Strategical roles of hydrological and geochemical methods in earthquake prediction research

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1.Introduction

＊Contribution to making a physical fault model

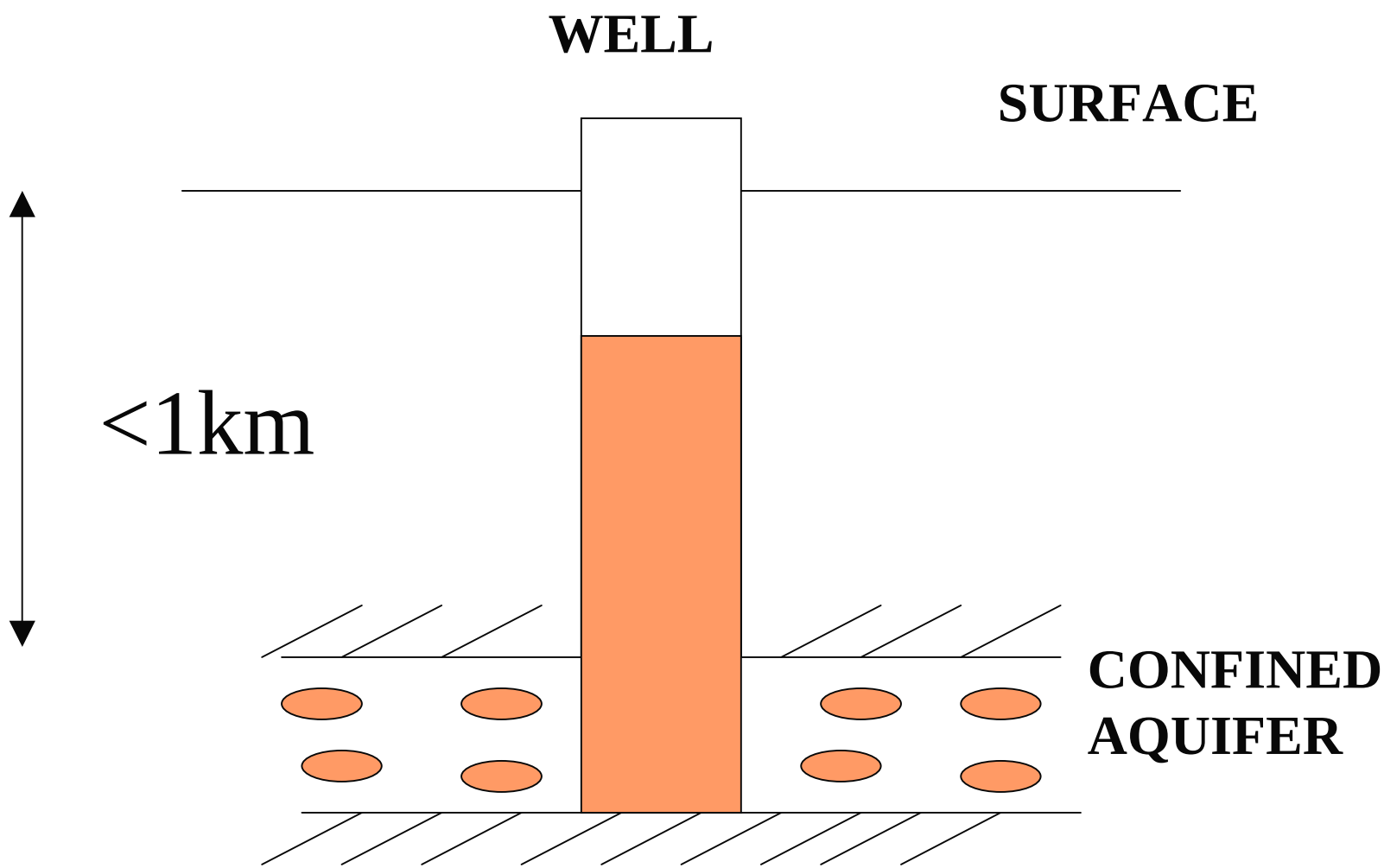
2.Estimation of earthquake-related volumetric strain changes from groundwater data

3.Estimation of earthquake-related pore pressure changes from groundwater data

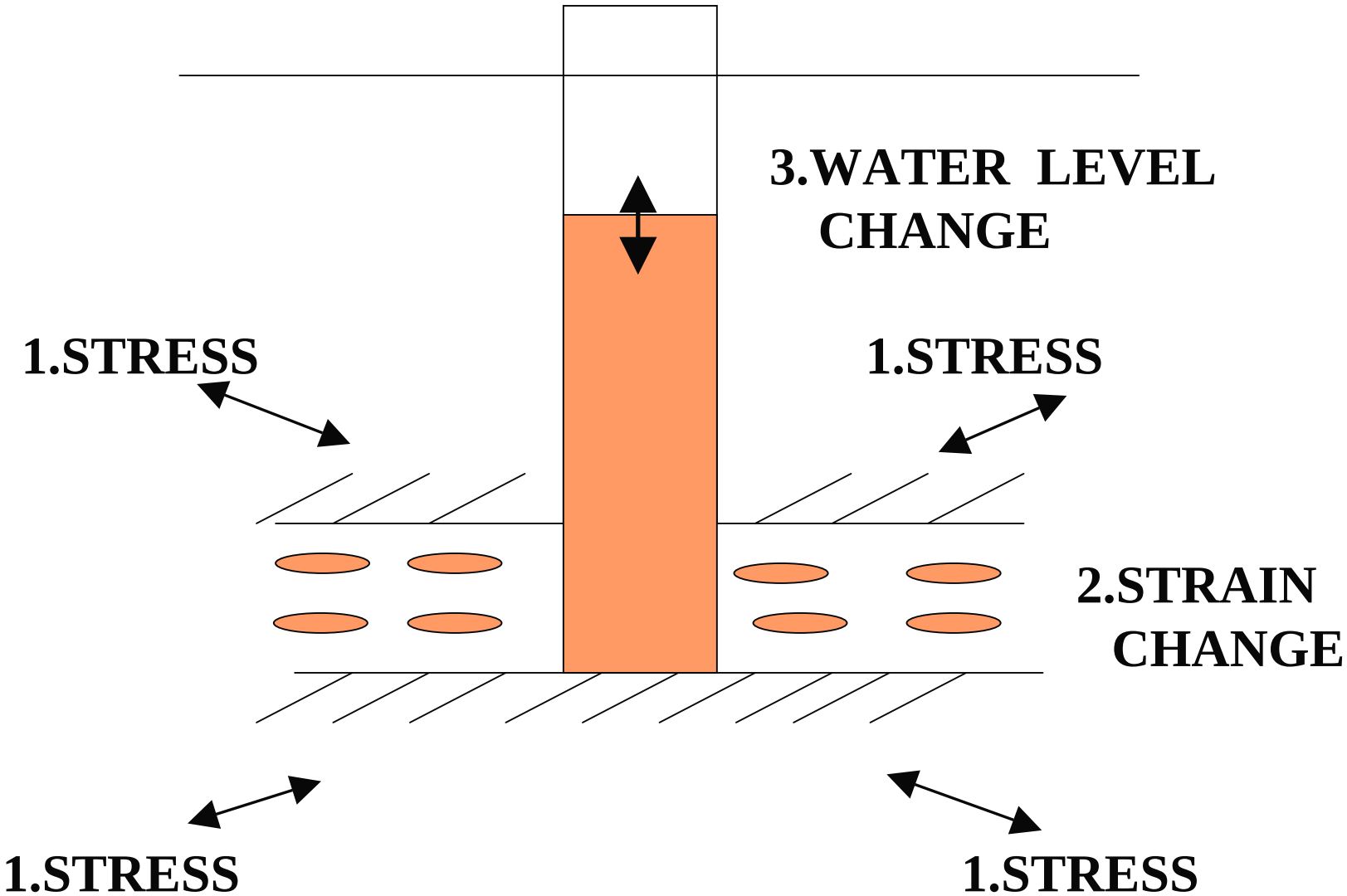
4.Supply of material information

5. Estimation of groundwater's effect on the long-term geodetic measurement

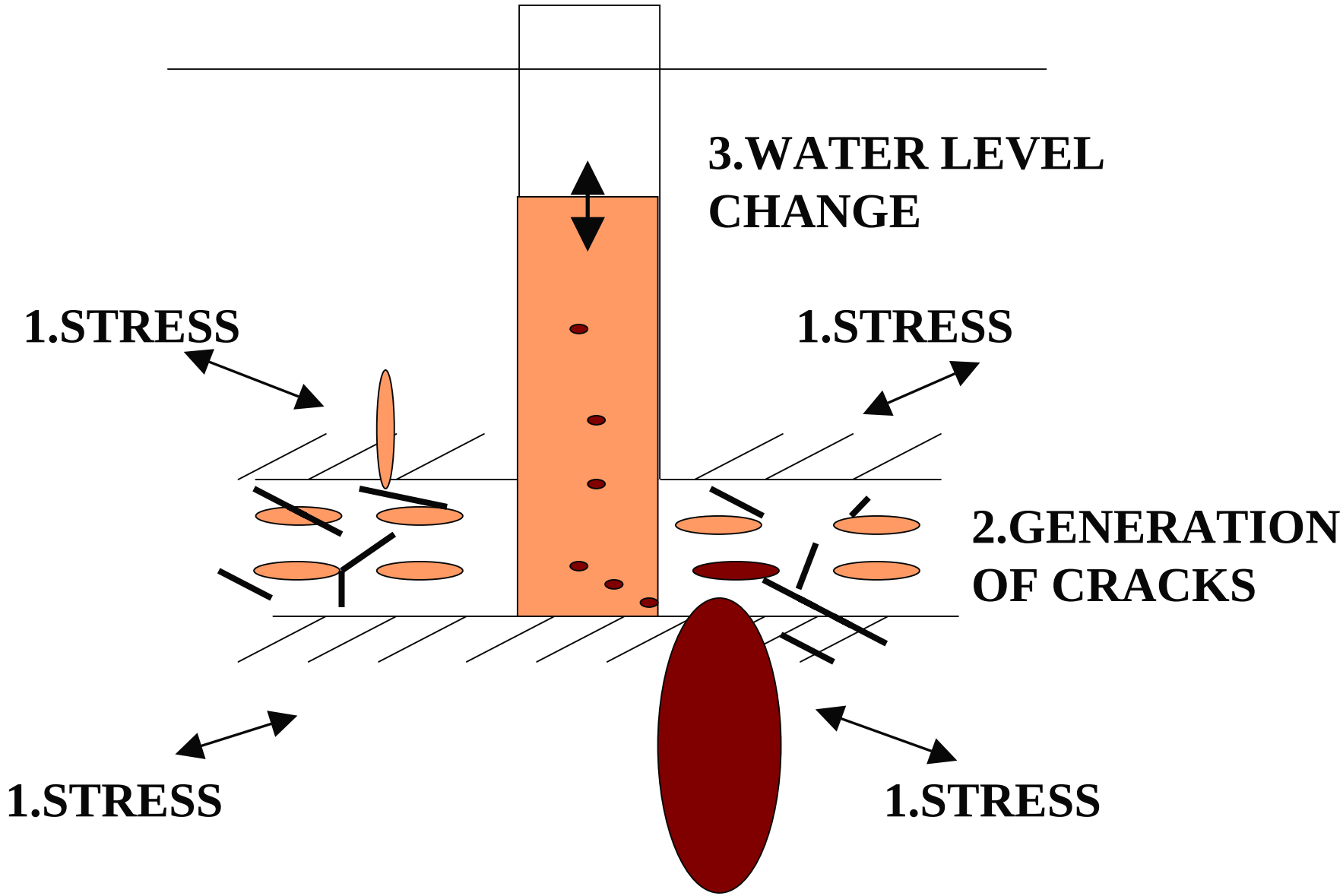
MODEL



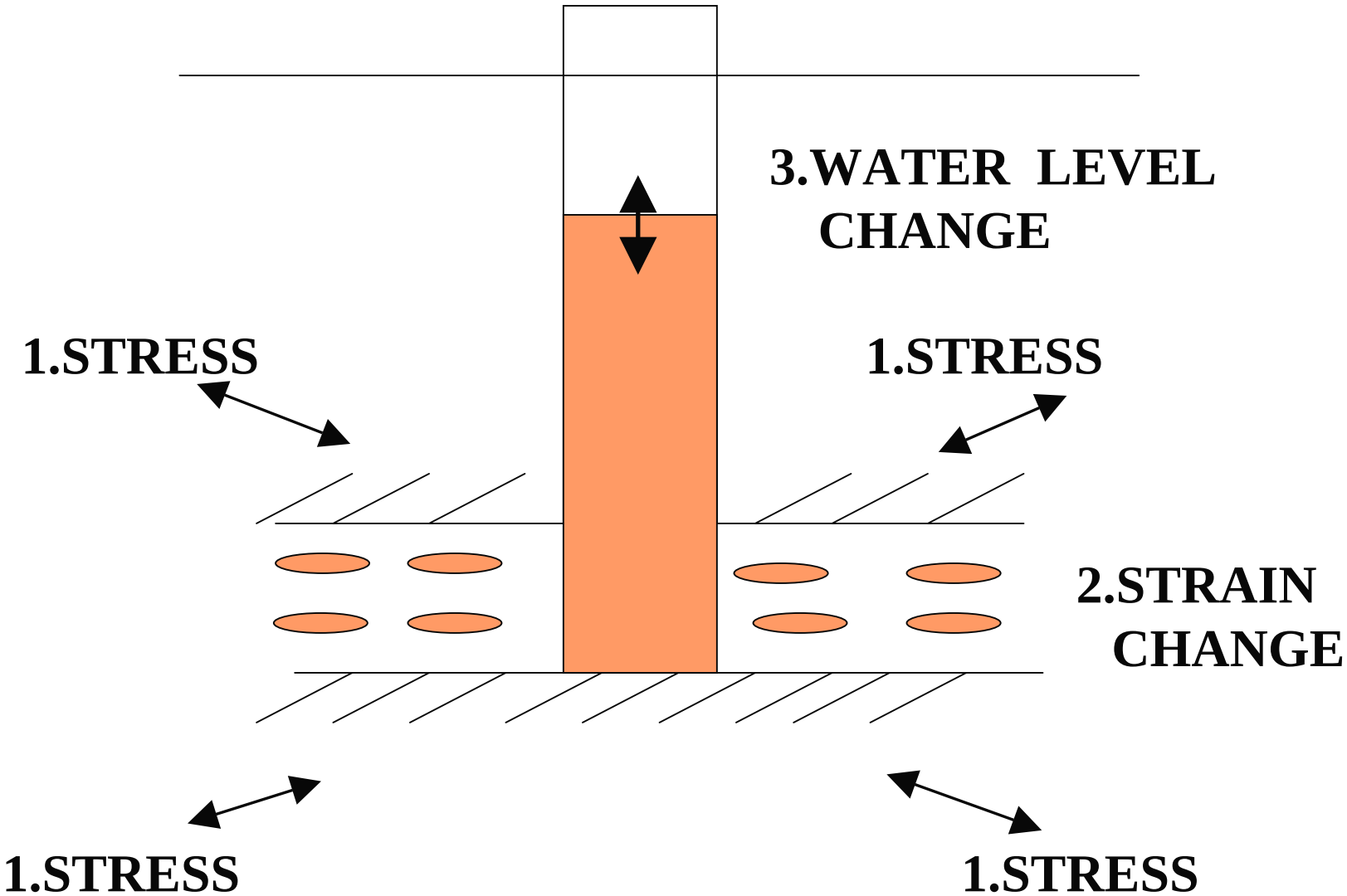
‘STRAIN MODEL’



CRACK MODEL


3.WATER LEVEL CHANGE
1.STRESS
1.STRESS
2.GENERATION OF CRACKS
1.STRESS
1.STRESS

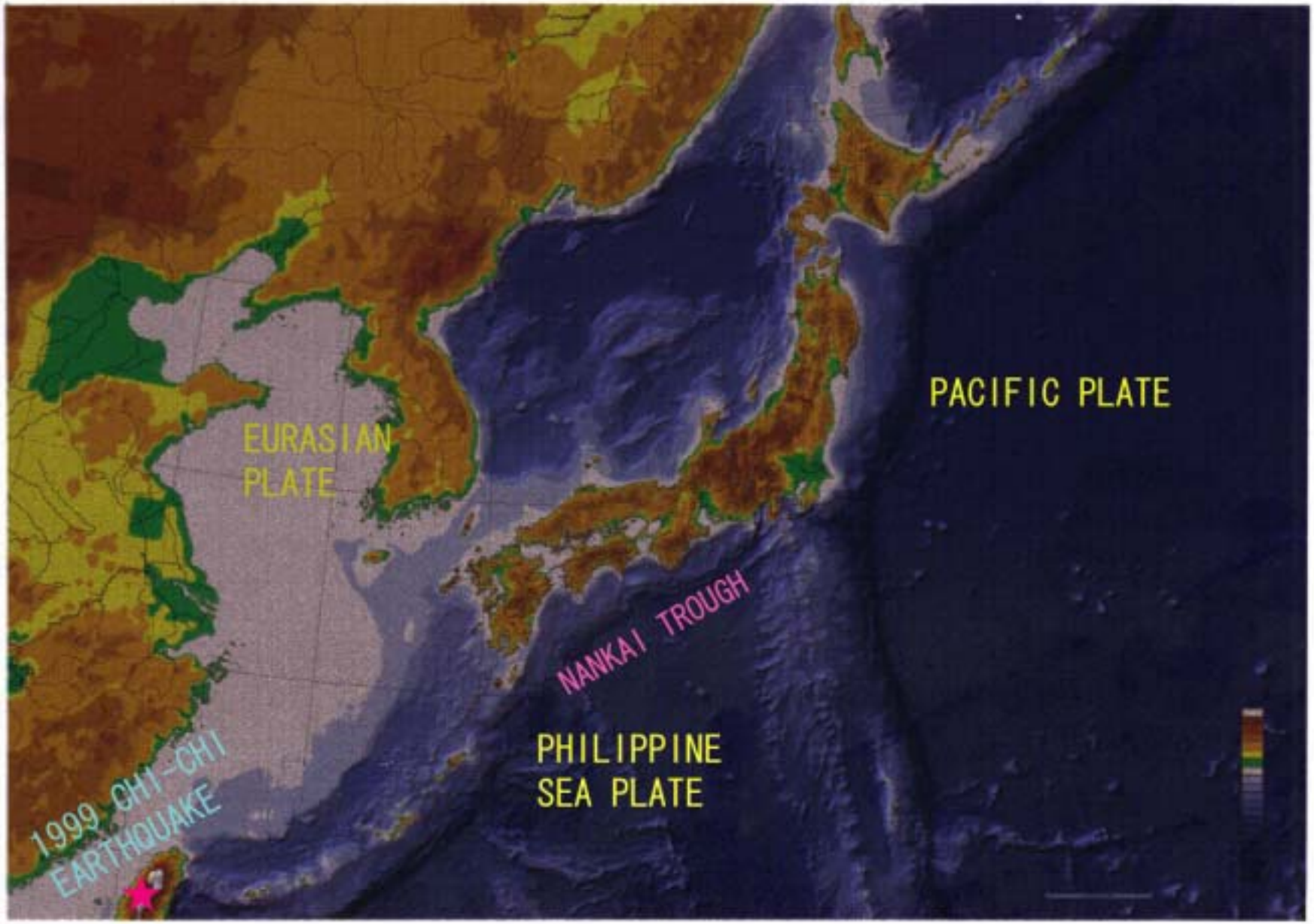
‘STRAIN MODEL’



2.Estimation of earthquake-related volumetric strain changes from groundwater data

1) CRUSTAL DEFORMATION
(VOLUMETRIC STRAIN CHANGE)
→ GROUNDWATER CHANGE
(QUQNTITATIVE ESTIMATION)

2) GROUNDWATER CHANGE →CRUSTAL DEFORMATION
(PAST, PRESENT) (VOLUMETRIC STRAIN CHANGE)
→DATABASE
→CONTRIBUTION TO MAKING PHYSICAL MODEL
(FAULT MODEL FOR PRE-SLIP AND MAIN SLIP)


EURASIAN
PLATE
PACIFIC PLATE
NANKAI TROUGH
PHILIPPINE
SEA PLATE
1999 CHI-CHI
EARTHQUAKE

LARGE EARTHQUAKES IN NANKAI TROUGH AND GROUNDWATER CHANGE

DATE	M	GROUNDWATER (KII)	GROUNDWATER(SIKOKU)
1. NOV. 29, 684	8 1/4	MURO HOT SPRING STOP	IYO HOT SPRING STOP
2. AUG. 26, 887	8 1/4	---	---
3. FEB. 22, 1099	8.2	---	---
4. AUG. 3, 1361	8.4	YUNOMINE HOT SPRING STOP	
5. FEB. 3, 1605	7.9	---	---
6. OCT. 28, 1707	8.4	4 HOT SPRINGS STOP	DOGO HOT SPRING STOP
7. DEC. 24, 1854	8.4	2 HOT SPRINGS STOP	---
8. DEC, 21, 1946	8		

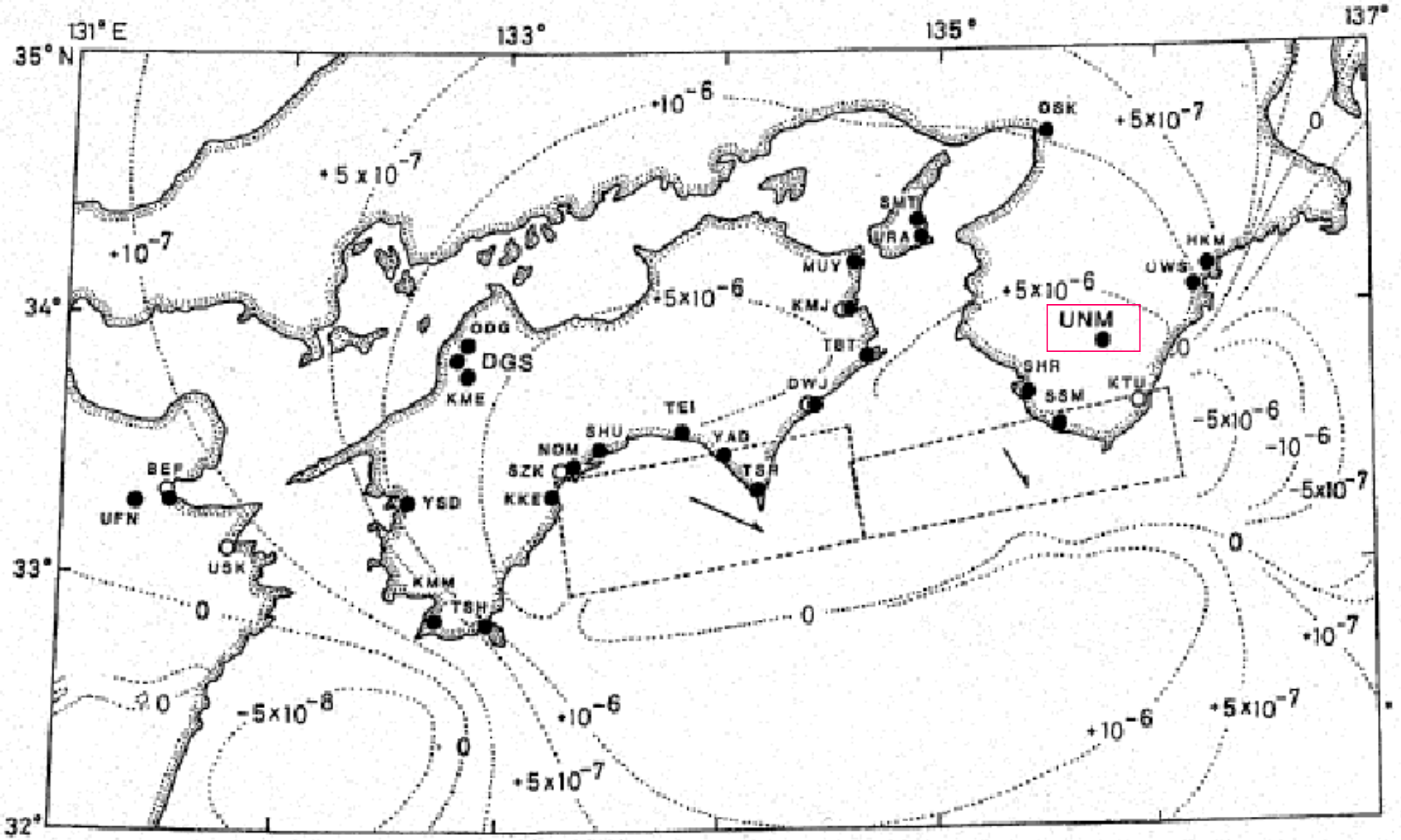
BEFORE AND AFTER THE EARTHQUAKE

DECREASE OF DISCHARGE
DECREASE OF LEVEL
(AT MANY WELLS)

DECREASE OF DISCHARGE
DECREASE OF LEVEL
(AT MANY WELLS)

E

USAMI(1987), KAWABE(1991)



● **DROP**

○ RISE

KAWABE(1991

LARGE EARTHQUAKES IN NANKAI TROUGH AND GROUNDWATER CHANGE

DATE	M	GROUNDWATER (KII)	GROUNDWATER(SIKOKU)
1. NOV. 29, 684	8 1/4	MURO HOT SPRING STOP	IYO HOT SPRING STOP
2. AUG. 26, 887	8 1/4	---	---
3. FEB. 22, 1099	8.2	---	---
4. AUG. 3, 1361	8.4	YUNOMINE HOT SPRING STOP	
5. FEB. 3, 1605	7.9	---	---
6. OCT. 28, 1707	8.4	4 HOT SPRINGS STOP	DOGO HOT SPRING STOP
7. DEC. 24, 1854	8.4	2 HOT SPRINGS STOP	---
8. DEC, 21, 1946	8	**BEFORE AND AFTER THE EARTHQUAKE** DECREASE OF DISCHARGE DECREASE OF LEVEL (AT MANY WELLS)	DECREASE OF DISCHARGE DECREASE OF LEVEL (AT MANY WELLS)

USAMI(1987), KAWABE(1991)

3.Estimation of earthquake-related pore pressure changes from groundwater data

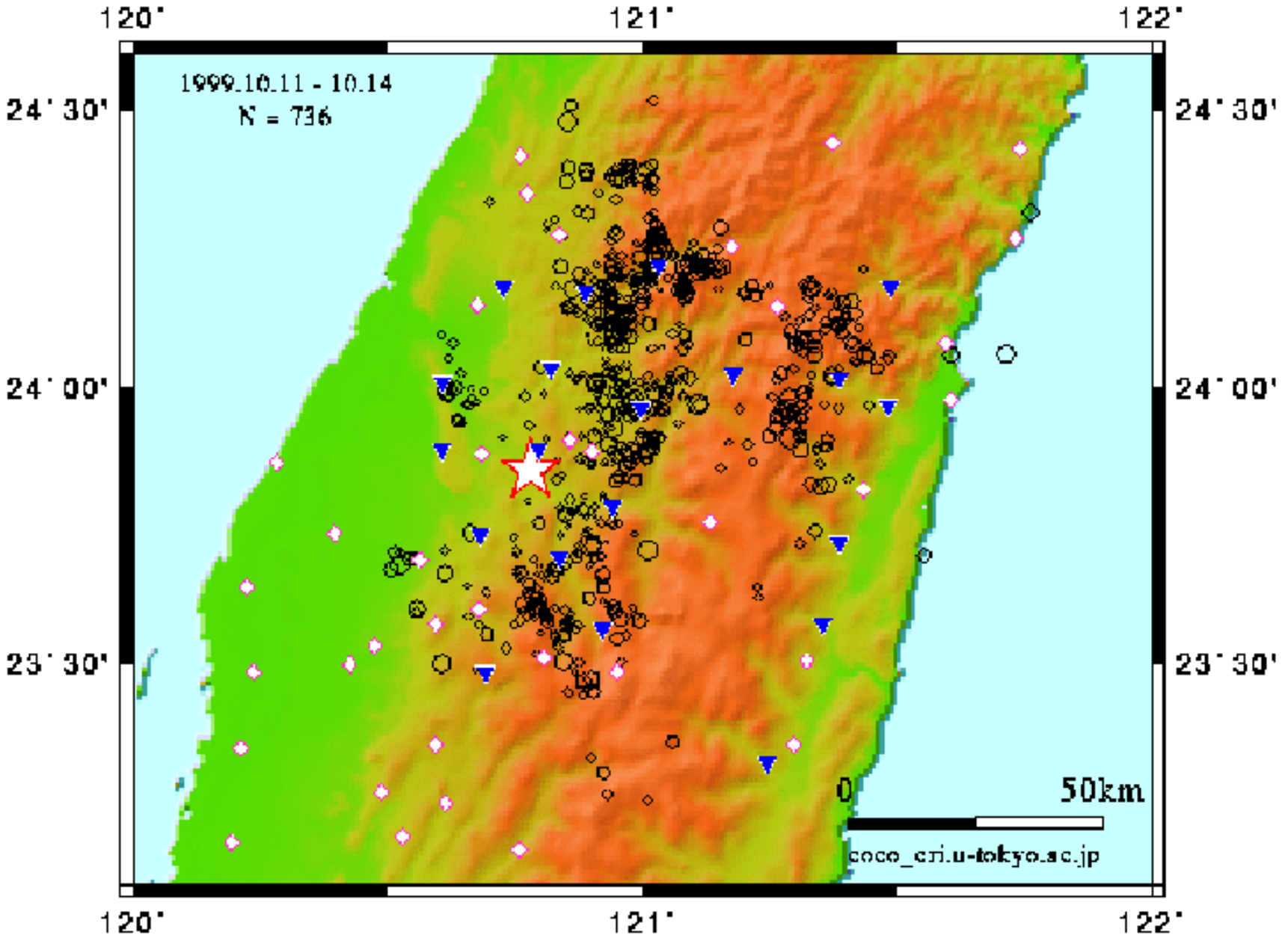
- POSTSEISMIC STRESS CHANGE ← → AFTERSHOCK DISTRIBUTION

  + pore pressure changes from

  OBSERVED deep groundwater data

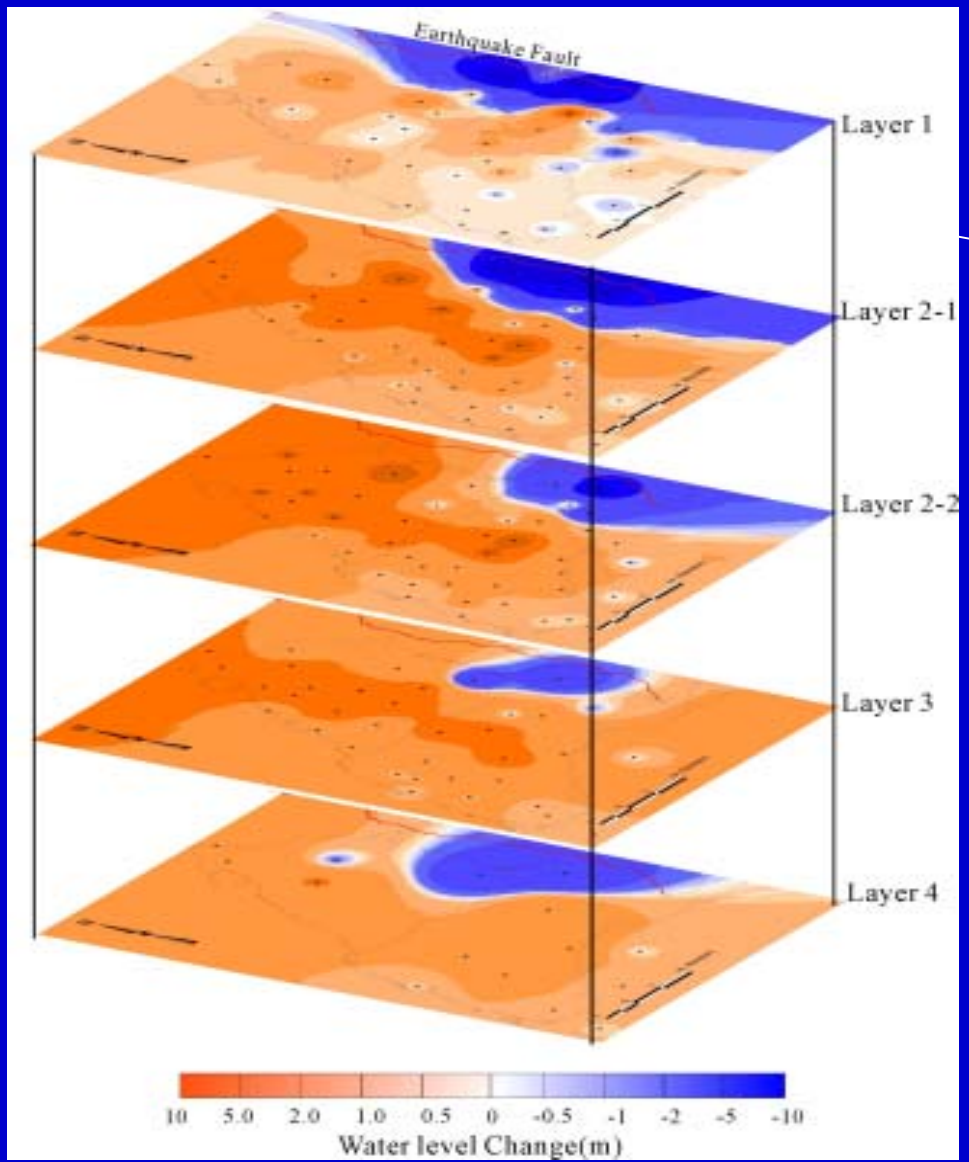
  (PRESENT, PAST) →DATABASE→MAKING A MODEL

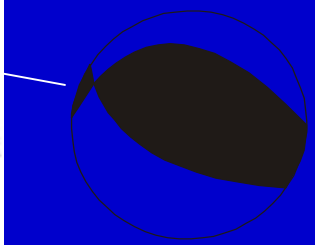
- POSTSEISMIC CRUSTAL DEFORMATION AND GROUNDWATER


120°
121°
122°
24° 30'
24° 00'
23° 30'
1999.10.11 - 10.14
N = 736
0
50km
coco_cri.u-tokyo.ac.jp

Distribution maps of the coseismic water level changes and the monitoring wells in different aquifers

- The coseismic decrease sites locates on the hill slope area

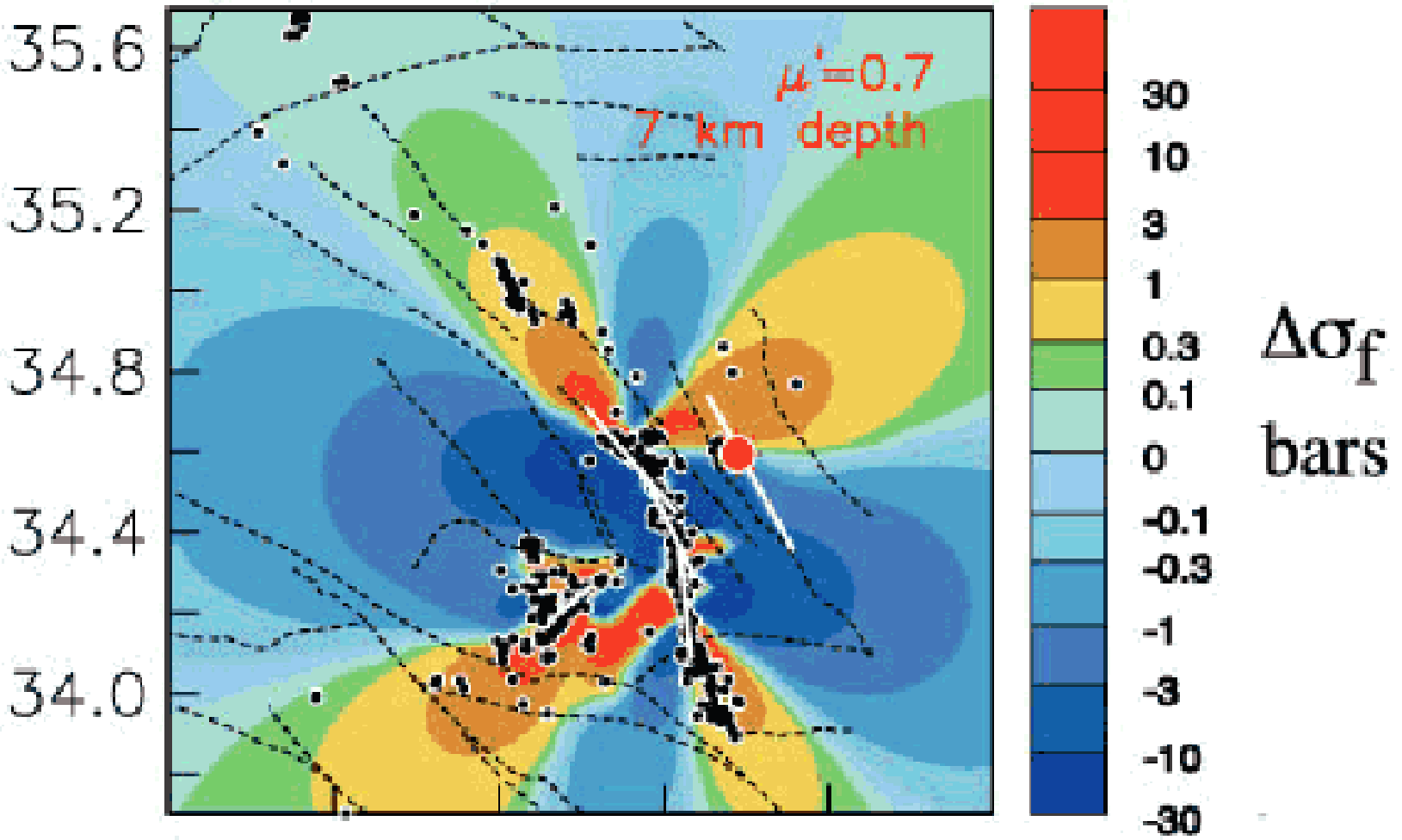




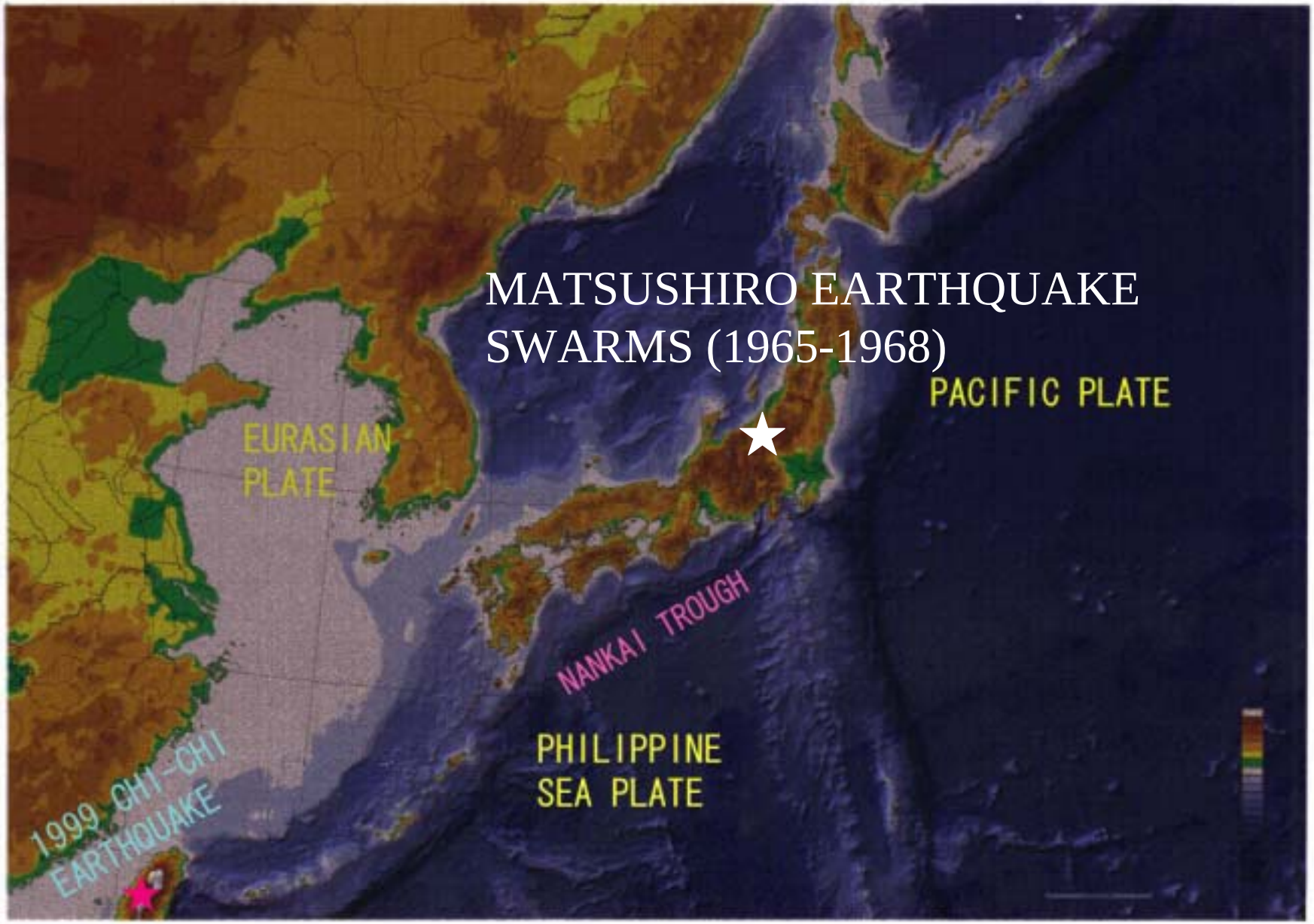
Pollitz(2001)

COSEISMIC

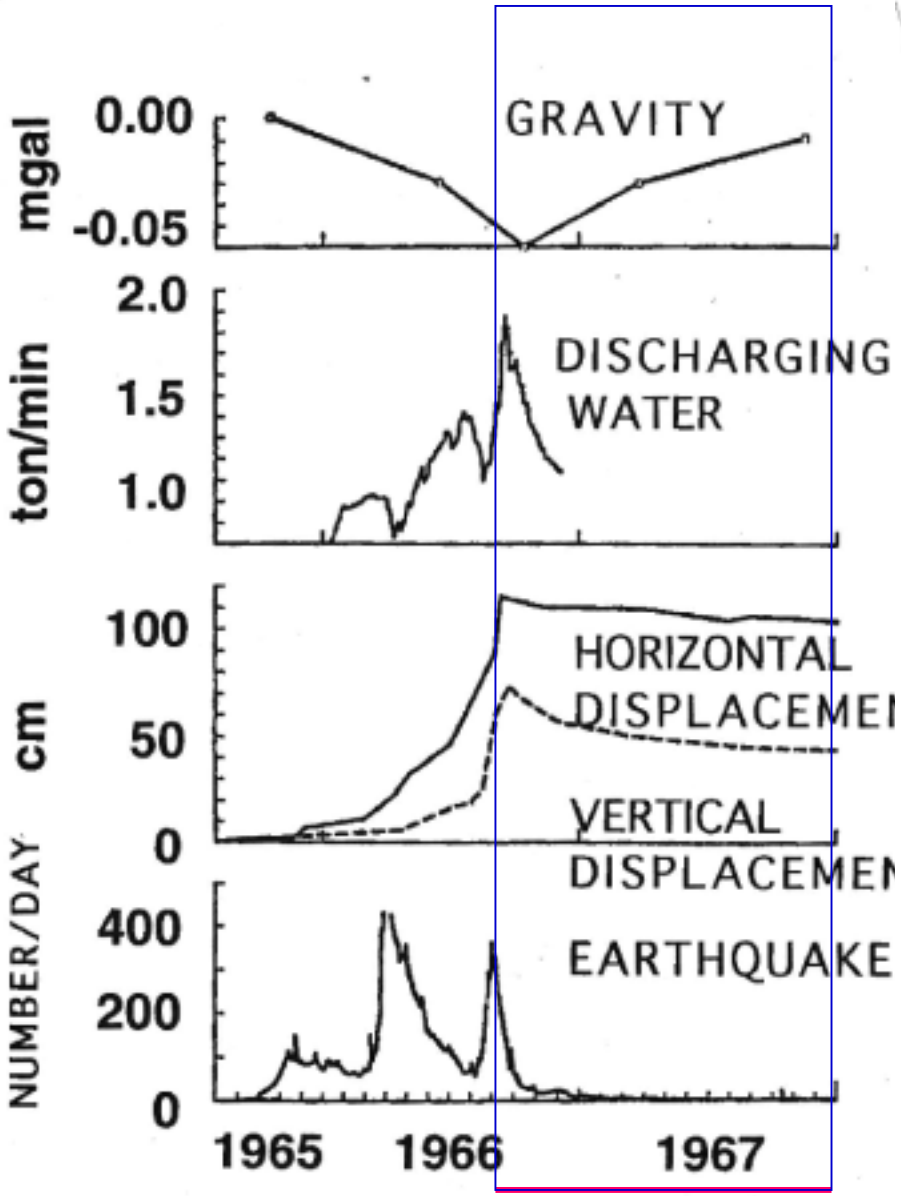
Just after 1992 Landers + Big Bear



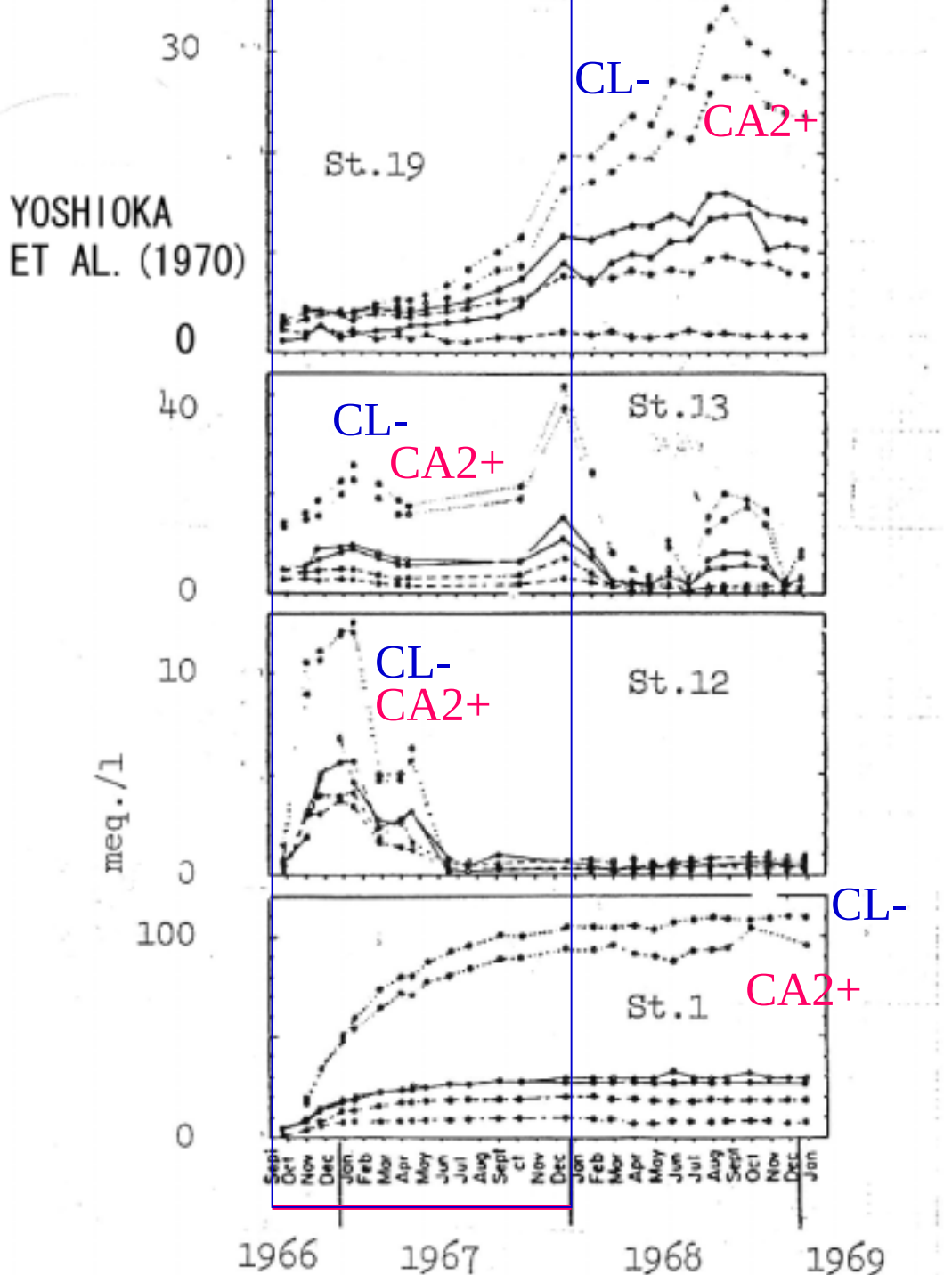
4. Supply of material information


MATSUSHIRO EARTHQUAKE
SWARMS (1965-1968)
PACIFIC PLATE
EURASIAN
PLATE
NANKAI TROUGH
PHILIPPINE
SEA PLATE
1999 CHI-CHI
EARTHQUAKE

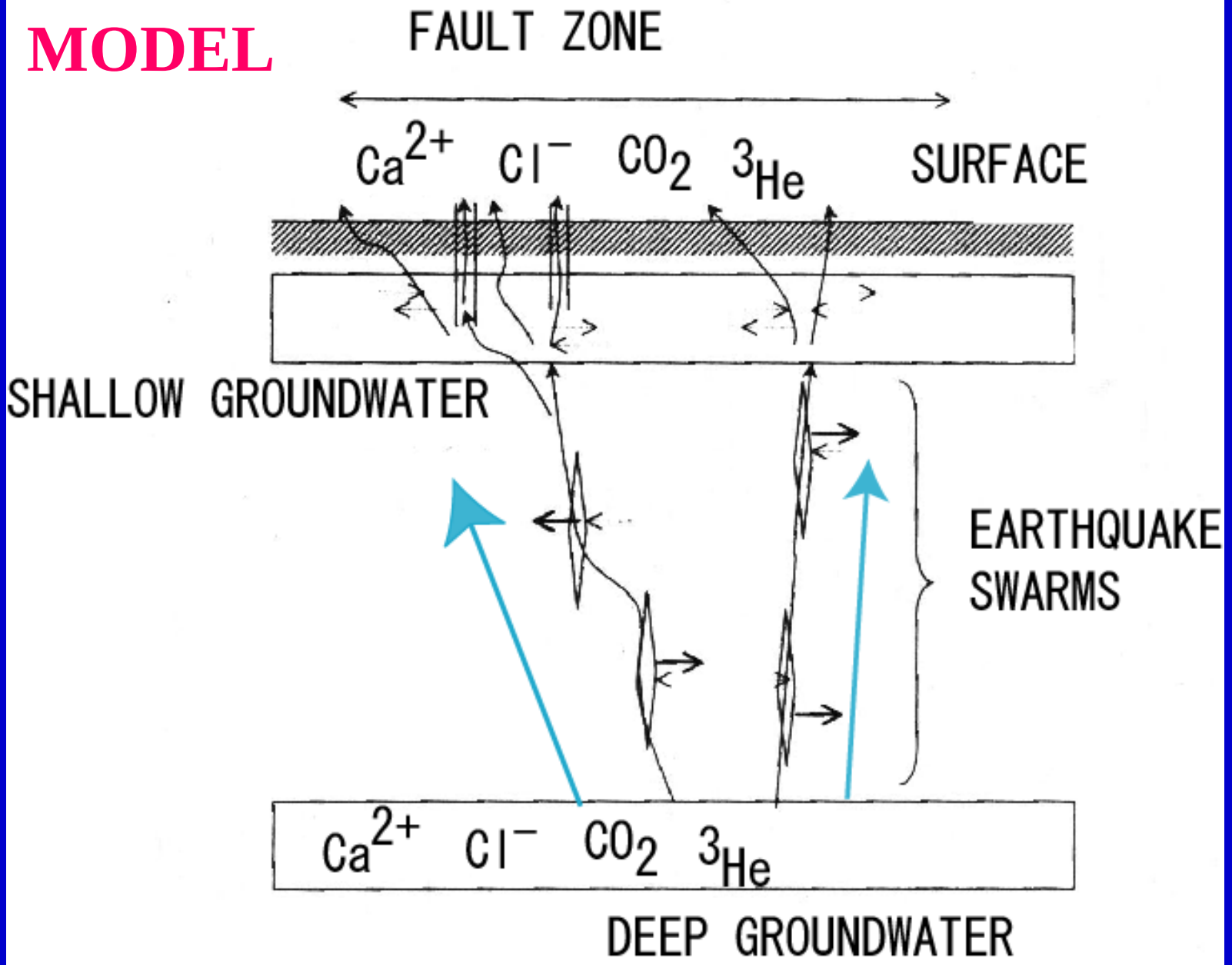
4.Supply of material information



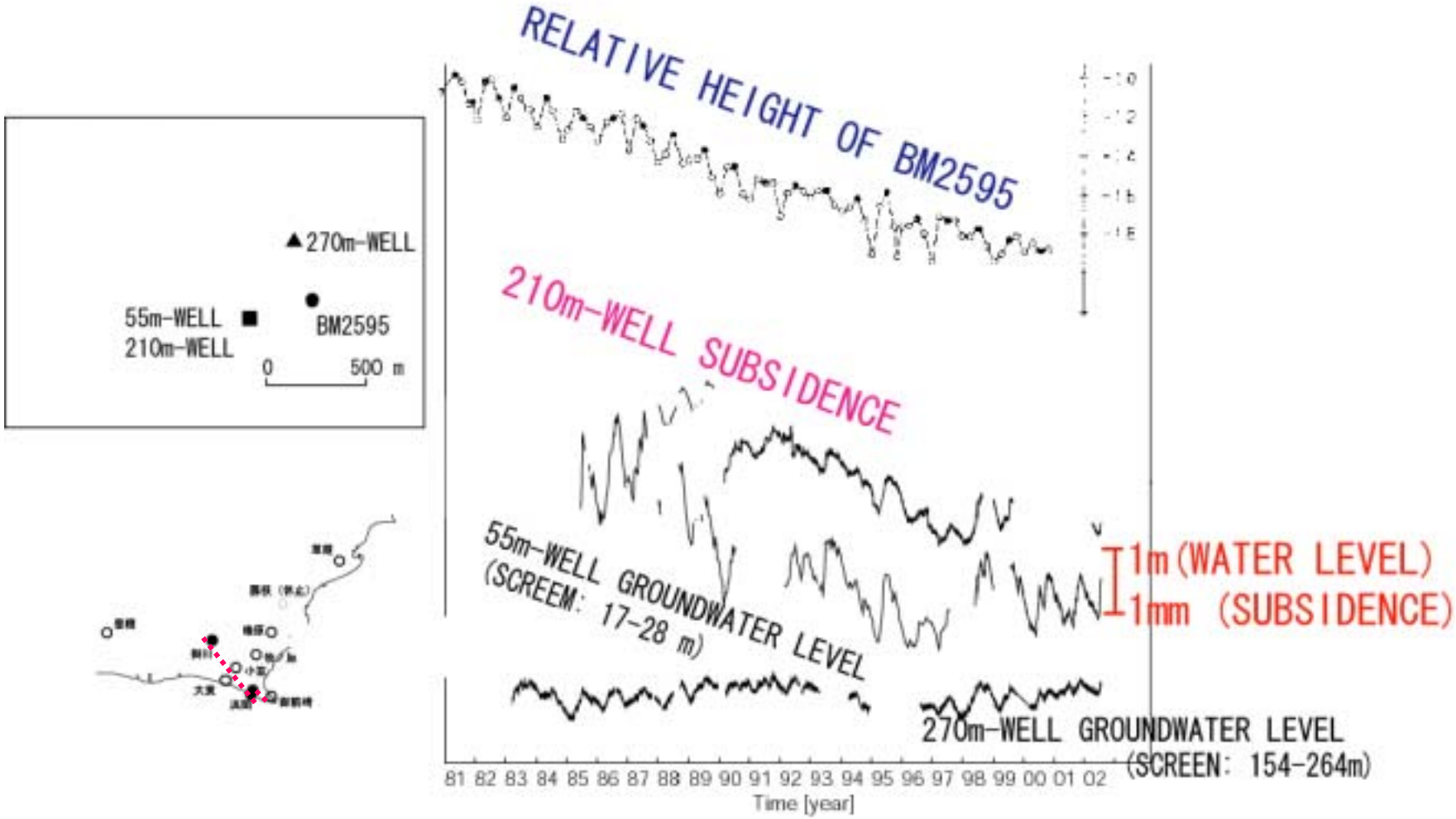
Ohtake(1976)

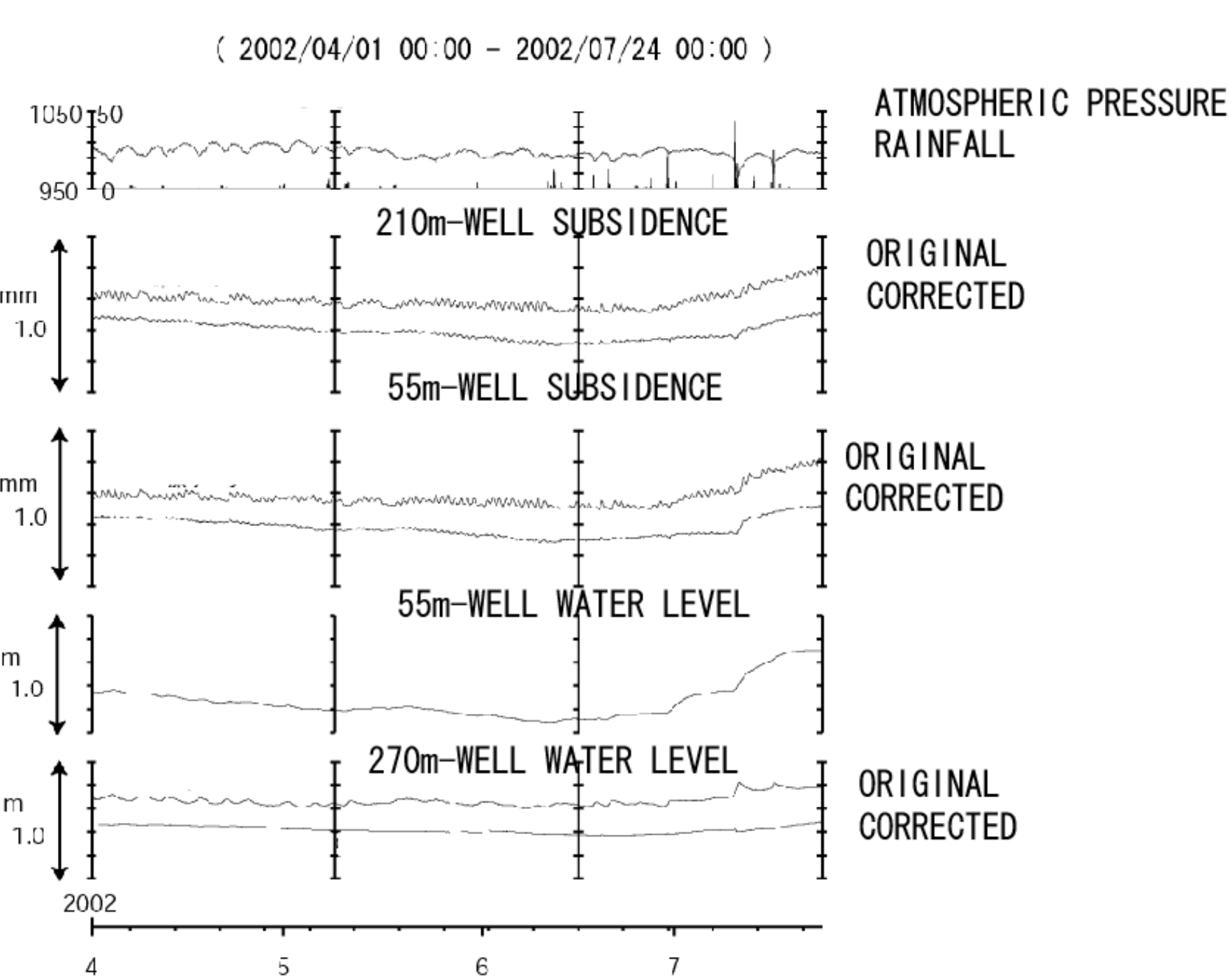


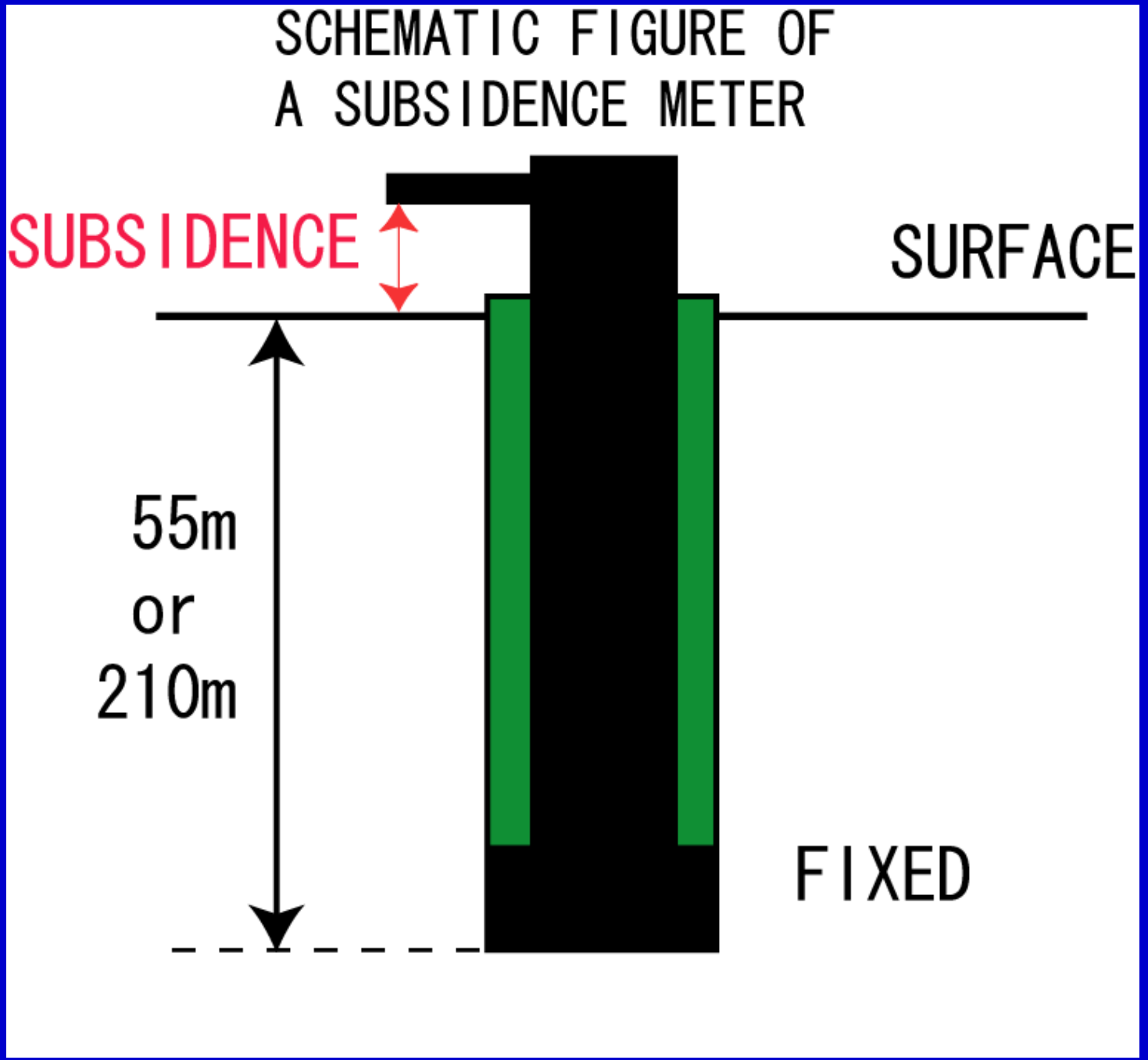
MODEL


FAULT ZONE
Ca^{2+} Cl^{-} CO_2 ^3He
SURFACE
SHALLOW GROUNDWATER
EARTHQUAKE SWARMS
Ca^{2+} Cl^{-} CO_2 ^3He
DEEP GROUNDWATER

5. Estimation of groundwater's effect on the long-term geodetic measurement




(2002/04/01 00:00 - 2002/07/24 00:00)
1050
950
50
0
ATMOSPHERIC PRESSURE
RAINFALL
210m-WELL SUBSIDENCE
mm
1.0
ORIGINAL
CORRECTED
55m-WELL SUBSIDENCE
mm
1.0
ORIGINAL
CORRECTED
55m-WELL WATER LEVEL
m
1.0
270m-WELL WATER LEVEL
m
1.0
ORIGINAL
CORRECTED
2002
4
5
6
7


SCHEMATIC FIGURE OF
A SUBSIDENCE METER
SUBSIDENCE
SURFACE
55m
or
210m
FIXED

*What are conditions of sensitive wells?

*How can we detect sensitive wells systematically? (Taiwan)

GPS data are useful or not? (Japan)

Relation among GPS data, groundwater level data and (borehole) strain data? (Japan)

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

*What is a mechanism of geochemical precursors? *How can we develop the ‘ crack model ‘?

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

* How should we design a long-term stable geochemical observation?

*How can we manage a condition of hith temperature,high pore pressure and high water or steam content?

Investigation of earthquakes in hydrothermal region is important. (USA)