U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

PRESENTATION TO THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

SUBJECT: NATURAL HYDROTHERMAL ANALOGUES

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Purpose

- Demonstrate our ability to simulate fluid–rock interactions in:
  - complex natural systems
  - systems of long duration (thousands of years)
- Enhance our ability to forecast potential fluid–rock interactions at Yucca Mt., and increase our confidence in our predictions of system performance

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Roles of proposed hydrothermal analogue study – Chapman (1987)

Quantitative

- "Type 1. As natural experiments which replicate a process, or a group of processes, which are being considered in a model."

Qualitative

- "Type 3. As simple signposts indicating which phenomena can occur in the system being modelled by reference to a parallel natural system."

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Criteria for selection of the Taupo Hydrothermal Area, New Zealand

- Rock type (rhyolitic tuff) and temperature range (< 300°C) are similar to Yucca Mt.
- Hydrothermal system active over about 500,000 years
- Well-characterized geology and hydrology
- Fluid chemistries well-known
- Secondary mineralogy known, appropriate, and characterized (zeolites, clays, carbonates, silica polymorphs, oxides, sulfides/ sulfates)

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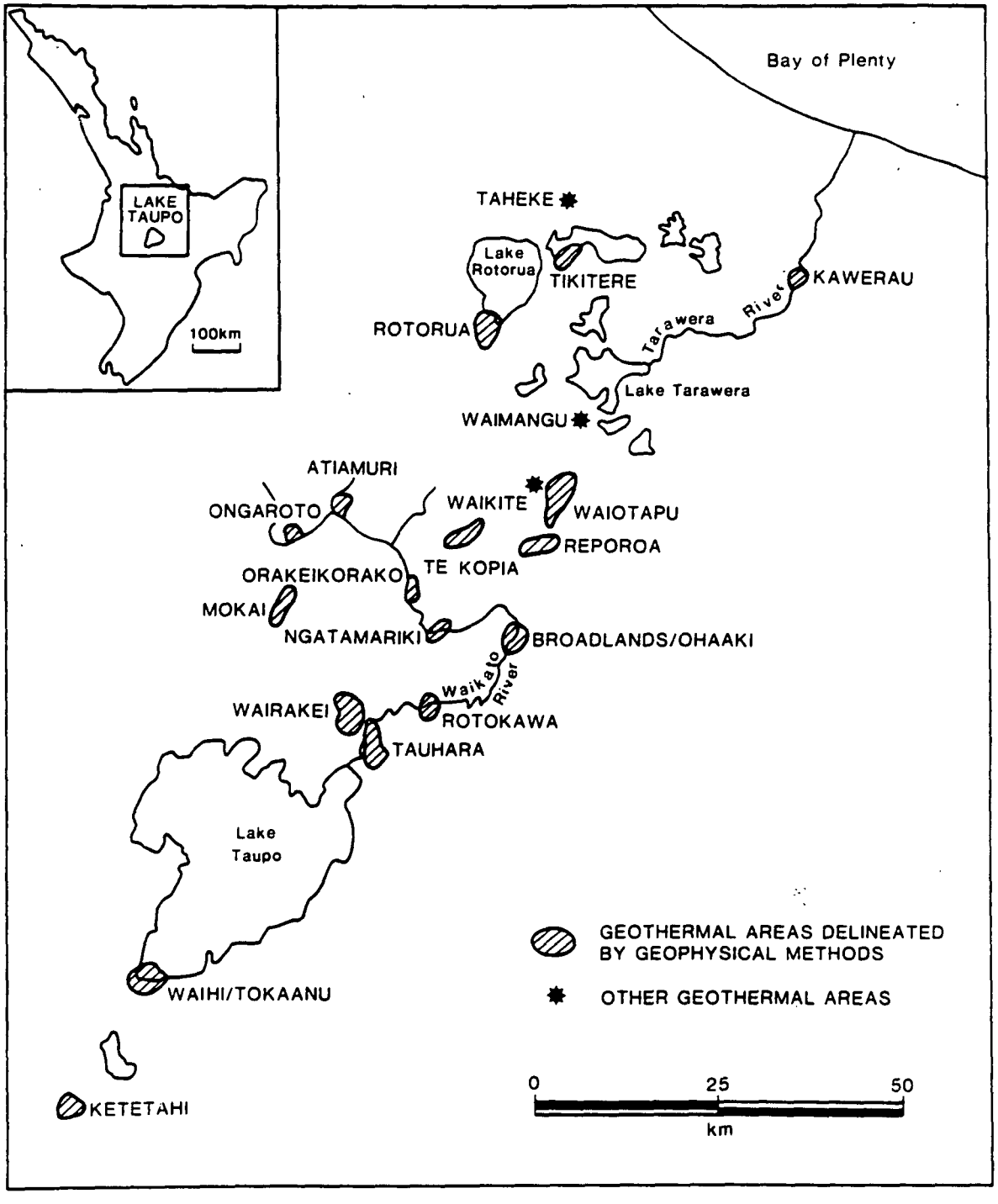
Criteria for selection of the Taupo Hydrothermal Area, New Zealand

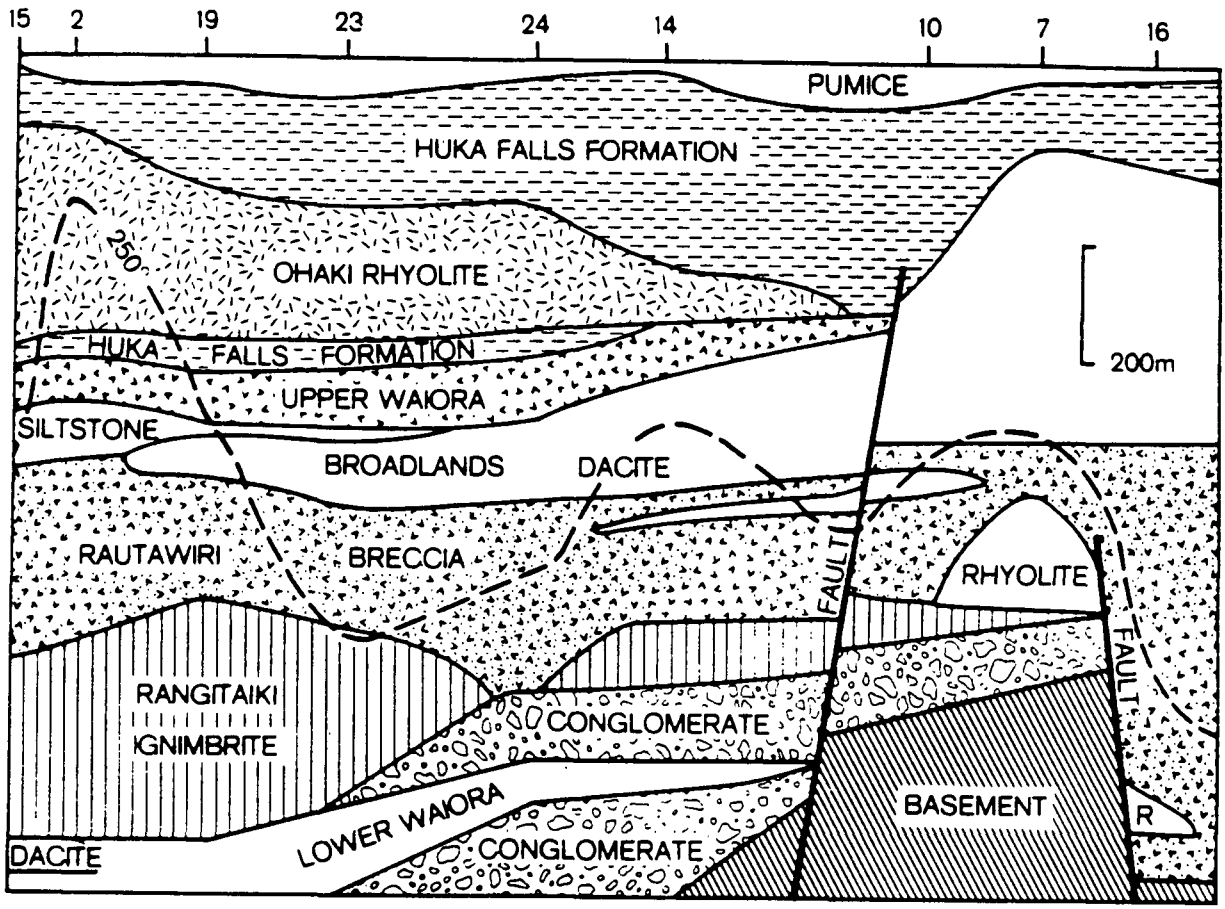
- Human activity at the site since 1953 has noticeably altered springs and water chemistry. We can test our ability to model perturbances in natural systems.
- Degradation of man-emplaced materials (metals, concrete) has been recorded and studied. We can study chemical consequences of emplacement of man-made materials in the site.

Geothermal areas in Taupo Volcanic Zone, New Zealand



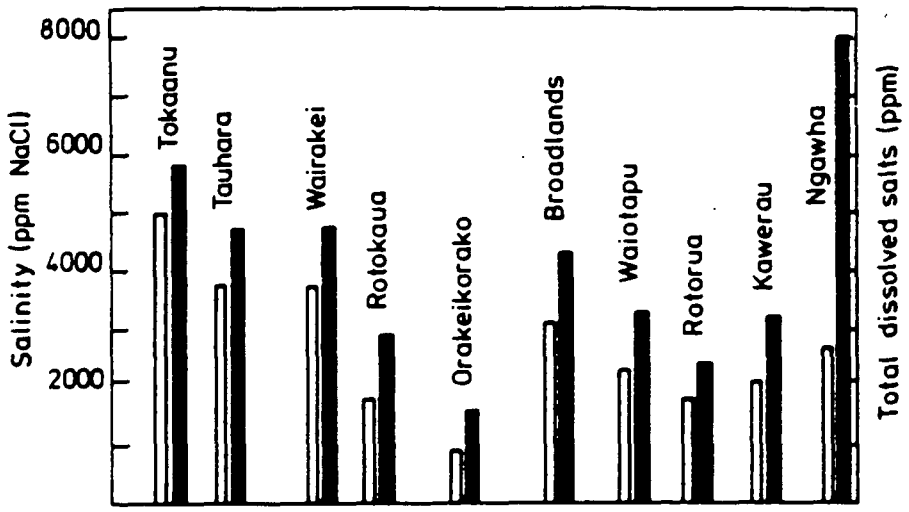
(from Lonker et al., 1990)

Stratigraphy and temperature in Broadlands-Ohaaki geothermal system



(from Weissberg, Browne and Seward, 1979)

Fluid chemistry in Taupo Volcanic Zone, New Zealand



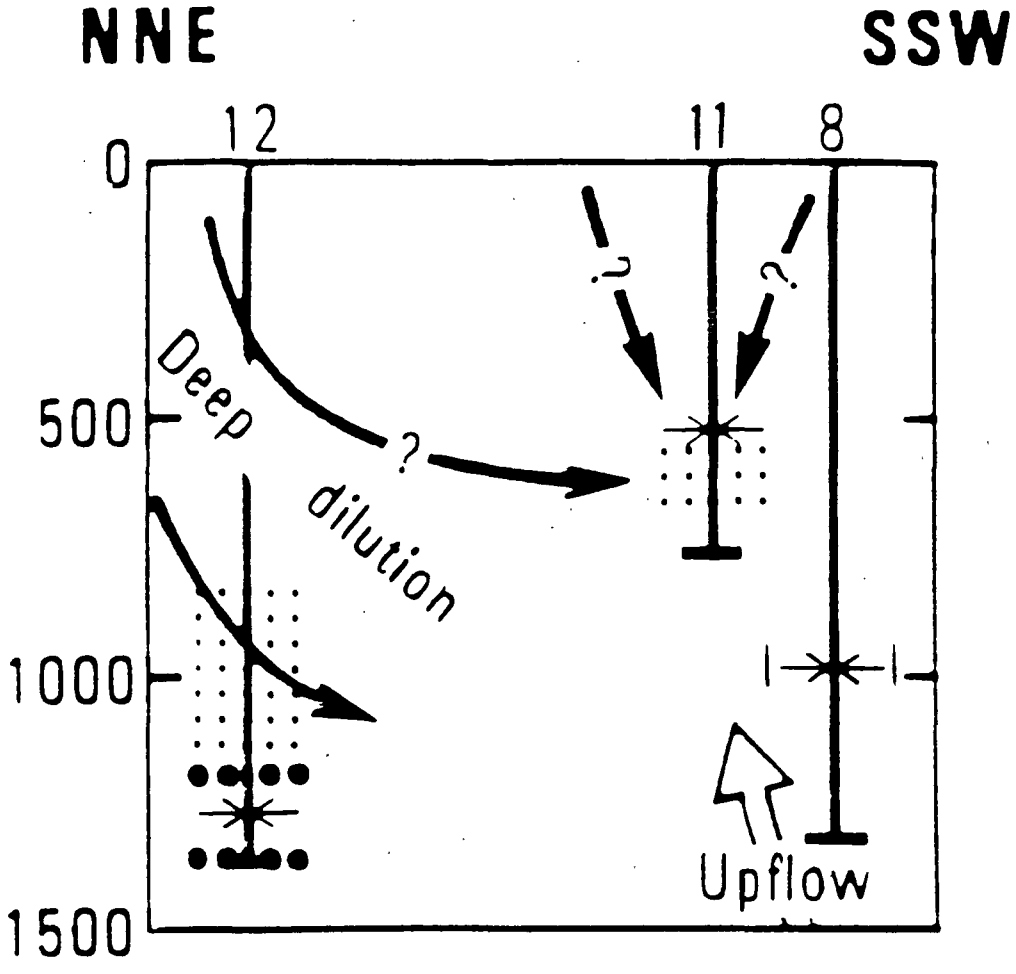
Composition of Steam and Gas in Some New Zealand Geothermal Areas

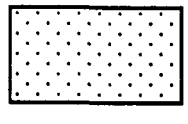
Area (well number)	Moles of gas per kg water in total discharge	Composition of gas (% by volume)				
		CO_2	H_2S	$\overline{HC}$ [a]	H_2	N_2
Ngawha (1)	0.5	93.9	0.7	3.9	0.5	1.0
Kawerau (8)	0.11	94.0	2.6	2.1	0.3	1.0
Wairakei (27)	0.012	90.0	4.1	2.1	0.5	2.4
Waiotapu (6)	0.026	88.0	10.3	0.2	1.0	0.5
Broadlands (2)	0.25	94.4	1.6	2.2	0.2	1.5
Karapiti fumarole, Wairakei	0.012	94.5	2.3	1.1	1.0	1.1
Tauhara fumarole	0.01	96.4	1.3	0.5	0.4	1.4

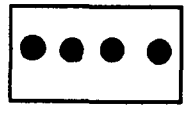
[a] $\overline{HC}$ = total hydrocarbons.

(from Ellis and Mahon, 1977)

Fluid flow in Broadlands-Ohaaki geothermal system




CO_2-H_2-RICH
Steam-heated water


Less permeable zone

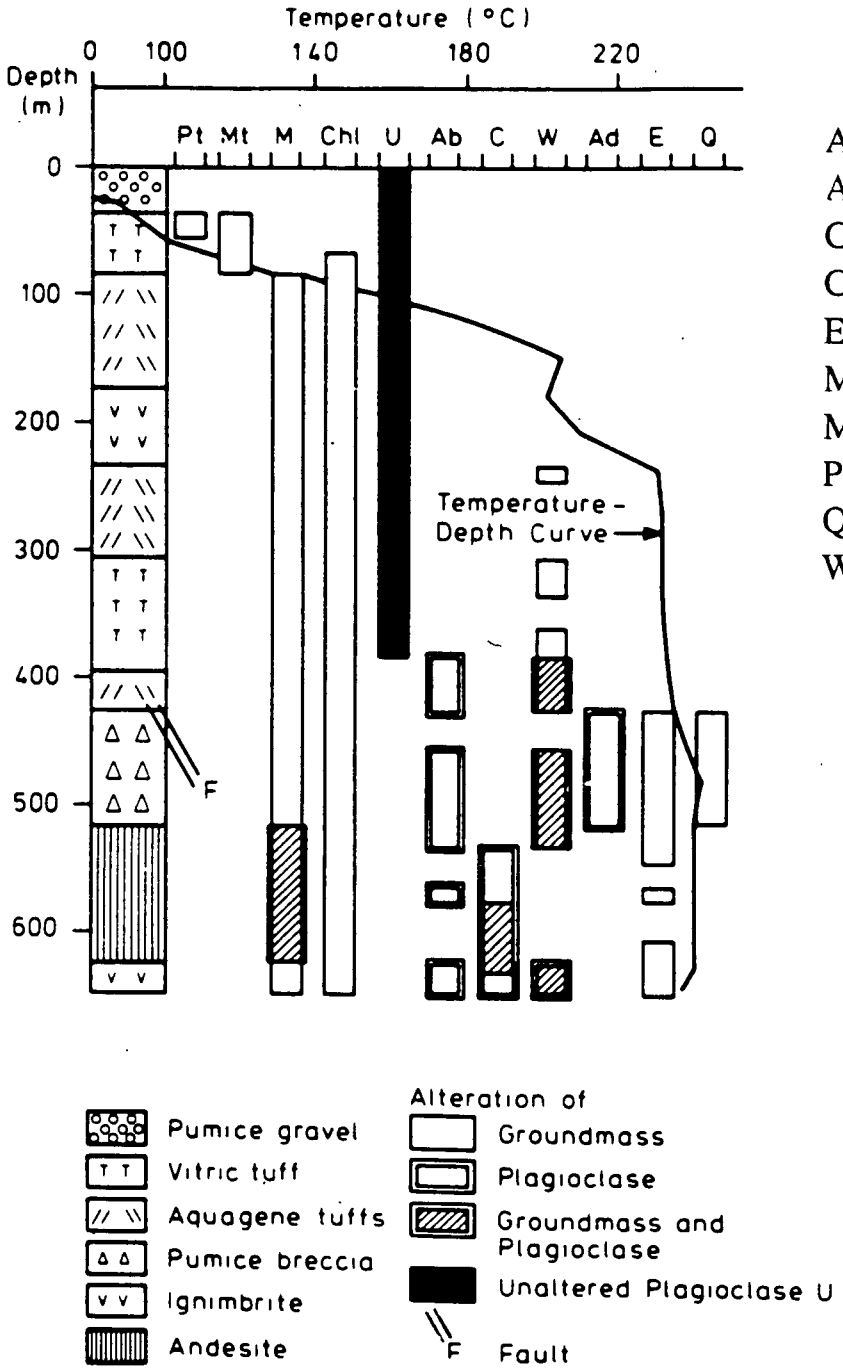
Active flow zone, this study

Zone of circulation loss

0 500m

(from Lonker et al., 1990)

Alteration mineralogy in Broadlands-Ohaaki geothermal system



Ab	albite
Ad	adularia
C	calcite
Chl	chlorite
E	epidote
M	micaceous clay
Mt	montmorillonite
Pt	ptilolite
Q	quartz
W	wairakite

(from Ellis, 1979)

Approach

Understand the system

Develop scenarios

Geochemical modeling of scenarios

Approach

Understand the system

- **Establish collaborative contacts**
- **Collect available data**
- **Acquire data as needed**
- **Develop understanding of physical and chemical evolution and current state of system**

Develop scenarios

Geochemical modeling of scenarios

Approach

Understand the system

Develop scenarios

- **Specific scenarios of fluid–rock interaction will be identified from our knowledge of the system.**
- **An example of a possible scenario is fluid-rock interaction accompanying fluid flow along a temperature gradient. We do not intend to develop a total system model.**
- **Each scenario embodies a set of processes.**

Geochemical modeling of scenarios

Approach

Understand the system

Develop scenarios

Geochemical modeling of scenarios

- **Scenarios will be simulated using geochemical and reactive transport modeling codes.**
- **Comparisons between modeling results and observed chemistries allow us to test, refine, and gain confidence in our modeling capabilities.**

Expected results

- The degree of match between modeling results and observed reactions will help us to identify whether:
  - our mathematical descriptions of the physical processes are adequate
  - we have correctly identified the controlling processes
  - we have used appropriate data and input parameters
- We can then proceed to refine and/or add to our models, and identify additional data needs.

Expected results

- It is our goal to be able to match observed trends in fluid chemistry, mineralogy and mineral chemistry for each scenario.
- We do not intend to achieve a perfect match between our models and field data.
- By choosing to study specific, defined scenarios of fluid–rock interaction, we will obtain results throughout the study.
- At each stage of the study, we hope to improve the ability of the geochemical models to describe fluid-rock interactions in complex natural systems. We thereby increase our confidence in forecasting fluid-rock interactions at Yucca Mt.