Evaluation of coseismic groundwater changes caused by the 2003 Tokachi-oki earthquake

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RELATIONSHIP AMONG 3 PRESENTATIONS OF Drs. KATO, MATSUMOTO AND ME

Establishment of Hydrological Method for Prediction (Dr. Matsumoto)

Poro-Elastic Theory

Physical Basis (Model) for Prediction of Great Interplate Earthquakes (Dr. Kato)

Application to the 2003 Tokachi-Oki Earthquake (Koizumi)
COOPERATION BETWEEN TAIWAN AND JAPAN

ESTABLISHMENT OF HYDROLOGICAL METHOD FOR PREDICTION

APPLICATION AND RESEARCH IN TAIWAN (DPRC, WRA)

PHYSICAL BASIS (MODEL) FOR PREDICTION OF GREAT INTERPLATE EARTHQUAKES
CONTENTS

1. OUTLINE OF THE HYDROLOGICAL CHANGES RELATED TO THE 2003 TOKACHI-OKI EARTHQUAKE

2. EVALUATION OF THE PRESEISMIC GROUNDWATER CHANGE

3. EVALUATION OF THE COSEISMIC GROUNDWATER CHANGE

PURPOSE

1. EVALUATION OF THE PORO-ELASTIC MODEL USED IN OUT HYDROLOGICAL METHOD FOR EARTHQUAKE PREDICTION

2. EVALUATION FOR LONG-TERM GROUNDWATER MOVEMENT FOR GEOLOGICAL DISPOSAL OF NUCLEAR WASTE
The Tokachi-oki earthquake in 2003
(M 8.0, 26 September, 2003)

Missing peoples: 2
Injured peoples: 847
Damage: 27 billion yen
1) OUTLINE OF THE 2003 TOKACHI-OKI EARTHQUAKE

Typical inter-plate thrust earthquake

DIP=23 degree
SLIP=4.84m
Mw = 8

(GSI, 2003)
Observed groundwaters in Hokkaido: **32, confined.** Screened depths: **24-1488m**, Most of them > **100m**
2) PRESEISMIC CHANGE

EXAMPLES OF THE LONG-TERM GROUNDWATER LEVEL CHANGES

- NO PRESEISMIC CHANGE
- CLEAR COSEISIC CHANGE

Graphs showing ground water level changes over time.
29 of the 32 coseismic changes can be explained by poro-elastic responses to the coseismic static volumetric strain changes.
Coseismic changes were also detected at 10 of the 42 wells in Honshu. 7 changes can be explained by the poro-elastic responses.
WHY IS THE COSEISMIC CHANGES IN HOKKAIDO EXPLAINED WELL BY STATIC VOLUMETRIC STRAIN CHANGES?

TWO MAIN FACTORS OF HYDROLOGICAL COSEISMIC CHANGES

- STATIC VOLUMETRIC STRAIN CHANGE
- SEISMIC WAVE (INTENSITY)
- Liquefaction
- Permeability Enhancement

UNCONFINED (SHALLOW) GROUNDWATER: X

CONFINED (DEEP) GROUNDWATER: ○

ATTENUATION: LARGER

NEAR-FIELD DEEP and CONFINED GROUNDWATER IS SENSITIVE TO COSEISMIC VOLUMETRIC STRAIN CHANGE.
Comparison of coseismic response to the 1952 Tokachi-oki earthquake with that to the 2003 Tokachi-oki earthquake.
2-2) COSEISMIC CHANGE (AMPLITUDE)

FOR CHECKING THE AMPLITUDES IN COSEISMIC CHANGES

OBSERVED TIDAL GROUNDWATER LEVEL CHANGE

THEORETICAL TIDAL STRAIN CHANGE

STRAIN SENSITIVITY OF THE GROUNDWATER LEVEL

THEORETICAL COSEISMIC STRAIN CHANGE FROM THE FAULT MODEL

PREDICTED COSEISMIC GROUNDWATER LEVEL CHANGE BASED ON PORO-ELASTIC THEORY

OBSERVED COSEISMIC GROUNDWATER LEVEL CHANGE

COMPARISON
2-2) COSEISMIC CHANGE (AMPLITUDE)

HOKKAIDO (7/29)
2-2) COSEISMIC CHANGE (AMPLITUDE)

Y: OBSERVED COSEISMIC GROUNDWATER LEVEL CHANGE

X: PREDICTED COSEISMIC GROUNDWATER LEVEL CHANGE (mm)

DETECTION LIMIT

HOKKAIDO

HONSHU

X: PREDICTED COSEISMIC GROUNDWATER LEVEL CHANGE (mm)

Y = 10X

Y = X

Y = 0.1X
2-2) COSEISMIC CHANGE (AMPLITUDE)

X: PREDICTED COSEISMIC GROUNDWATER LEVEL CHANGE (mm)

Y: OBSERVED COSEISMIC GROUNDWATER LEVEL CHANGE (mm)

Water level changes:
- Increase
- Decrease

Detection Limit

HOKKAIDO

HONSHU

DT1

DT2

OB1

YN

SR1

SP2

SP1

OBK2

TKB3

KNM

OBK1

KWN-O

TNN

Y = X

Y = 0.1X

Y = 10X

Detection Limit

A: Theoretical groundwater level change (mm)
Positions of the Five Wells, Four Large Earthquakes (Mw > 7.5) in 1993–1994 and the 2003 Tokachi-oki Earthquake
Coseismic strain steps vs groundwater level changes in the 5 wells after the 5 large earthquakes.
Coseismic strain steps vs groundwater level changes in the 5 wells after the 5 large earthquakes.
## COMPARISON OF WELL STRUCTURES IN SP1 AND SP2

<table>
<thead>
<tr>
<th>Well Name</th>
<th>Screened Depth (m)</th>
<th>gwl Change</th>
<th>Strain (10^-8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP1</td>
<td>288-310</td>
<td>-6</td>
<td>53.2</td>
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<tr>
<td></td>
<td>354-376</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SP2</td>
<td>539-594</td>
<td>-16</td>
<td>53.2</td>
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</table>

**2-2) COSEISMIC CHANGE (AMPLITUDE)**
### COMPARISON OF WELL STRUCTURES IN OB1 AND OB4

<table>
<thead>
<tr>
<th>well name</th>
<th>Screened Depth (m)</th>
<th>gwl change (cm)</th>
<th>strain (10-8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OB1</td>
<td>950-1060</td>
<td>130</td>
<td>191</td>
</tr>
<tr>
<td>OB4</td>
<td>1235-1400</td>
<td>430</td>
<td>170</td>
</tr>
</tbody>
</table>

SOME POSSIBILITY OF MIXING SHALLOW GROUNDWATERS
CONCLUSION

1. EVALUATION OF THE PRESEISMIC GROUNDWATER CHANGE

NEITHER GROUNDWATER CHANGE NOR CRUSTAL DEFORMATION RELATED TO THE PRESLIP (PRESEISMIC SLIDING)

THERE WAS NO PRESLIP (Mw>6) IN THE FOCAL REGION OF THE 2003 TOKACHI-OKI EARTHQUAKE.
2. EVALUATION OF THE COSEISIMIC GROUNDWATER CHANGE

2-1 SIGNS OF THE COSEISMIC CHANGES

There are well explained by volumetric strain changes and poro-elastic theory.

It is probably because they are near-field deep confined groundwater responses to the earthquake.

2-2 AMPLITUDES OF THE COSEISMIC CHANGES

Some well-waters show simple poro-elastic responses. But the reason or condition for it is not clear.
THANK YOU FOR YOUR INTEREST!!

The detailed information

The reprints are placed over there.
2-2) COSEISMIC CHANGE (AMPLITUDE)

Y: OBSERVED DISCHARGE RATE CHANGE L/MIN
X: THEORETICAL DISCHARGE RATE CHANGE L/MIN

DISCHARGE RATE
■: INCREASE
□: DECREASE

Y = 10X
Y = X
Y = 0.1X

DETECTION LIMIT

Geological Survey of Japan, AIST
### All observation wells in OB

<table>
<thead>
<tr>
<th>well name</th>
<th>Screened Depth (m)</th>
<th>gwl change(cm)</th>
<th>strain (10^-8)</th>
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<tbody>
<tr>
<td>OB6</td>
<td>165-193</td>
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<td>190.3</td>
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<td>OB5</td>
<td>560-670</td>
<td>-170</td>
<td>189.8</td>
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<tr>
<td>OB1</td>
<td>950-1060</td>
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<td>OB3</td>
<td>1258-1478</td>
<td>-100</td>
<td>169.6</td>
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<tr>
<td>OB2</td>
<td>1286-1506</td>
<td>-130</td>
<td>172.4</td>
</tr>
</tbody>
</table>

**SOME POSSIBILITY OF MIXING SHALLOW GROUNDWATERS**