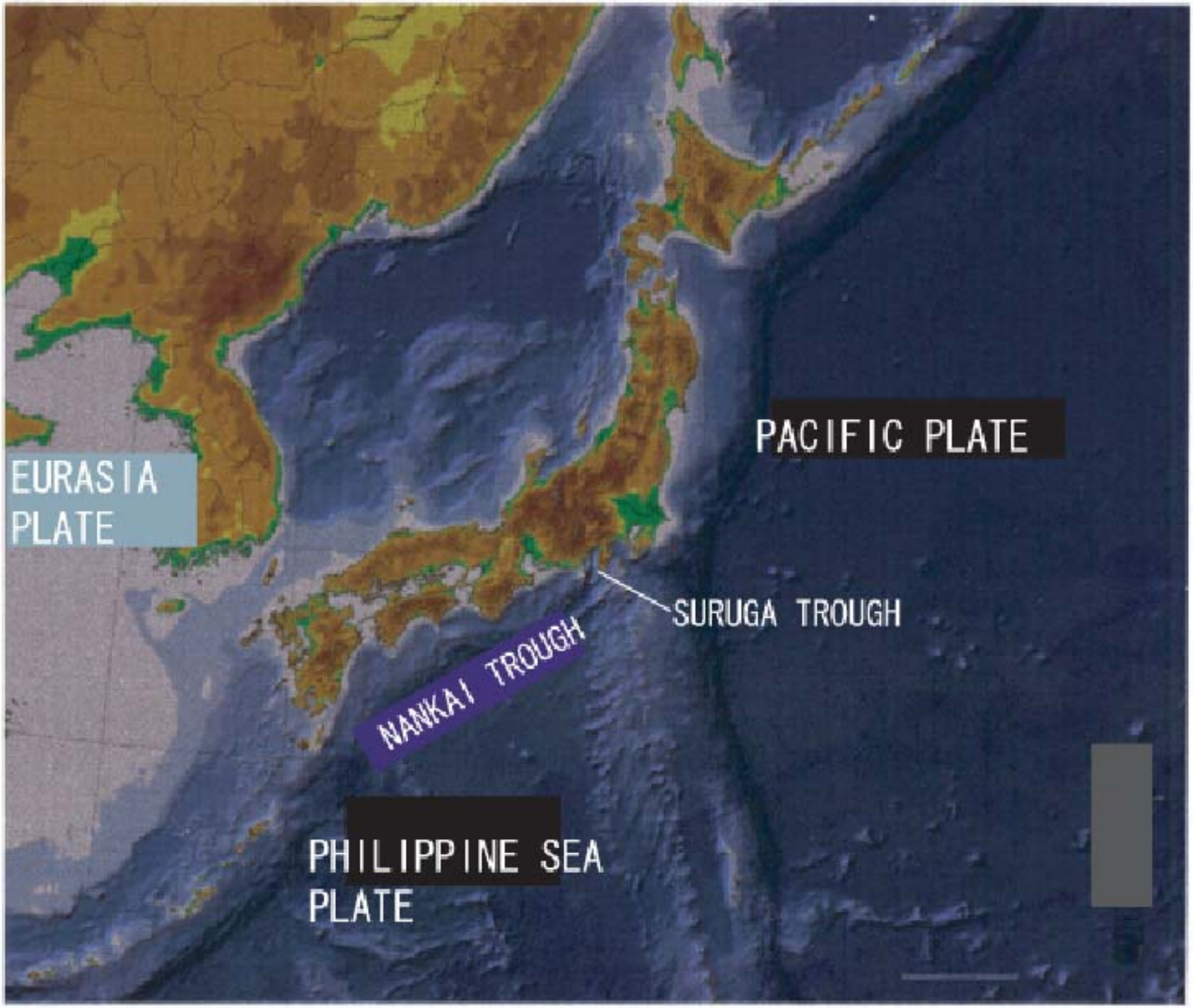
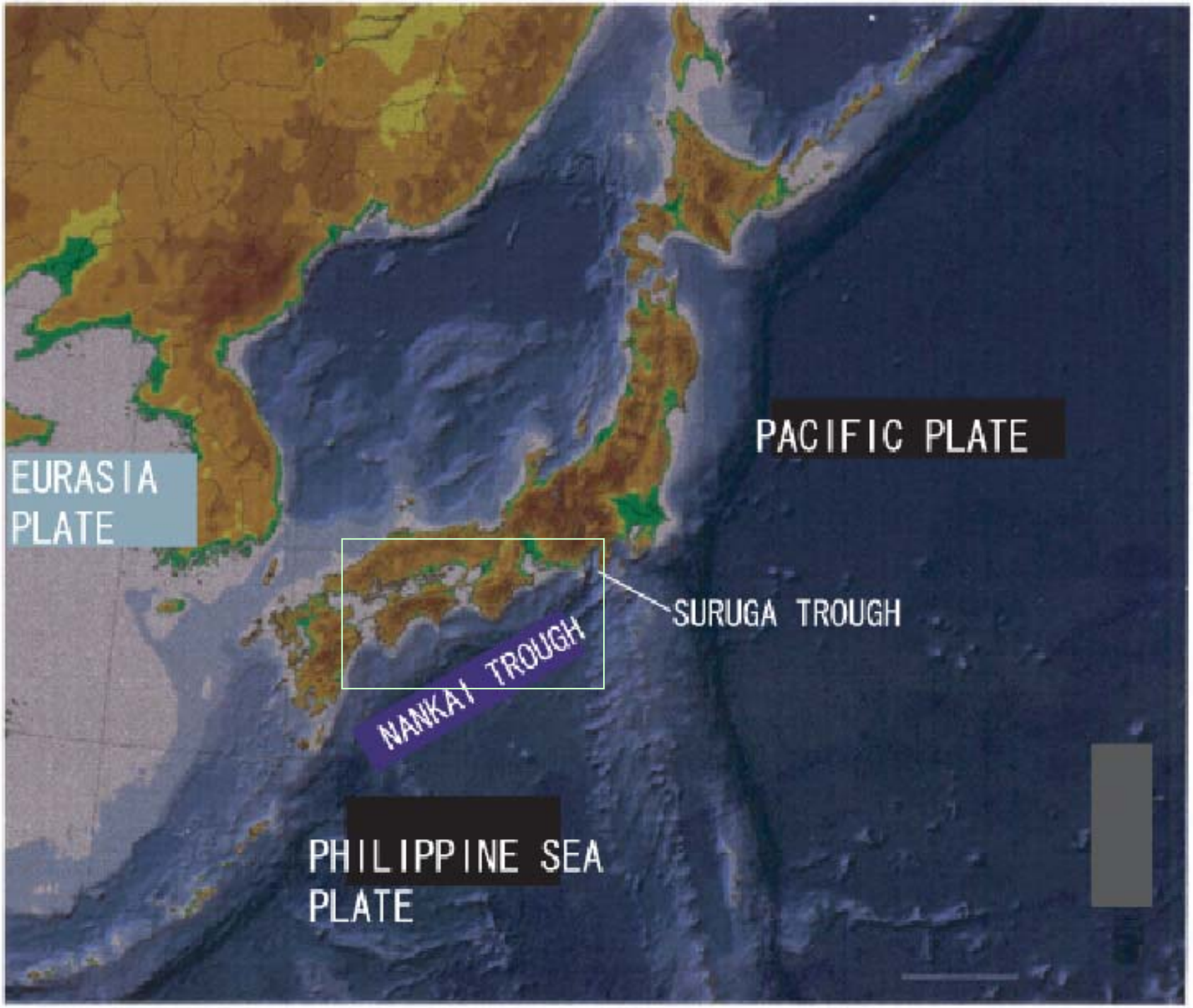
Evaluation of the preseismic groundwater changes before 1946 Nankai Earthquake through groundwater survey in Shikoku, Japan

N. KOIZUMI, M. TAKAHASHI and Y. KITAGAWA

(Geological Survey of Japan, AIST)


EURASIA
PLATE
PACIFIC PLATE
SURUGA TROUGH
NANKAI TROUGH
PHILIPPINE SEA
PLATE


EURASIA
PLATE
PACIFIC PLATE
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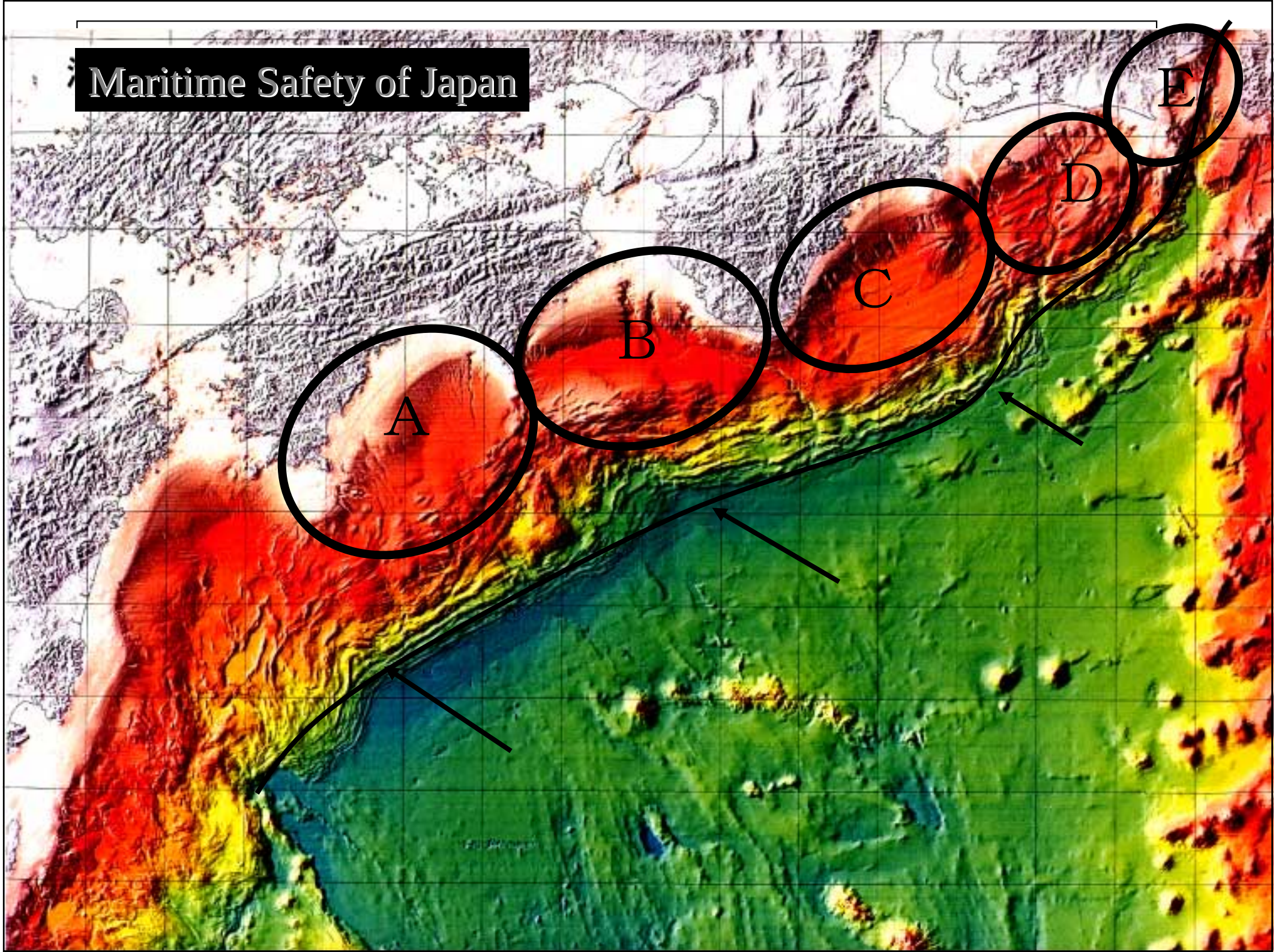
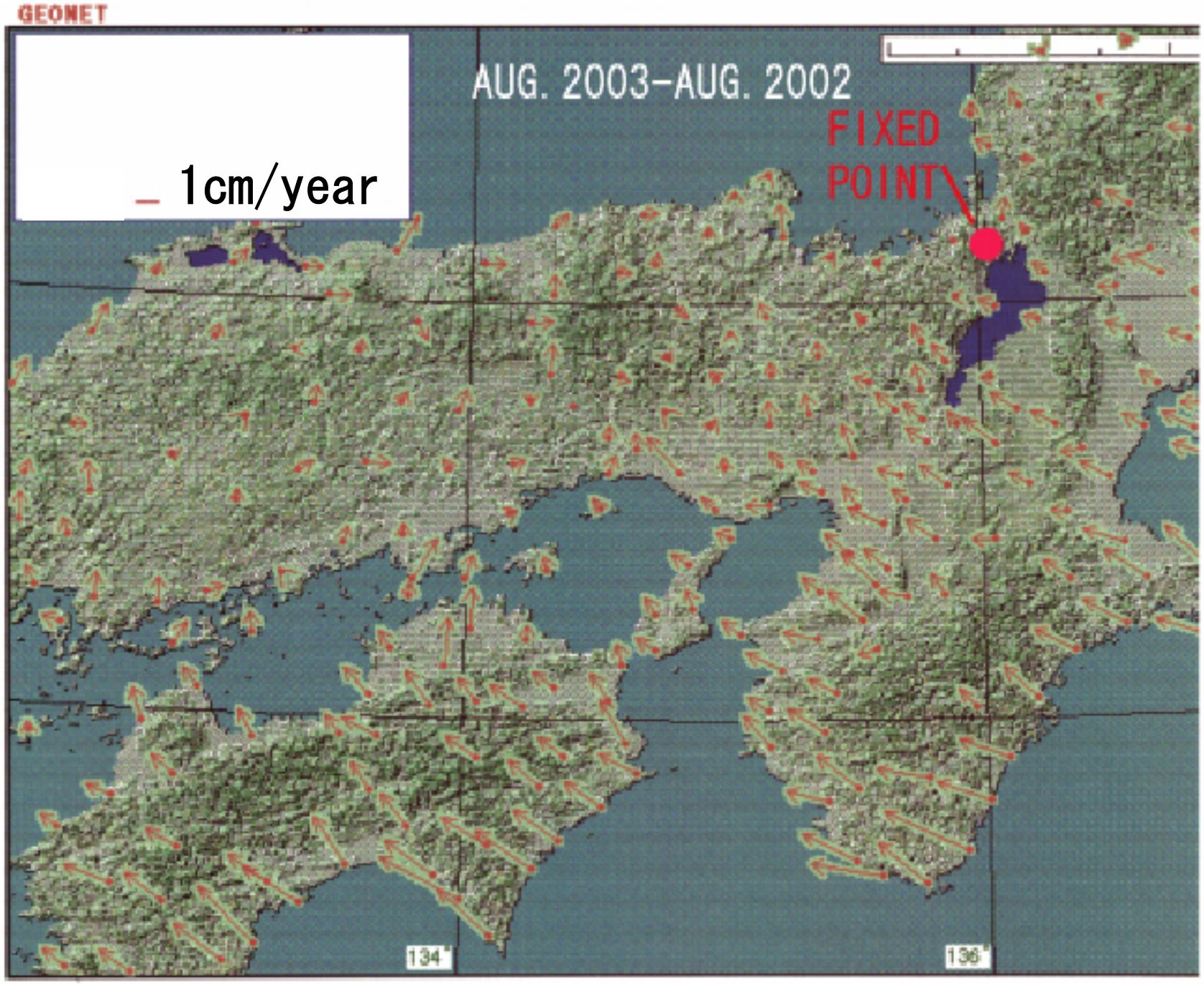
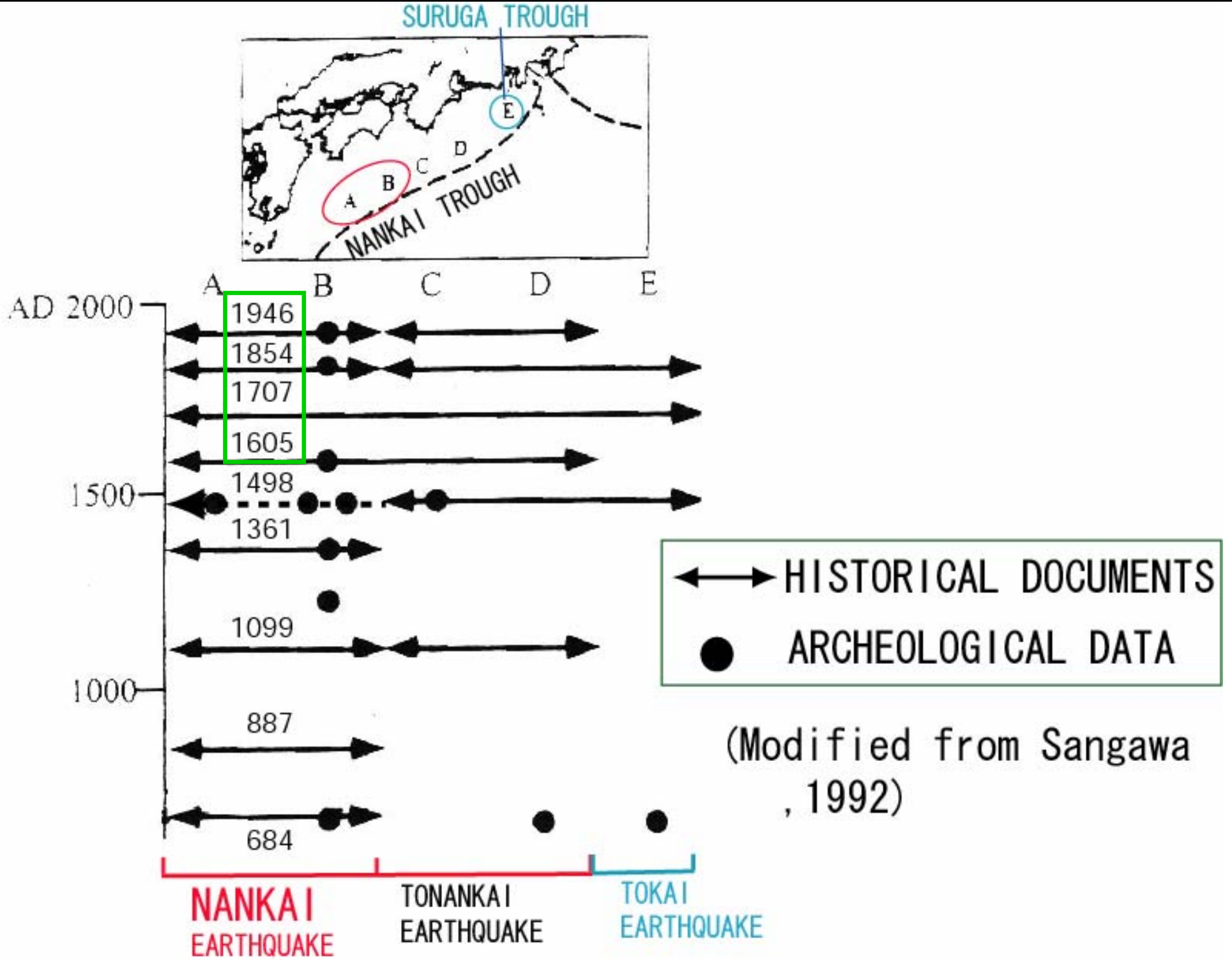
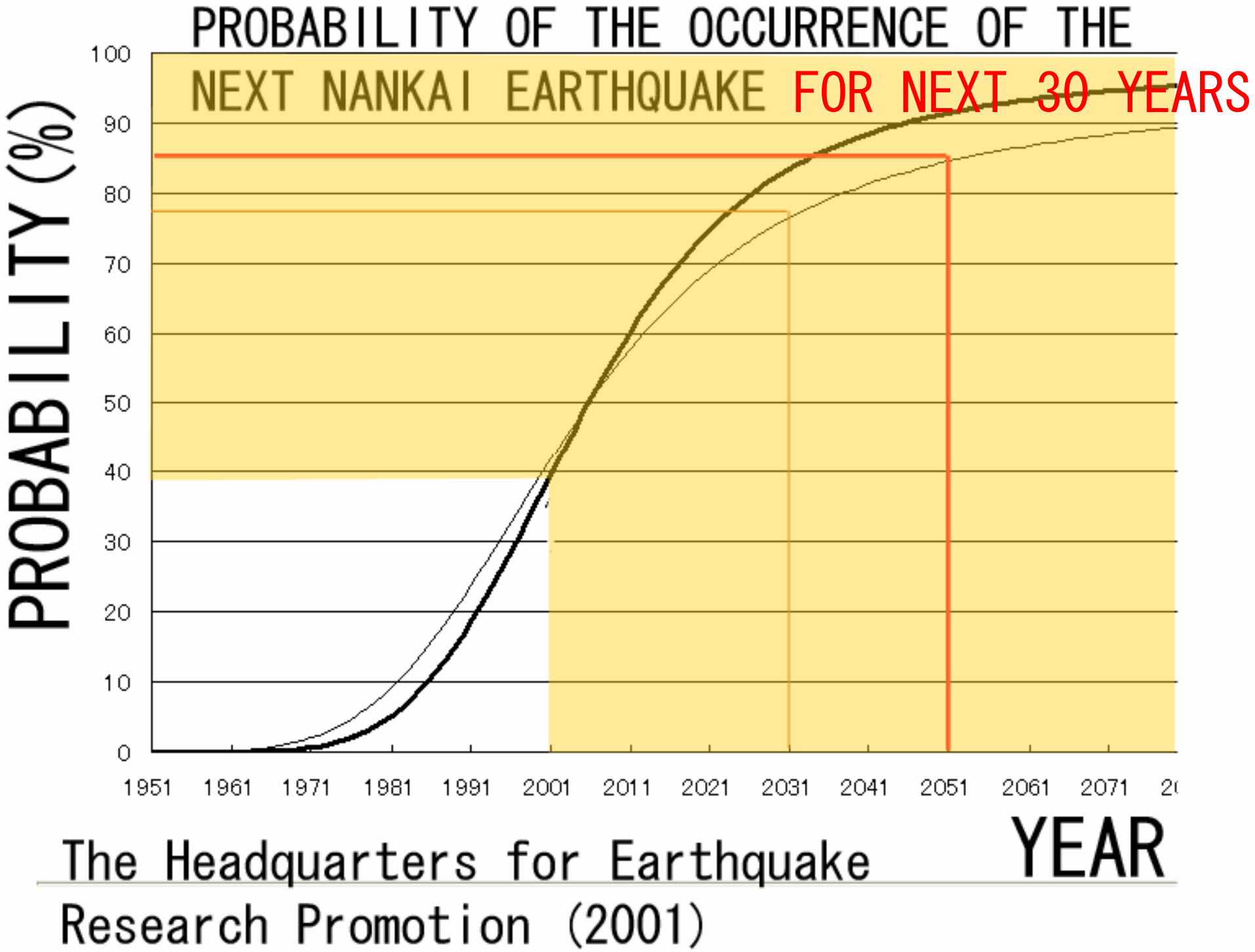
NANKAI TROUGH
PHILIPPINE SEA
PLATE

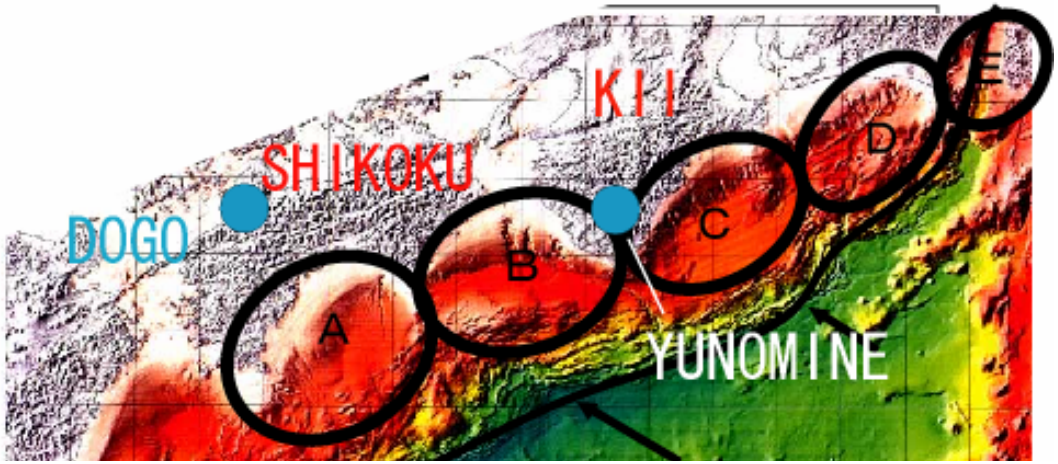

Maritime Safety of Japan
A
B
C
D
E

HORIZONTAL DISPLACEMENT BY GPS OBSERVATION

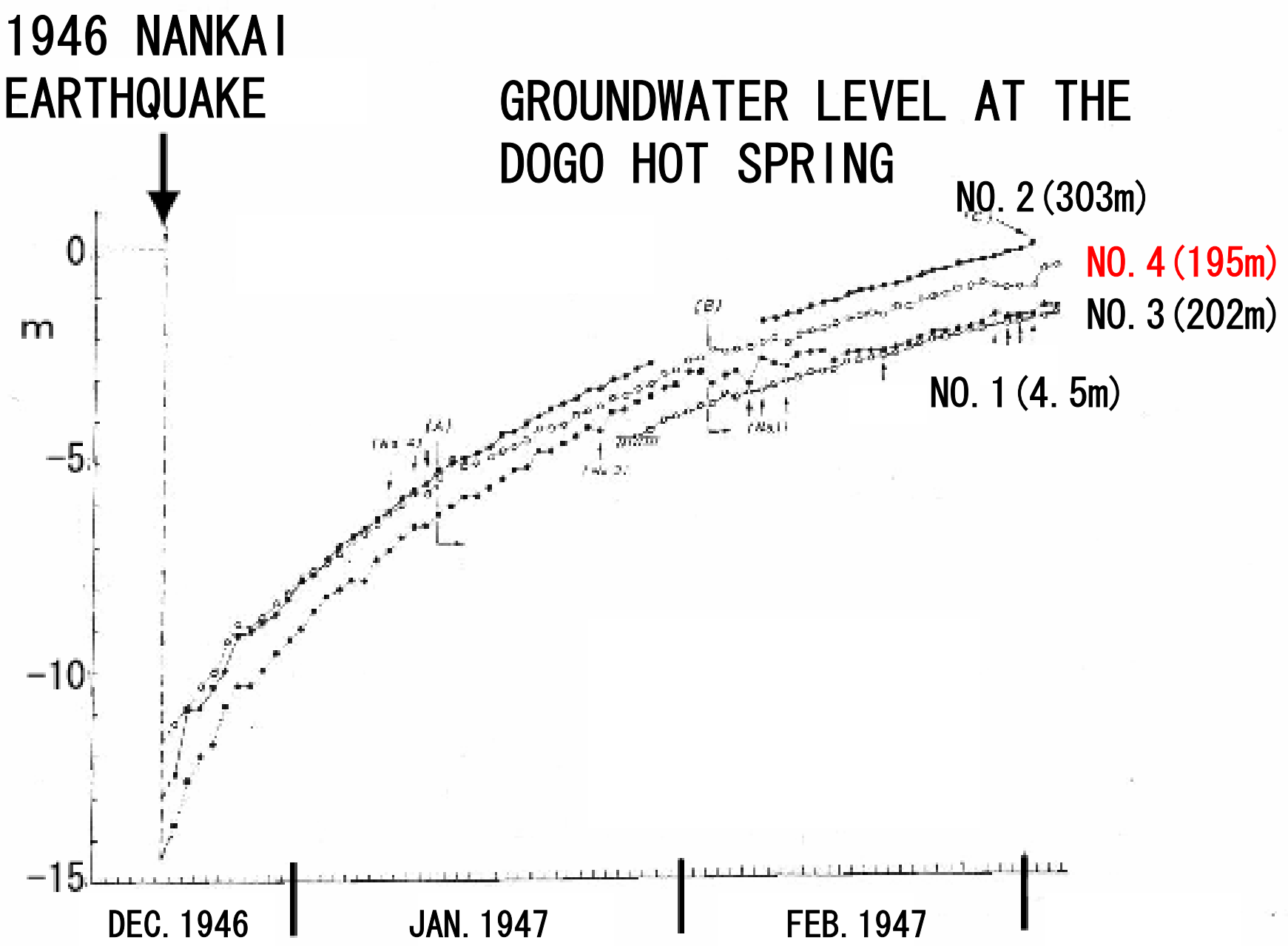



SURUGA TROUGH
E
D
C
B
A
NANKAI TROUGH
A
B
C
D
E
AD 2000
1500
1000
1946
1854
1707
1605
1498
1361
1099
887
684
HISTORICAL DOCUMENTS
ARCHEOLOGICAL DATA
(Modified from Sangawa ,1992)
NANKAI EARTHQUAKE
TONANKAI EARTHQUAKE
TOKAI EARTHQUAKE


PROBABILITY OF THE OCCURRENCE OF THE
NEXT NANKAI EARTHQUAKE FOR NEXT 30 YEARS
PROBABILITY (%)
100
90
80
70
60
50
40
30
20
10
0
1951
1961
1971
1981
1991
2001
2011
2021
2031
2041
2051
2061
2071
YEAR
The Headquarters for Earthquake
Research Promotion (2001)

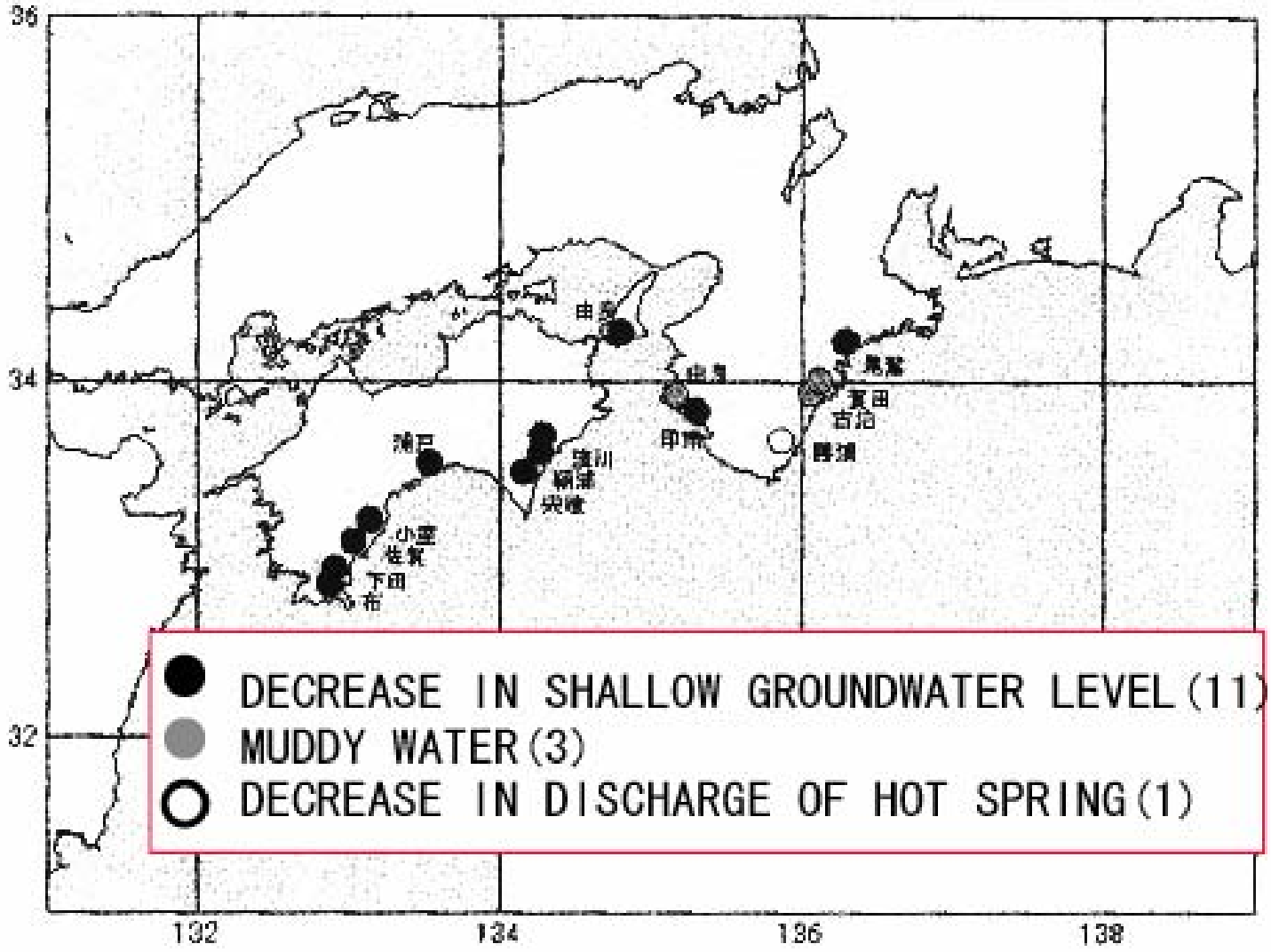


	DATE	MAGNITUDE	GROUNDWATER IN SHIKOKU	GROUNDWATER IN THE KII PENINSULA
1	NOV. 29, 684	8 1/4	STOP OF DISCHARGE IN DOGO HOT SPRING	STOP OF DISCHARGE IN MURO HOT SPRING
2	AUG. 26, 887	8 1/4	--	--
3	FEB. 22, 1099	8.2	--	--
4	AUG. 3, 1361	8.4	--	STOP OF DISCHARGE IN YUNOMINE HOT SPRING
5	SEP. 20, 1498	8.2-8.4	--	STOP OF DISCHARGE IN YUNOMINE HOT SPRING
6	FEB. 3, 1605	7.9	--	--
7	OCT. 28, 1707	8.4	STOP OF DISCHARGE IN DOGO HOT SPRING (145DAYS)	STOP OF DISCHARGE IN YUNOMINE HOT SPRING AND THE OTHER 3 HOT SPRINGS
8	DEC. 24, 1854	8.4	STOP OF DISCHARGE IN DOGO HOT SPRING	STOP OF DISCHARGE IN YUNOMINE HOT SPRING AND SHIRAHAMA HOT SPRING
9	DEC. 21, 1946	8	COSEISMIC DECREASE OF DISCHARGE IN DOGO HOT SPRING , PRESEISMIC AND POSTSEISMIC SHALLOW GROUNDWATER LEVEL DECREASE IN THE COASTAL REGIONS	DECREASE OF DISCHARGE IN YUNOMINE HOT SPRING , PRESEISMIC AND POSTSEISMIC SHALLOW GROUNDWATER LEVEL DECREASE IN THE COASTAL REGIONS

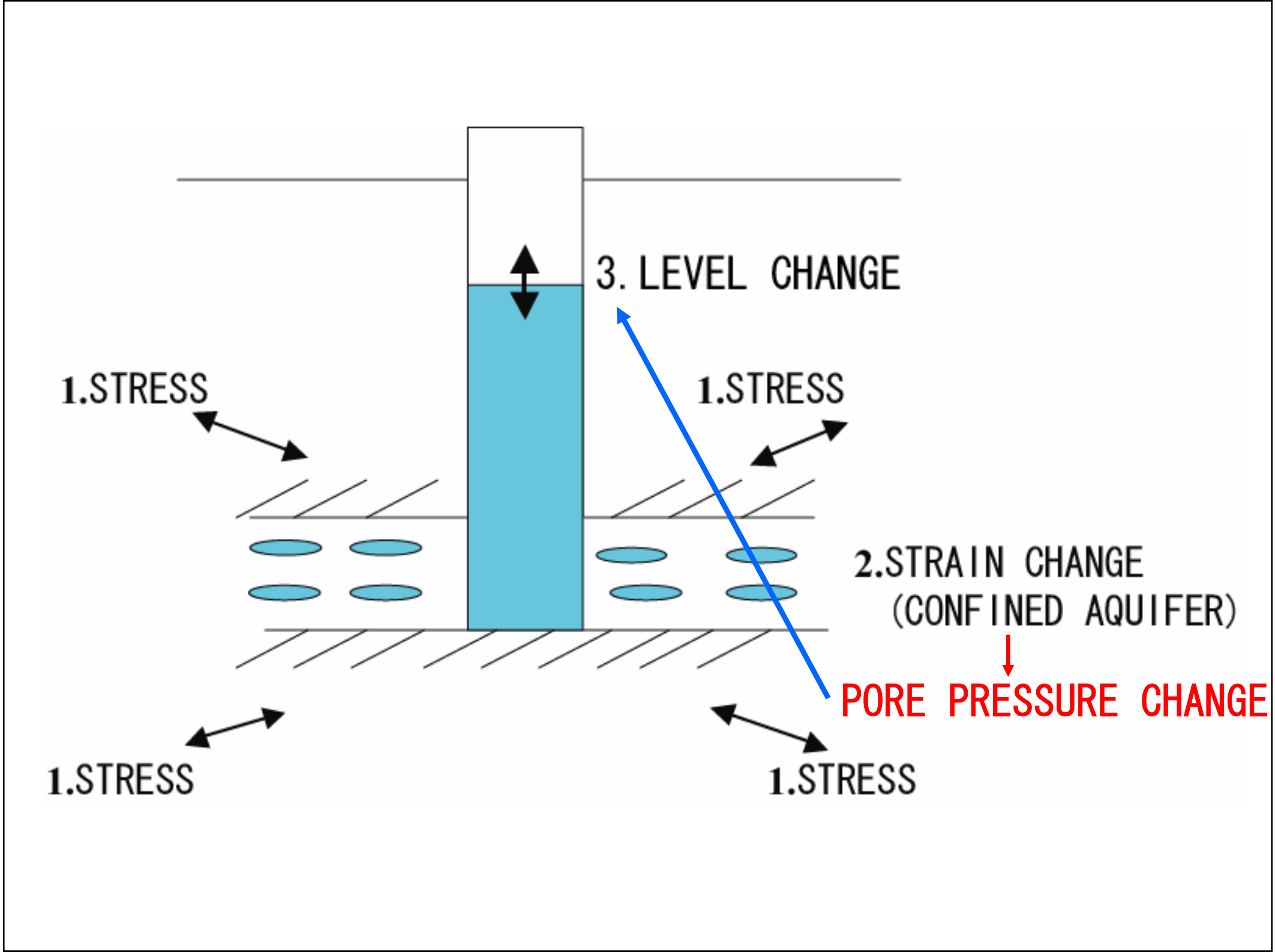


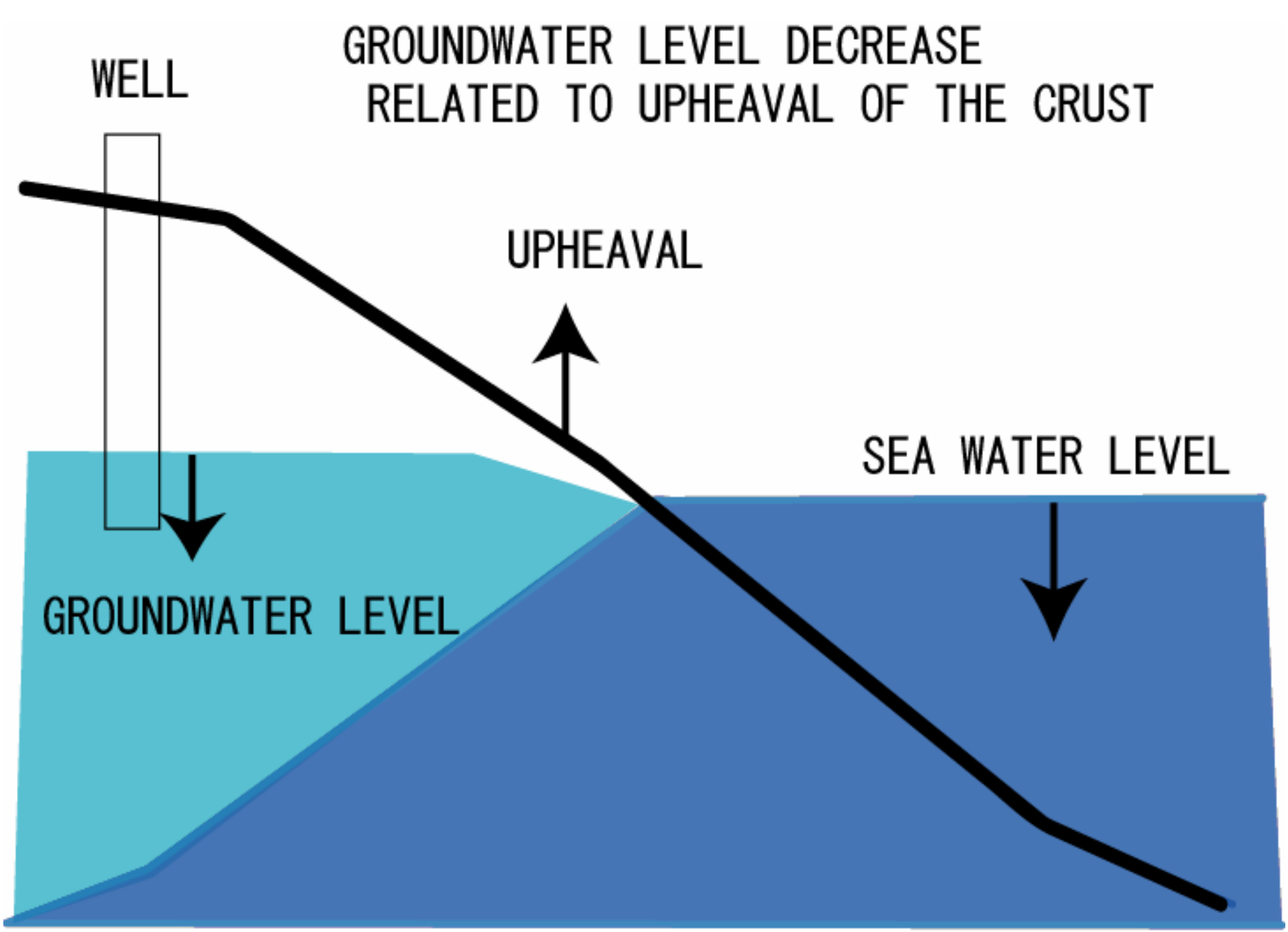
MODIFIED FROM
KAWABE(1991)

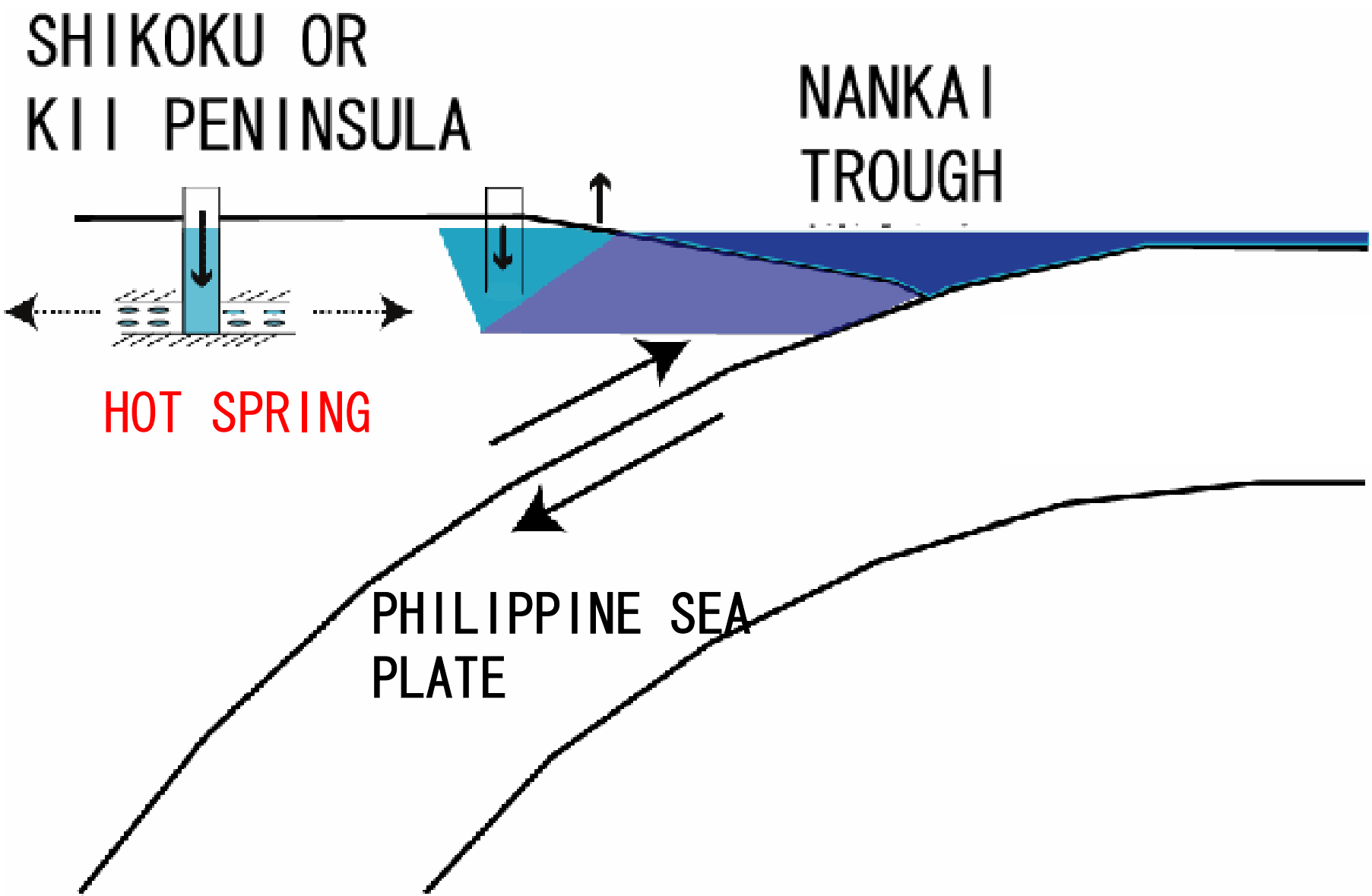
PRESEISMIC GROUNDWATER CHANGES BEFORE THE 1946 NANAKAI EARTHQUAKEG

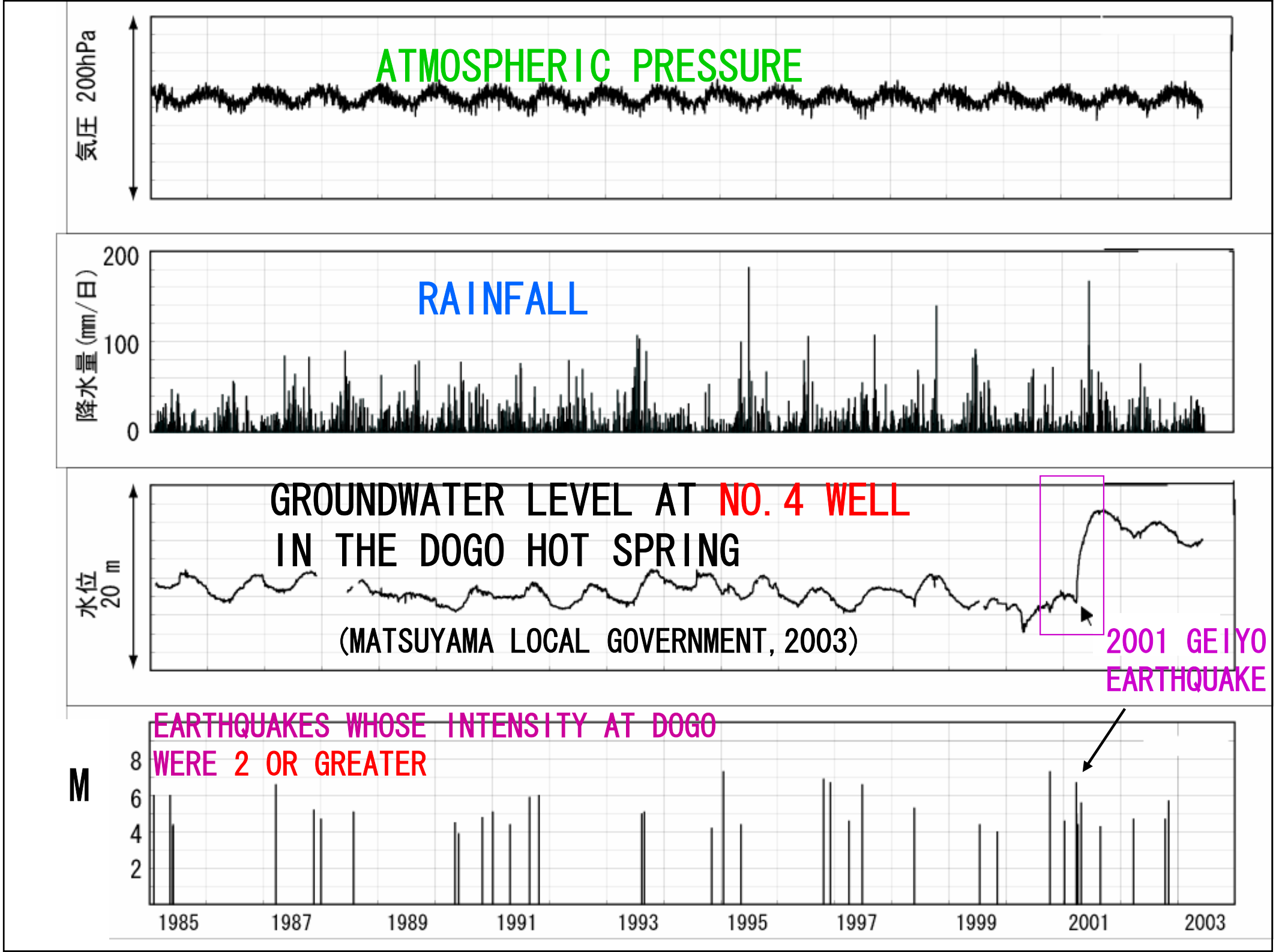


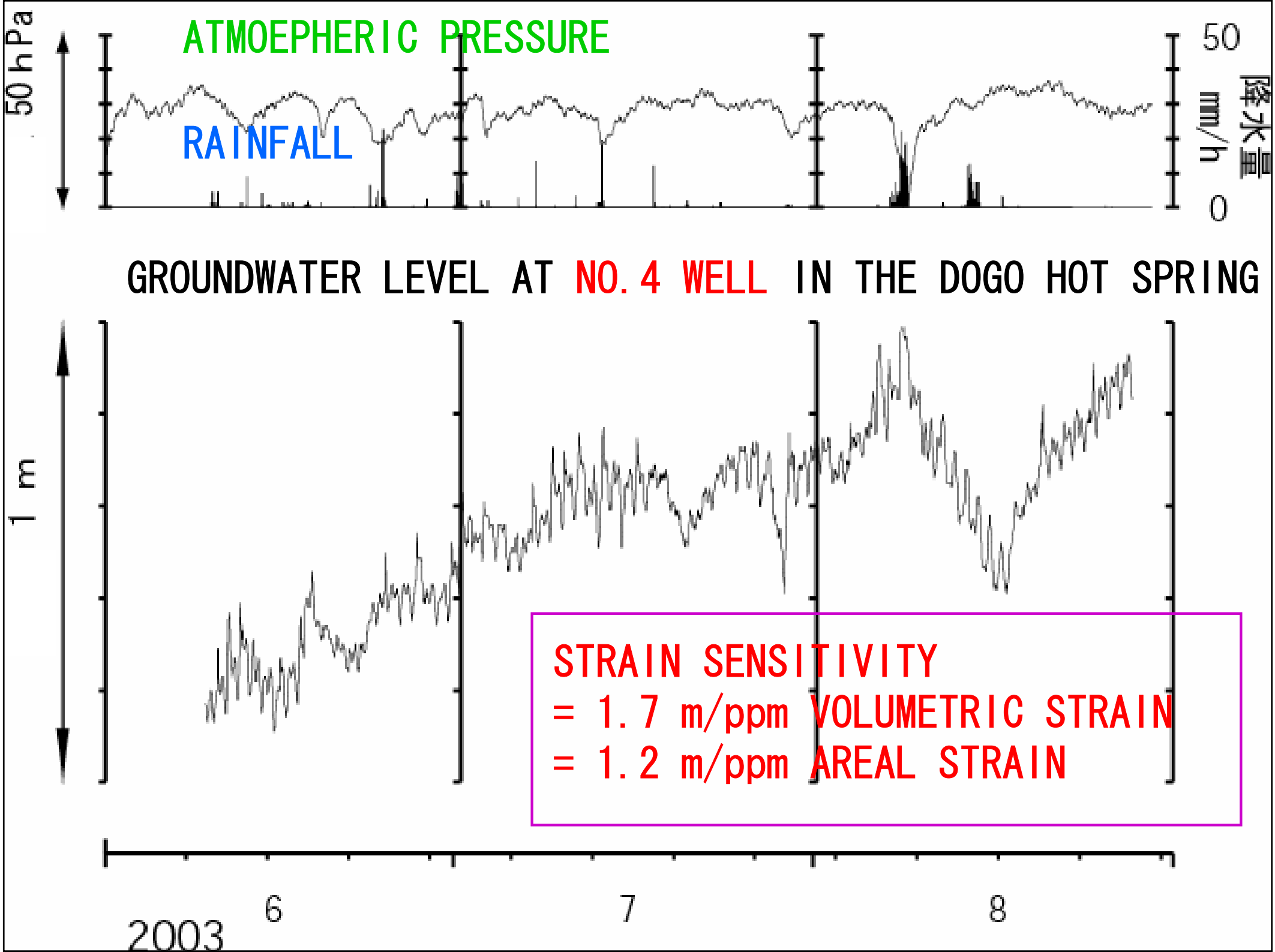
MODIFIED FROM UMEDA(2003)

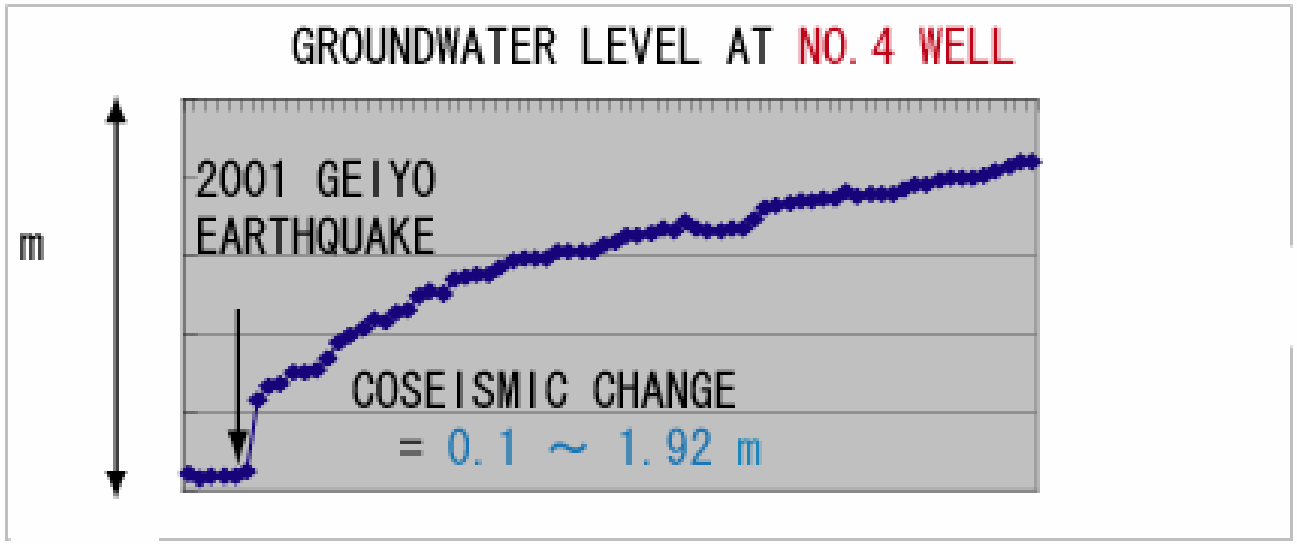

3. LEVEL CHANGE
1.STRESS
1.STRESS
2.STRAIN CHANGE
(CONFINED AQUIFER)
PORE PRESSURE CHANGE
1.STRESS
1.STRESS

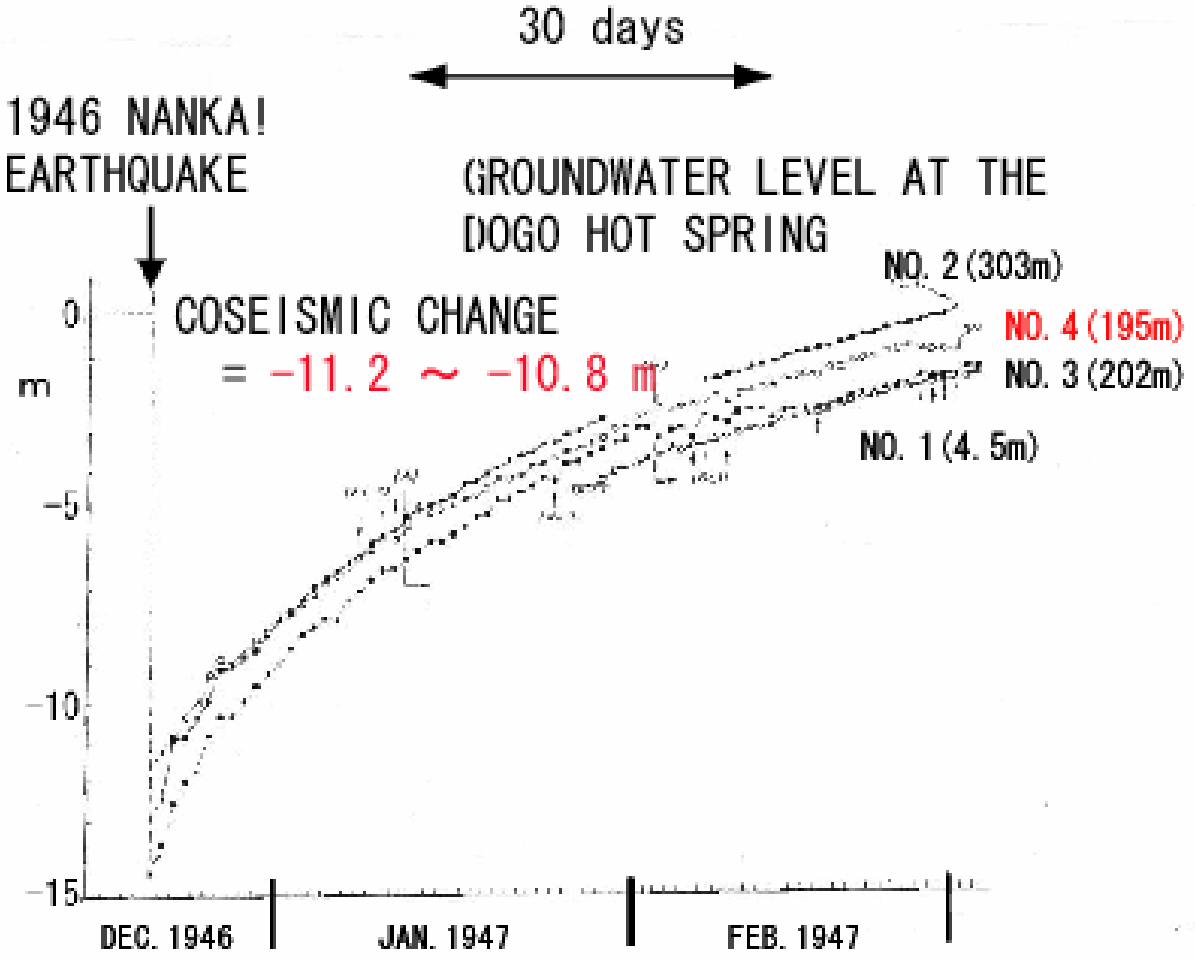

GROUNDWATER LEVEL DECREASE
RELATED TO UPHEAVAL OF THE CRUST
WELL
UPHEAVAL
SEA WATER LEVEL
GROUNDWATER LEVEL


SHIKOKU OR
KII PENINSULA
NANKAI
TROUGH
HOT SPRING
PHILIPPINE SEA
PLATE

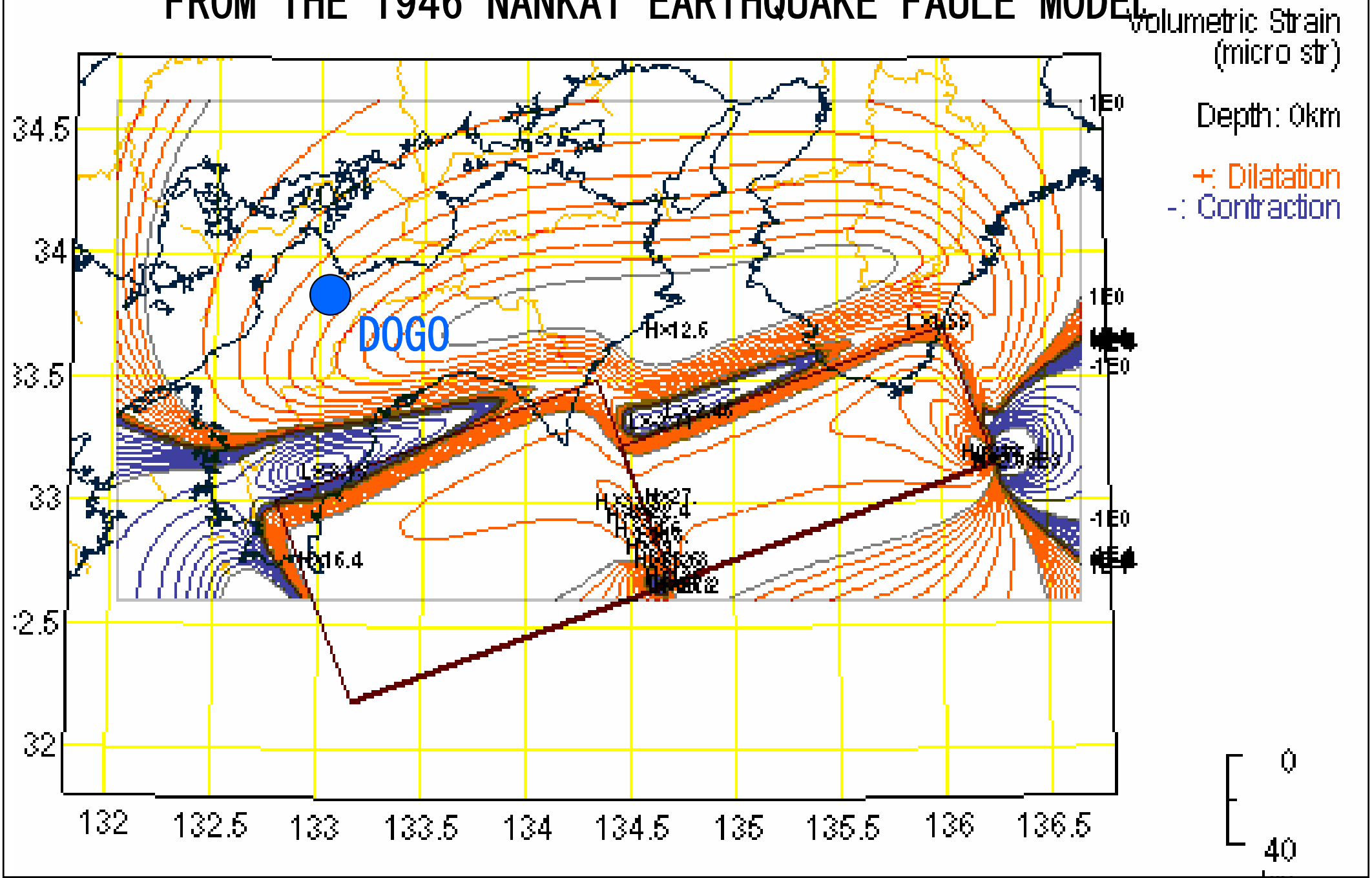

気圧 200hPa
ATMOSPHERIC PRESSURE
降水量(mm/日)
200
100
0
RAINFALL
水位
20 m
GROUNDWATER LEVEL AT NO.4 WELL
IN THE DOGO HOT SPRING
(MATSUYAMA LOCAL GOVERNMENT, 2003)
2001 GEIYO
EARTHQUAKE
M
EARTHQUAKES WHOSE INTENSITY AT DOGO
WERE 2 OR GREATER
8
6
4
2
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003


ATMOEPHERIC PRESSURE
RAINFALL
50 hPa
50
0
mm/h
降水量
GROUNDWATER LEVEL AT NO.4 WELL IN THE DOGO HOT SPRING
1 m
STRAIN SENSITIVITY
= 1.7 m/ppm VOLUMETRIC STRAIN
= 1.2 m/ppm AREAL STRAIN
2003
6
7
8

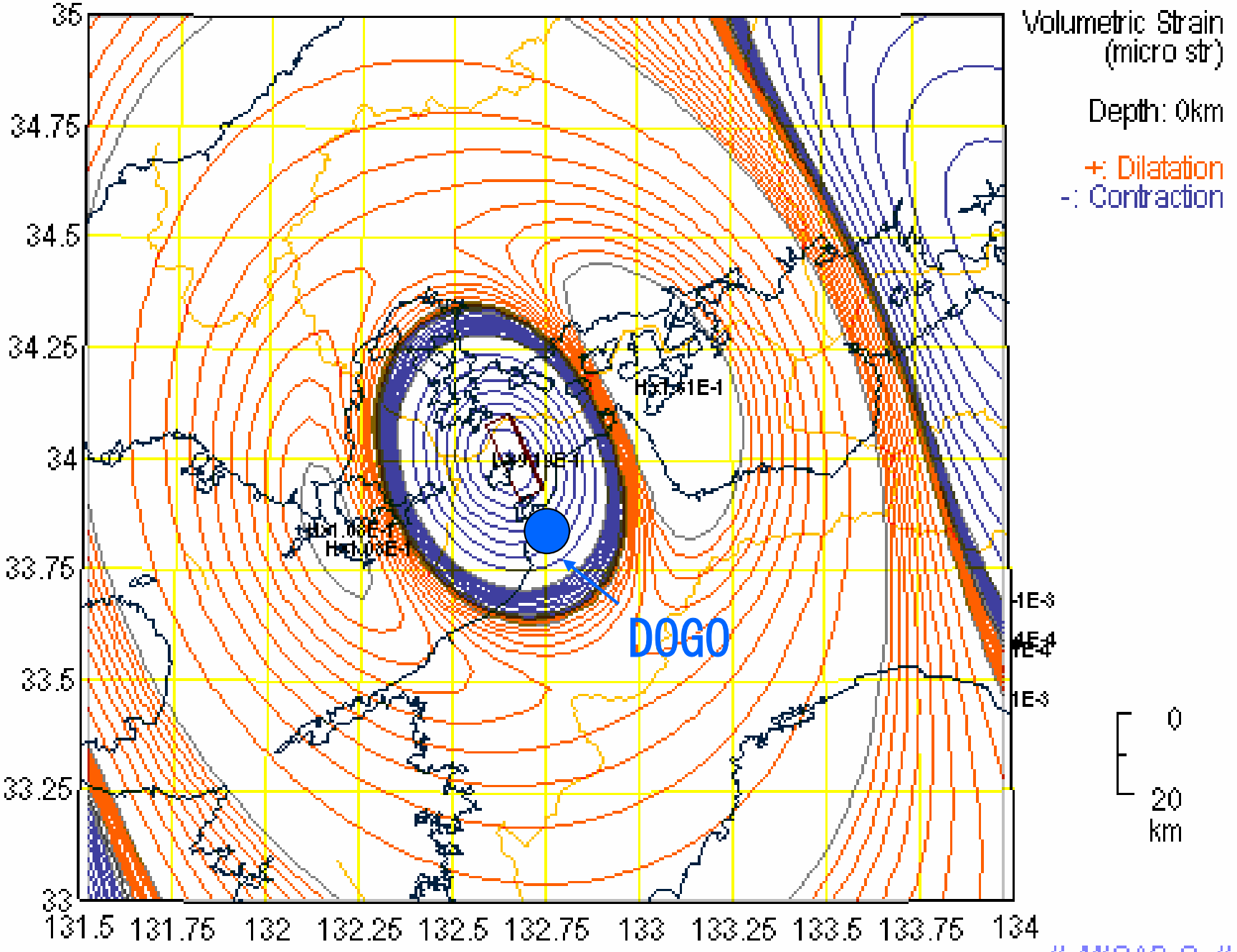

GROUNDWATER LEVEL AT NO. 4 WELL
10 m
2001 GEIYO
EARTHQUAKE
COSEISMIC CHANGE
= 0.1 ~ 1.92 m

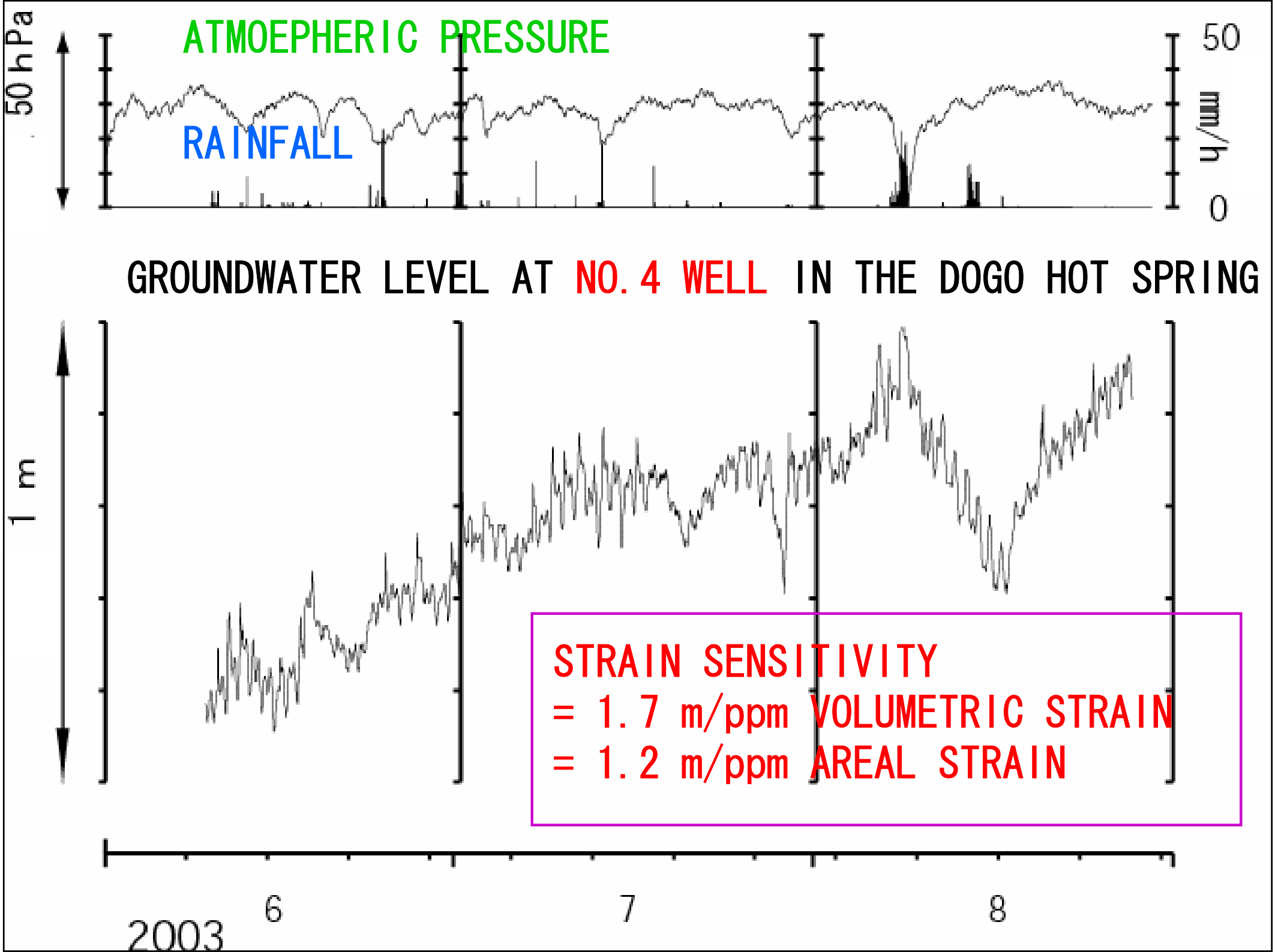

30 days
1946 NANKAI
EARTHQUAKE
GROUNDWATER LEVEL AT THE
DOGO HOT SPRING
NO. 2 (303m)
NO. 4 (195m)
NO. 3 (202m)
NO. 1 (4.5m)
COSEISMIC CHANGE
= -11.2 ~ -10.8 m
0
m
-5
-10
-15
DEC. 1946
JAN. 1947
FEB. 1947

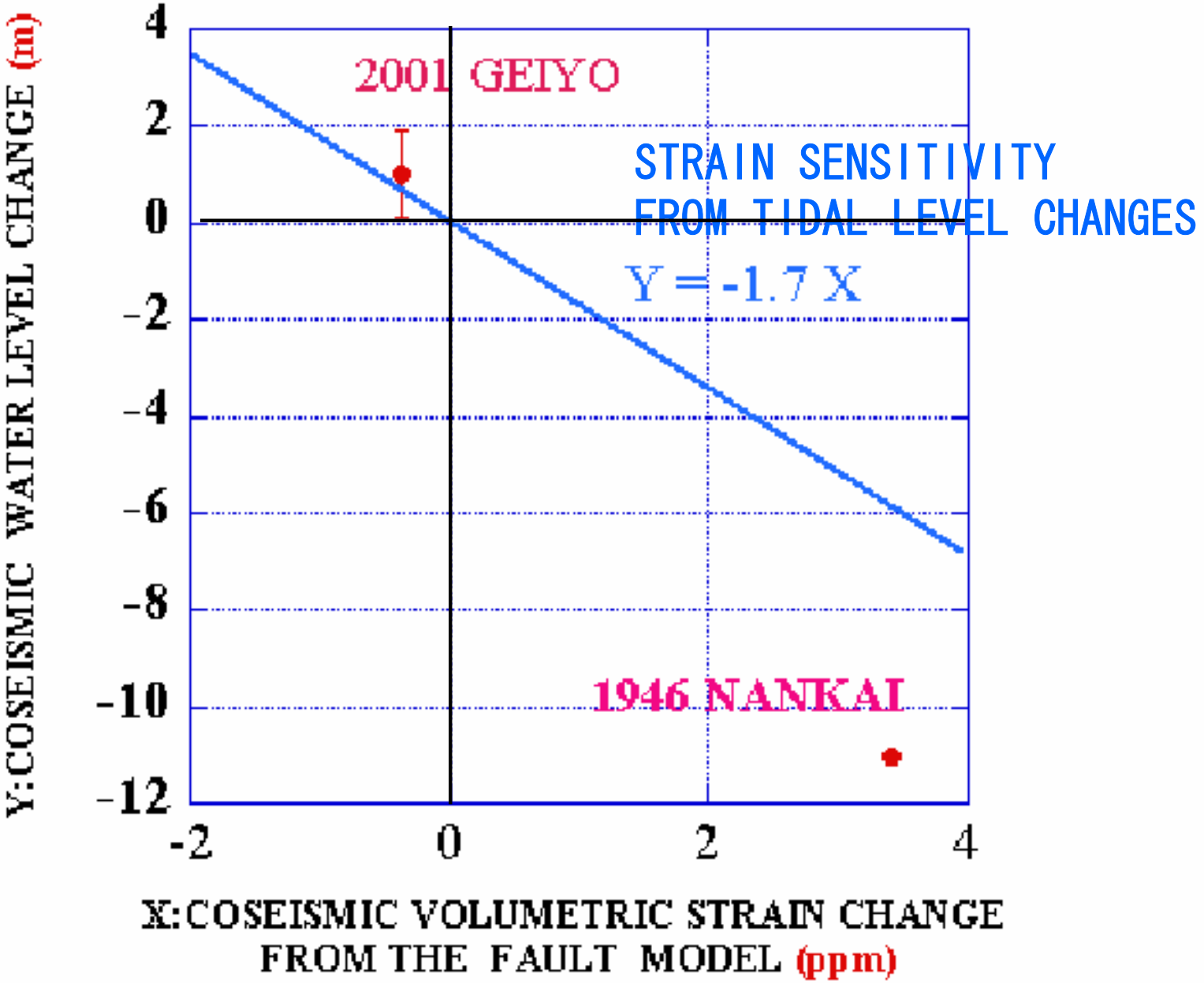
COSEISMIC VOLUMETRIC STRAIN CHANGES CALCULATED FROM THE 1946 NANKAI EARTHQUAKE FAULE MODEL



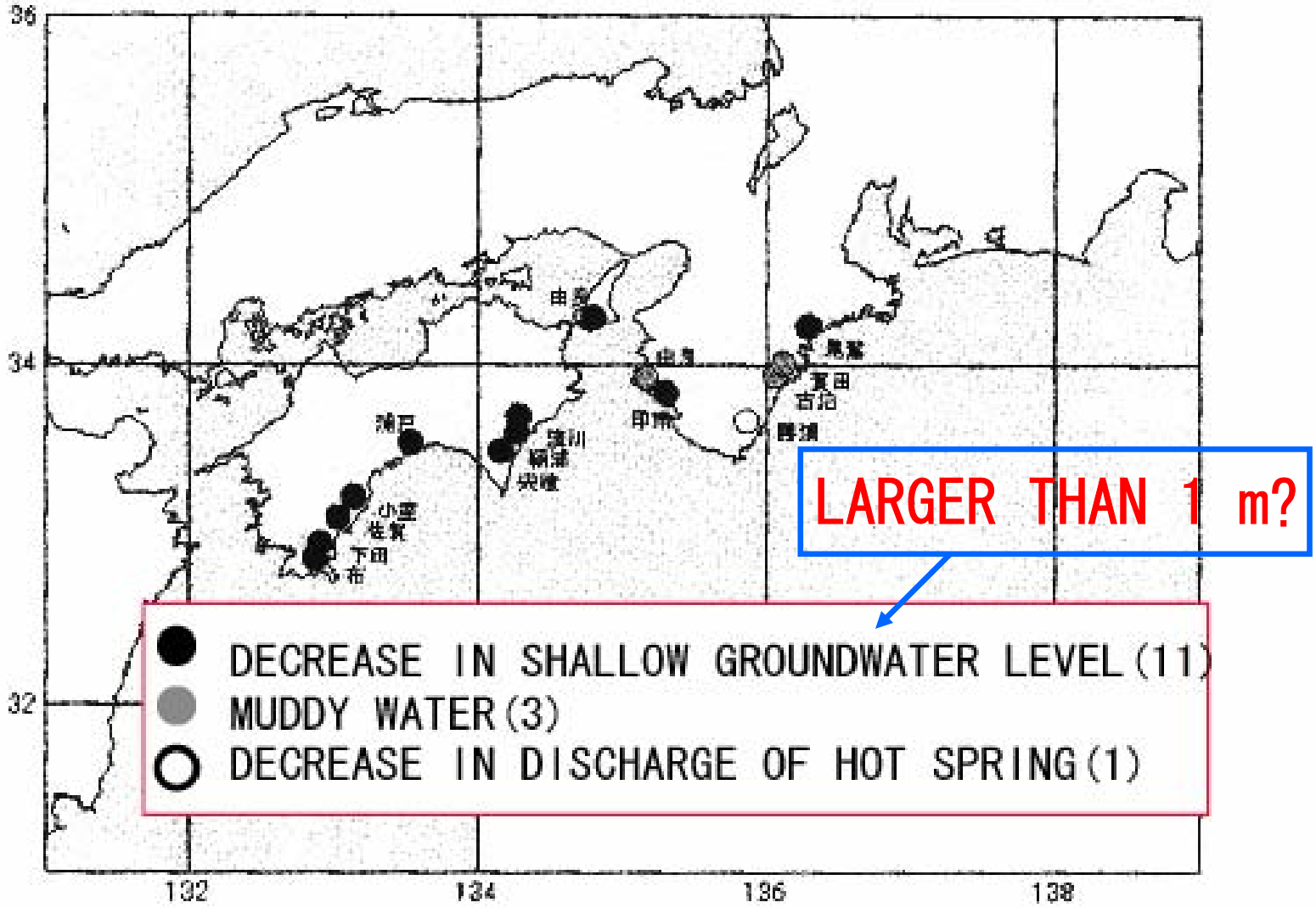
COSEISMIC VOLUMETRIC STRAIN CHANGES CALCULATED FROM THE 2001 GEIYO EARTHQUAKE FAULE MODEL




ATMOEPHERIC PRESSURE
50 hPa
RAINFALL
50
mm/h
0
GROUNDWATER LEVEL AT NO.4 WELL IN THE DOGO HOT SPRING
1 m
STRAIN SENSITIVITY
= 1.7 m/ppm VOLUMETRIC STRAIN
= 1.2 m/ppm AREAL STRAIN
2003
6
7
8


2001 GEIYO
STRAIN SENSITIVITY
FROM TIDAL LEVEL CHANGES
Y = -1.7 X
1946 NANKAI
Y:COSEISMIC WATER LEVEL CHANGE (m)
X:COSEISMIC VOLUMETRIC STRAIN CHANGE
FROM THE FAULT MODEL (ppm)
4
2
0
-2
-4
-6
-8
-10
-12
-2
0
2
4

PRESEISMIC GROUNDWATER CHANGES BEFORE THE 1946 NANAKAI EARTHQUAKEG



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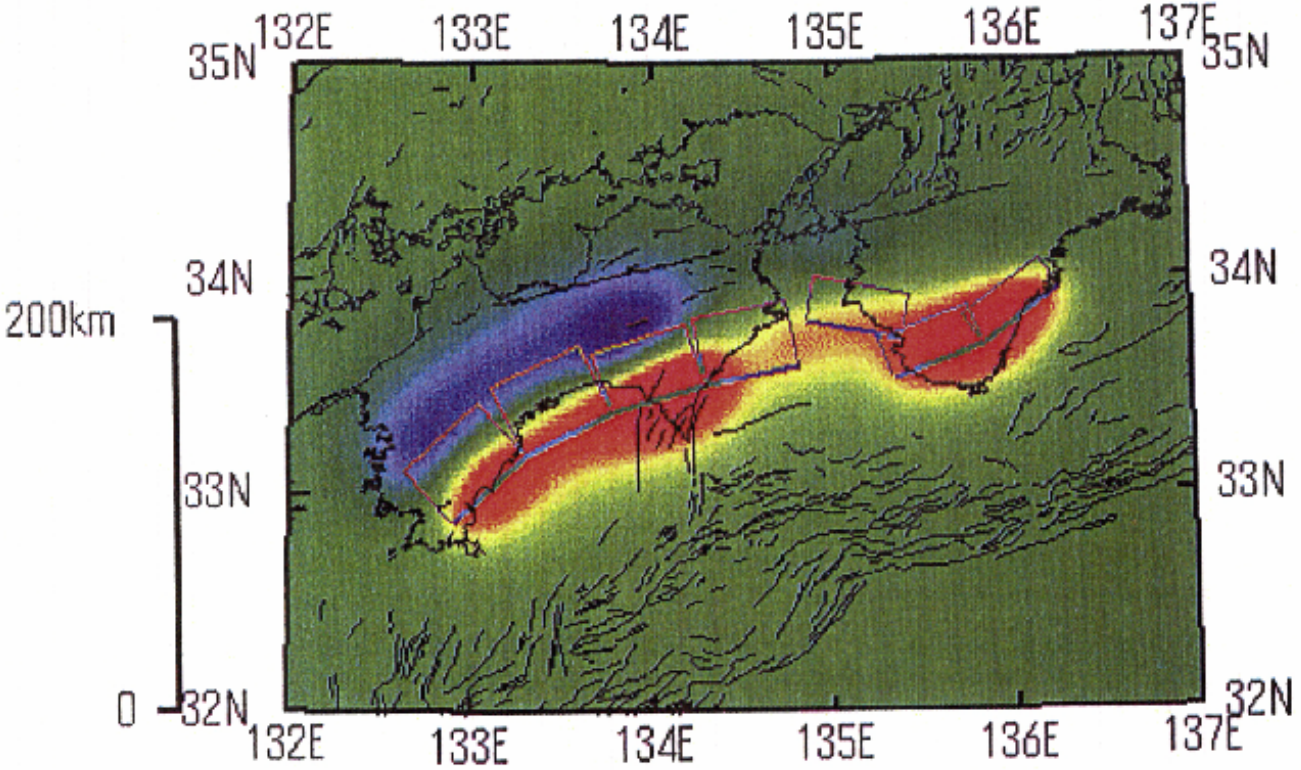
PRESEISMIC VERTICAL MOVEMENTS AT THE SURFACE
EXPECTED FROM A PRE-SLIP MODEL FOR
THE 1946 NANKAI EARTHQUAKE



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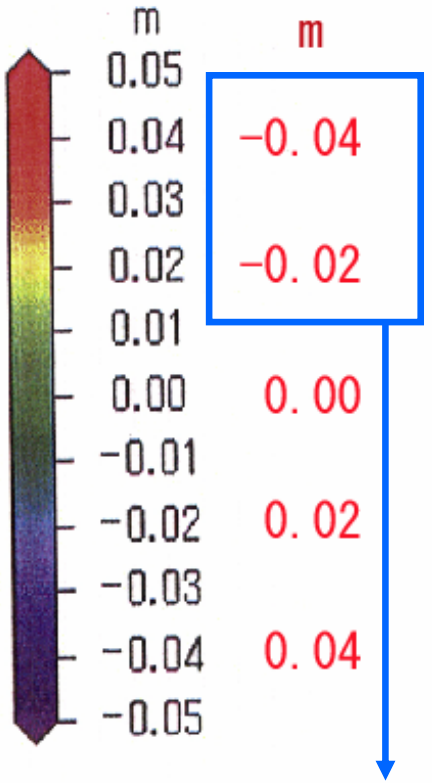
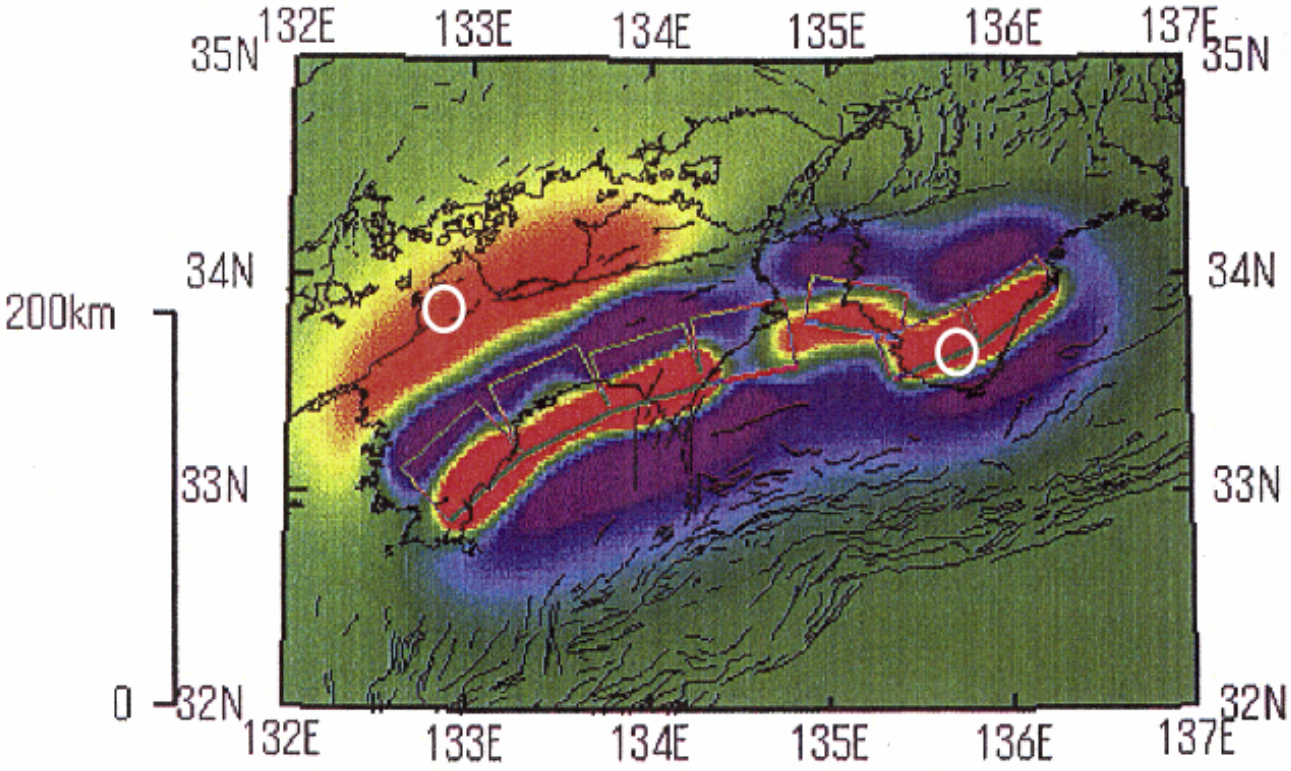
UNCONFINED
GROUNDWATER
LEVEL CHANGE



TOO SMALL!

PRESEISMIC AREAL STRAIN CHANGES
EXPECTED FROM A PRE-SLIP MODEL FOR
THE 1946 NANKAI EARTHQUAKE



MODIFIED FROM HASHIMOTO(2003)

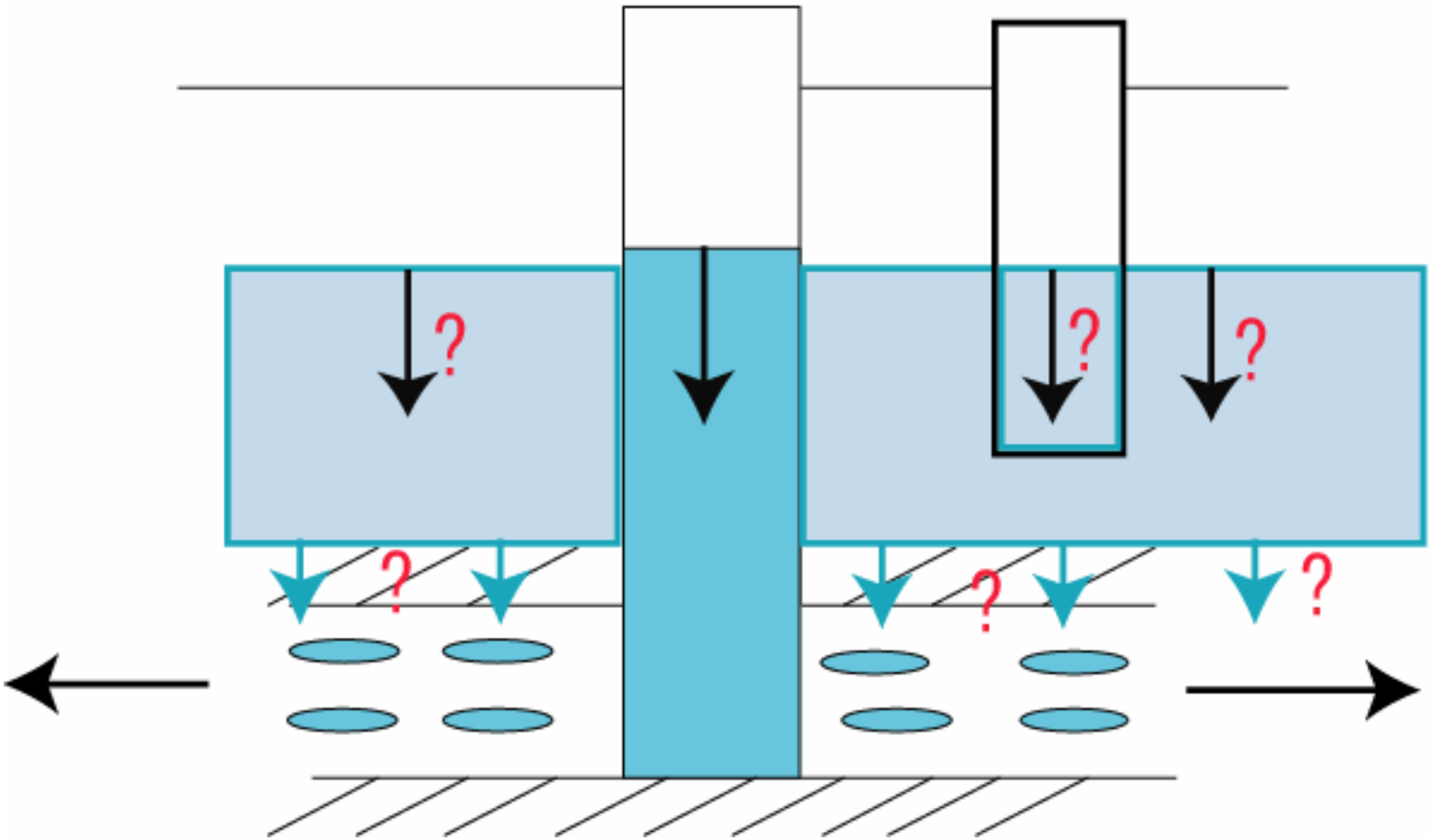
AREAL STRAIN CAHNGE

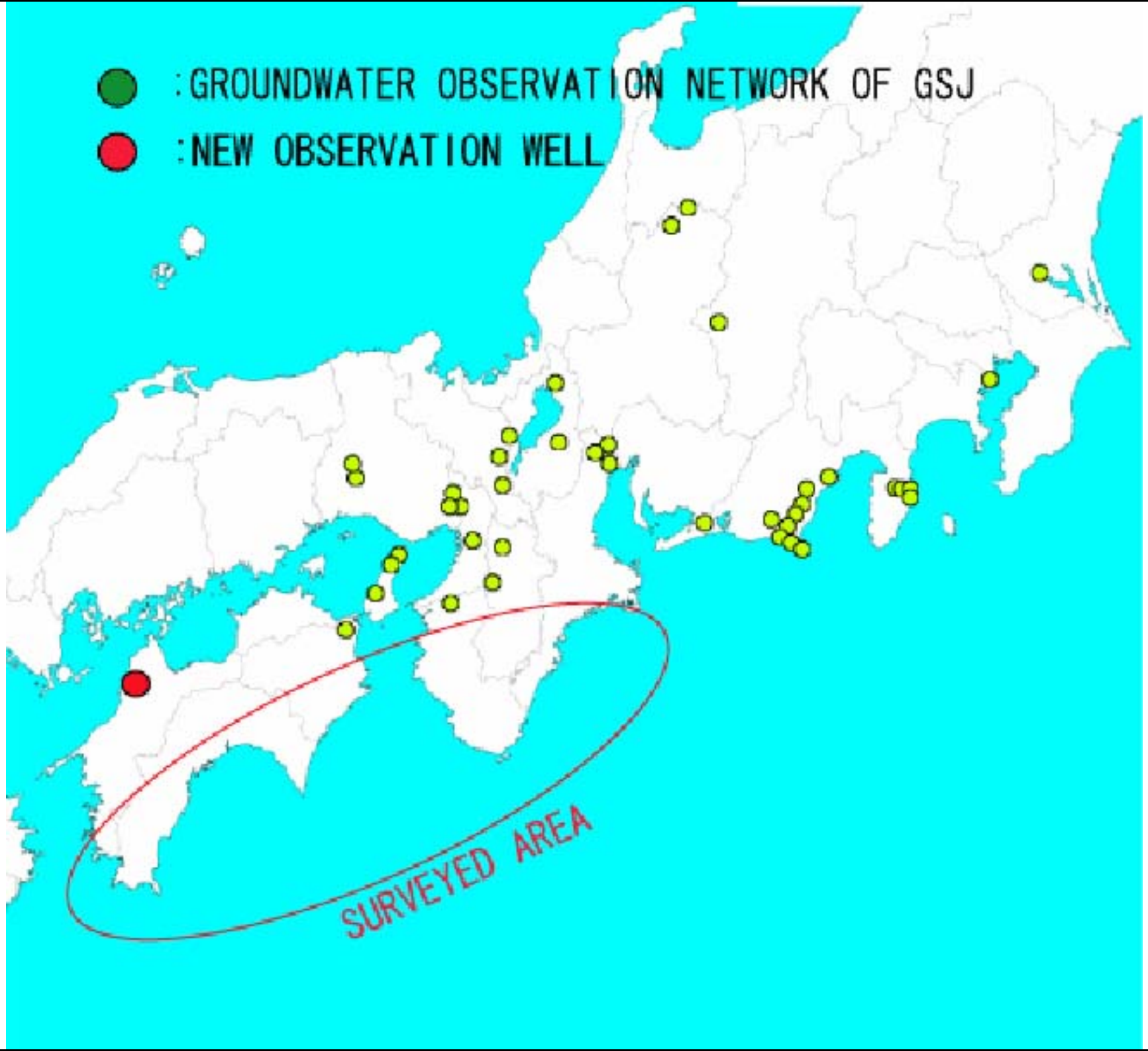
CONFINED GROUNDWATER LEVEL CHANGE (−1m/ppm)

ppm	m
0.50	
0.40	−0.40
0.30	
0.20	−0.20
0.10	
−0.00	0.00
−0.10	
−0.20	0.20
−0.30	
−0.40	0.40
−0.50	

DETECTABLE CHANGES!

CONNECTED SYSTEM BETWEEN CONFINED AND UNCONFINED GROUNDWATER?




:GROUNDWATER OBSERVATION NETWORK OF GSJ
:NEW OBSERVATION WELL
SURVEYED AREA

Conclusions

・Repeatedly recorded groundwater changes related to the Nankai earthquakes can be qualitatively explained by the fault slip at the focal region.

・Coseismic groundwater level changes at the Dogo hot spring can be almost quantitatively explained.

・Preseismic groundwater level changes before the 1946 Nankai earthquake cannot be quantitatively explained.

・If the pre-slip also occurs before the impending Nankai earthquake, preseismic groundwater level changes can be detected at some strain-sensitive wells.