Permeability increase by seismic waves

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Menu

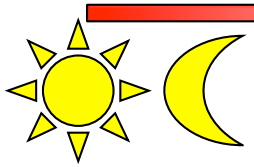
1. Tidal records by hydraulic wells

2. The Piñon Flat Observatory spectacular results

3. Some tentative explanations

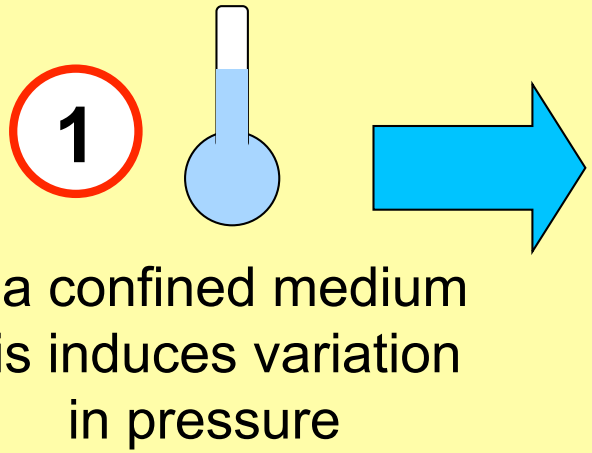
Summary: *1) Passive monitoring of hydraulic properties,*
2) Seismic waves disturbs permeability

Pore recording on tides



Two effects
1-Poroelastic response of the formation
2- Hydraulic properties of the formation

Tides deform the Earth and the formation surrounding the well

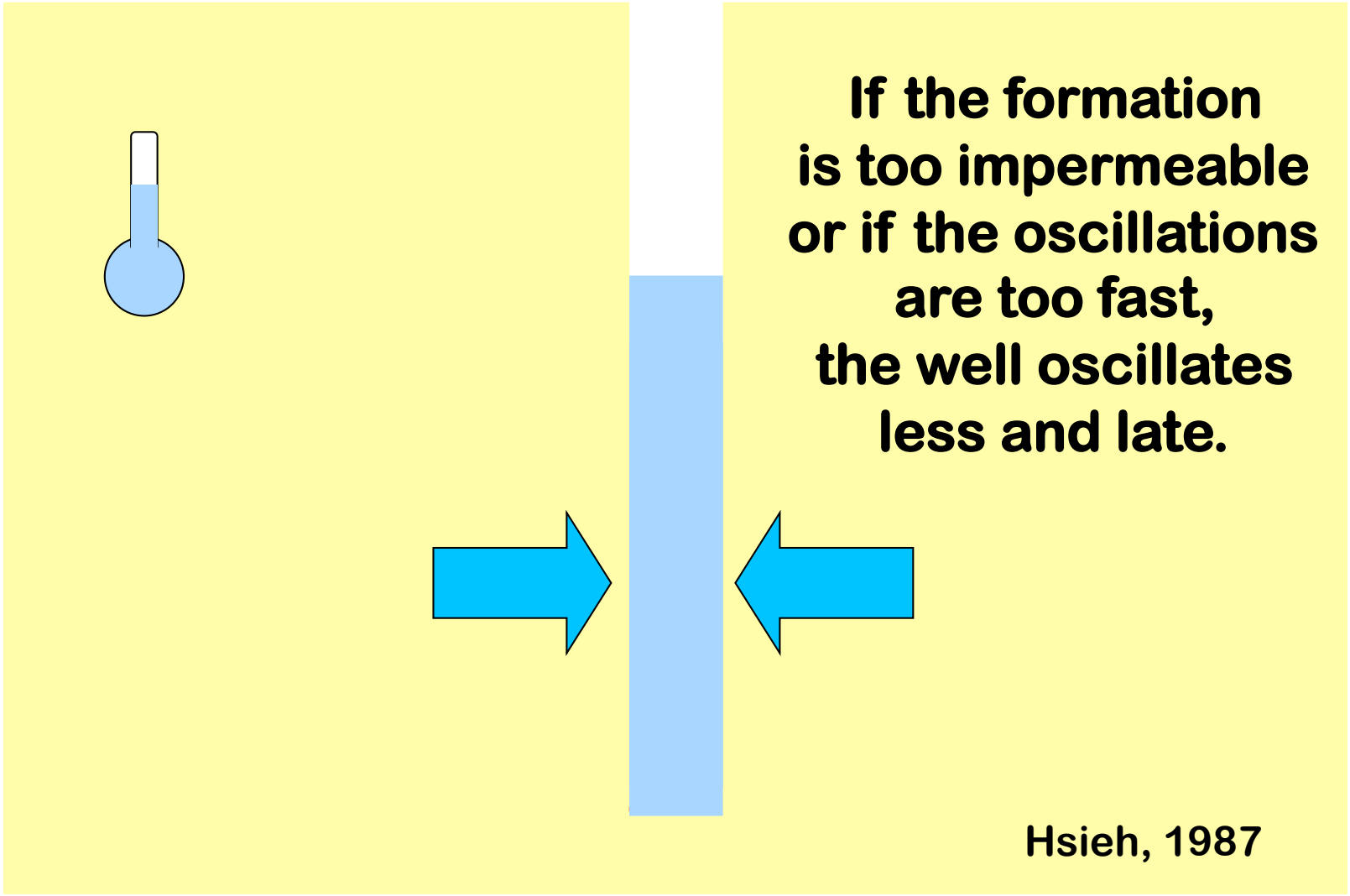


In a confined medium this induces variation in pressure

Water flows to the well to equilibrate the pressure

Tides are used for in-situ calibration

Permeability alters the tidal response



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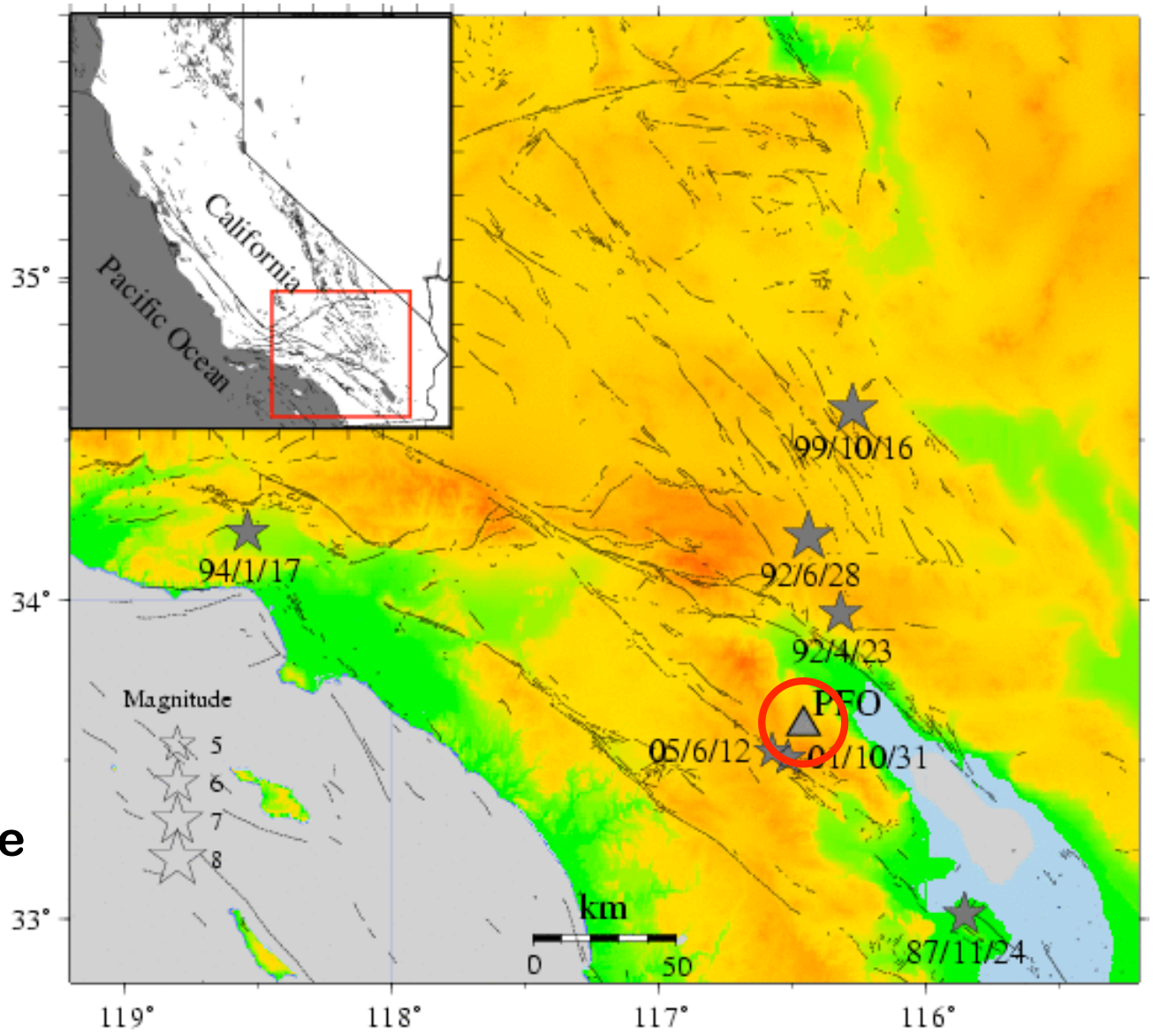
Piñon Flat Observatory

Dedicated to monitoring strain at the surface

More than 20 years of data

Setting: Fractured granite

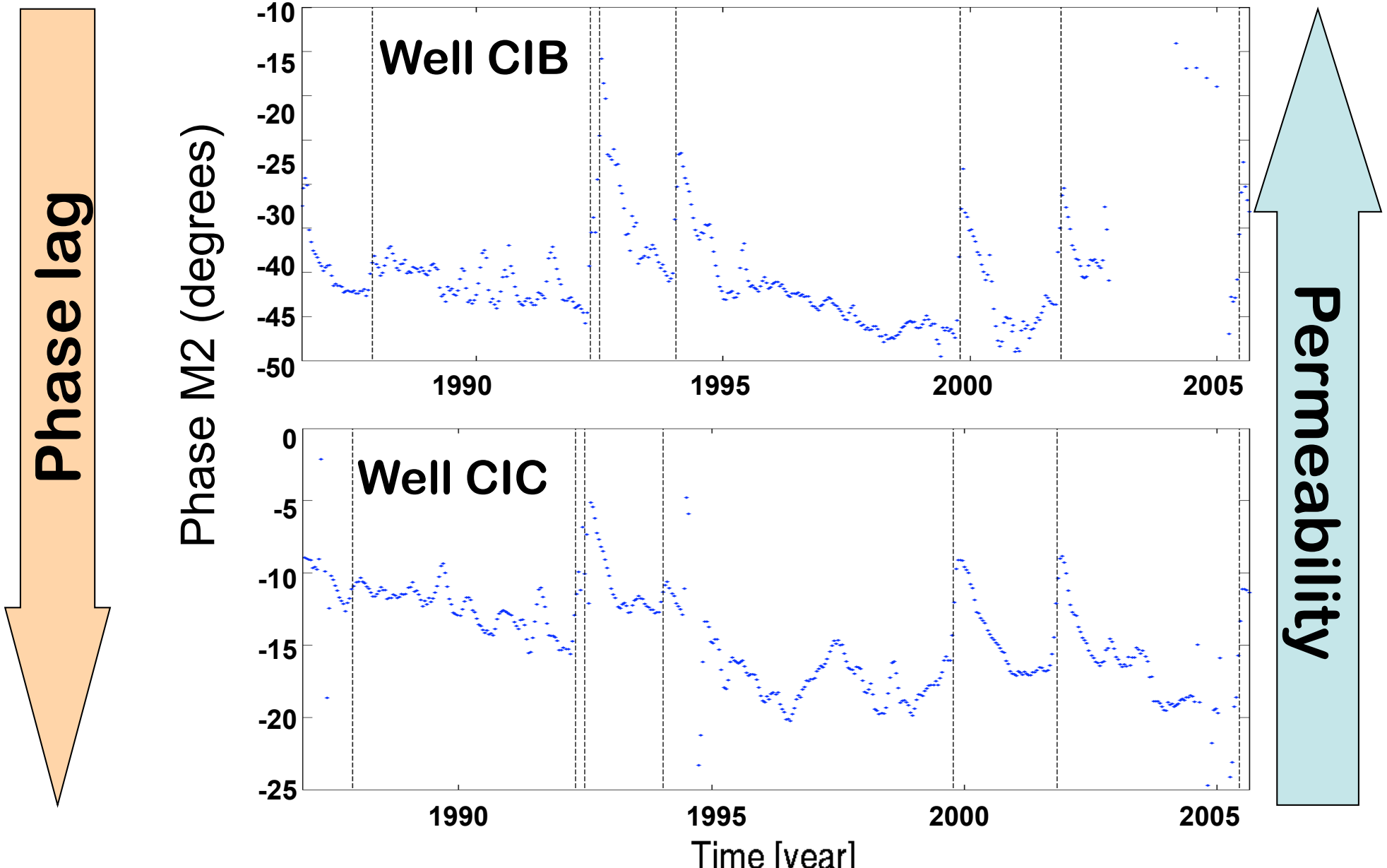


Elkhoury et al. 2006

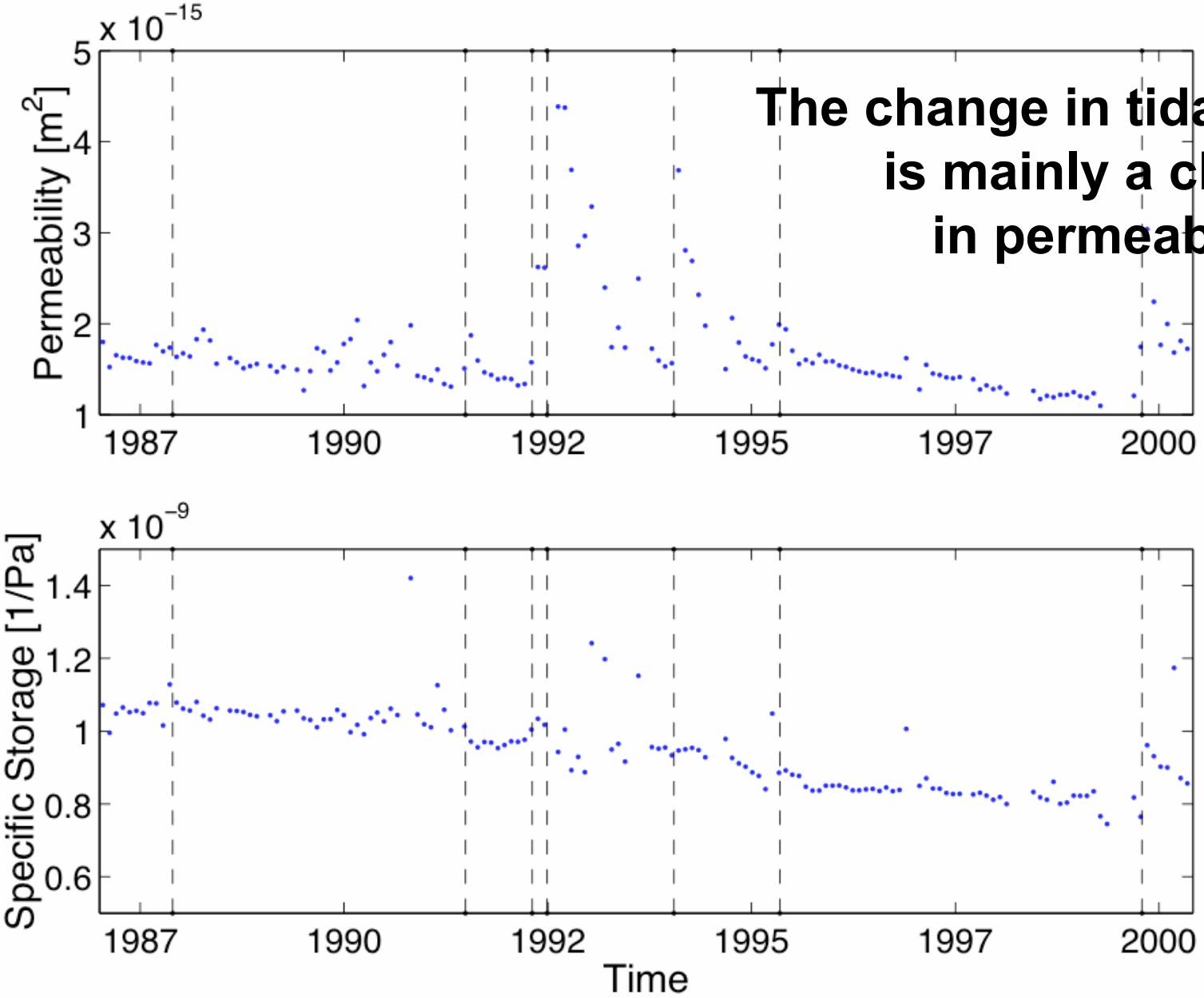
Seismic waves increase permeability

Tidal response ⇔ Permeability

Elkhoury et al. 2006

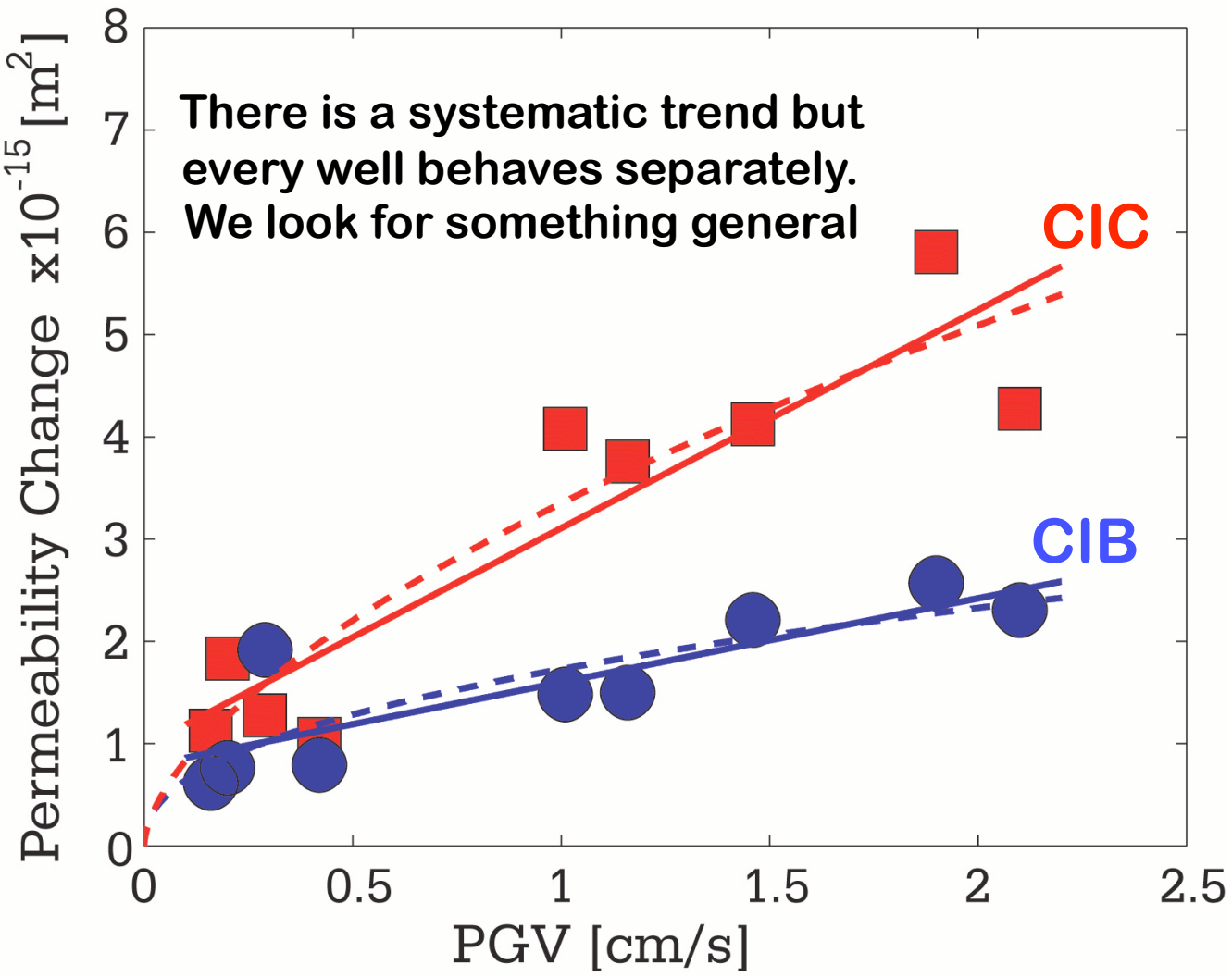


Inverting from Hsieh model



The change in tidal response is mainly a change in permeability

Seismic waves increase permeability



Elkhoury et al. 2006

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Seismic waves increase permeability

Why ?

Mechanical response?

But:

- teleseismic waves induce small displacement (~50µm)

-the strainmeters at the surface were not affected.

- aquifer storage is poorly affected

- how to explain the recovery ?

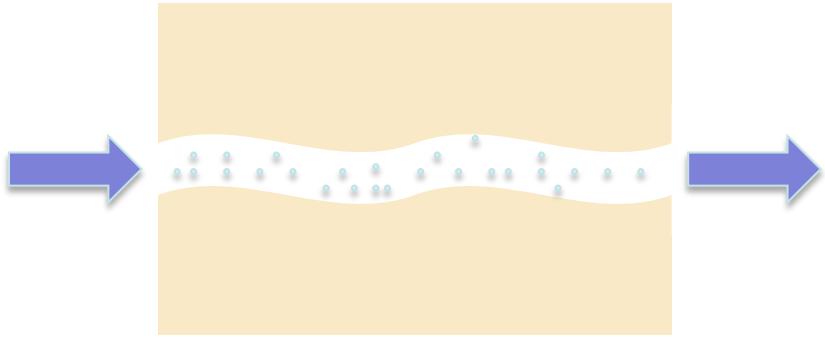
Unclogging of fractures?

Why ?

~~Mechanical response?~~

Hydraulic change ?

Why not explaining the recovery of the tidal response to the initial behavior with unclogging of fracture ?



(1) Initially fracture is clogged by a colloidal mixture / granular packing formed with the particles separated from granite by weathering

(2) The particles could be flushed by water flow generated from the seismic waves

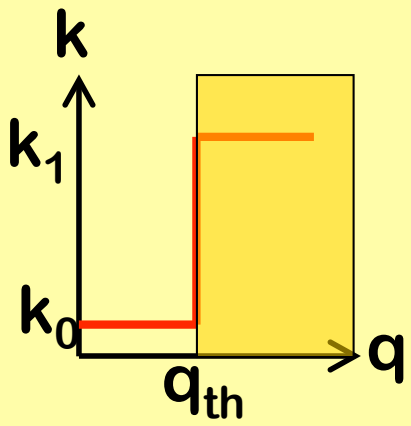
Unclogging

Problem : Large wavelength of seismic oscillatons

⇨ Uniform hydraulic head ⇨ No flow

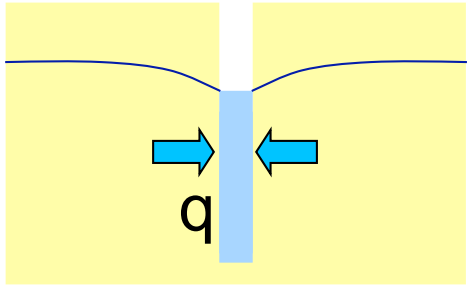
Hydraulic head

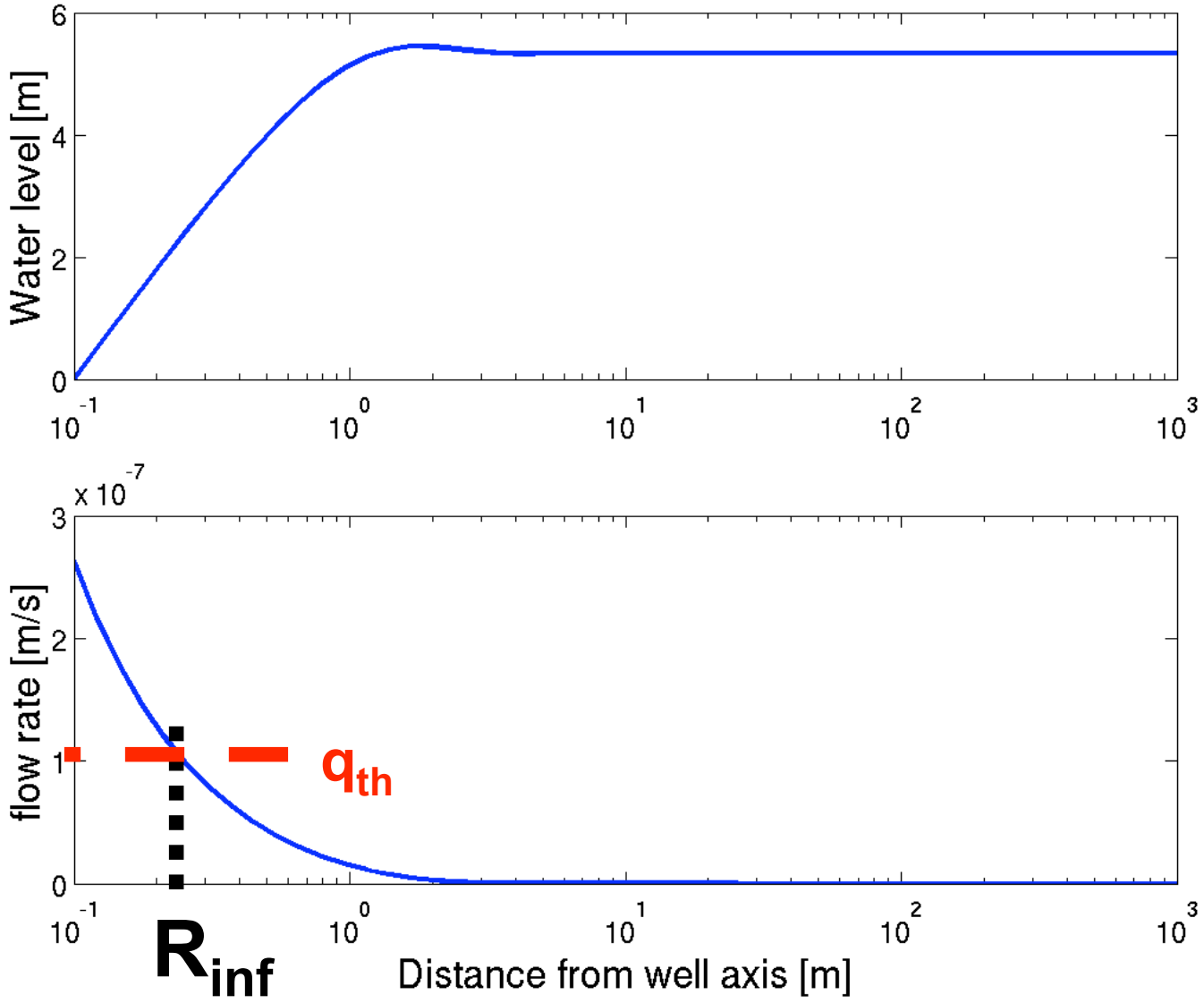
q

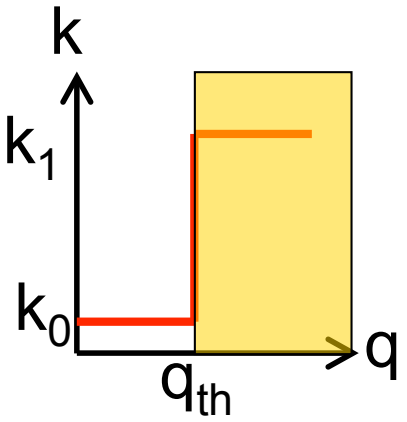


Flow induced by the borehole

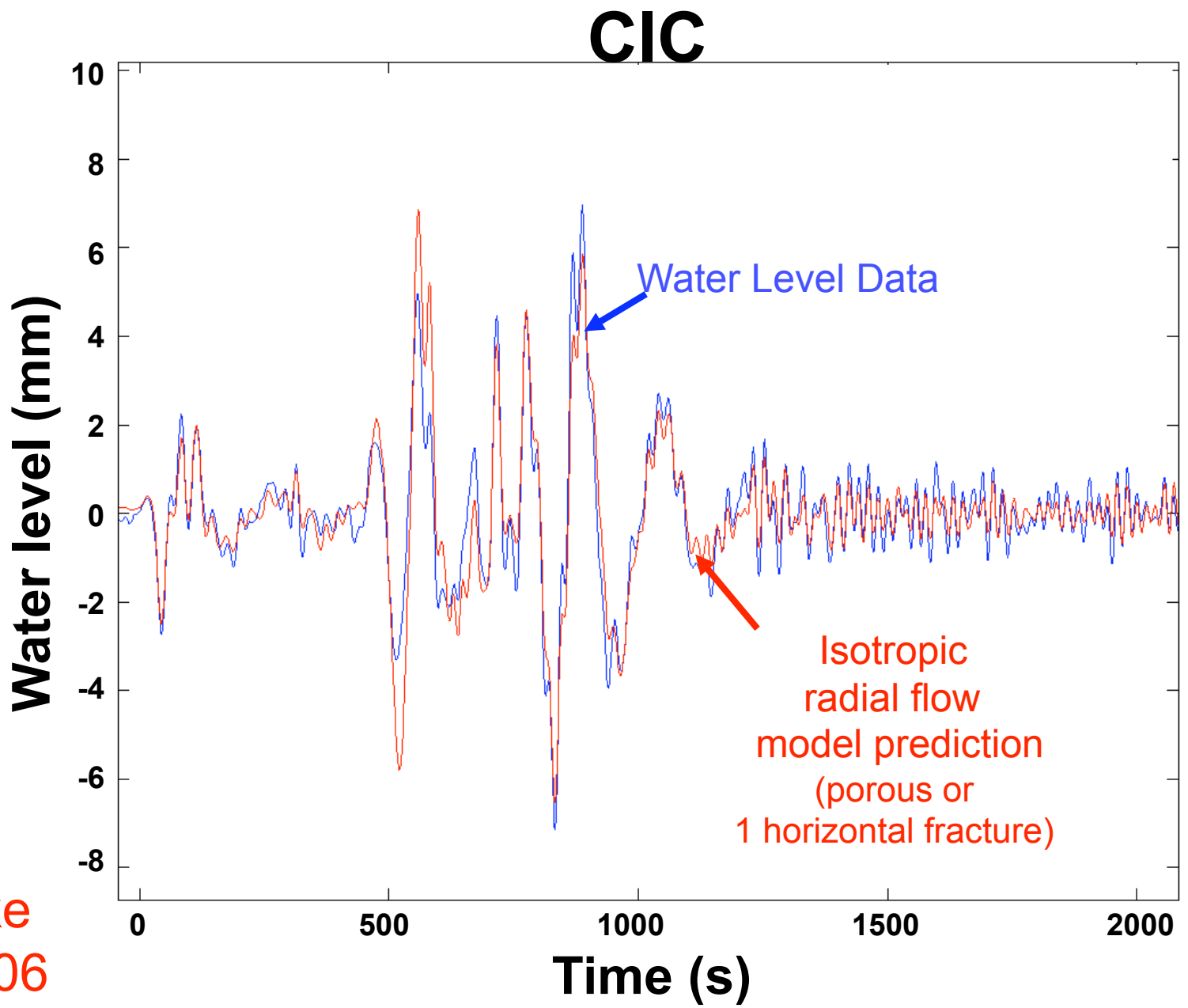
We adapt the Hsieh model to predict the flow around the hole.
Hyp: radial flow -> Porous medium or horizontal fracture





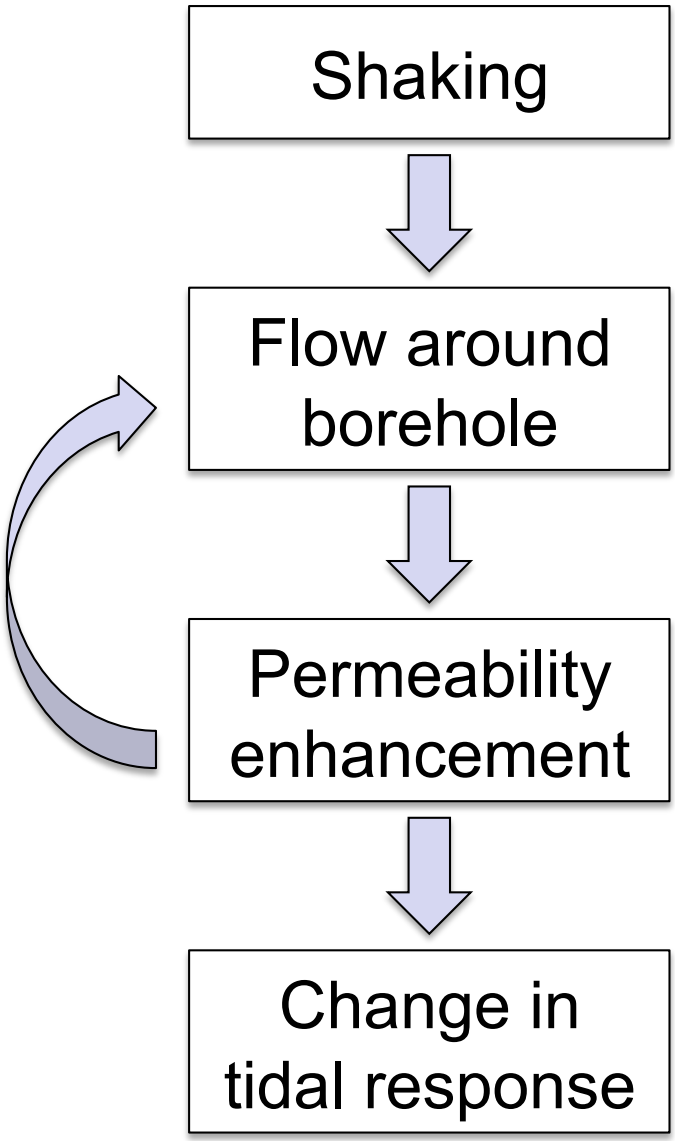


The flow model works!



Kuriles
earthquake
Nov 15 2006

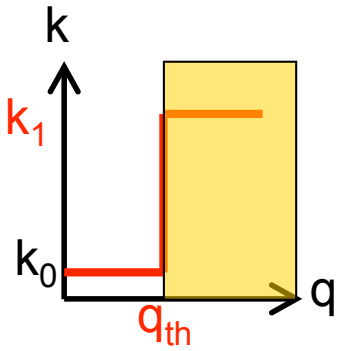
Computation effect unclogging



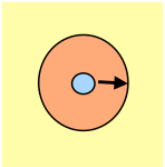
We start with the volumetric strain derived from the seismograms

Adapted from Hsieh, 1987

Ad-hoc model wih only two parameters

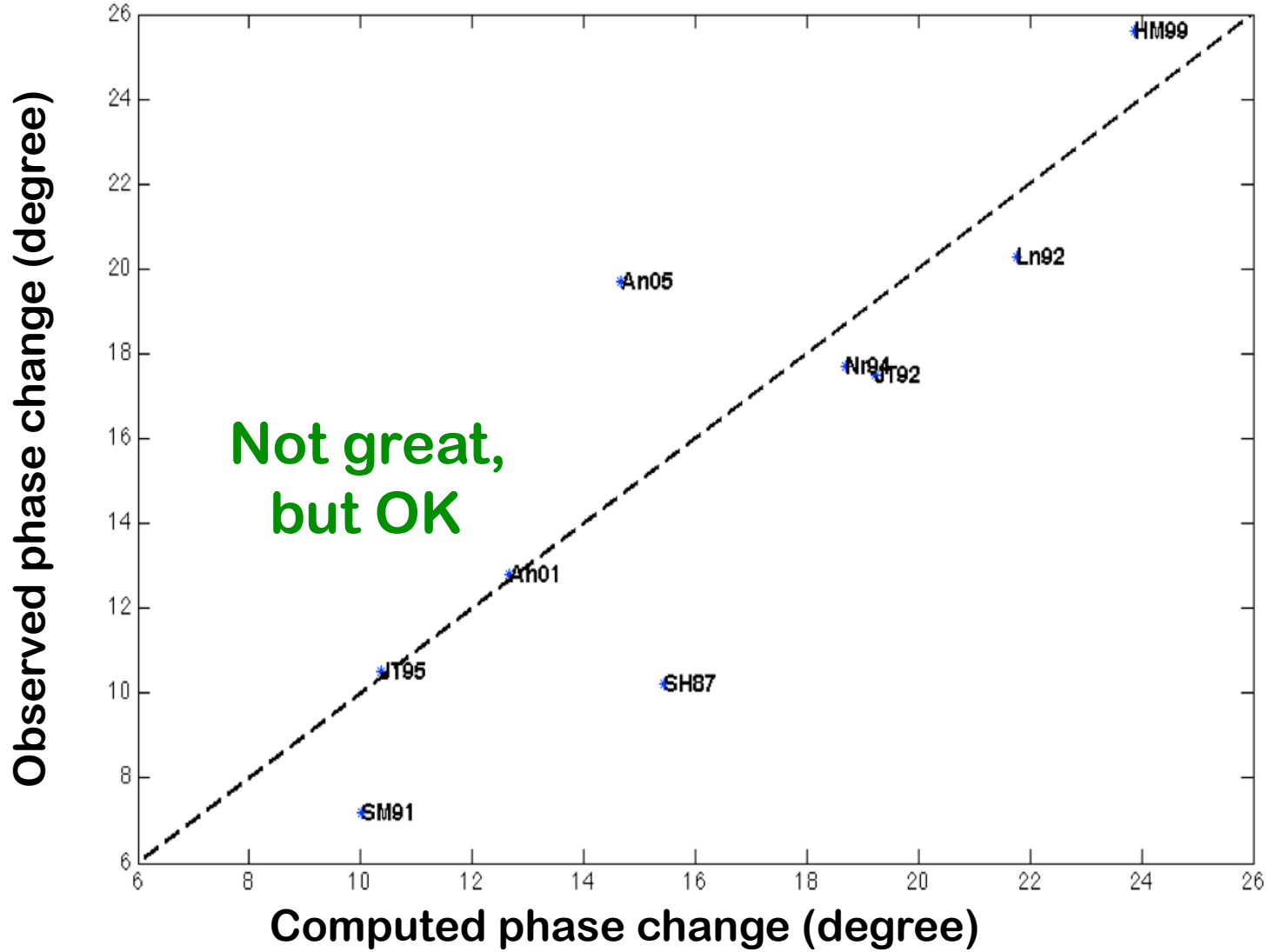


Tidal response computed within a heterogeneous medium



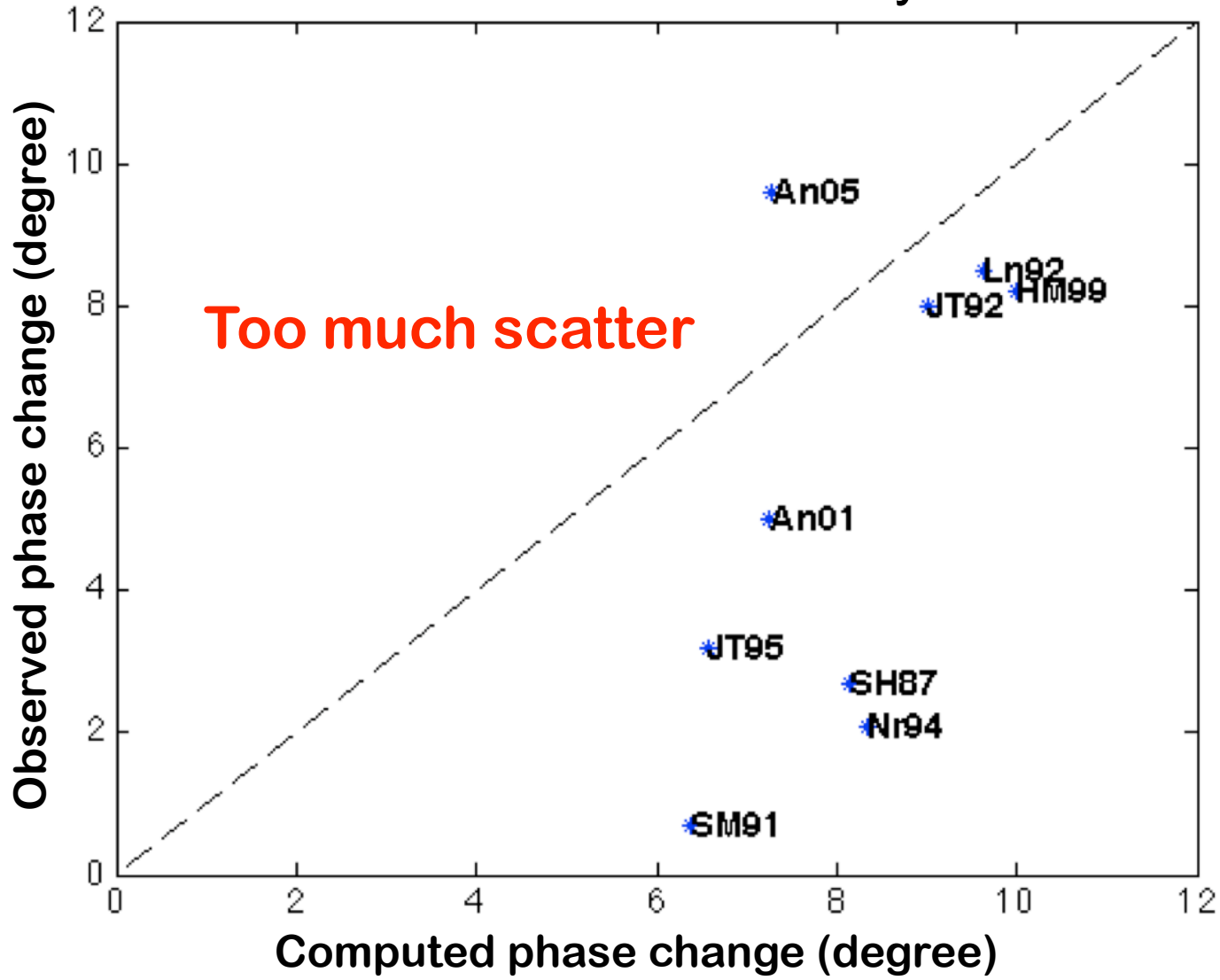
Best fit CIB

$T_0=10^{-5}$m/s $q_{th}=10^{-9}$m/s
Enhancement by 6



Best fit CIC

$T_0=10^{-5}$m/s $q_{th}=10^{-8}$m/s
Enhancement by 6



Conclusions

Hydraulic properties of rock was affected by seismic waves

A possible explanation might be
the unclogging of fracture by fluid flow

In the case of the Piñon Flat Observatory,
the hydraulic system is poorly constrained:
no fracture network mapping, no pumping test…

We can do better!
Is LSBB a better site to study
fracture network sensitivity to shaking?