Trigger and Mechanism of Co-seismic Groundwater Level Changes

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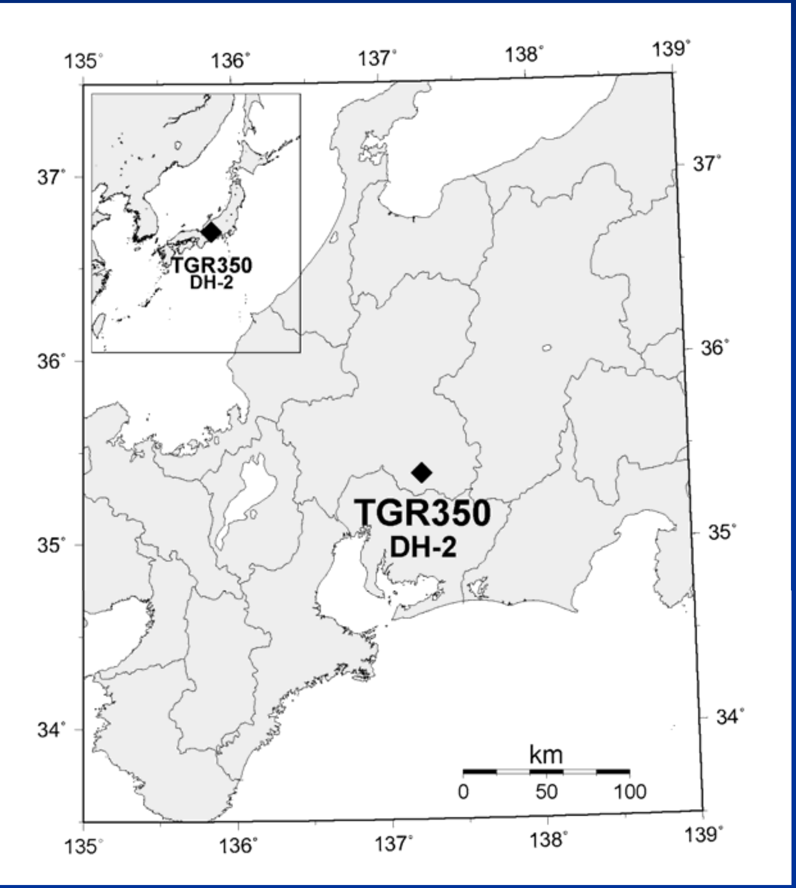
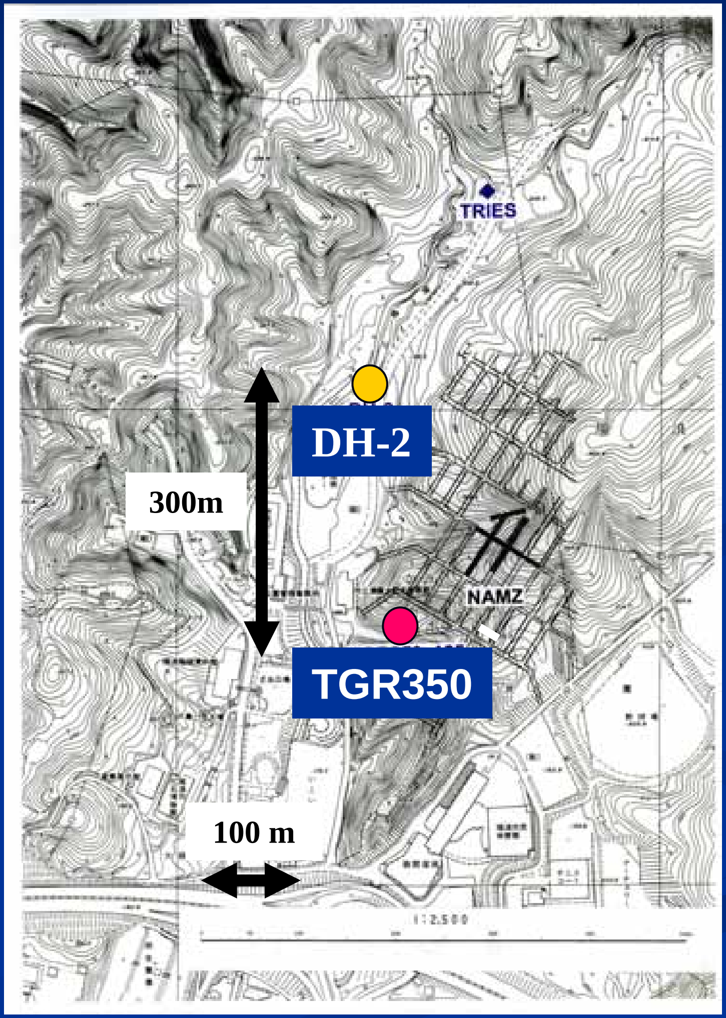
- Feature of co-seismic GWL changes
- Relationship between dynamic strain/tilt observation and co-seismic GWL changes

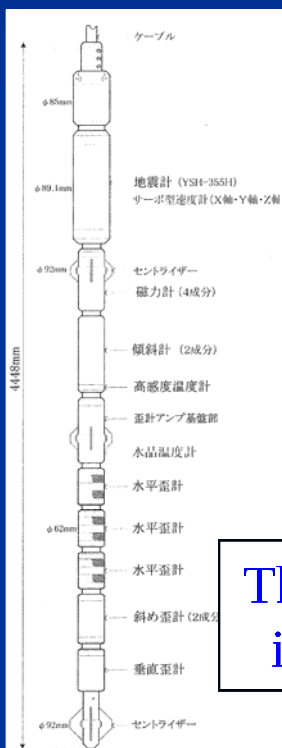
  --- Finding of the threshold of dynamic strain/tilt variations
- Applying the 1-dimensional finite porous aquifer model
- Mechanism of the co-seismic GWL change

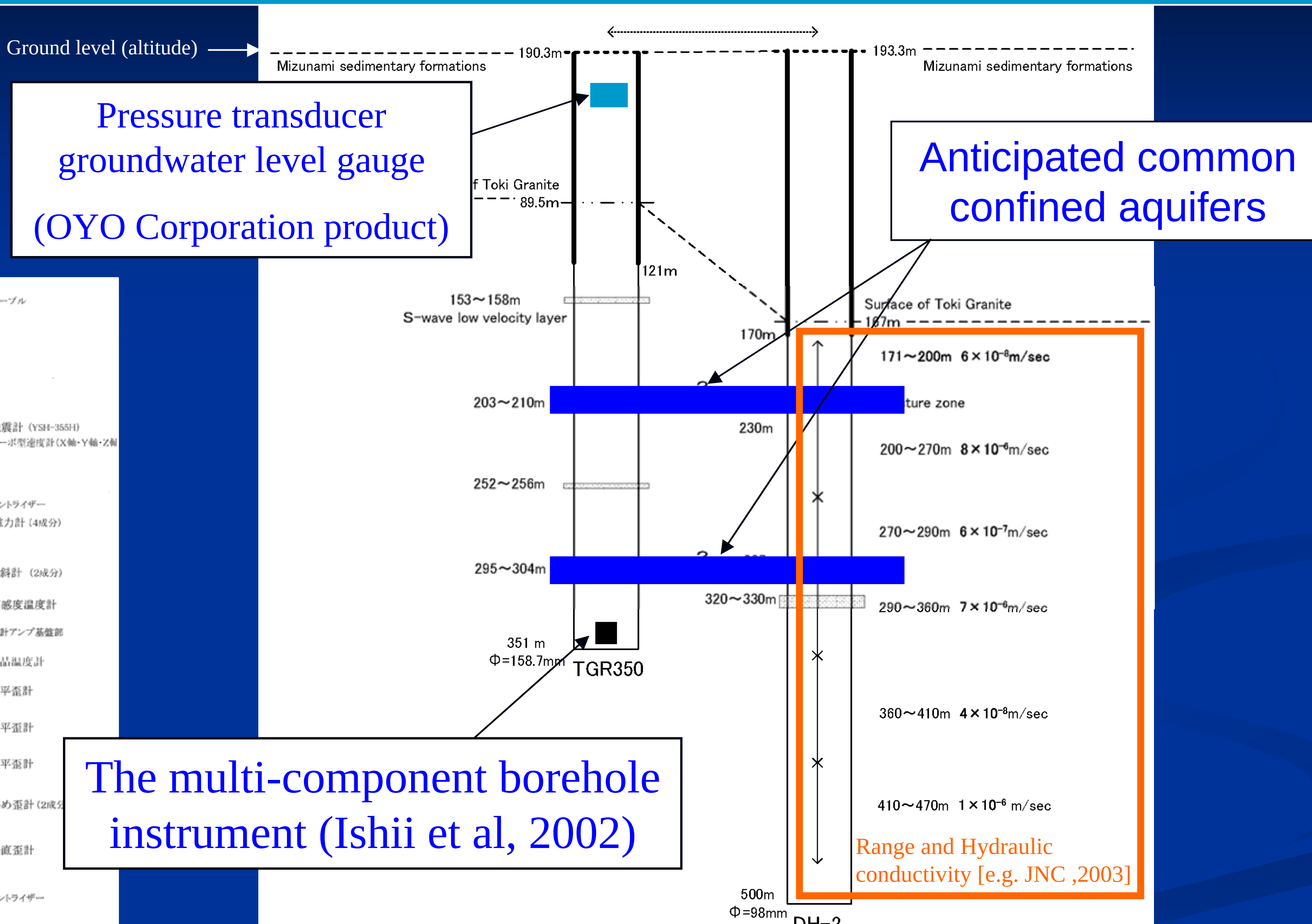
Togari Crustal Activity Borehole Observatory（TGR350）





Borehole profile, geological and hydrological environment in and around TGR350 and DH-2.



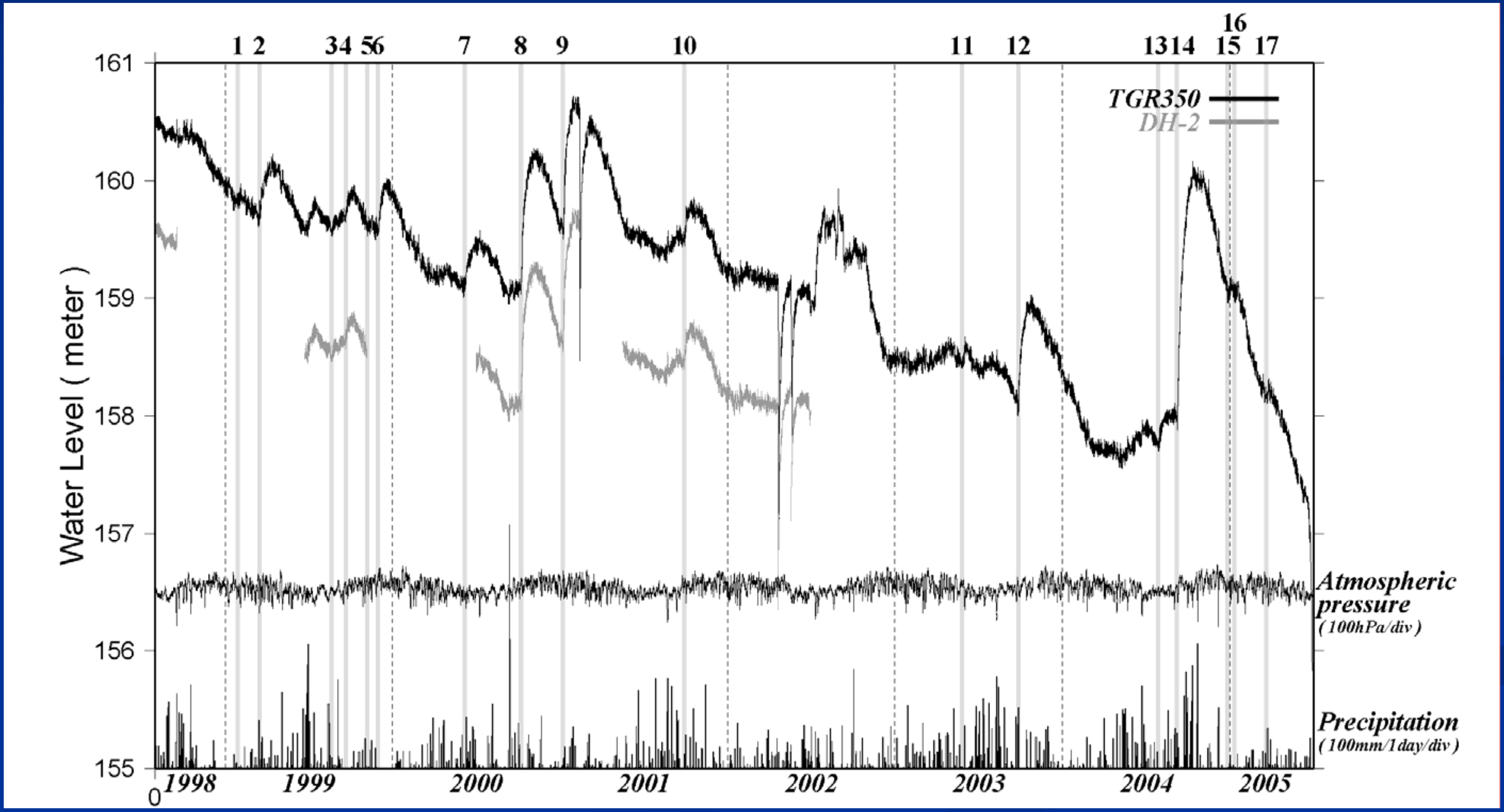


Groundwater Level : Since May,1998 [1-hour]

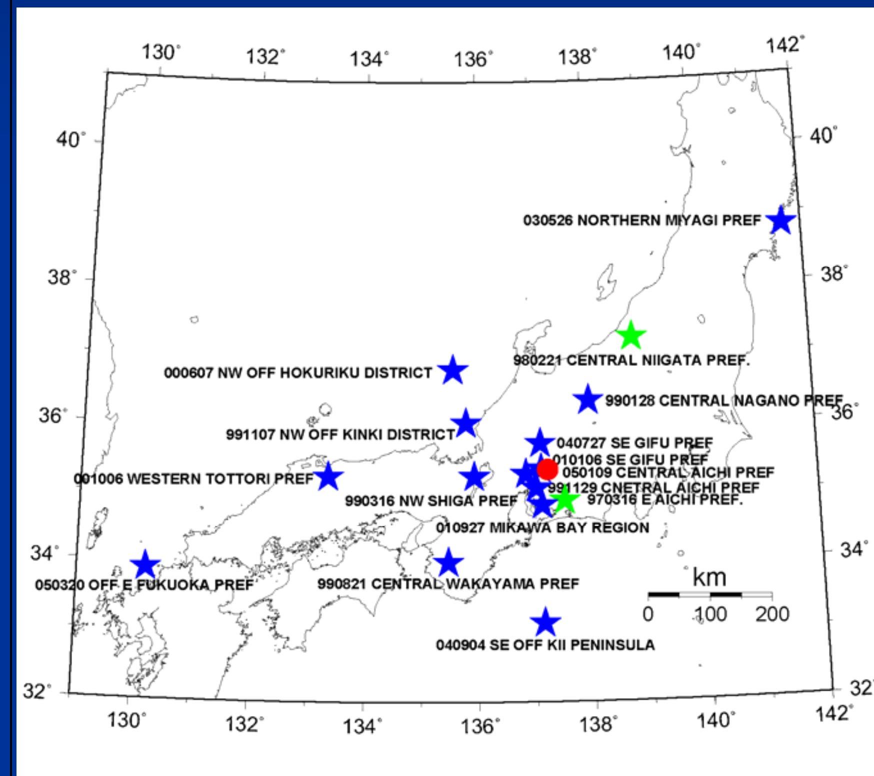
Crustal movement (Strain, Tilt): Since January,1999 [10-sec] ; July,2000 [1-Hz]

TGR350 and DH-2, groundwater level (hourly record)

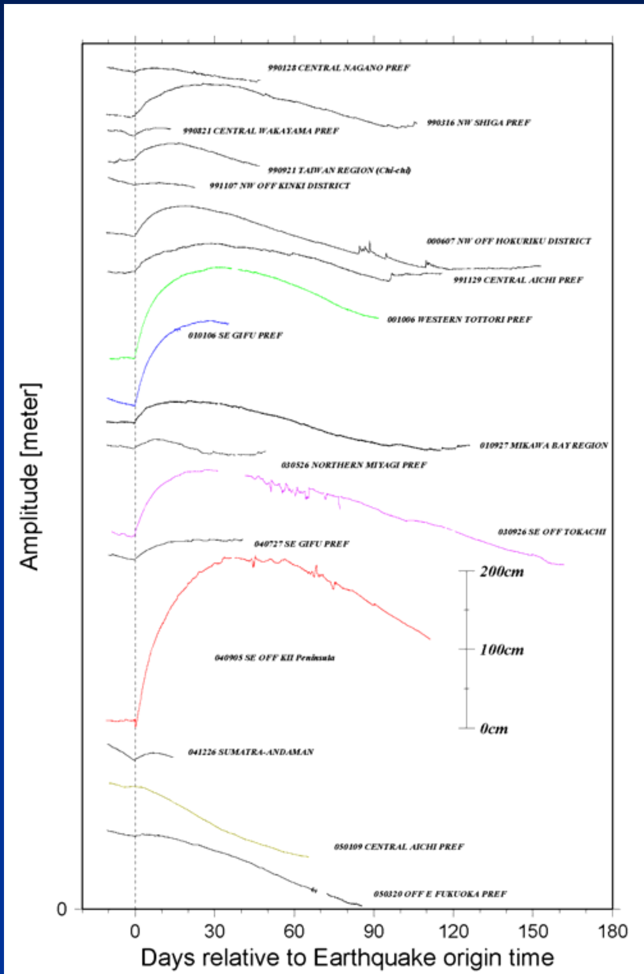
We observed 17 groundwater level changes in response to local and distant earthquakes.



Locations of TGR350 and epicenters.

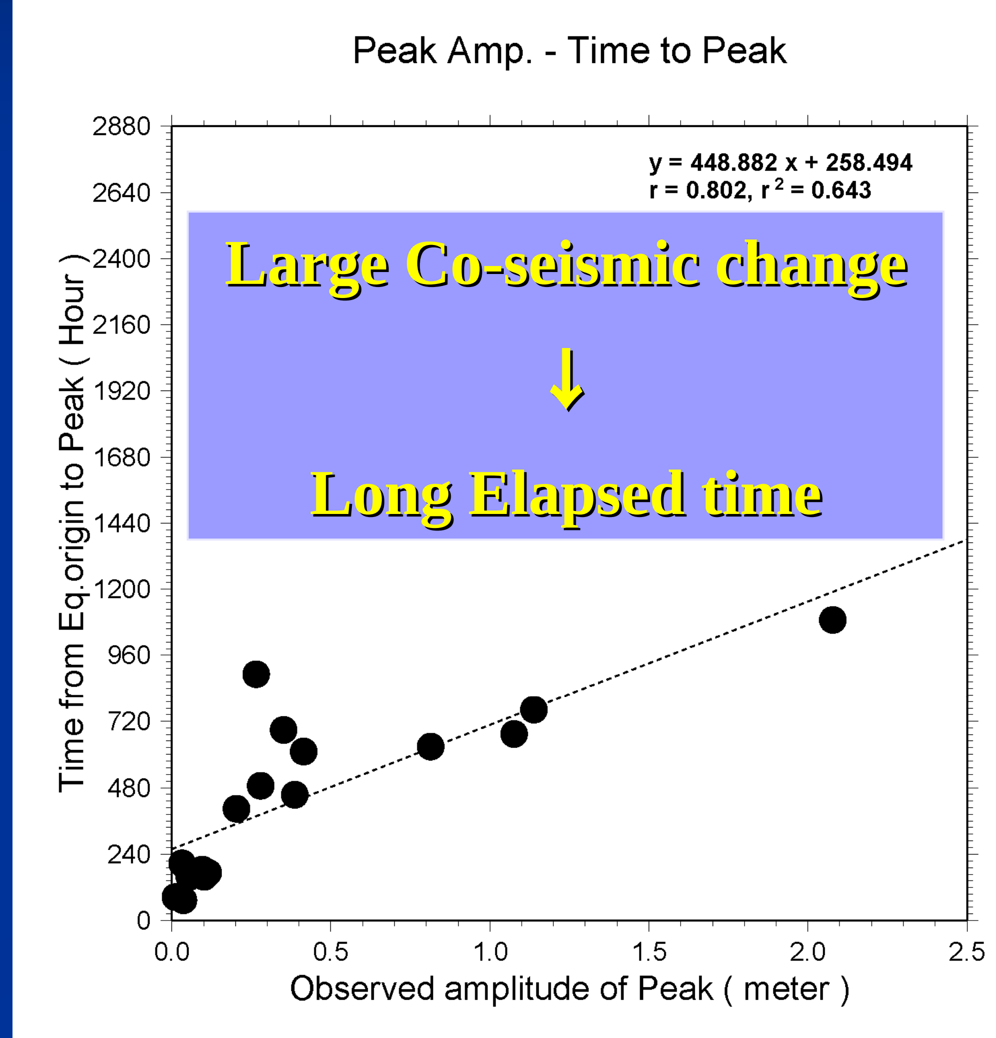


Feature of co-seismic GWL changes

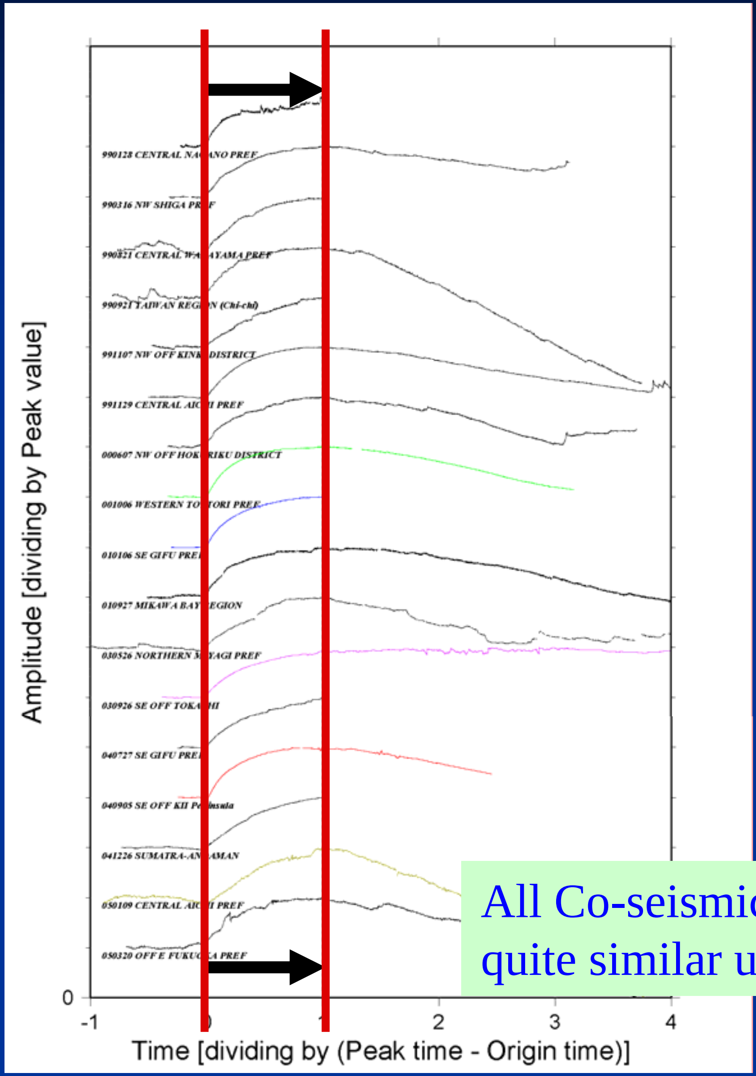


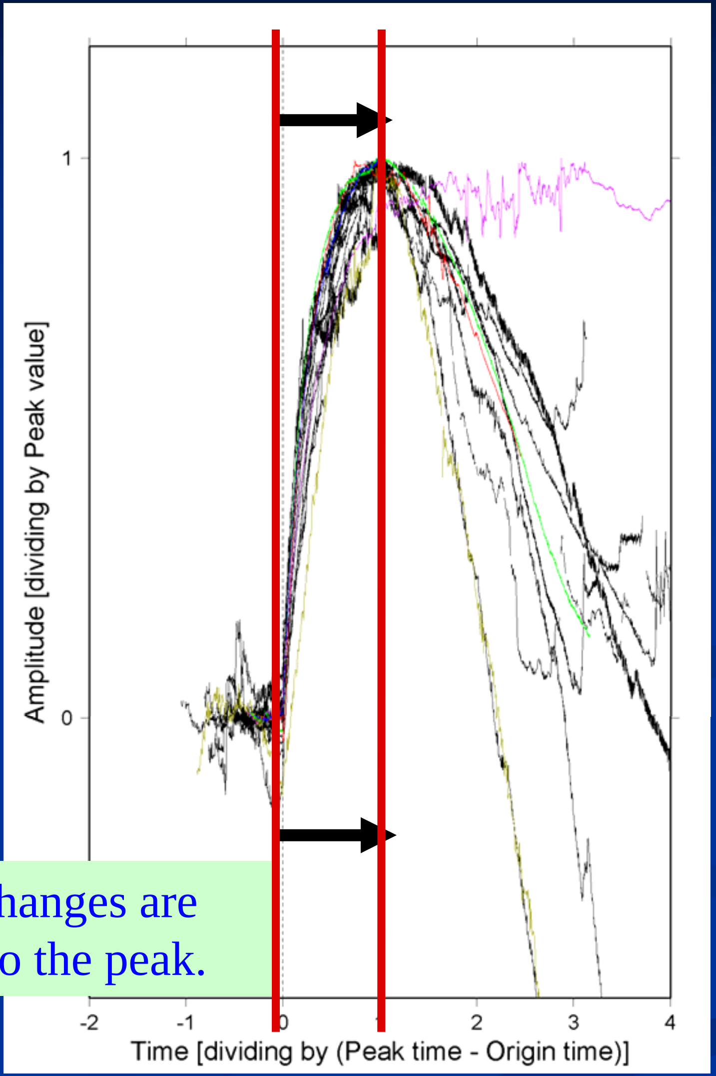
Tidal component and Atmosheric pressure response are removed by using BAYTAP-G program.

The common feature of all co-seismic GWL changes is ‘rise’



All normalized all co-seismic groundwater level changes

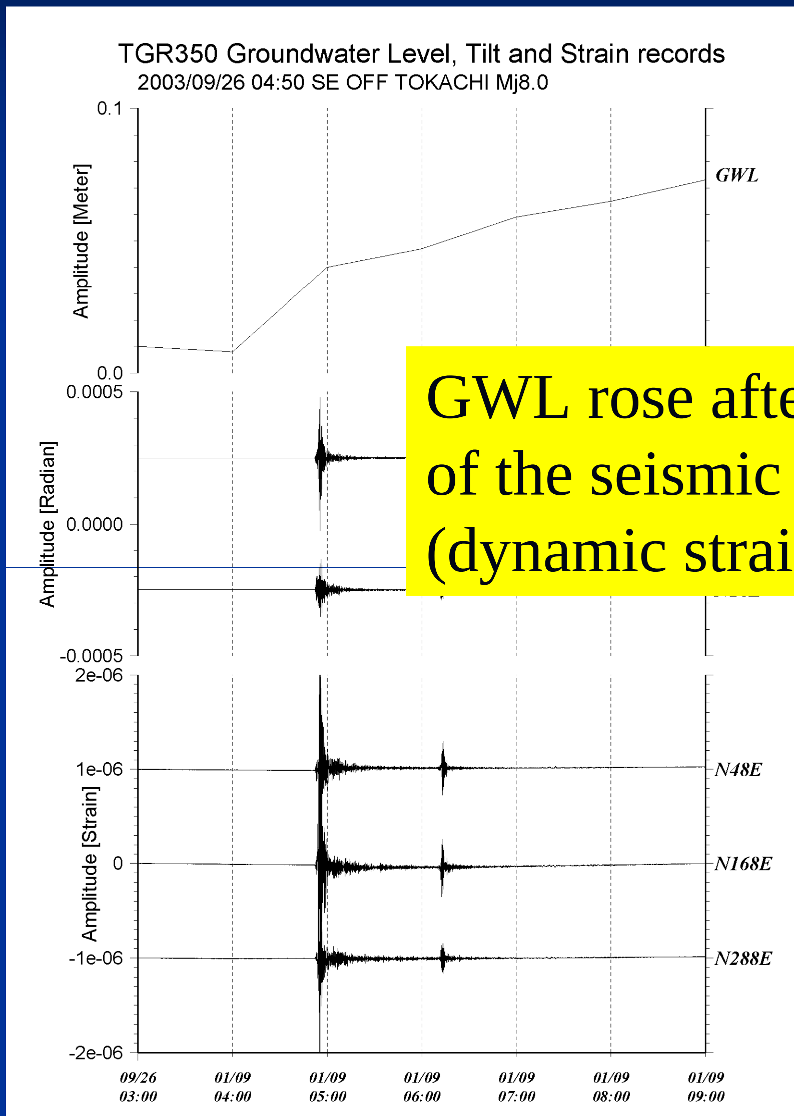


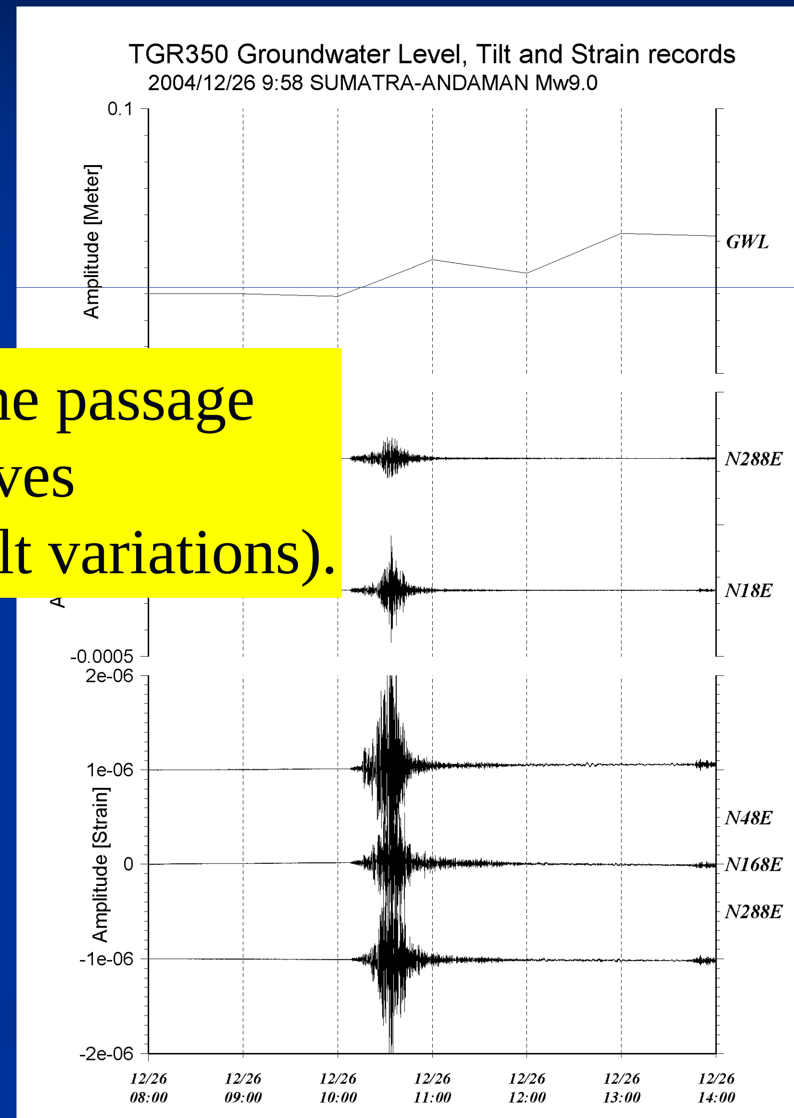


All Co-seismic changes are quite similar up to the peak.

This result suggest that the source for co-seismic changes has a linear response to the input.

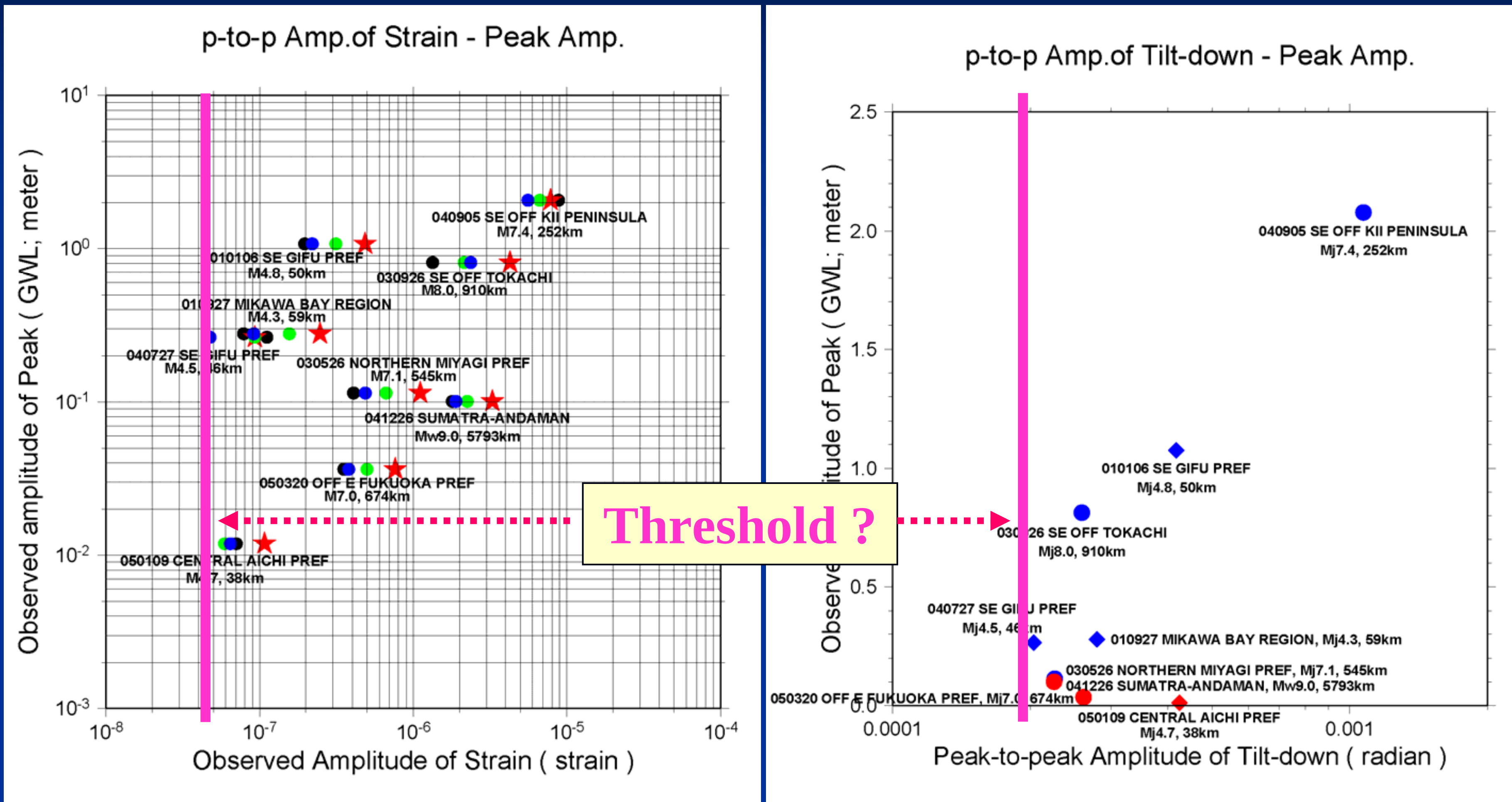
Relationship between dynamic strain/tilt variation and co-seismic GWL changes





GWL rose after the passage of the seismic waves (dynamic strain/tilt variations).

Comparison of Co-seismic GWL change and Dynamic strain/tilt variations



Large dynamic strain/tilt variations

→ Large Co-seismic change

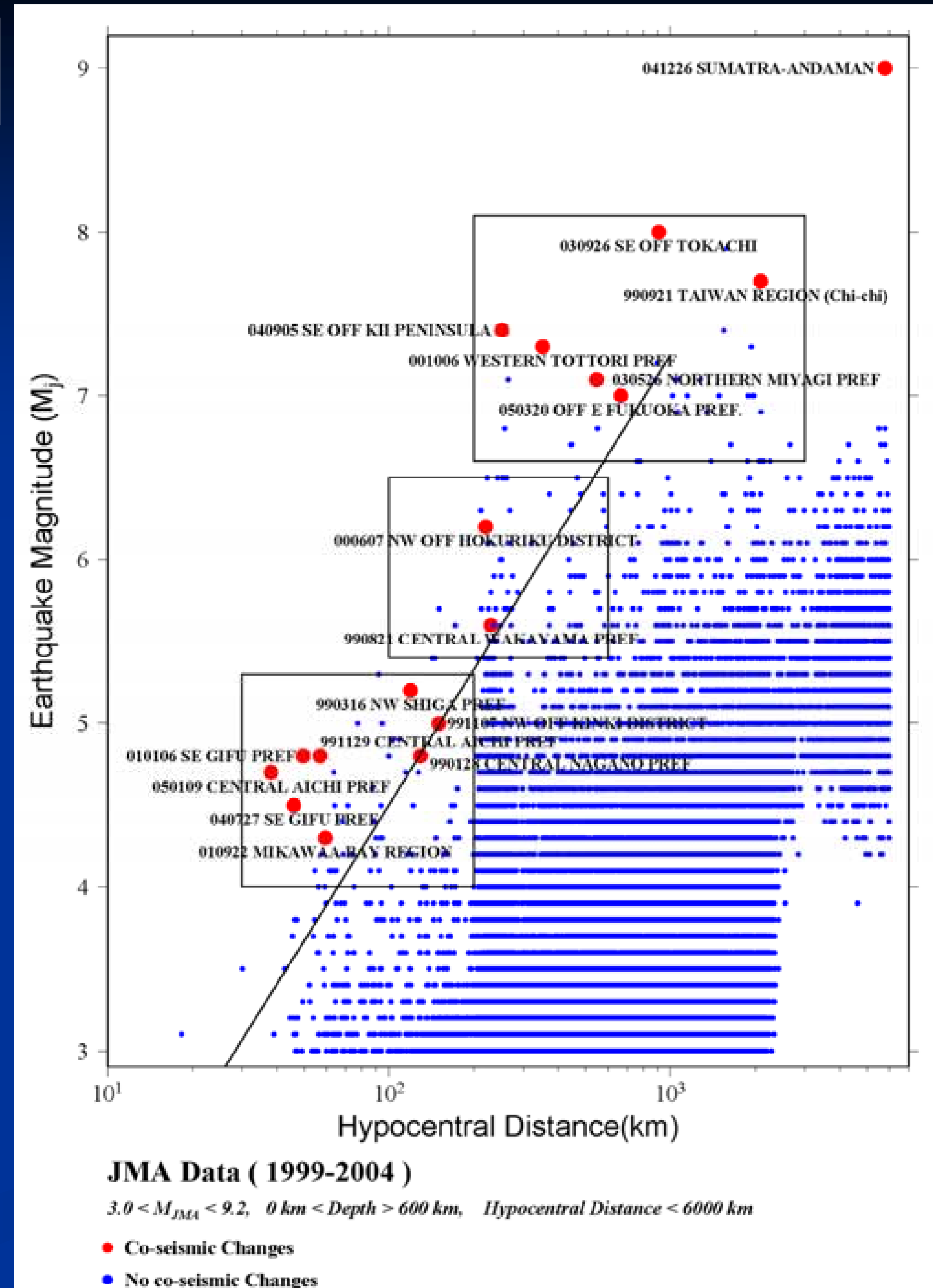
Verification of the threshold

$M_{JMA} \geqq -0.45+2.45\log_{10}D$
(Haibara; Matsumoto and Roeloffs, 2003)

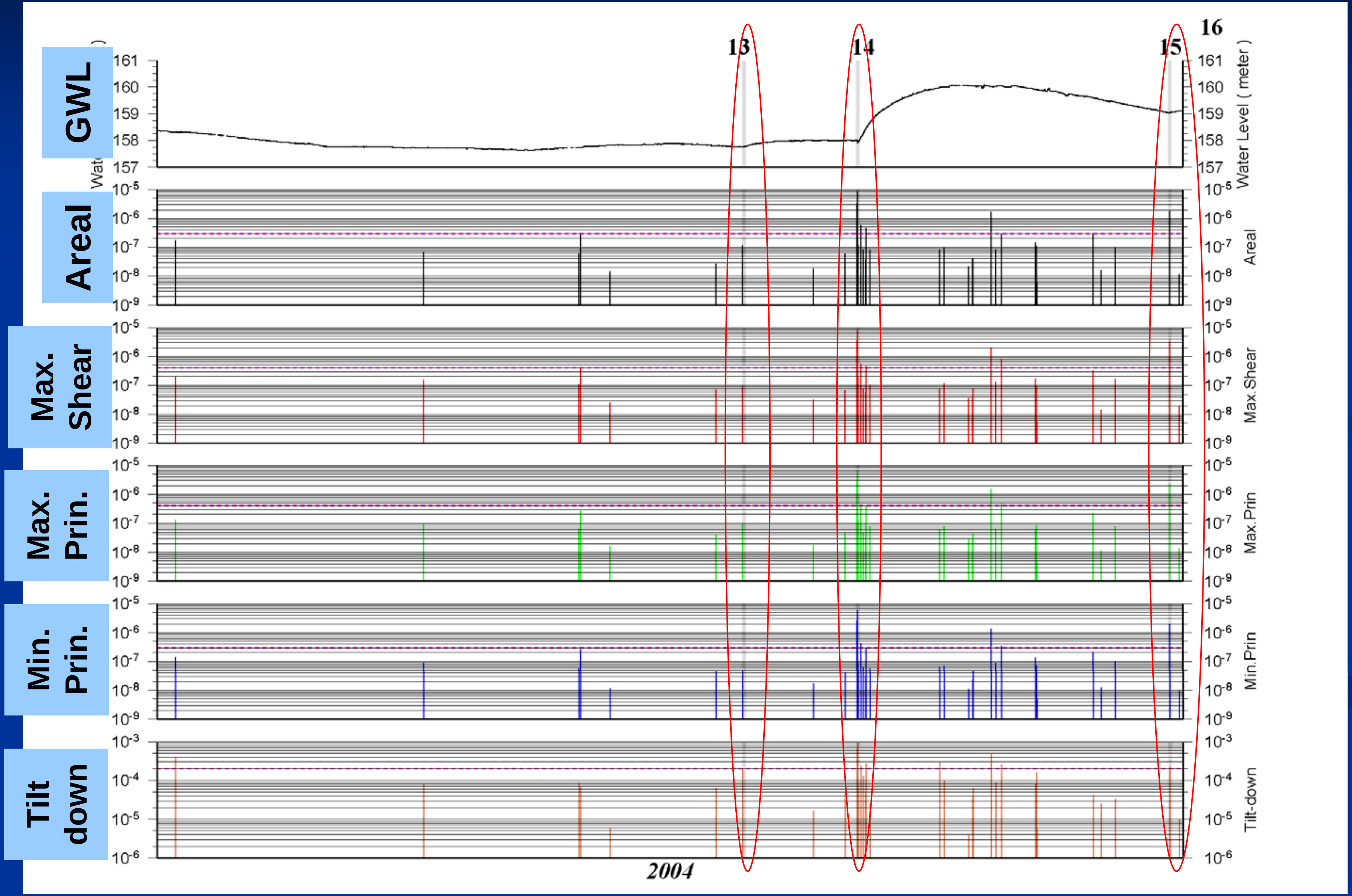
$M_{JMA} \geqq -1.0+2.75\log10D$
(TGR350; This study)

However, there are many earthquakes caused no co-seismic GWL changes even when magnitude M_{JMA} and D satisfy above the relation.

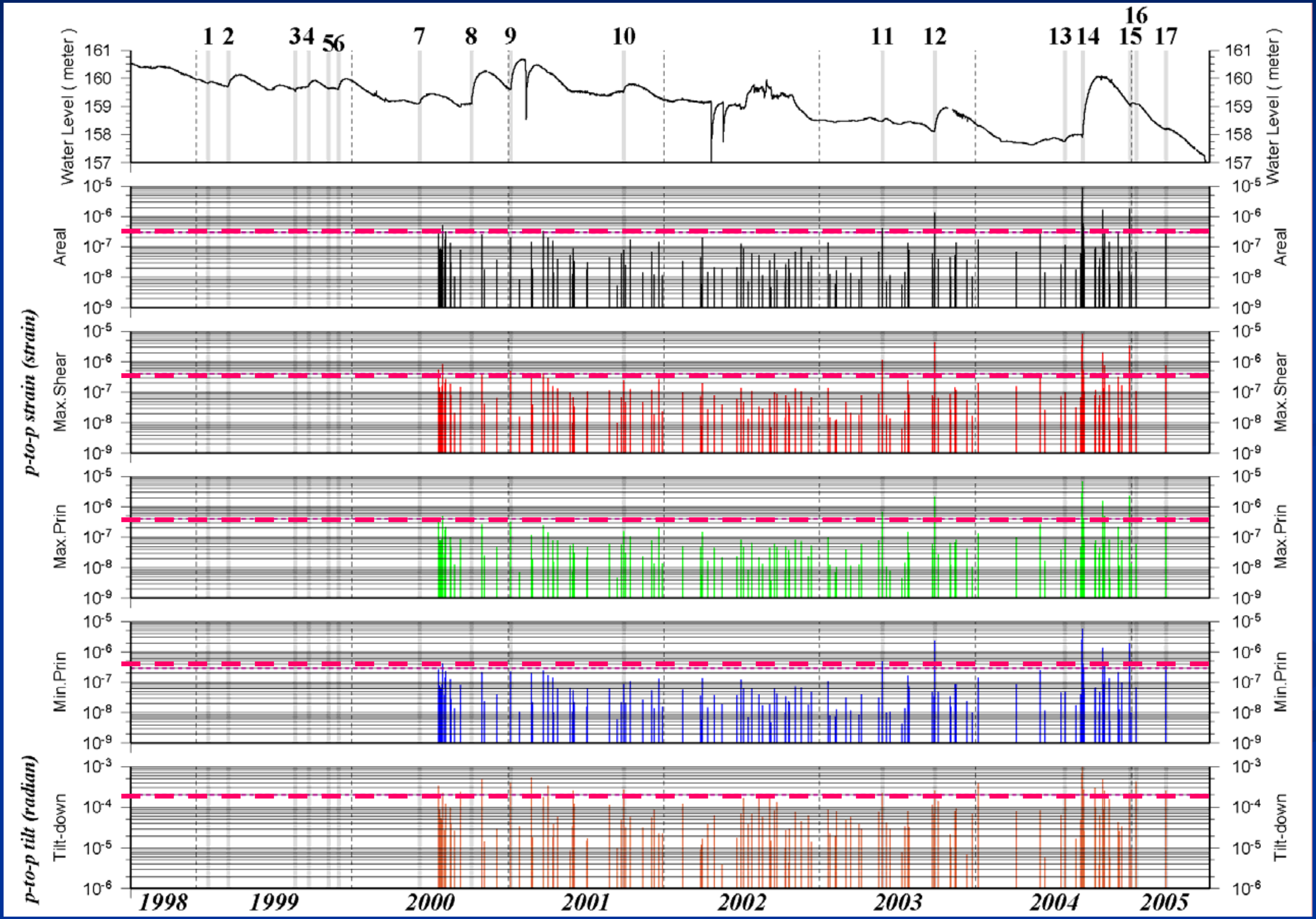
We check the peak-to-peak amplitudes of 142 dynamic strain/tilt variations that caused no co-seismic GWL changes (blue mark) in the period July 2000 to December 2004.



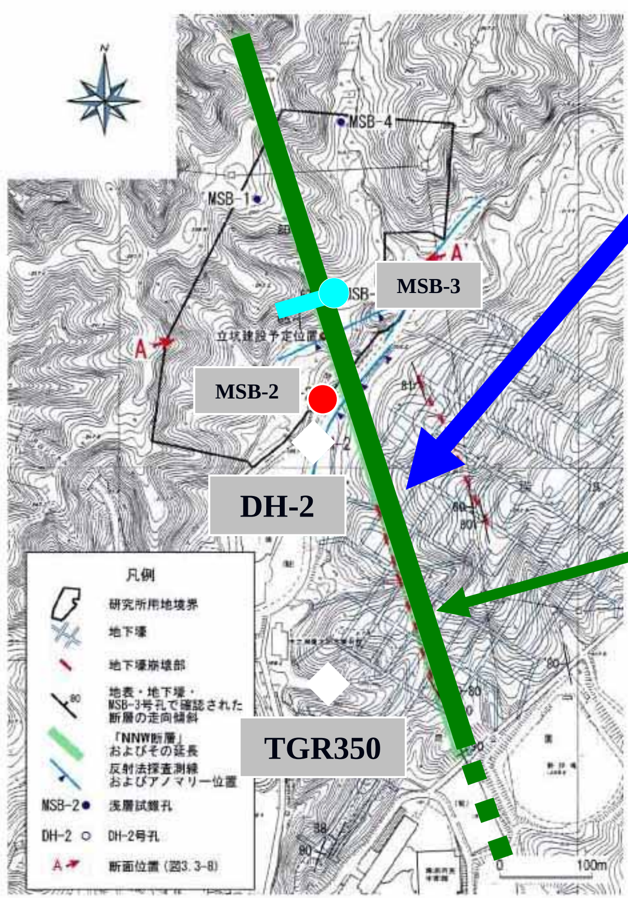
Groundwater level changes and peak-to-peak amplitudes of the dynamic strain variations and tilt-down variations in 2004



Finding of the threshold of approximately $3x10^{-4}$ strain and $2x10^{-4}$ radian.



Geological and hydrological information in and around TGR350. Modified from JNC (2003).



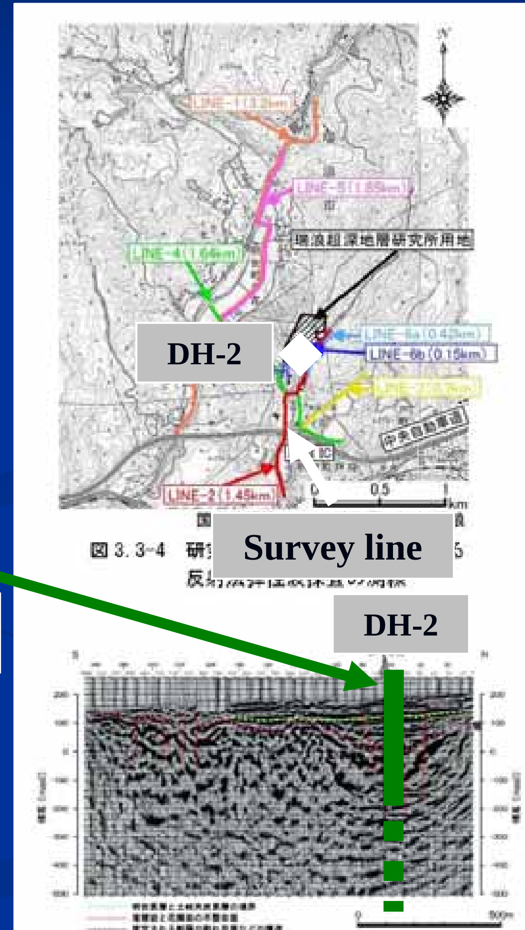
Trace of NNW fault

Steady state flow

NNW fault

=

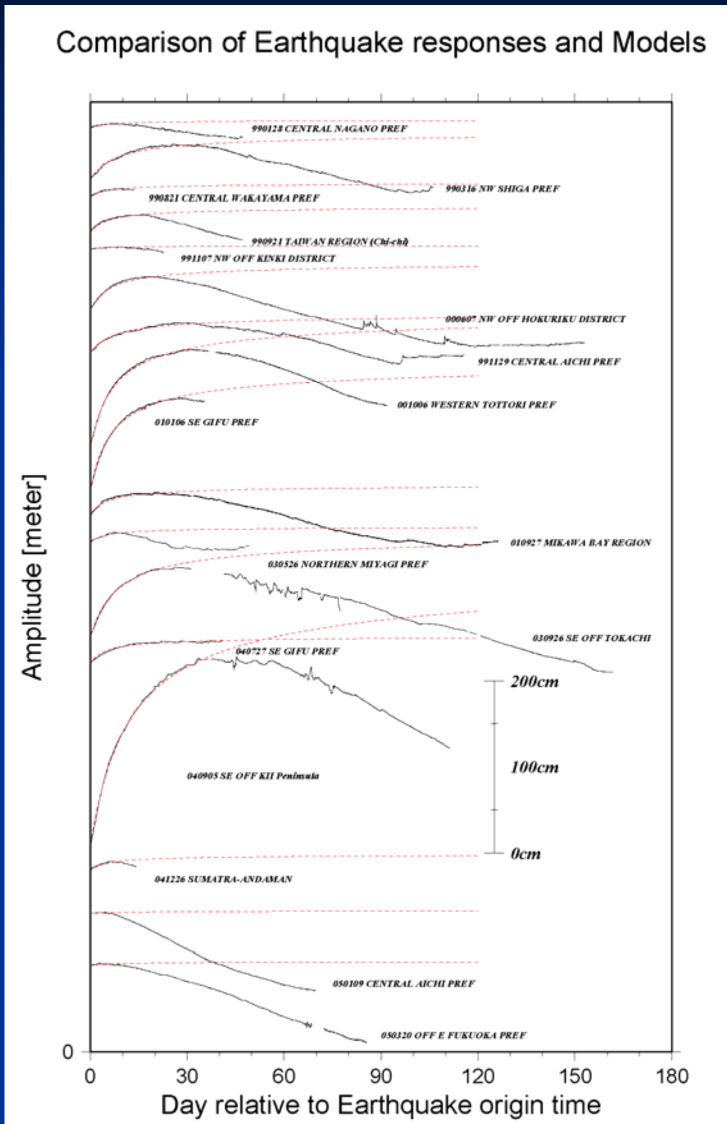
Low permeability



Depth section by Seismic reflection survey

Applying the Roeloffs(1998)'s mechanism

---Diffusion of a localized co-seismic pressure increase in an isotropic homogeneous 1-dimensional finite porous aquifer



Observed (black lines)
Theoretical (red dashed line)

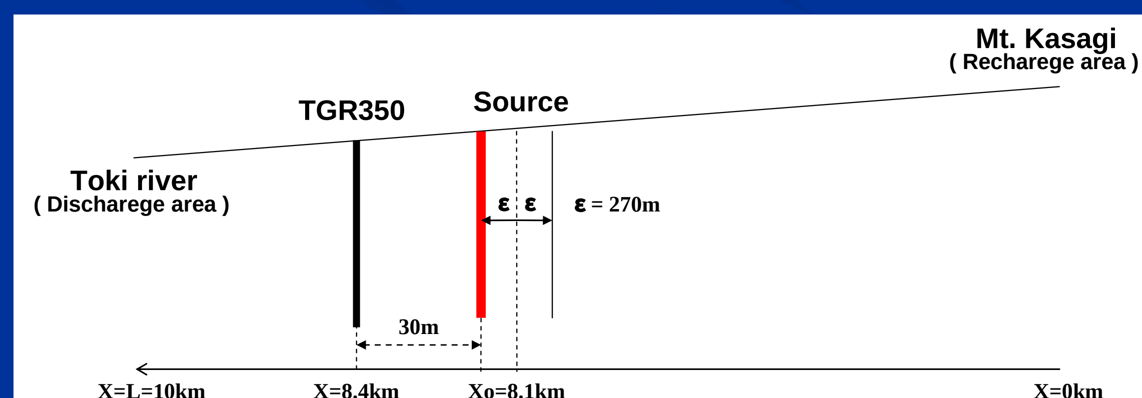
The head, $h_s(x,t;K_h,S_s)$, satisfies the diffusion equation

$$\frac{\partial^2 h_s}{\partial x^2} = \frac{S_s}{K_h}\frac{\partial h_s}{\partial t} = \frac{1}{c_h}\frac{\partial h_s}{\partial t}$$

Horizontal hydraulic diffusivity ***Ch=Kh/Ss*** (m^2/sec)

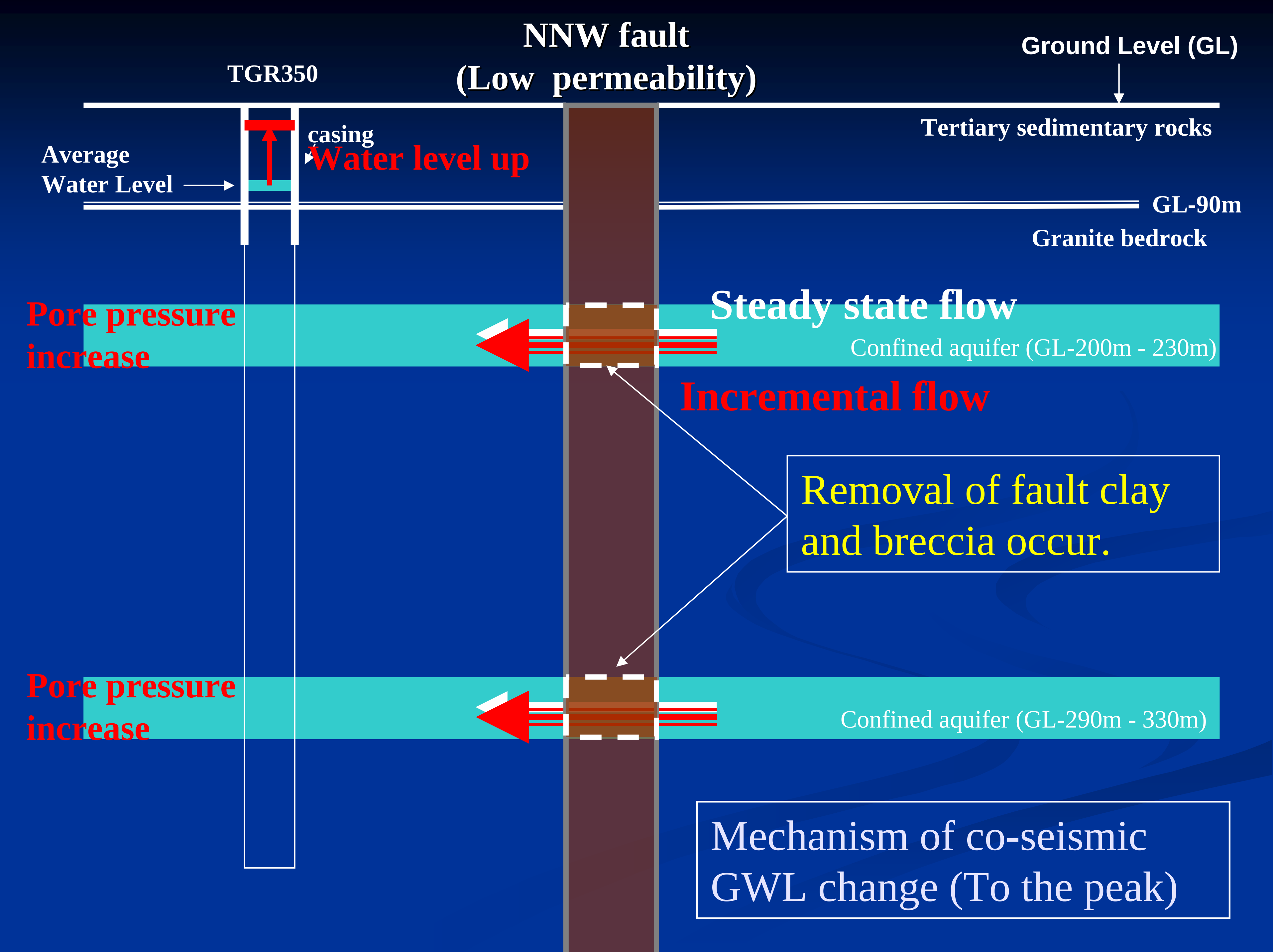
Kh: hydraulic cnductivity [m/sec]

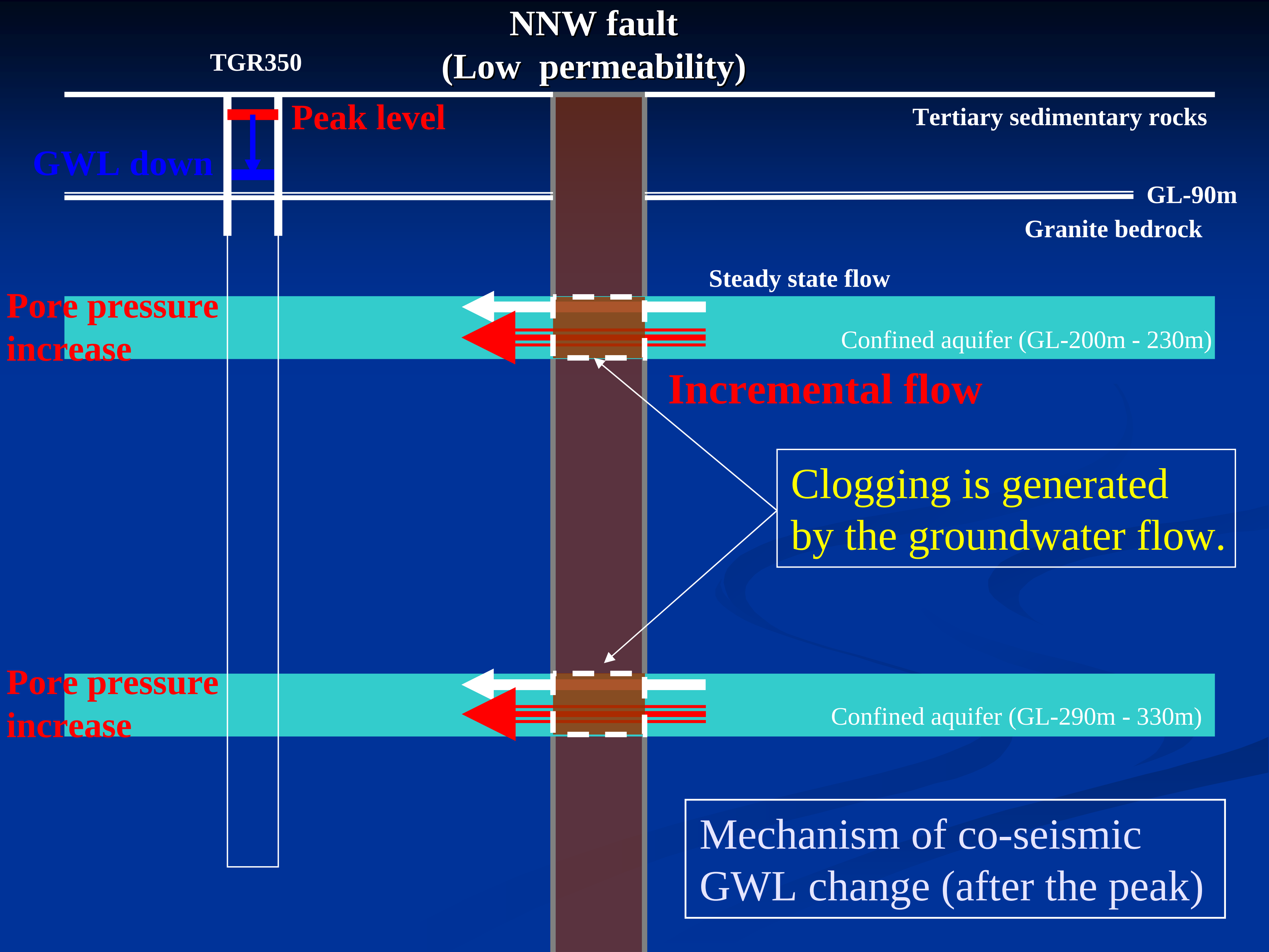
Ss specific storage [m^{-1}]



- Observed co-seismic GWL changes.
- Finding of the threshold of dynamic strain/tilt variations.
- Edge of the source is located upstream of TGR350.
- Geological and hydrological information in and around TGR350.

We propose a realistic mechanism of the co-seismic GWL changes.


NNW fault
(Low permeability)
Ground Level (GL)
TGR350
casing
Water level up
Average
Water Level
Tertiary sedimentary rocks
GL-90m
Granite bedrock
Steady state flow
Pore pressure
increase
Confined aquifer (GL-200m - 230m)
Incremental flow
Removal of fault clay
and breccia occur.
Pore pressure
increase
Confined aquifer (GL-290m - 330m)
Mechanism of co-seismic
GWL change (To the peak)



NNW fault
(Low permeability)
TGR350
Peak level
GWL down
Tertiary sedimentary rocks
GL-90m
Granite bedrock
Steady state flow
Pore pressure increase
Confined aquifer (GL-200m - 230m)
Incremental flow
Clogging is generated by the groundwater flow.
Pore pressure increase
Confined aquifer (GL-290m - 330m)
Mechanism of co-seismic GWL change (after the peak)

Conclusions

- During the period from August, 1998 to June 2005, 17 co-seisismic groundwater level changes are observed in TGR350, Central Japan. All changes are 'rise'. The elapsed time of the peak is in proportion to the peak amplitude.

- Peak amplitude of co-seismic groundwater changes are in proportion to the peak-to-peak amplitude of dynamic strain/tilt variations with peak-to-peak amplitudes only above a certain threshold value.

- We propose the realistic mechanism of Co-seismic groundwater level changes, which is consistent with geological and hydrological information.