Frequency characteristics of the response of water pressure in closed well to volumetric strain in high frequency domain

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Outline

1) Observation results due to the seismic wave of the 2010 Chile earthquake (Mw8.8)

Frequency characteristics of response of water level/pressure to strain

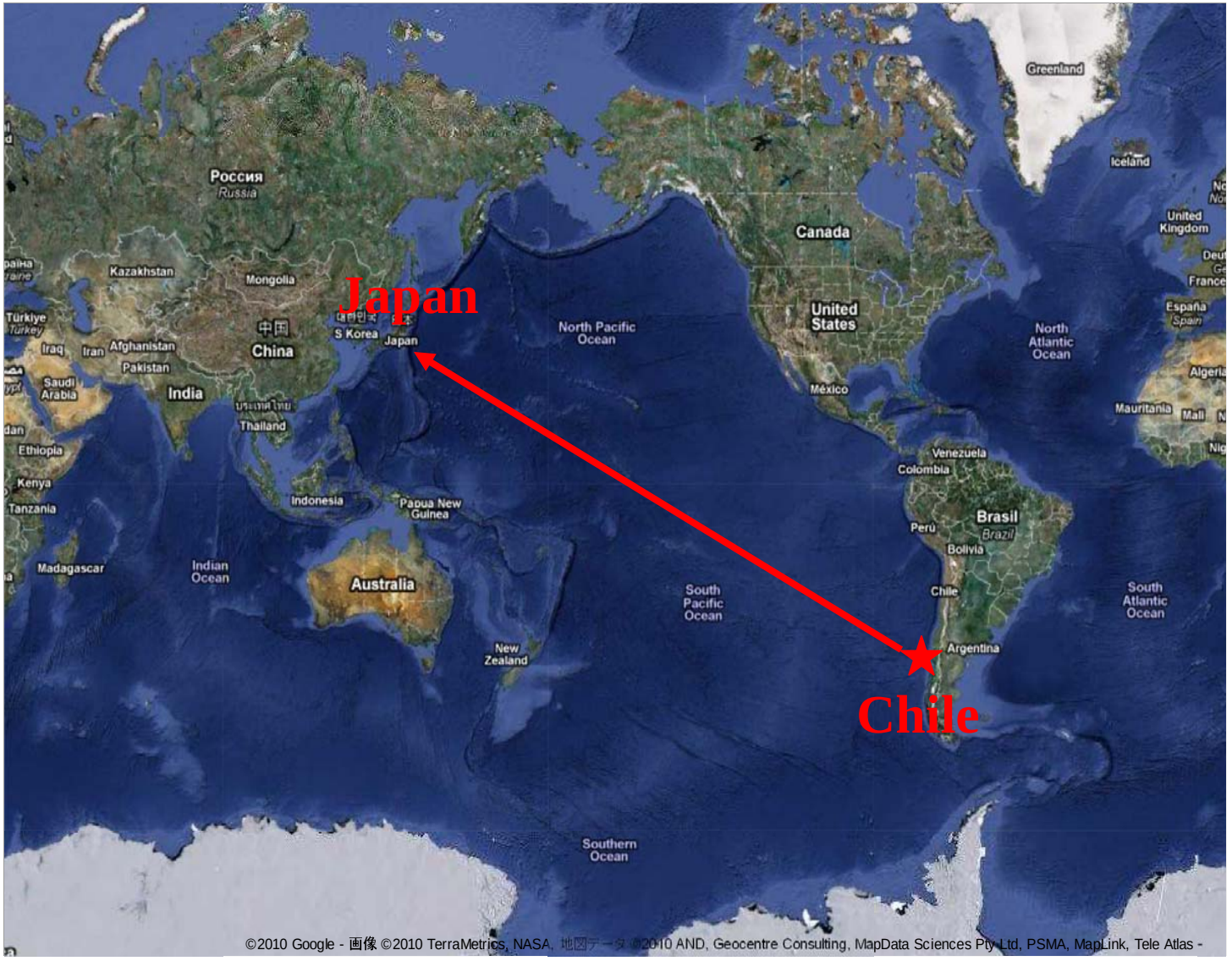
2) Formulation of water pressure response in closed well to volumetric strain

Previous researches for water level in open well

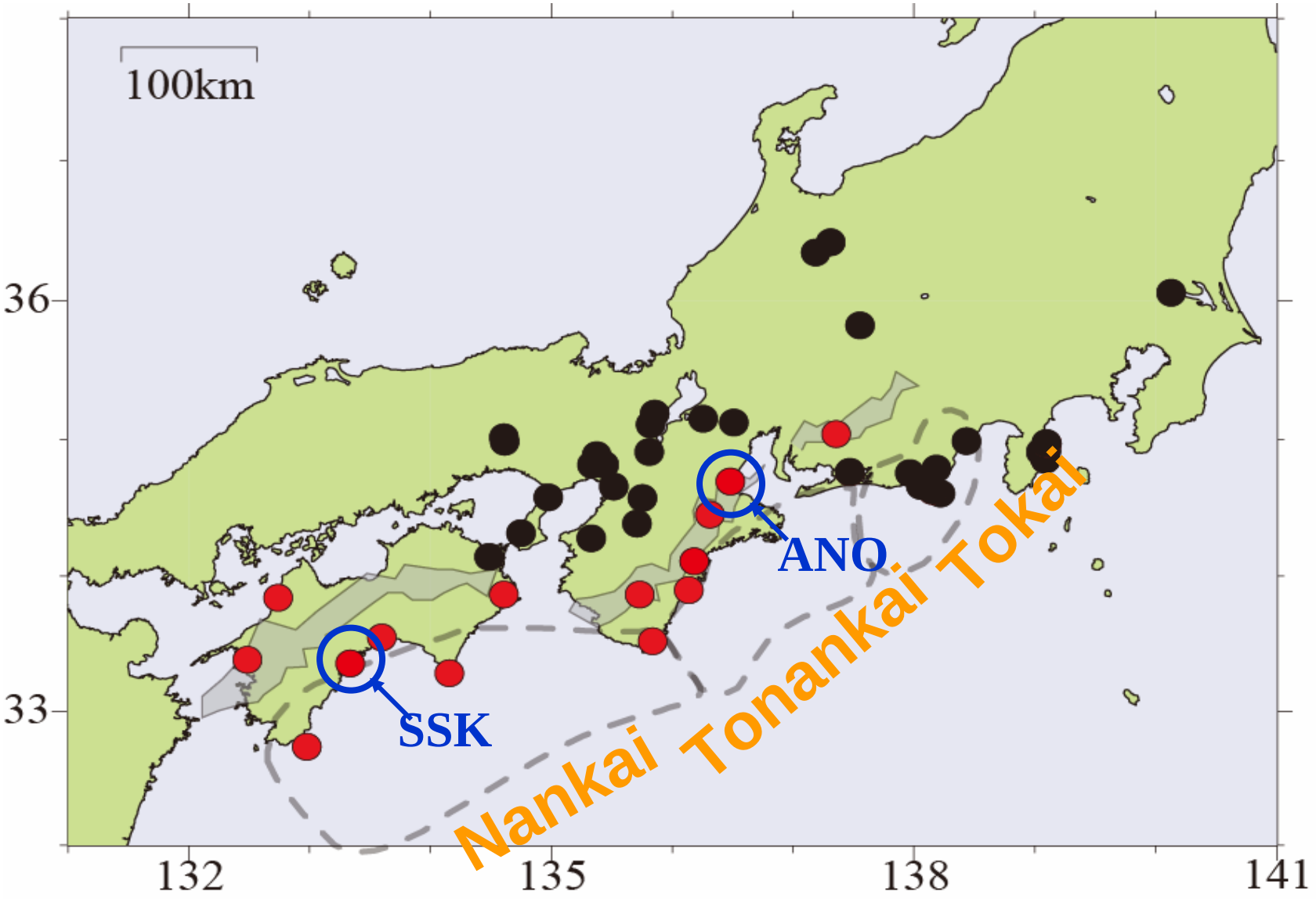
Key point of the formulation

Comparison the observations with formulation for water pressure in closed well

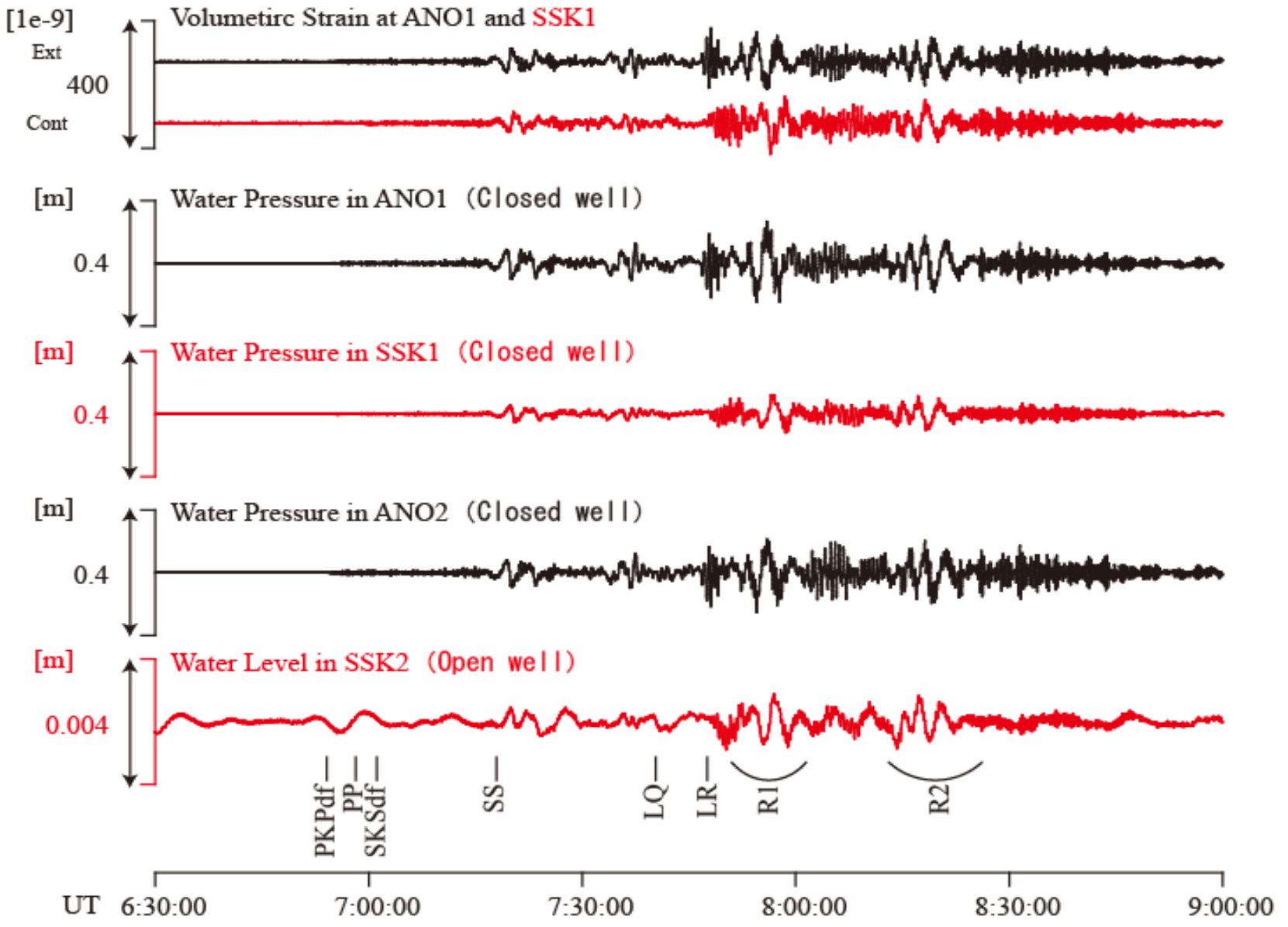
Epicenter of 2010 Chile EQ



Integrated Groundwater Observation Stations of GSJ, AIST

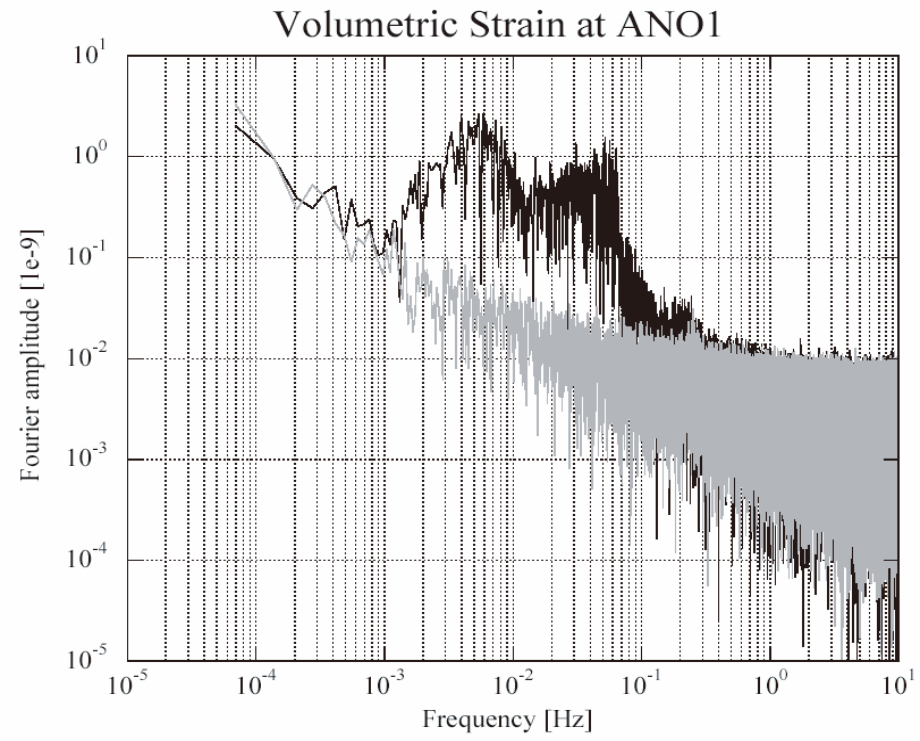


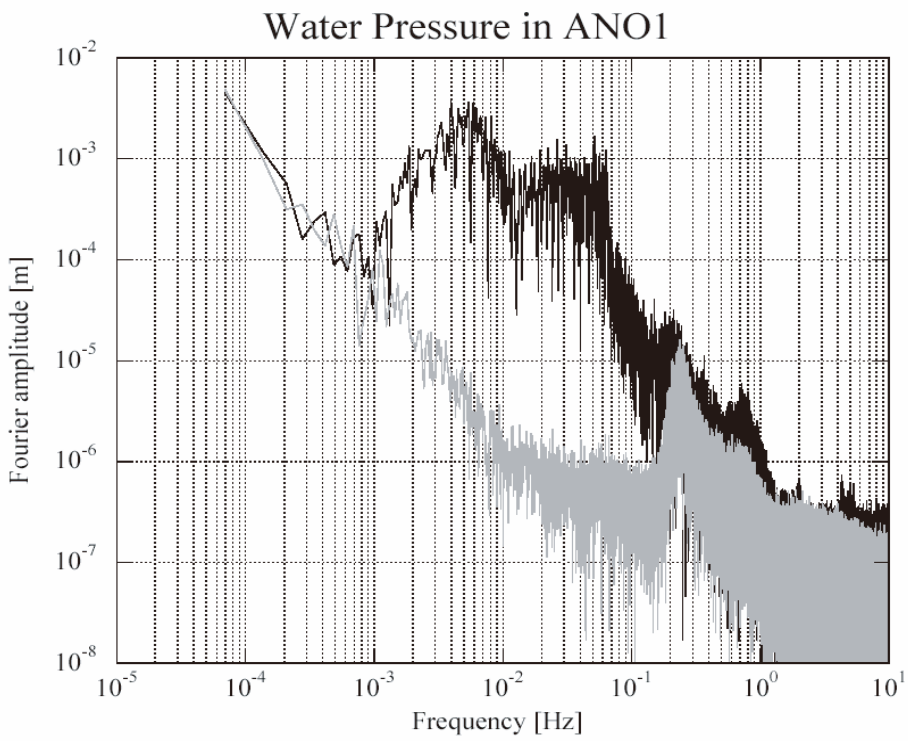
Observation results



The traces by applying a band-pass filter from 0.002 Hz to 0.1 Hz

Amplitude spectrums

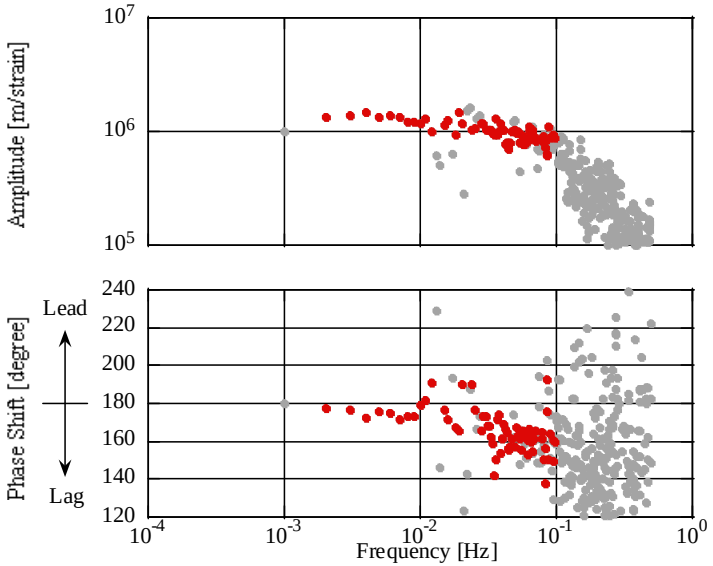




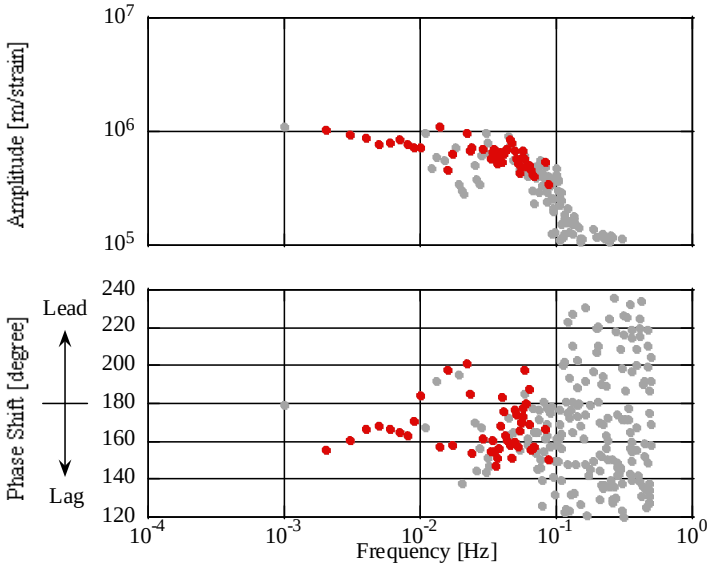
Signal due to the seismic wave of the earthquake is from 0.002 to 0.1 Hz around 0.004-0.006 Hz and 0.03-0.06 Hz

Amplitudes and phase shifts of the responses

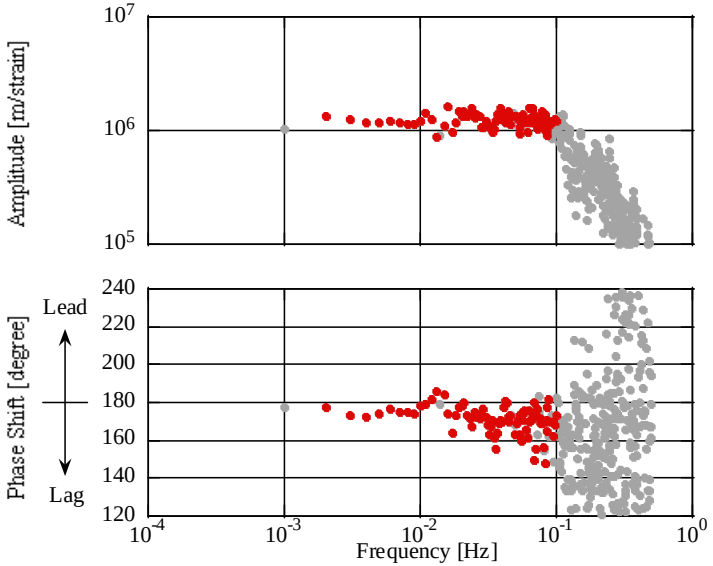
ANO1 Closed well



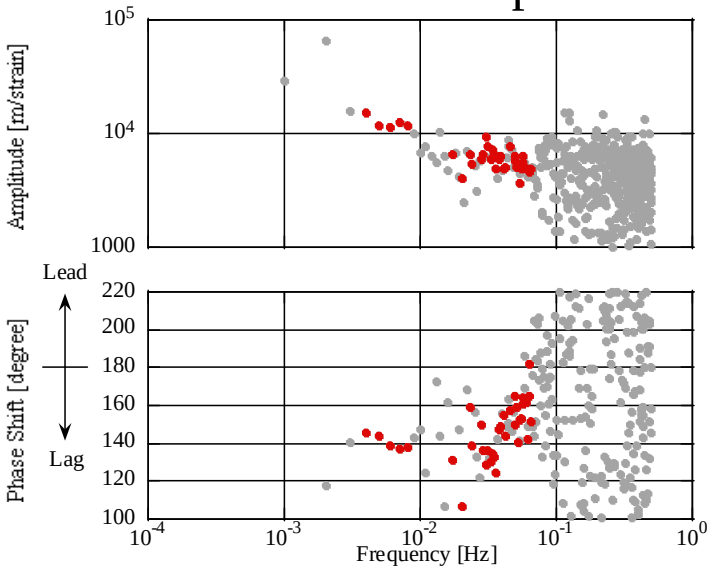
SSK1 Closed well



ANO2 Closed well



SSK2 Open well



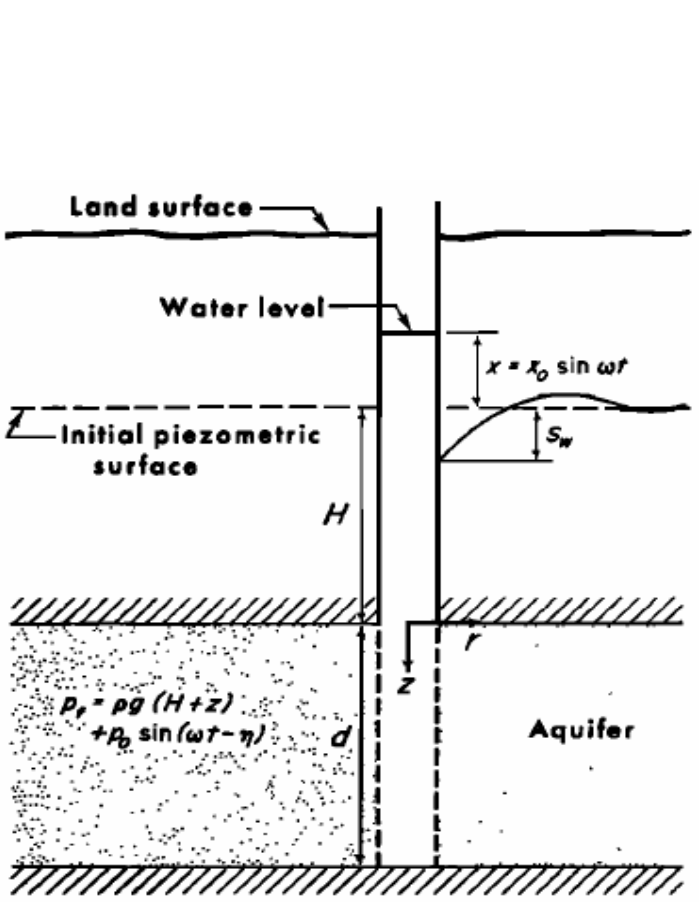
Summary of the responses

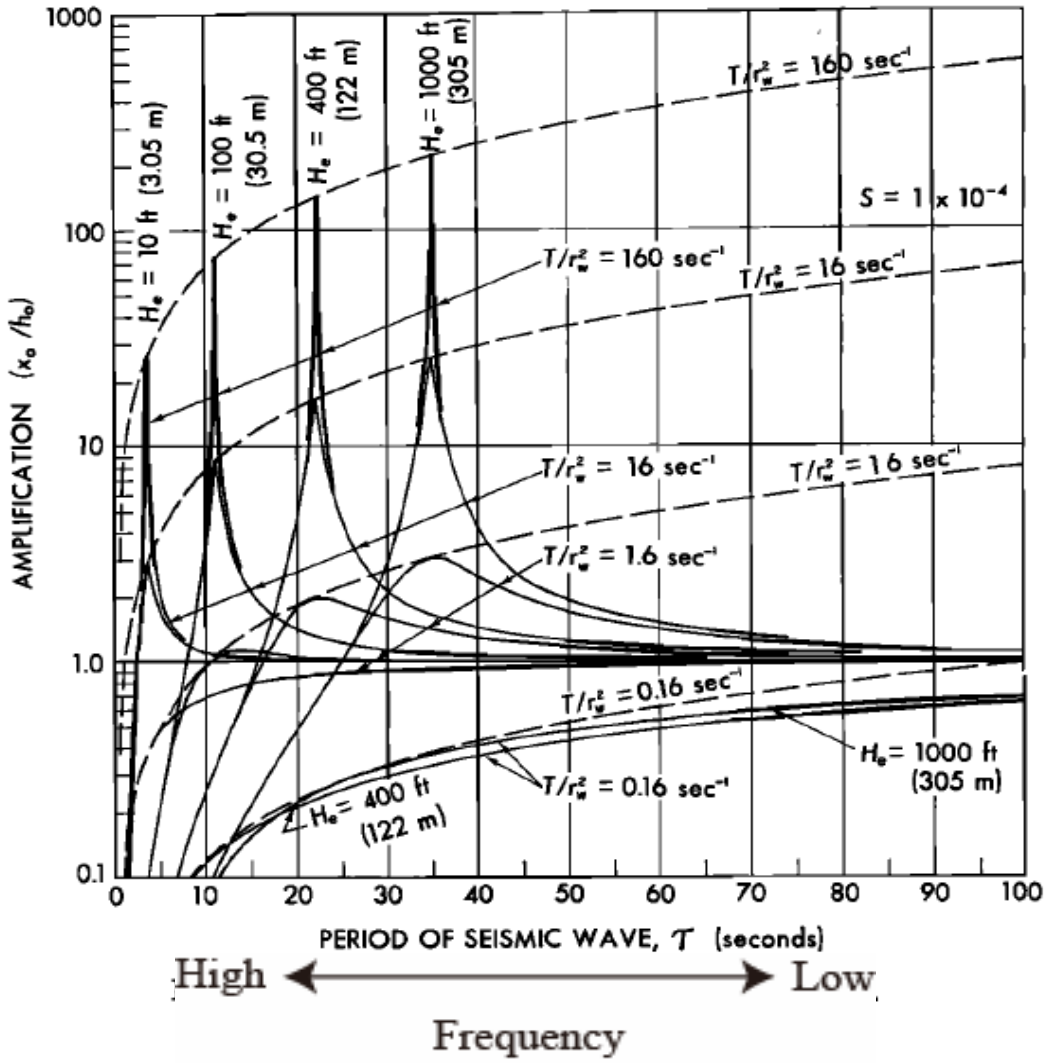
1) ANO1 and SSK1 (closed wells) are characterized by small amplitude and a little phase lag in the high frequency side.

2) ANO2 (closed well) has constant amplitude and a little phase lag .

3) SSK2 (open well) is characterized by very small amplitude and large phase lag.

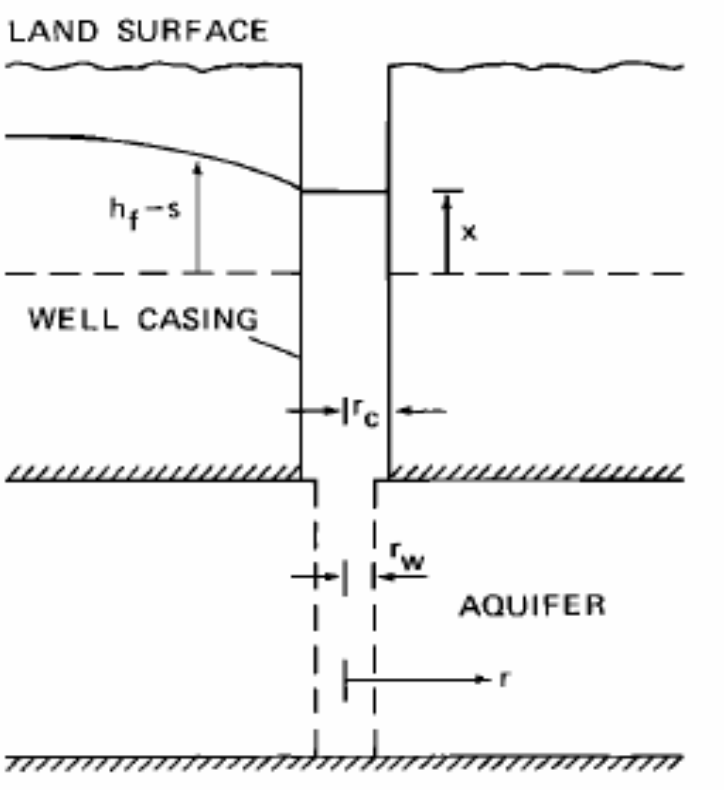
Previous research : Cooper et al. (1965)

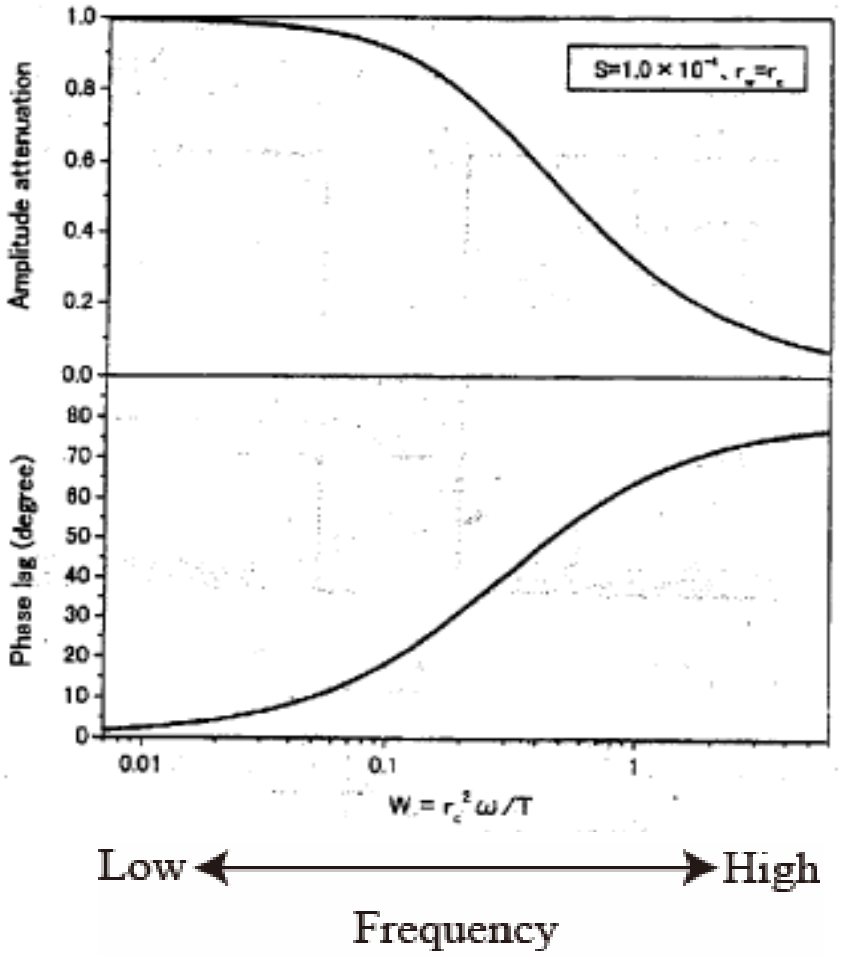




the amplification of the response due to resonance
the attenuation of the response in the high frequency range

Previous research : Hsieh et al. (1987)

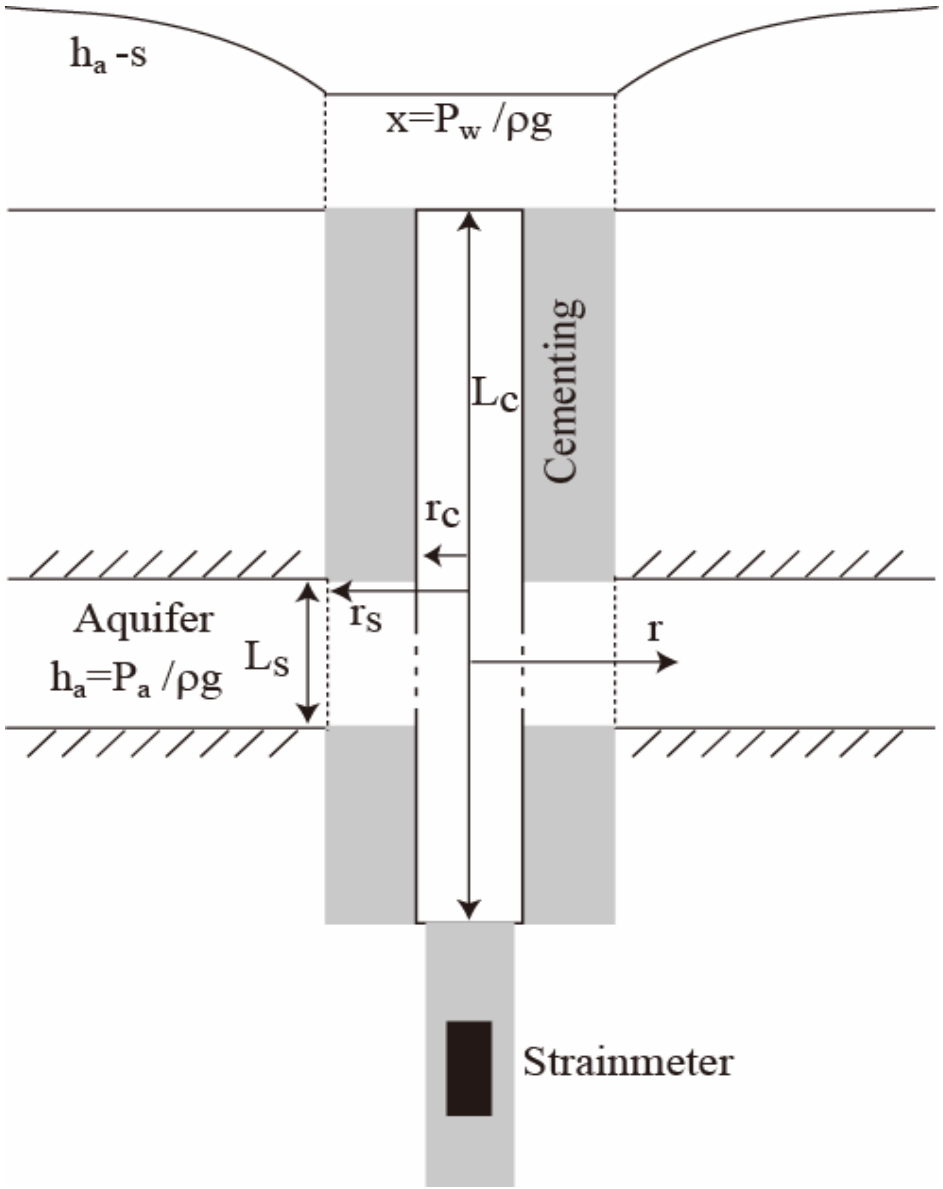




From Hosoya and Tokunaga (2003)

the attenuation of the amplitude and large phase lag
in the high frequency range

Formulation for water pressure response in closed well



Key point is the elastic deformation of water

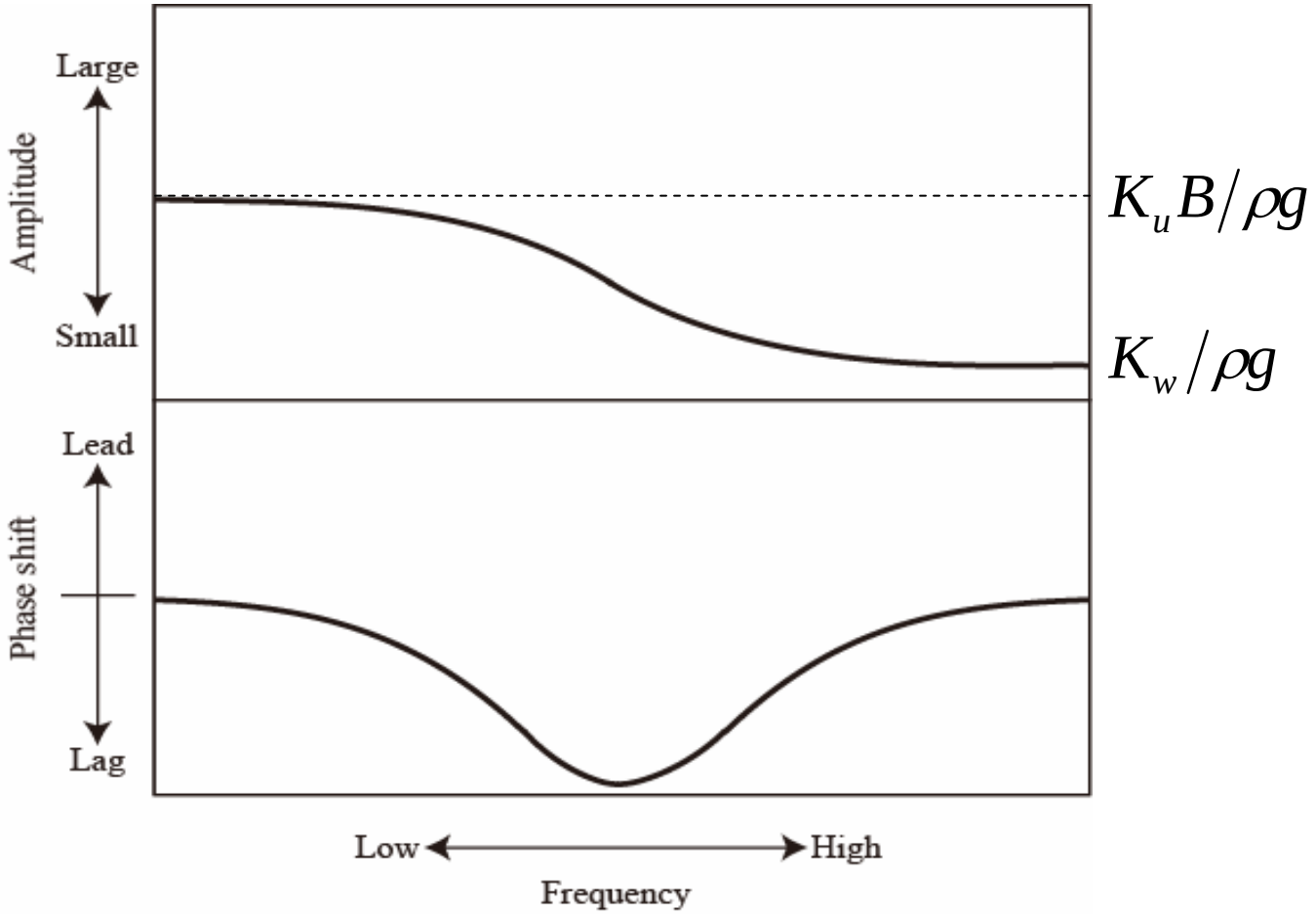
$$P_{\varepsilon_{kk}} = -K_w \varepsilon_{kk}$$

$P_{\varepsilon_{kk}}$: water pressure in closed well

K_w: the bulk modulus of water

ε_{kk} : volumetric strain change of the well-aquifer system

Schematic of the responses of water pressures to strain



K_w : the bulk modulus of water

K_u : the undrained bulk modulus of the aquifer

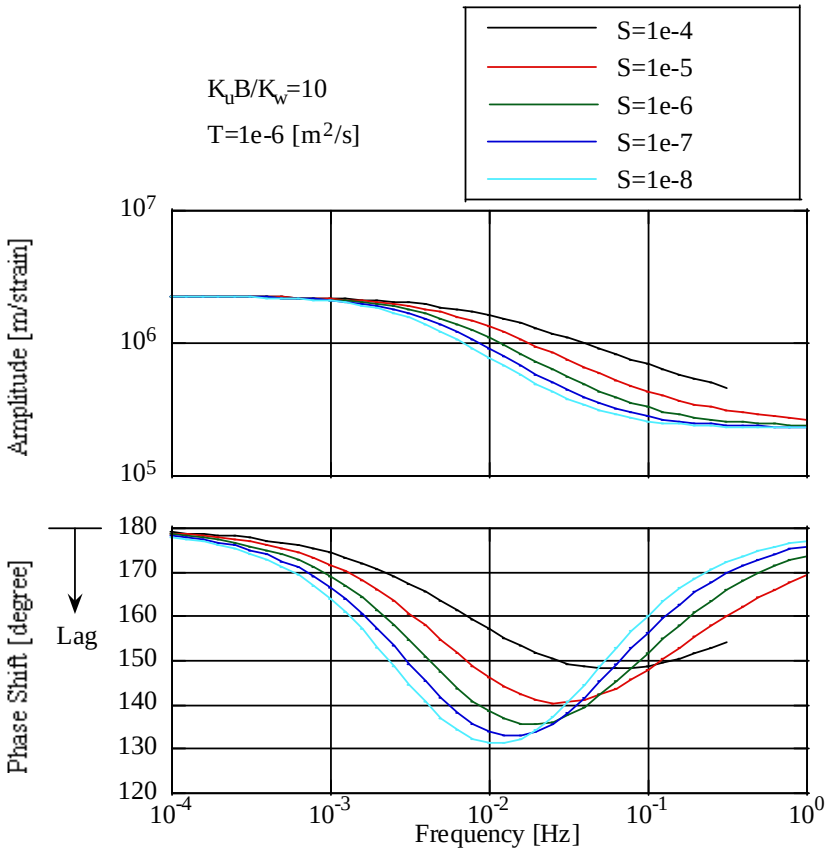
B : the Skempton coefficient

ρ : the density of water

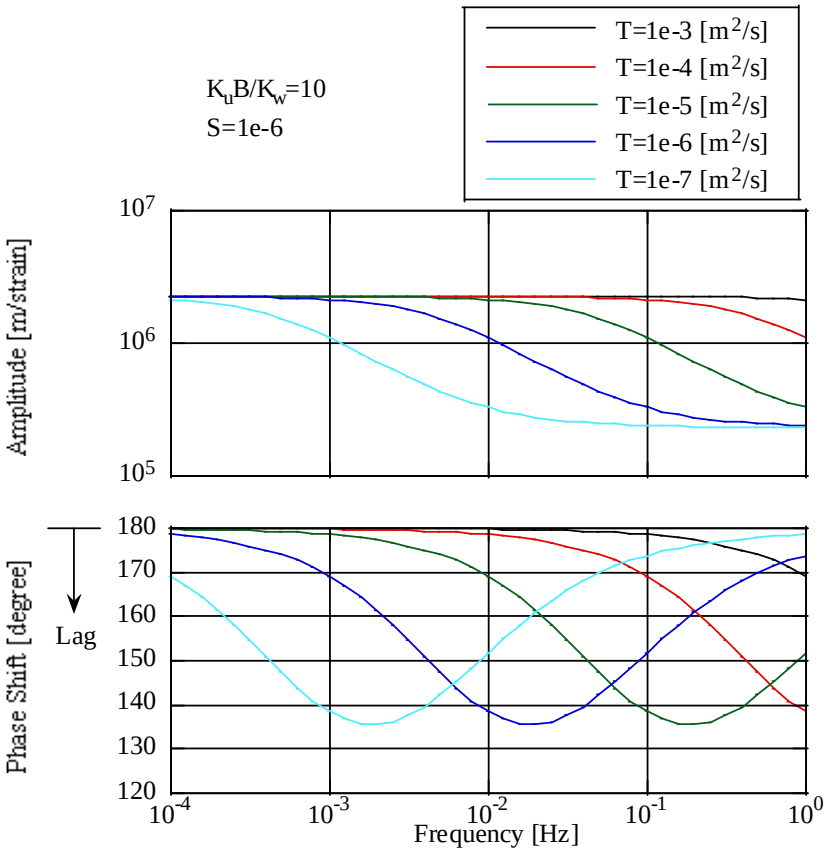
g : the gravity acceleration

Calculated example of the responses of water pressures to strain

For the storage coefficient (S) of the aquifer



For the transmissivity (T) of the aquifer



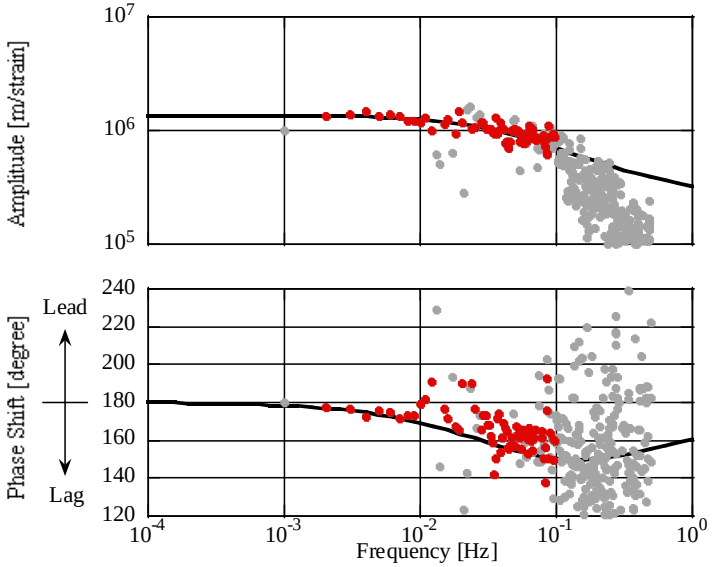
Open well vs closed well

Open well
-- the undrained response with no phase shift at low frequency side
-- the amplification of the response due to resonance in the specific frequency range
-- the attenuation of the amplitude and large phase lag in the high frequency range

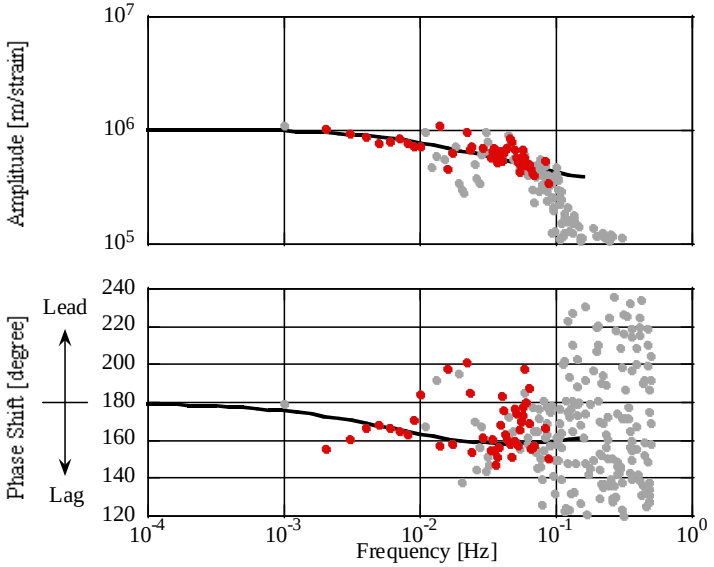
Closed well
-- the undrained response with no phase shift at low frequency side
-- a frequency dependency in the intermediate frequency range
-- the response of elastic deformation of water with no phase shift at the high frequency range

Comparison the observations with formulation

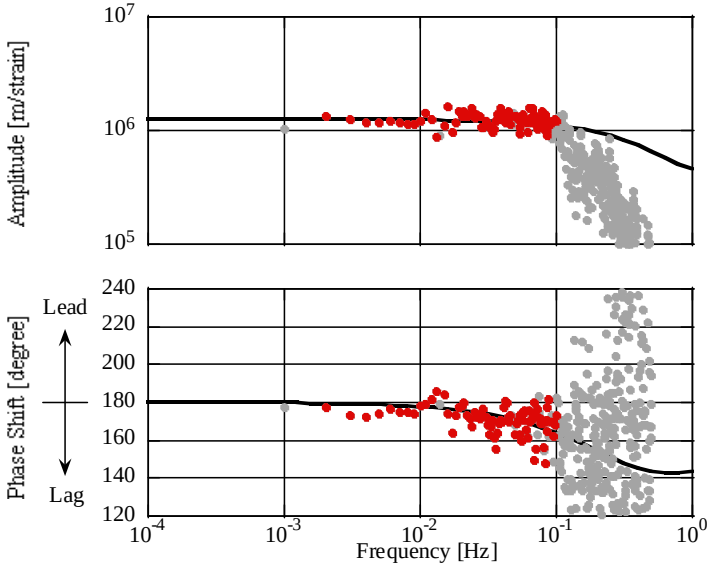
ANO1 Closed well



SSK1 Closed well



ANO2 Closed well



The curves by the formulation explained the responses estimated from the observations

Summary

1. The oscillations of water pressures due to the seismic wave of the 2010 Chile earthquake are observed.

2. The frequency characteristics of the responses of water pressures in closed wells are estimated.

3. The formulation for the response of water pressure in closed well to crustal strain is newly developed.

4. The formulation explained the responses estimated from the observations.

Thank you for your attention