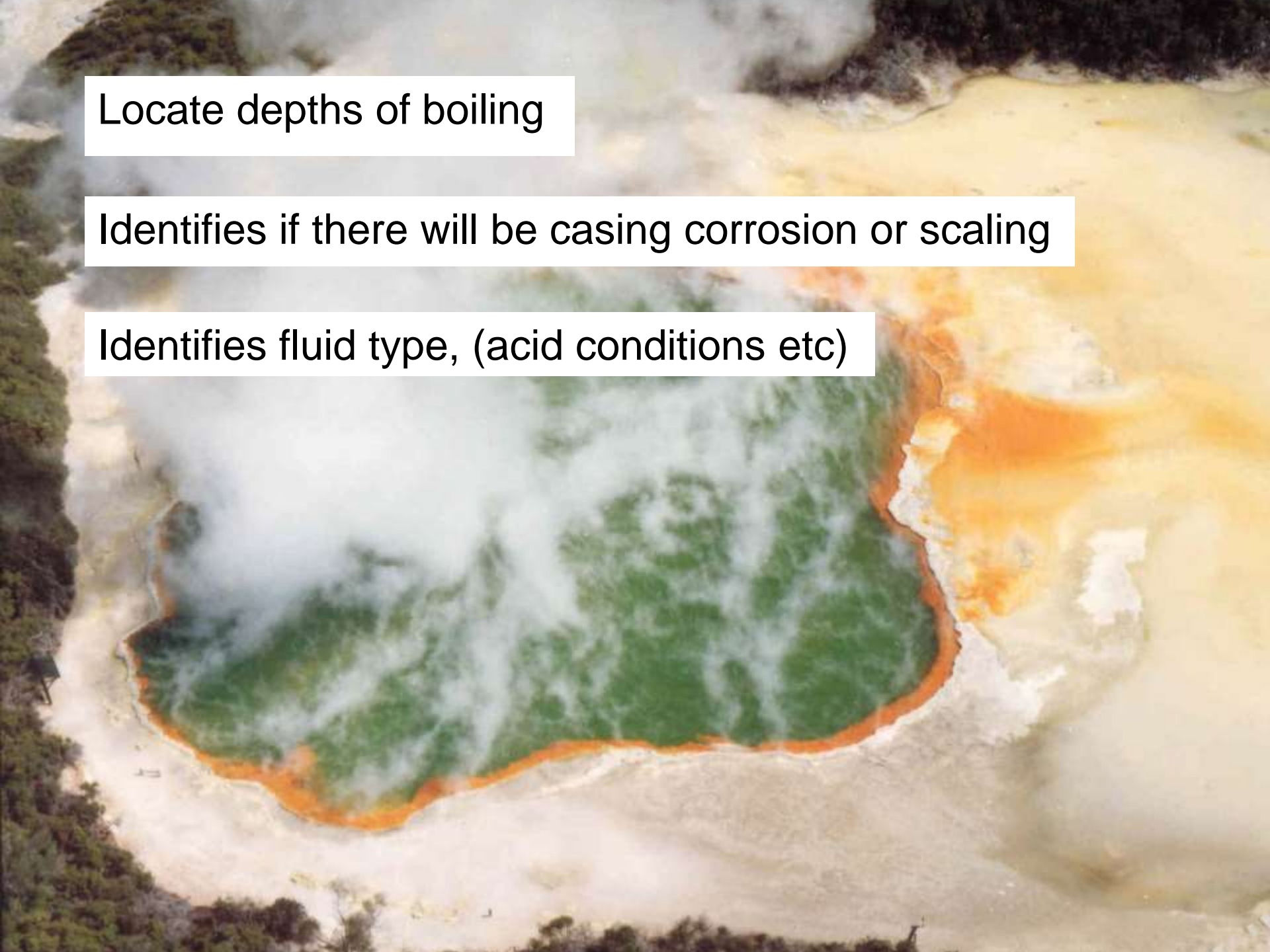
Identifies production depths

Identifies aquifers and aquitards

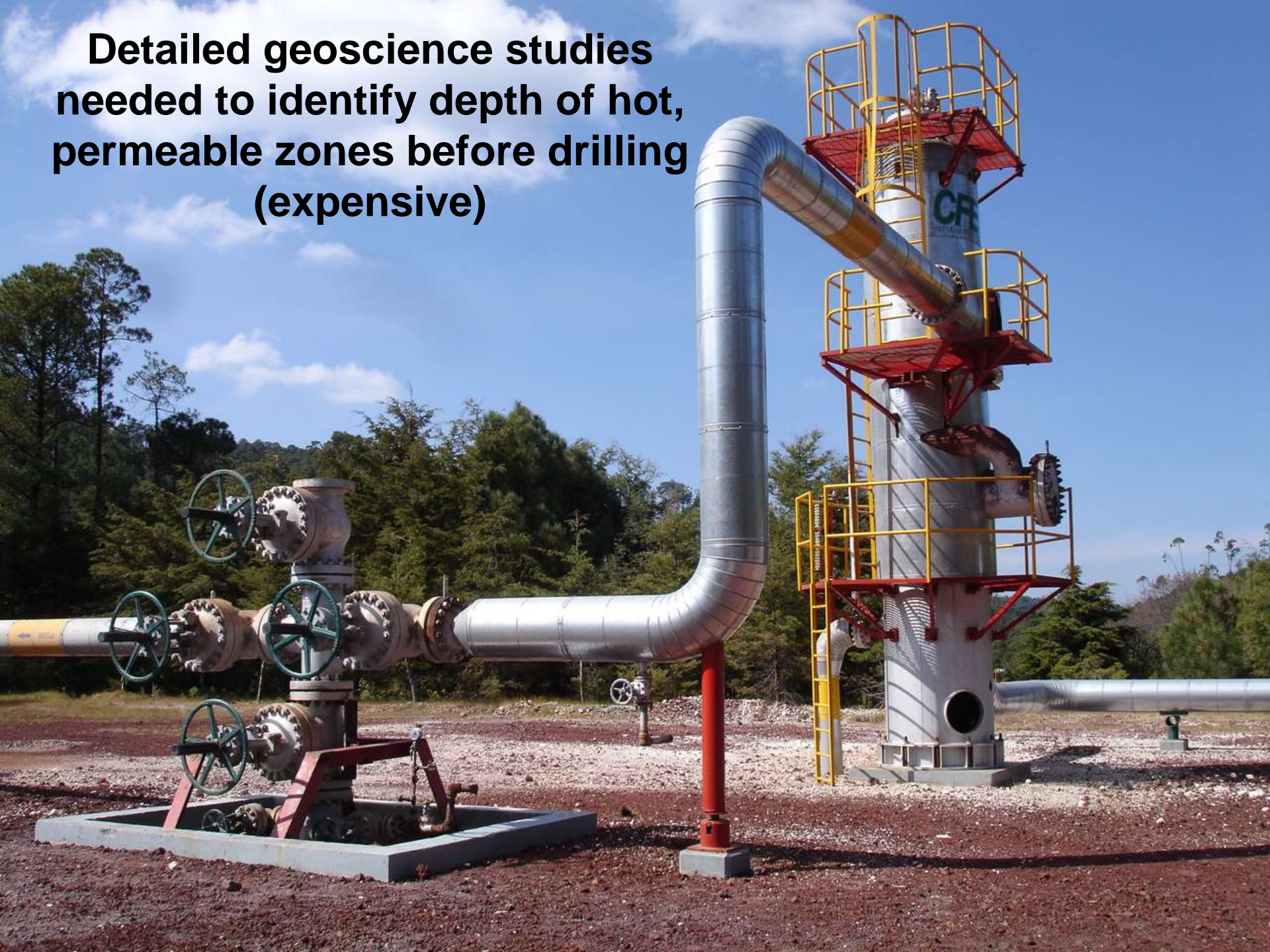
Locate depths of boiling

Identifies if there will be casing corrosion or scaling

Identifies fluid type, (acid conditions etc)

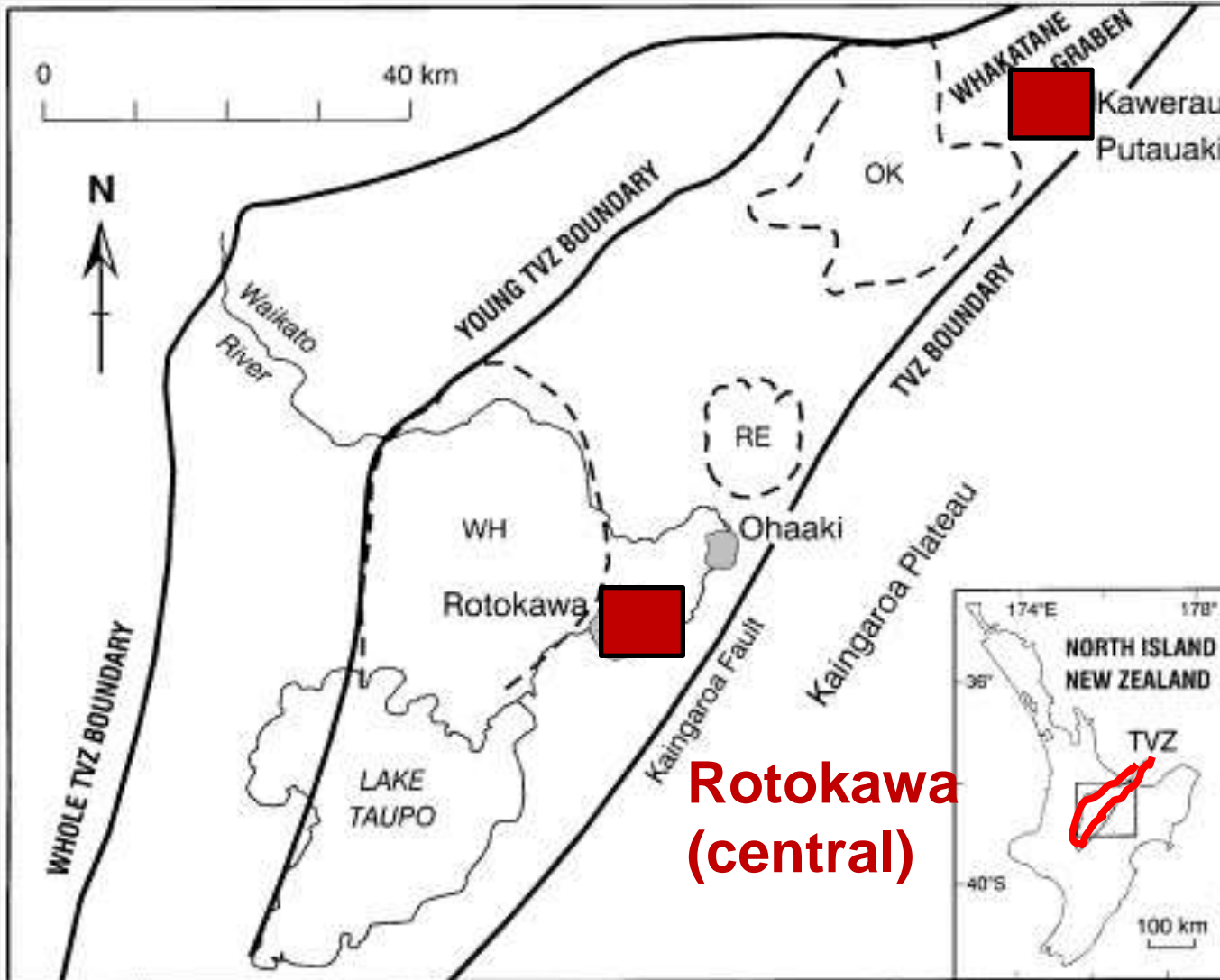


**Detailed geoscience studies
needed to identify depth of hot,
permeable zones before drilling
(expensive)**



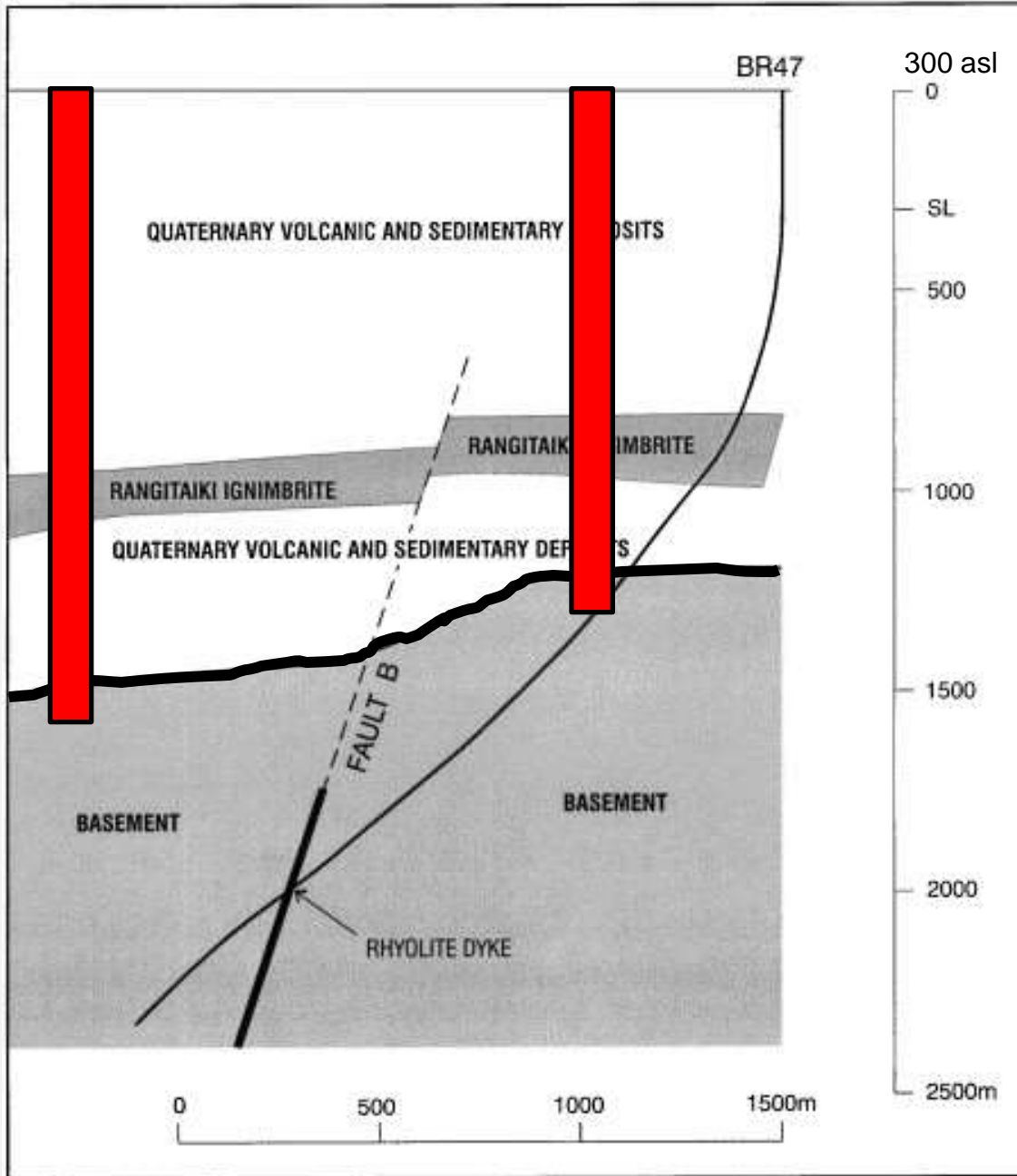
Example of why a geologist's role is important

2 NZ geothermal fields with different reservoir depths but produce from the same formation



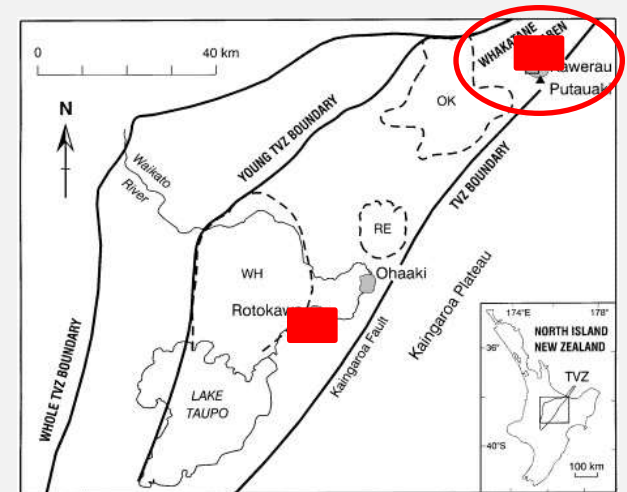
**Kawerau
(north)**

**Rotokawa
(central)**



Kawerau (north)

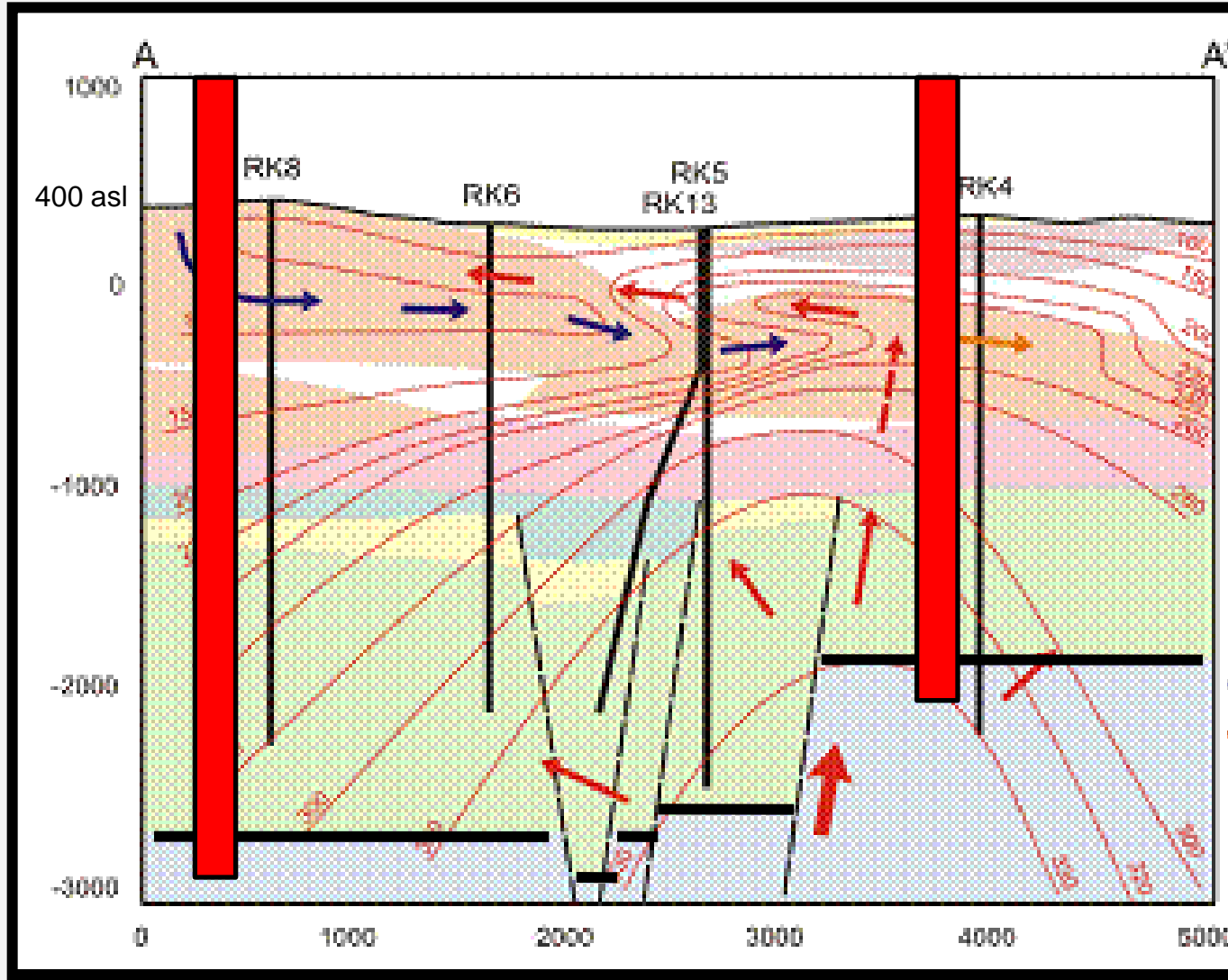
Greywacke Basement
1500 -1800 m depth



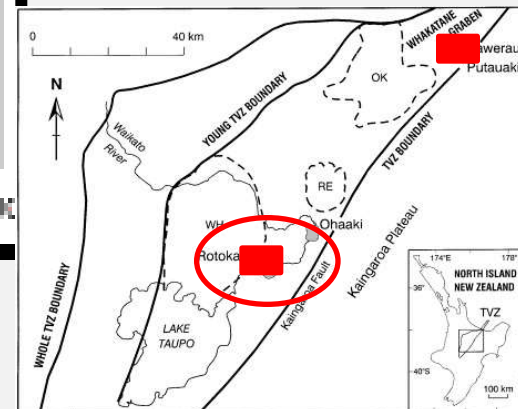
From: Wood, C.P., Brathwaite, R.L., Rosenberg, M. 2001. Basement structure, lithology and permeability at Kawerau and Ohaaki geothermal fields, New Zealand. *Geothermics*, vol. 30, issue 4, 461-481

Rotokawa (central)

Greywacke
Basement
2500 – 3000 m
depth



From: NZ Geothermal Association Website



Let's look at the tasks of a **geochemist**



Role of a GEOCHEMIST

Analyse water compositions

Assess:

- reservoir temperature
- fluid compositions

Assess processes affecting fluid compositions and determine reservoir conditions and changes over time

Assess effects of boiling and/or mixing

Monitor and manage potential contaminants (water and gas)

Factors influencing fluid chemistry

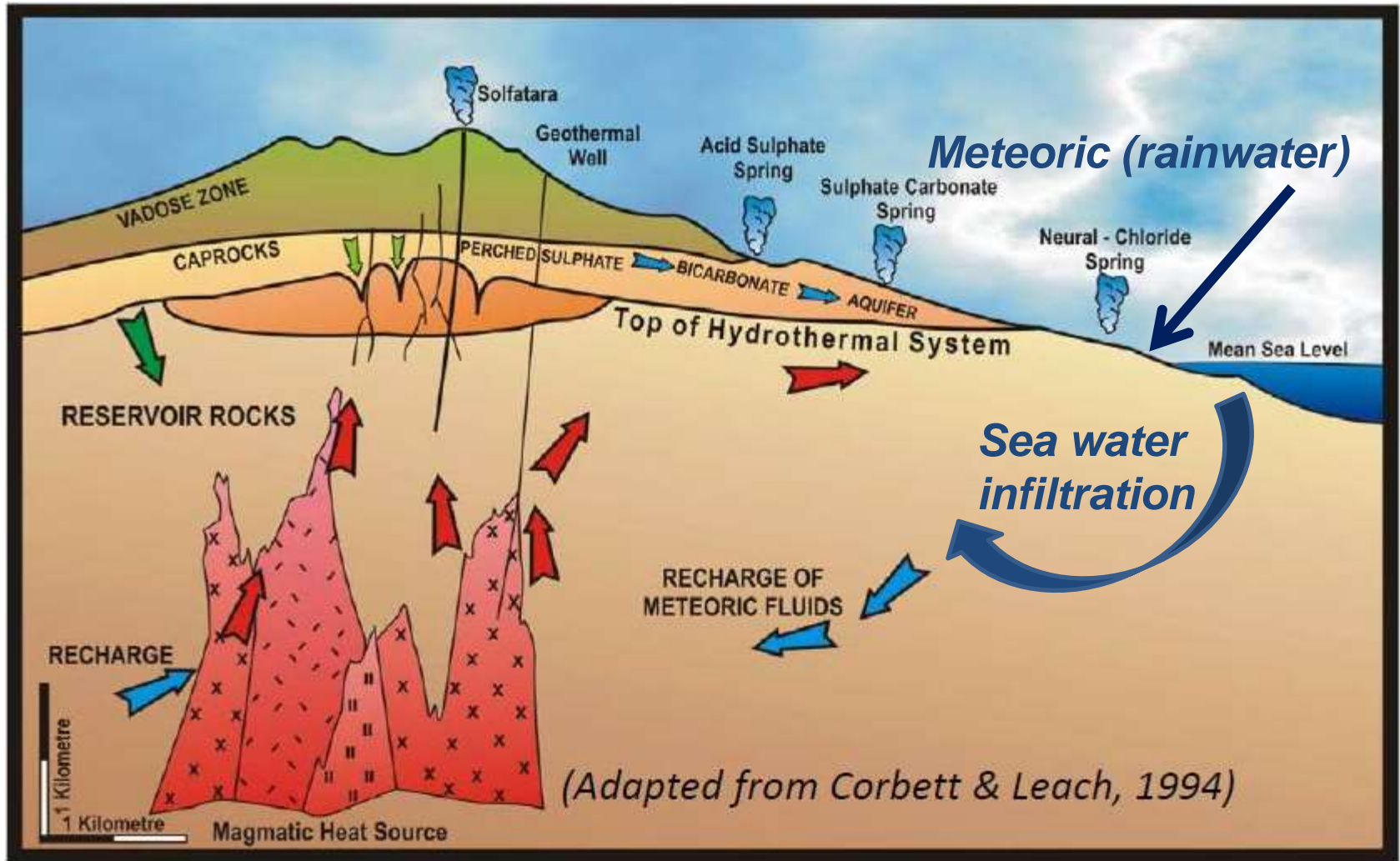


Input of magmatic gases

Fluid – mineral equilibria

Boiling or dilution

Water origin



Volcanic system geothermal model schematic

Common fluid types in geothermal systems

A photograph of a geothermal landscape, likely a hot spring or geyser area. The scene is dominated by mineral-rich water pools in various colors: bright yellow, orange, and white. The water is contained within rocky basins. In the background, there is a large, dark, rocky structure, possibly a geyser vent or a large mineral deposit. The overall environment appears rugged and geologically active.

Alkali chloride water

Acid sulphate water

Bicarbonate or CO₂-rich water

Heated ground water

Mixtures of the above

Special case - sea water



Different types of water

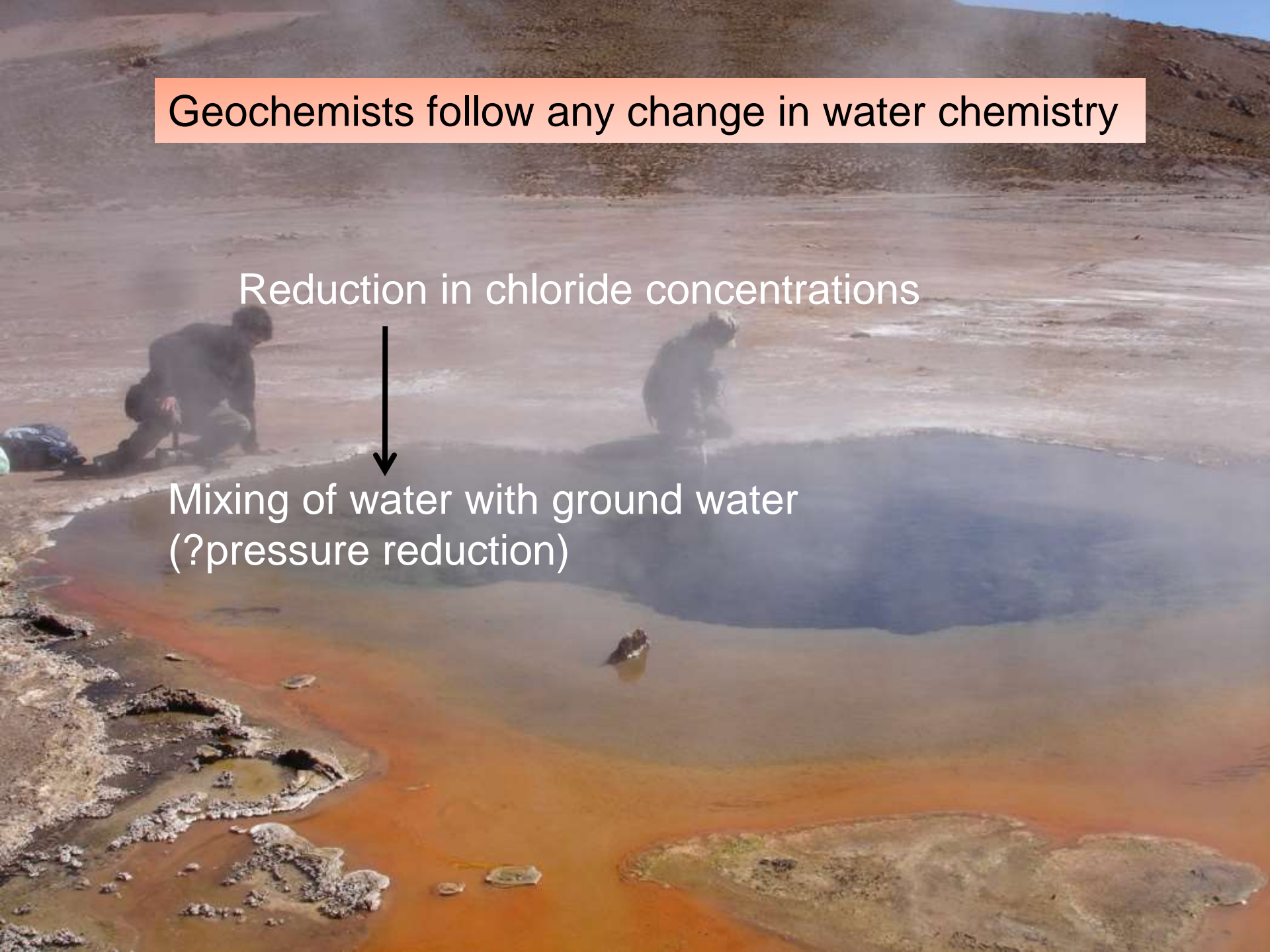


Geochemists follow any change in water chemistry

Reduction in chloride concentrations



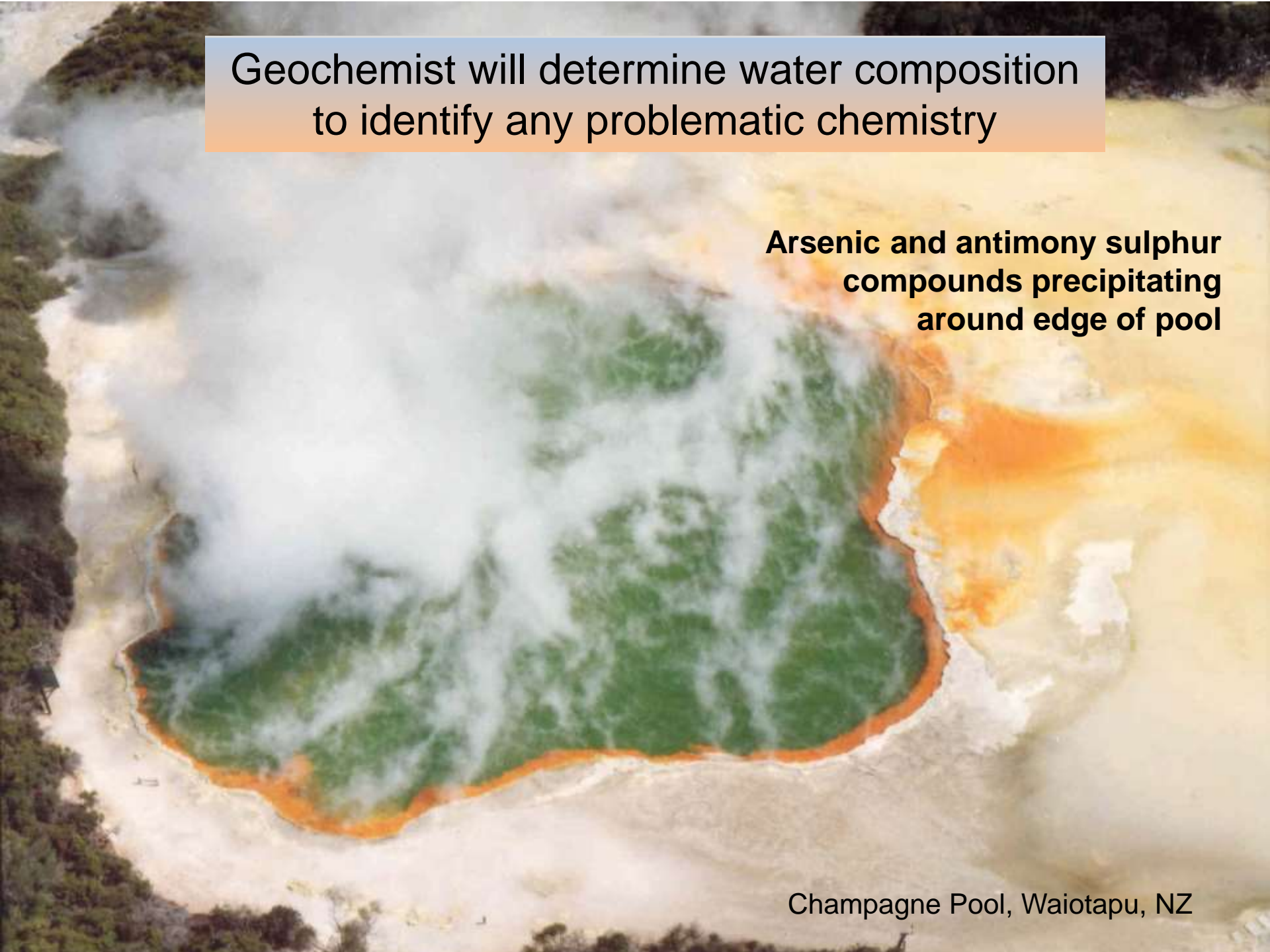
Mixing of water with ground water
(?pressure reduction)



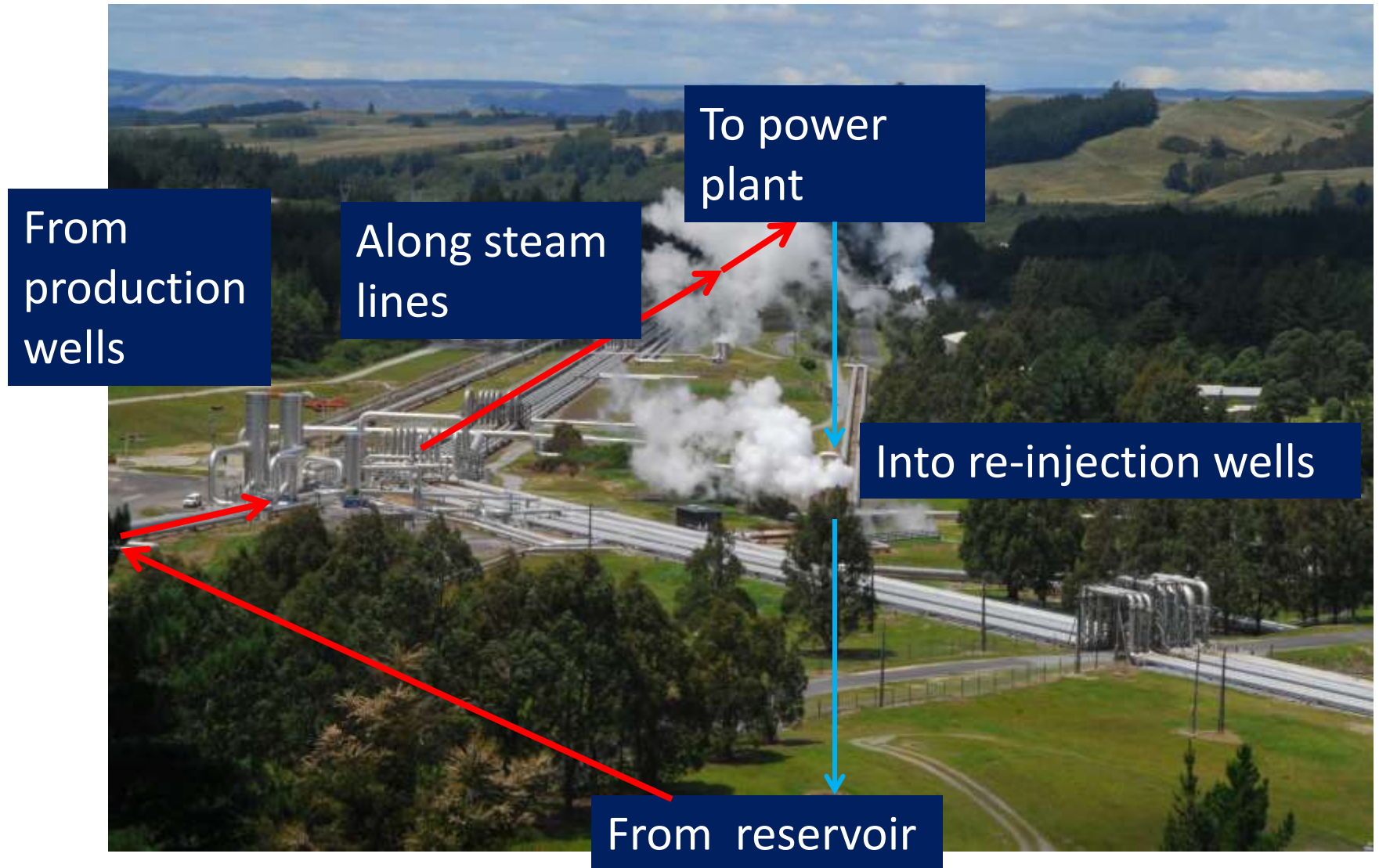
Geochemist will determine water composition to identify any problematic chemistry

Arsenic and antimony sulphur compounds precipitating around edge of pool

Champagne Pool, Waiotapu, NZ



From reservoir to production wells to re-injections wells





Geochemistry can determine if any nasty chemical constituents are going to be a problem for the development of the power plant



Silica scale rich in gold and silver

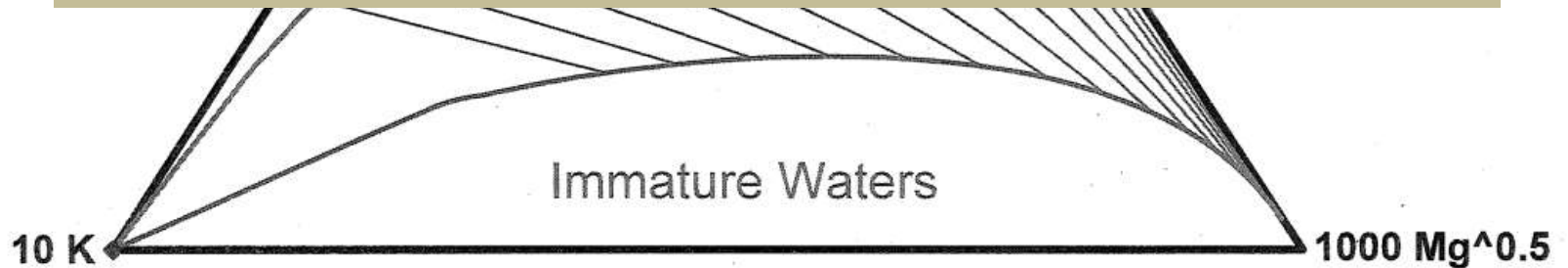


Reduces pipe diameter

Na

Trilinear Plots

Water must be in equilibrium with the host rocks if you want to use water chemistry to tell you about your reservoir AND GET RELIABLE RESULTS



Geochemists use plots of the water composition to tell them information

Geothermometry calculations

Using chemical equations based on the water chemistry to determine the deep reservoir temperatures

Many rules on where and when you can use geothermometry to get accurate results

Toxic gases

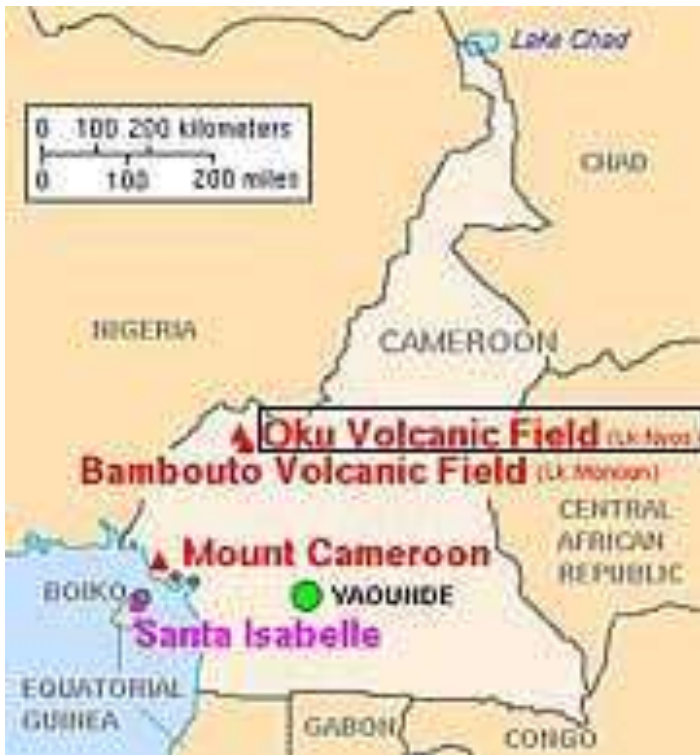
Main gases discharging from geothermal systems are:

H_2S
 CO_2

Monitor toxic gases



TOXIC GASES – CO₂



Lake Nyos – crater lake located in the NW region of Cameroon

Within the Oku Volcanic Field Lake Nyos is located high on flanks of inactive volcano

August 21, 1986

Magma beneath lake leaked CO₂ into the water
and Lake Nyos discharged large quantities of CO₂
CO₂ heavier than air and settled in low lying areas

1700 people died
3500 livestock died



Villages around lake edge

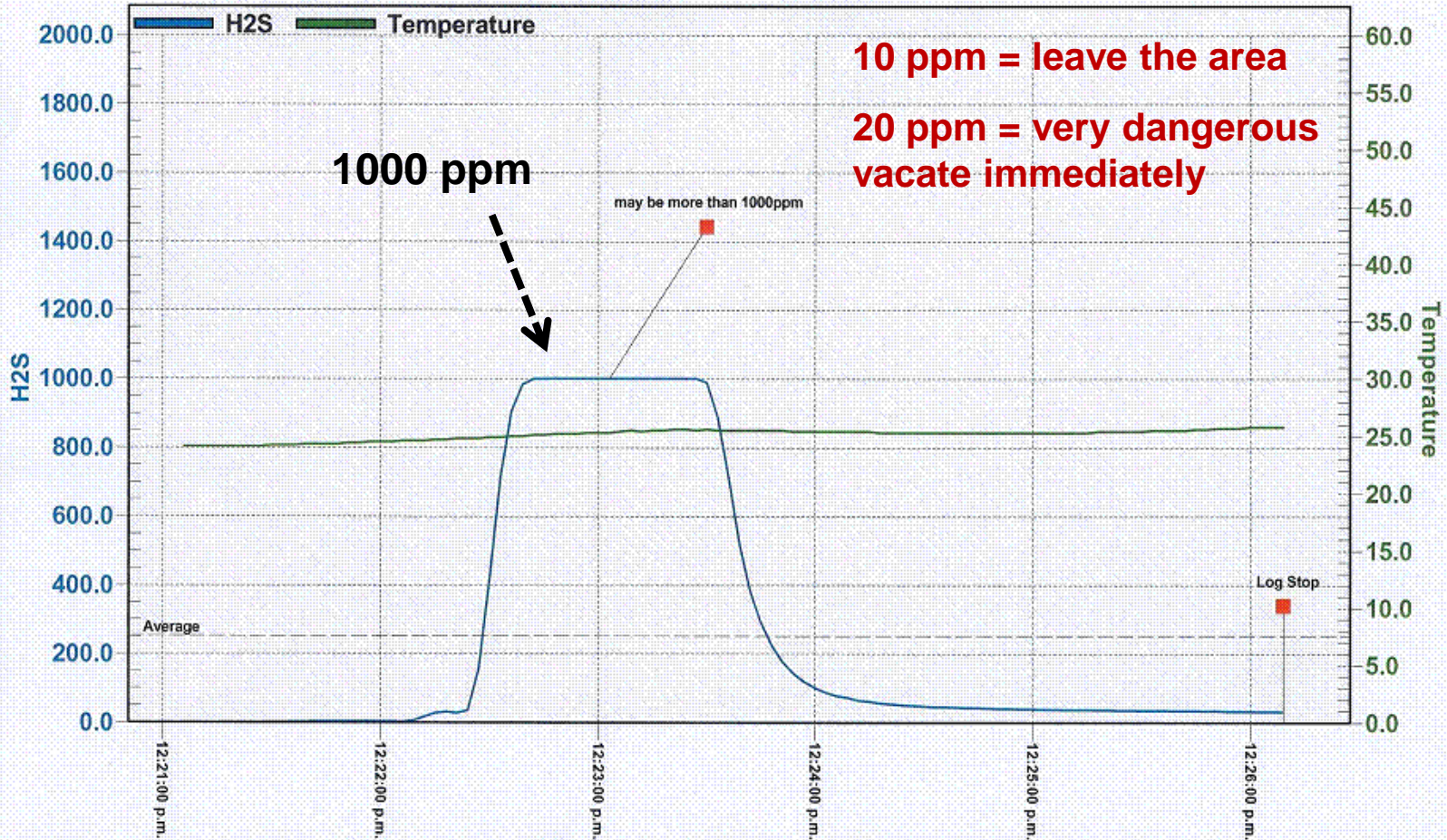
Lake Nyos



Rotorua H₂S case study

Sulphur Point Rotorua

Sulphur mound cold



10 ppm = leave the area
20 ppm = very dangerous
vacate immediately

Period Displayed: 23/02/2010 (Oda File: 20100224_OL45025824_01.oda -- Serial Number: OL45025824)

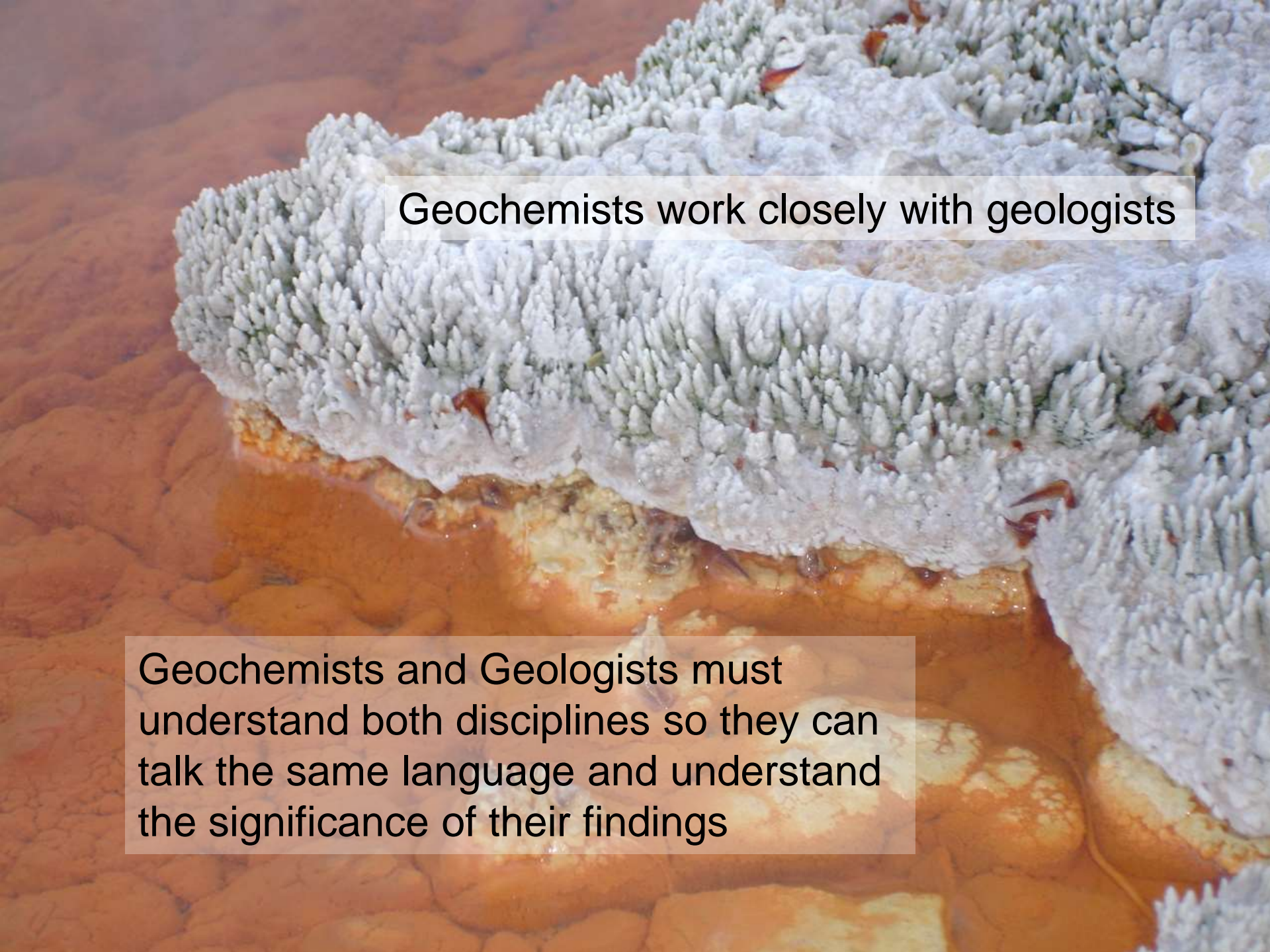
Average 252.3PPM ▲ Day Transition Min 0.0PPM Max 1000.0PPM

Clues to significant H_2S emissions



5 ppm





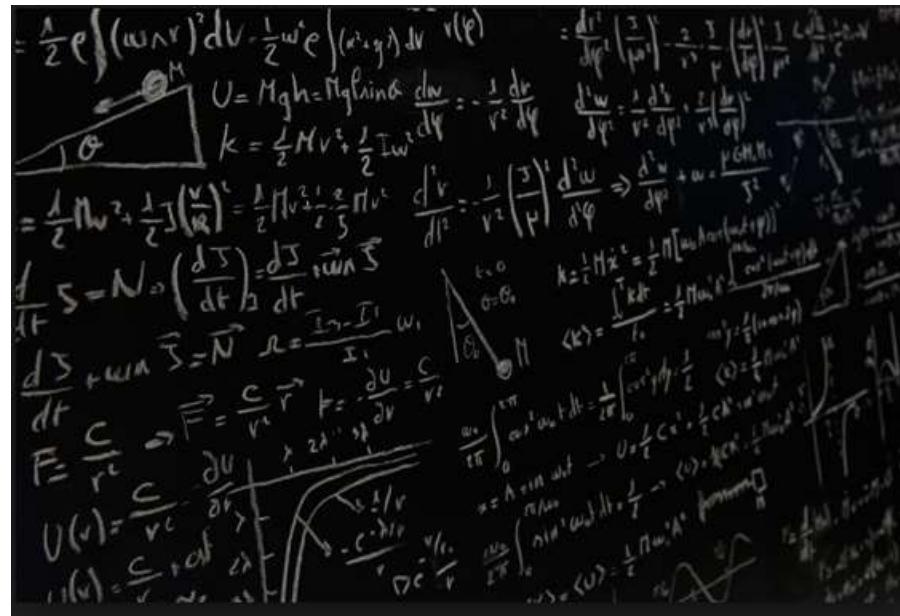
Geochemists work closely with geologists

Geochemists and Geologists must understand both disciplines so they can talk the same language and understand the significance of their findings

Role of a geophysicist

Geophysics uses the principals of physics to study and understand the Earth's subsurface to several km deep

Otherwise only accessible by drilling (expensive)



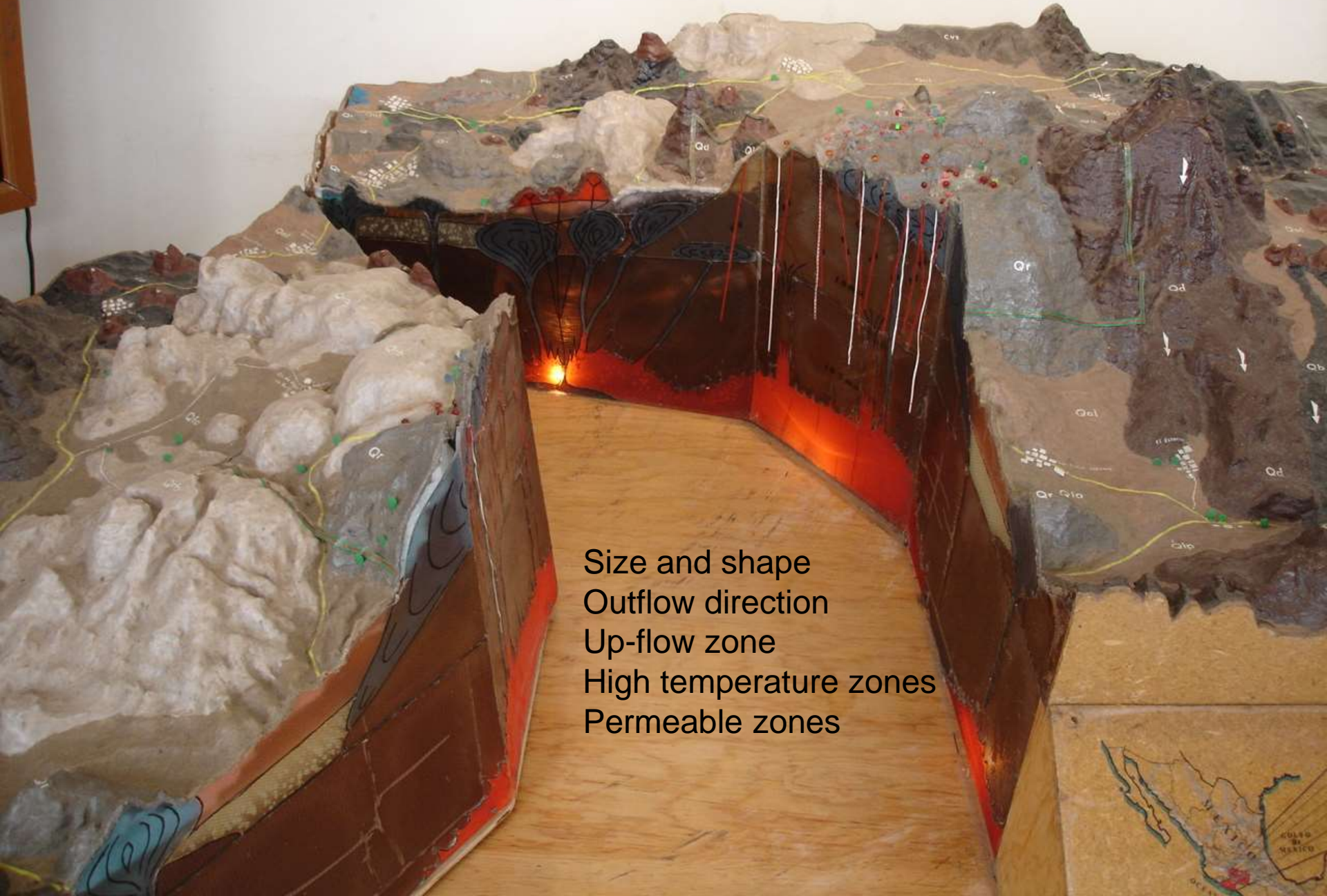


Use a variety of techniques to image the subsurface



X-ray vision

Geophysics is used to image subsurface



Size and shape
Outflow direction
Up-flow zone
High temperature zones
Permeable zones

What properties of geothermal systems are we interested in?

Subsurface temperature

Subsurface fluid

Permeability of rocks (faults and fractures)

Reservoir size

Reservoir rocks

What can we measure?

Density

Magnetism

Resistivity

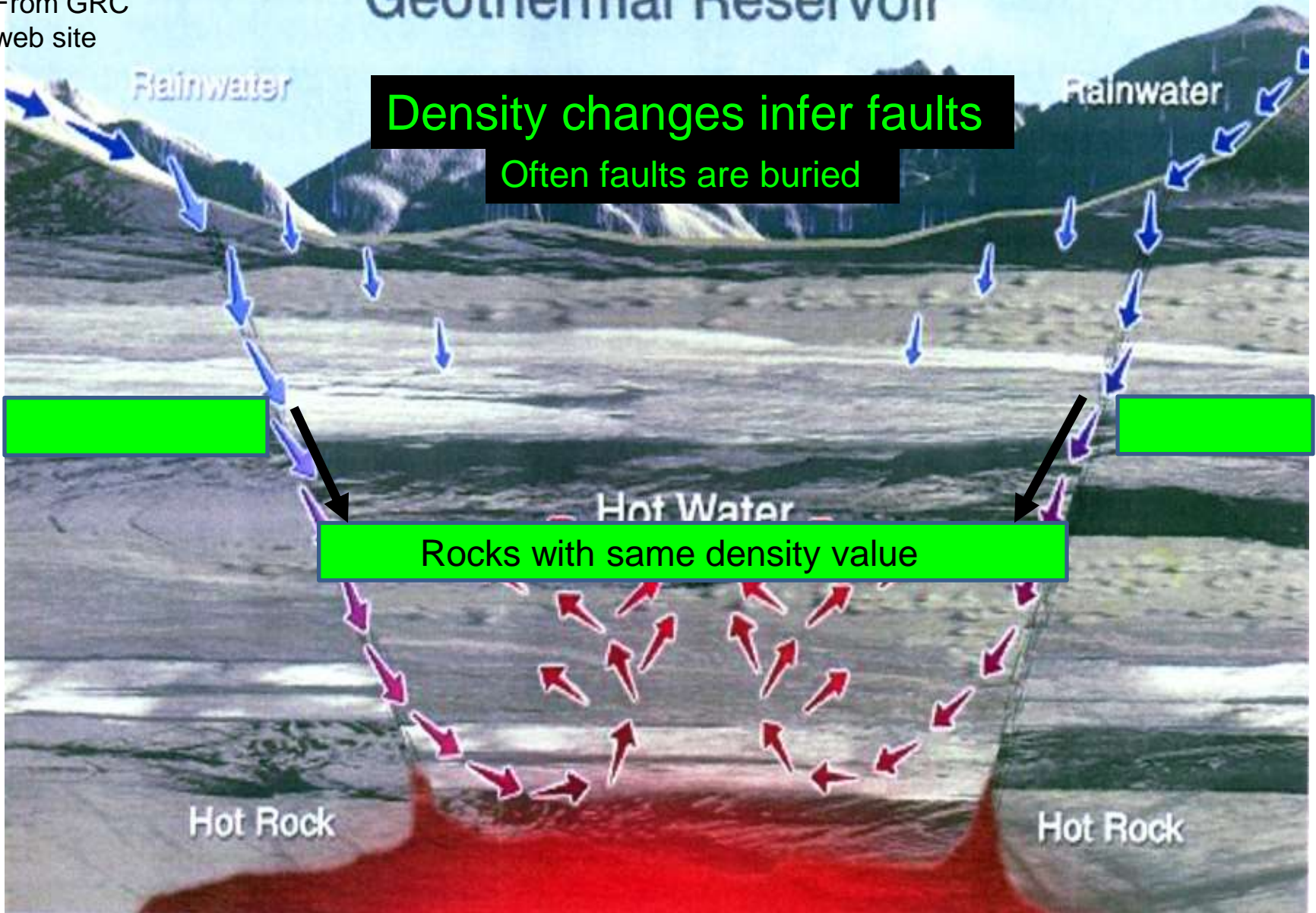
Elastic properties of rocks (hard or soft)

Geophysics tools

- Gravity
- Magnetics
- Resistivity (DC and Electromagnetic)
 - Seismicity (Passive and Active)

From GRC
web site

Geothermal Reservoir



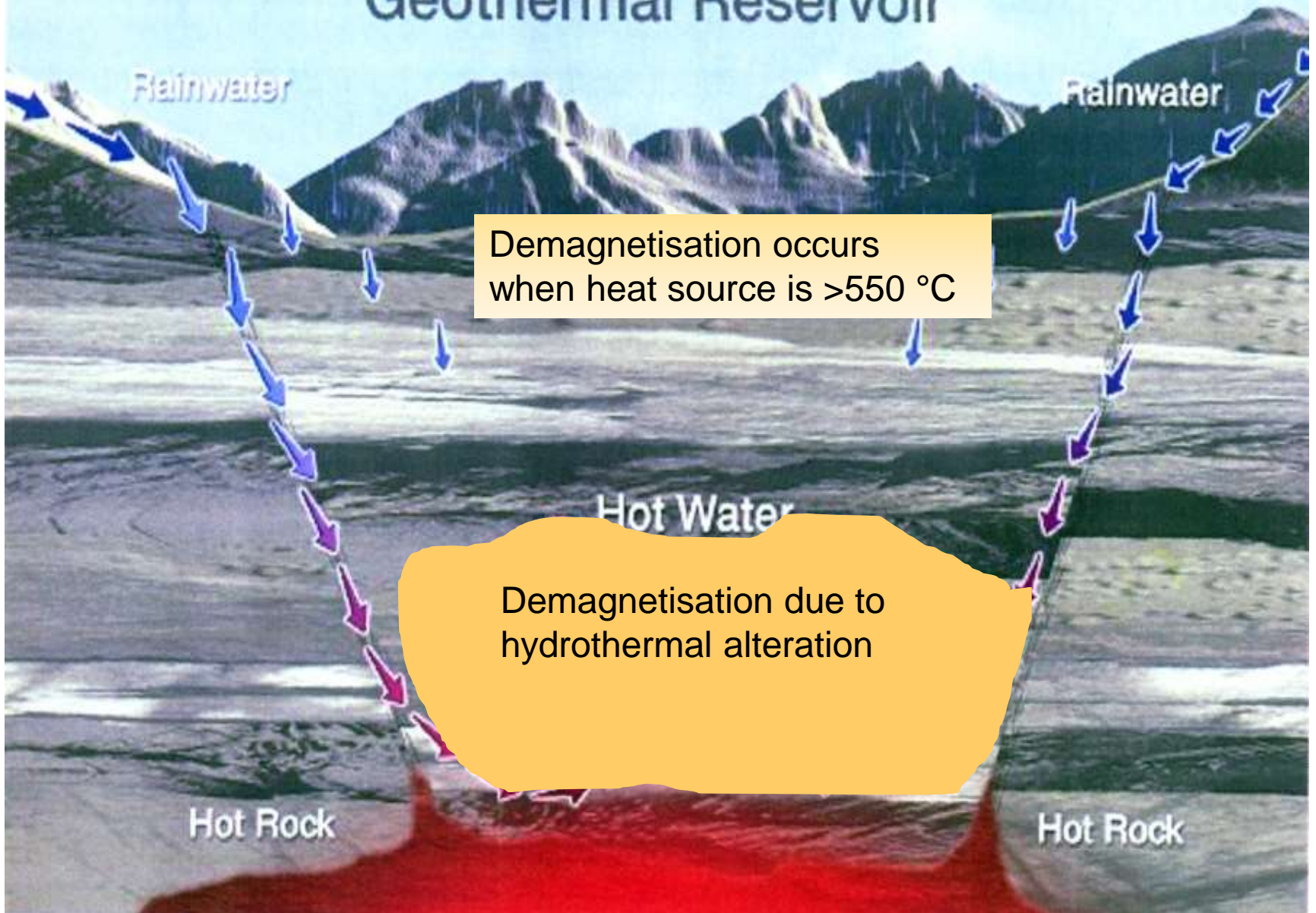
Density changes infer faults

Often faults are buried

Rocks with same density value

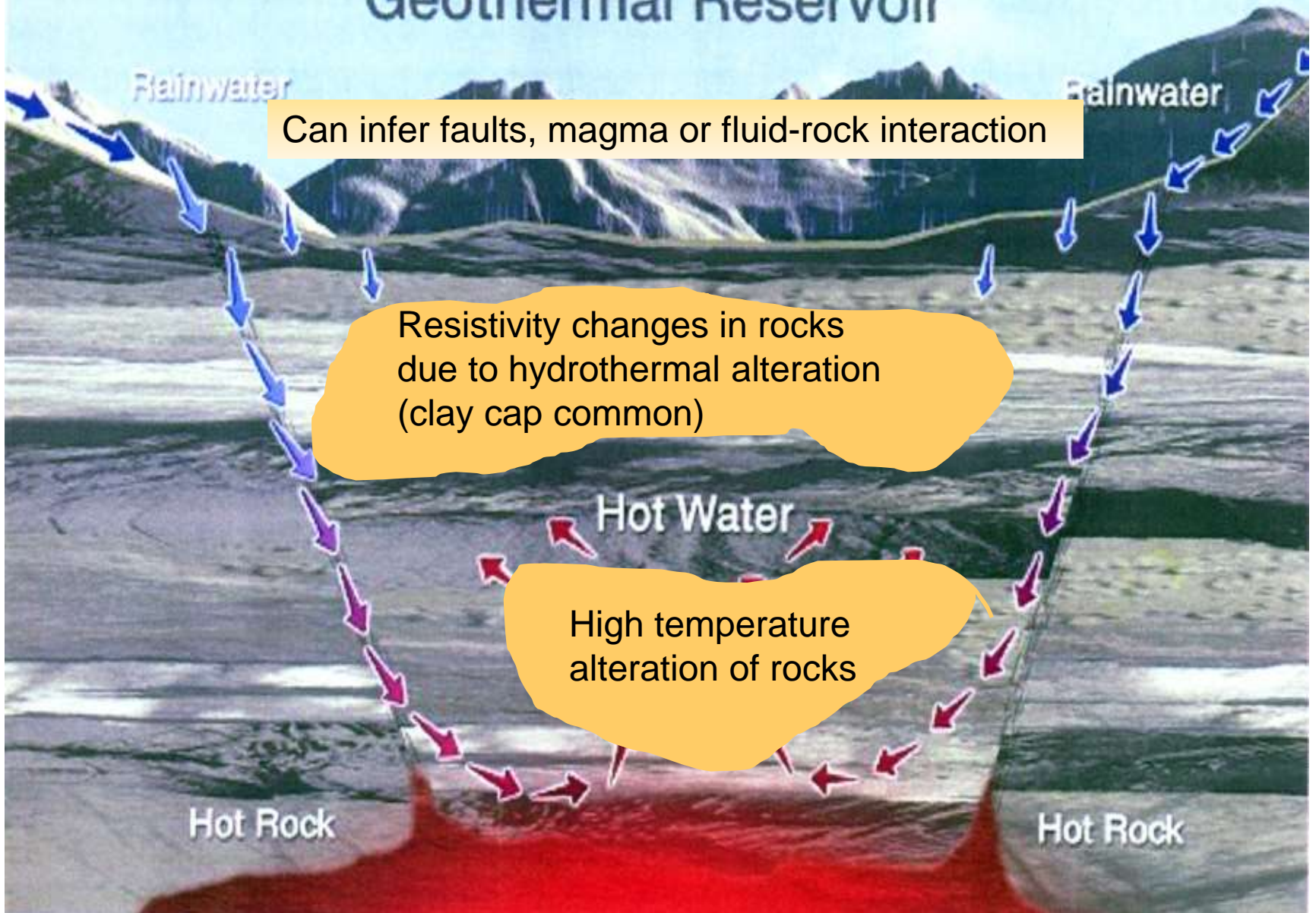
Basic Conceptual Model: Density changes

Geothermal Reservoir



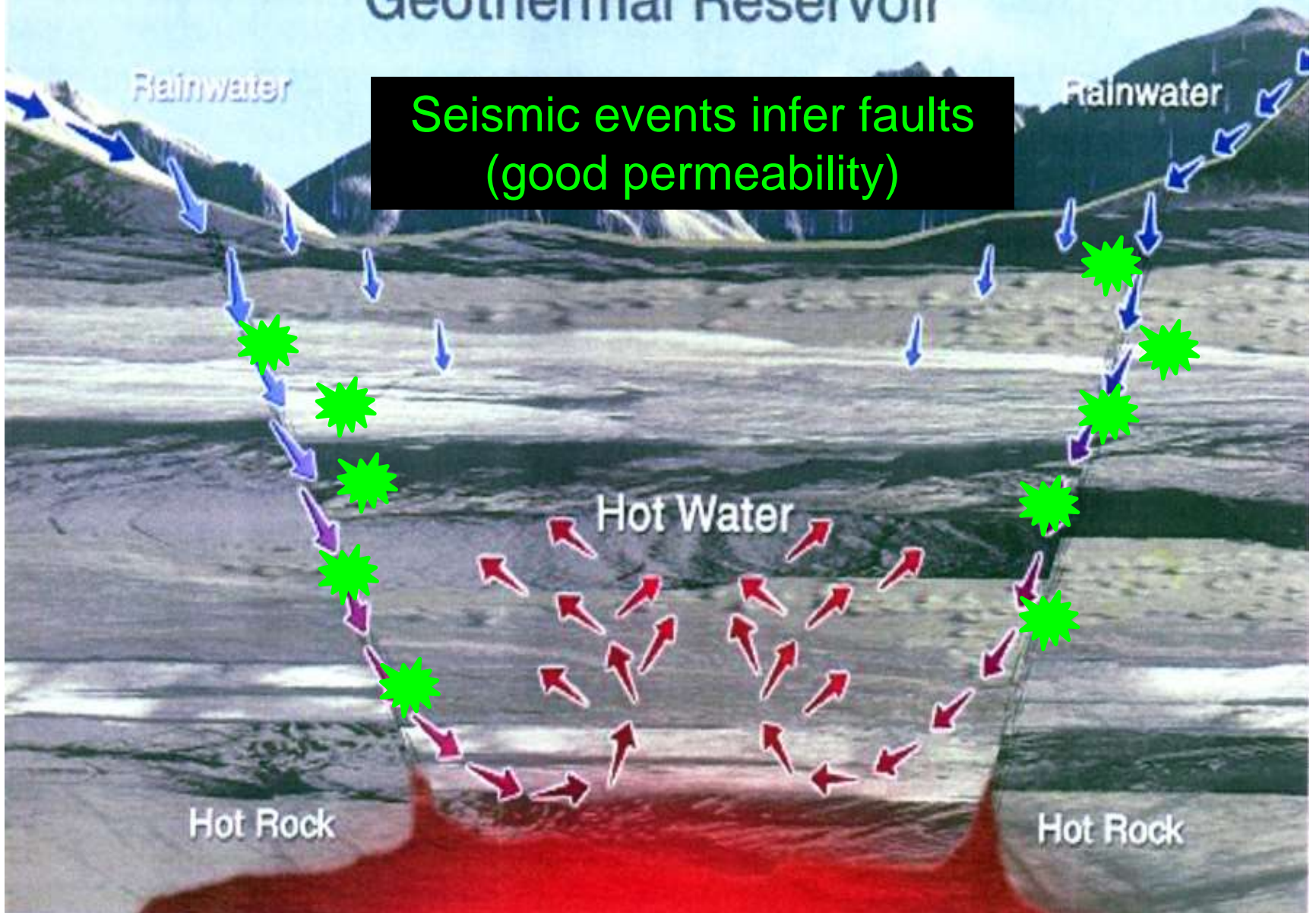
Basic Conceptual Model: Magnetic changes

Geothermal Reservoir



Basic Conceptual Model: Resistivity changes

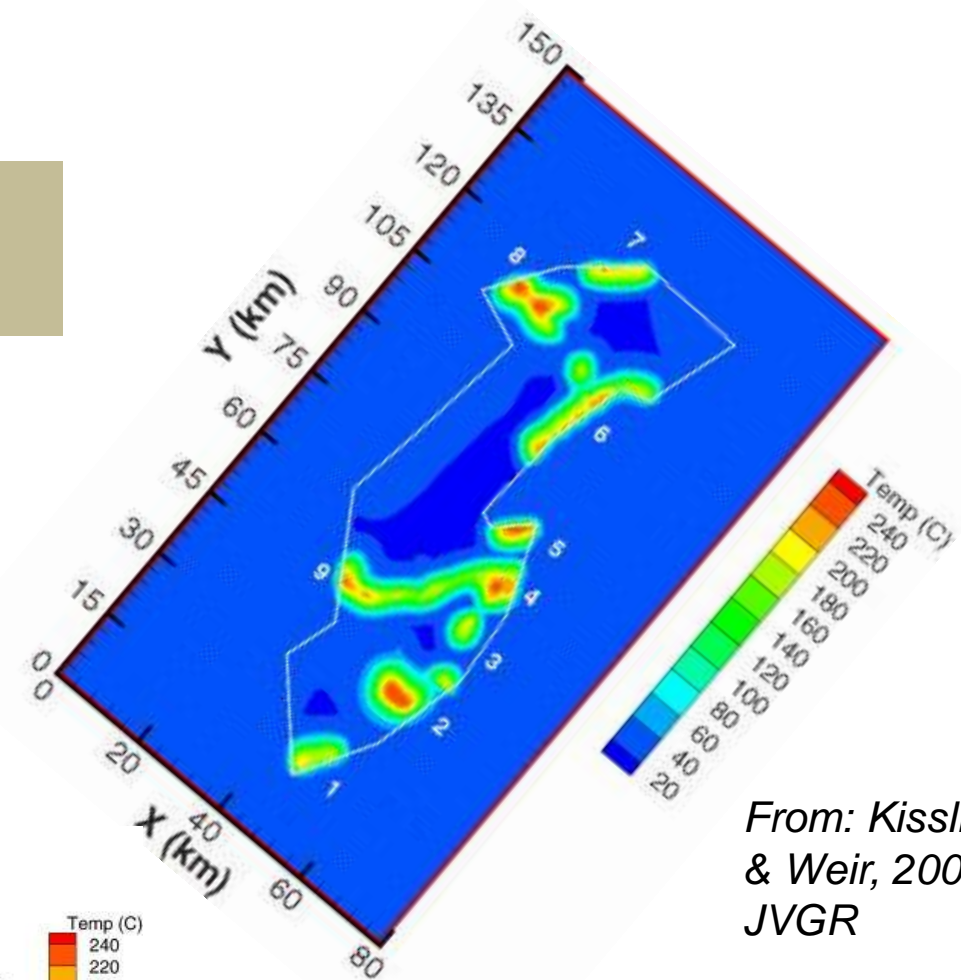
Geothermal Reservoir



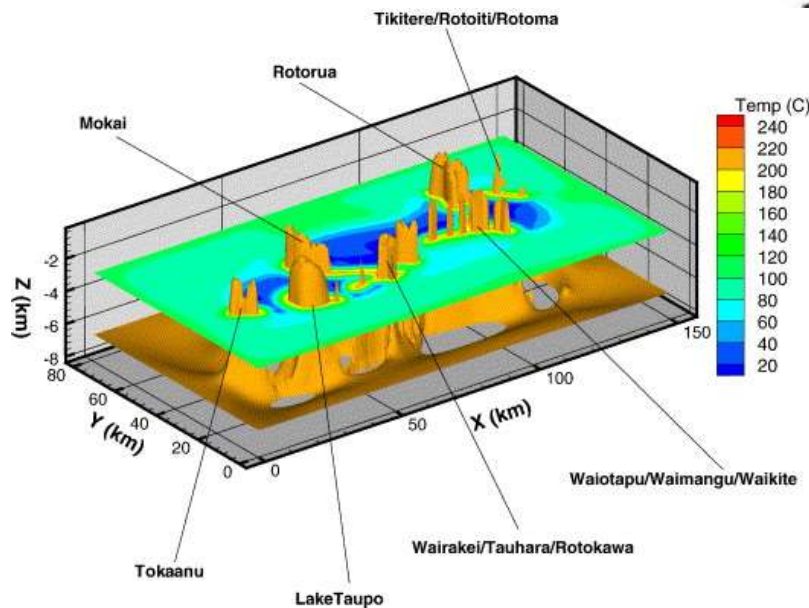
Seismic events infer faults
(good permeability)

Basic Conceptual Model: Seismicity recordings

How geophysics methods image the subsurface



From: Kissling & Weir, 2006, JVGR



In summary:

Team of geoscientists prove resource



Drilling



Engineers develop pipelines, power plant, etc



Reservoir modelling helps manage resource

