Review of cooperative hydrological and geochemical research for earthquake prediction in Taiwan

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Result of our Cooperative Research

1.First Stage (2001〜2005)

1-1・Construction of 16 Stations for Monitoring Earthquake-related Groundwater Changes

1-2・Analysis of Coseismic and Postseismic Groundwater Level Changes Related to the 1999 Chi-chi Earthquake

←○Ground Shaking X Volumetric Strain

 1.Groundwater Level Drop in Mountain or Slope Area←Permeability Enhancement

 (Enhancement of Specific Storage)

 2.Groundwater Level Rise in the Alluvial Fan ←Liquefaction
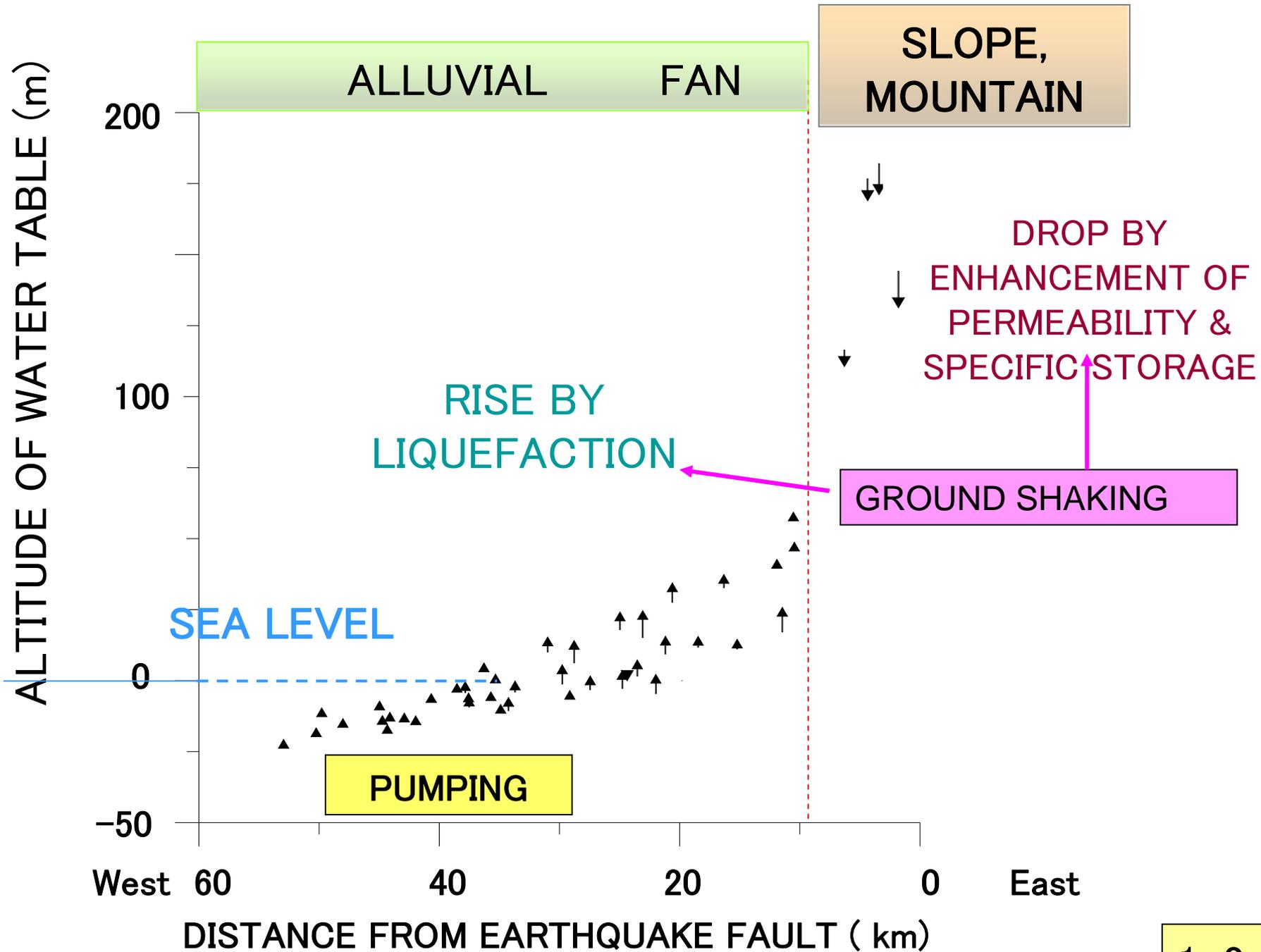
FOCAL REGION OF THE 1999 CHI-CHI ERTHQUAKE

ALLUVIAL FAN

SLOPE OR MOUNTAIN
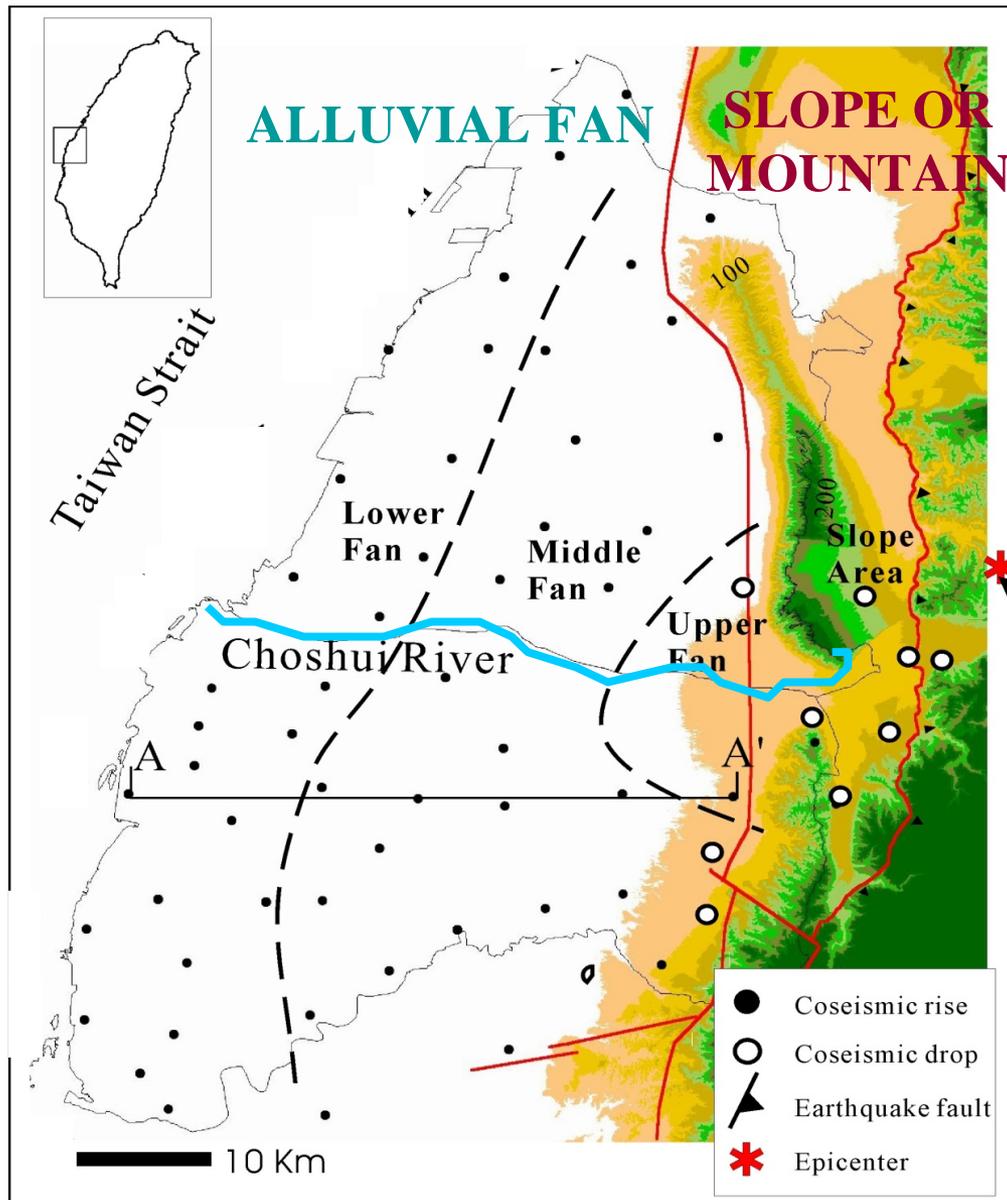
SEISMIC INTENSITY (JMA SCALE) 4～6

CALUCULATED FROM SEISMIC ACCELERATION DATA USING KAWASUMI'S FORMULA

EPICENTER

Lai et.al(2004)

Legend:
- ● Coseismic rise
- ○ Coseismic drop
- ▲ Earthquake fault
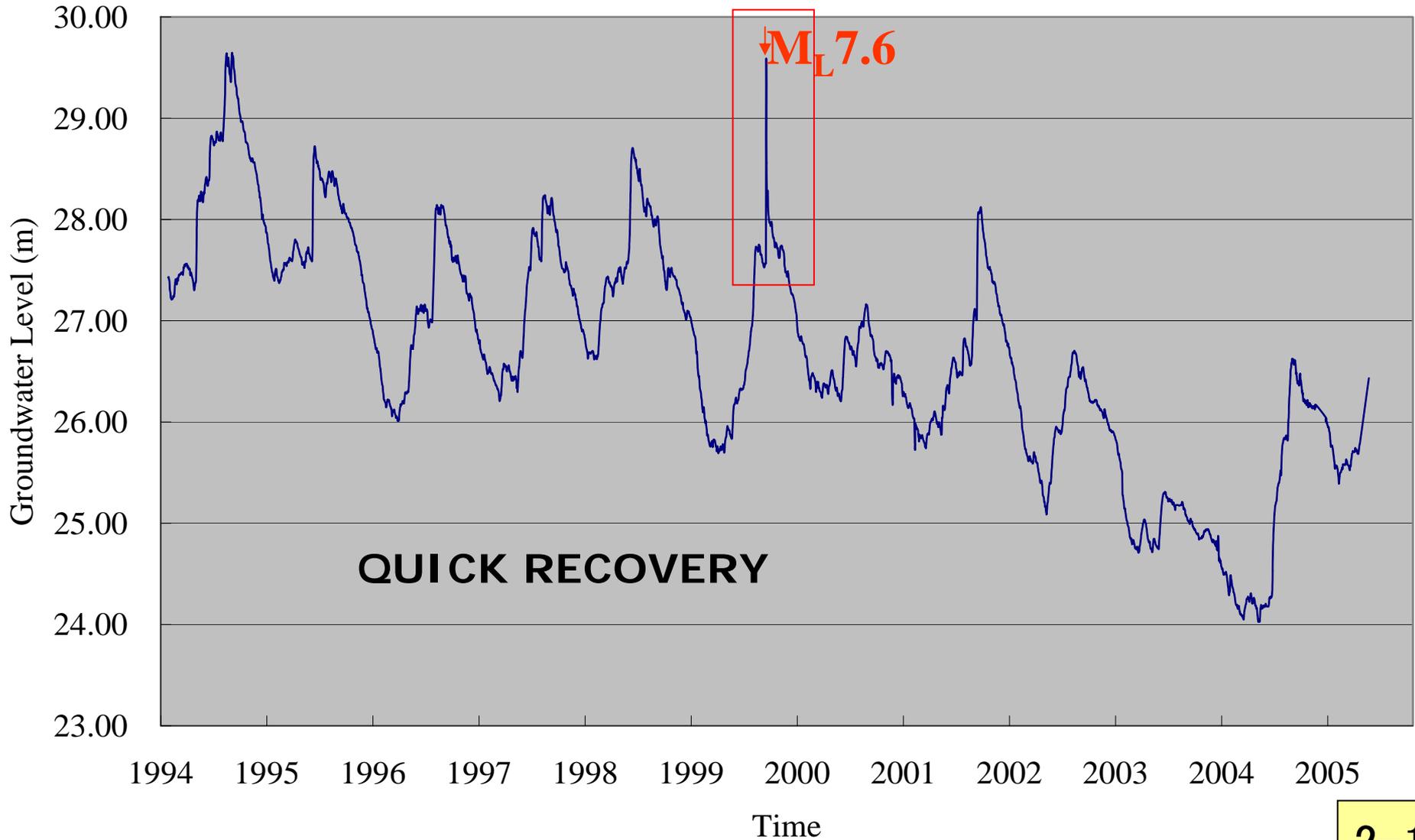- ✳ Epicenter

10 Km

2.Second Stage（2006〜2009）

2-1・Long-term Groundwater Level Changes or Recoveries after the 1999 Chi-chi Earthquake

1.Recovery of the Groundwater Level Drops in Mountain or Slope Area Needed Several Years or Longer.
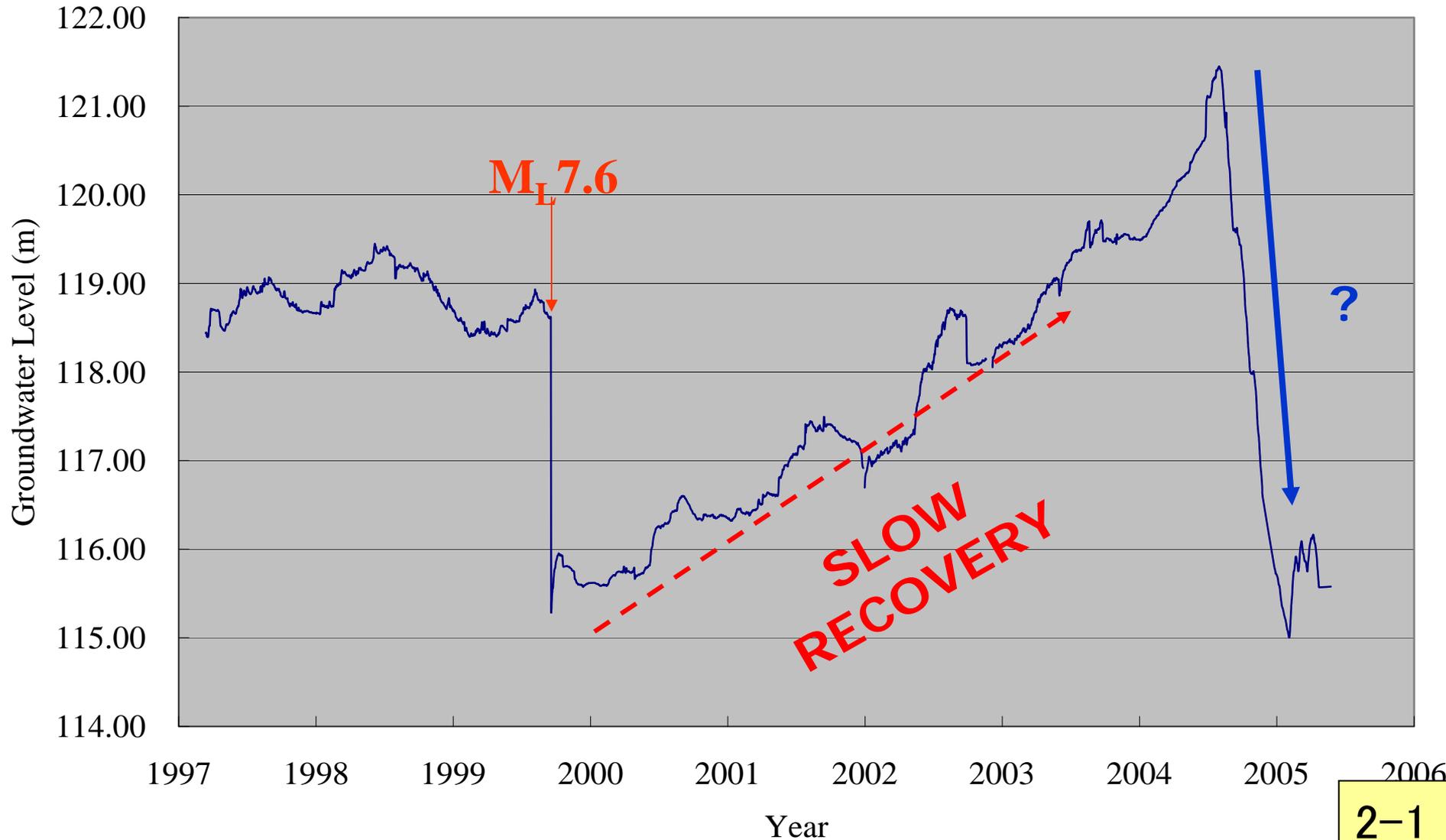
2.Recovery of the Groundwater Level Rises in the Alluvial Fan Needed only 3 Months or Shorter.
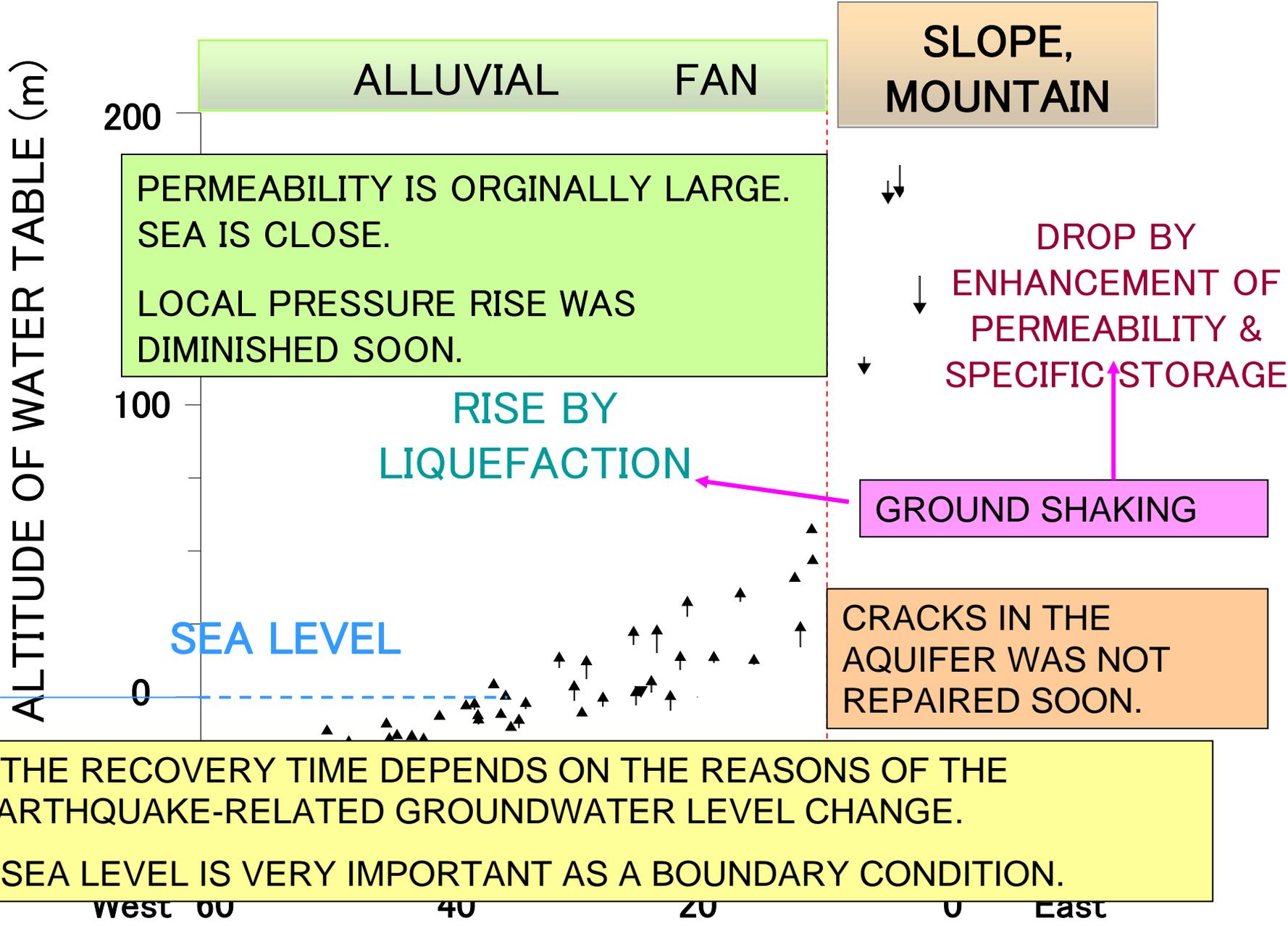
2-2・Monitoring Earthquake-related Groundwater Changes at the 16 Stations.→Lai-san's Presentation

GROUNDWATER LEVEL IN THE ALLUVIAL FAN

M_L7.6

QUICK RECOVERY

Groundwater Level (m)

Time

2-1

GROUNDWATER LEVEL IN SLOPE OR MOUNTAN AREA

ALTITUDE OF WATER TABLE (m)

ALLUVIAL FAN

SLOPE, MOUNTAIN

200

PERMEABILITY IS ORGINALLY LARGE. SEA IS CLOSE.

LOCAL PRESSURE RISE WAS DIMINISHED SOON.

DROP BY ENHANCEMENT OF PERMEABILITY & SPECIFIC STORAGE

100

RISE BY LIQUEFACTION

GROUND SHAKING

SEA LEVEL

CRACKS IN THE AQUIFER WAS NOT REPAIRED SOON.

0

1.THE RECOVERY TIME DEPENDS ON THE REASONS OF THE EARTHQUAKE-RELATED GROUNDWATER LEVEL CHANGE.

2.SEA LEVEL IS VERY IMPORTANT AS A BOUNDARY CONDITION.

West 60   40   20   0   East

DISTANCE FROM EARTHQUAKE FAULT (km)   V/H〜250

2-1

7 PROBLEMS SUGGESTED IN THE FIRST WORKSHOP IN SEP.2002

(1) What are conditions of sensitive wells? Or how can we detect sensitive wells systematically?

(2) What is a mechanism of preseismic changes in unconfined groundwater level?

(3) What is a mechanism of geochemical precursors? Or how can we develop the ' crack model '?

(4) Can we suggest information of pore pressure and permeability in the seismic region? And how can we?

(5) How should we design a long-term stable geochemical observation?

(6) How can we manage a condition of high temperature, high pore pressure and high water or steam content?
(For observation near the focal region)

(7) What is relationship among GPS data, groundwater level data and (borehole) strain data?

(3)What is a mechanism of geochemical precursors?
   Or how can we develop the ' crack model '?

Crack Model

Concentration of Stress→ Cracks → Increasing
   Permeability of Gas and Liquid→Preseismic Chemical
   Change in Groundwater or Soil Gas.

Problem: Monitoring both of Chemical Chage and
   Permeability

 →Tunomori-san's New Method in 2009

(5) How should we design a long-term stable geochemical
   observation?

→Presentations of Tsunomori-san and Tanaka-san

(4)Can we suggest information of pore pressure and
   permeability in the seismic region?

 And how can we?

Kitagawa-san's and Kano-san's Presentations are
   Possible Answers.

(6) How can we manage a condition of high temperature, high pore pressure and high water or steam content? (For observation near the focal region)

We have not managed them for observation.

(1) What are conditions of sensitive wells?
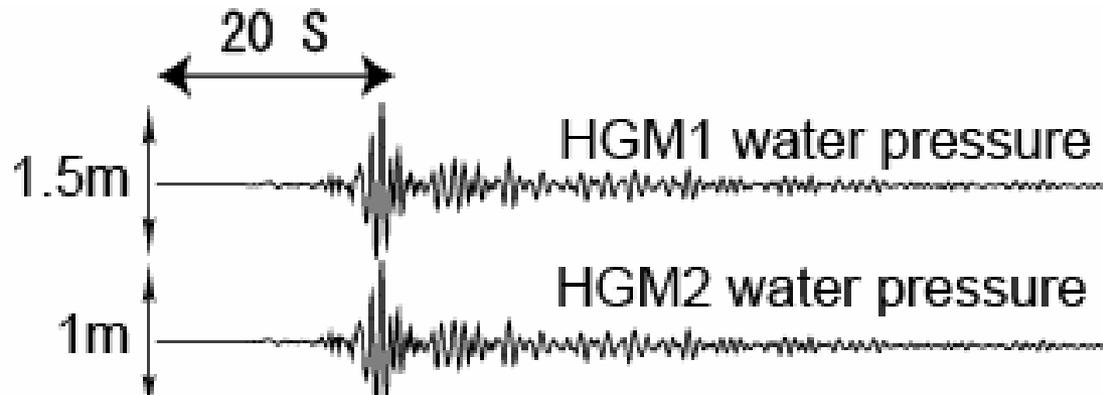　　Or how can we detect sensitive wells systematically?

Sensitive Well:

　There are Many Coseismic and/or Postseismic Persistent
　　Groundwater Changes.

　Distant Earthquakes can Cause Groundwater Changes in
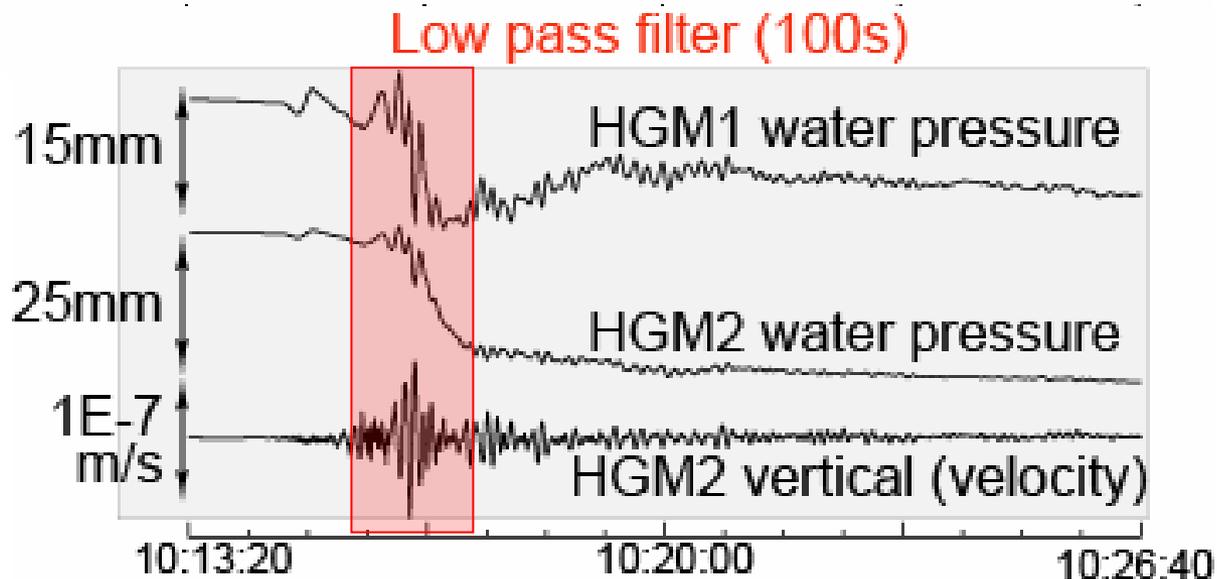　　Such Wells.

　Dynamic Strain Changes Caused by Surface Waves is one
　　Solution.

A possible Mechanism is a Fracture Cleaning Effect
　（Brodsky et al., 2003）.

20 S

1.5m — HGM1 water pressure

1m — HGM2 water pressure

Fracture Cleaning by the Surface Wave?
(Brodsky,2003)

Low pass filter (100s)

15mm — HGM1 water pressure

25mm — HGM2 water pressure

1E-7 m/s — HGM2 vertical (velocity)

10:13:20   10:20:00   10:26:40

Itaba et al.(2008)

(2) What is a Mechanism of Preseismic Changes in Unconfined Groundwater?

Unconfined Groundwater: It is not Sensitive to Strain Changes.

A Crack Model is one Possible Answer.

There were Many Reliable Preseicmic Groundwater Level Drops Before the 1946 Nankai Earthquakes. Itaba-san and Umeda-san are now Collecting Old Records Related to those Phenomena and Trying to Quantify those

We also Have Been Monitoring Crustal Deformation and Groundwater by New observation system in and around the Souce Regions of Nankai Earthquake.

- ● : CONSTRUCTED IN 1978-2004
- ● : CONSTRUCTED IN 2006-2010
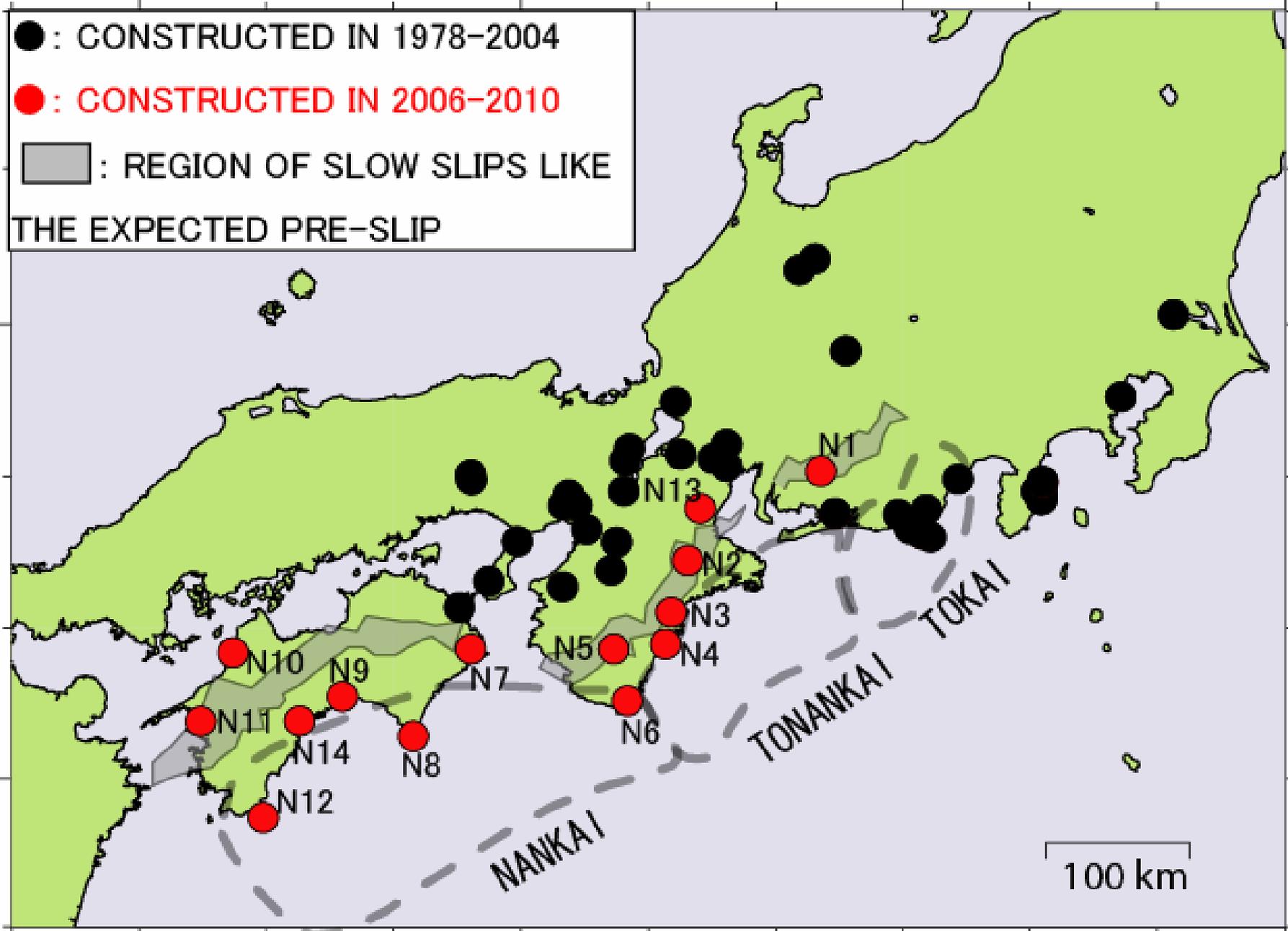- ▨ : REGION OF SLOW SLIPS LIKE THE EXPECTED PRE-SLIP
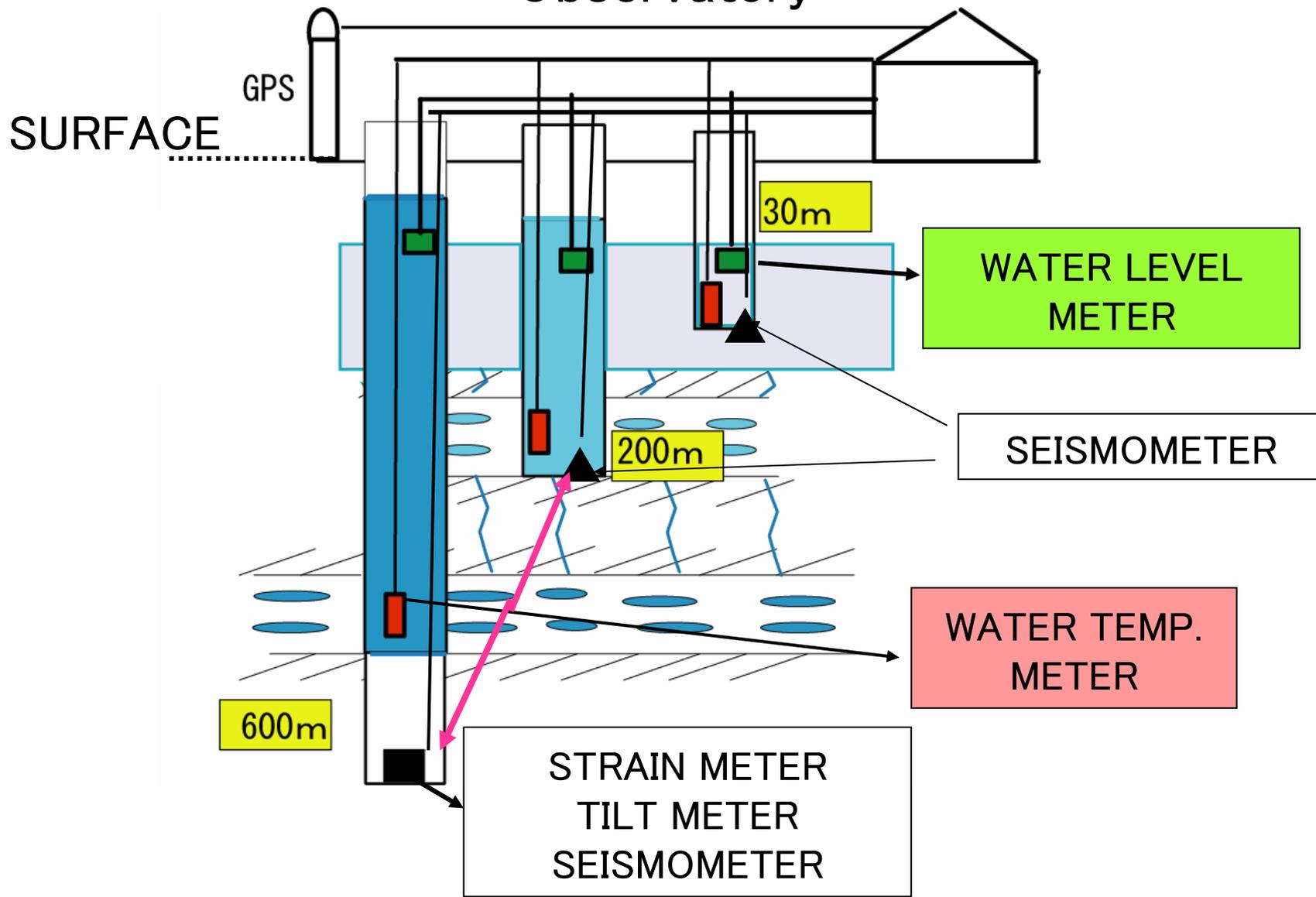
New Integrated Groundwater Observatory

(7)What is Relationship among GPS Data, Groundwater Level Data and (Borehole) Strain Data?
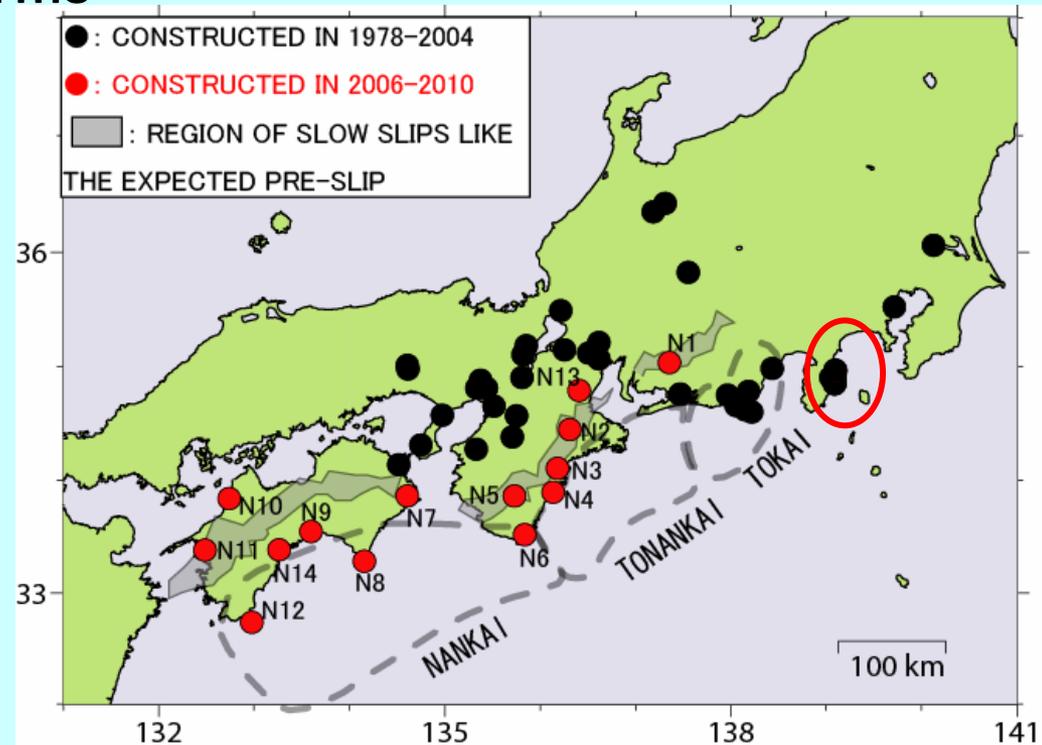
There is a Diffusion Process in Groundwater Movement.

Strain Rate > 1E-8/Day・・・Earth Tide

　→Groundwater Can Detect the Strain Change.

1.Magma-Induced Seismic Swarms

　→Izu Area

(We will Go Tomorrow).

ATMOSPHERIC PRESSURE (OMR)

1020 hPa — 50 mm/h

RAINFALL (OMR)

970 — 0

GROUNDWATER LEVEL (OMR)   EARTHQUAKE SWARMS

ACTIVE   INACTIVE

PRESEISMIC DROP

0.8m

ORIGINAL

CORRECTED

M5.0 M5.1

VOLUMETRIC STRAIN (HGS)

ORIGINAL

CORRECTED

1E-6

EVENTS/HOUR   NUMBER OF EATHQUAKES RECORDED AT KMT

300

0

11 12 13 14 15 16 17 18 19 20 21 22

DECEMBER 2009

(7)What is Relationship among GPS Data, Groundwater Level Data and (Borehole) Strain Data?

There is a Diffusion Process in Groundwater Movement.
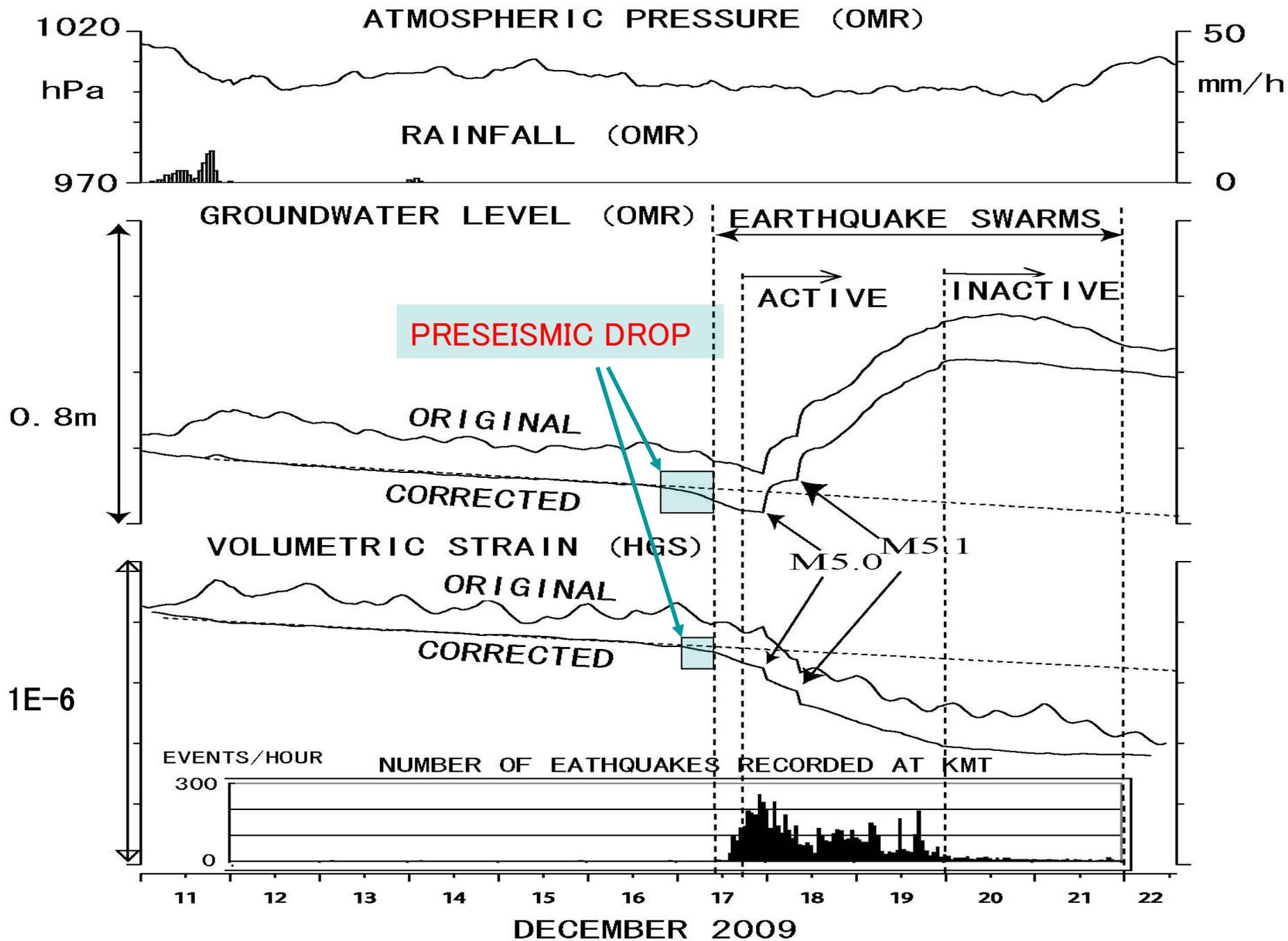
Strain Rate > 1E-8/Day・・・Earth Tide

　→Groundwater Can Detect the Strain

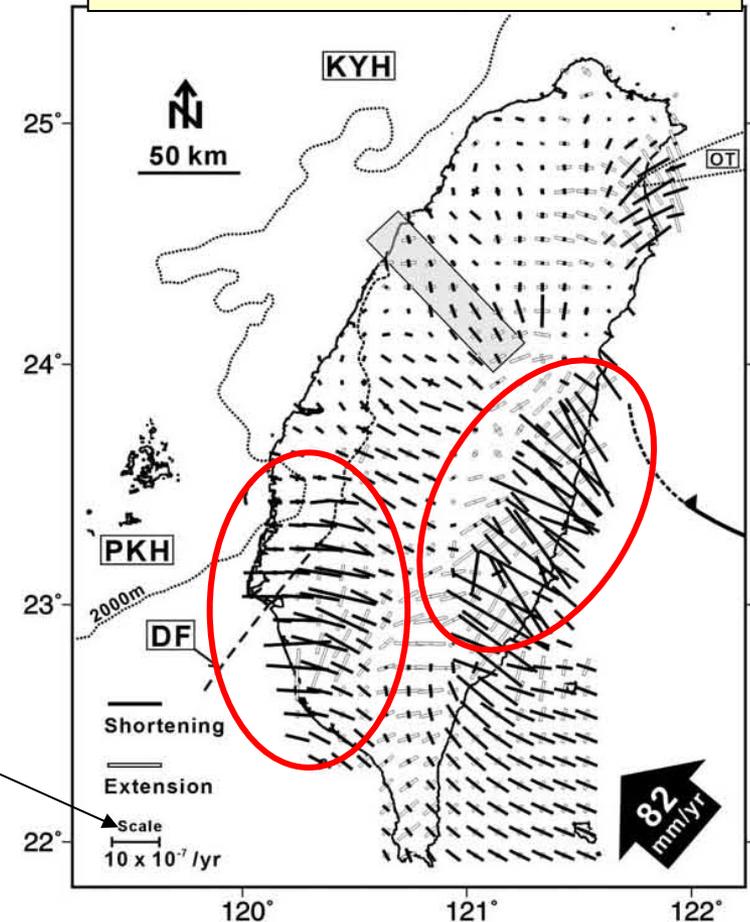2.Eastern and Southern Taiwan

Groundwater Level Data in These Areas Seems Important.

Strain Rate from GPS Chang et al.(2003)

1E-6/Year

0.3E-8/Year

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