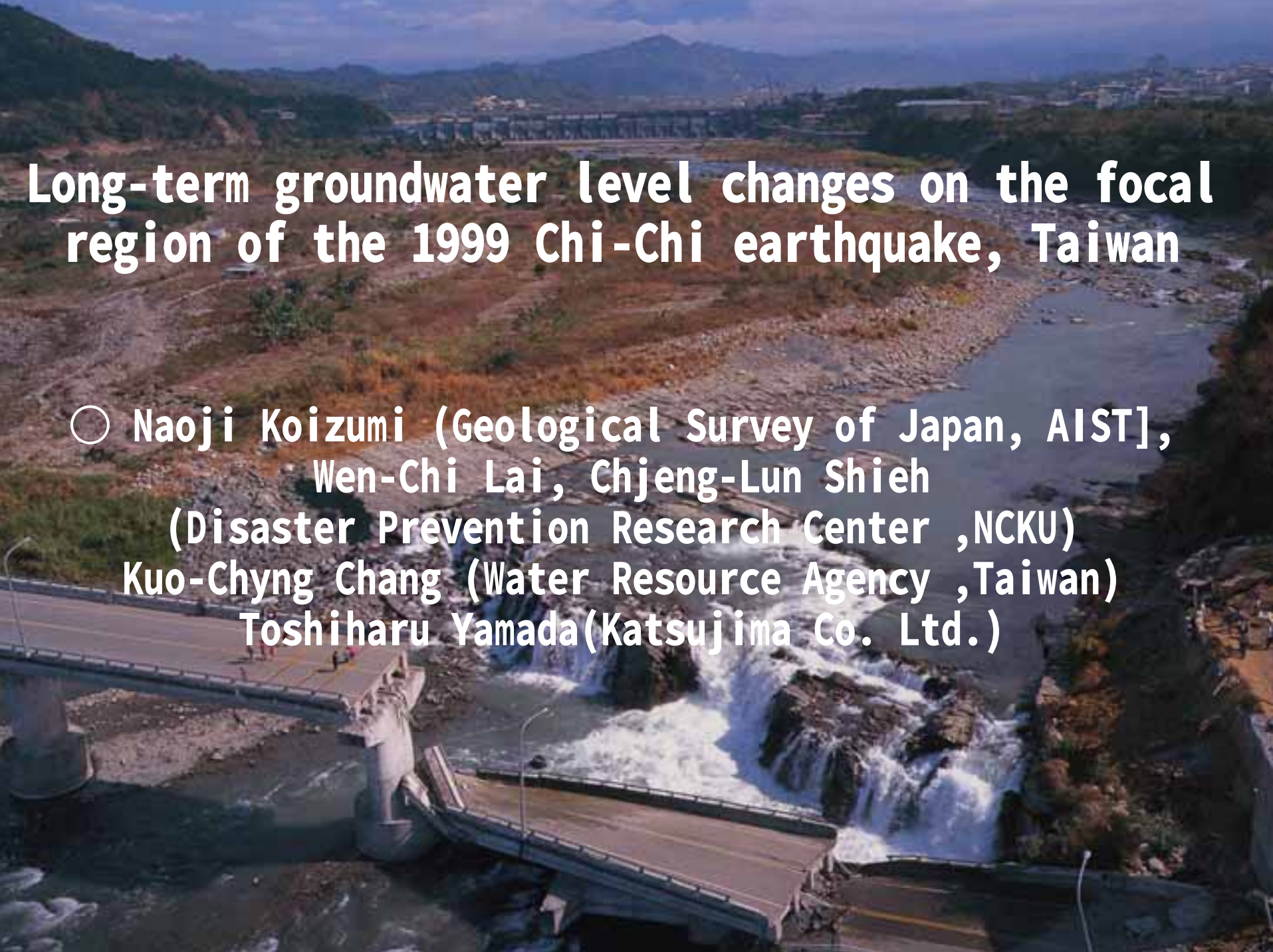
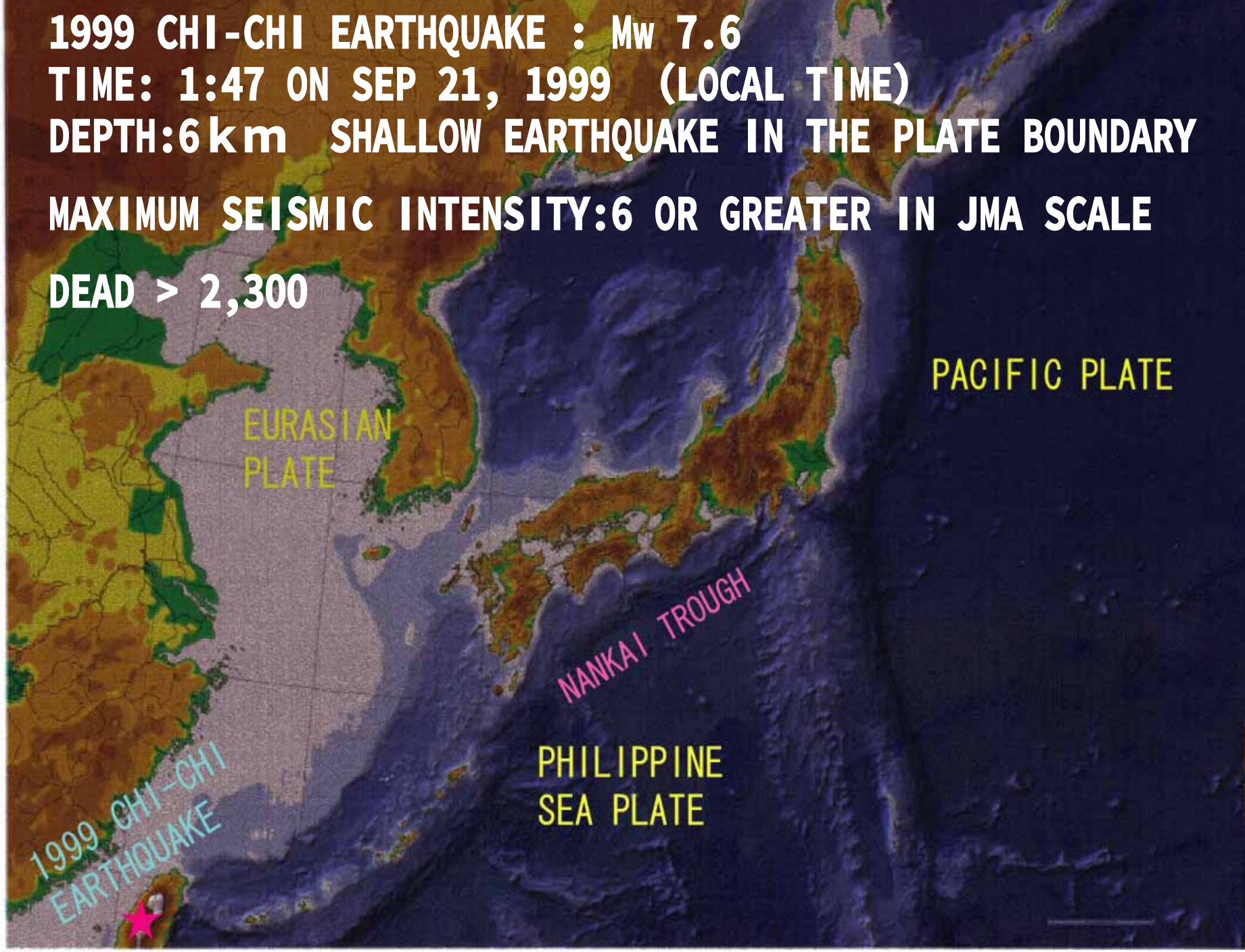


Long-term groundwater level changes on the focal region of the 1999 Chi-Chi earthquake, Taiwan

○ Naoji Koizumi (Geological Survey of Japan, AIST],
Wen-Chi Lai, Chjeng-Lun Shieh
(Disaster Prevention Research Center ,NCKU)
Kuo-Chyng Chang (Water Resource Agency ,Taiwan)
Toshiharu Yamada(Katsujima Co. Ltd.)


1999 CHI-CHI EARTHQUAKE : Mw 7.6
TIME: 1:47 ON SEP 21, 1999 (LOCAL TIME)
DEPTH:6km SHALLOW EARTHQUAKE IN THE PLATE BOUNDARY
MAXIMUM SEISMIC INTENSITY:6 OR GREATER IN JMA SCALE
DEAD > 2,300
PACIFIC PLATE
EURASIAN PLATE
NANKAI TROUGH
PHILIPPINE SEA PLATE
1999 CHI-CHI EARTHQUAKE

Program for Earthquakes and Active-fault Research (PEAR)

2001-2005

- Seismogenic-zone structures
- Earthquake geology
- Seismicity and seismotectonics
- Crustal deformations
- Earthquake physics (including physics, chemistry,rock mechanics, and hydrology related to earthquakes)
- Strong-motion seismology and engineering seismology

DPRC,WRA
(GSJ)

2006～

OBSERVATION WELLS OF WRA

NUMBER > 550
RESOLUTION: 1-2 cm
UNIFORM INVESTIGATION OF HYDRO-GEOLOGICAL STRUCTURE

1 STATION HAS 2 OR 3 WELLS. ONE IS SHALLOW (5-30M) THE OTHERS ARE DEEP (100-300M).

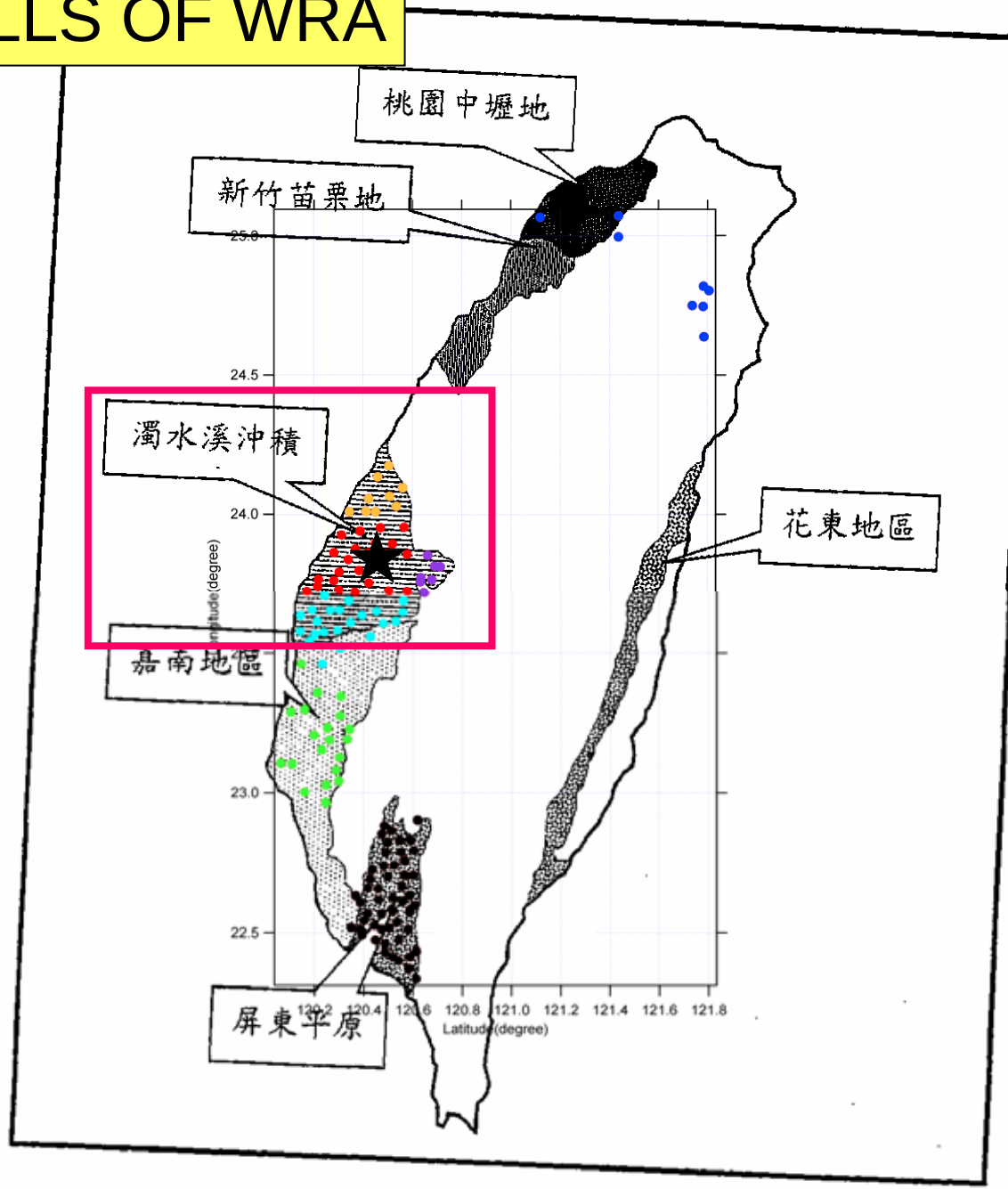
- PUMPING EFFECT IS LARGE.
- NON-UNIFORM DISTRIBUTION

FOCAL REGION

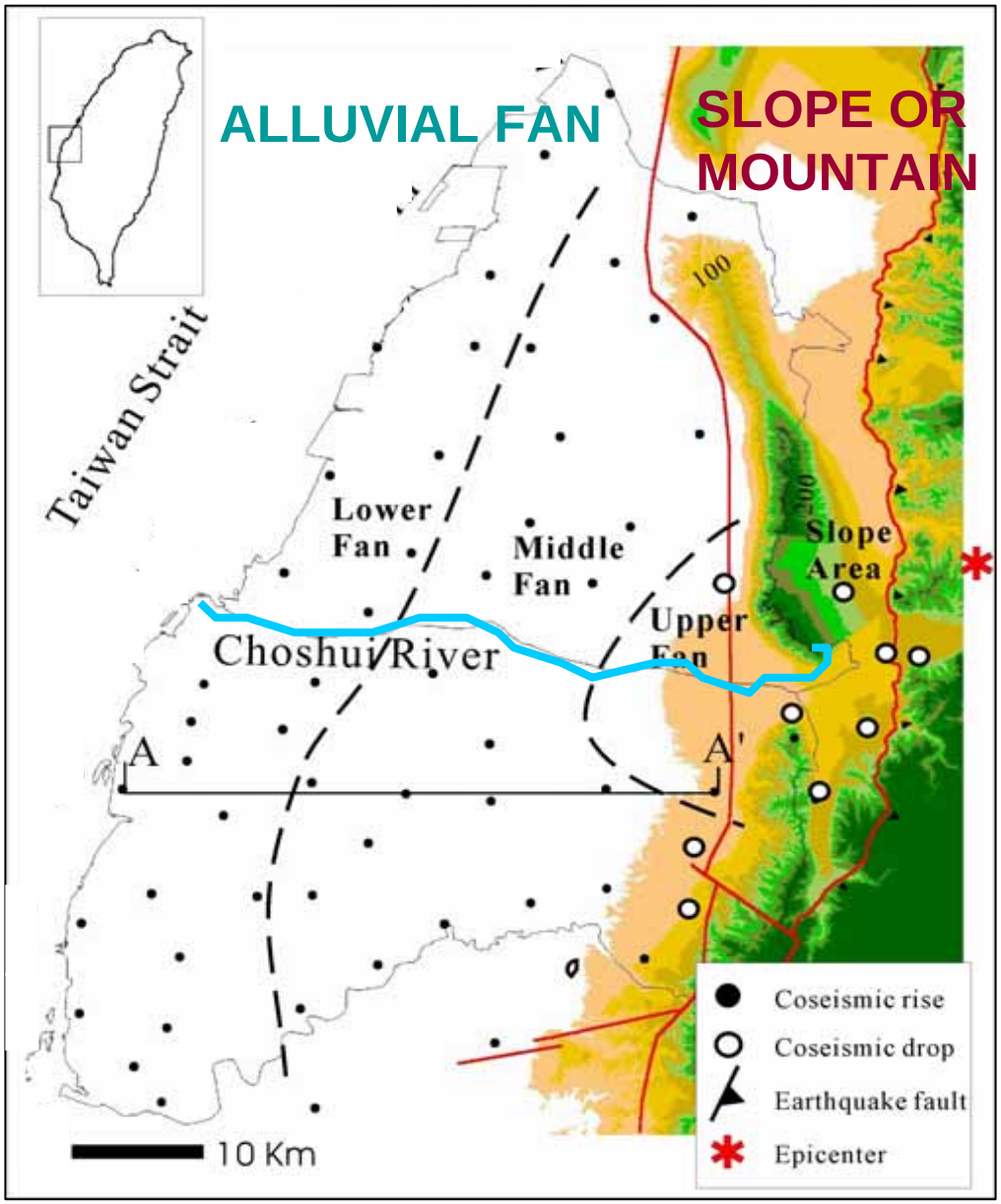
66STATIONS

168WELLS

DEPTH:15m～306m



ON AND AROUND FOCAL REGION OF THE 1999 CHI-CHI ERTHQUAKE



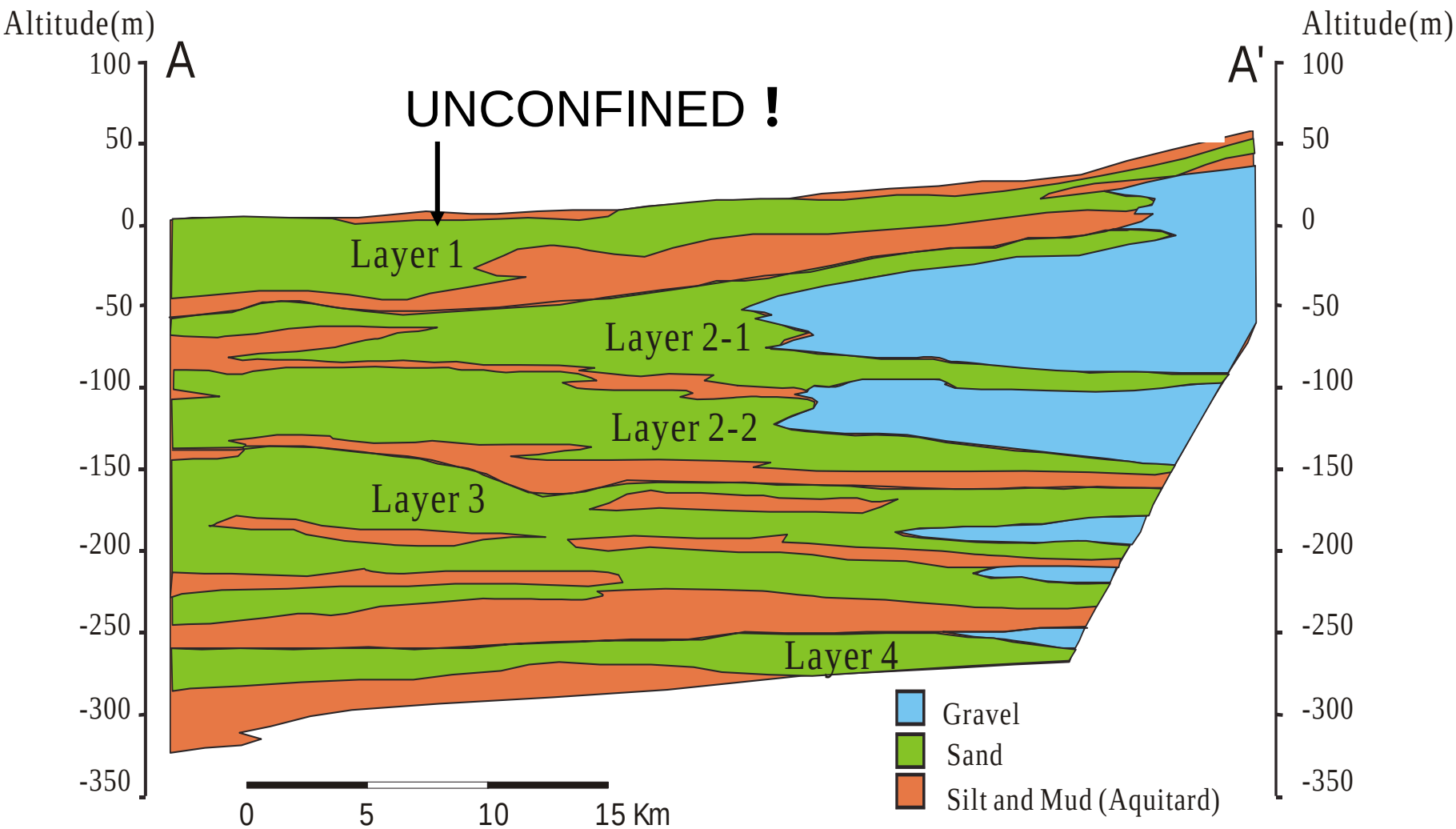
SEISMIC INTENSITY(JMA SCALE) 4～6

CALUCULATED FROM SEISMIC ACCELERATION DATA USING KAWASUMI'S FORMULA

EPICENTER

Wen-Chi Lai et.al(2004)

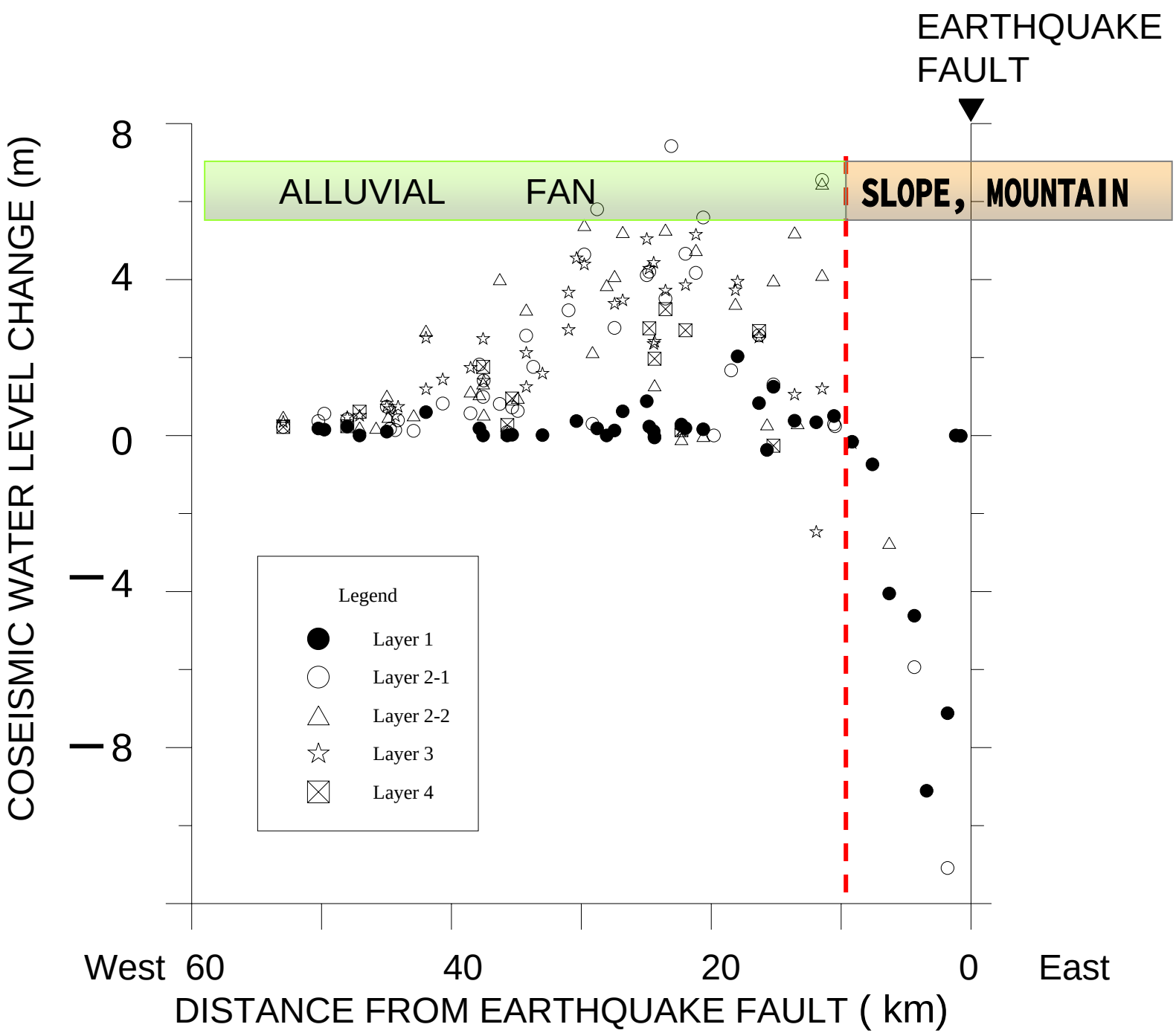
AQUIFERS

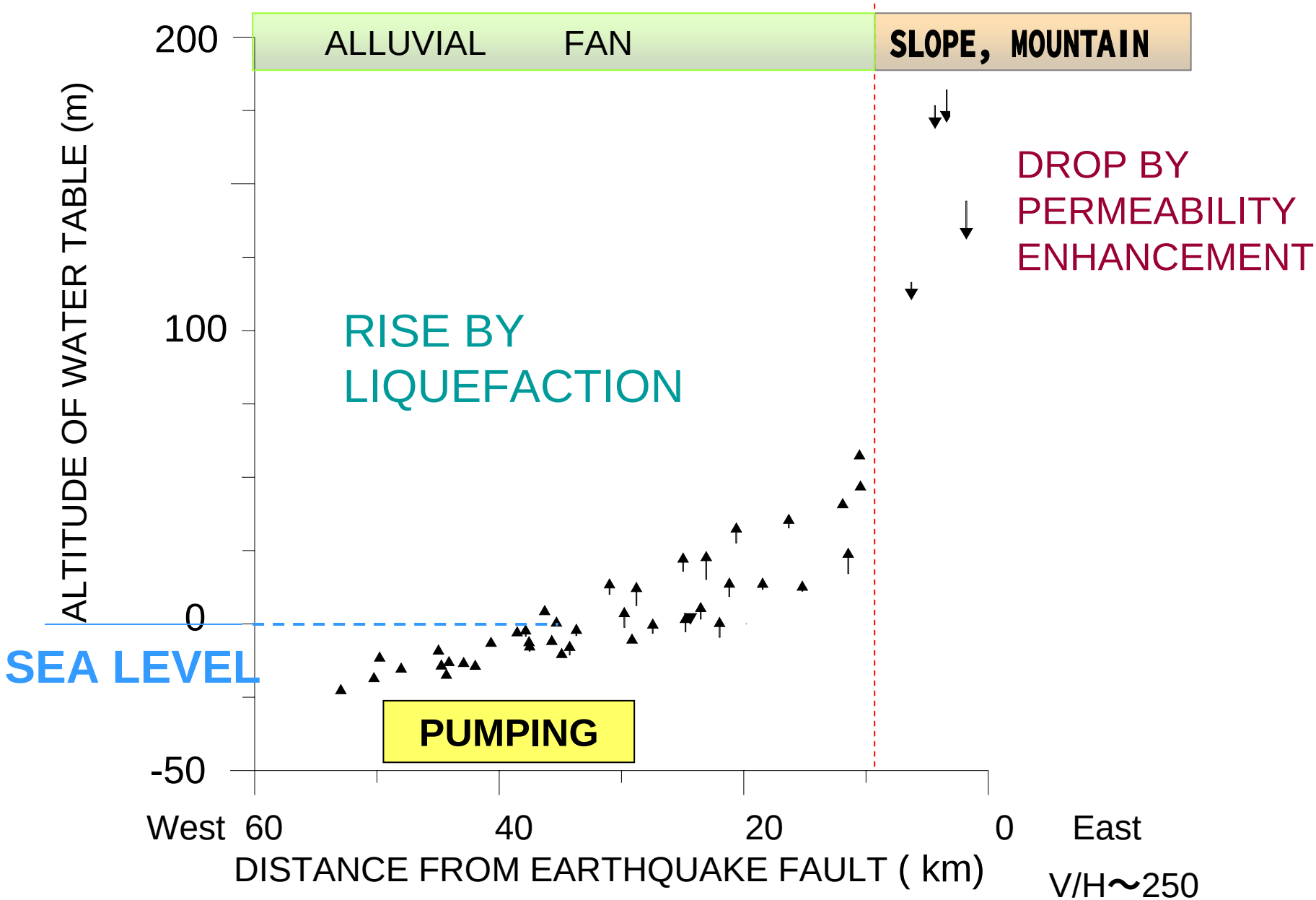


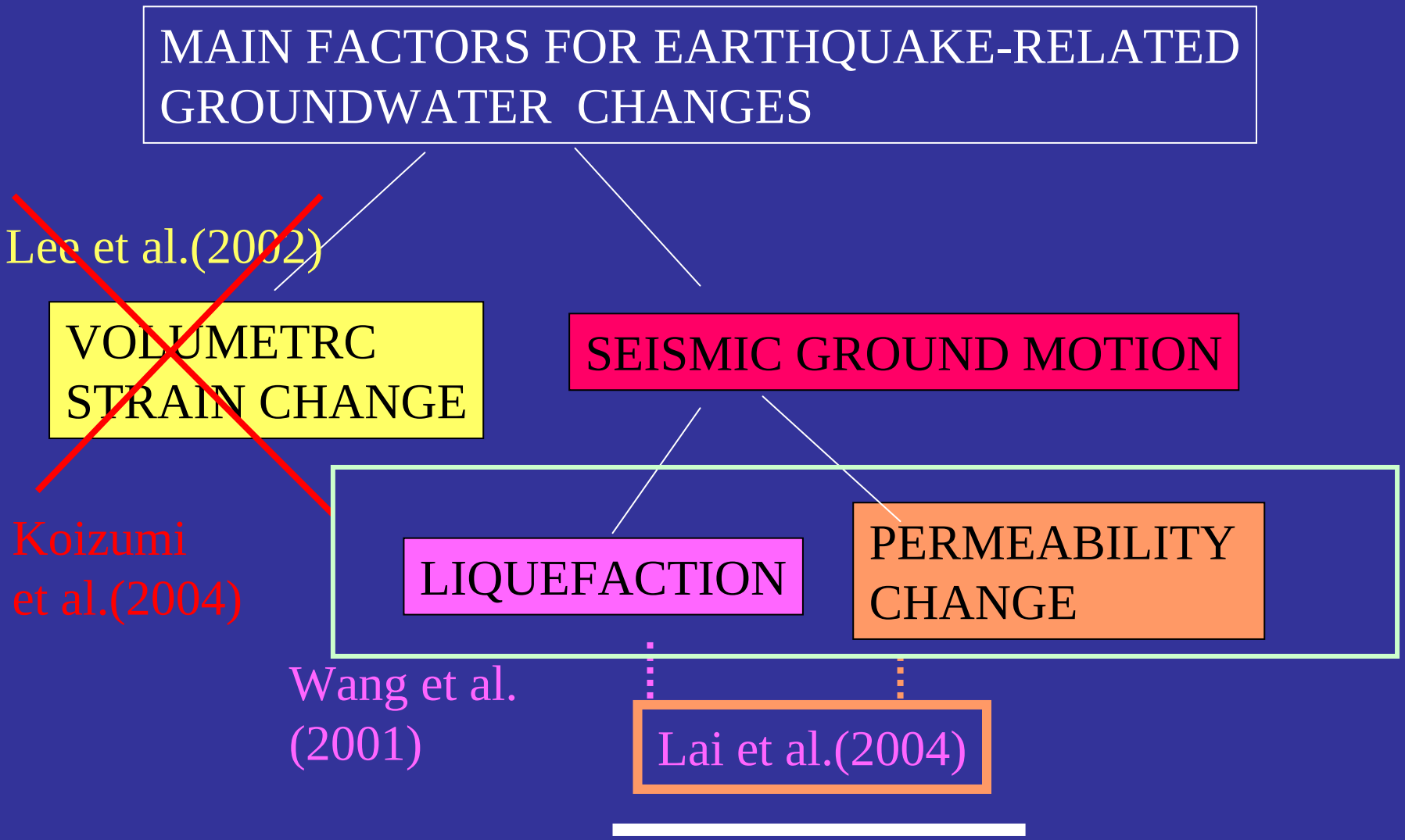
H:V=1:100

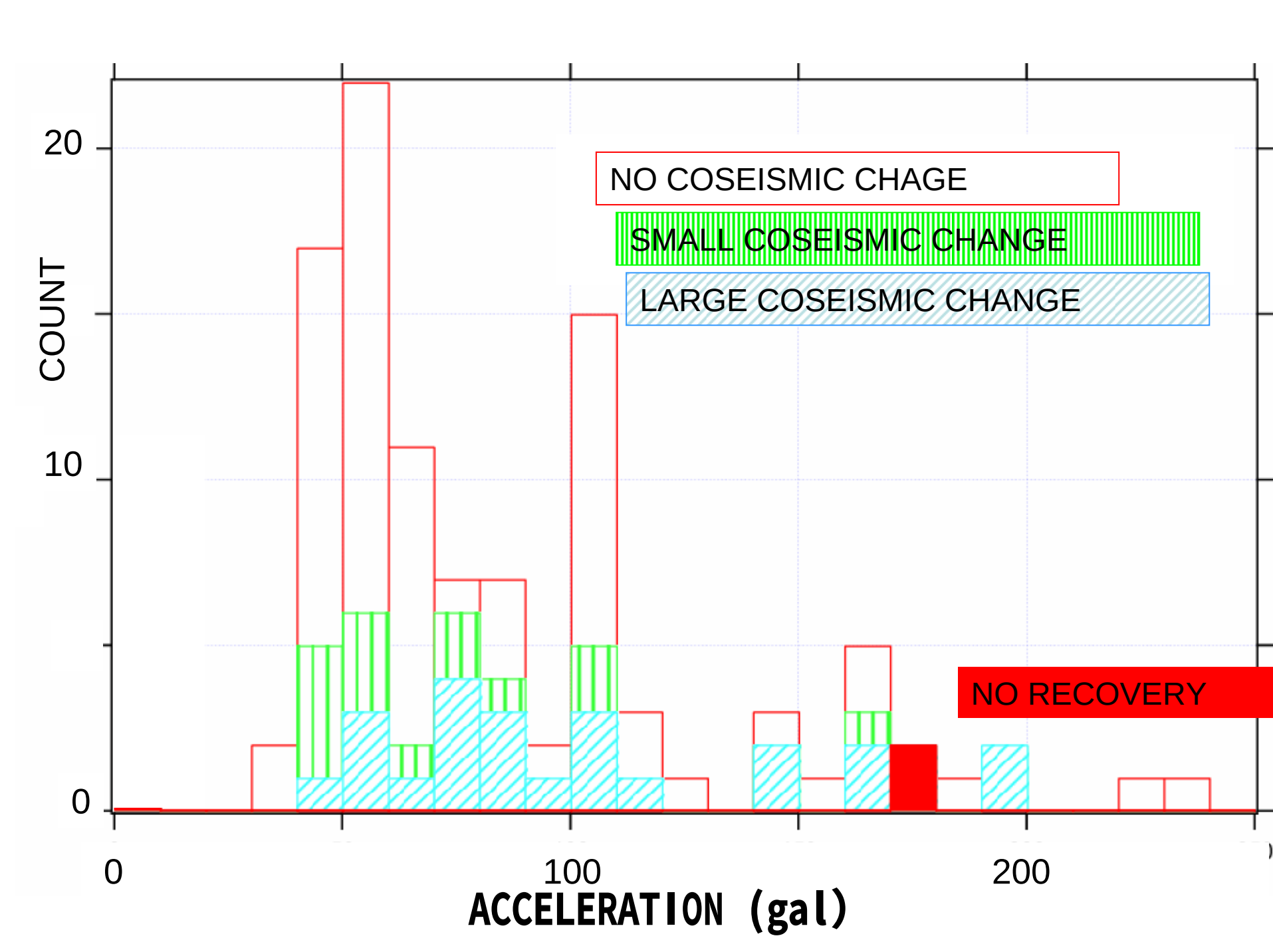
Wen-Chi Lai et.al

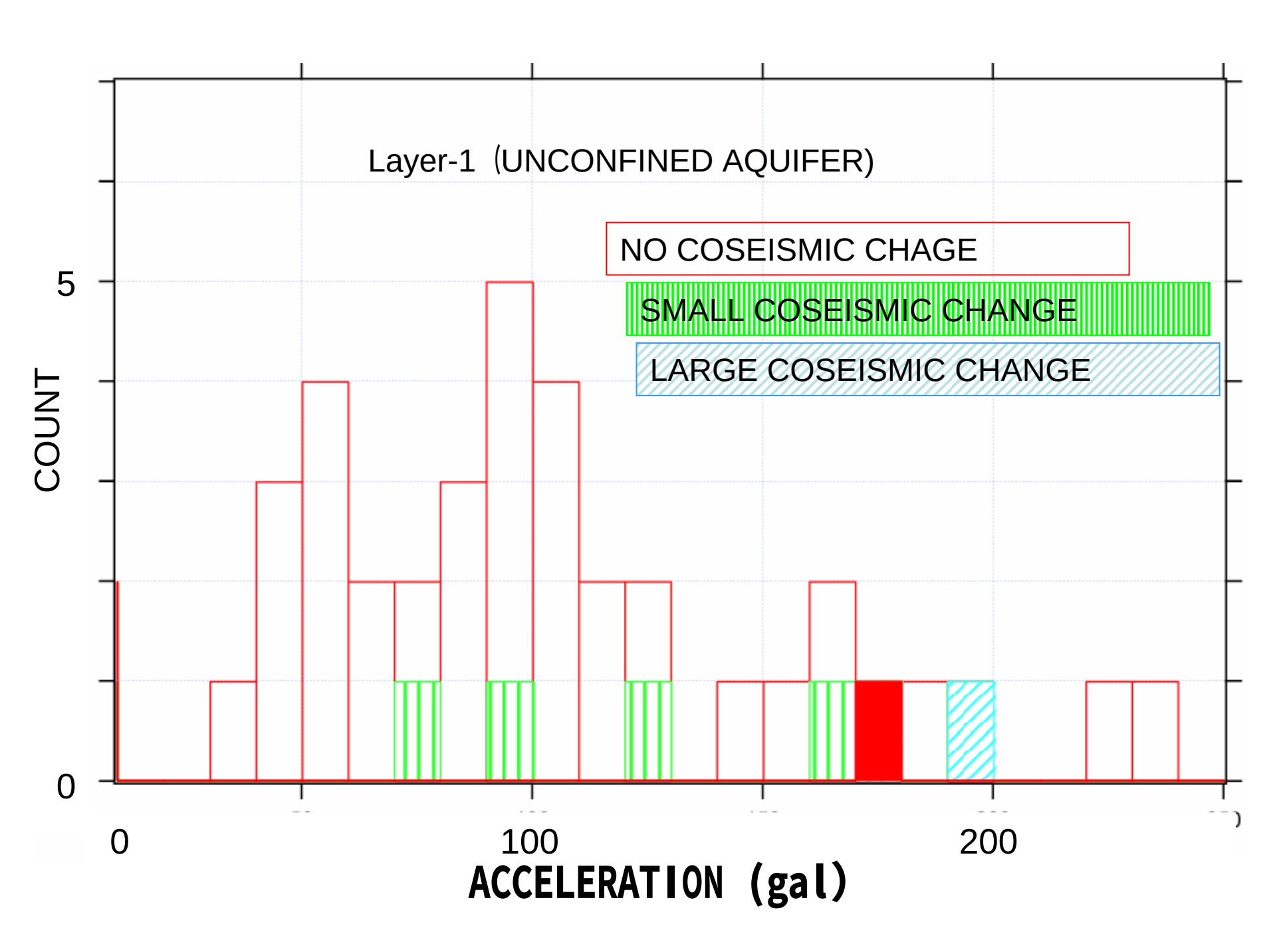
AQUIFER	SITUATION	NO.OF WELLS	COSEISMIC CHANGES	PERCANTAGE (%)
LAYER1	UNCONFINED	39	7	18
LAYER2(1+2)	CONFINED	78	43	55
LAYER 3	CONFINED	38	28	74
LAYER 4	CONFINED	13	9	69
ALL		168	87	52

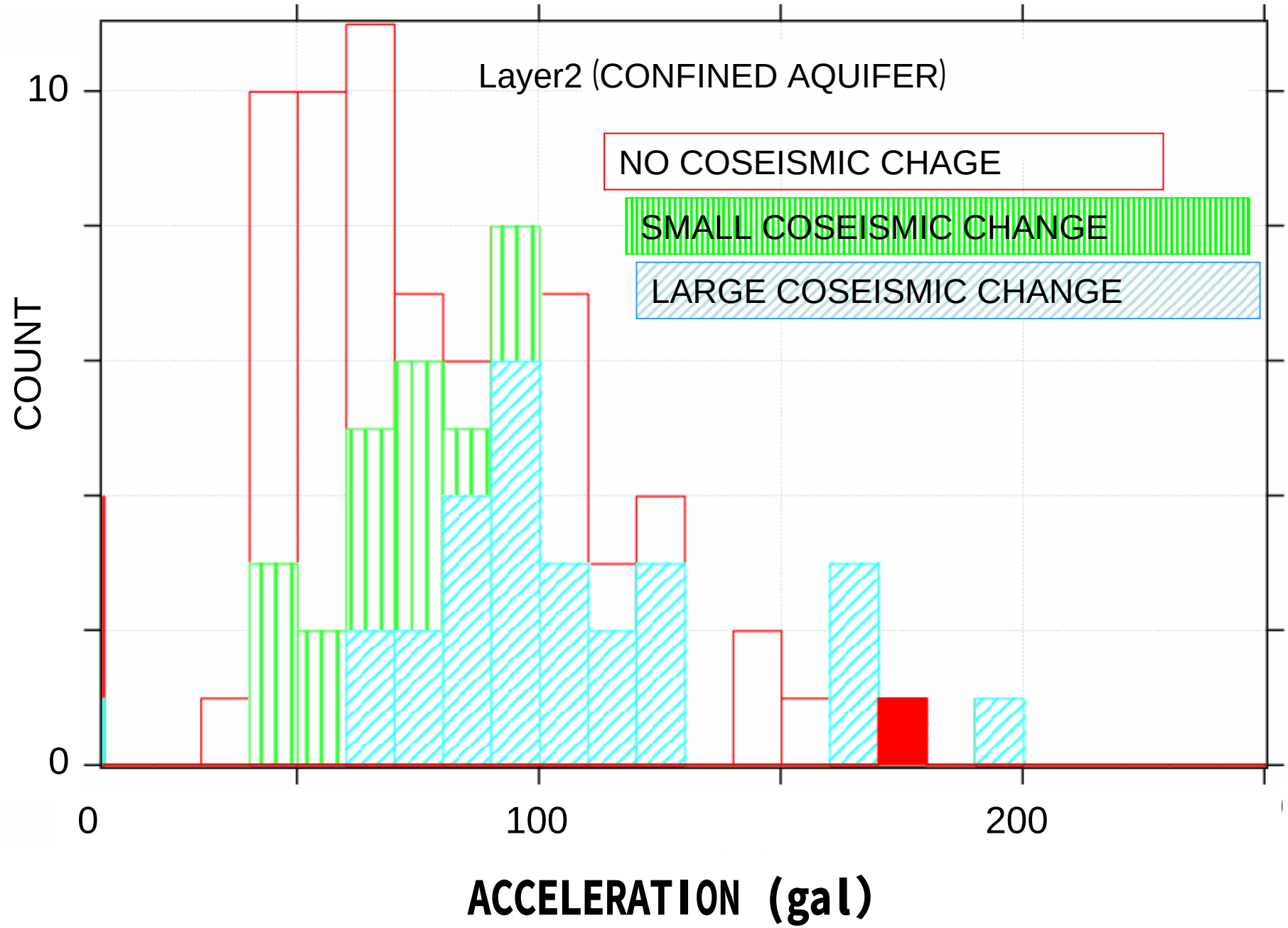

EARTHQUAKE FAULT
ALLUVIAL FAN
SLOPE, MOUNTAIN
COSEISMIC WATER LEVEL CHANGE (m)
8
4
0
−4
−8
Legend
Layer 1
Layer 2-1
Layer 2-2
Layer 3
Layer 4
West
60
40
20
0
East
DISTANCE FROM EARTHQUAKE FAULT (km)


ALLUVIAL FAN
SLOPE, MOUNTAIN
200
100
0
-50
ALTITUDE OF WATER TABLE (m)
SEA LEVEL
RISE BY
LIQUEFACTION
DROP BY
PERMEABILITY
ENHANCEMENT
PUMPING
West
60
40
20
0
East
DISTANCE FROM EARTHQUAKE FAULT (km)
V/H～250

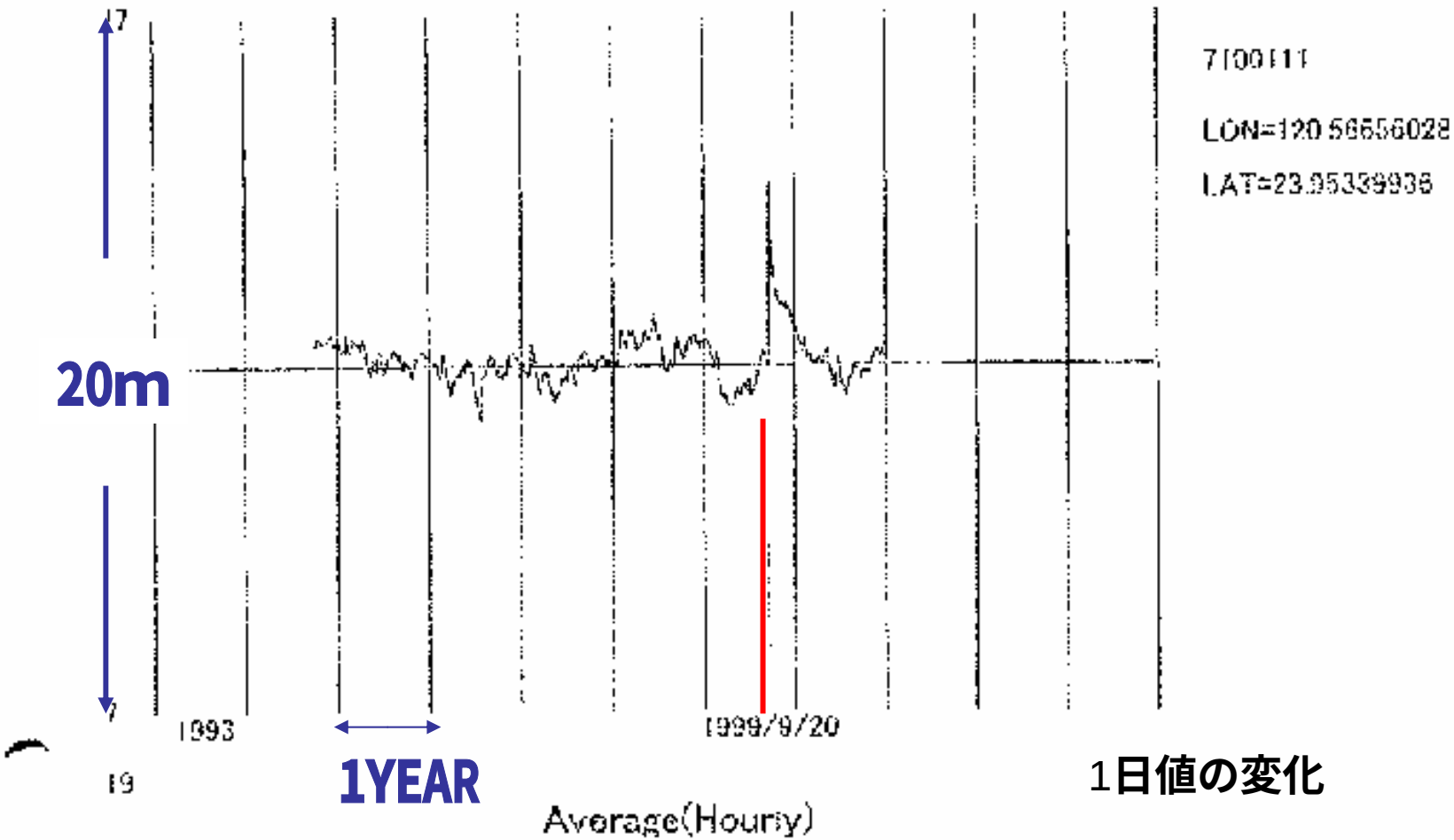

MAIN FACTORS FOR EARTHQUAKE-RELATED GROUNDWATER CHANGES
Lee et al.(2002)
VOLUMETRC STRAIN CHANGE
SEISMIC GROUND MOTION
Koizumi et al.(2004)
LIQUEFACTION
PERMEABILITY CHANGE
Wang et al. (2001)
Lai et al.(2004)


NO COSEISMIC CHAGE
SMALL COSEISMIC CHANGE
LARGE COSEISMIC CHANGE
NO RECOVERY
COUNT
20
10
0
0
100
200
ACCELERATION (gal)

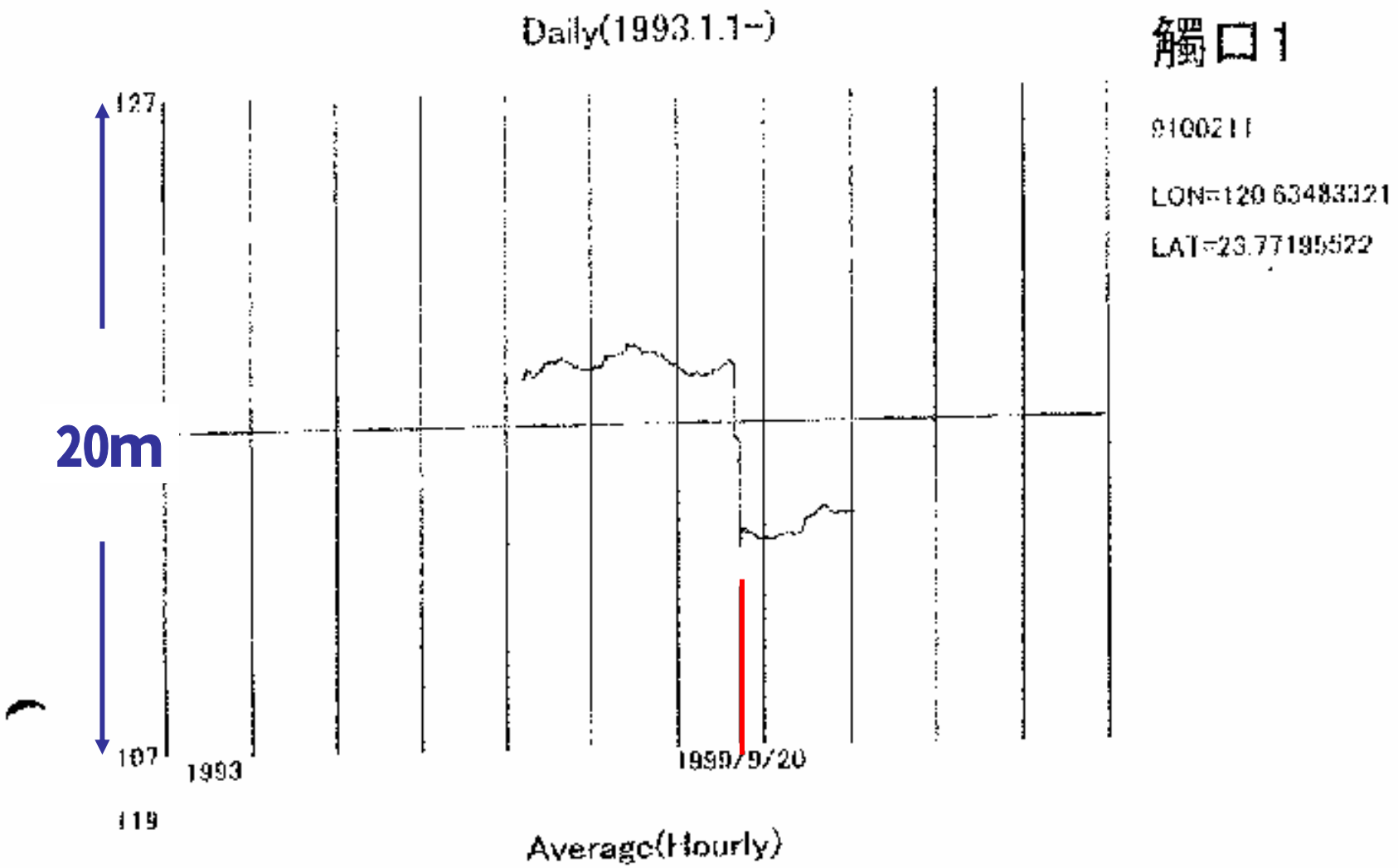

Layer-1 (UNCONFINED AQUIFER)
NO COSEISMIC CHAGE
SMALL COSEISMIC CHANGE
LARGE COSEISMIC CHANGE
COUNT
5
0
0
100
200
ACCELERATION (gal)

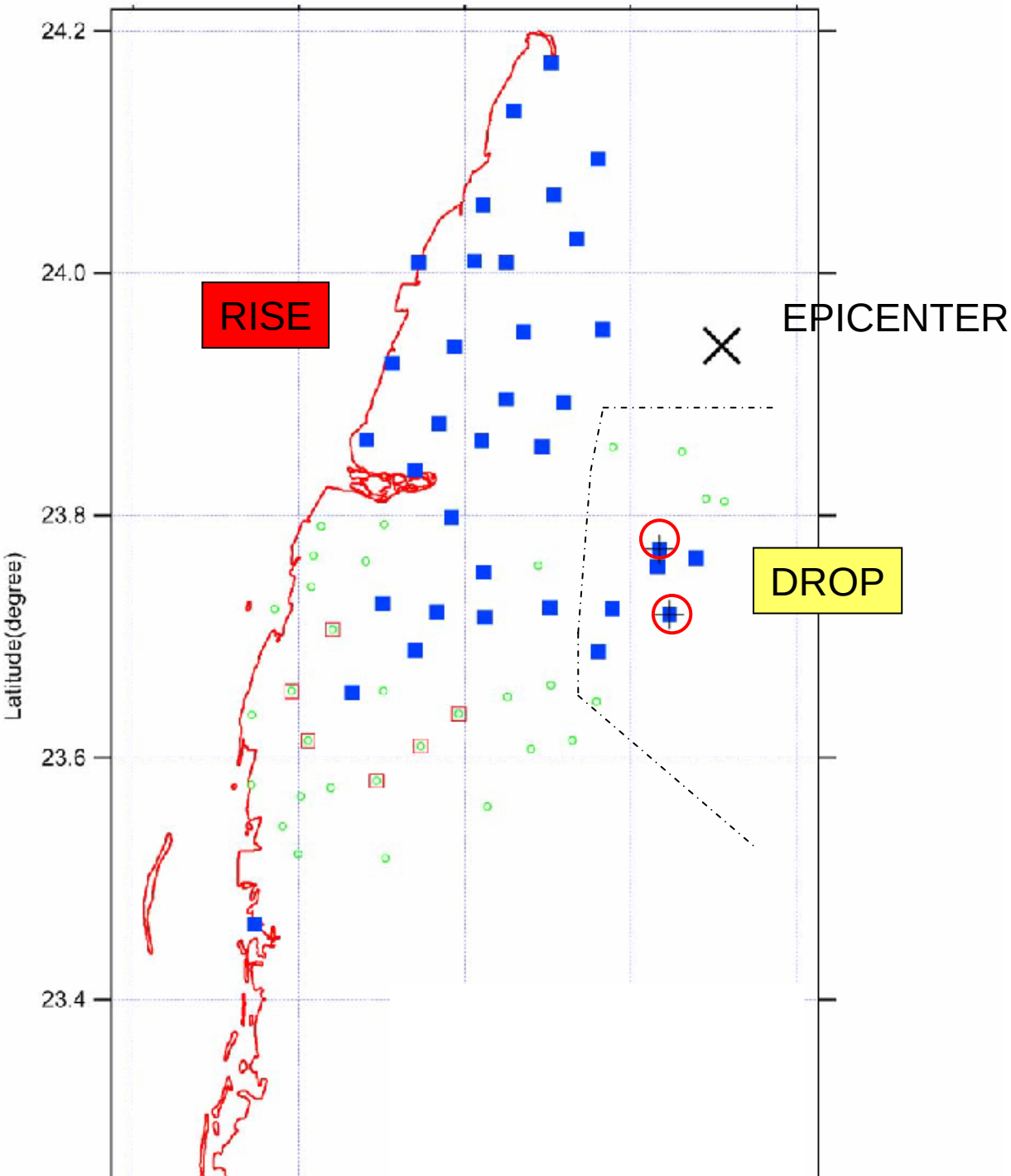

Layer2 (CONFINED AQUIFER)
NO COSEISMIC CHAGE
SMALL COSEISMIC CHANGE
LARGE COSEISMIC CHANGE
COUNT
10
0
0
100
200
ACCELERATION (gal)

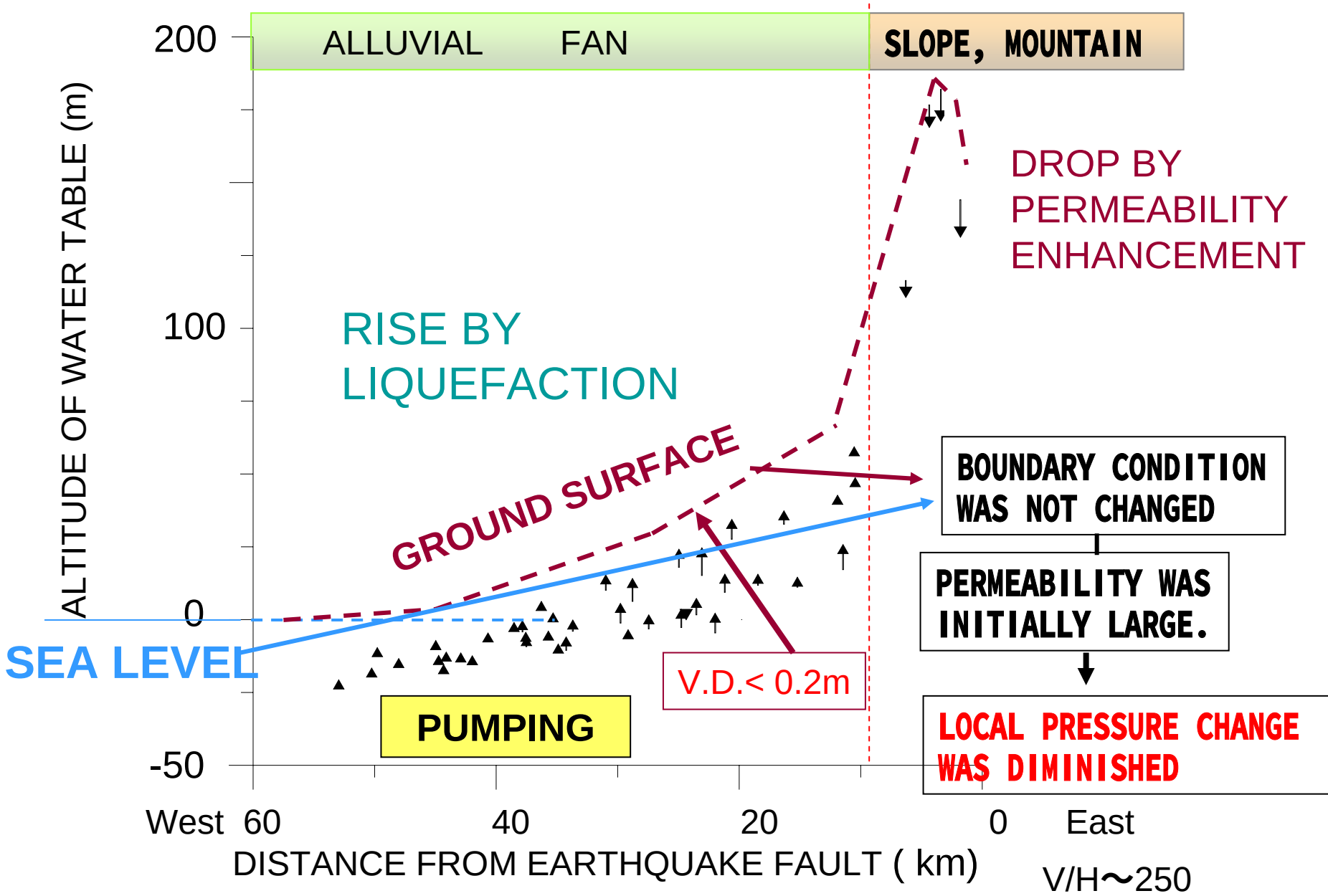
DAILY VALUE (1993-2000)



1日値の変化


Daily(1993.1.1~)
觸口1
9100211
LON=120.63483321
LAT=23.77195522
127
20m
107
1993
1999/9/20
119
Average(Hourly)


24.2
24.0
23.8
23.6
23.4
Latitude(degree)
RISE
EPICENTER
DROP


ALLUVIAL FAN
SLOPE, MOUNTAIN
200
100
0
-50
ALTITUDE OF WATER TABLE (m)
DROP BY PERMEABILITY ENHANCEMENT
RISE BY LIQUEFACTION
GROUND SURFACE
BOUNDARY CONDITION WAS NOT CHANGED
PERMEABILITY WAS INITIALLY LARGE.
SEA LEVEL
V.D.< 0.2m
PUMPING
LOCAL PRESSURE CHANGE WAS DIMINISHED
West 60
40
20
0
East
DISTANCE FROM EARTHQUAKE FAULT (km)
V/H～250

CONCLUSIONS

- We investigated water level changes in the 66 stations (168 wells) on and around the focal region of the 1999 Chi-Chi earthquake during the period from 1993 to 2000. The depths of the wells range between 15m and 306m.
- Most of the well water levels which changed coseismically recovered by December 2000. All of the well water levels in the alluvial fan recoverd.
- 3 well water levels, which dropped coseismically by permeability enhancement, did not recover. They are situated in the slope or mountain zones near the earthquake fault.
- The possible reasons are as follows; (1) Permeabilities of the aquifers in the alluvial fan are originally large, (2) Levels of neighboring sea, rivers and lakes or ponds, which are important boundary conditions controlling groundwater pressures, did not largely change after the 1999 Chi-Chi earthquake.

AQUIFER	SITUATION	NO.OF WELLS	COSEISMIC CHANGES	PERCANTAGE (%)
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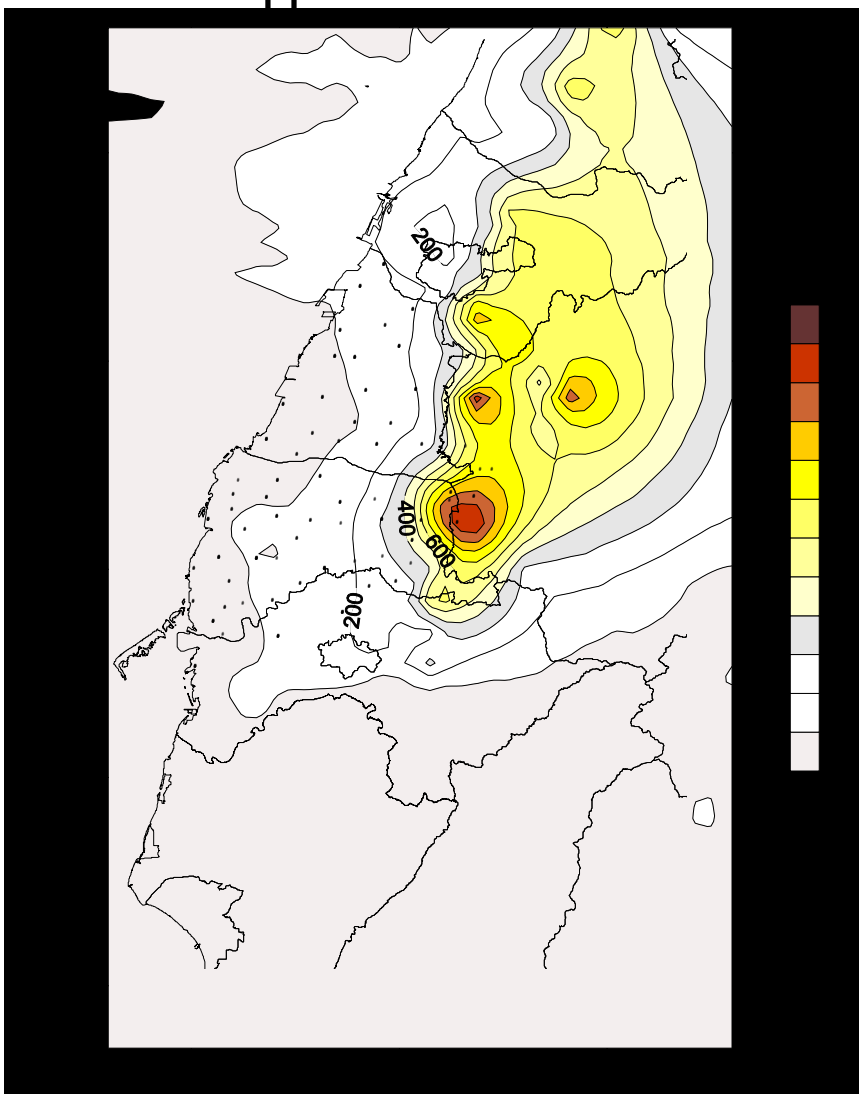
LAYER 3	CONFINED	38	28	74
LAYER 4	CONFINED	13	9	69
ALL		168	87	52

Spatial distribution (P.G.A. and Vol. strain)

- PGA_H



- Volumetric strain