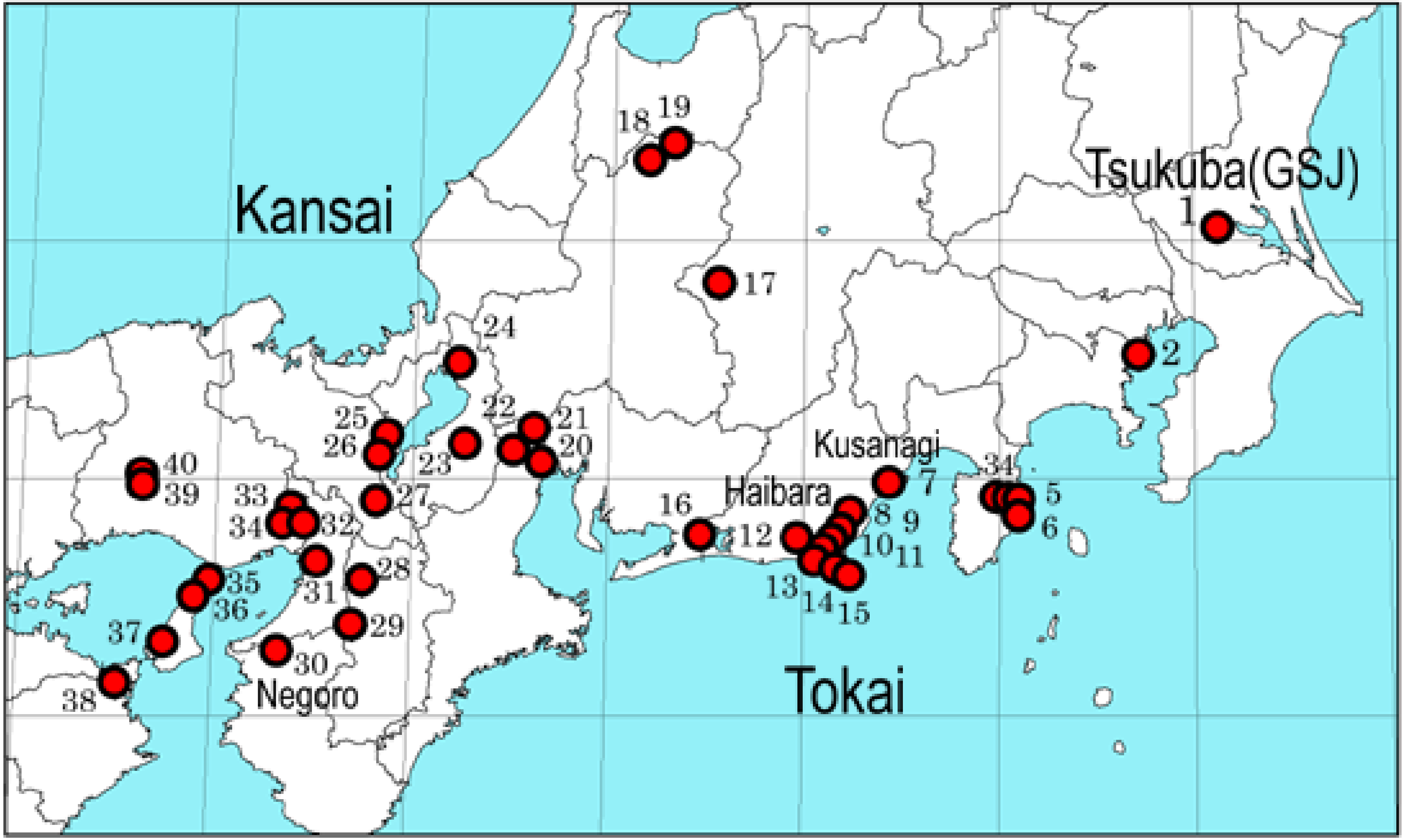
Hydrological and geochemical research for earthquake prediction by Geological Survey of Japan, AIST

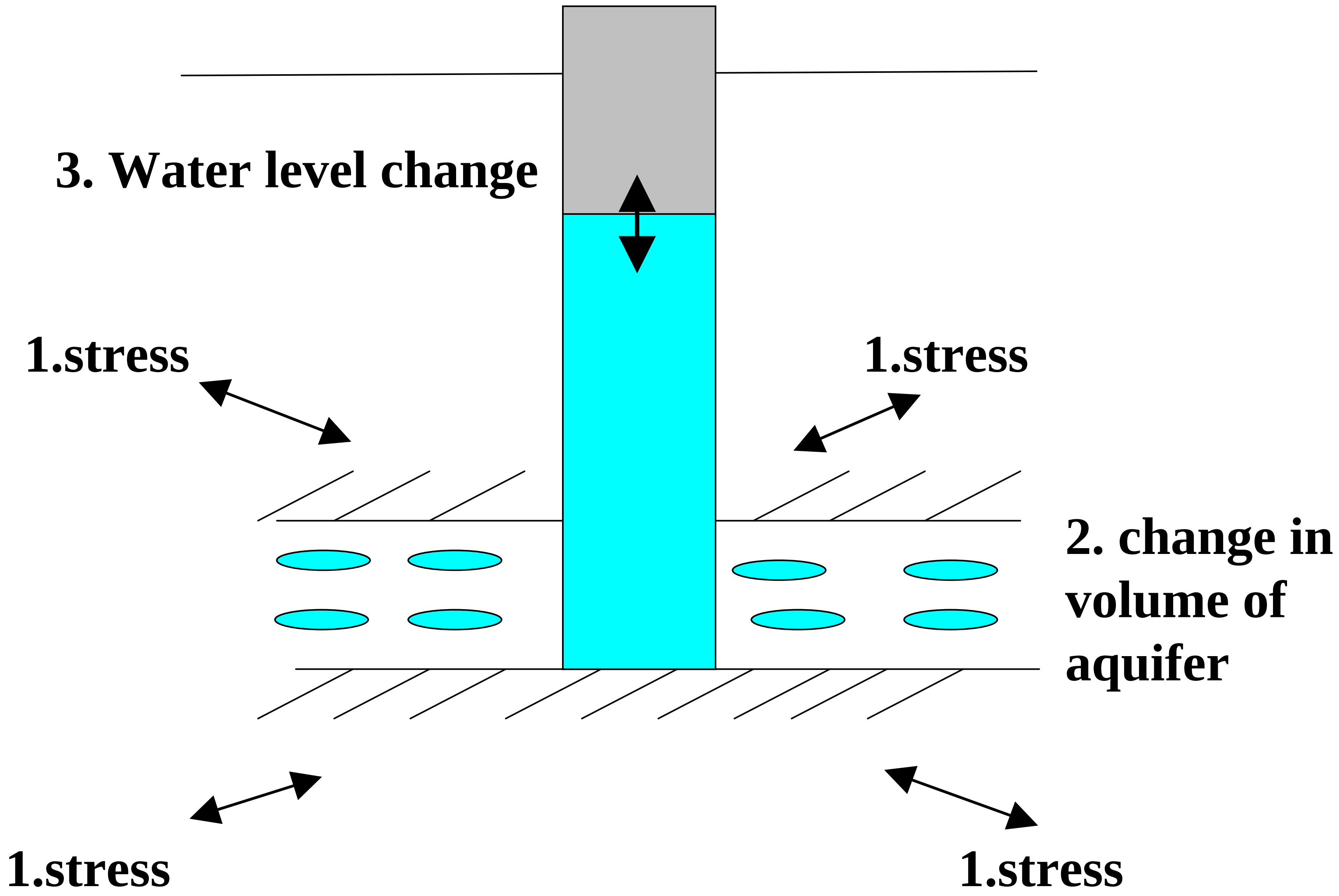
Norio MATSUMOTO and Naoji KOIZUMI

(Tectono-Hydrology Research Group, Institute of Geoscience, GSJ, AIST)

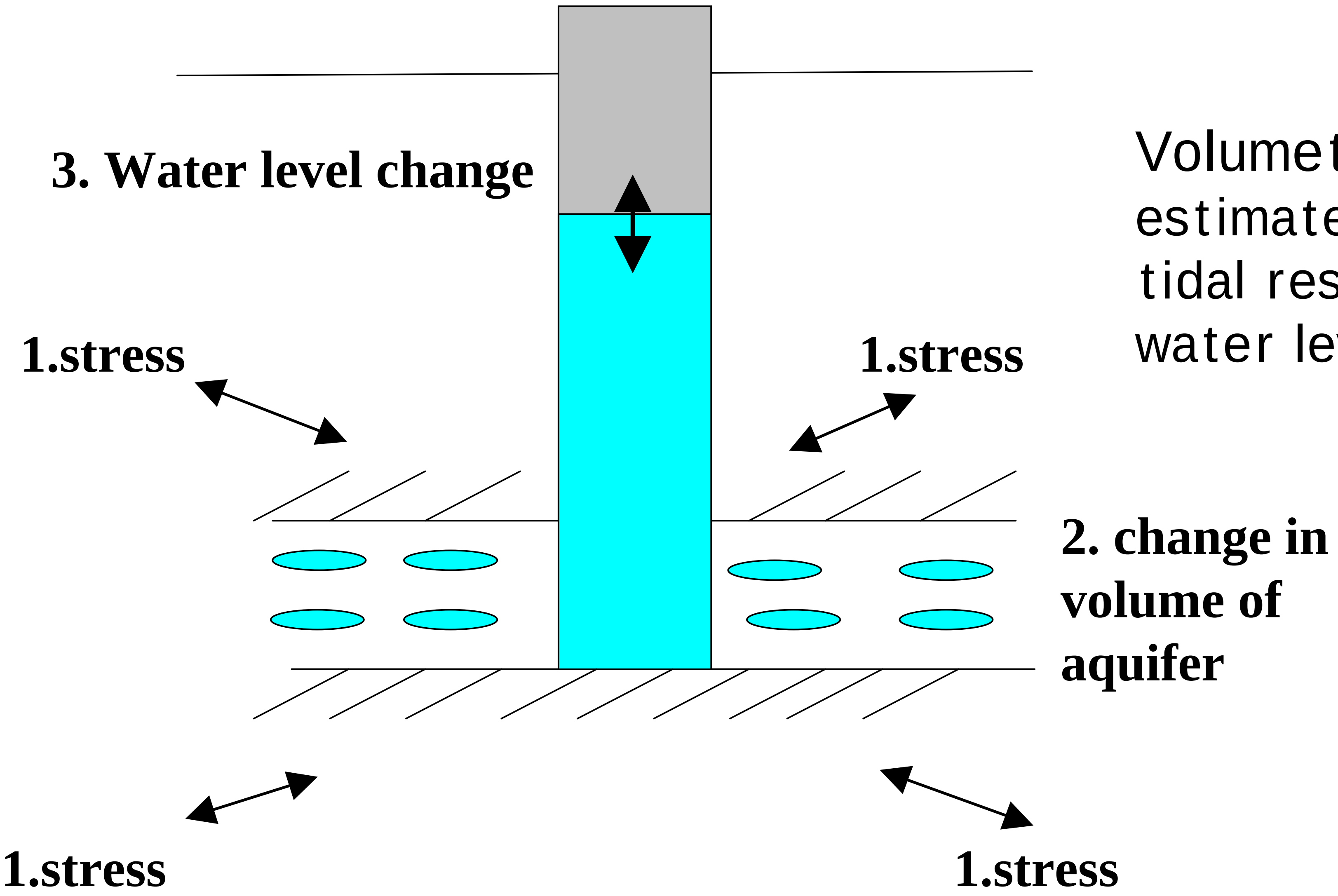
AIST groundwater observation wells



Water level change in a confined aquifer ‘strain model’

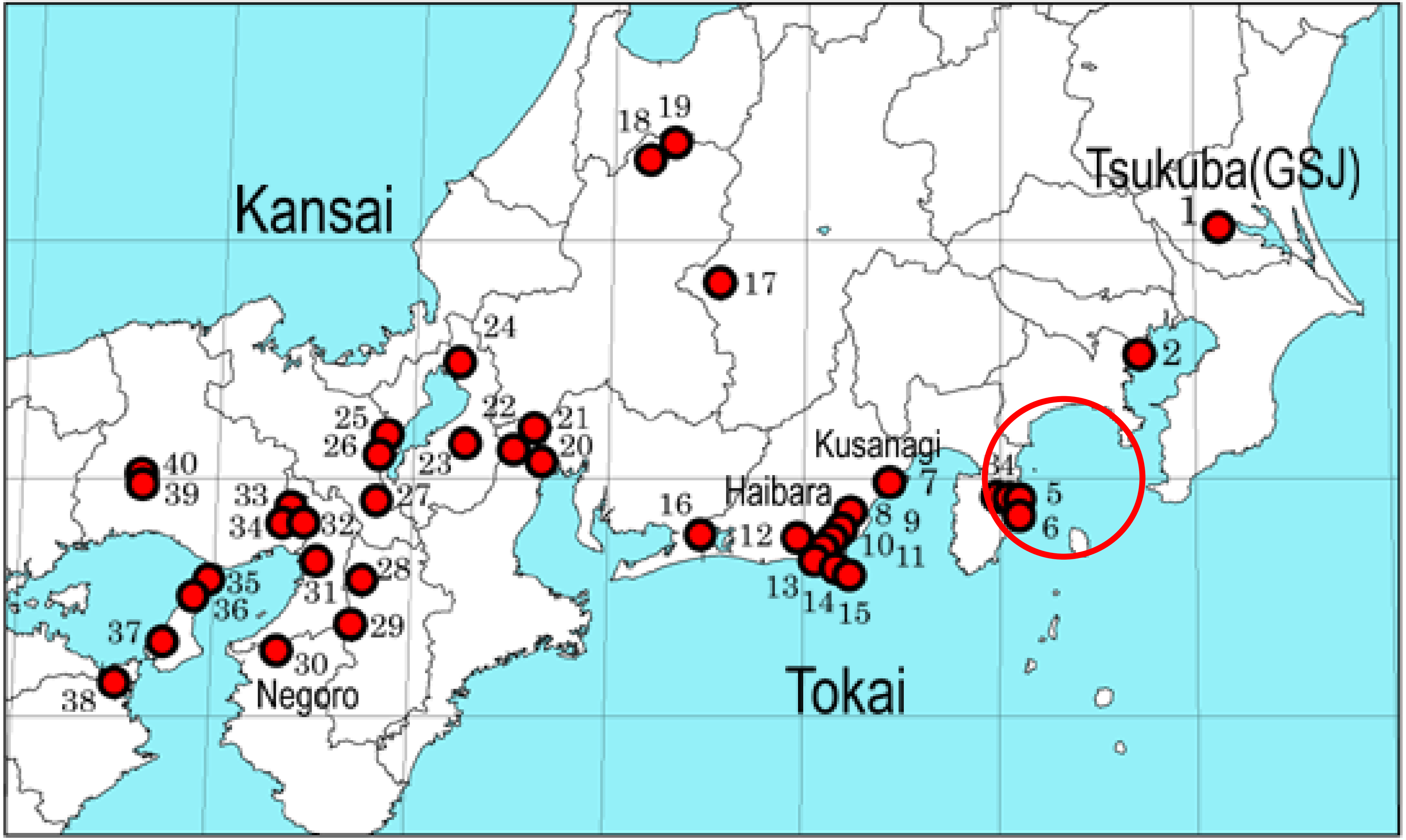


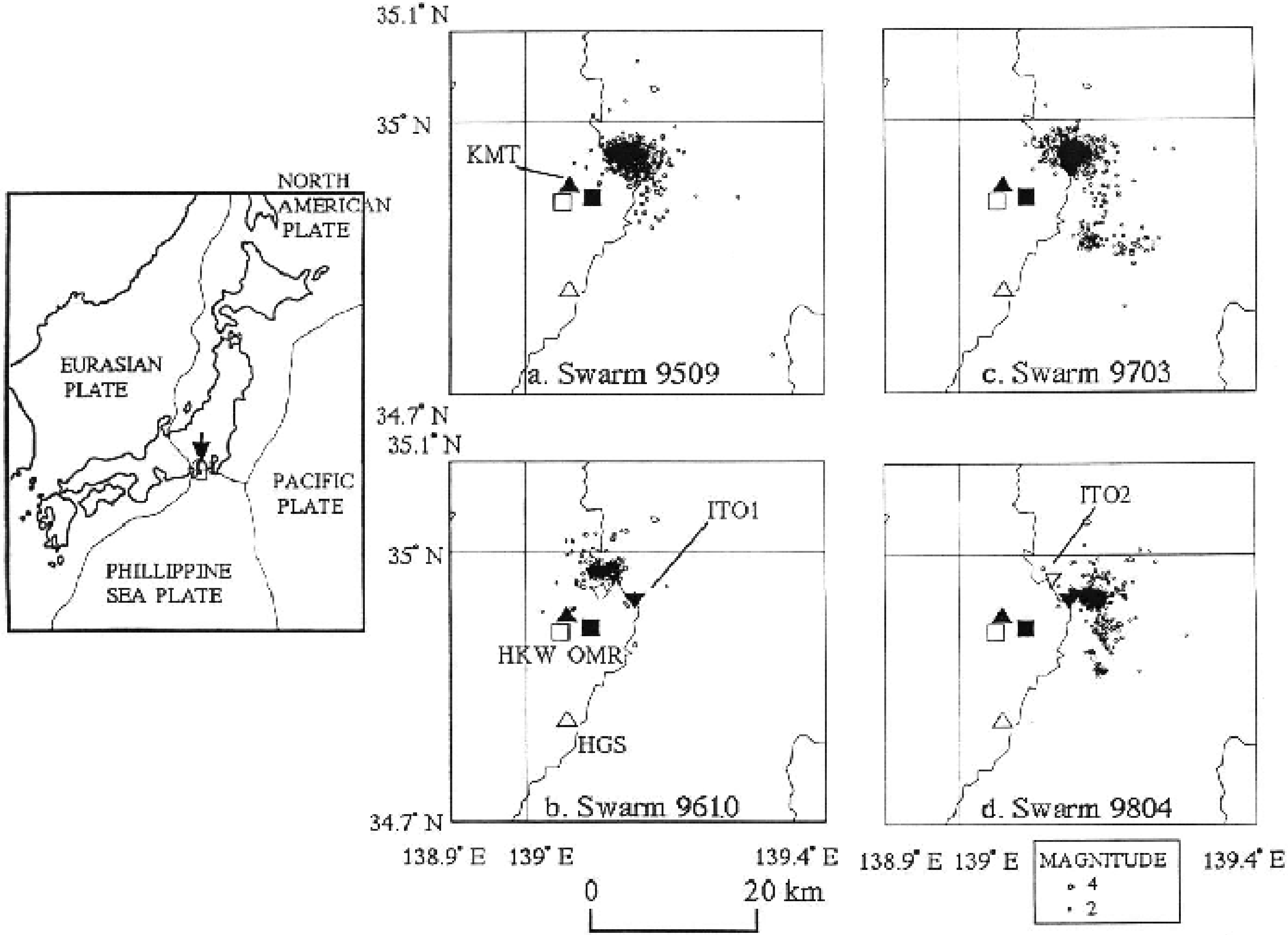
Water level change in a confined aquifer 'strain model'



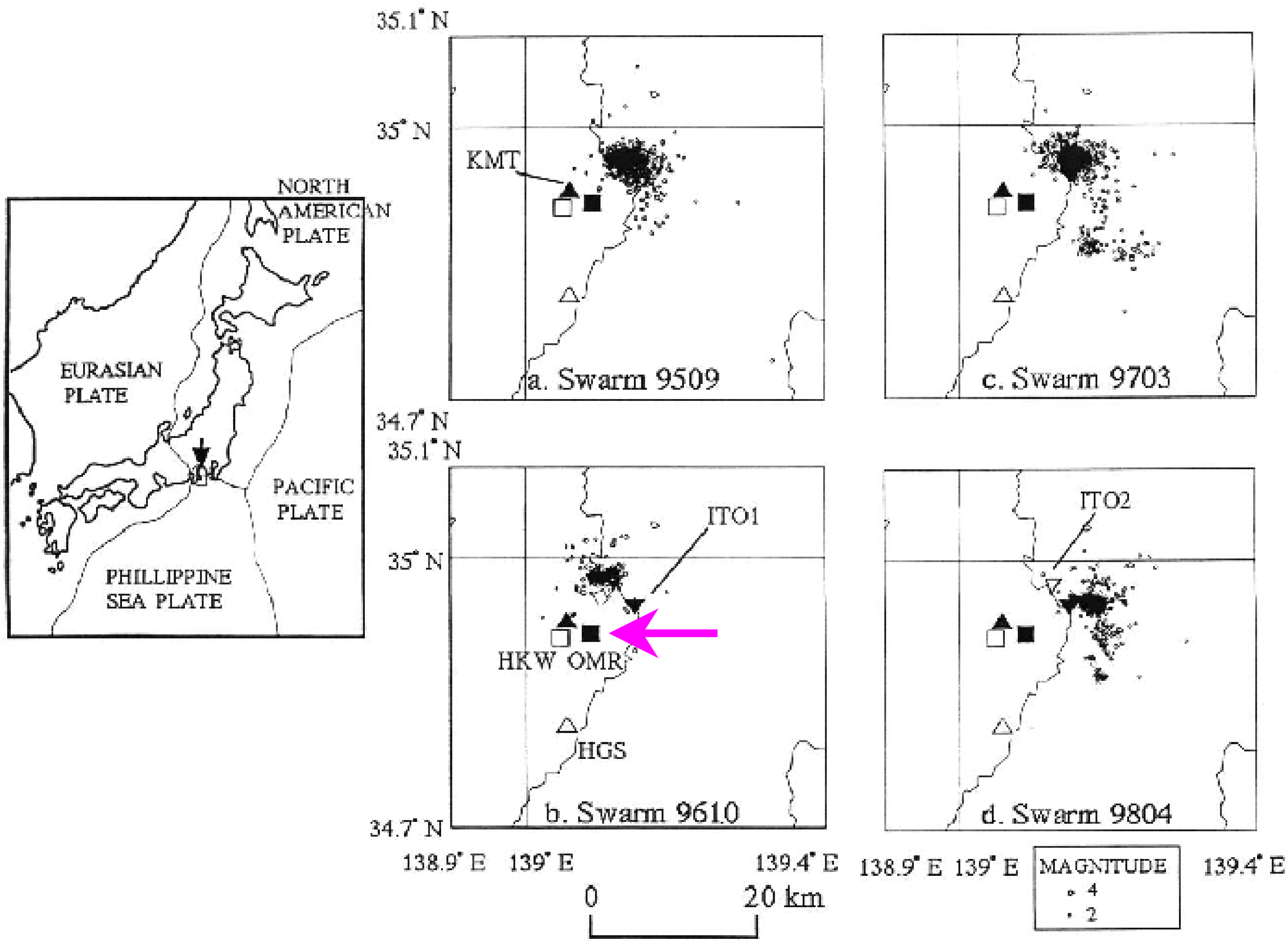
Volumetric strain is estimated by using tidal response of water level.

Water level change and earthquake swarms in Izu Peninsula

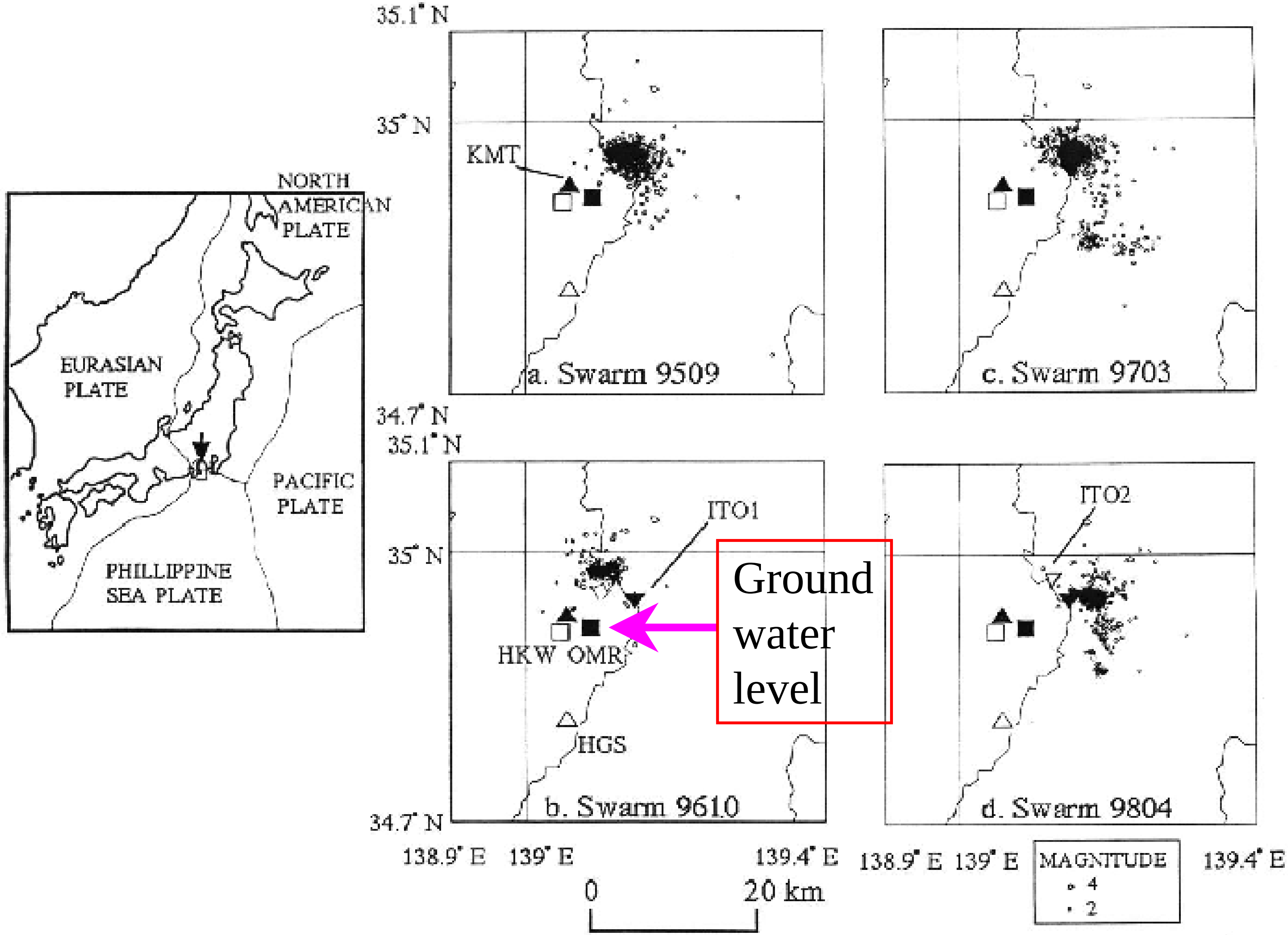




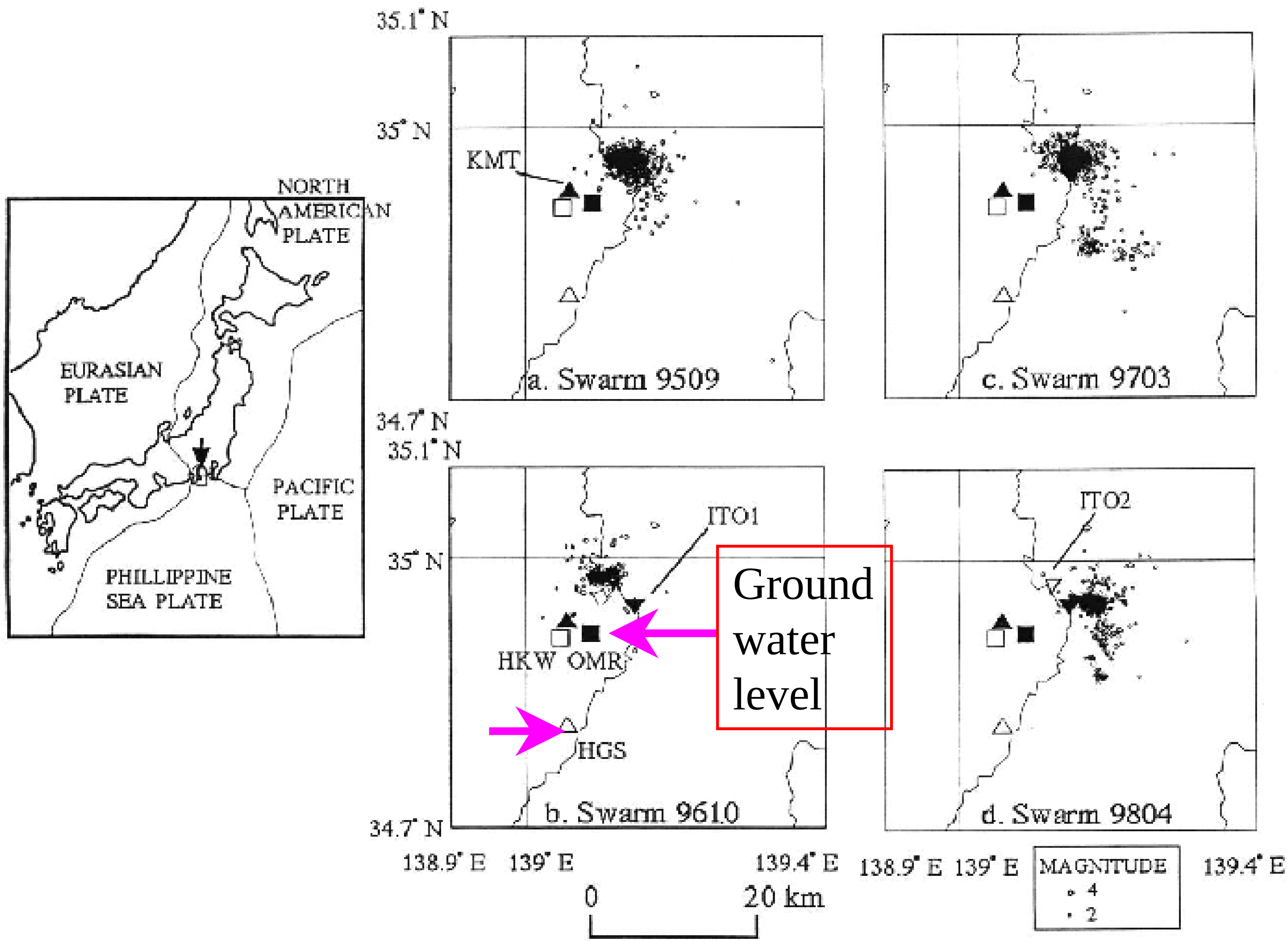
NORTH AMERICAN PLATE
EURASIAN PLATE
PACIFIC PLATE
PHILLIPPINE SEA PLATE
35.1° N
35° N
34.7° N
KMT
ITO1
ITO2
HKW OMR
HGS
a. Swarm 9509
b. Swarm 9610
c. Swarm 9703
d. Swarm 9804
138.9° E
139° E
139.4° E
0
20 km
MAGNITUDE
4
2



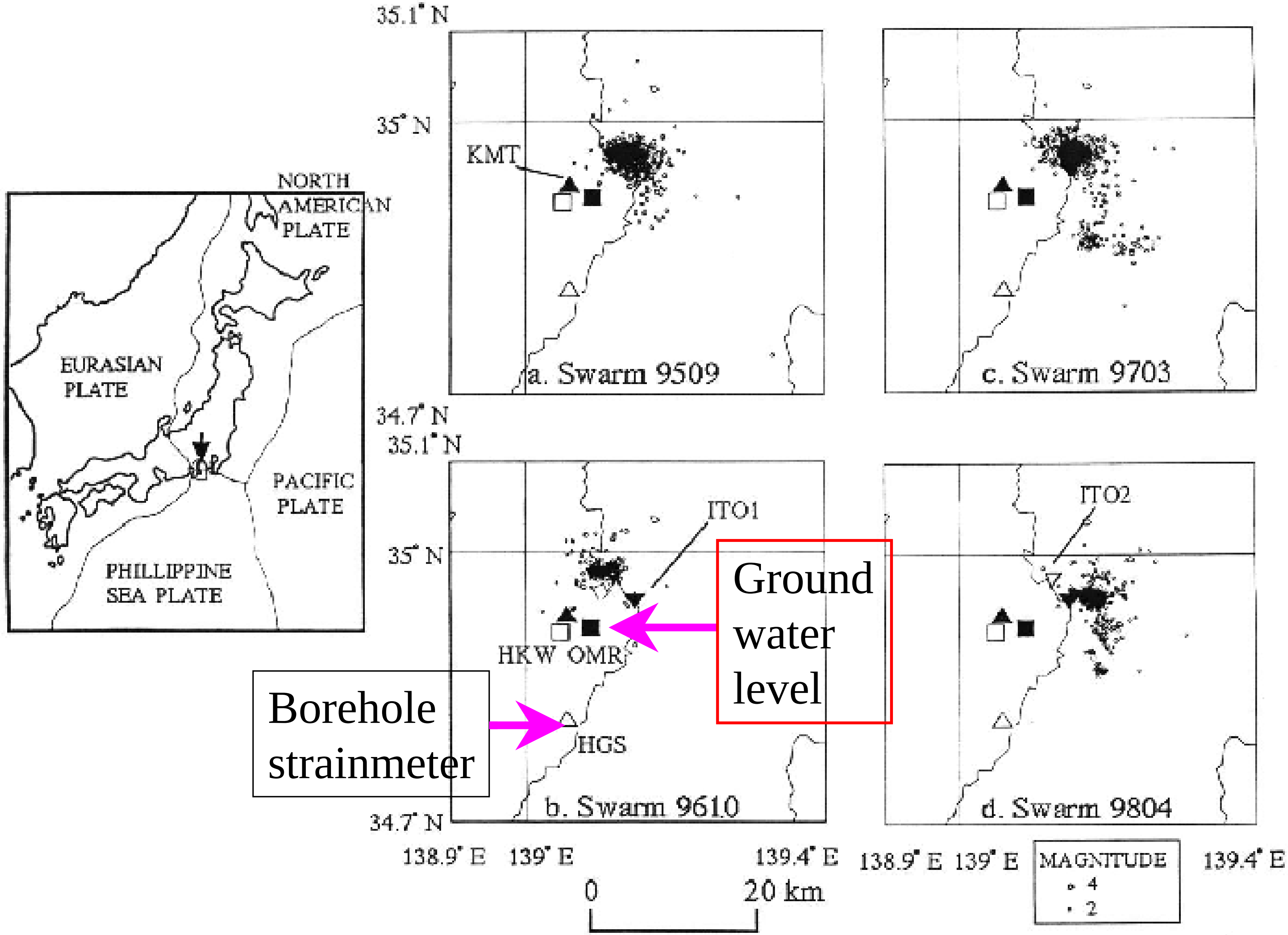
NORTH AMERICAN PLATE
EURASIAN PLATE
PACIFIC PLATE
PHILLIPPINE SEA PLATE
35.1° N
35° N
34.7° N
KMT
ITO1
ITO2
HKW OMR
HGS
a. Swarm 9509
b. Swarm 9610
c. Swarm 9703
d. Swarm 9804
138.9° E
139° E
139.4° E
0
20 km
MAGNITUDE
4
2



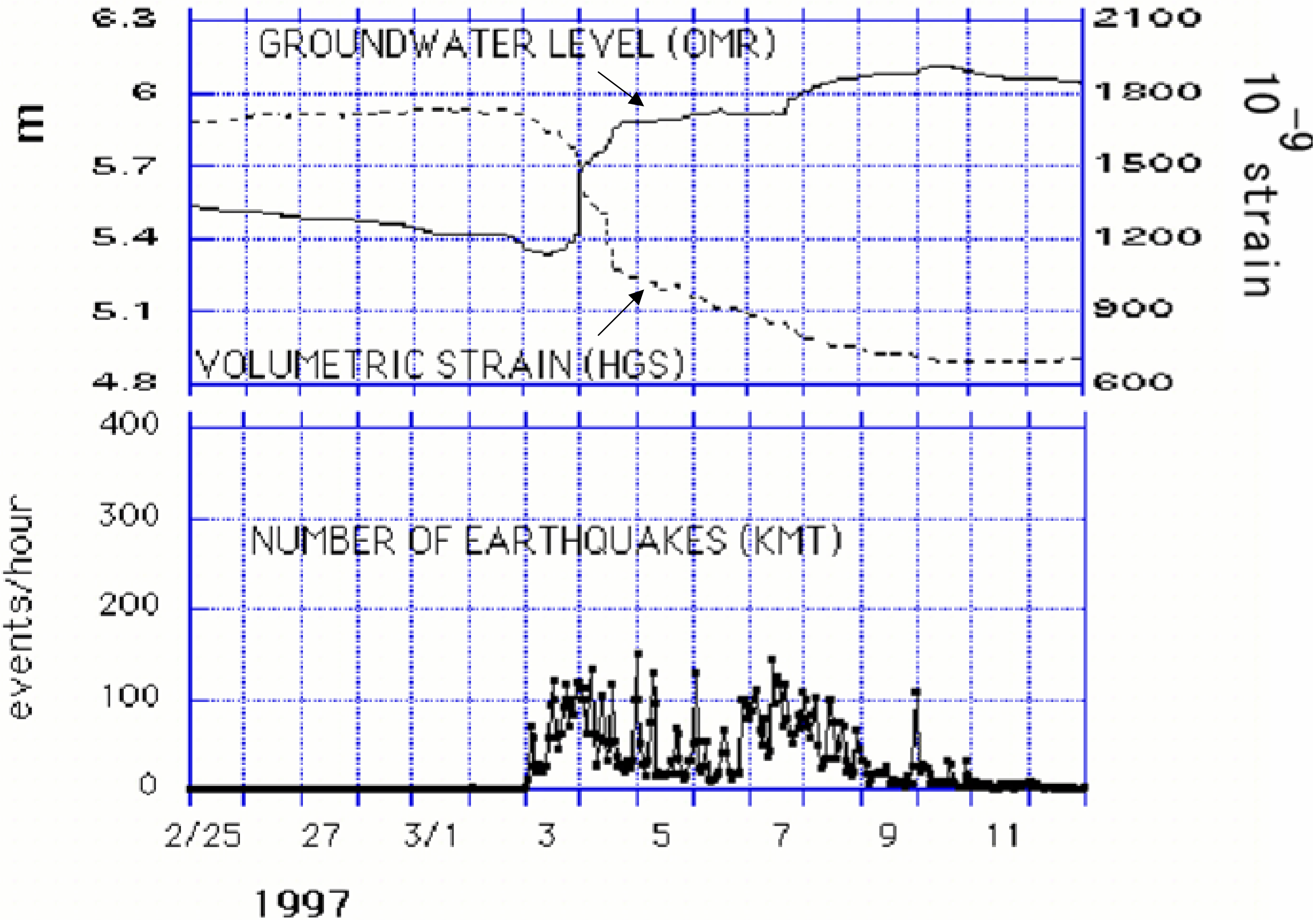
NORTH AMERICAN PLATE
EURASIAN PLATE
PACIFIC PLATE
PHILLIPPINE SEA PLATE
35.1° N
35° N
34.7° N
KMT
a. Swarm 9509
c. Swarm 9703
ITO1
ITO2
Ground water level
HKW OMR
HGS
b. Swarm 9610
d. Swarm 9804
138.9° E
139° E
139.4° E
0
20 km
MAGNITUDE
4
2



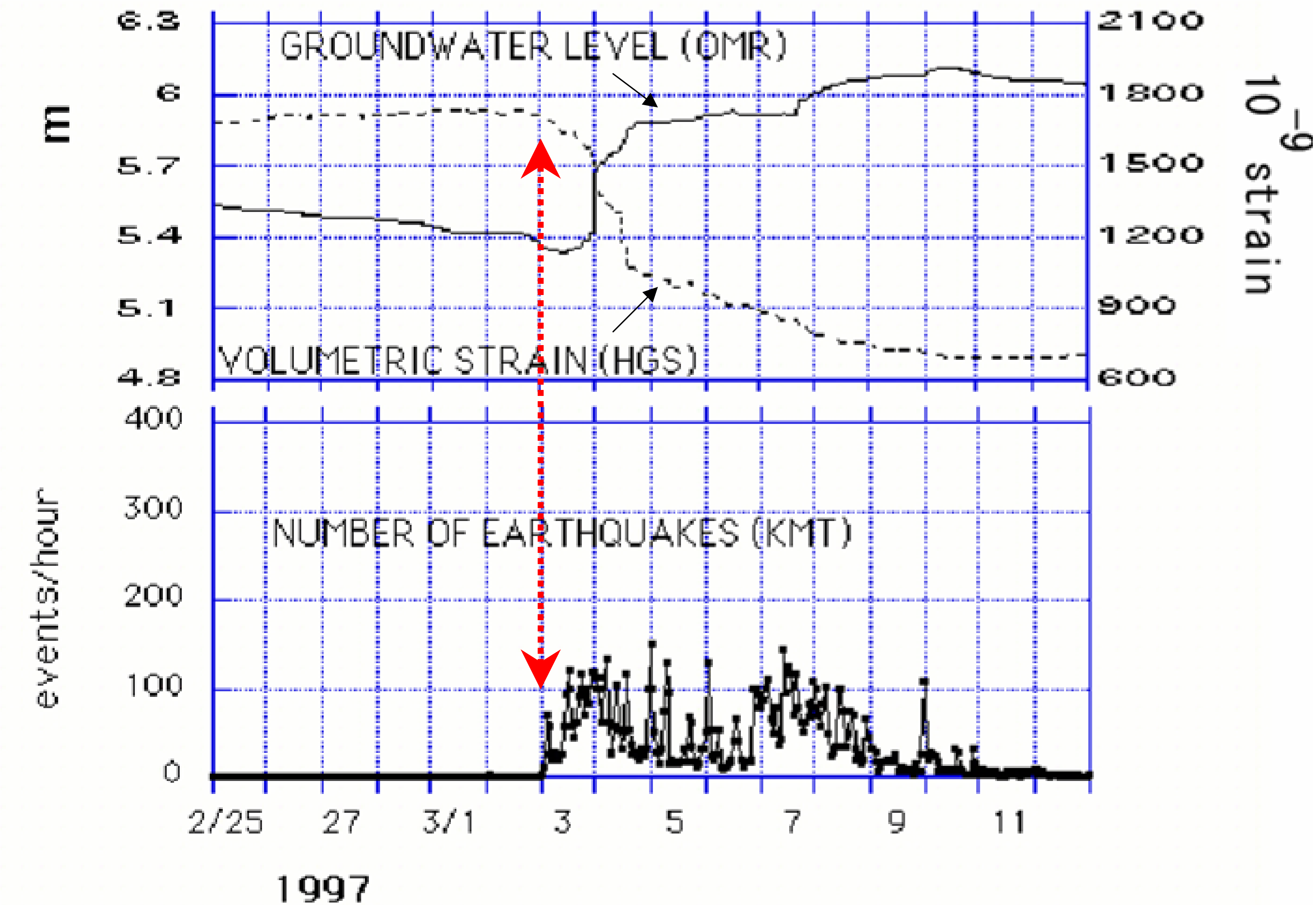
NORTH AMERICAN PLATE
EURASIAN PLATE
PACIFIC PLATE
PHILLIPPINE SEA PLATE
35.1° N
35° N
34.7° N
KMT
a. Swarm 9509
c. Swarm 9703
ITO1
ITO2
HKW OMR
HGS
b. Swarm 9610
d. Swarm 9804
138.9° E 139° E 139.4° E
0 20 km
MAGNITUDE
4
2
Ground water level



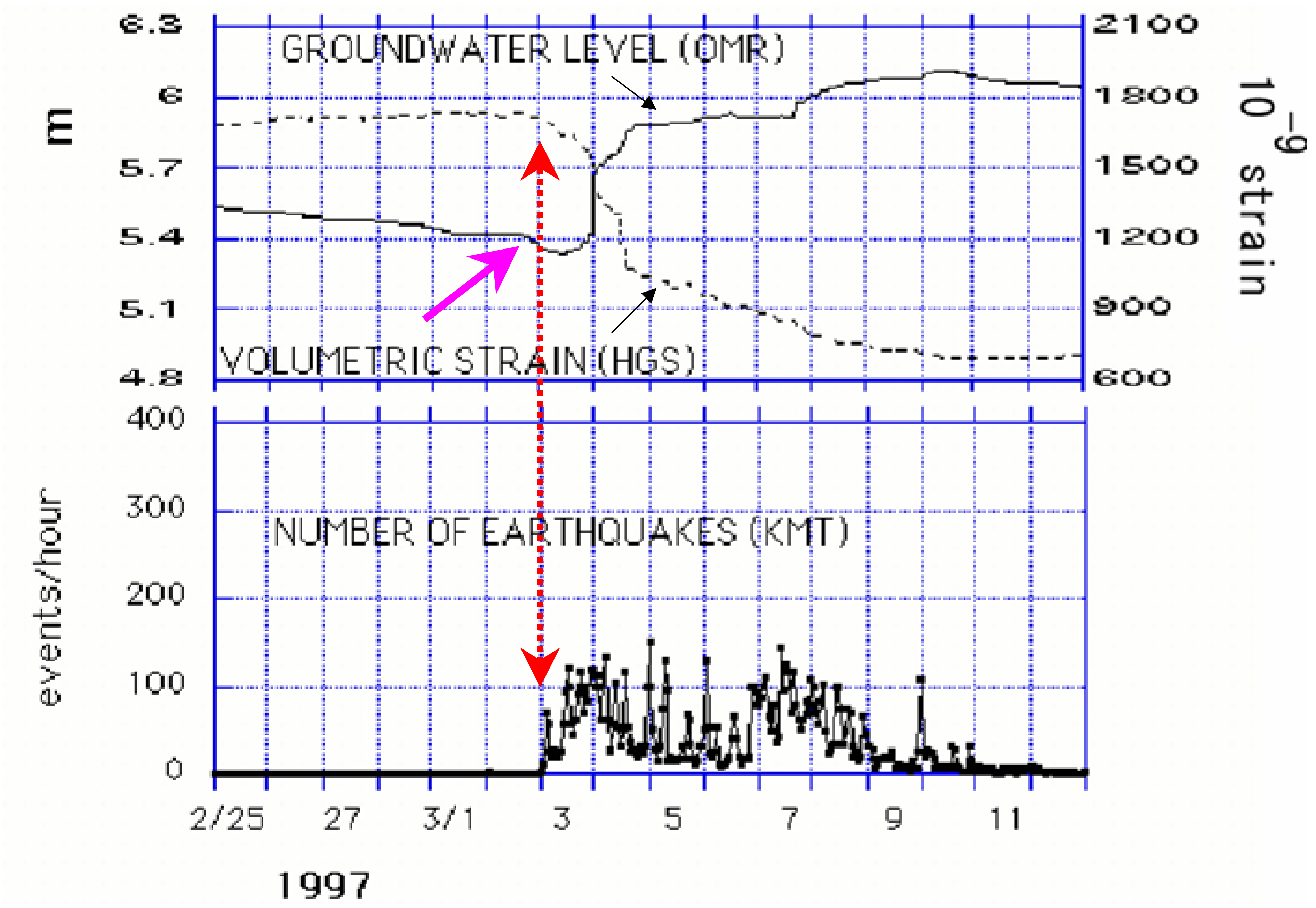
NORTH AMERICAN PLATE
EURASIAN PLATE
PACIFIC PLATE
PHILLIPPINE SEA PLATE
35.1° N
35° N
34.7° N
KMT
a. Swarm 9509
c. Swarm 9703
ITO1
ITO2
HKW OMR
HGS
b. Swarm 9610
d. Swarm 9804
Ground water level
Borehole strainmeter
138.9° E
139° E
139.4° E
0
20 km
MAGNITUDE
4
2



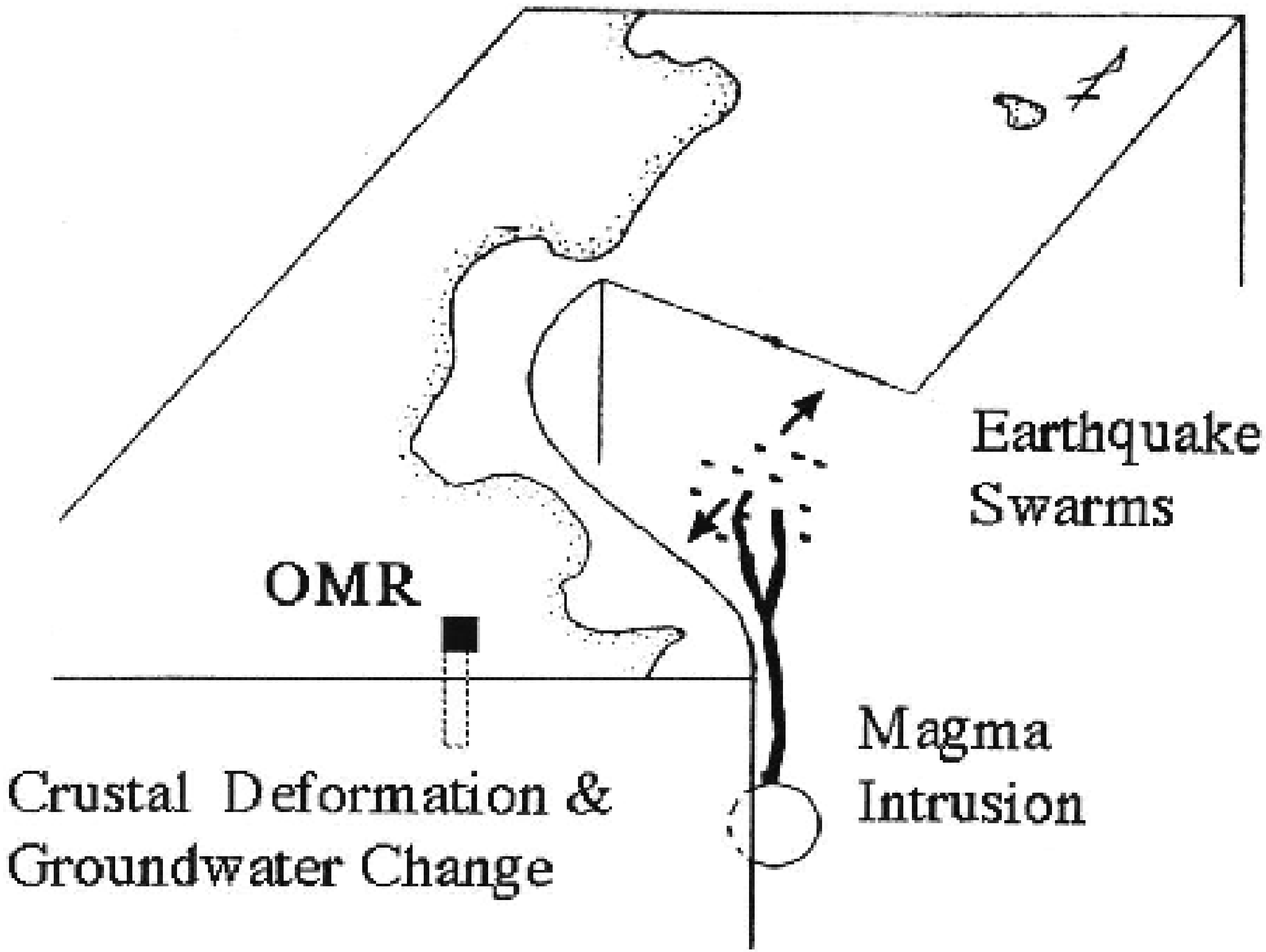
GROUNDWATER LEVEL (OMR)
VOLUMETRIC STRAIN (HGS)
m
6.3
6
5.7
5.4
5.1
4.8
2100
1800
1500
1200
900
600
10^{-9} strain
NUMBER OF EARTHQUAKES (KMT)
events/hour
400
300
200
100
0
2/25
27
3/1
3
5
7
9
11
1997



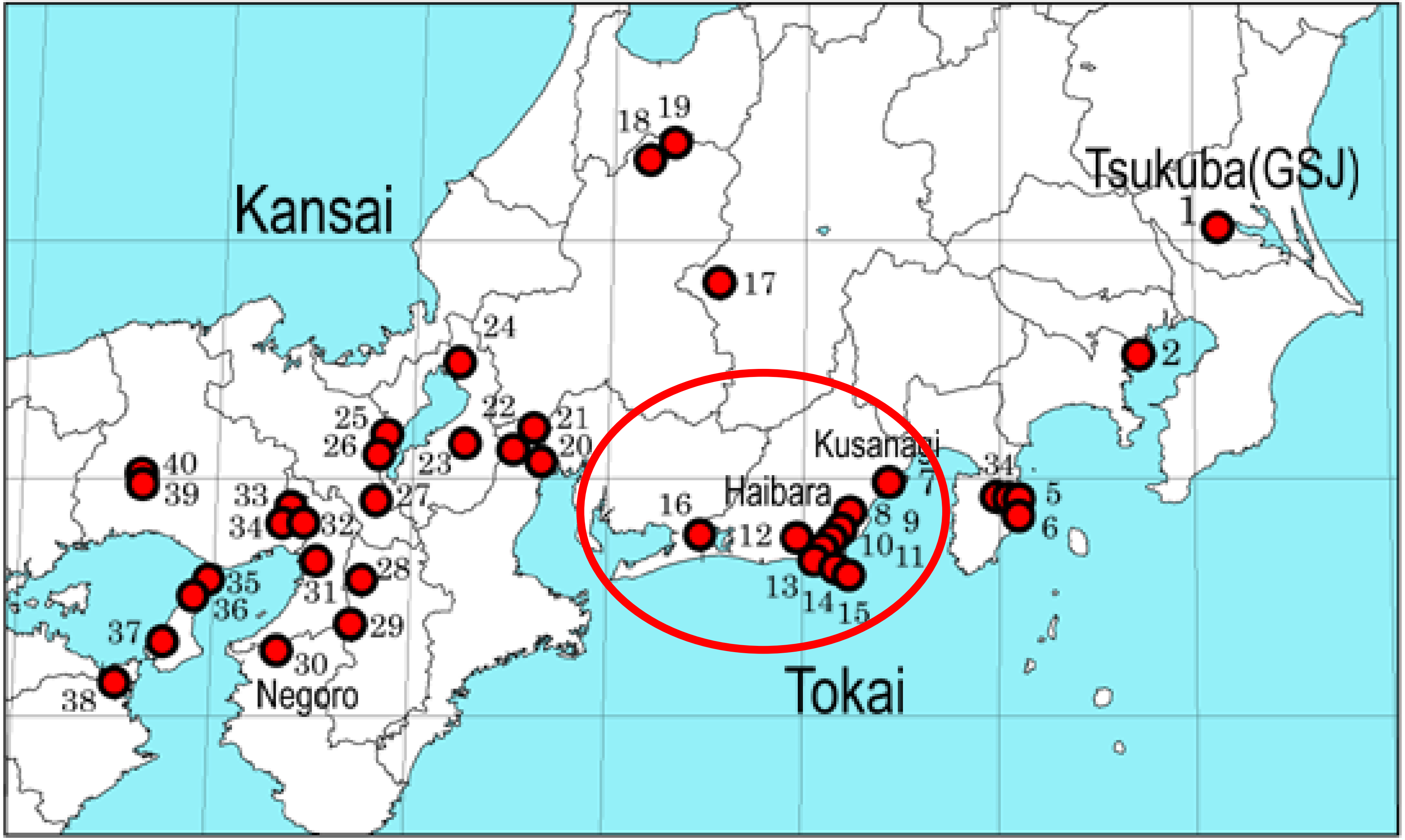
GROUNDWATER LEVEL (OMR)
VOLUMETRIC STRAIN (HGS)
NUMBER OF EARTHQUAKES (KMT)
m
6.3
6
5.7
5.4
5.1
4.8
2100
1800
1500
1200
900
600
10^-9 strain
events/hour
400
300
200
100
0
2/25
27
3/1
3
5
7
9
11
1997



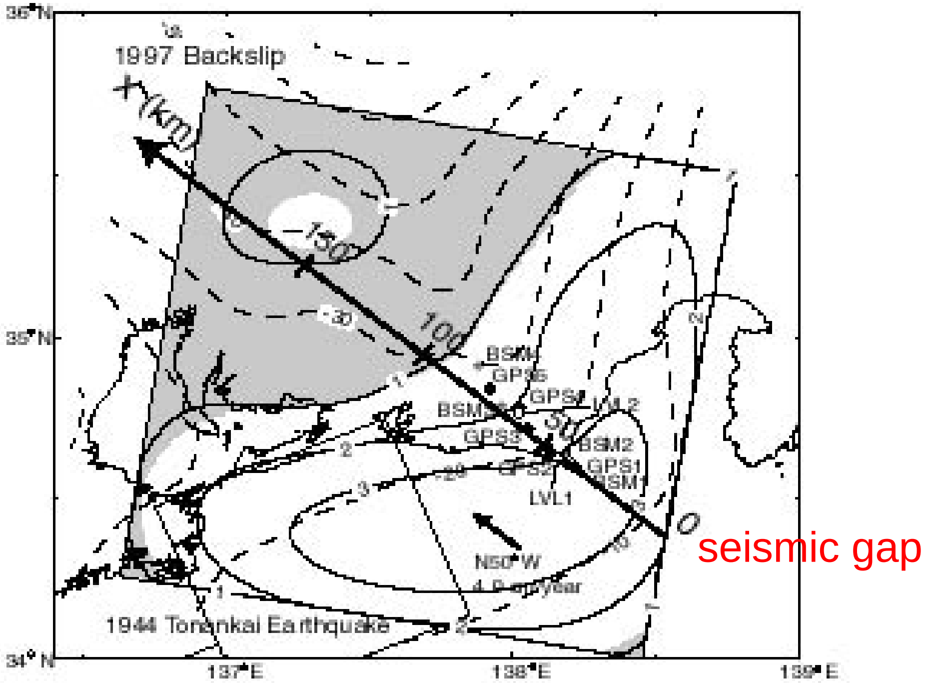
GROUNDWATER LEVEL (OMR)
VOLUMETRIC STRAIN (HGS)
NUMBER OF EARTHQUAKES (KMT)
m
6.3
6
5.7
5.4
5.1
4.8
2100
1800
1500
1200
900
600
10^{-9} strain
events/hour
400
300
200
100
0
2/25
27
3/1
3
5
7
9
11
1997


Earthquake
Swarms
OMR
Magma
Intrusion
Crustal Deformation &
Groundwater Change

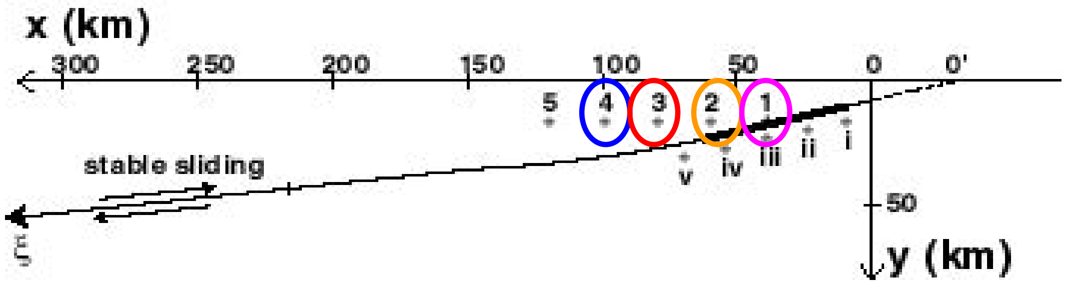
Estimation of groundwater level change due to preseismic sliding before the anticipated Tokai earthquake



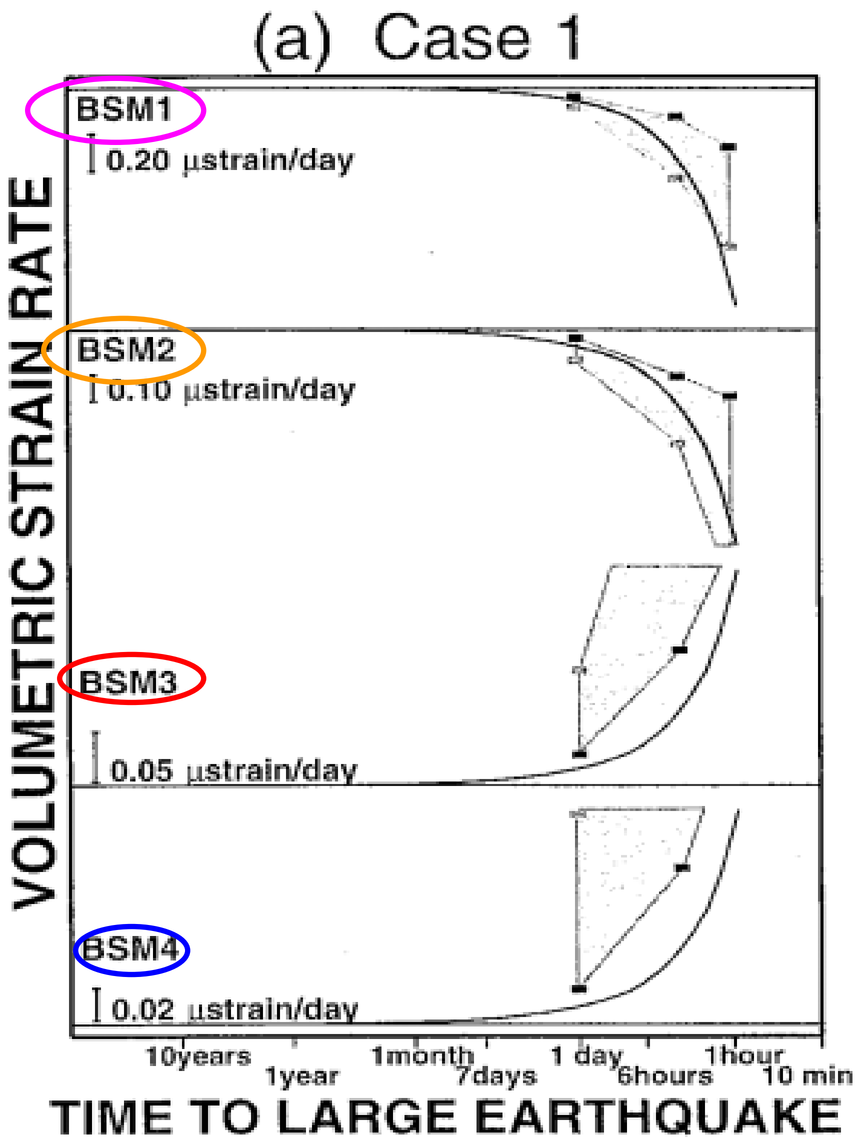
Model for preseismic sliding at the Tokai seismic gap



Back slip distribution estimated from GPS data by Sagiya (1999)

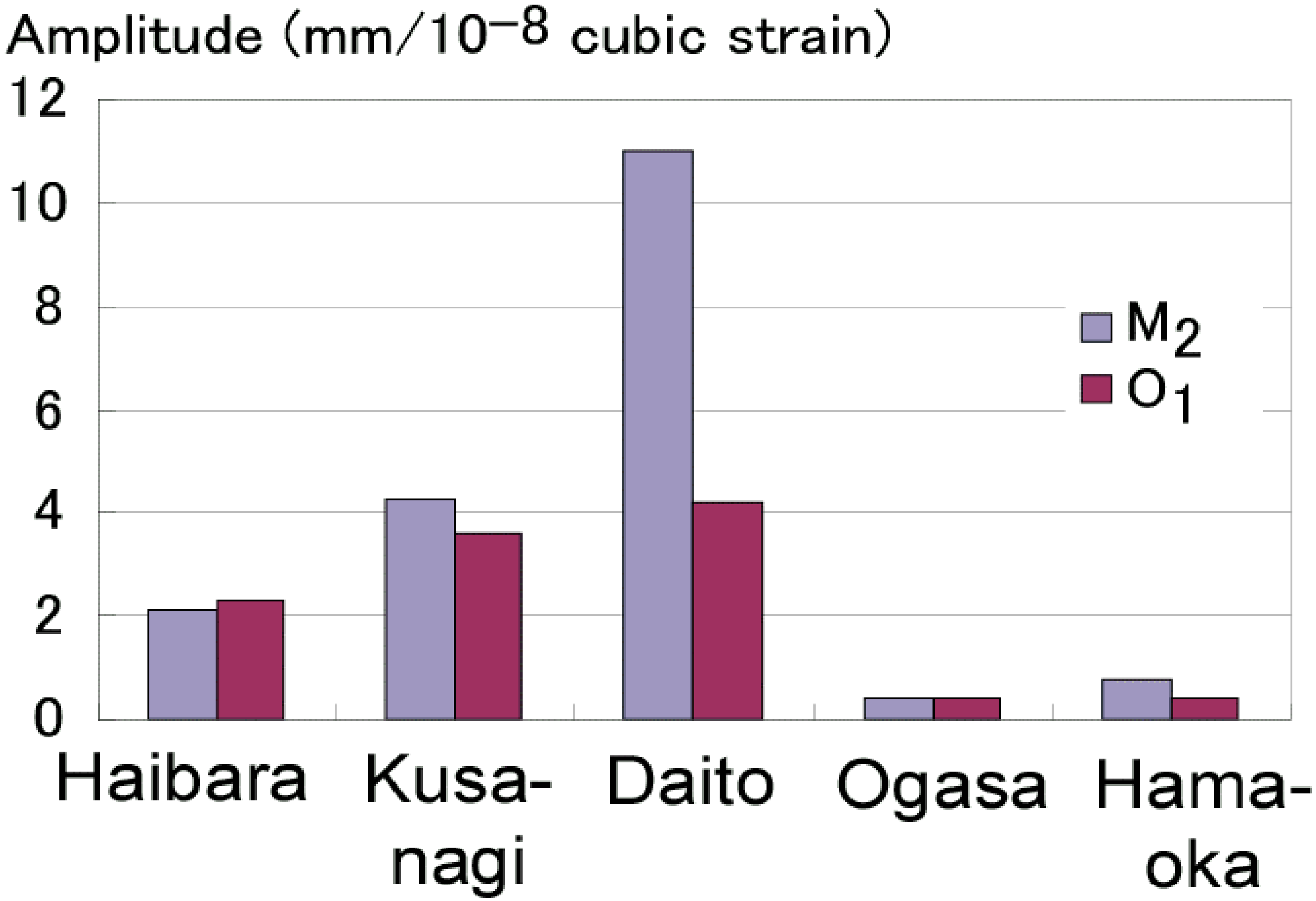


2-D model for the Tokai earthquake
Kato and Hirasawa (1999)



Kato and Hirasawa (1999)

Tidal response in groundwater level



Smaller amplitude is used as a tidal response of the site.

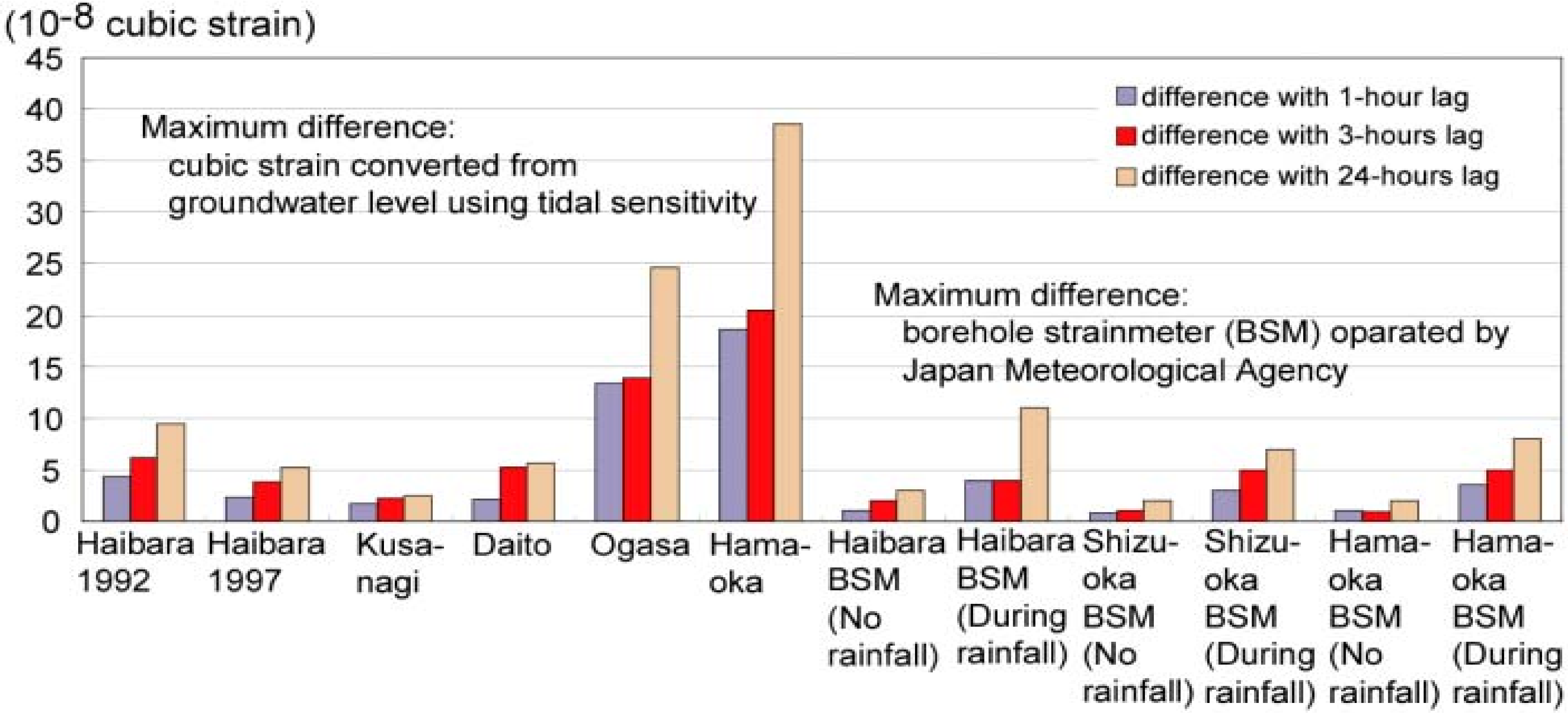
“Maximum value of noise component”

difference (mm)	Number
x < −6	0
−6 < x < −4	1
−4 < x < −2	99
−2 < x < 0	2150
0 < x < 2	2013
2 < x < 4	119
4 < x < 6	2
6 < x < 8	1
8 < x	0

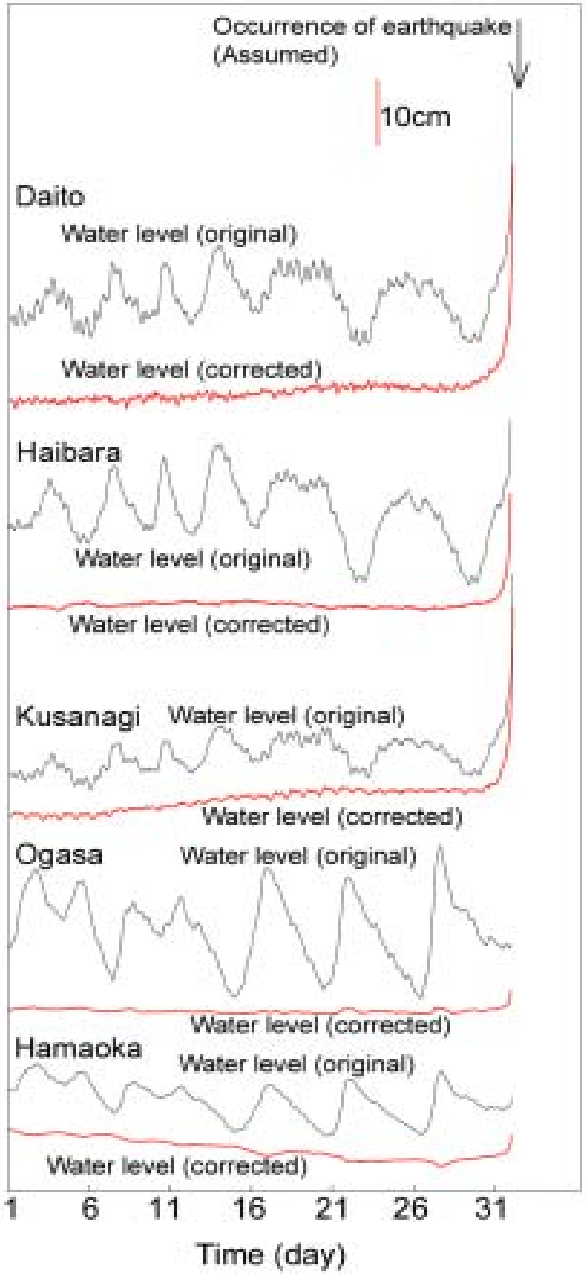
Difference with data of 1-hour lag at Kusanagi well from Oct., 1999 to March, 2000.

- Take difference with data of 1-hour, 3-hours and 24-hours lag.
- Get maximum absolute value for each difference.
- In this case, 6.0 mm is the maximum value (standard deviation is 1.0 mm)

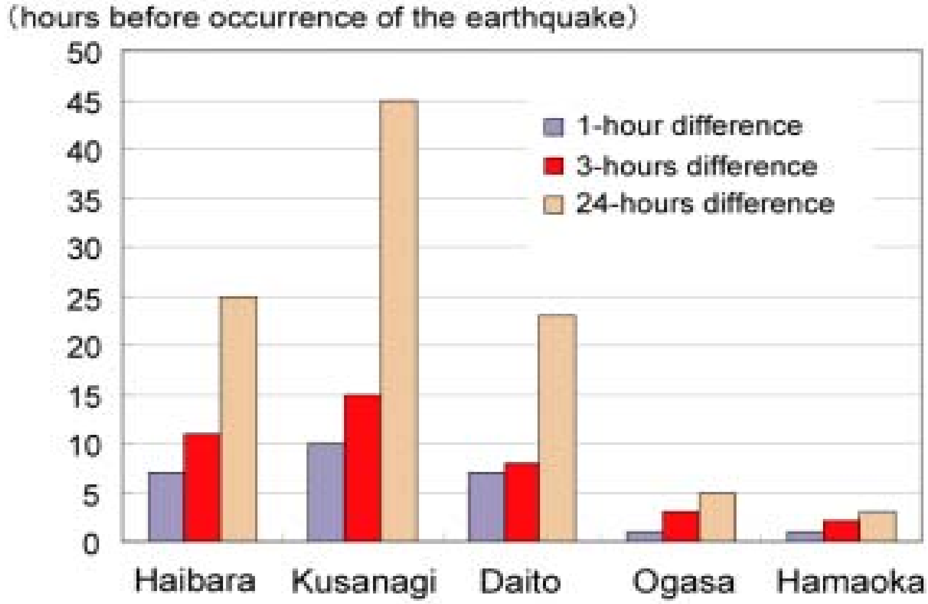
Maximum difference – comparison groundwater levels with borehole strainmeters



Detectivity of preseismic sliding using groundwater levels

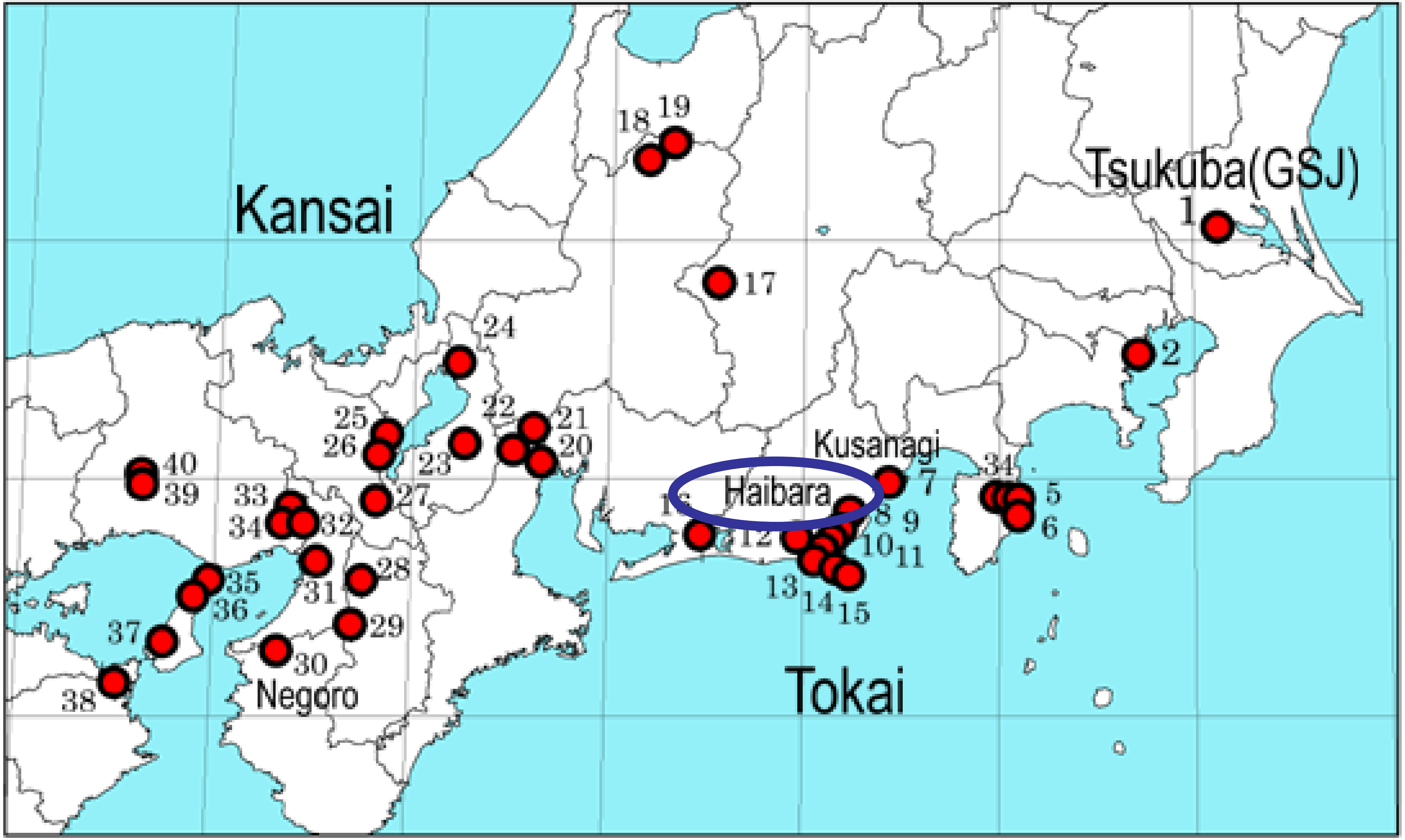


We assume M6 preseismic sliding started three days before the mainshock at 10 km depth under each well.

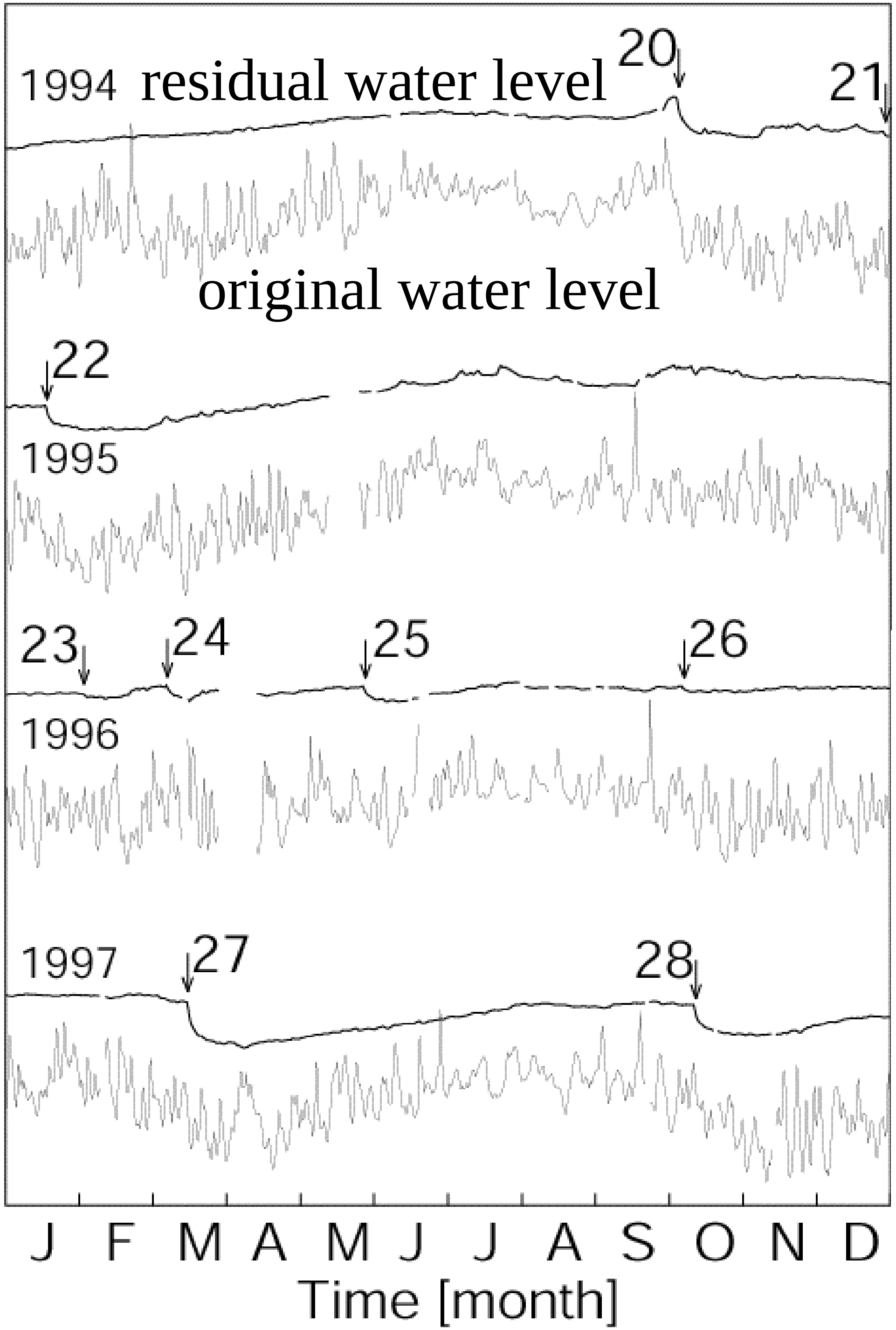


We can observe anomalous groundwater level data associated with the preseismic sliding 1 - 45 hours before the mainshock.

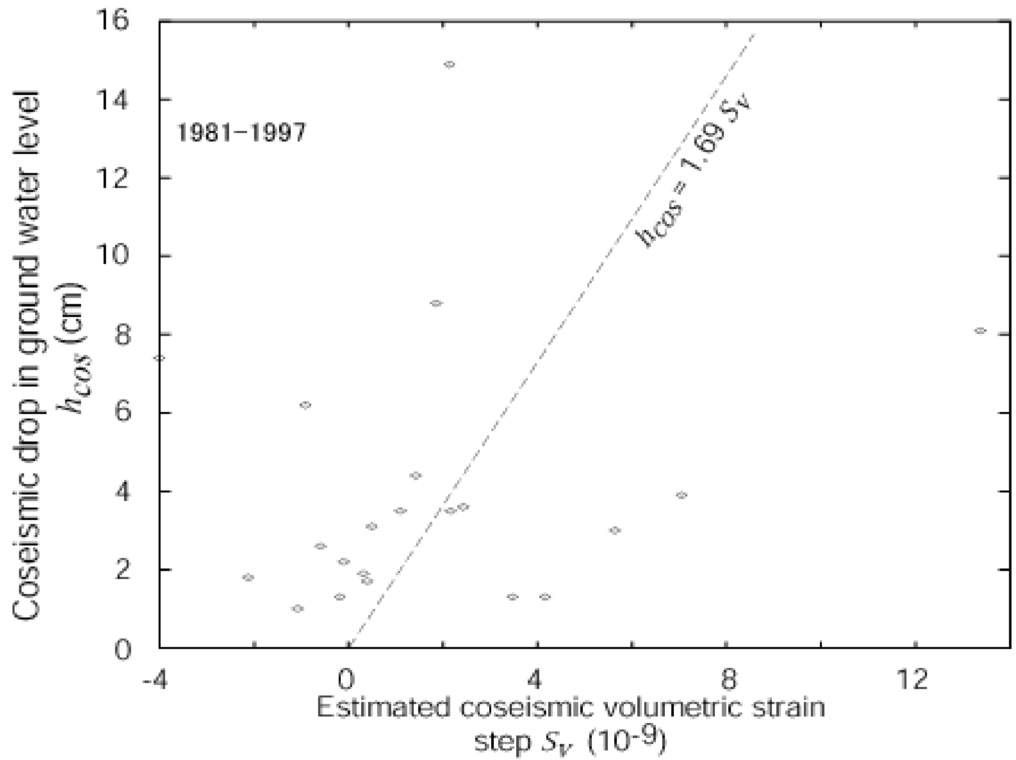
Coseismic changes in water level vs. volumetric strain?

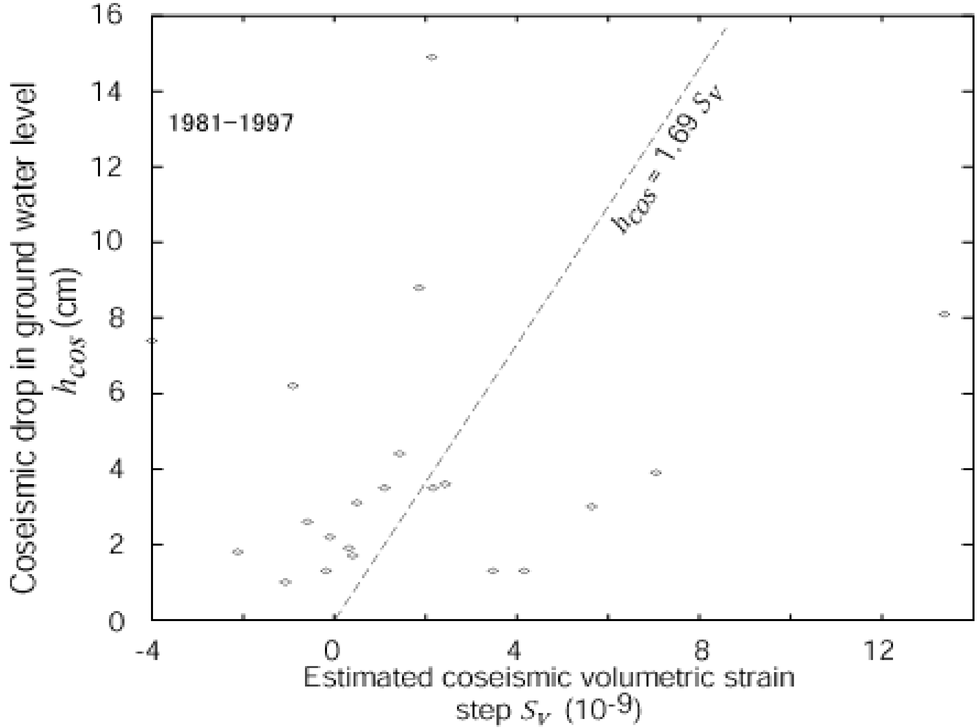


Water-level in the Haibara well



- 28 coseismic changes in 16 years
- Poor relationship between coseismic water level and strain change





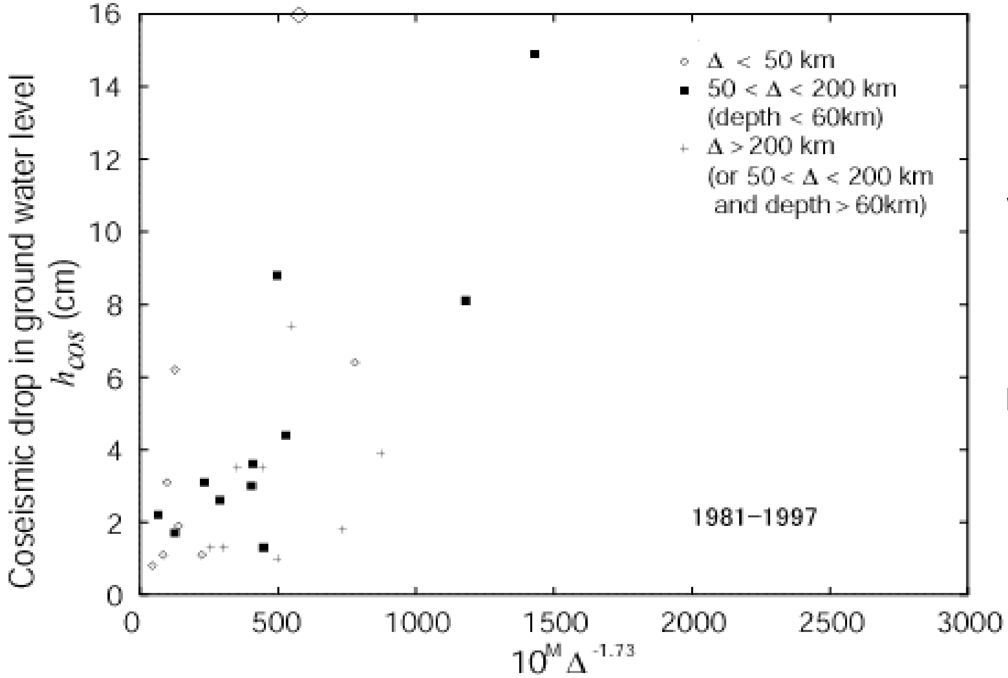
- (water level change)

  = 1.69 x (vol. strain change)

  by using coseismic changes.
- (water level change)

  = 0.02 x (vol. strain change)

  by using tidal response.
- 33% of estimated coseismic volumetric-strain step are contraction.



Water level vs. estimated vertical ground motion ($10^{M}\Delta^{-1.73}$)

- Better relationship than water level vs. volumetric strain

Possible mechanisms of changes in water level

- Volumetric strain
- Shaking-induced dilatancy
- Mobilization of bubble gas
- Fracture of impermeable fault
- Unknown reason?

Mechanism of coseismic changes in water level

- Mechanism of preseismic water level change

Mechanism of coseismic changes in water level

- Mechanism of preseismic water level change

Mechanism of coseismic pore-pressure changes

Mechanism of coseismic changes in water level

- Mechanism of preseismic water level change

Mechanism of coseismic pore-pressure changes

  - Triggered seismicity
  - Aftershock

CONCLUSION

- We established 40 observation wells in confined aquifer. We detect water level change before earthquake swarms related to volumetric changes. We also estimate water-level change related to preseismic sliding before the anticipated Tokai earthquake.

- However, we observed coseismic changes poorly related to strain change. We described possible mechanisms of the coseismic change. We need to know the mechanism not only for investigating preseismic water-level changes but also for triggered seismicity and aftershock.