Pre-earthquake signals from geomagnetic total intensity analysis

Reporter : Chen Chun-Rong

REFERENCES

* Ken'ichi Yamazaki, Shin'ya Sakanaka, 2011. **Localized changes in geomagnetic total intensity values prior to the 1995 Hyogo-ken Nanbu (Kobe) earthquake.** Journal of Geodynamics 51, 37-43.
* Satoshi Fujiwara, Teruaki Nishiki, Hiroki Shirai, Hideo Hamzaki, and P. Golovkov, 2001. **Modeling the daily mean values of regional total force field changes in Japan.** Earth Planets Space 53, 69-73

OUTLINE

- Introduction
- Method
- Result & Discussion
- Conclusion

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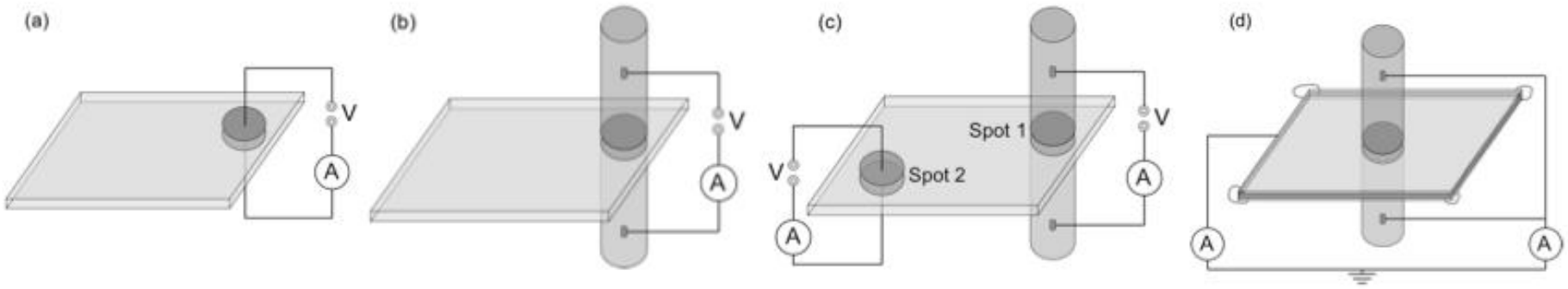
Introduction

* Some possible **precursory phenomena** of big earthquake has detected including **changes in seismicity**, **geochemistry**, **electromagnetic field**, and **geomagnetic**.

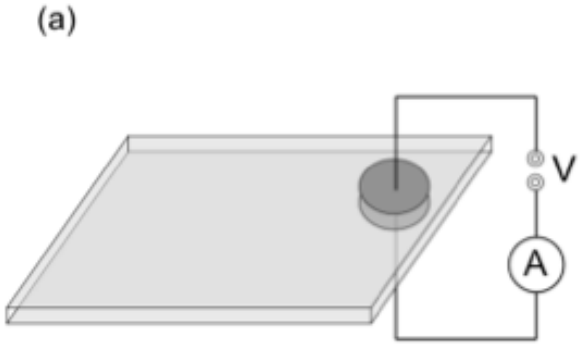
* If pre-seismic variations in the geomagnetic field can be detected, it is important to investigate the relation between geomagnetic and earthquakes.

* Such variations would also provide information on the physical state of the Earth prior to the event.



F. T. Freund (2007)

- (A) Standard procedure, no load
- (B) Under load
- (C) Measuring at two places, one under load
- (D) measuring a battery current



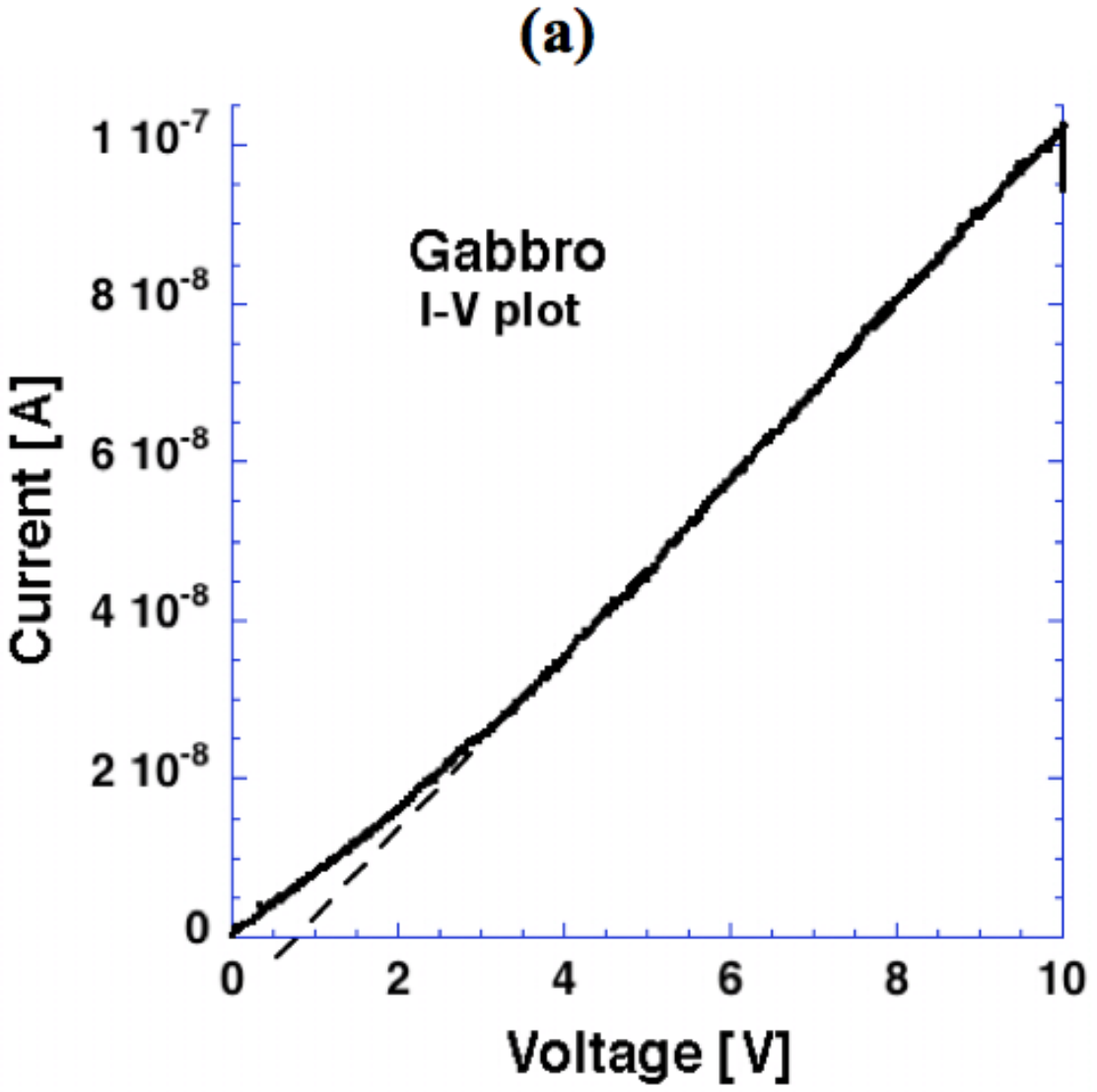
$\sigma = 1 / \rho$

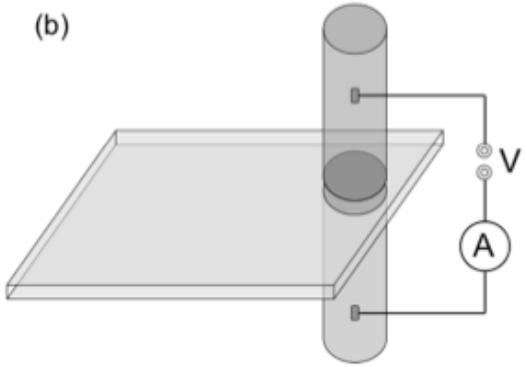
σ : conductivity

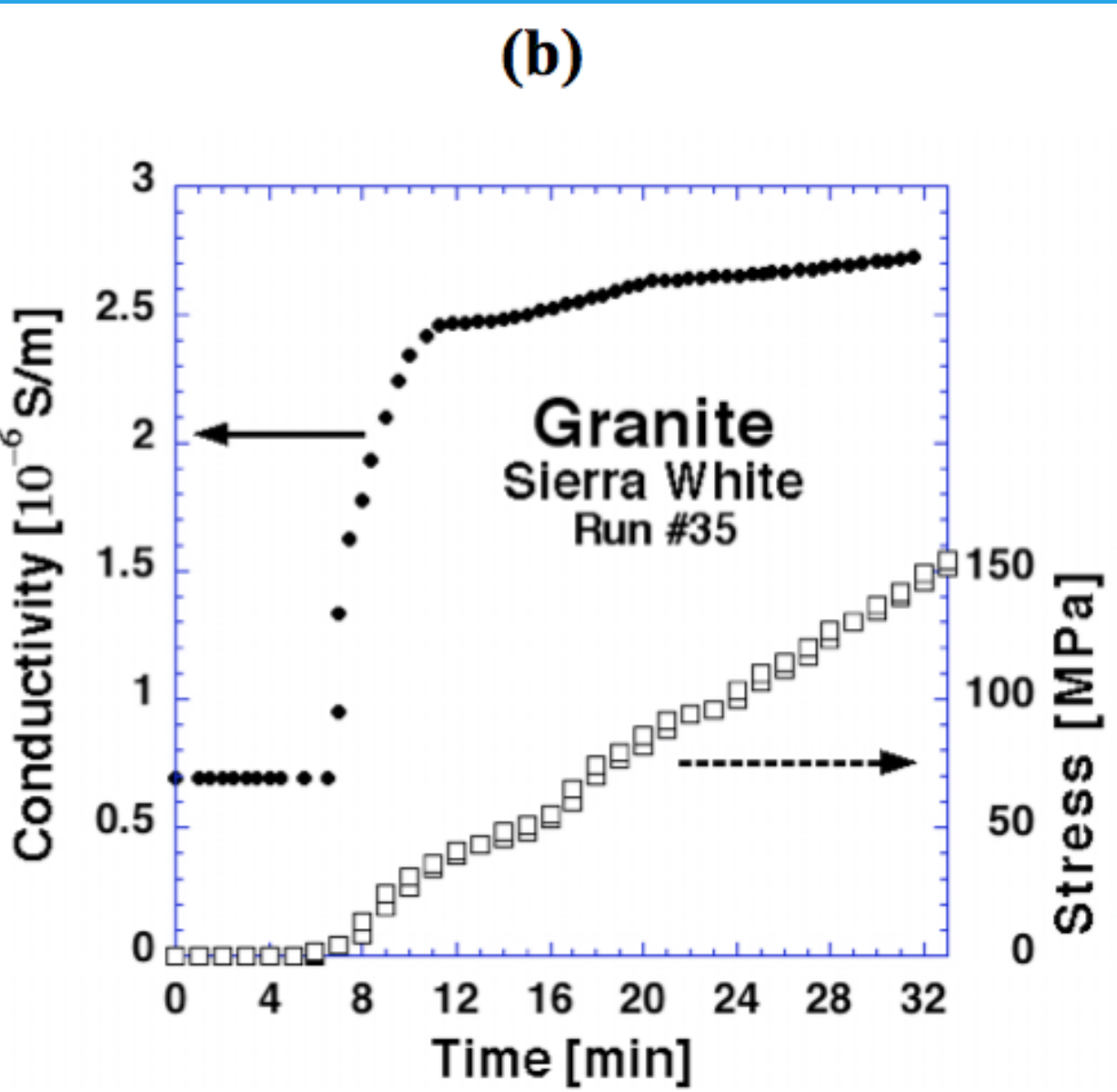
ρ : resistivity

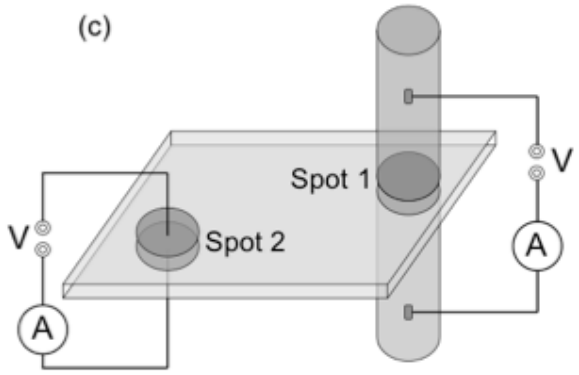
$V = I R$

$V / I = R$




(b)
V
A


(b)
Granite
Sierra White
Run #35
Conductivity [10⁻⁶ S/m]
Stress [MPa]
Time [min]
0
0.5
1
1.5
2
2.5
3
0
50
100
150
0
4
8
12
16
20
24
28
32



$\sigma = 1 / \rho$

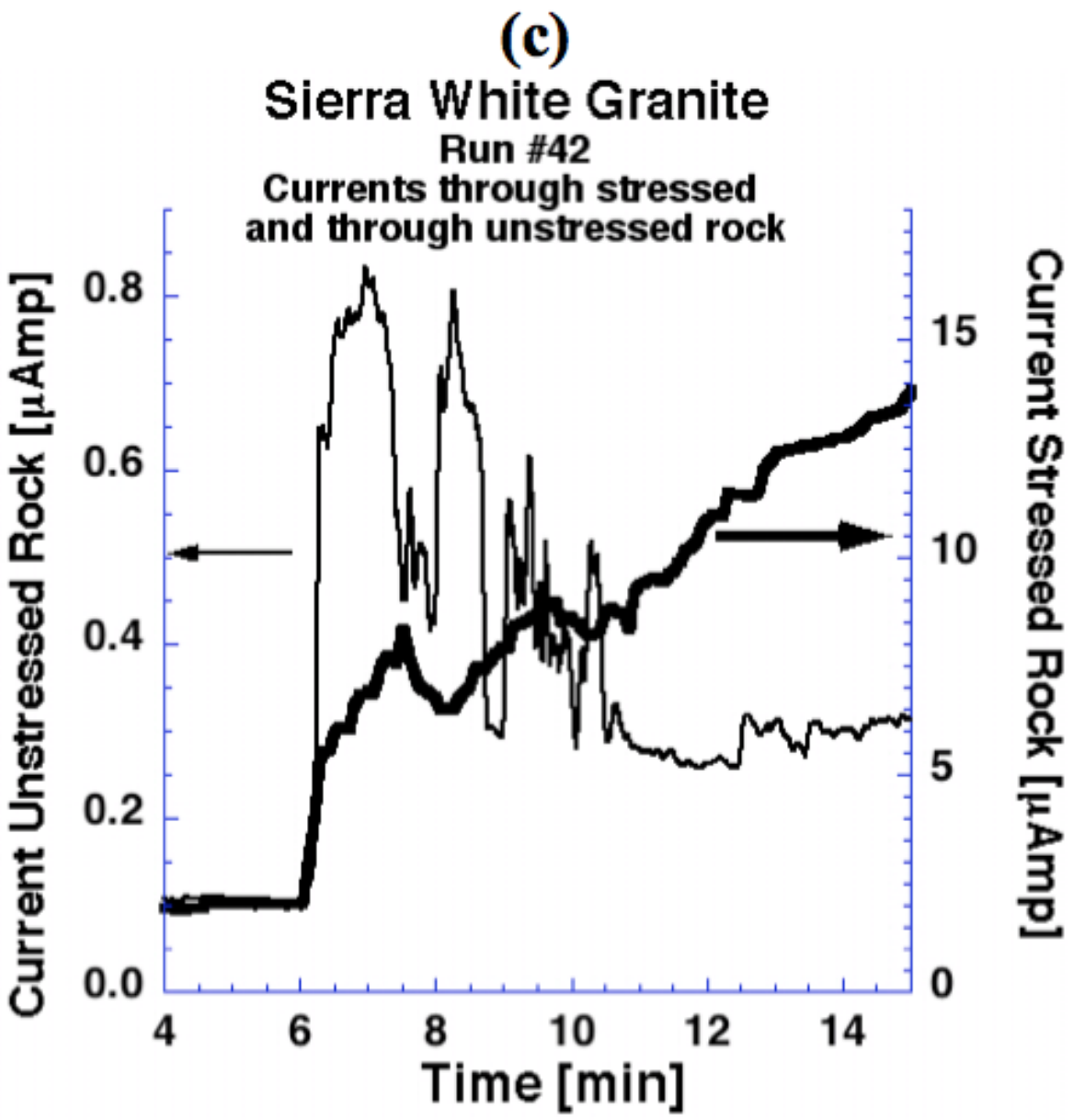
σ : conductivity

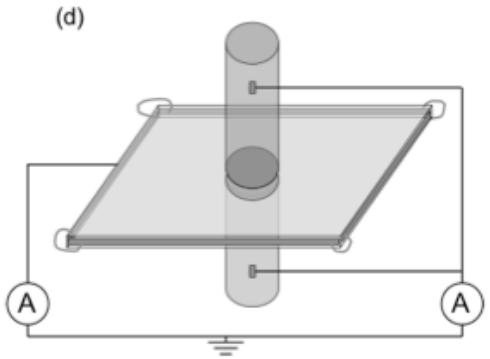
ρ : resistivity

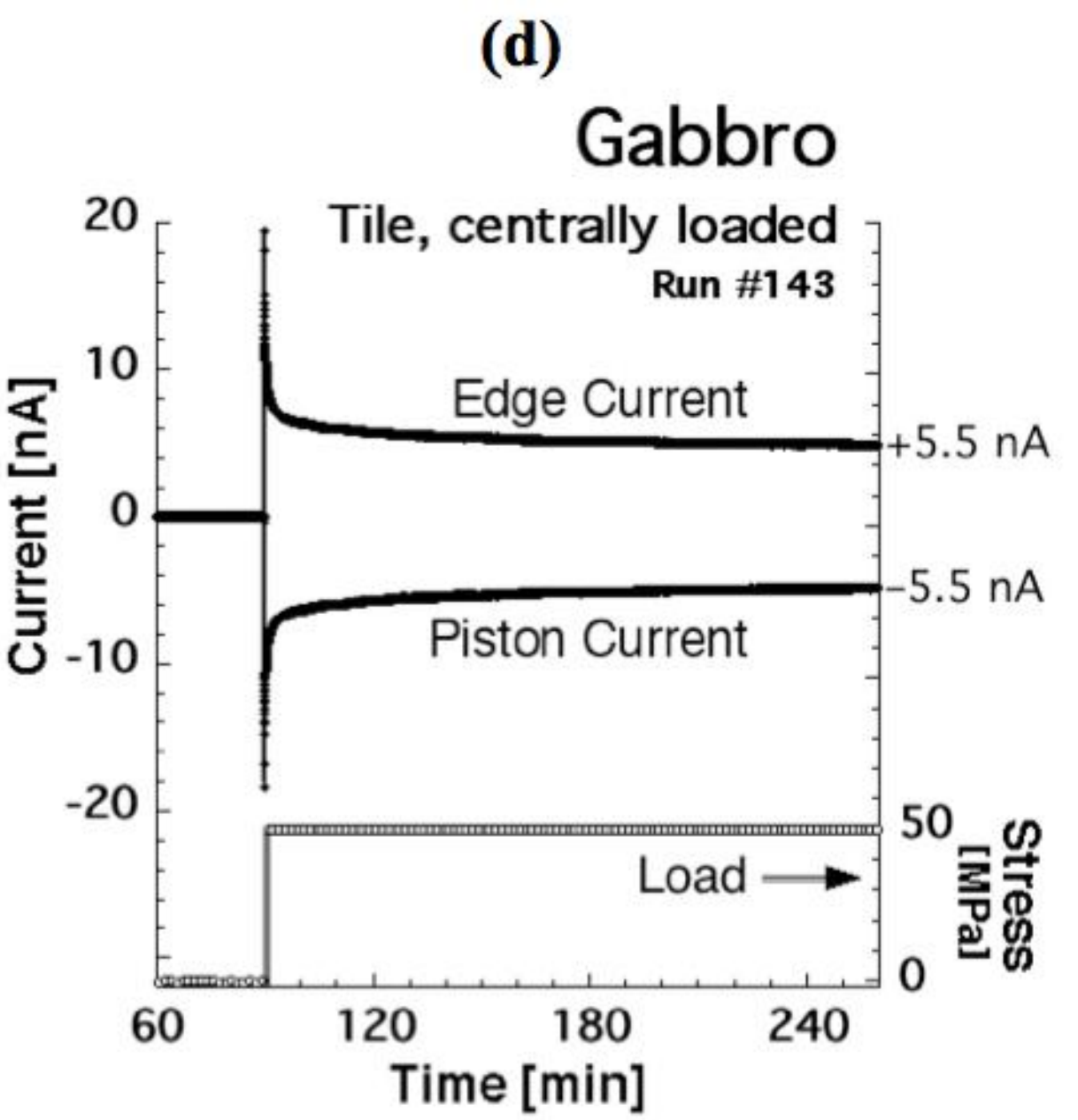
$V = I R$

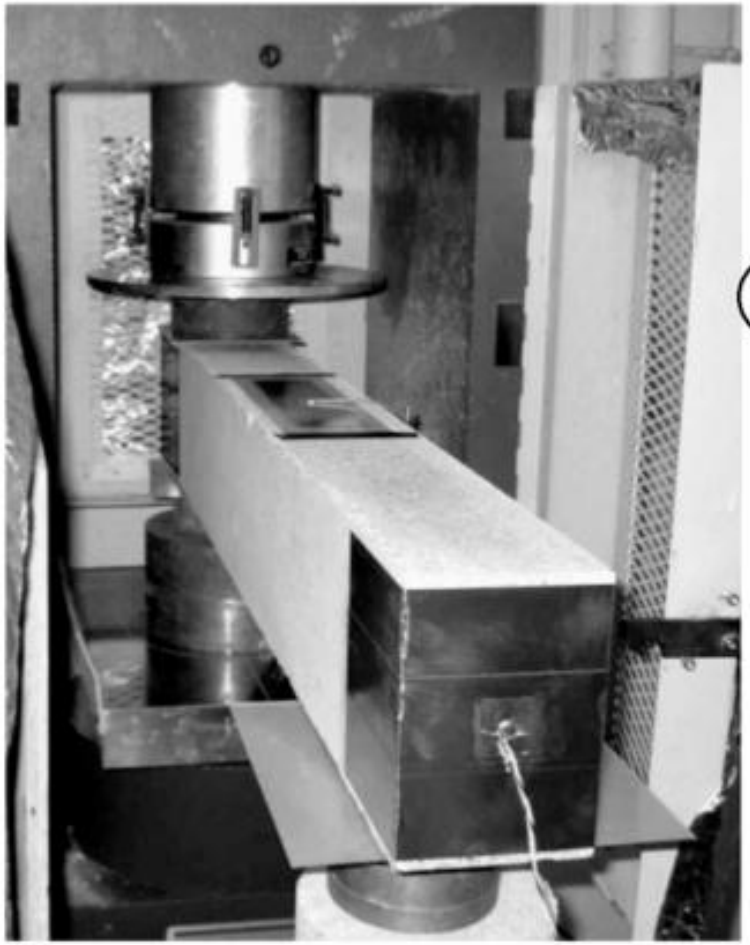
$V / I = R$

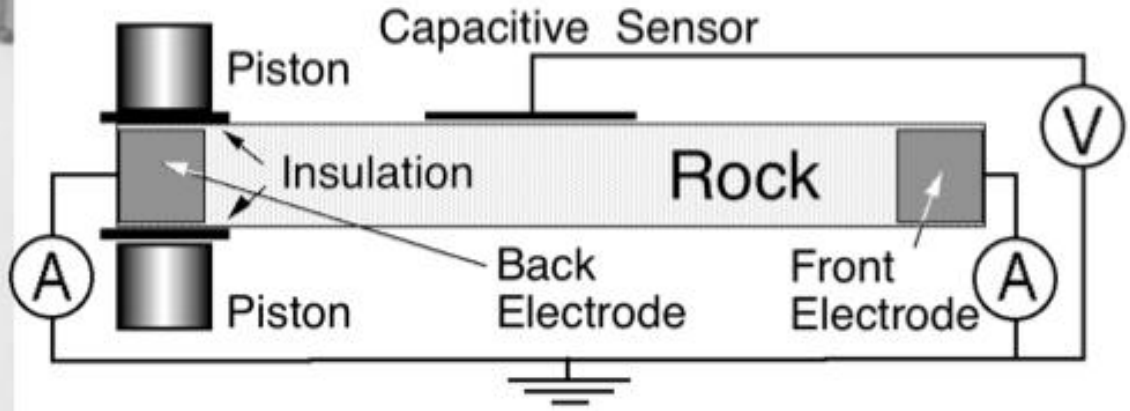
$1 / R = I / V$

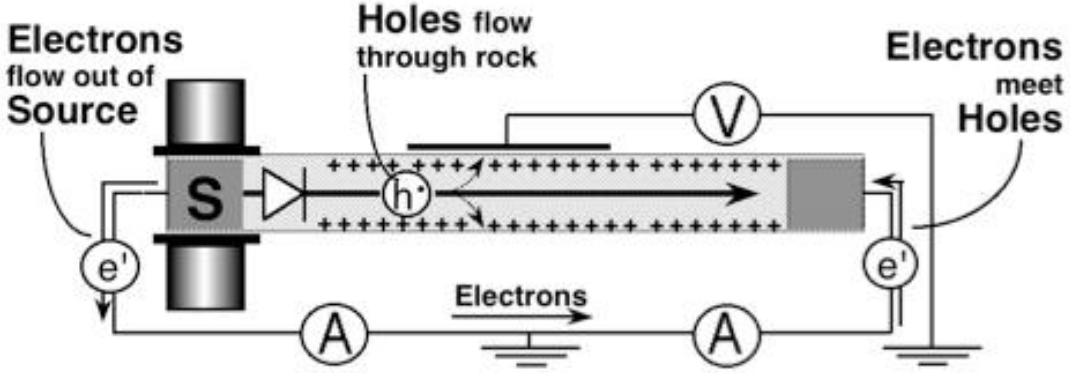


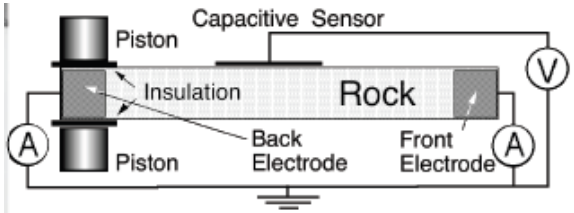

(d)
A
A

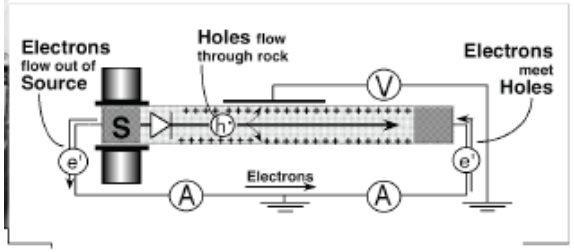

(d)
Gabbro
Tile, centrally loaded
Run #143
Edge Current
+5.5 nA
Piston Current
-5.5 nA
Load
Current [nA]
20
10
0
-10
-20
50
0
Stress [MPa]
60
120
180
240
Time [min]

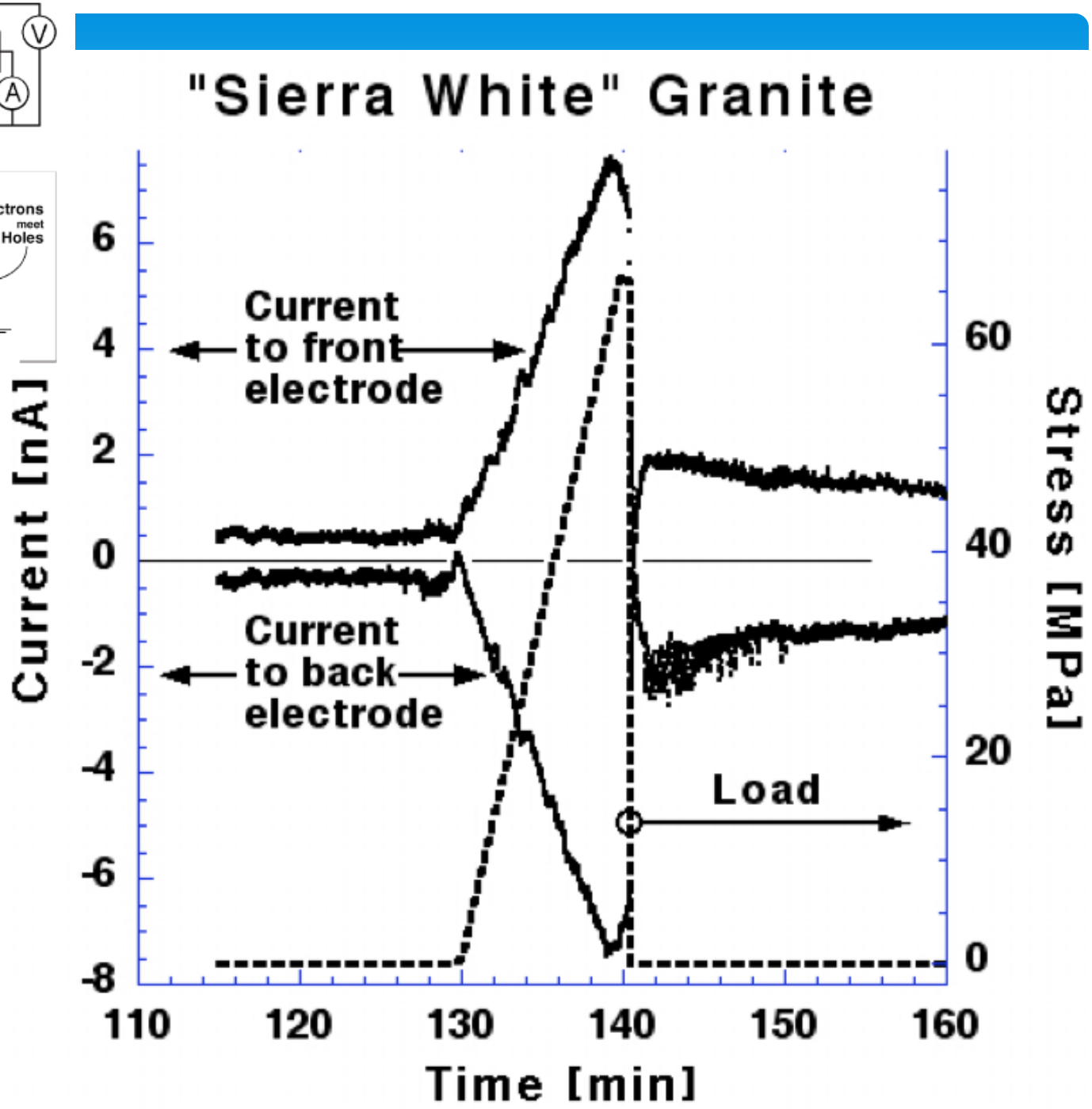


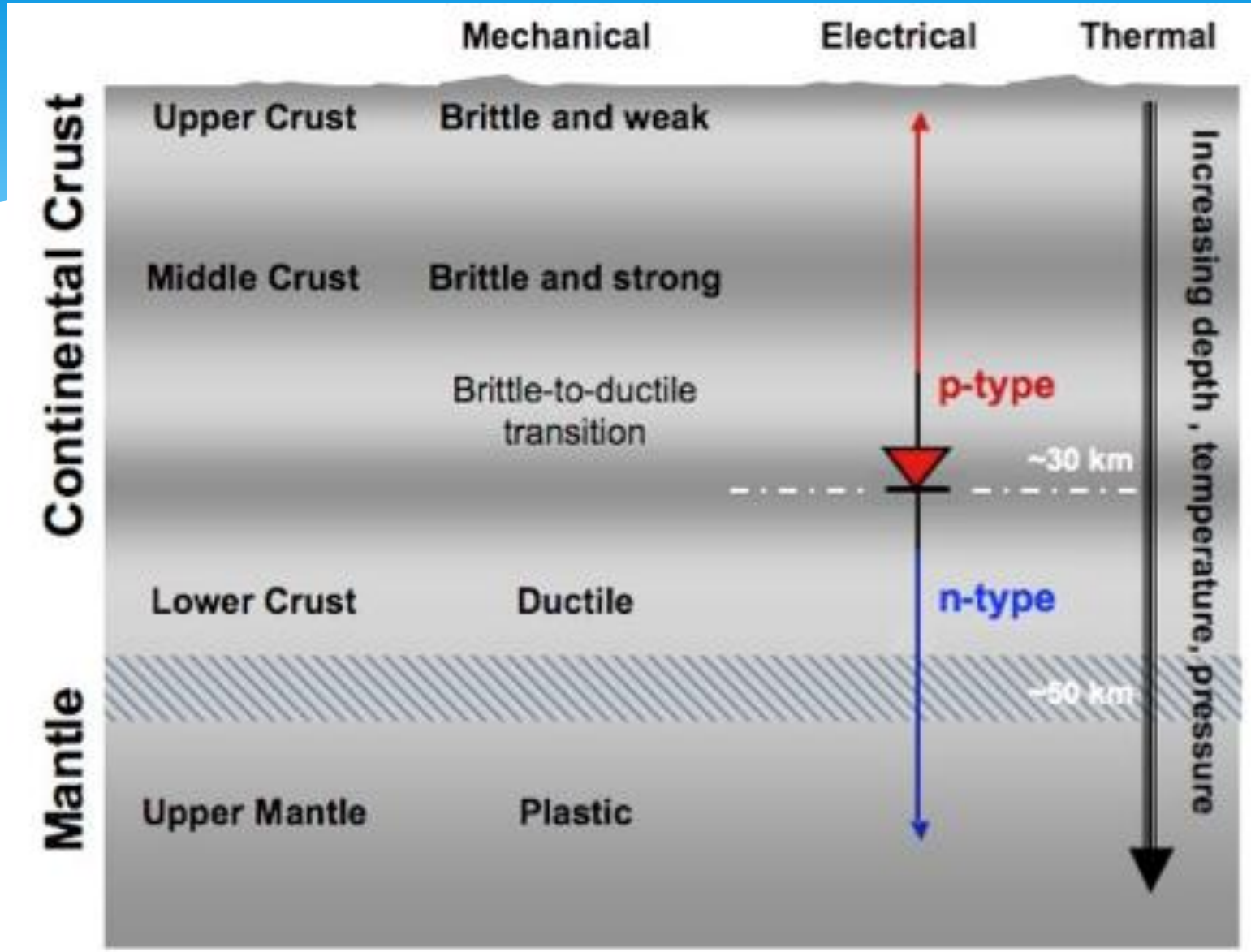

Capacitive Sensor
Piston
Insulation
Rock
V
A
Back
Electrode
Front
Electrode
A
Piston

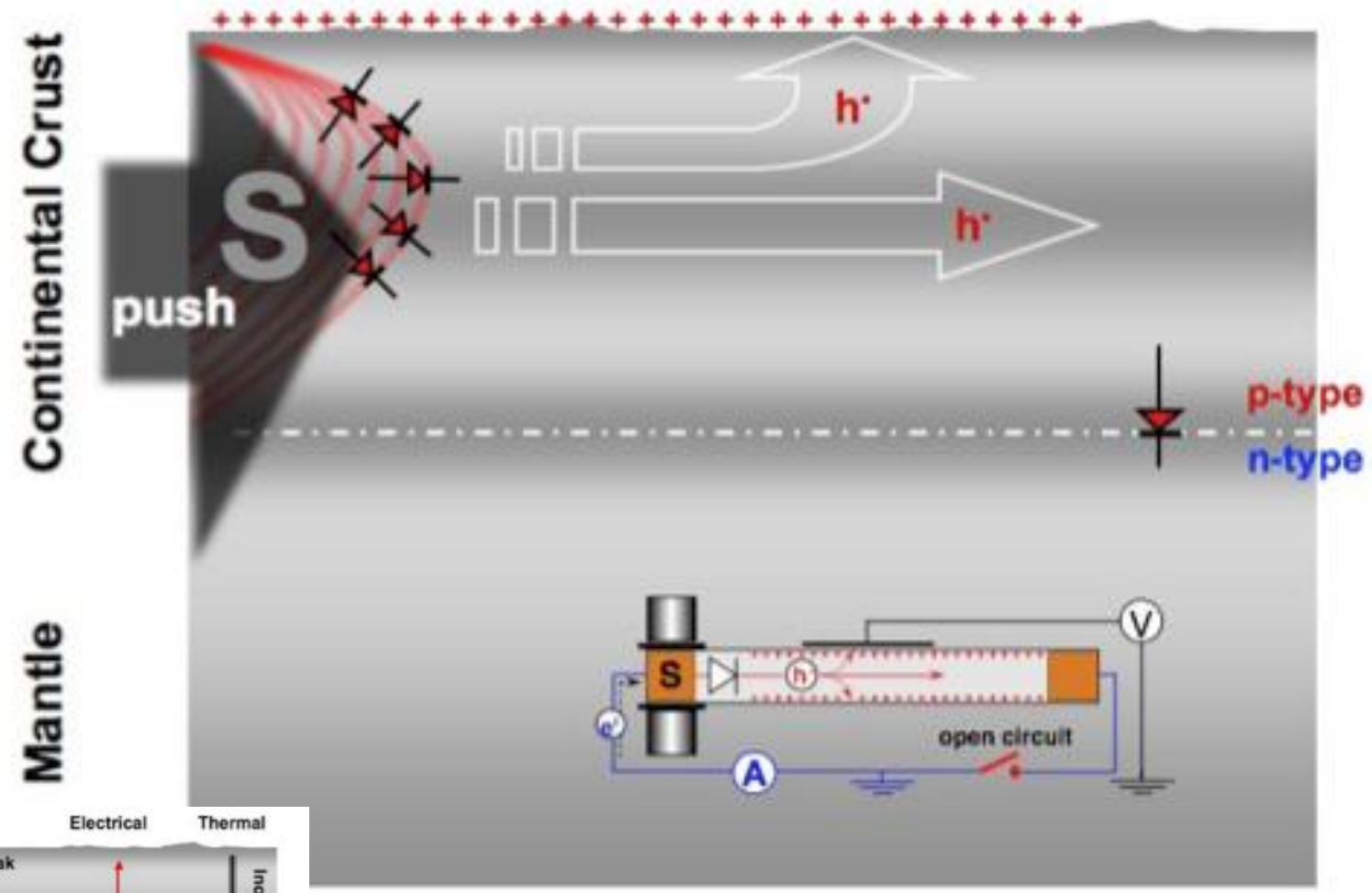

Electrons
flow out of
Source
Holes flow
through rock
Electrons
meet
Holes
V
S
h
e'
e'
Electrons
A
A

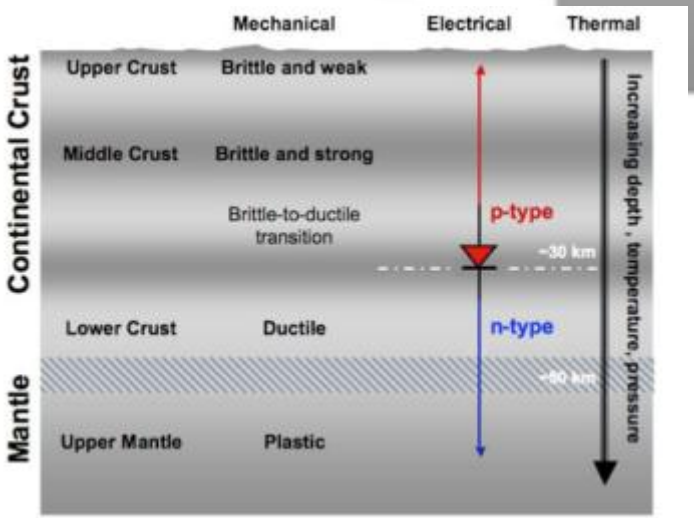

Capacitive Sensor
Piston
Insulation
Rock
V
A
Back
Electrode
Front
Electrode
A
Piston


Electrons
flow out of
Source
Holes flow
through rock
Electrons
meet
Holes
V
S
h+
e-
e-
A
Electrons
A

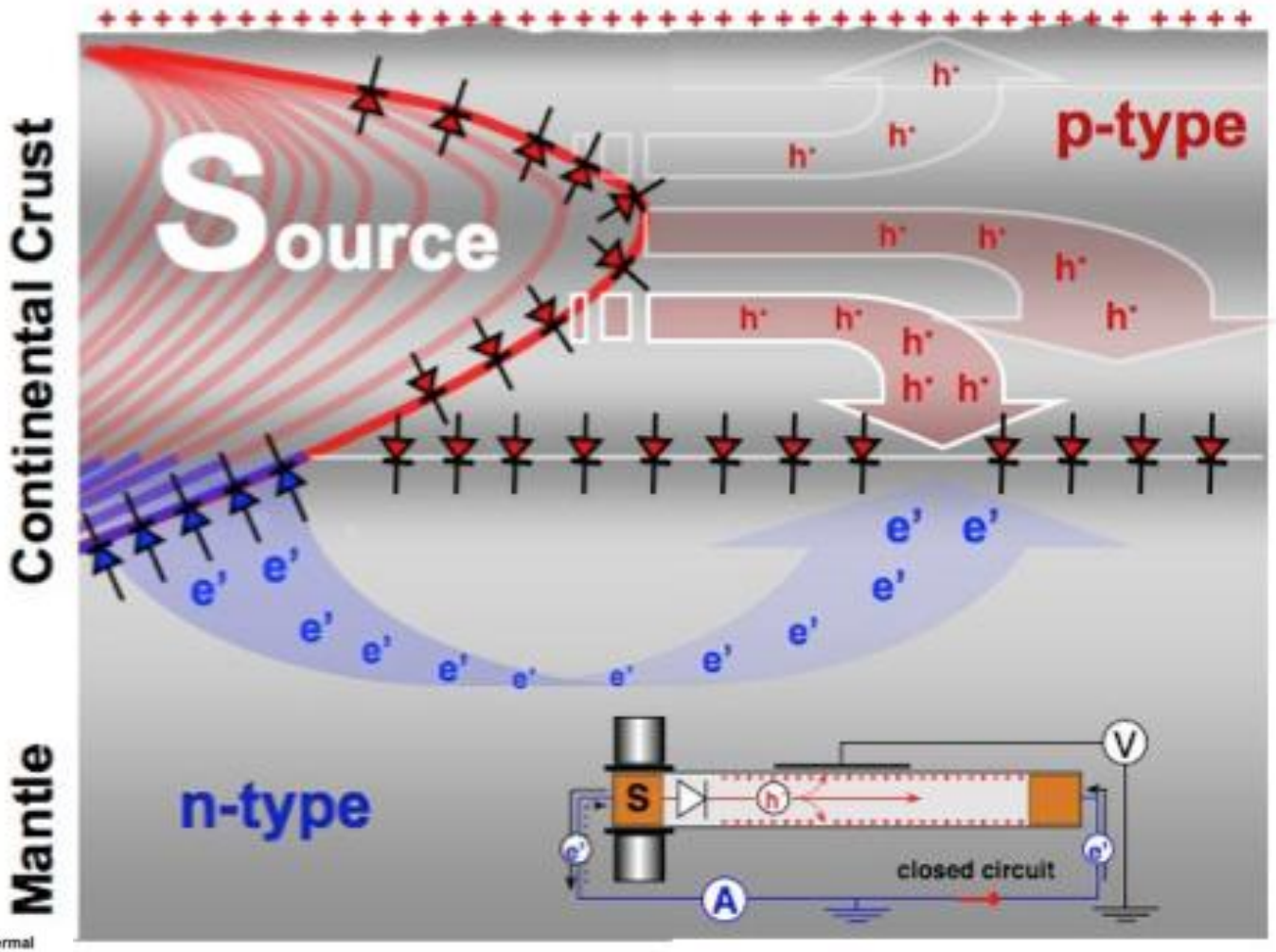

"Sierra White" Granite
Current [nA]
Stress [MPa]
Time [min]
Current
to front
electrode
Current
to back
electrode
Load
6
4
2
0
-2
-4
-6
-8
60
40
20
0
110
120
130
140
150
160


Mechanical
Electrical
Thermal
Continental Crust
Upper Crust
Brittle and weak
Middle Crust
Brittle and strong
Brittle-to-ductile transition
p-type
~30 km
Lower Crust
Ductile
n-type
~50 km
Mantle
Upper Mantle
Plastic
Increasing depth, temperature, pressure

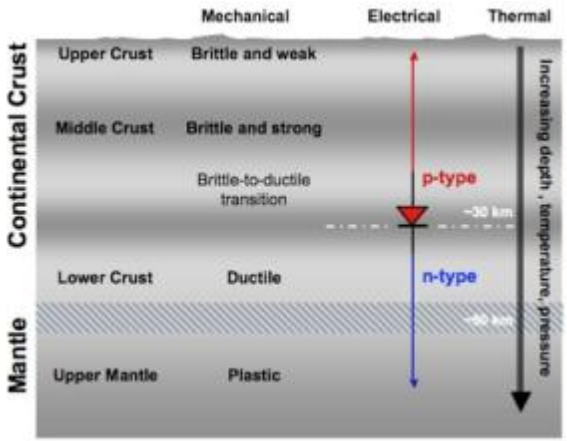




Case 1: Battery circuit open

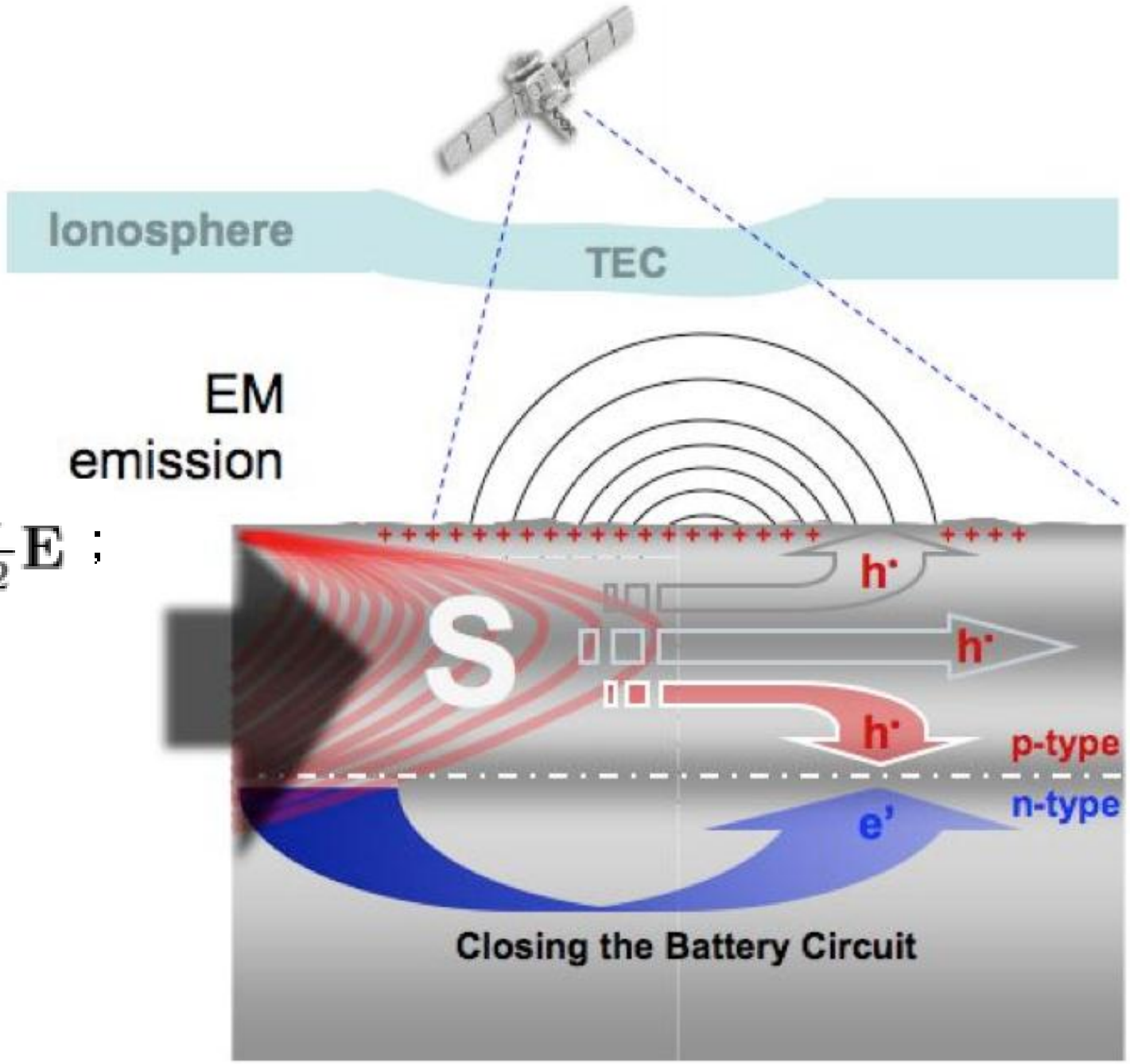


Case 2: Battery circuit closed



Maxwell :

$$\mathbf{B} = \mathbf{v} \times \frac{1}{c^2}\mathbf{E} \; ;$$



1995 Hyogo-ken Nanbu earthquake

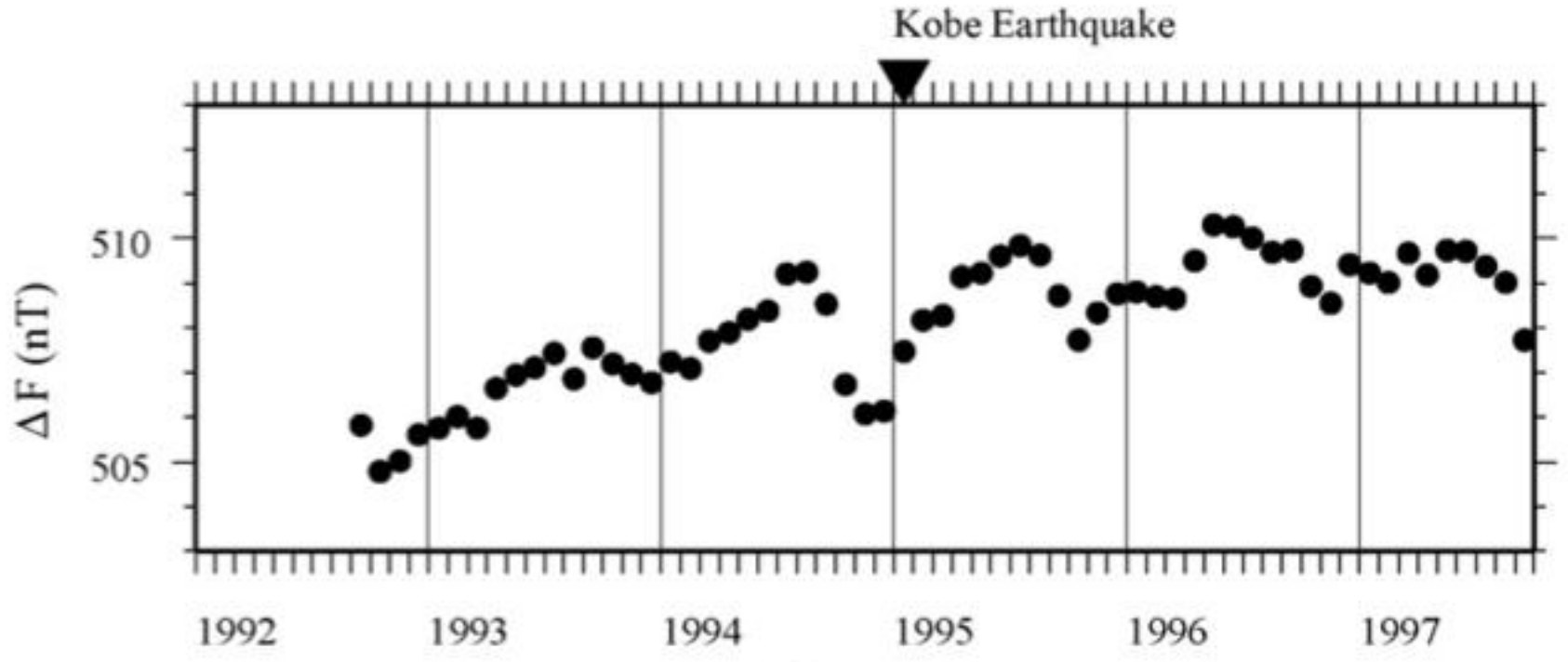
* 1995 Hyogo-ken Nanbu earthake

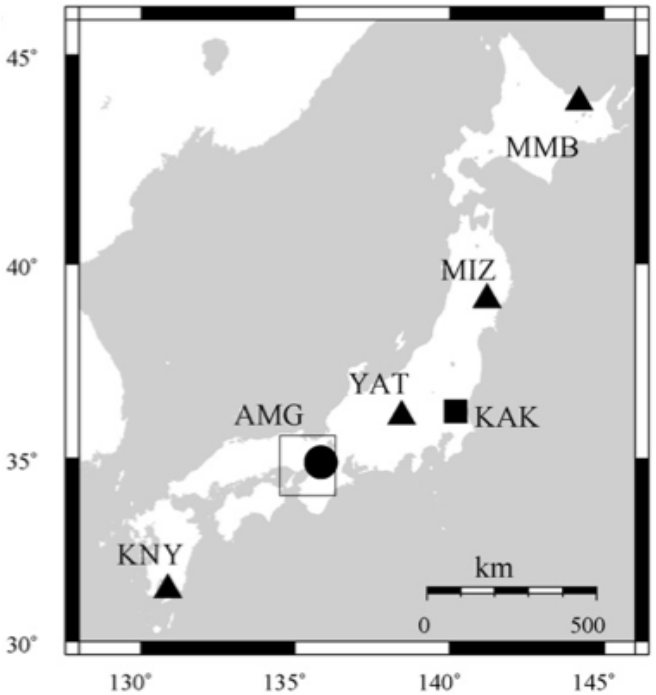
Date: January 17, 1995 5:46:52 (JST)

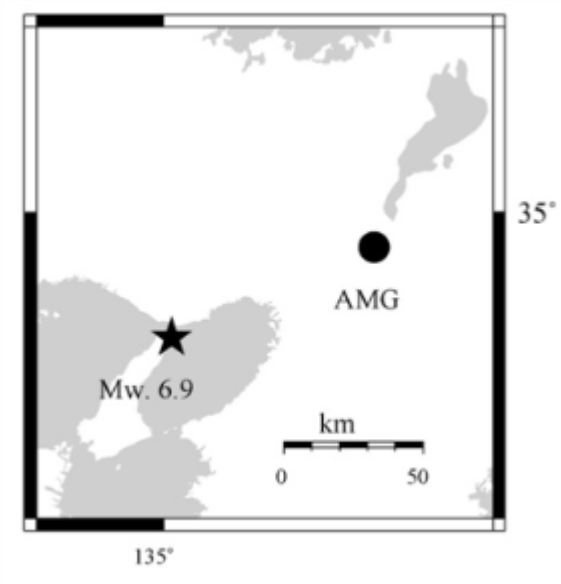
Magnitude: Mw 6.8

Depth: 16 km

Casualties: 6,434 killed, around 300,000 left homeless


Kobe Earthquake
510
505
ΔF (nT)
1992
1993
1994
1995
1996
1997
Year


45°
40°
35°
30°
130°
135°
140°
145°
MMB
MIZ
YAT
AMG
KAK
KNY
km
0
500


35°
AMG
Mw. 6.9
km
0
50
135°

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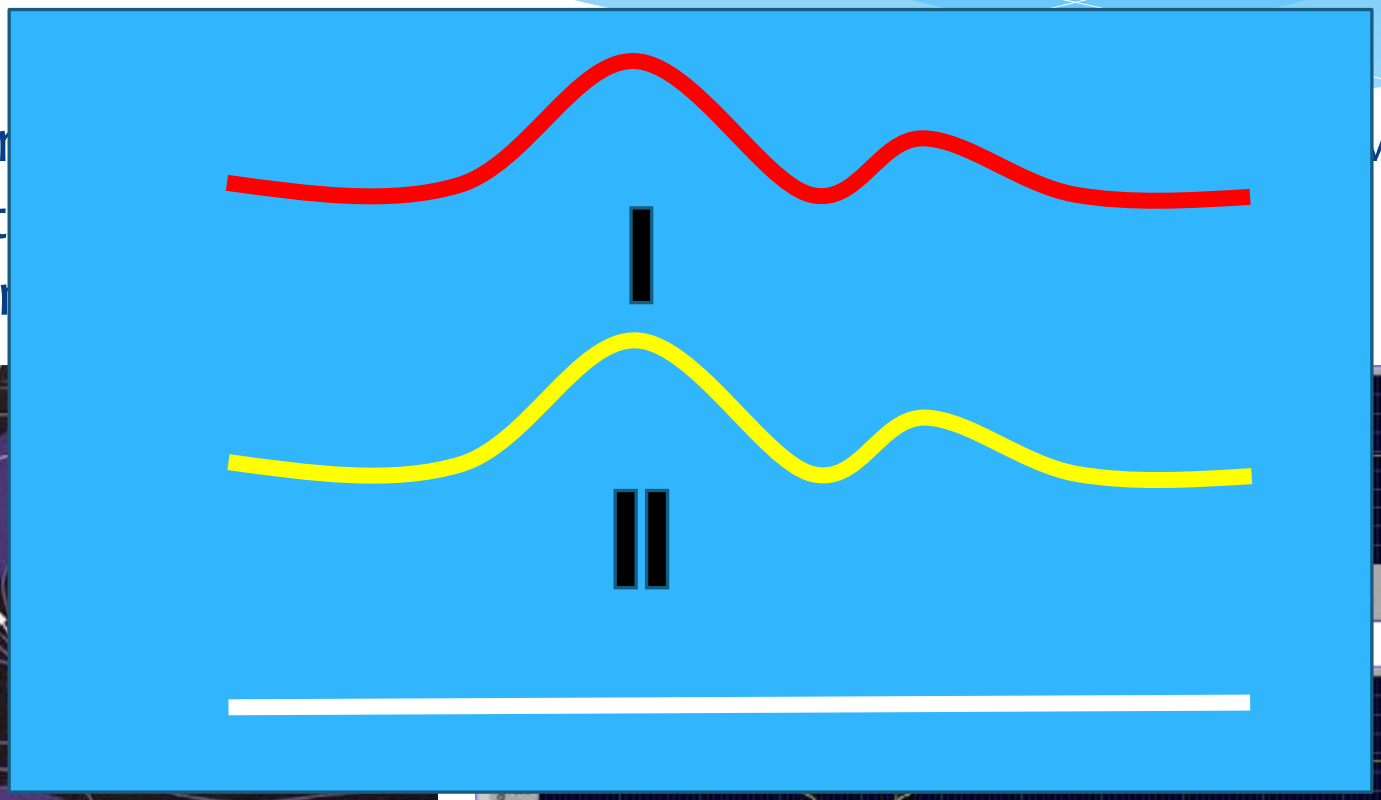
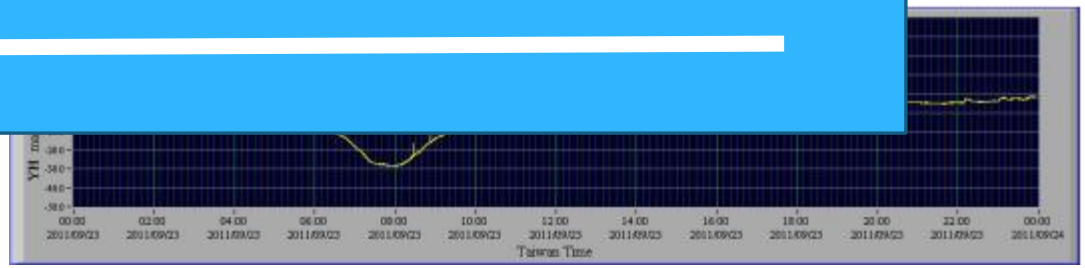
Method

* In order … vity from ot… criterion





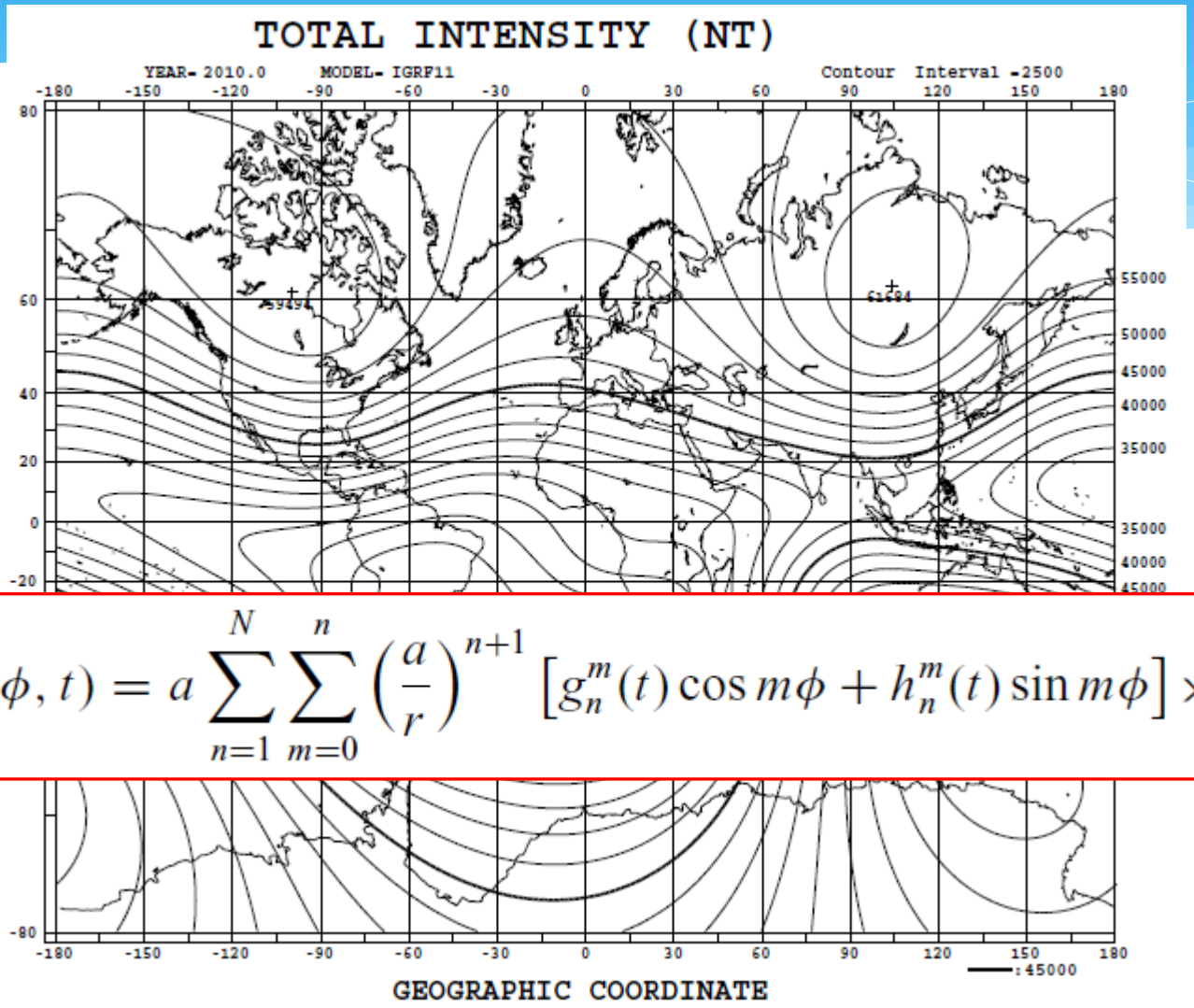
Method

* This method is somewhat crude when seeking to detect variations as small as **nanotesla (nT)**

* To extract only the **localized variations** from the **simple differences**, we used **geomagnetic field models** which describe **reference values** of the geomagnetic field as a function of location and time

* The well-known **International Geomagnetic Reference Field** (IGRF) and **Natural Orthogonal Components** (NOCs)

IGRF



$$V(r,\theta,\phi,t) = a\sum_{n=1}^{N}\sum_{m=0}^{n}\left(\frac{a}{r}\right)^{n+1}\left[g_n^m(t)\cos m\phi + h_n^m(t)\sin m\phi\right]\times P_n^m(\cos\theta)$$

NOCs-Natural Orthogonal Components

$$V(r,\theta,\phi,t) = a\sum_{n=1}^{N}\sum_{m=0}^{n}\left(\frac{a}{r}\right)^{n+1}\left[g_n^m(t)\cos m\phi + h_n^m(t)\sin m\phi\right]\times P_n^m(\cos\theta)$$

NOCs ： $$H(\varphi,\lambda,t) = \sum_{i=0}^{I}\sum_{j=0}^{J}\sum_{k=0}^{K} a_{ijk}F(\varphi)_i \cdot G_j(\lambda)\cdot D_k(t)$$

φ and λ ：the geographical coordinates

t：is the time a_{ijk} : amplitude

$$H(\varphi,\lambda,t) = \sum_{m=1}^{M} b_m E_m(\varphi,\lambda,t).$$

$$b_m = a_{ijk},\ E_m(\varphi,\lambda,t) = F_i(\varphi)G_j(\lambda)D_k(t)$$

$$\int E_m(x)\cdot E_l(x)dx \begin{cases} = 0, & l \neq m, \\ \neq 0, & l = m. \end{cases}$$

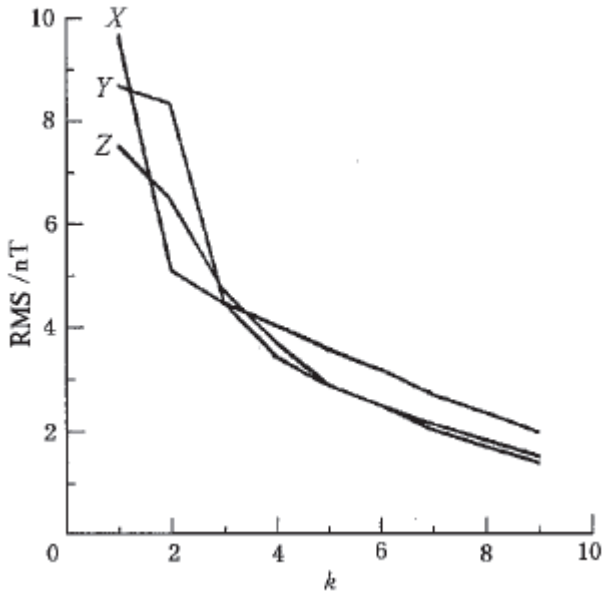
NOCs

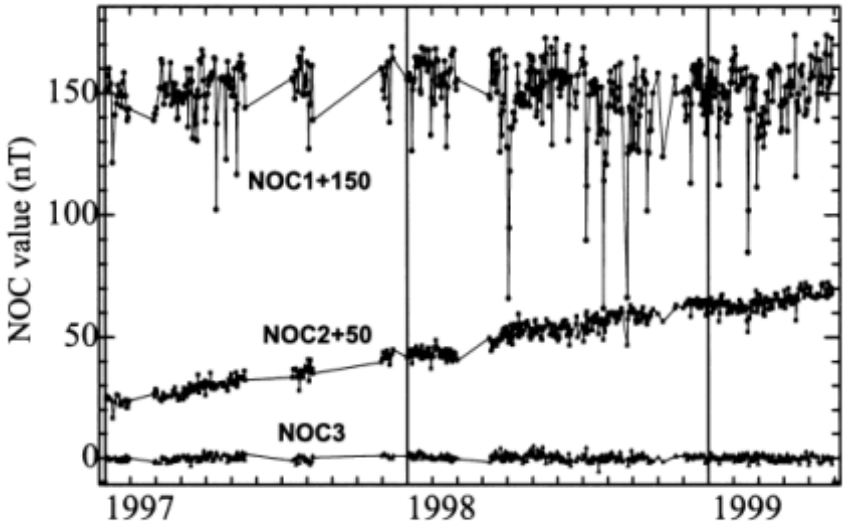
The Observed value $H_{ij} = \sum_k X_{kj} T_{ki} + \delta_{ij}$

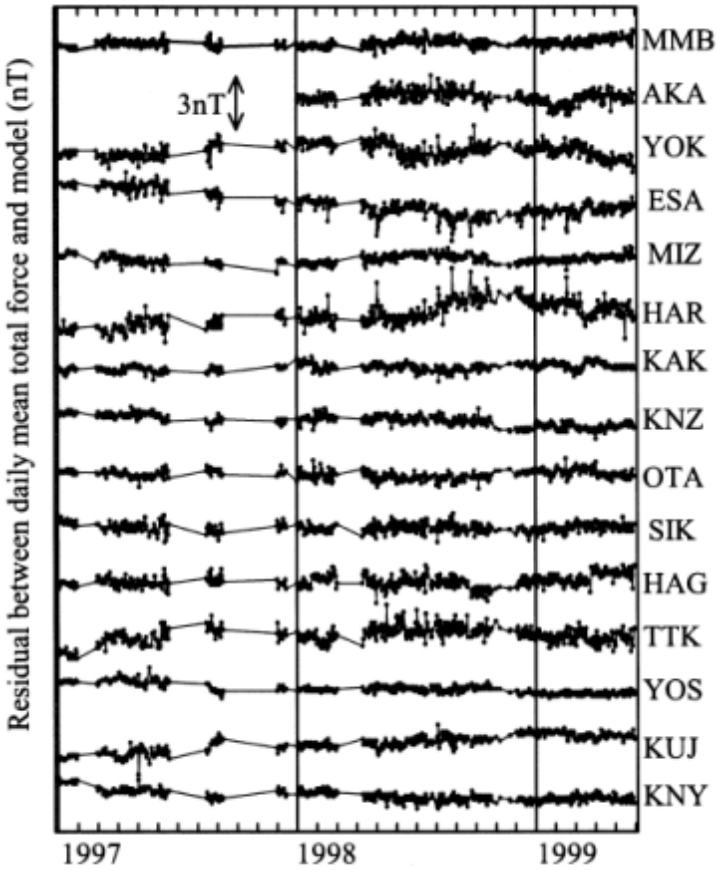
$$\sum_i X_{ki} X_{li} \equiv 0 \quad \text{if } k \neq l \qquad , \qquad \sum_j T_{kj} T_{lj} \equiv 0 \quad \text{if } k \neq l$$

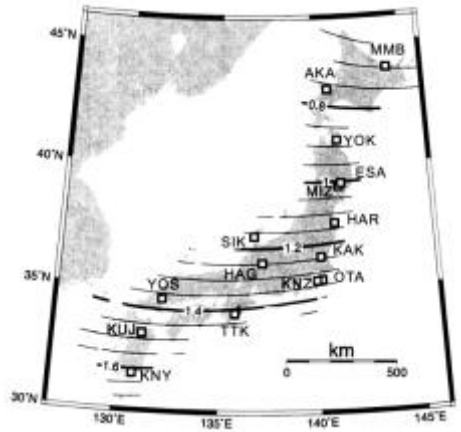
$$\sum_i X_{ki} X_{li} \neq 0 \quad \text{if } k = l, \qquad \sum_j T_{kj} T_{lj} \neq 0 \quad \text{if } k = l.$$

$$\sum_i \sum_j \left[H_{ij} - \sum_k T_{ki} X_{kj} \right]^2 = \min$$

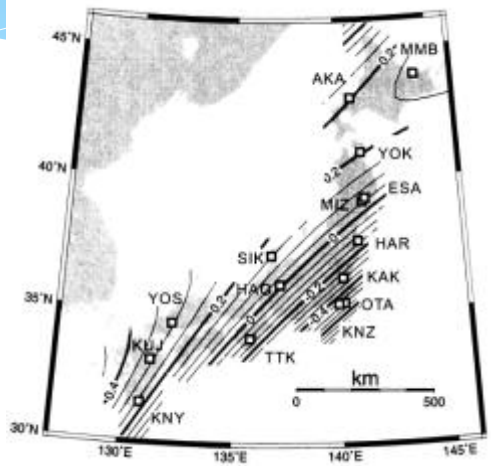




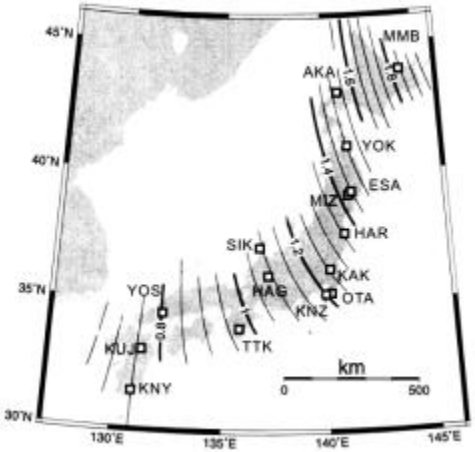




NOC1



NOC2



NOC3

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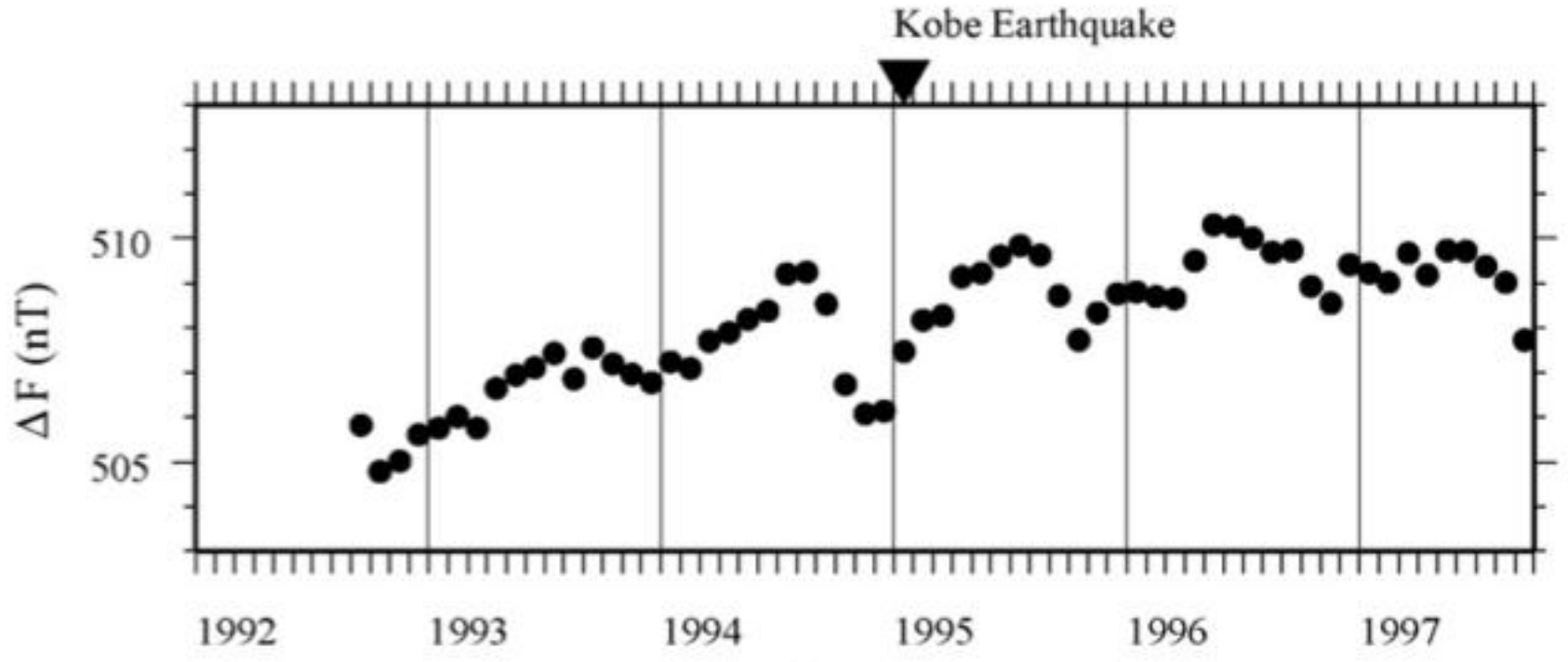
Kobe Earthquake
510
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ΔF (nT)
1992
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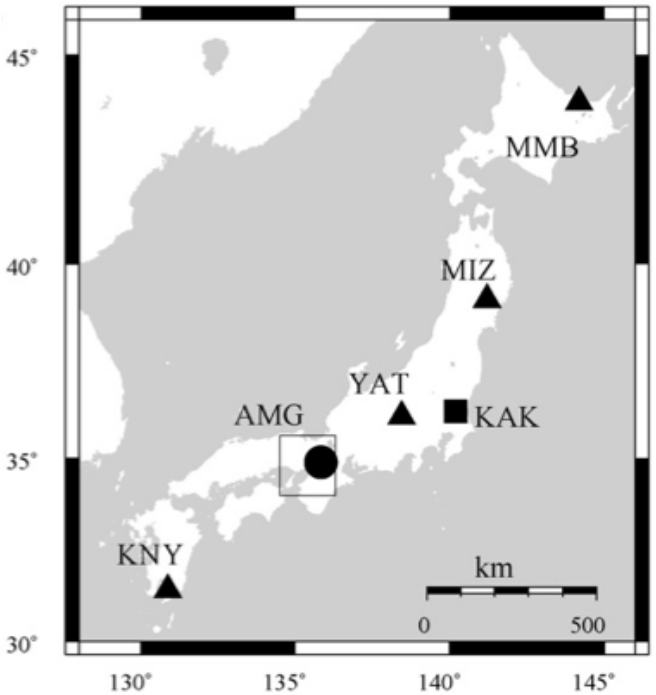
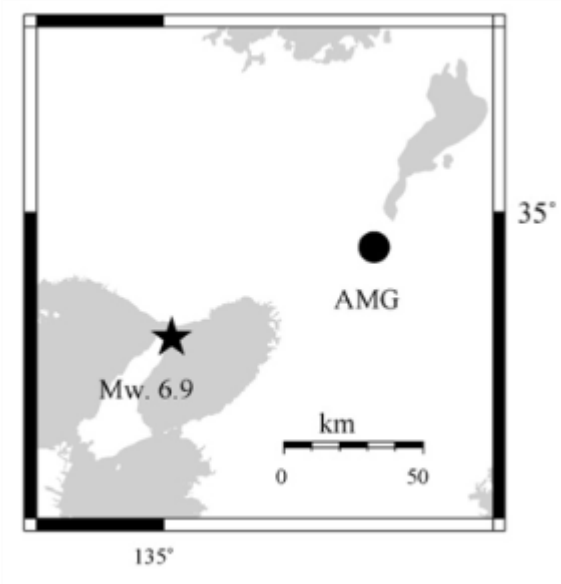
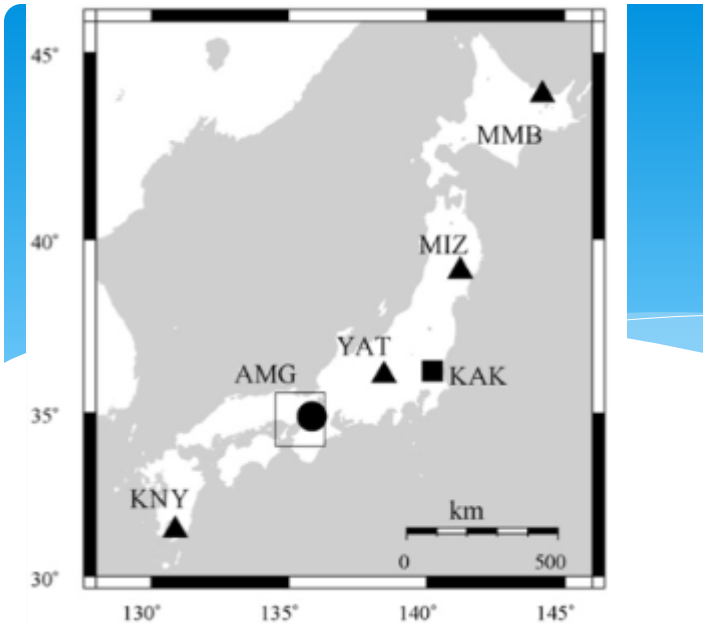
Year


45°
40°
35°
30°
130°
135°
140°
145°
MMB
MIZ
YAT
AMG
KAK
KNY
km
0
500

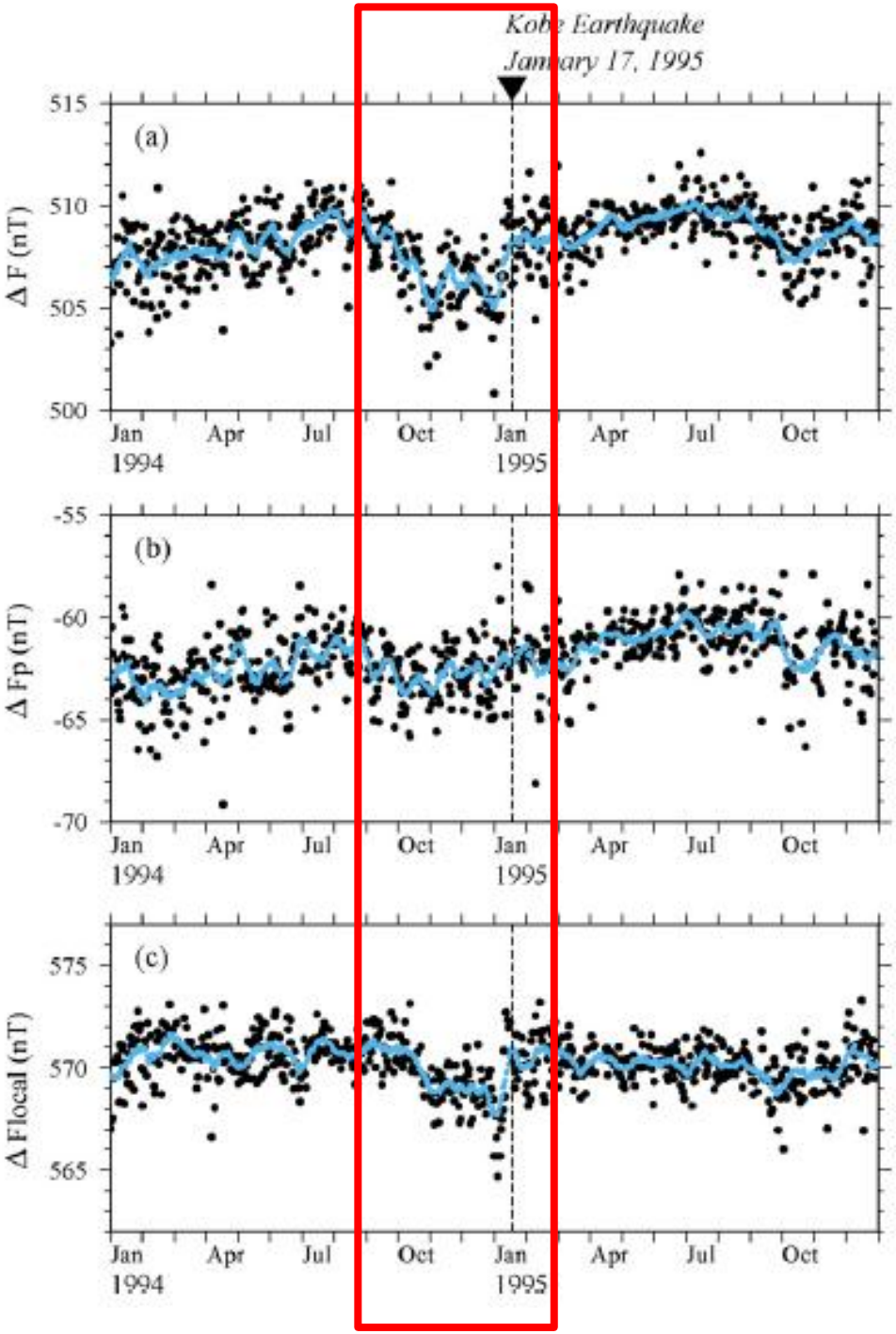

35°
AMG
Mw. 6.9
km
0
50
135°

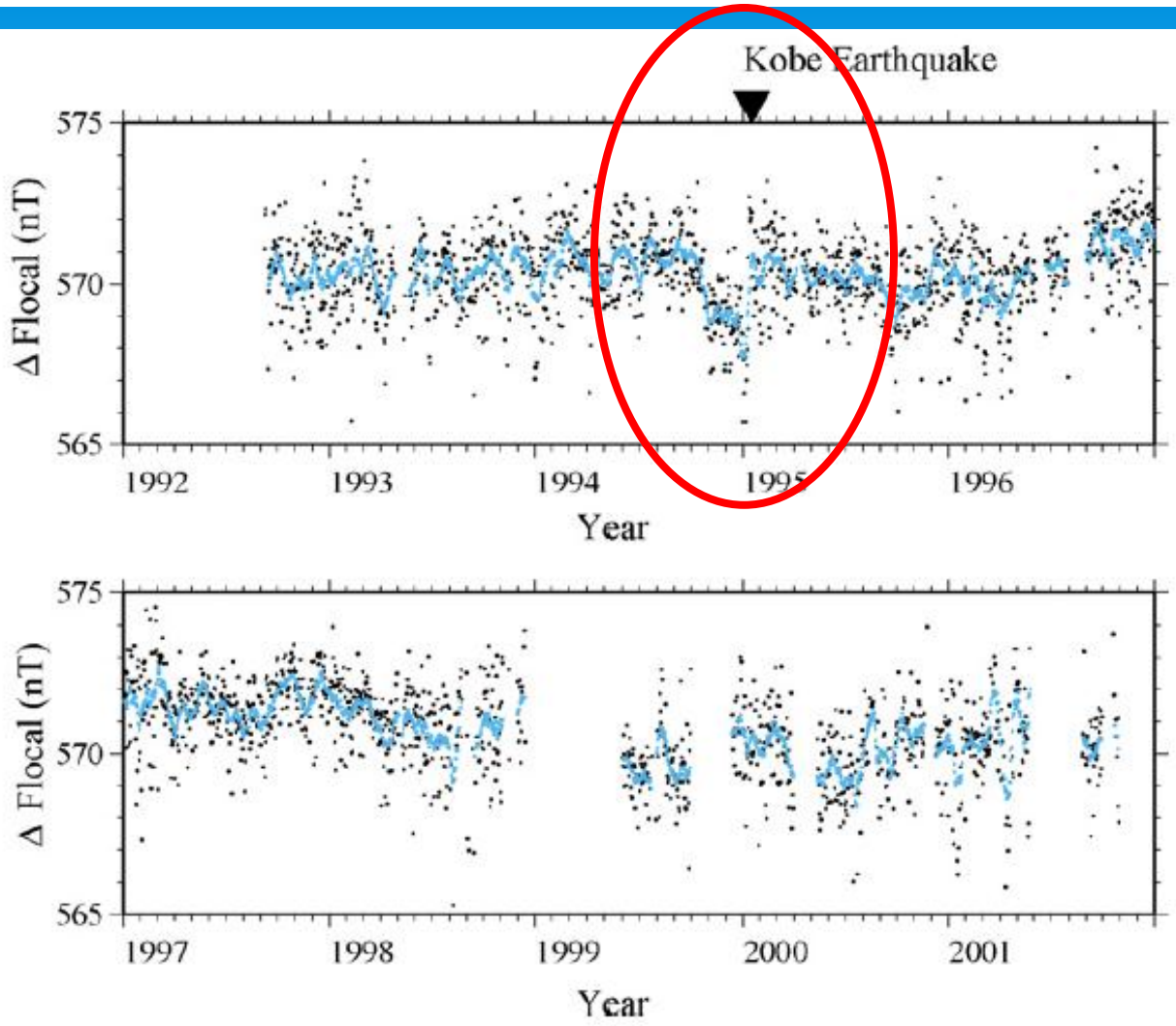


ΔF = simple difference between AMG and reference station KAK

ΔF_p = total geomagnetic field model at AMG to reference those at KAK

$\Delta F_{local} = \Delta F - \Delta F_p$

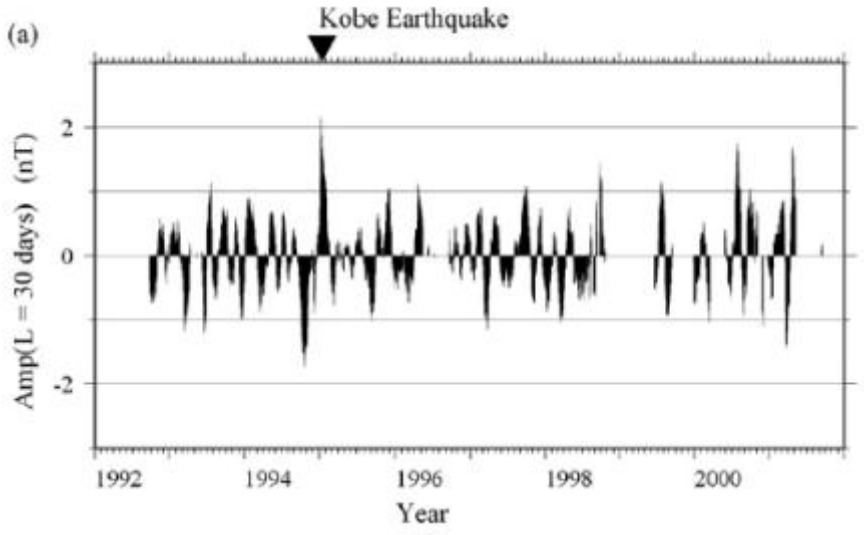


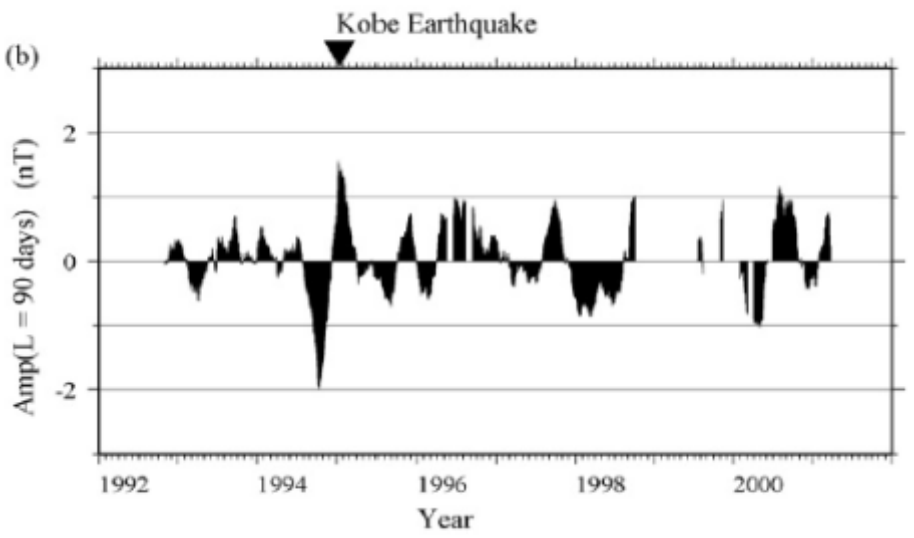


$$F_p(x, y, t_n) = \sum_{k=1}^{K} X_k(x, y) T_k(t_n) \quad (j = 1, \ldots, J),$$

$$Amp(L;t) = \frac{1}{L}\sum_{n=-L}^{-1} \Delta F_{local}(t_n) - \frac{1}{L}\sum_{n=0}^{L-1} \Delta F_{local}(t_n).$$

Amp expresses differences in L-day running means between two successive periods.

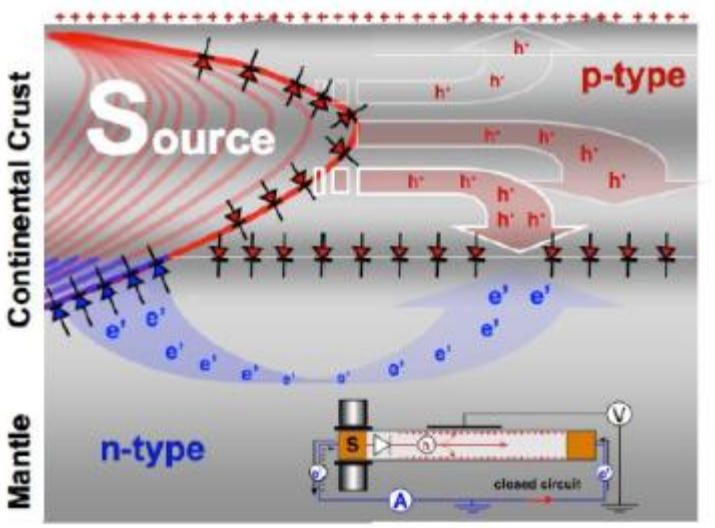


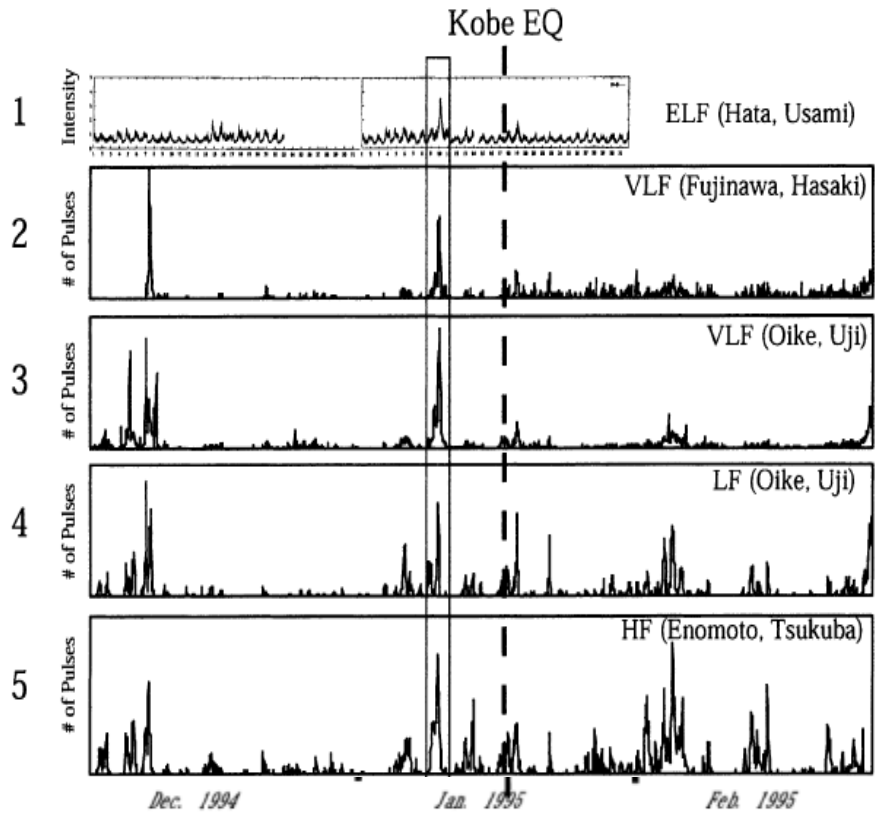


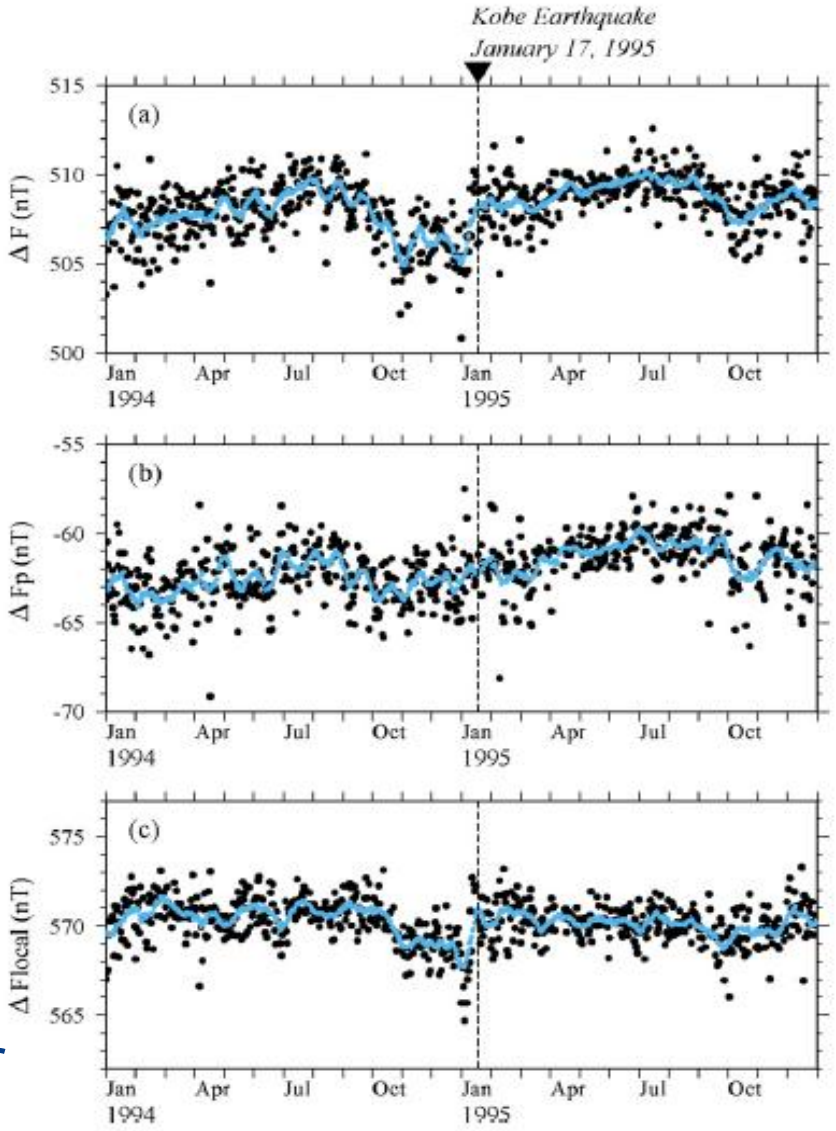
Result & Discussion

* The detected anomalies in the magnetic field **resulted from regional-scale changes** in the physical status of the Earth's crust.

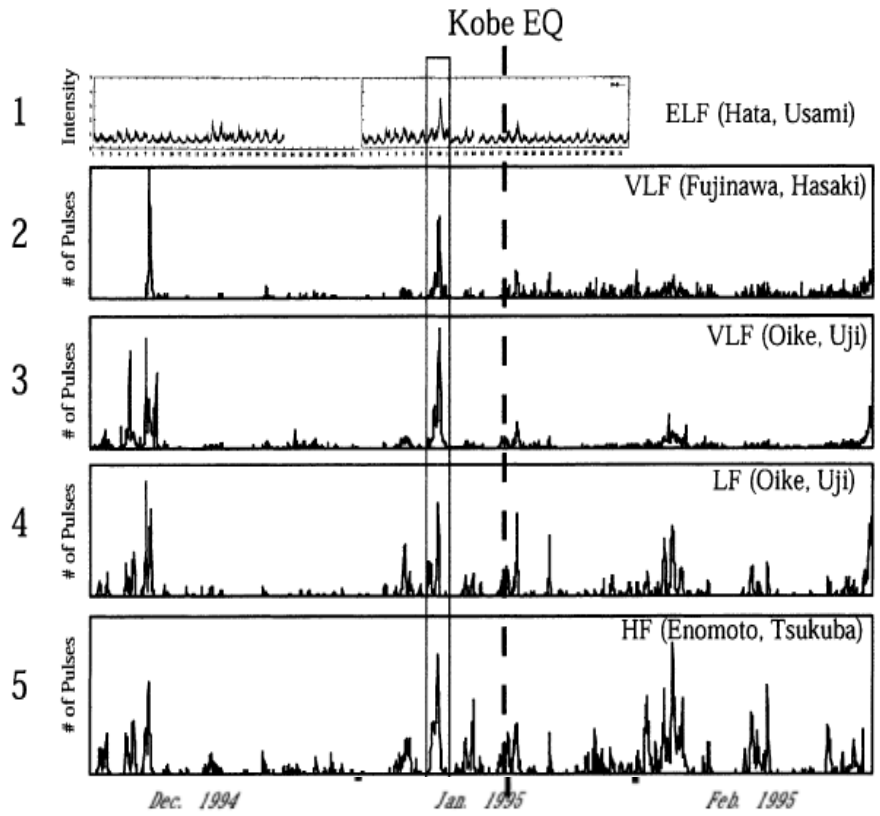
* One explanation is that **changes in the stress field generate voltage differences** in the crust.

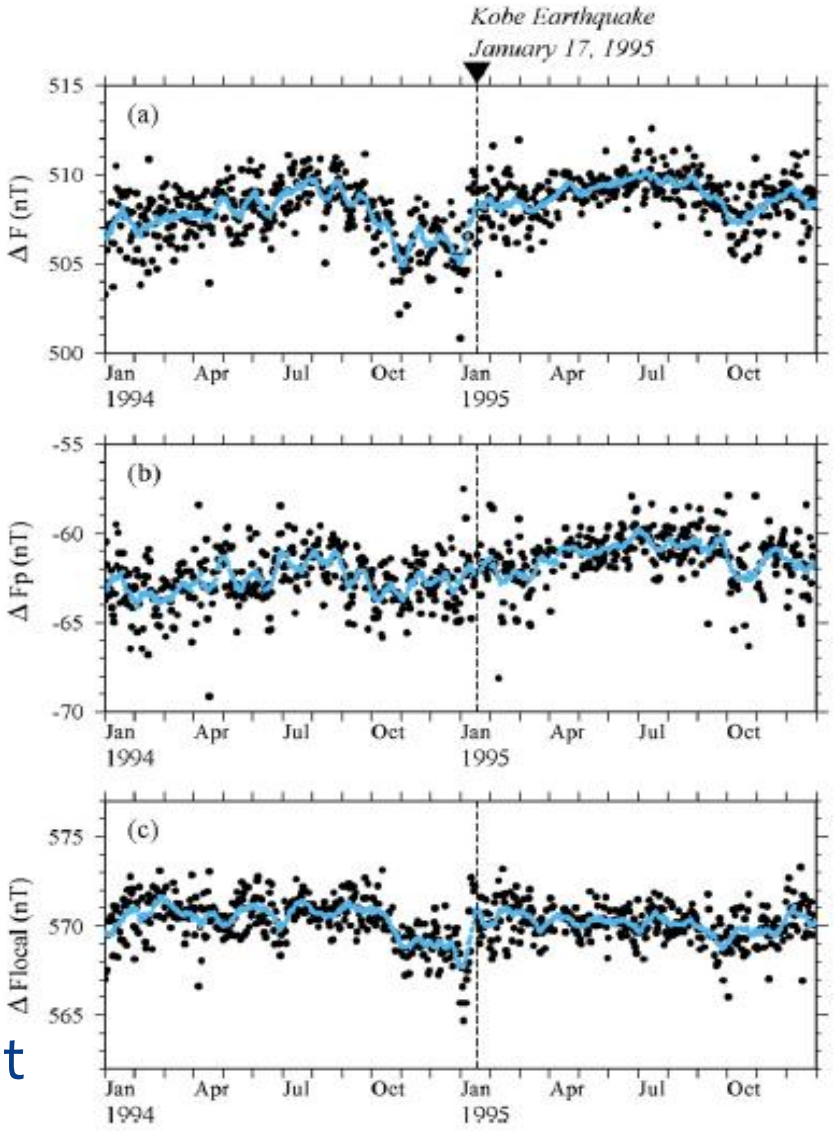






The timing of the sudden increase in the total force value recorded just before the Kobe earthquake is similar to the timing of electromagnetic waves reported by Nagao et al. (2002)





This coincidence supports the hypothesis that pre-seismic anomaly in the electrical properties of the crust is the sources of changes in the magnetic field

OUTLINE

- Introduction
- Method
- Result & Discussion
- Conclusion

Conclusion

* The **conductivity** of rock **under loading** was change obviously and the interaction with country rocks is like a battery.
* This phenomenon could come to a hypothesis that a pre-seismic **anomaly in the electrical properties** of the crust is the **sources of changes in the magnetic field**
* Prominent **variations in total geomagnetic field intensities** were observed by a proton magnetometer prior to the 1995 Hyogo-ken Nanbu(Kobe)earthquake.
* Base on the **difference between observed variations** and those predicted by a **regional total geomagnetic field intensity model**, the variations observed prior to the earthquake are identified **as local phenomena**, possibly **arising form the Earth crust**.

Thank you for your attention !!!