Earthquake-related Electromagnetic Study in China

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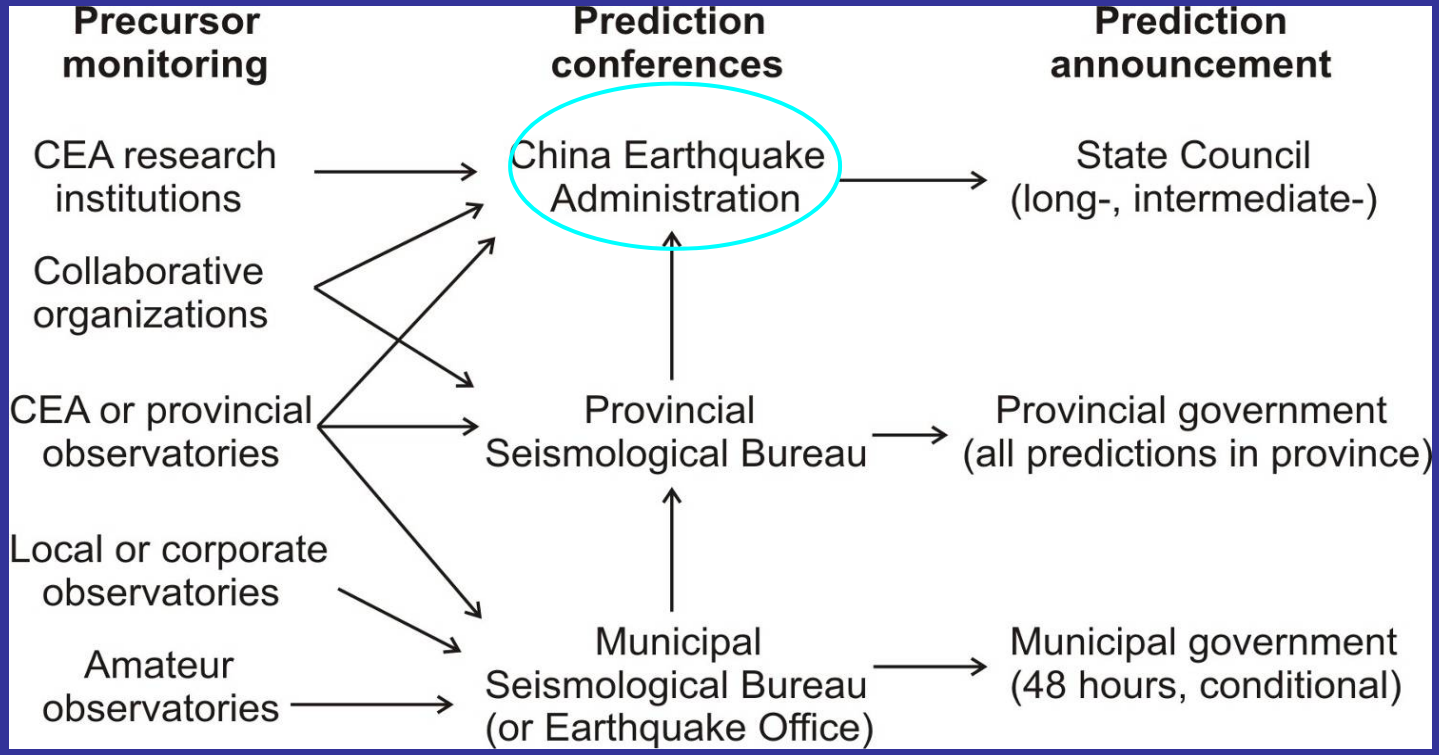
Contents

- Earthquake prediction in China
- Earthquake-related electromagnetics in China
- Future study on earthquake-related electromagnetics

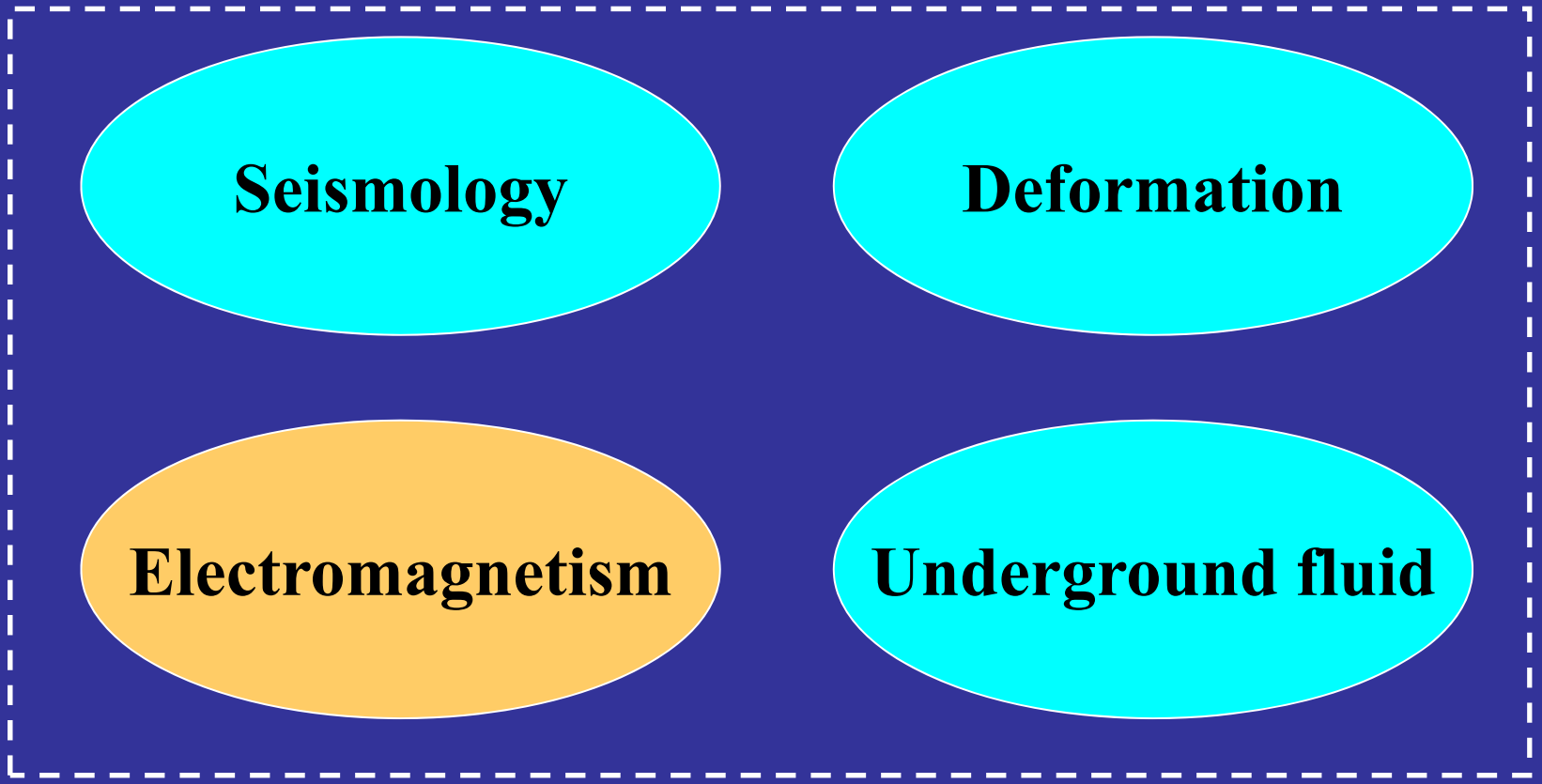
Law of the People's Republic of China on Protecting Against and Mitigating Earthquake Disasters

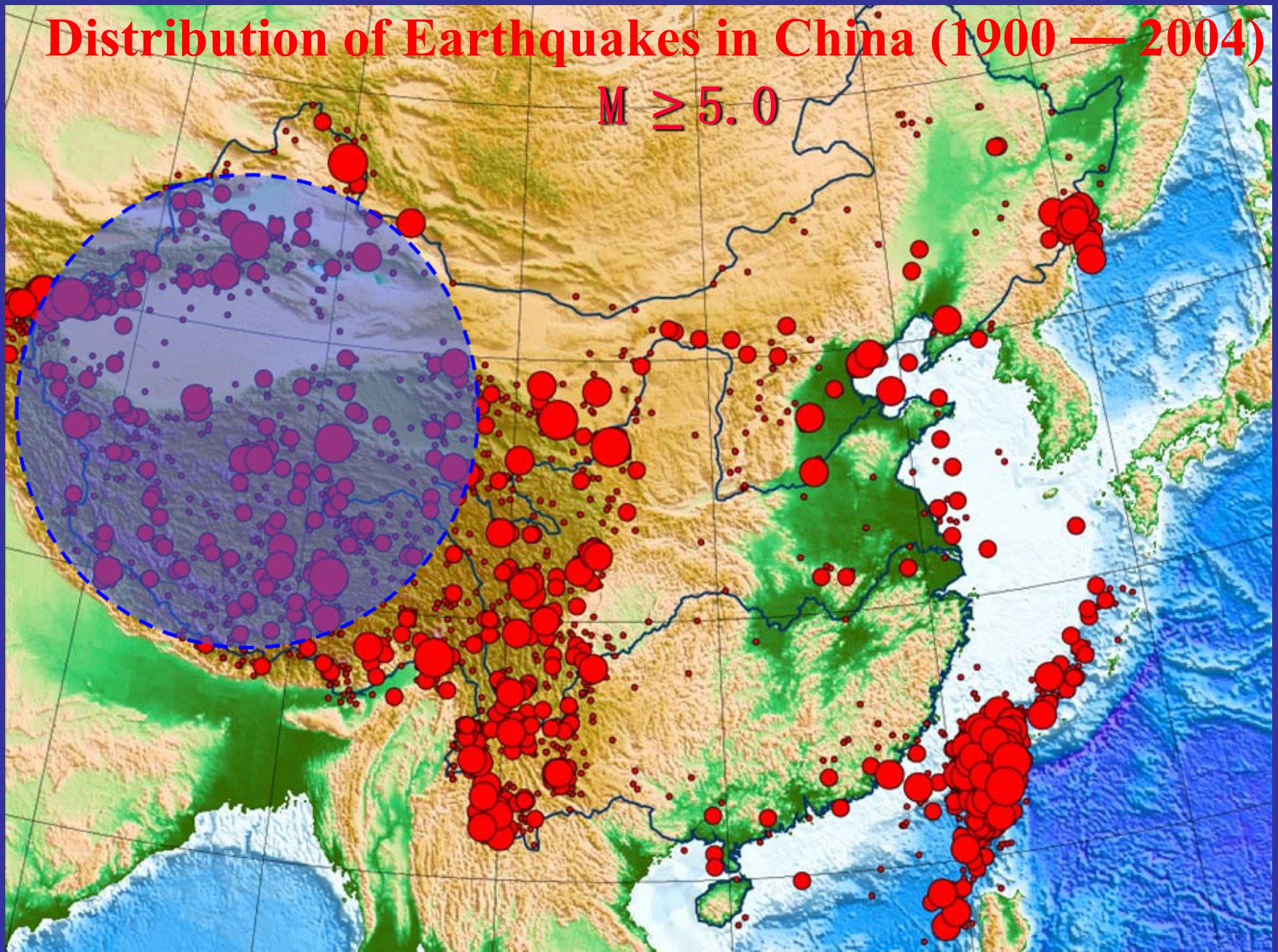
Article 16. The State adopts the practice of unified release of earthquake prediction. Short-term and imminent earthquake prediction shall be released by the people's governments of provinces, autonomous regions and municipalities directly under the Central Government in accordance with the procedures prescribed by the State Council …



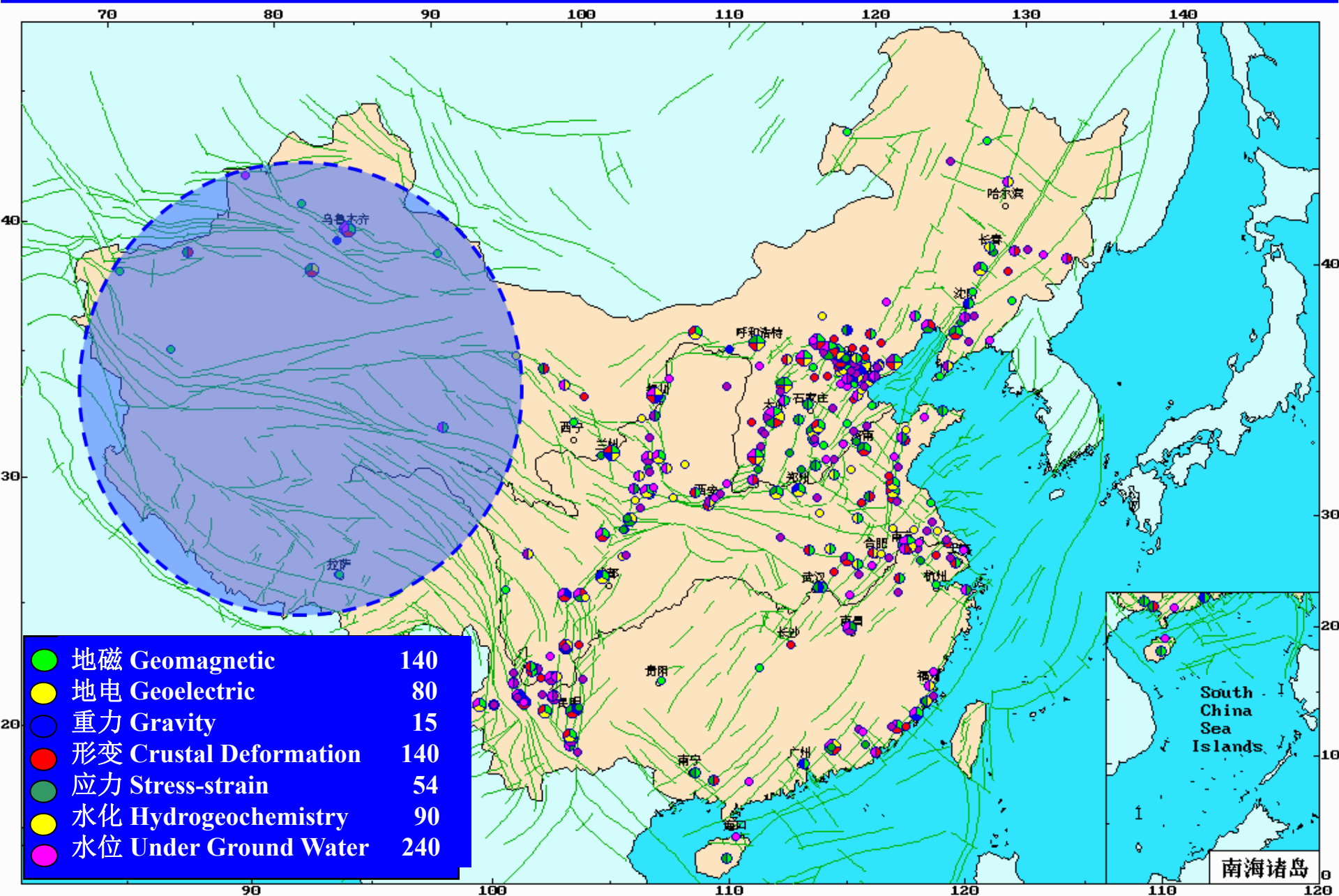
Conrtesy of Qifu Chen and Kelin Wang

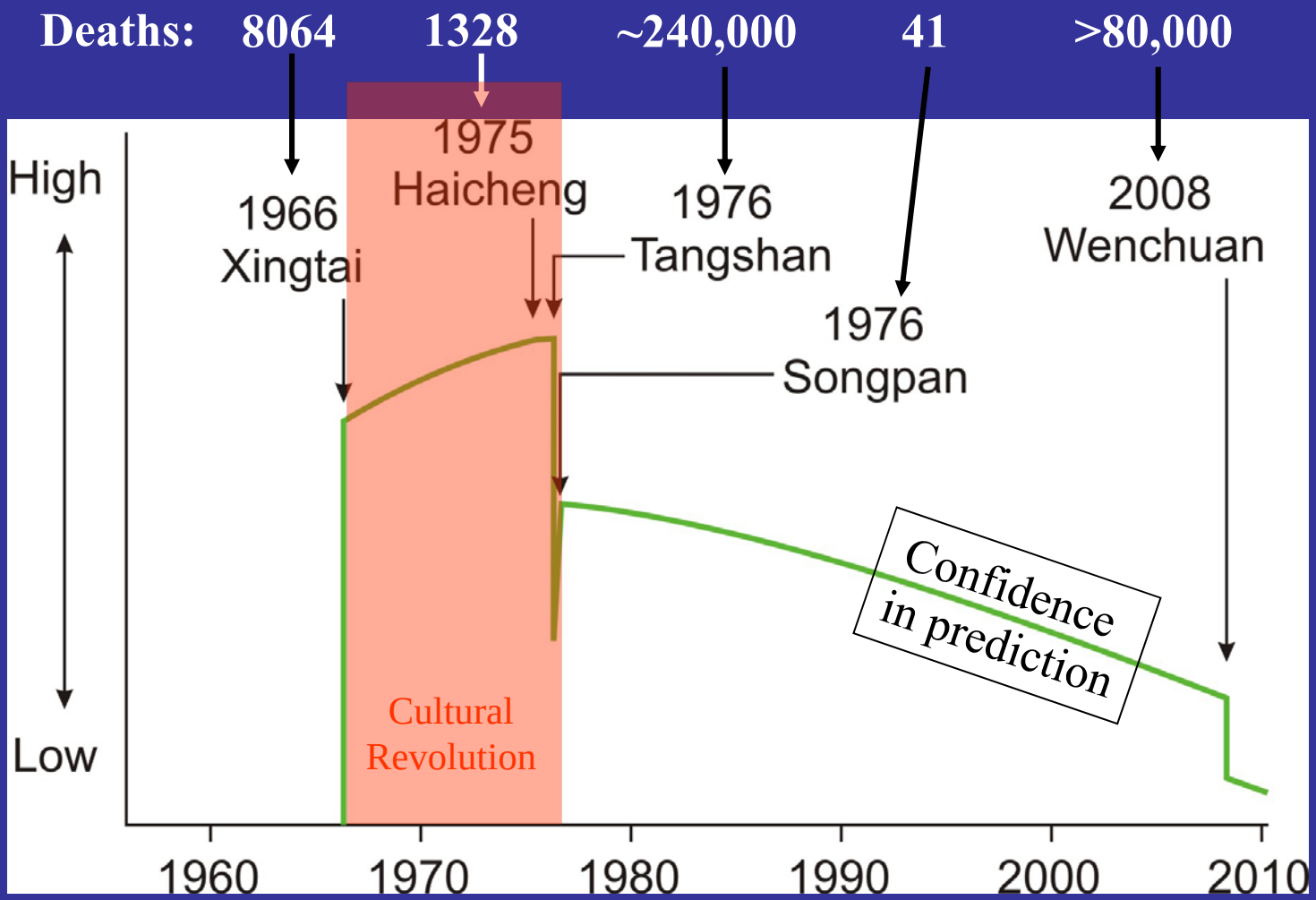
Main precursors monitored by China Earthquake Administration (CEA)




Distribution of Earthquakes in China (1900 — 2004)
M ≥ 5.0

Precursor monitoring network in China





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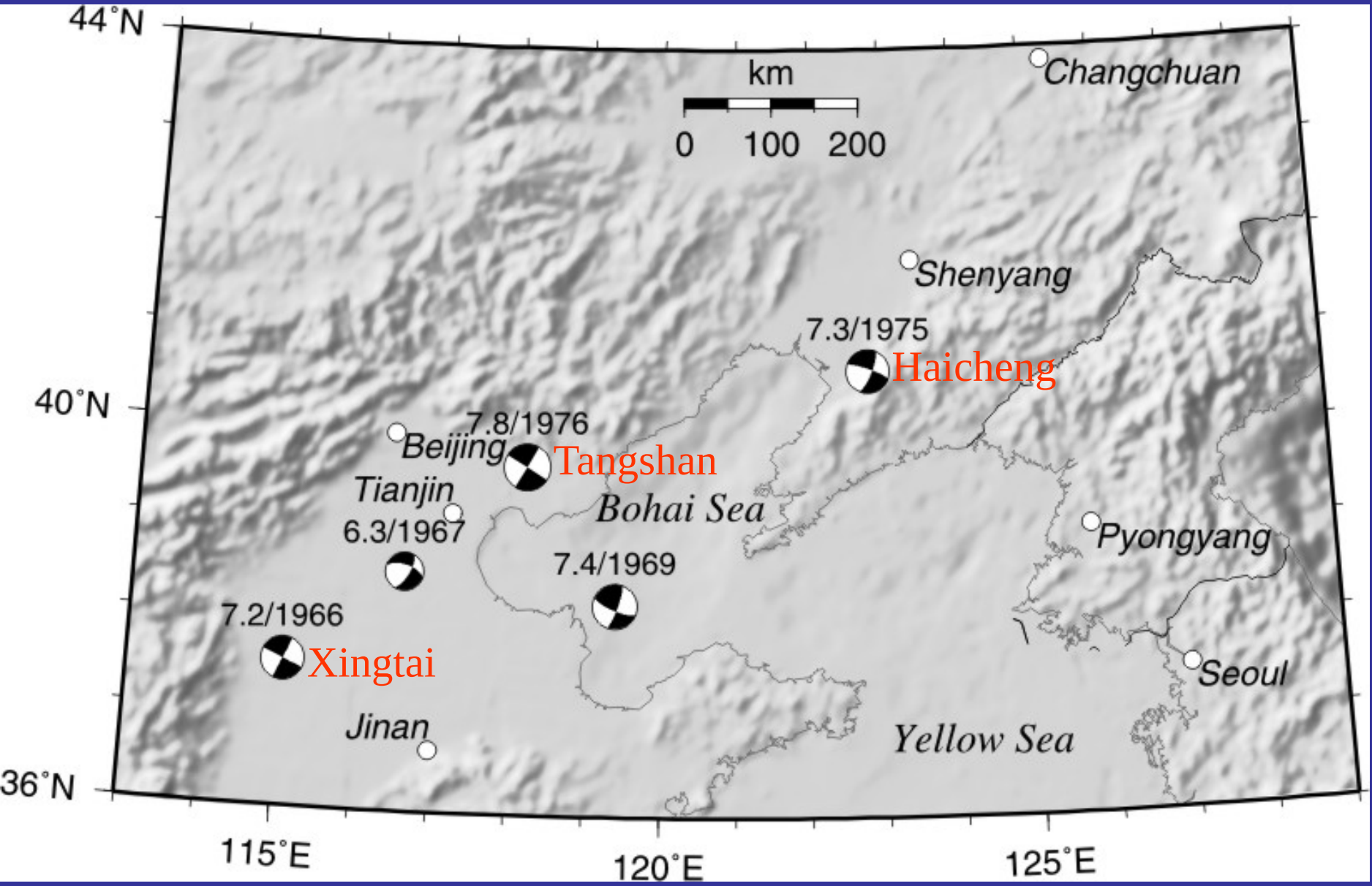
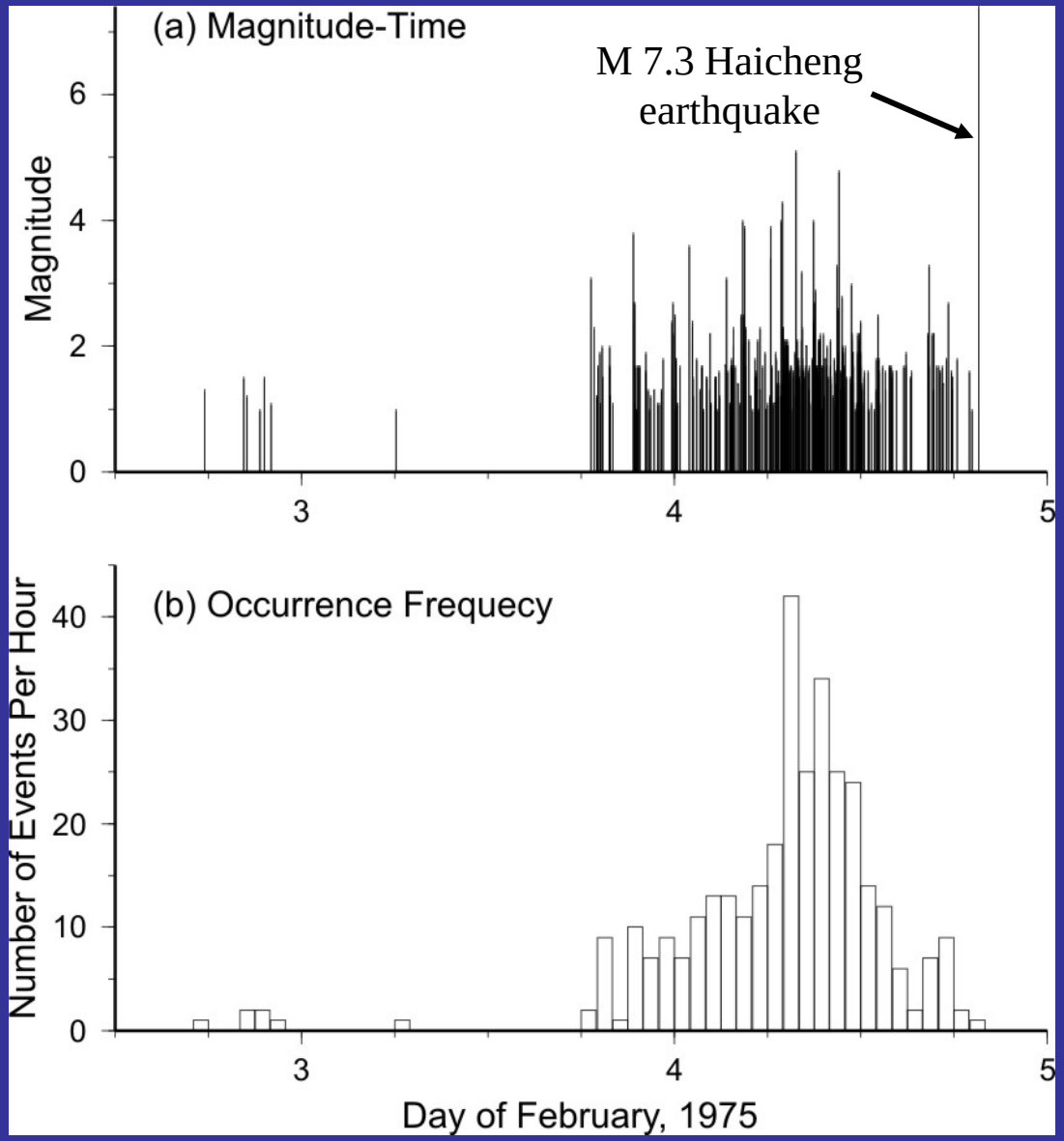


Conrtesy of Qifu Chen and Kelin Wang

Prediction of the 1975 Haicheng earthquake (Ms 7.3)

An unusually pronounced foreshock sequence triggered imminent prediction.

Massive amateur participation had educational effects but made no contribution to prediction.



Conrtesy of Qifu Chen and Kelin Wang

Tangshan (Ms 7.8), 1976, expected seismic intensity VI.
No seismic design was required. Actual intensity in earthquake: XI.

1－4　震前的唐山市路南区建筑鸟瞰。

Bird's eye view of the buildings in Lunan district of Tangshan before the earthquake.

1－3　震后的唐山市路南区，建筑荡然无存，成了一片废墟（11度区）。

No building left in the Lunan district of Tangshan. All the buildings were turned into ruins after the earthquake (in the area of intensity 11).

before earthquake

after earthquake

Conrtesy of Qifu Chen and Kelin Wang

Beichuan, 2008, expected seismic intensity VII.
Seismic design was required. Actual intensity in earthquake: XI.

before earthquake **after earthquake**

Although the seismic design standard was later recognized to be too low, buildings that met the standard generally withstood shaking.

Conrtesy of Qifu Chen and Kelin Wang

Bailu School in Penzhou City. Surface rupture runs between two classroom buildings with ~3 m vertical offset. No one died.

Conrtesy of Qifu Chen and Kelin Wang

Some remarks

- It is presently impractical to rely on prediction to mitigate earthquake disasters. Prediction requires long-term research.
- Improved hazard assessment and seismic design in China from 1976 to 2008 saved numerous lives in the Wenchuan earthquake.
- Poor enforcement of the seismic design code was responsible for many deaths (poorly enforced in many urban areas, not enforced at all in rural areas).

Conrtesy of Qifu Chen and Kelin Wang

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- Earthquake-related electromagnetics in China
- Future study on earthquake-related electromagnetics

Related associations in China

- Committee of Earthquake-related Electromagnetic Research, Seismological Society of China
- Committee of Geo-electromagnetism, Chinese Geophysical Society

Seismo-electromagnetic monitoring in China

Four parameters

(1) apparent resistivity

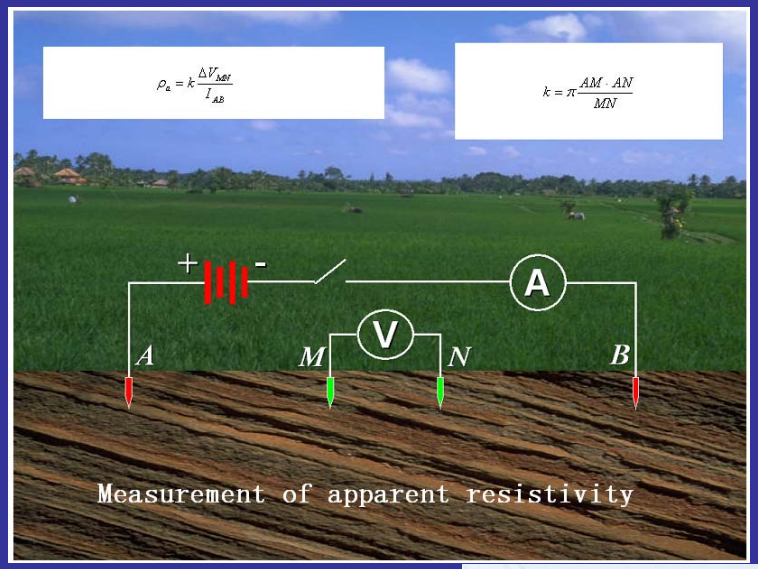
(2) geoelectric field

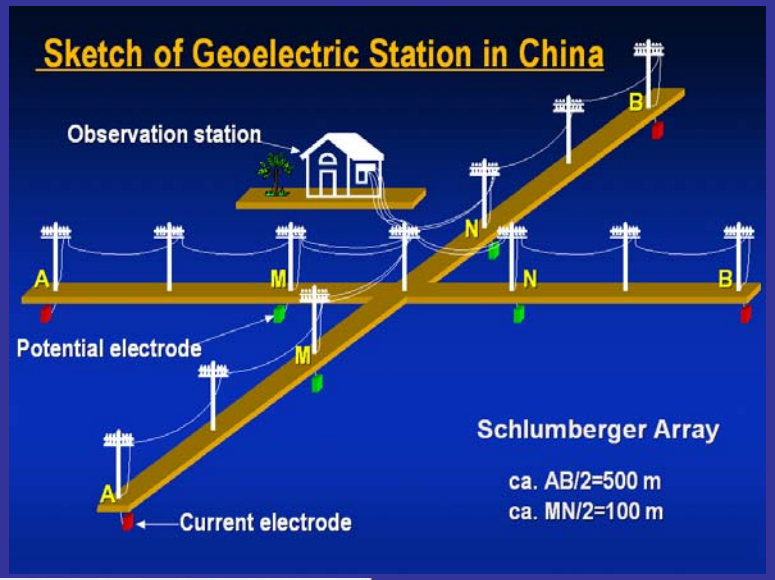
(3) geomagnetic field

(4) electro-magnetic disturbances

Project of Chinese Seismo-Electromagnetic Satellite

Configuration for measuring apparent resistivity





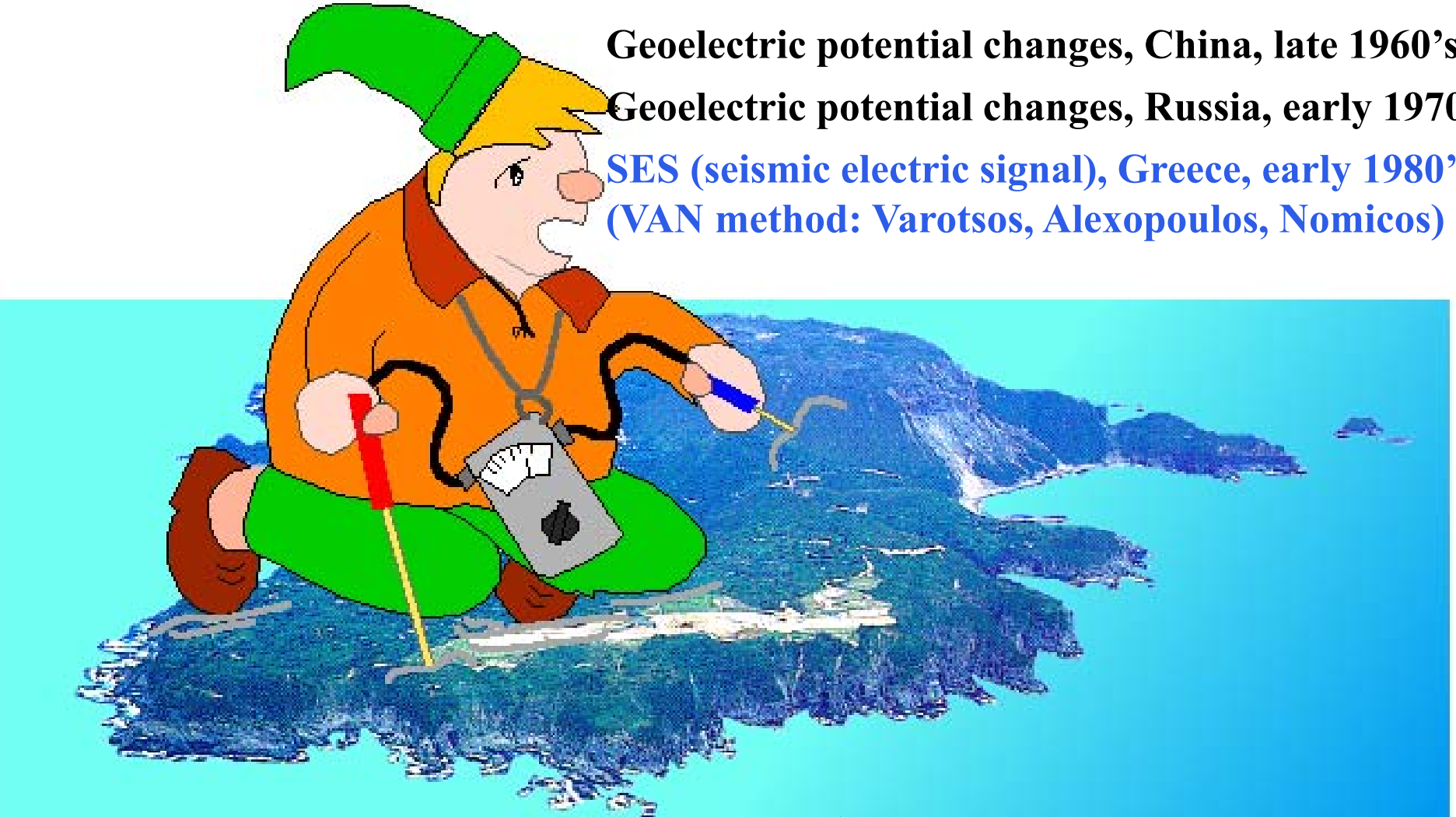
Tengchong Geoelectric Station

Geoelectric potential changes

Geoelectric potential changes, China, late 1960's

Geoelectric potential changes, Russia, early 1970's

SES (seismic electric signal), Greece, early 1980's
(VAN method: Varotsos, Alexopoulos, Nomicos)



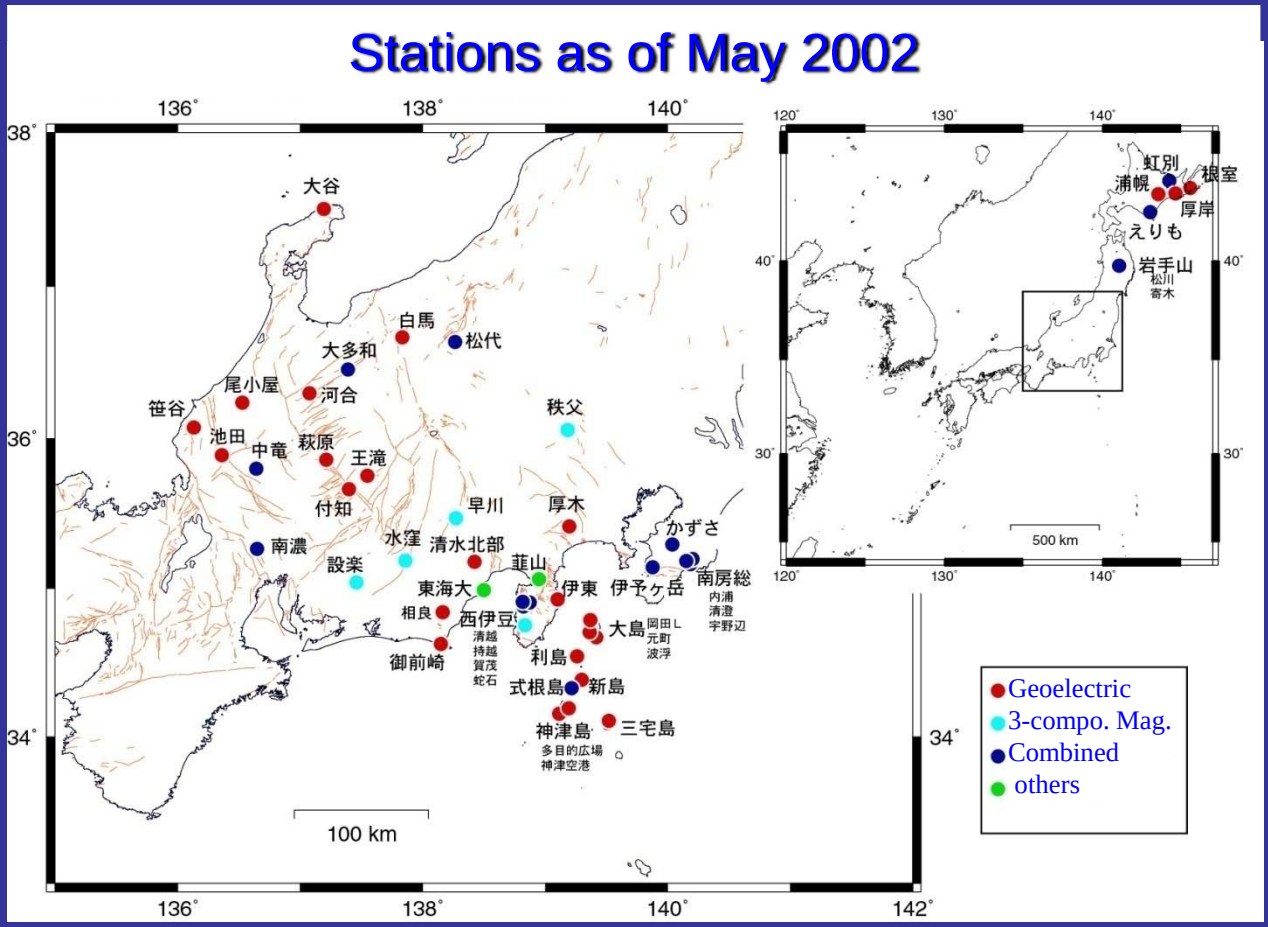
VAN method (Varotsos, Alexopoulos, Nomicos)

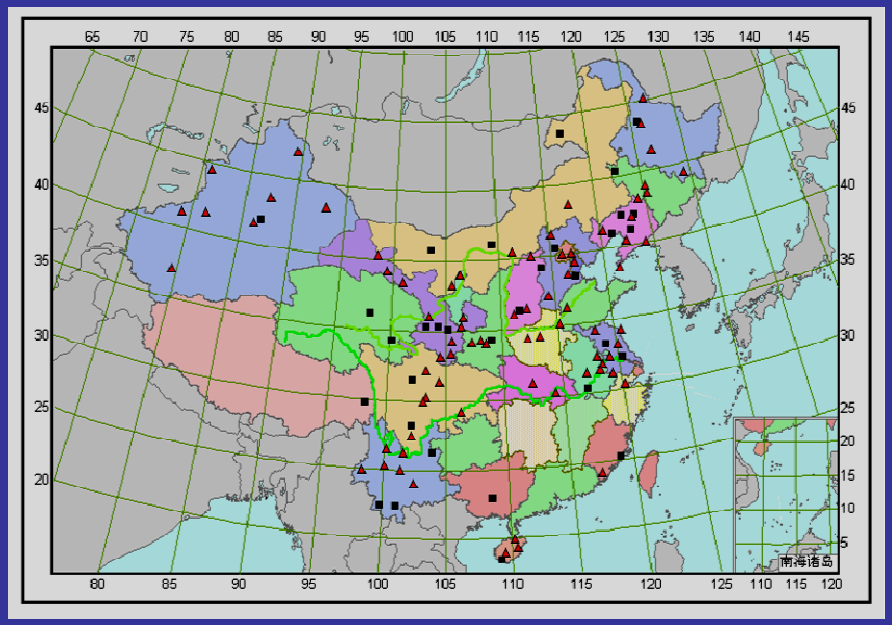
A short-term earthquake prediction method based on seismic electric signal (SES), which is a kind of precursory geoelectric potential changes

Test in Japan: Prof. Seiya Uyeda

International Frontier Research Group on Earthquakes

The Institute of Physical and Chemical Research (RIKEN)

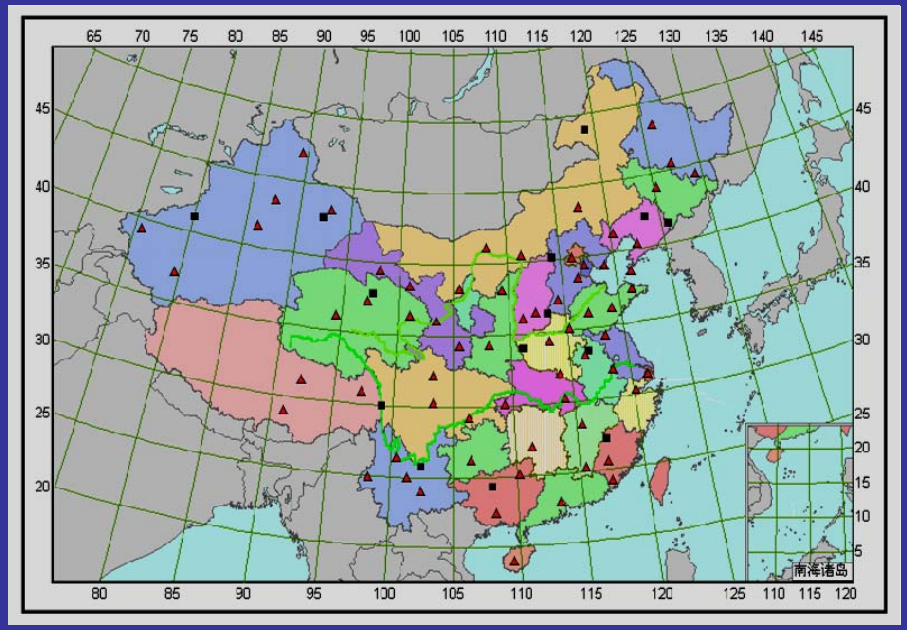




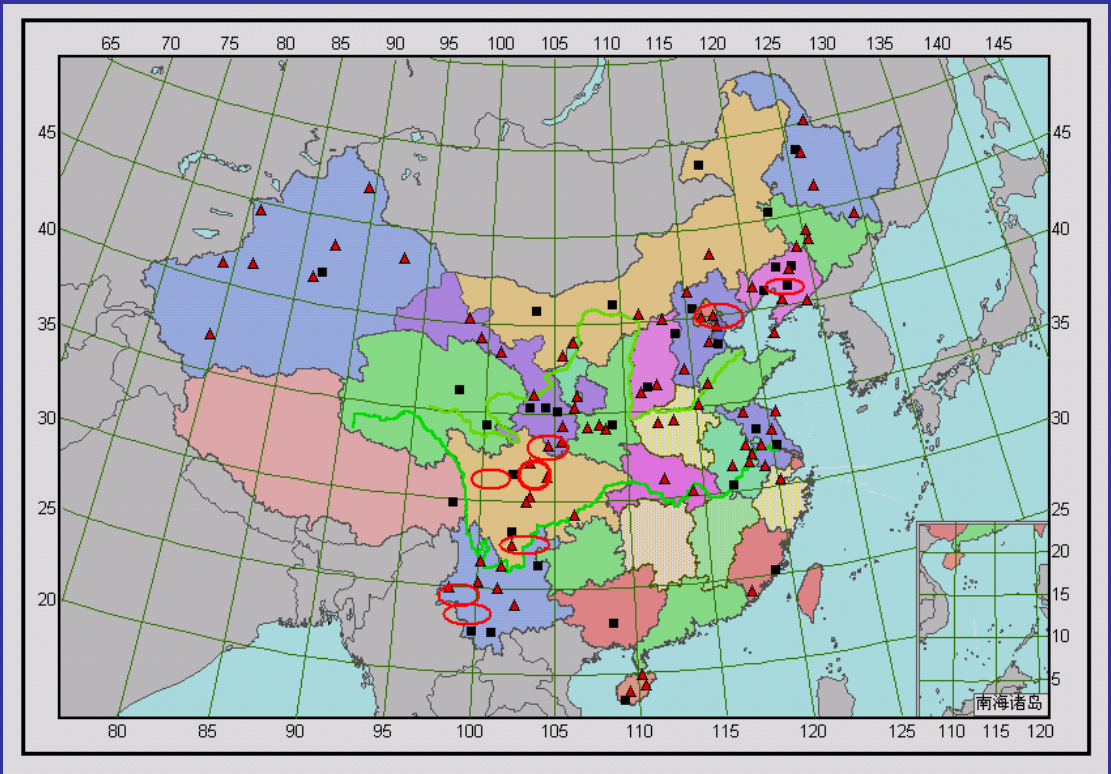
Network of geoelectric observation

(including the stations of apparent resistivity and the stations of geoelectric field)

Network of geomagnetic observation



Case study: **apparent resistivity**

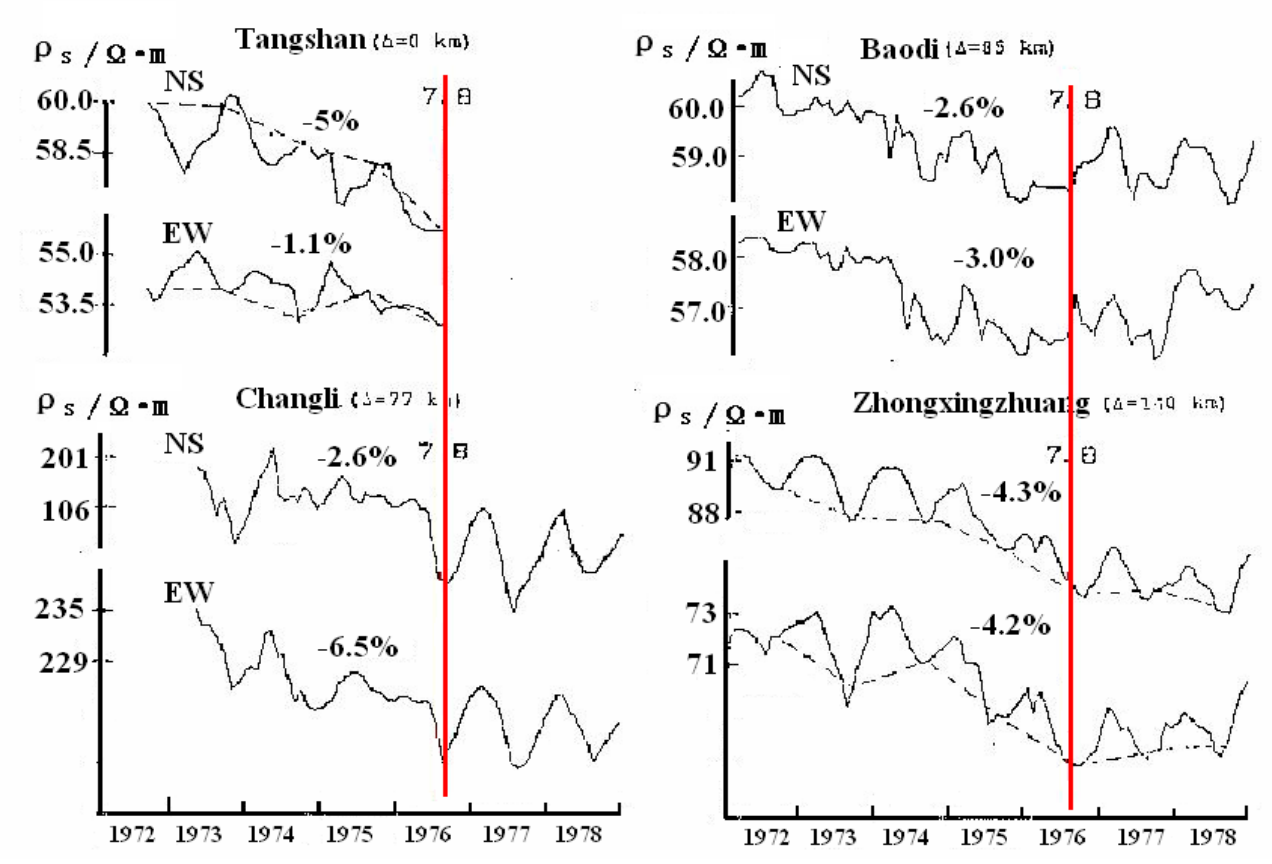


M>7

1973.2.6 四川 炉霍 7.9
1974.5.11 云南 昭通 7.1
1975.2.4 辽宁 海城 7.3
1976.5.29 云南 龙陵 7.5
1976.7.28 河北 唐山 7.8
1976.8.16 四川 松潘 7.2
1988.11.5 云南 澜沧 7.6
2008.5.12 四川 汶川 8.0

Conrtesy of Jiadong Qian

Tangshan M7.8 EQ, 28 July 1976



Conrtesy of Jiadong Qian

Tangshan M7.8 EQ, 28 July 1976

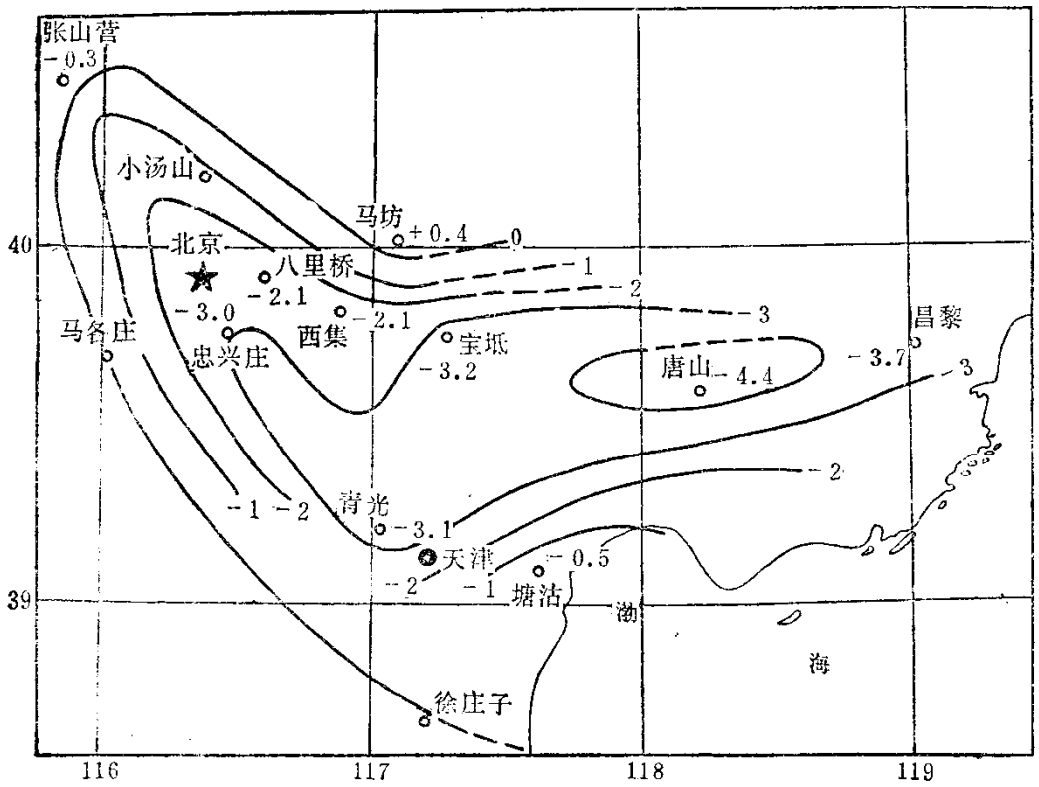
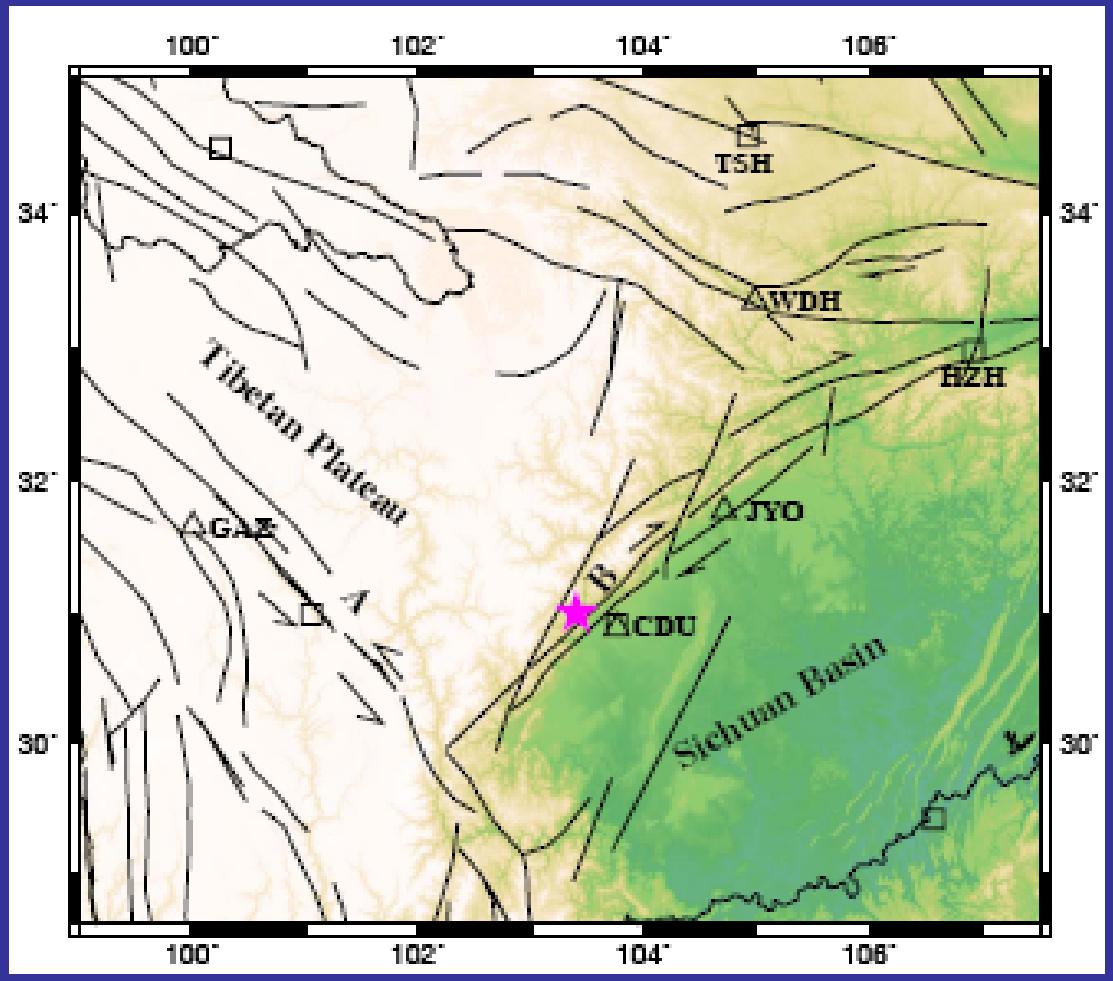


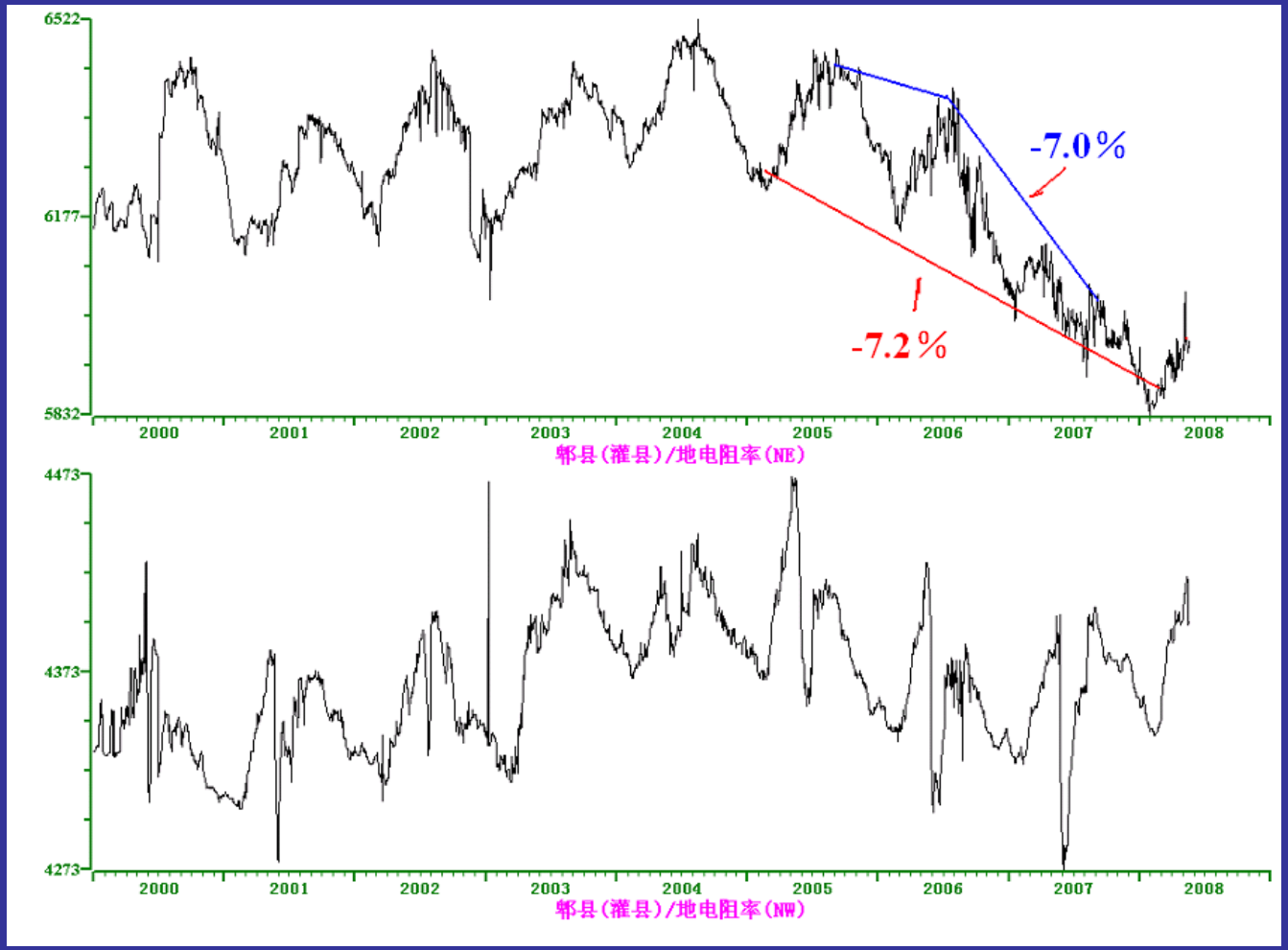
图5.17　京津唐地区南北向地电阻率异常幅度$\Delta\rho_{Sa}/\rho_{Sa}$等值线图

Conrtesy of Jiadong Qian

Wenchuan M8.0 EQ , 12 May 2008

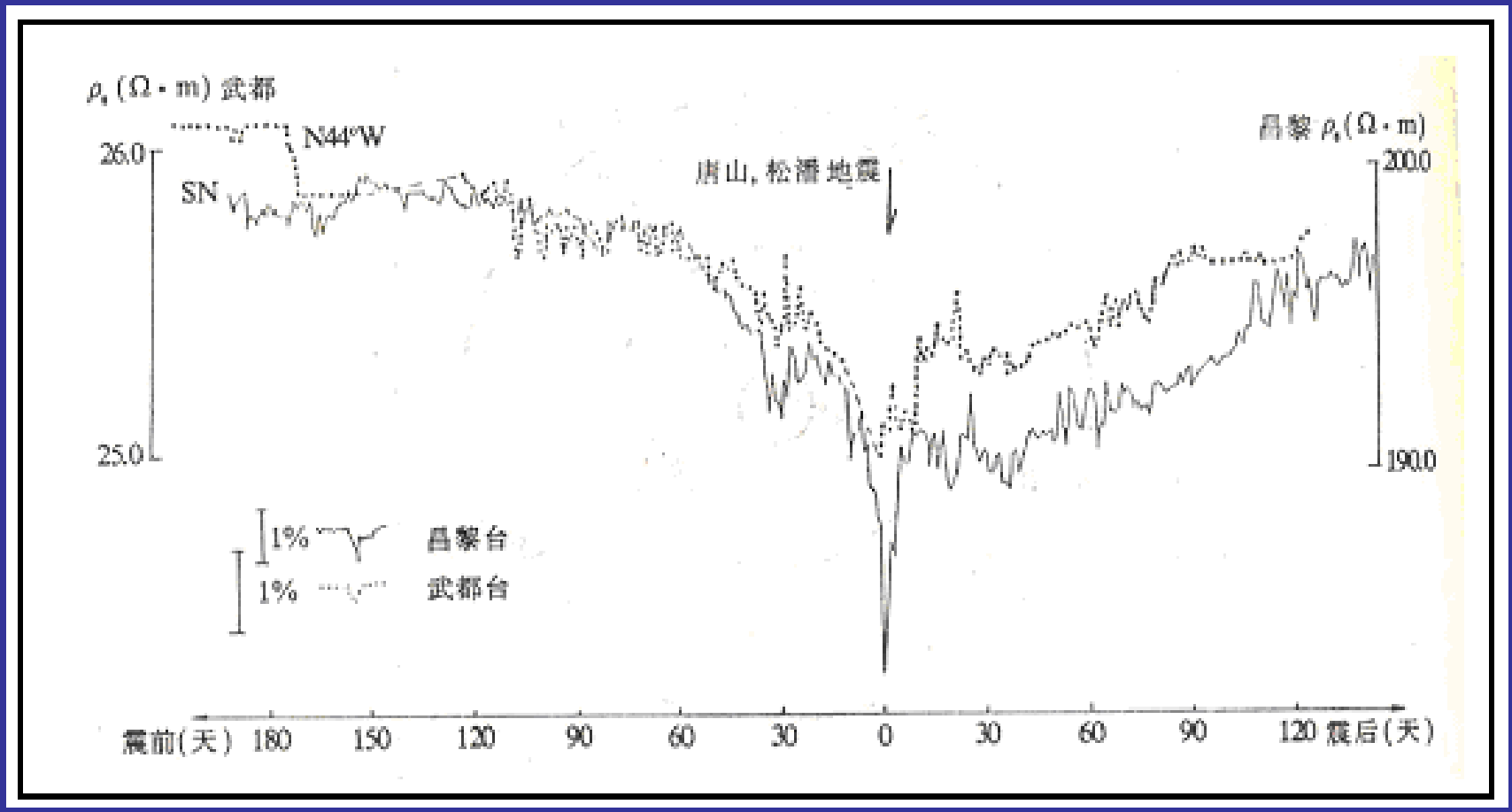


Wenchuan M8.0 EQ , 12 May 2008



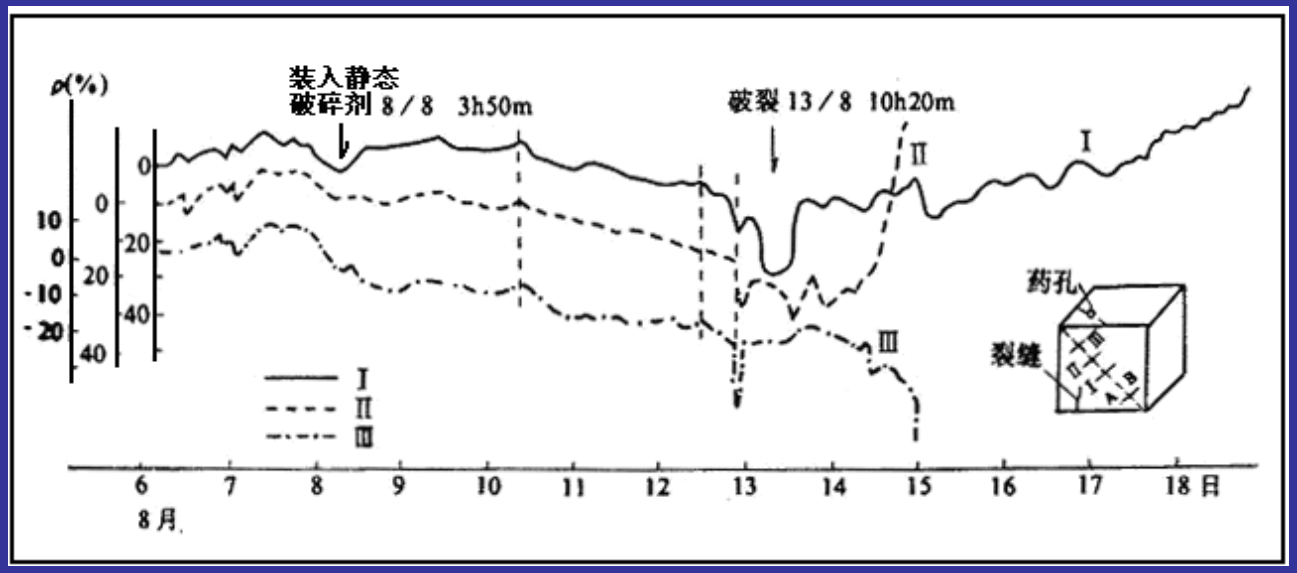
Conrtesy of Jiadong Qian

Similar change pattern of two EQs



Conrtesy of Jiadong Qian

Experiment of large rock sample



Conrtesy of Jiadong Qian

Reports

- Conductivity anomalies (Tan
- Geoelectric potential cha ussia, VAN, IFREQ RIKEN
- Geomagnetic char
- Electromagne n various frequency (DC/ULF-V
- Second a : Ionospheric distu noise, apparatus anomalies (TV n switch on/off)

Existence of EQ-related EM signals

e.g., radio noise b Migawa EQ (M6.8,1945), Tangshan EQ (1978), Kobe EQ (1995)

Study on EQ-related EM

- **Field observations**

  √ Existence of EQ-related EM signals (empirical stage)

- **Lab experiments**

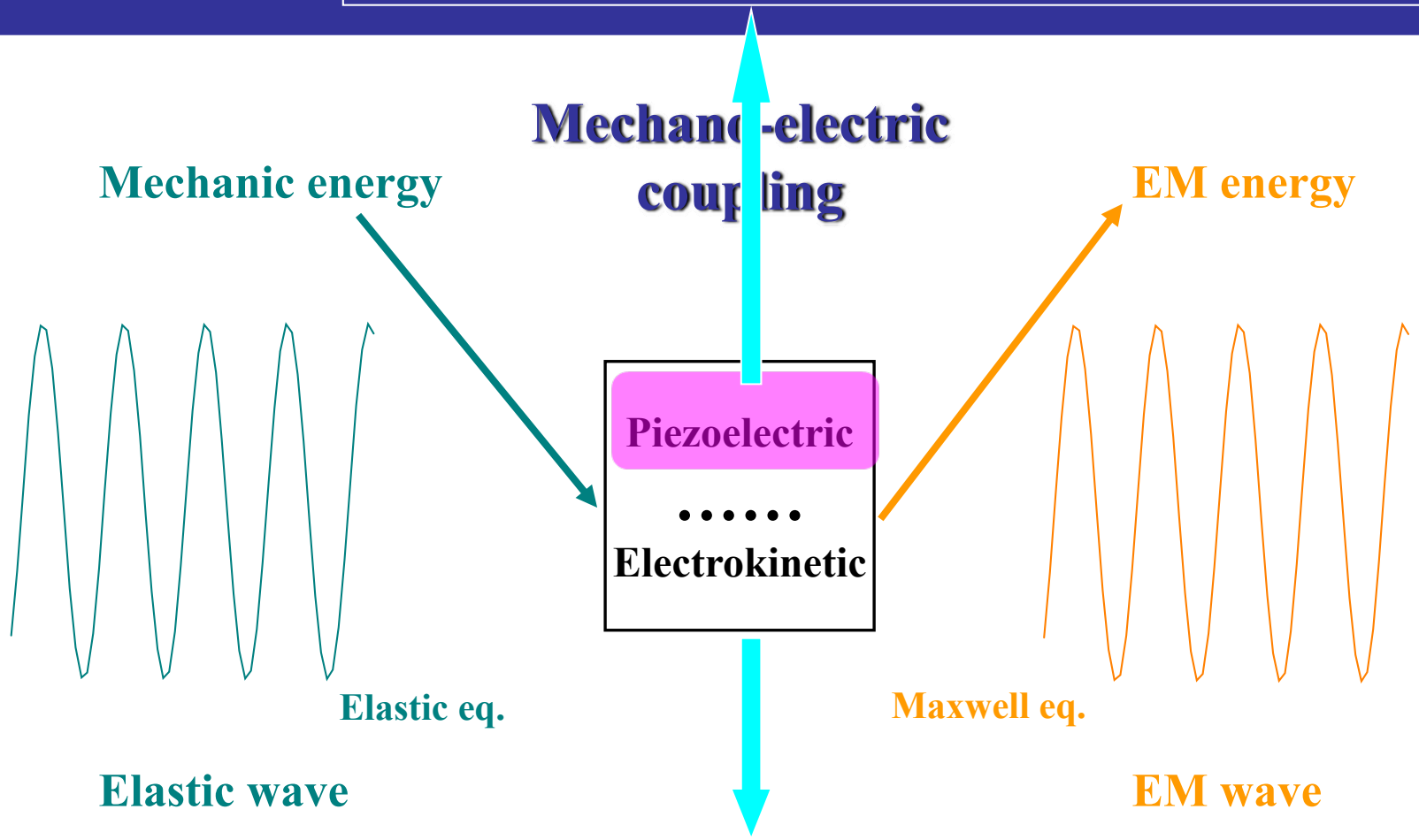
  Experimental evidence of mechanisms

- **Explanation of EQ-related EM signals?**

  →Key problem (physics-based study?)

Generation mechanisms

Sasaoka et al, 1998. GRL; Yoshida et al., 1997. JGR



Jouniaux & Pozzi, 1997. JGR; Yoshida et al., 2001. JGR

Piezoelectric effect

- **Evidence of rock experiments**

  Yoshida et al, 1997. J Geophys Res

  Sasaoka et al, 1998. Geophys Res Lett

- **Controversy：Is the piezoelectric effect of natural rocks too small to generate observable signals?**

  Finkelstein & Powell,1970.Nature

  Tuck et al, 1977. Tectonophysics

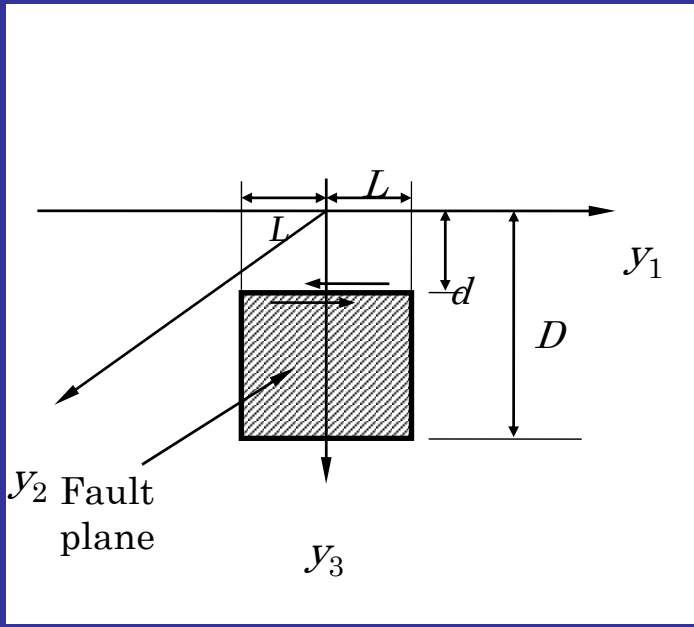
  Ghomshei & Templeton, 1989. Phys Earth Planet Inter

- **How to explain co-seismic electric signals?**

Study on co-seismic electric signals (Huang, 2002)

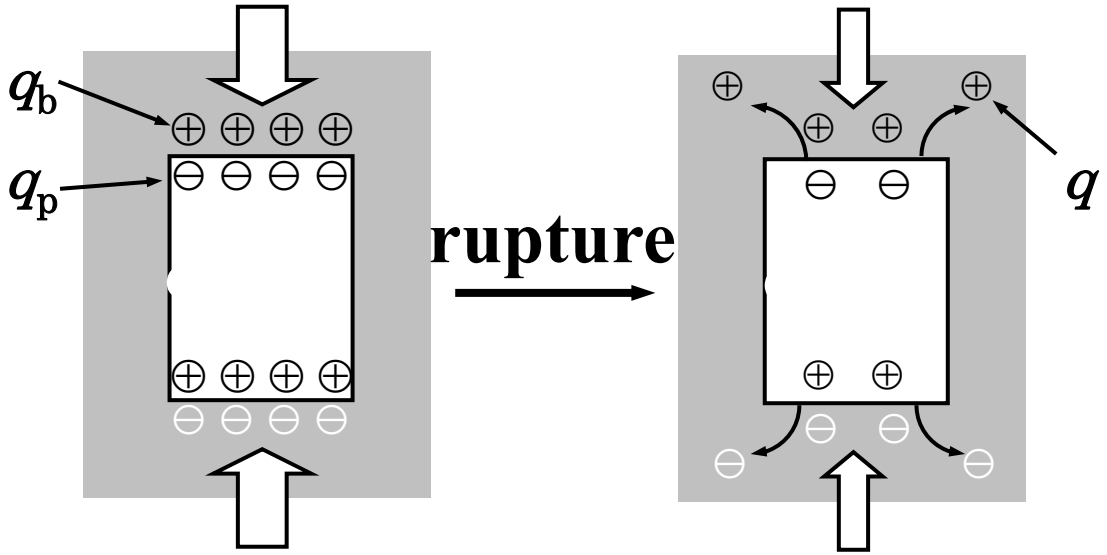
- A mathematical fault model
- An electromagnetic model

  (piezoelectric effect)



An electromagnetic model

q_b: bound charge
q_p :polarization charge



$q = q_b - q_p = 0$ $\qquad$ $q = q_b - q_p \neq 0$

Supported by rock experiments

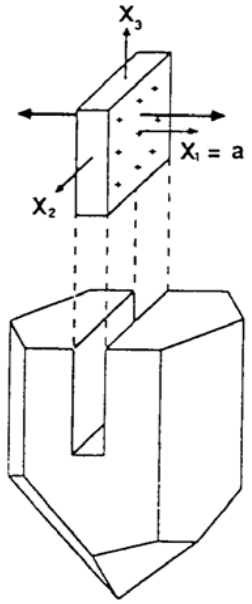
Piezoelectric polarization of a single quartz,

$P_{ip} = \sum d_{ij} S_j$, $\qquad$ $i = 1, 2, 3$ and $j = 1, 2, ..., 6.$

d_{ij}: piezoelectric moduli

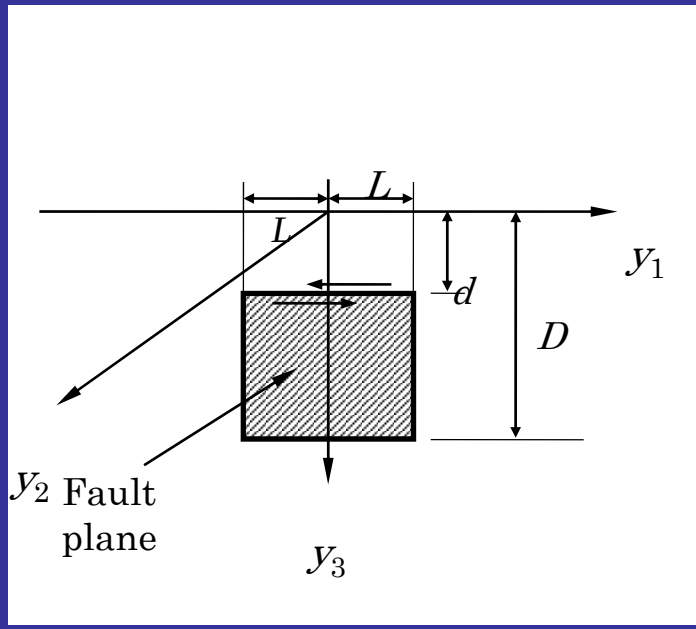
S_j: stress

$$\begin{pmatrix} \sigma'_{11} & \sigma'_{12} & \sigma'_{13} \\ \cdots & \sigma'_{22} & \sigma'_{23} \\ \cdots & \cdots & \sigma'_{33} \end{pmatrix} \Rightarrow \begin{pmatrix} S_1 & S_6 & S_5 \\ \cdots & S_2 & S_4 \\ \cdots & \cdots & S_3 \end{pmatrix} \Rightarrow \begin{pmatrix} S_1 \\ S_2 \\ S_3 \\ S_4 \\ S_5 \\ S_6 \end{pmatrix}$$



Study on co-seismic electric signals (Huang, 2002)

- A mathematical fault model
- An electromagnetic model
  (piezoelectric effect)
- Effective piezoelectricity
  (Rock/Piezo-crystal)



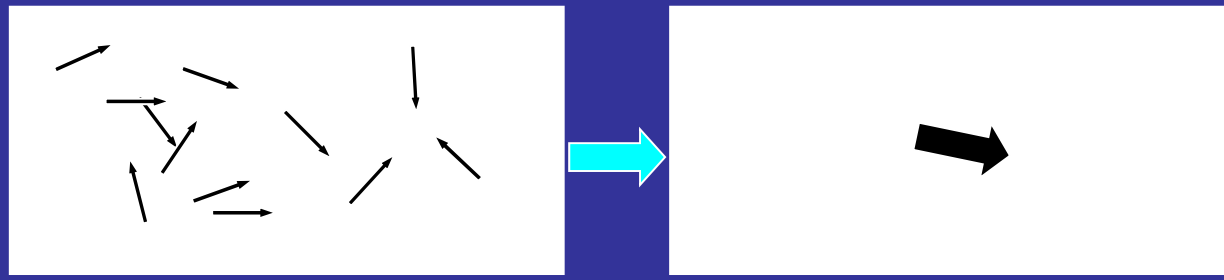
$\alpha_{eff} = n^{1/2}/N\ \alpha_{qz} = \eta/n^{1/2}\ \alpha_{qz}$ (η :volume fraction of quartz)

$\alpha_{eff} = (\varsigma n + n^{1/2})/N\ \alpha_{qz}$ (ς :fraction of preferred orientation)

Lab experiments → 10^{-2} ~10^{-3}

Sasaoka et al, 1998. GRL

Effective piezoelectric coefficient of detectable signals in field observations : 10^{-6}



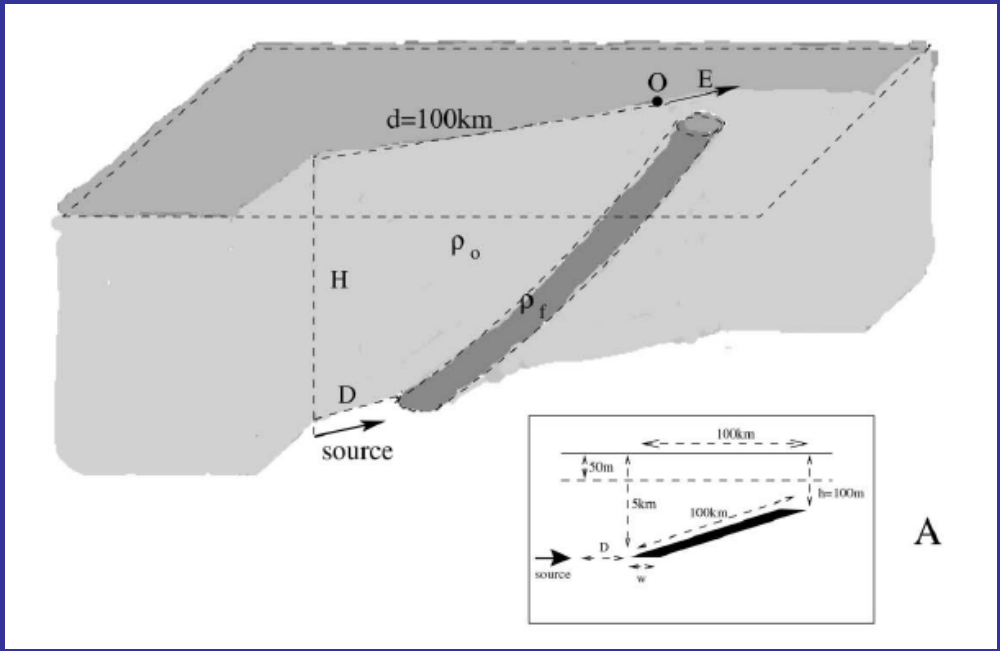
Weak preferred orientation could lead to observable signals

Another debated problem

- How to explain “selectivity” of EM signals?

Possible explanations

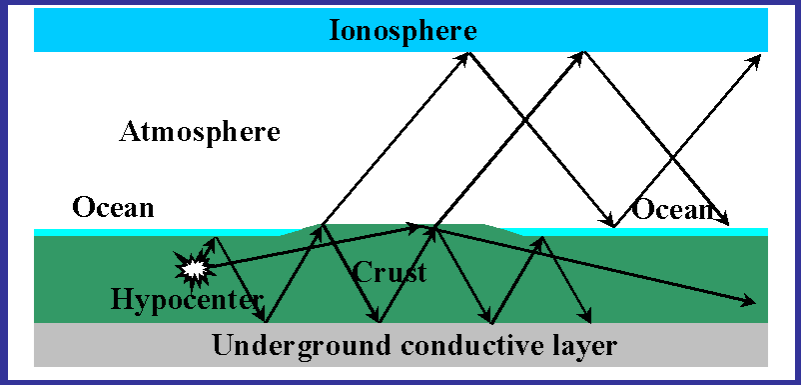
- **Special underground conductive channel (Varatsos et al., 1998)**

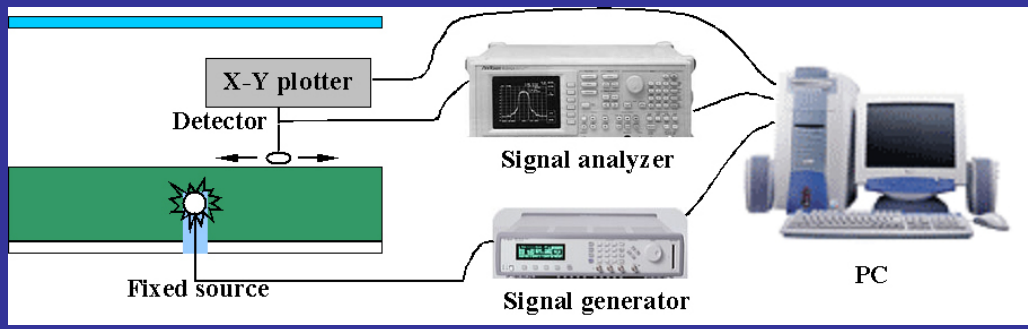


Amplification effect at the end of the conductive channel

Possible explanations

- Special underground conductive channel (Varatsos et al., 1998)
- Analogue experiment（Huang and Ikeya, 1998; Huang and Ikeya, 1999; Huang, 2005 ）
  - Give an experimental explanation for long distance propagation and “selectivity” of SEMS, especially in frequency of VLF-ELF band
  - Effect of inhomogeneity of surface conductivity on propagation



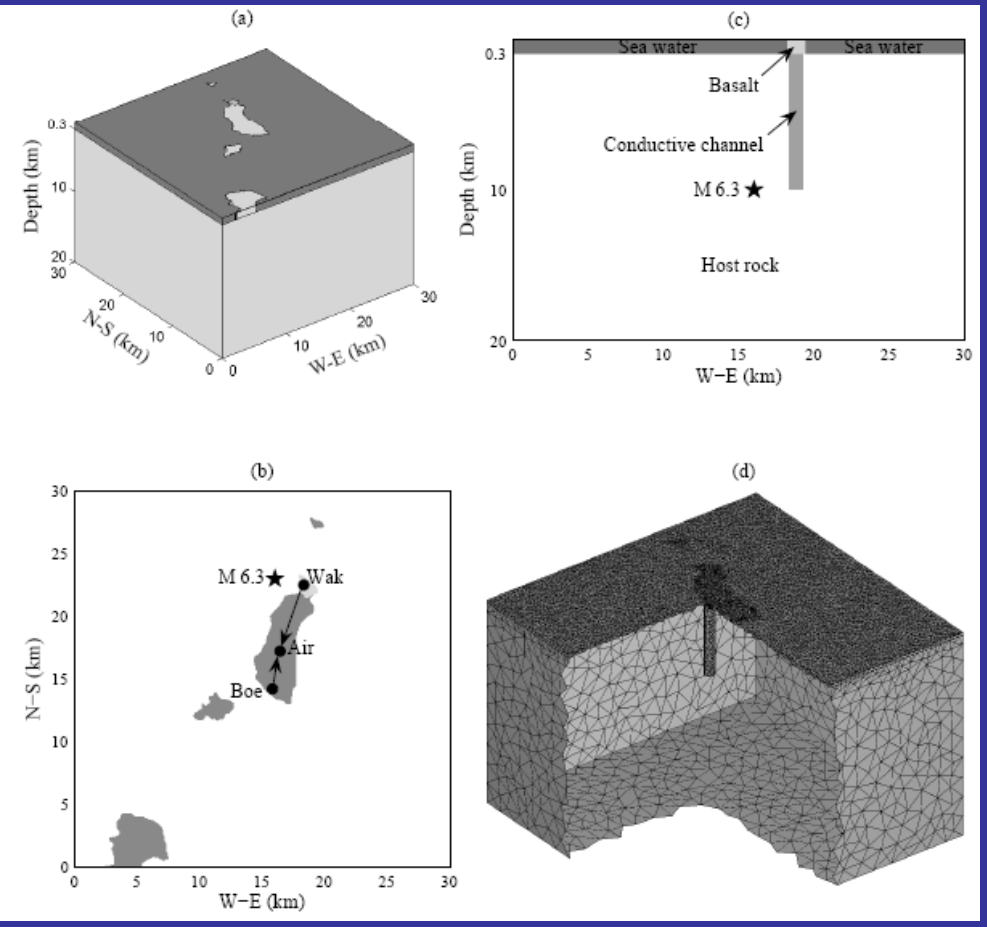


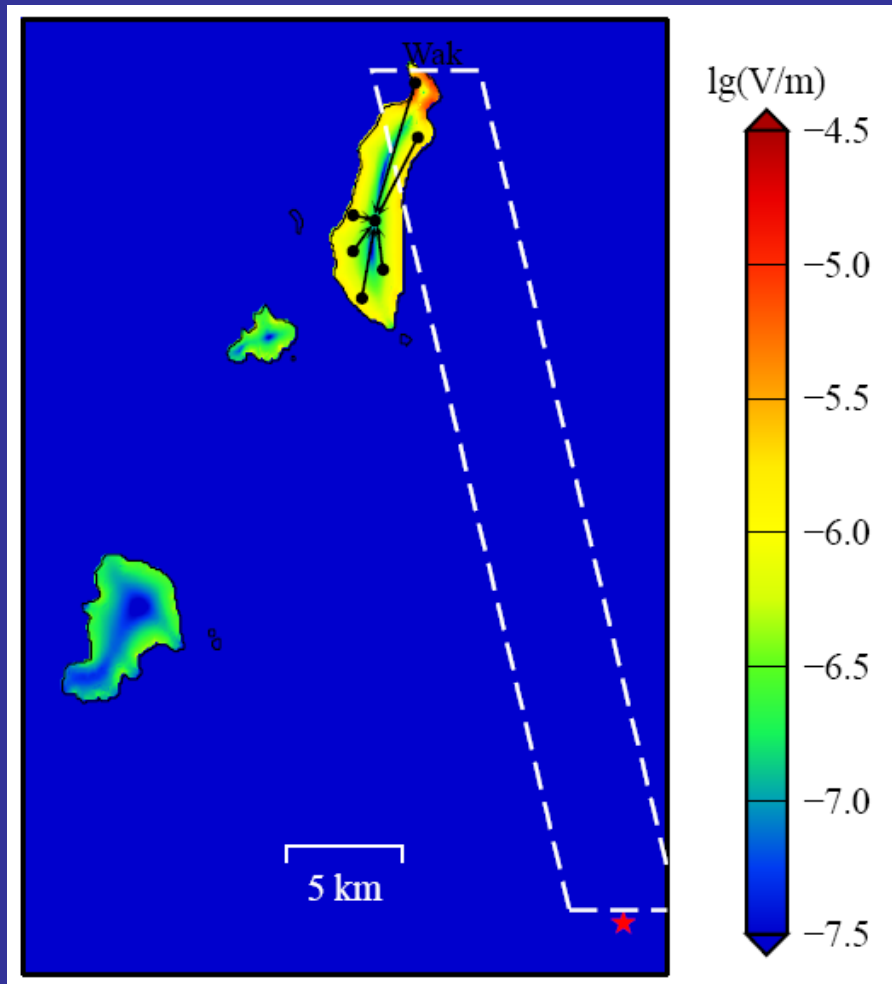
Waveguide model　Similarity　Experimental sketch

Possible explanations

- Special underground conductive channel (Varatsos et al., 1998)
- Analogue experiment（Huang and Ikeya, 1998; Huang and Ikeya, 1999; Huang, 2005）
- Numerical simulation (Ke and Huang, 2007; Huang and Lin, 2010)

Case study: SES selectivity of Izu EQ swarm
(Huang and Lin, 2010)





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Problems

- **Field observation?**

  √ Existence of EQ-related EM signals

- **Methodology?**

  Improvement of instrument

  Increase of environmental EM noise

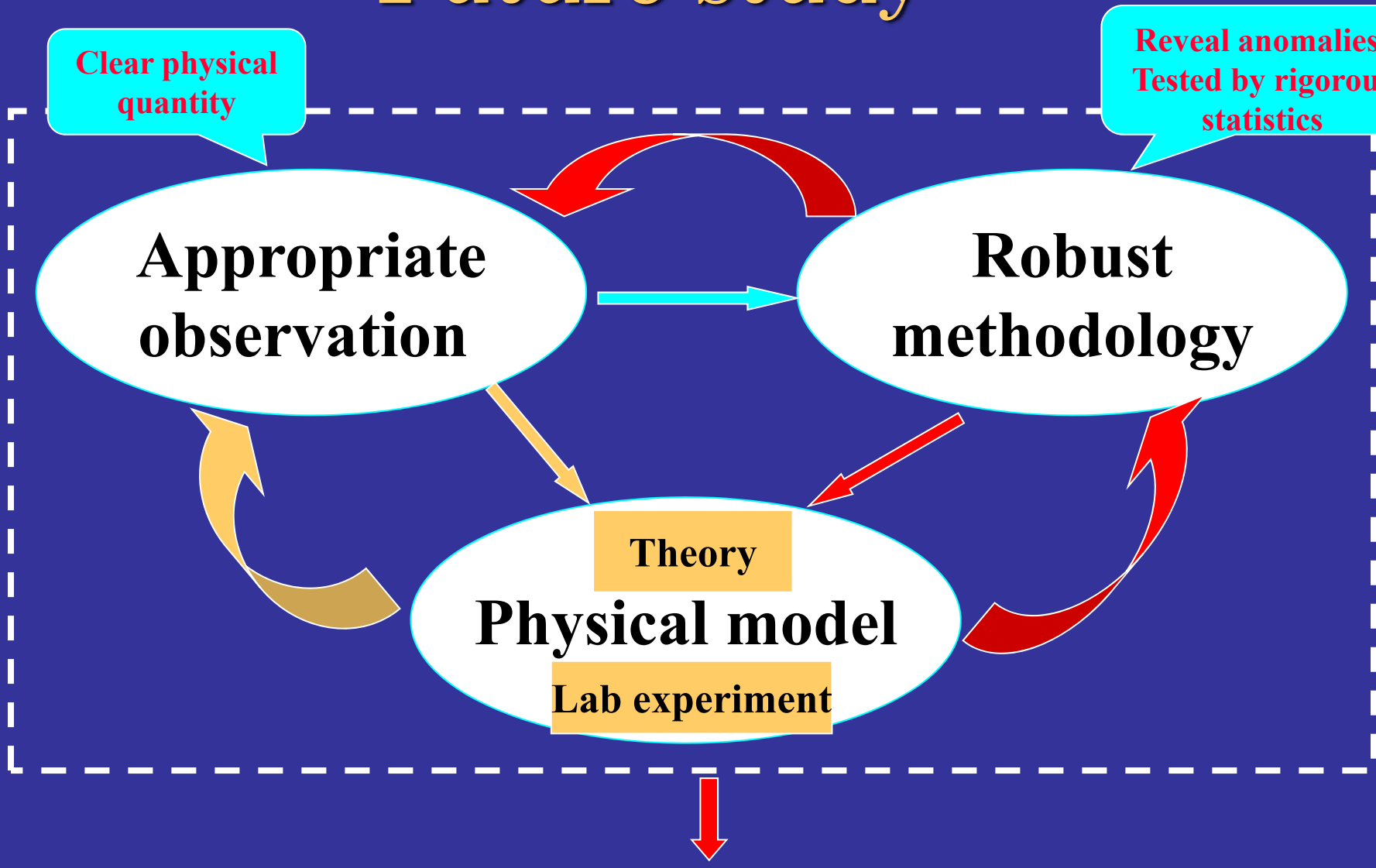
  How to reveal weak signals from noisy background: robust methodology?

- **Physical explanation?**

  Lab experiment

  Theoretical model

Future study



Physics-based study on earthquake-related signals

Association of Pacific Ring Universities (APRU) Annual Symposium on Natural Hazard (2010)

- August 26-28, Peking University, Beijing, China

Joint meeting of Chinese Geophysical Society and Seismological Society of China

- October 17-21, Ningbo, China
- International Session (Q Huang, L Zhao, T Kato, Q Chen)

Look forward to seeing you in China.

Thank You !