



IESE
Institute of
Earth Science
and Engineering
Aotearoa

Singapore Geothermal Conference 09Dec09

Creating a Resource Index Map for Geothermal Exploration, Assessment & Production

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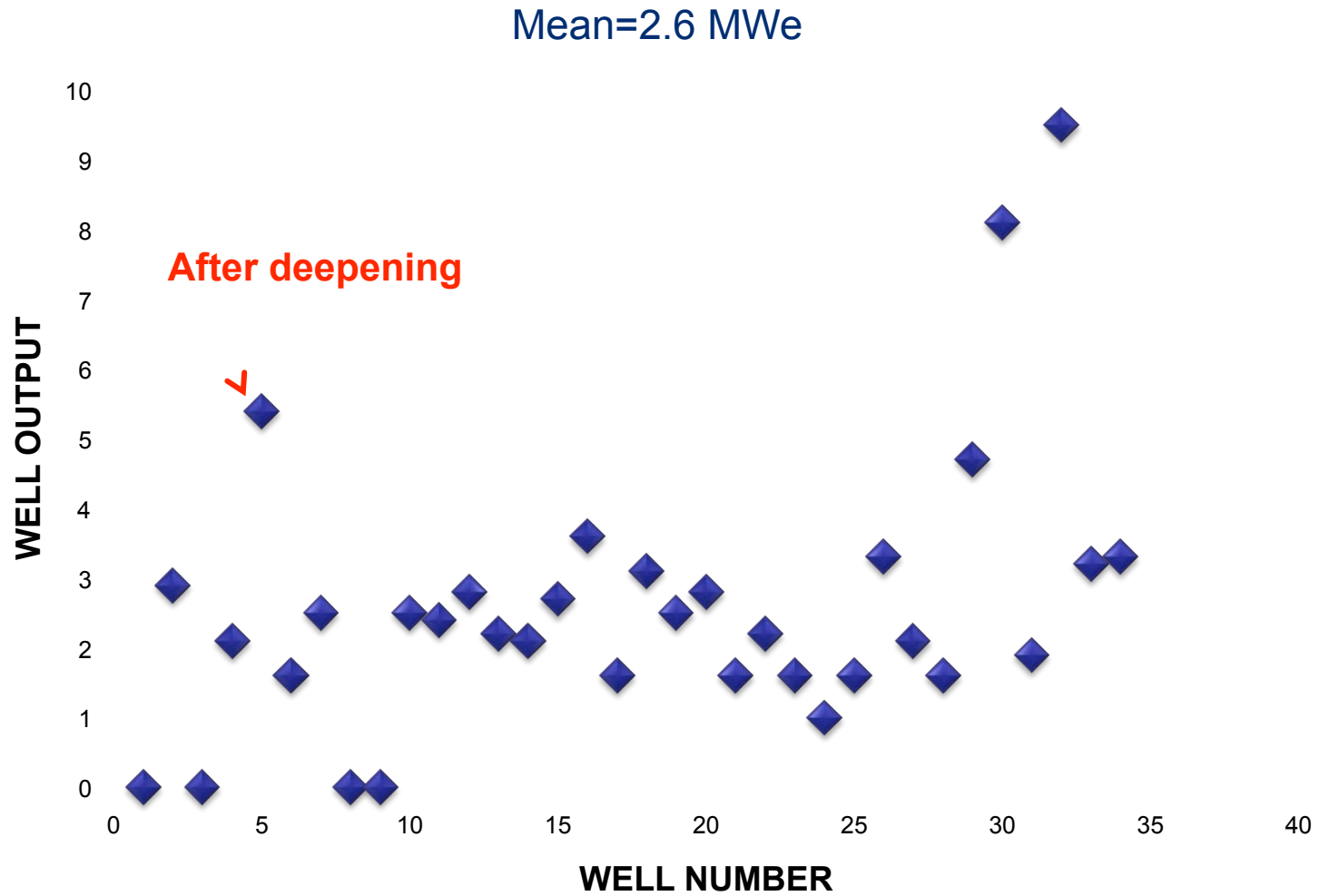
University of Auckland

Summary - Why geothermal is risky business?

- What is IESE?
- What is a Resource Index Map?
 - a high-production geothermal-well targeting guide!
- What type of data can be used?
 - anything having do with: Heat (cond /conv/adv)
 - Fluid (water)
 - Permeability (fractures)
- How can these be combined to create the Map?
 - via Joint Geophysical Imaging, “JGI” !
- How do we know it works?
 - examples from: Kenya
 - Iceland
 - USA
 - Caribbean

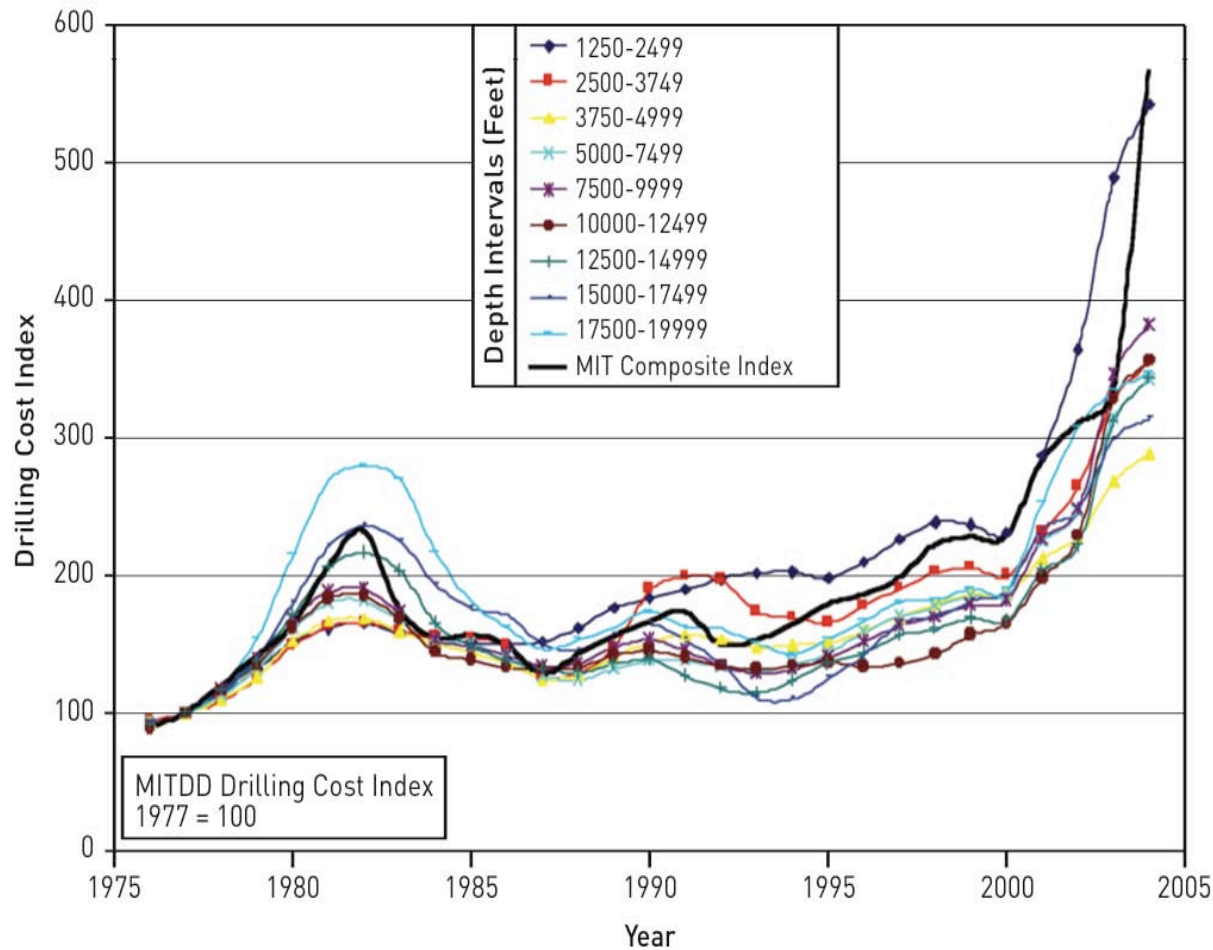
Why geothermal is risky business:

example of geothermal field well outputs – New Zealand



Why geothermal is even riskier business now:

THE DRILLING COSTS!



THE IESE R&D RESPONSE!

- Exploration
 - Targeting permeability
 - Example: Olkaria, Kenya
 - \$75 Million savings (?)
 - (UNEP Press Release)
- Production
 - Fewer replacement wells
 - Example: Krafla, Iceland
 - 8 -> 18 -> 32 Mwe
 - (Landsvirkjñ, per. com.)

What role does IESE play in this quest?

Industry

IESE

University of Auckland

Contract Based

Project Based

Grant Based

Market Driven

Balance

Knowledge Driven

Products & Services

New Practical Knowledge

Research &



What is a Resource Index Map ? e.g. Fracture density map, Casa Diablo Geothermal Field

Shear wave splitting

Time-difference fracture-density tomography maps at depth

Fracture direction
on
Time difference

weak

strong



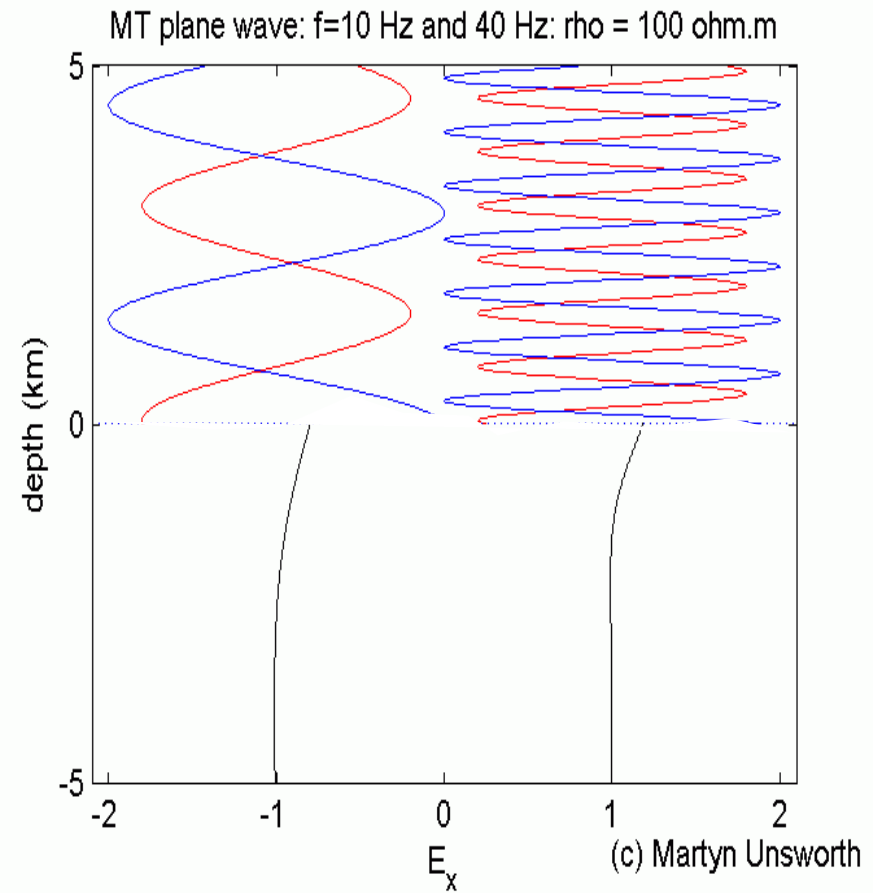
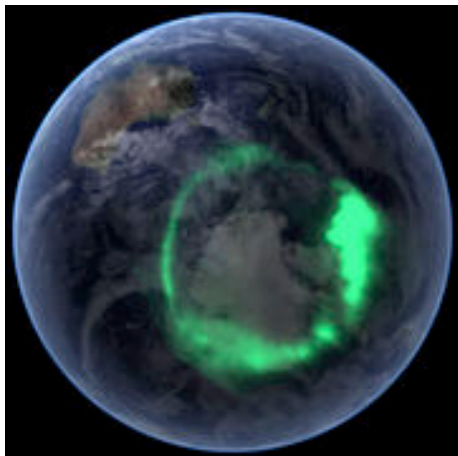
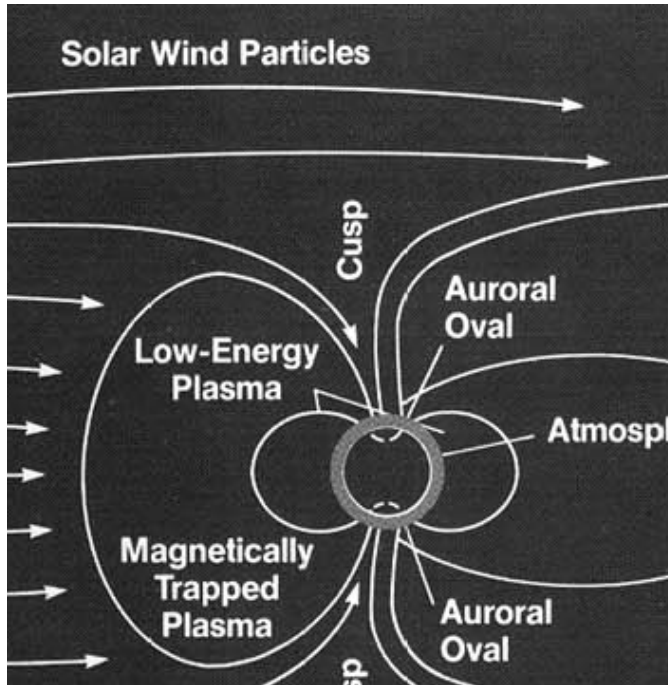
Fractures

Earthquake Shear-wave from below

Fig. 8. Three dimensional tomographic results of the splitshear-wave inversion displayed as horizontal slices 1.0 km apart. The model is represented by the value of the dimensionless crack-density parameter $CD = Na^3/N$, where orange and red regions

What type of data can be used? -anything having do with: Heat, Fluid, Permeability (Fractures)

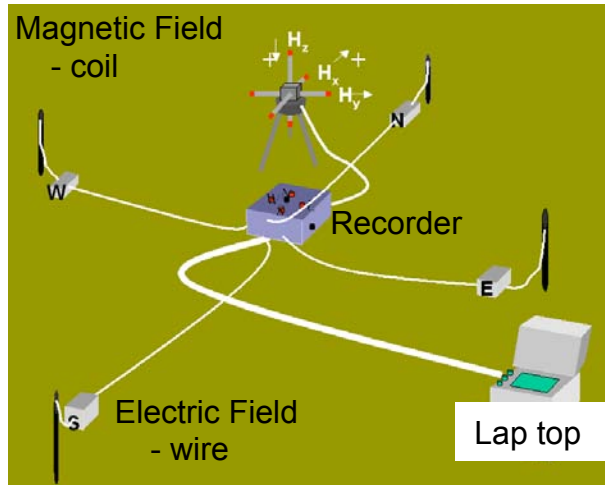
Electrical Resistance - Magnetotellurics



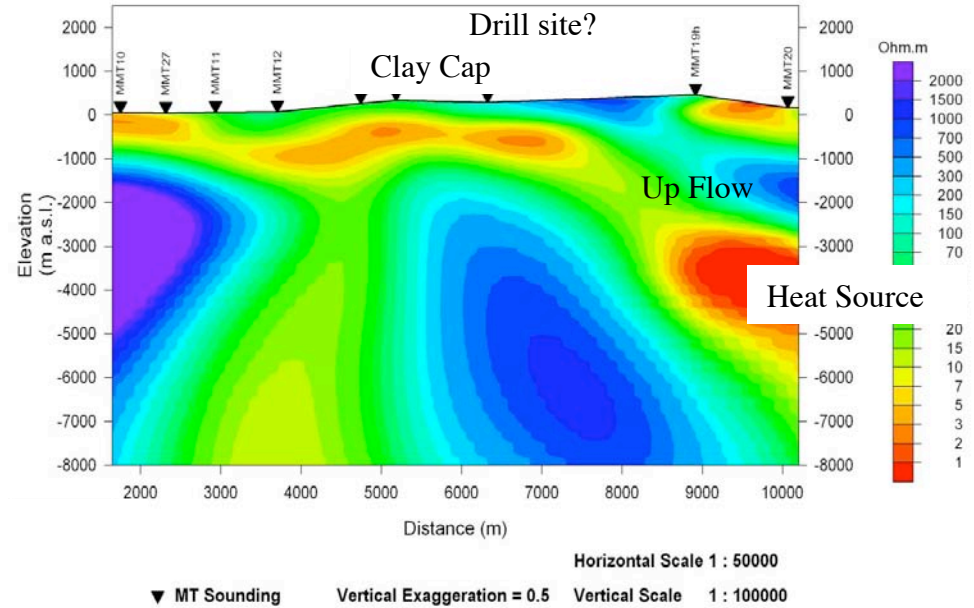
- High lightning activity $f > 1\text{ Hz}$
- Intermediate ionospheric resonance $1 > f > 0.01\text{ Hz}$
- Low solar wind variation $0.1 > f > 0.00001\text{ Hz}$

Magnetotelluric profiling

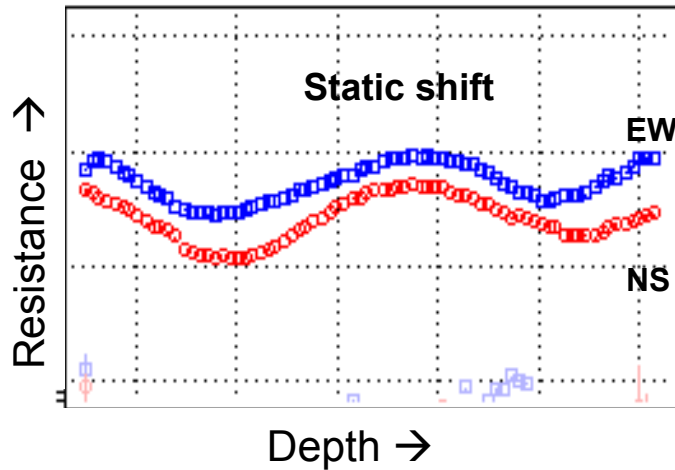
Common setup



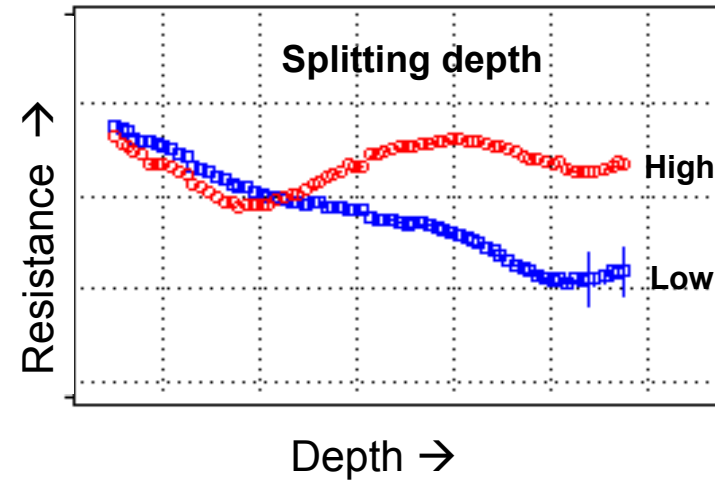
Common interpretation



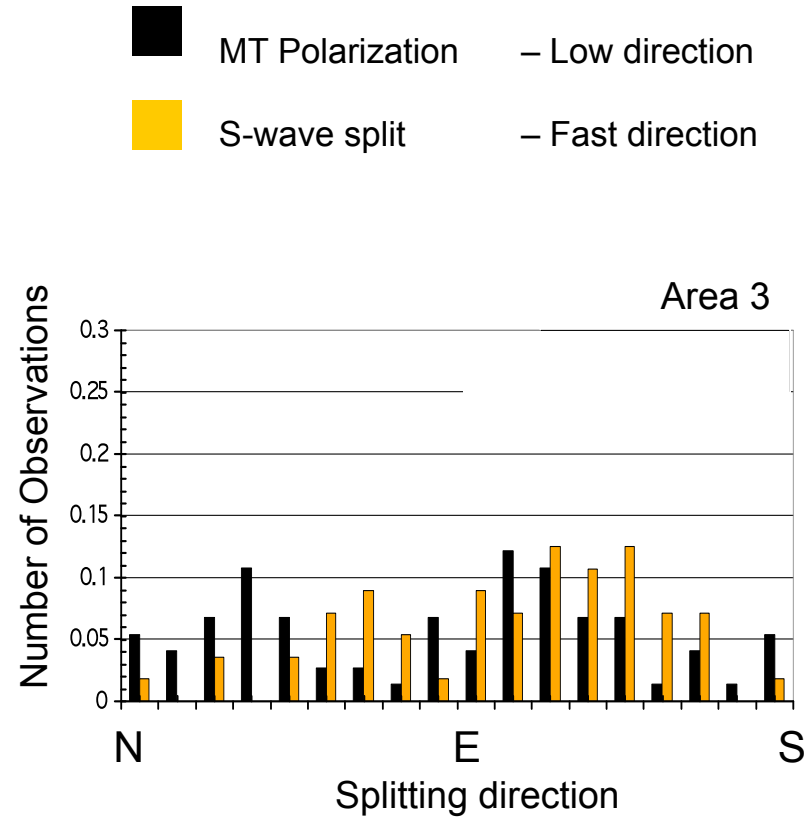
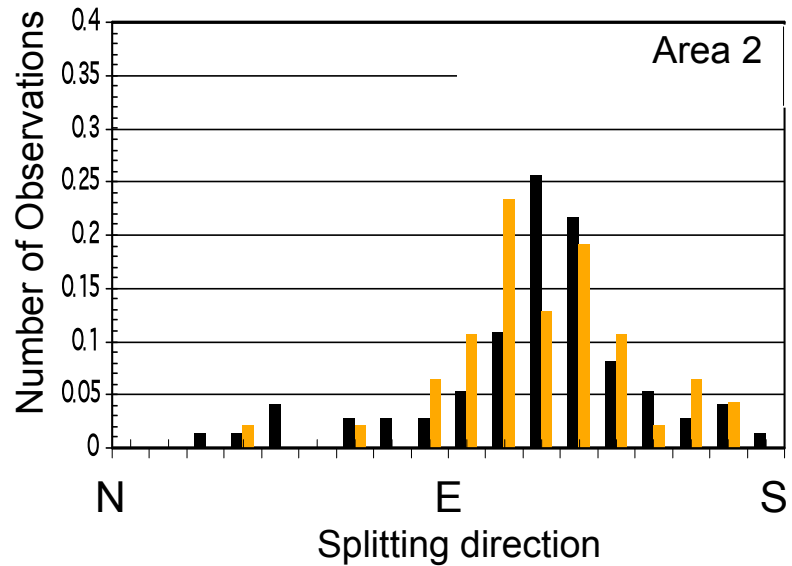
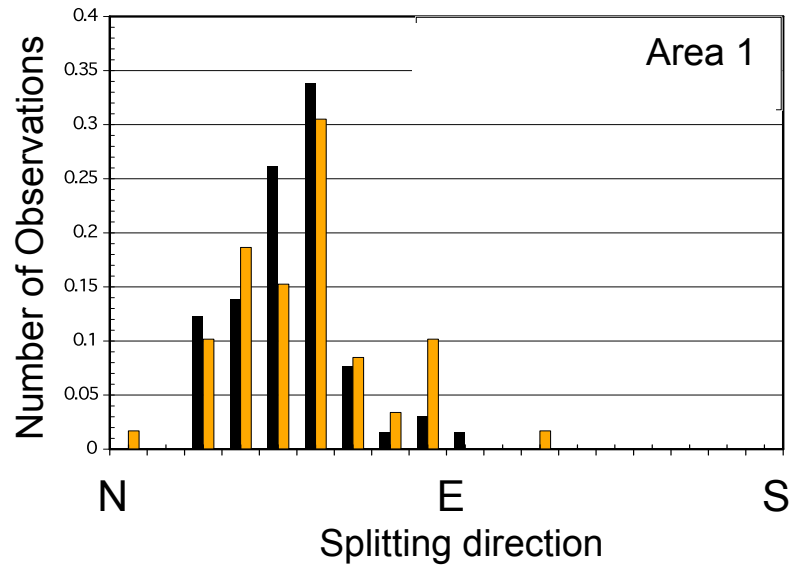
Common data



....Uncommon data



Areas of Aligned and No Aligned Fractures!



MT Polarization – Low direction
 S-wave split – Fast direction

Example: successful geothermal wells - Iceland

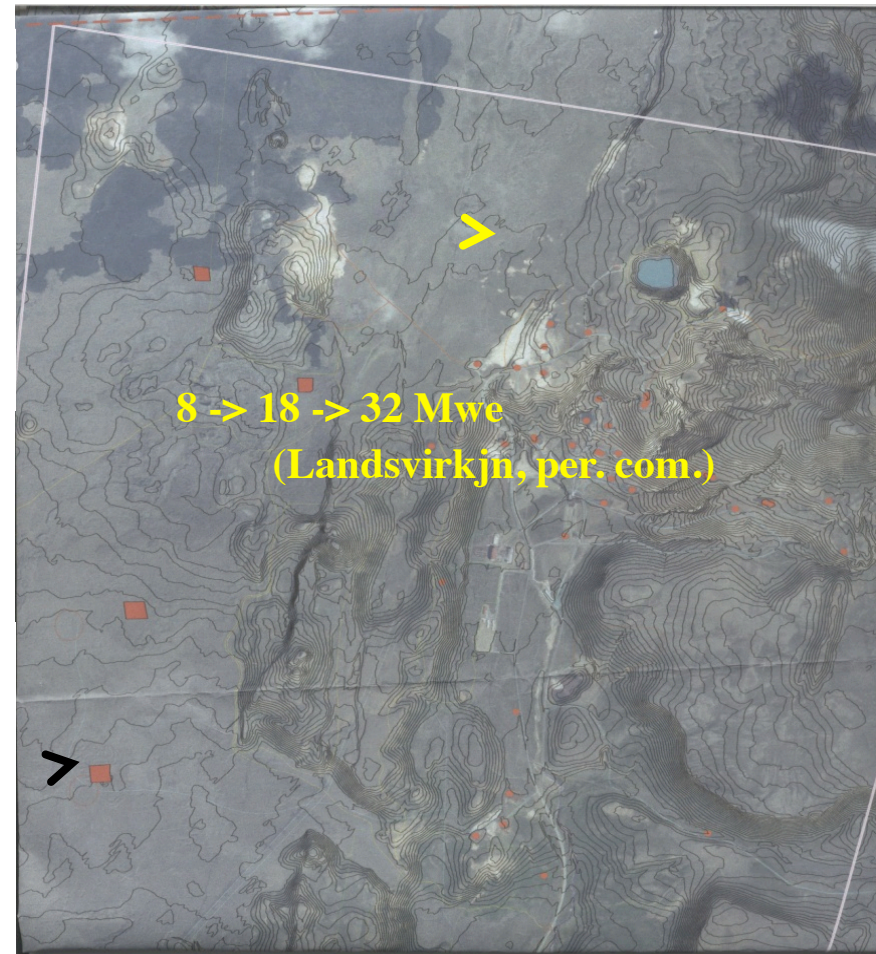
Both S-wave & MT splitting

3 successful wells - one 32 MW

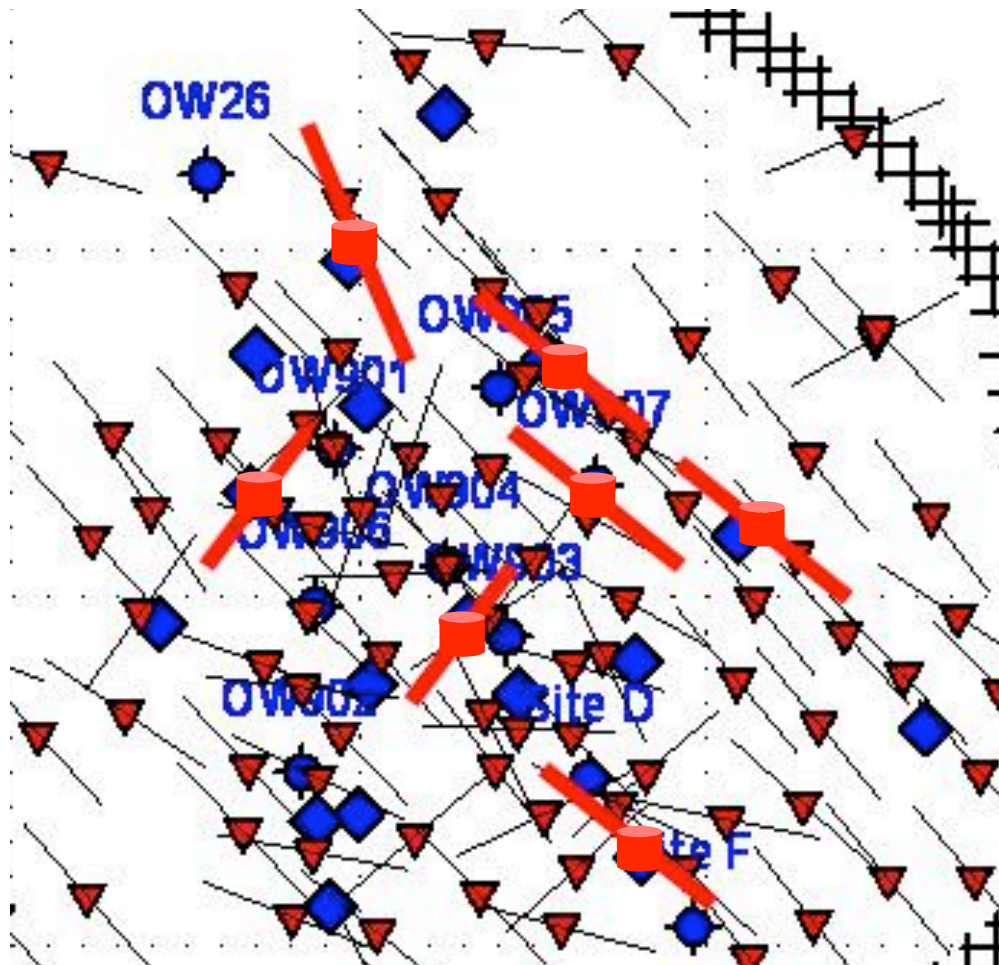
No splitting & polarization

1 dry well drilled

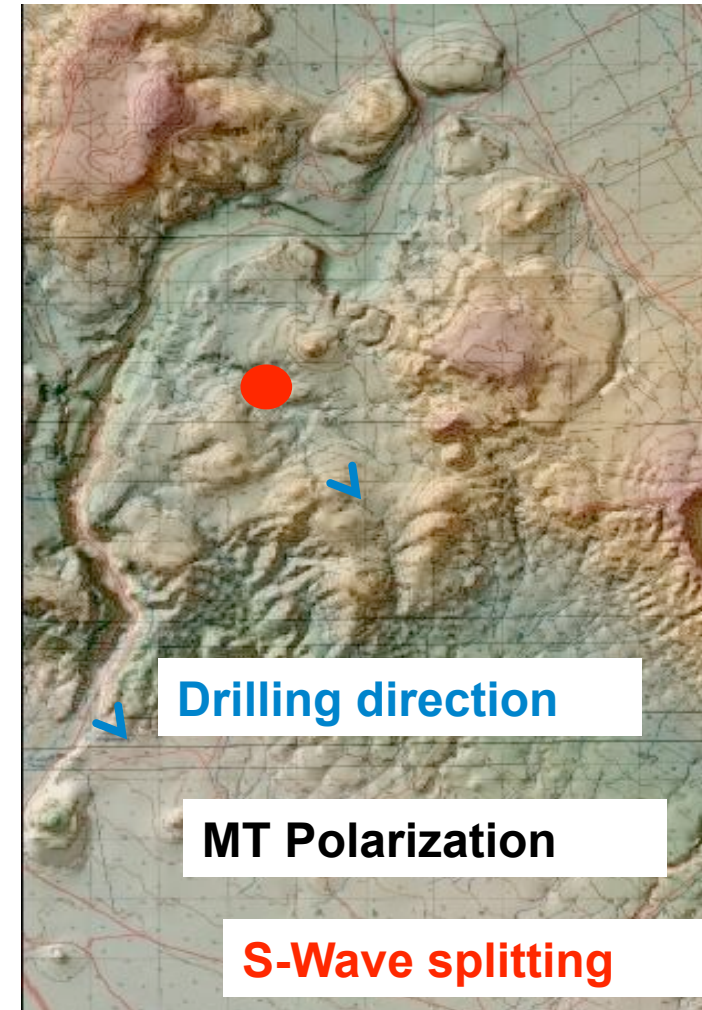
Pre – MEQ & MT drilling plan



Example: successful geothermal wells - Kenya

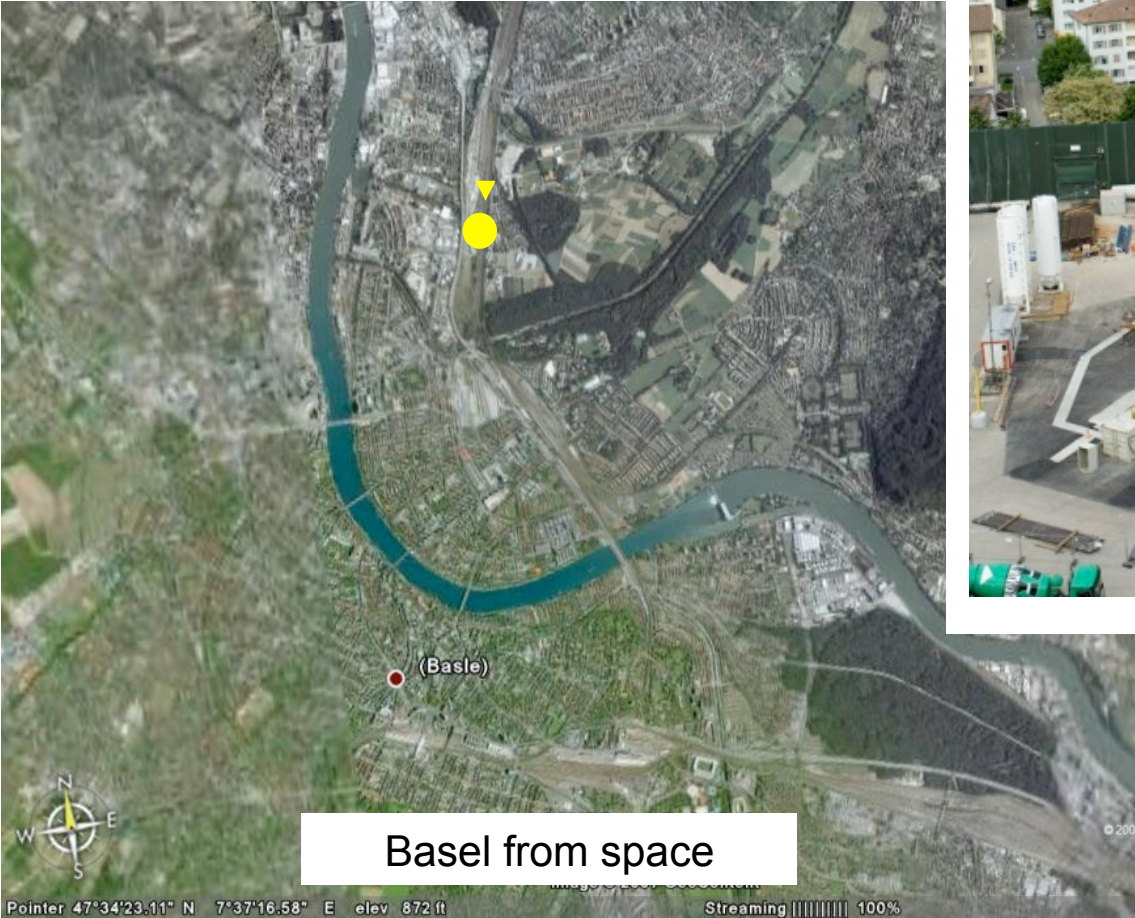


- ▼ MT site & low resistance direction
- Earthquake station & fast direction
- ◆ Drill site



Induced Earthquakes and Geothermal in
Downtown Basel, Switzerland!

“Hot/Dry Rock” well



Guess who got invited to
monitor the drilling?



Meanwhile....

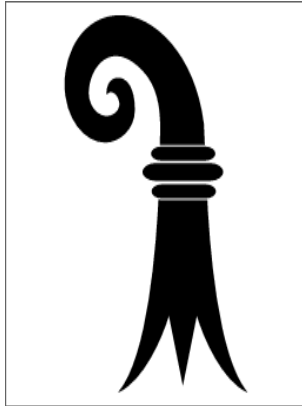
October 18, 2006 - 7:56 AM News

swissinfo.ch

Swiss emergency officials have been participating in a huge earthquake preparedness exercise

.... disaster simulation coincides with the 650th anniversary of the great Basel earthquake of October 18, 1356 – a 6.5 magnitude quake which destroyed most of the city.





swissinfo.ch

December 9, 2006 - 6:43 PM

Man-made tremor shakes Basel !

Drilling for a planned geothermal power plant triggered a small earthquake that caused minor damage to buildings.

.....The Basel City prosecutor has launched an investigation to find if the company behind the Deep Heat Mining project should pay for repairs.....

Prosecution

.....The prosecutor's office launched its investigation on Friday evening. The police have already seized computer data....

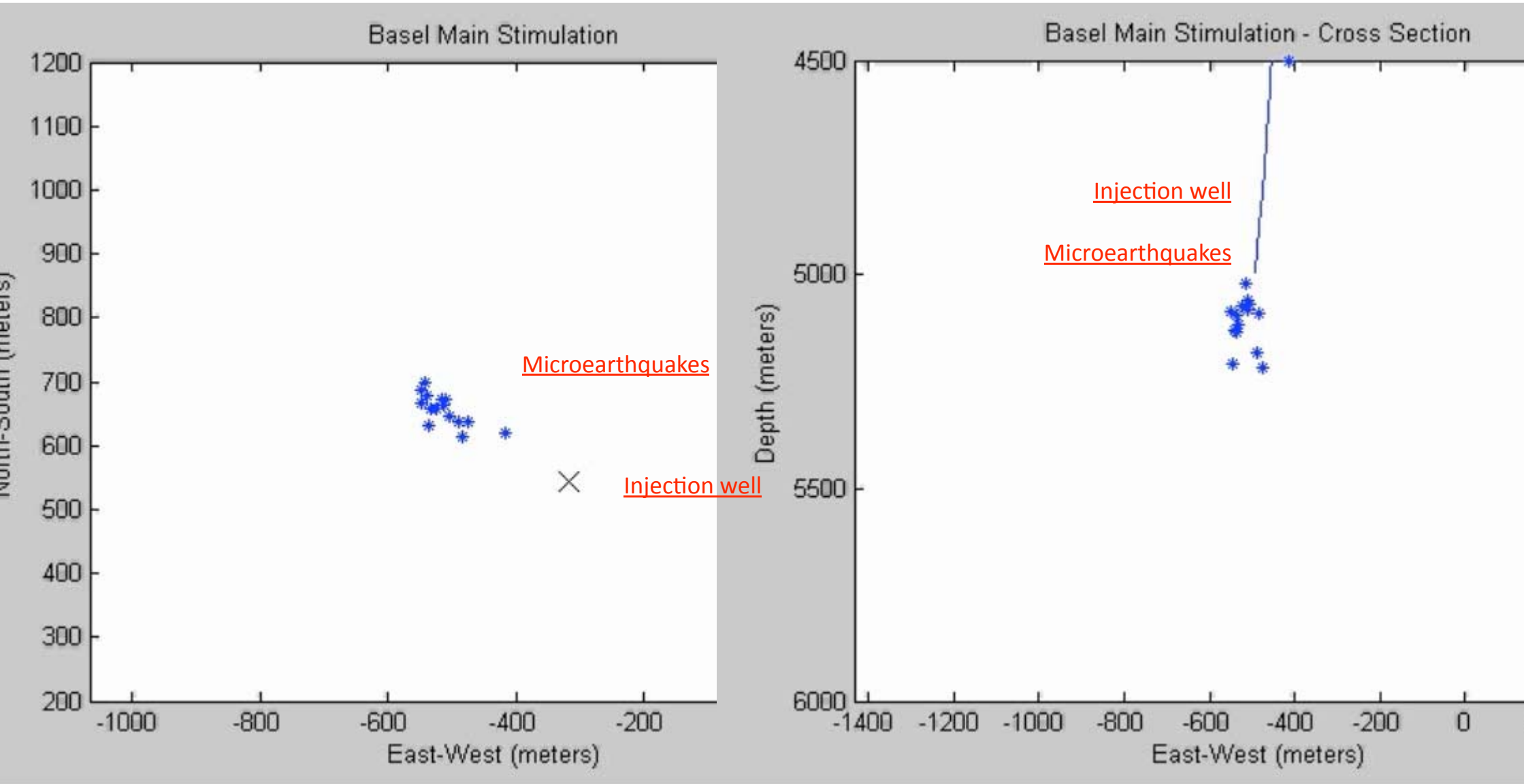


Hand over those
earthquakes, you
seismologist scum...

But *sir!*
I was just working on
my *PhD*...



The source of the problem – the connection between earthquakes and fluid flow



MAP

CROSS SECTION

What happened?

Number of event per hour:

Detected

Located

Magnitude

Magnitude



THANKS !



For the chance to share the
ADVENTURE!