Science Lecture at PCSHS Loei
What is seismograph and
How to use seismograms

Lecture by Yoshio Okamoto

PCSHS Loei on 13th Dec. 2022

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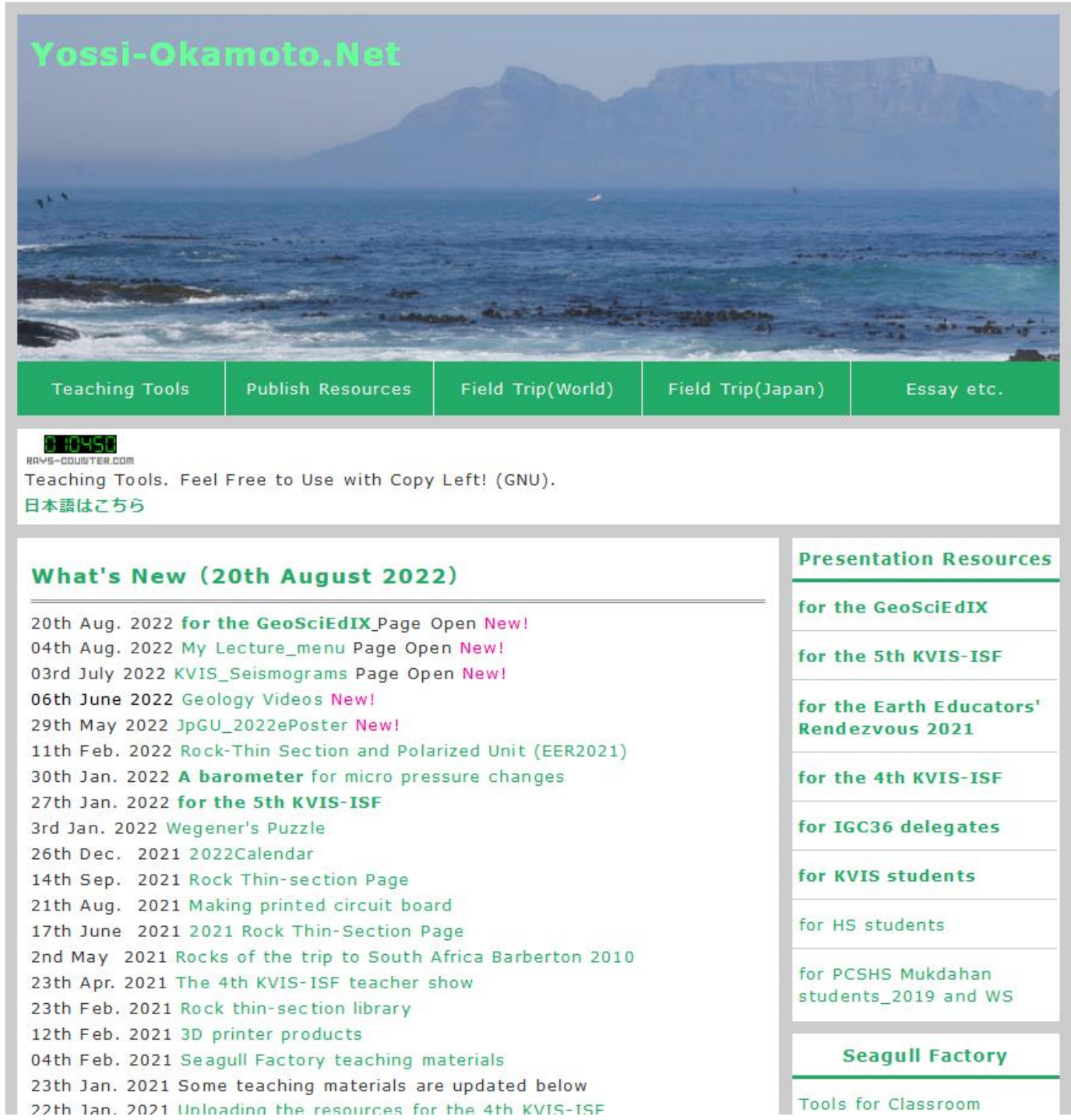
http://www.yossi-okamoto.net/index_e.html

Wh

- Earth science high scho
- Study at a teacher trair
- Associate professor an
  Osaka-Kyoiku Univers
- Earth Science visiting te
  at PCSHS Mukdahan
- School seismograph sys
  this year: PCSHS Loei
- **3D seismicity map**, tsu
- Polarized microscope u
- Linux Programing (awk, tc.)
- 3D printing (2019-)



My policy! for science education

- I will show you two videos of the volcanic eruptions.

- What is the fundamental difference between the two videos?


1991 Unzen Pyroclastic Flow

A Day in Pompei AD79

Comparison of two videos

- Real (Fact) VS. CG (Artificial)
- Low-resolution High-

- Fact

Science is based on!!

- Artificial

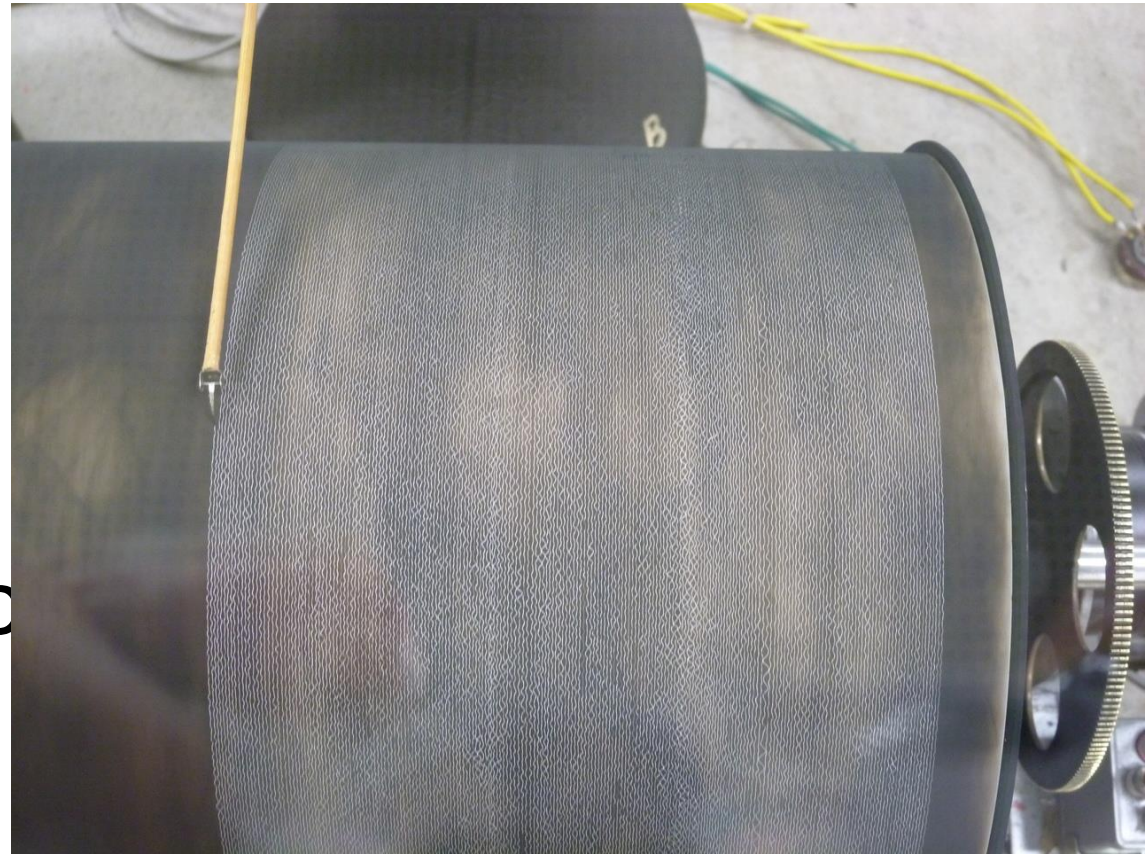
Seismology: studying earthquake

- In Japan, there are many earthquakes; so the study of earthquakes kicked off at the end of 19 century in Japan by inviting foreign professors.
- Most of them were from Europe, so they did not know about earthquakes, but they were very surprised at the moving ground at Yokohama or Tokyo within a week’s stay.
- So, some of them established “Japan seismological society”.
- This is the first seismological society in the world.

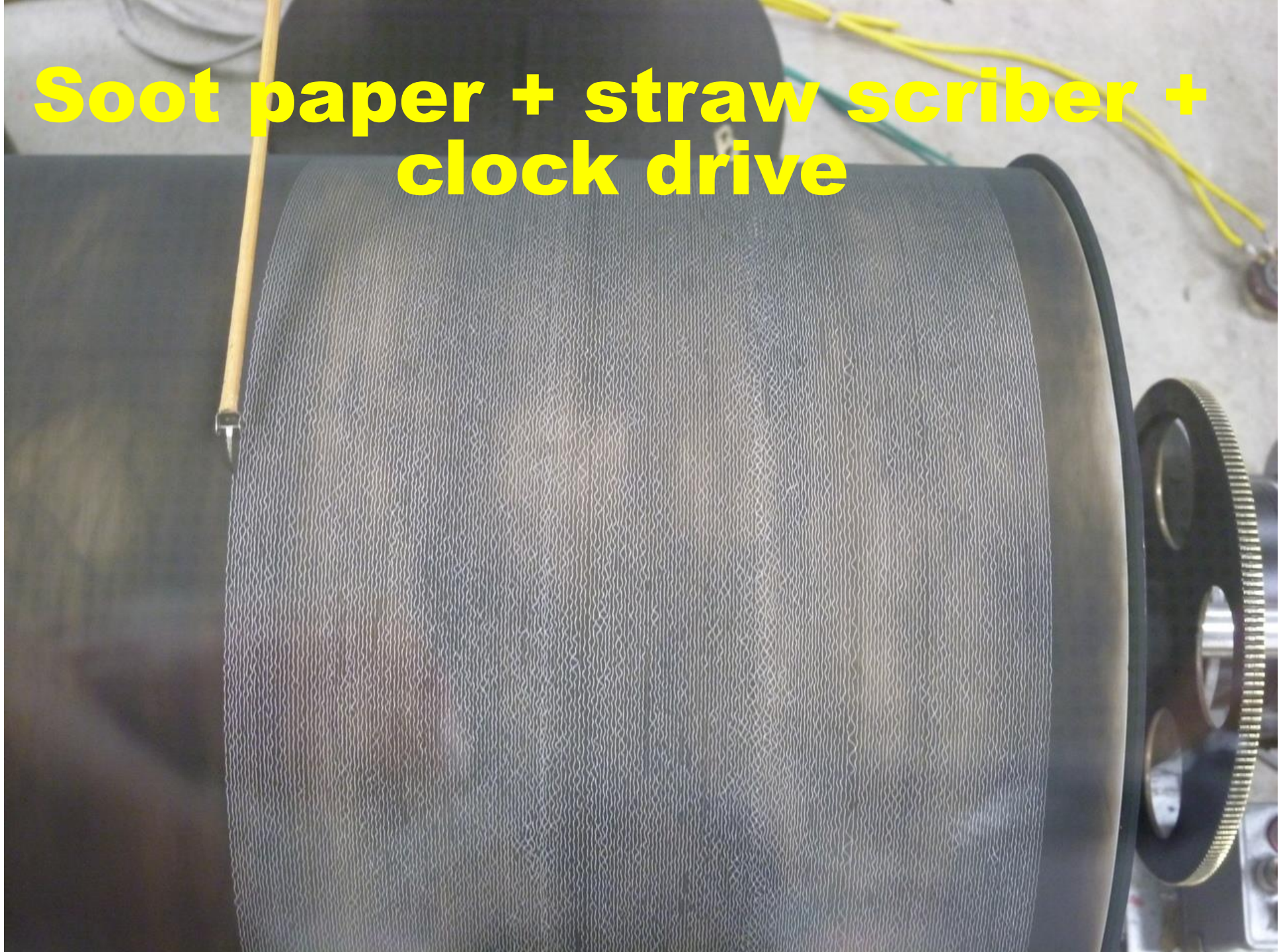
Principle of Seismometer

Shaking in Latin

- Fixed mass in shaking
- Another movement in an earthquake shaking
- Pendulum (Vertical / Horizontal)
- Sensor + Amplifier
- →Mechanic (lever)
  - →Electro-magnetic
  - →Capacitance
- Recording system
  - →Old: straw and soot paper
  - Pho
  - paper/Galvanometer
  - →New: PC



Omori type mechanical seismograph (1896) Seismograph museum at ERI (Tokyo Univ.)


Soot paper + straw scriber +
clock drive

Off course these system are too old fashioned!
However old system is completely visible and comprehensive!

Modern seismograph systems at Matsushiro seismic observatory (Japan Meteorological Agency)

Film case Seismometer 1997

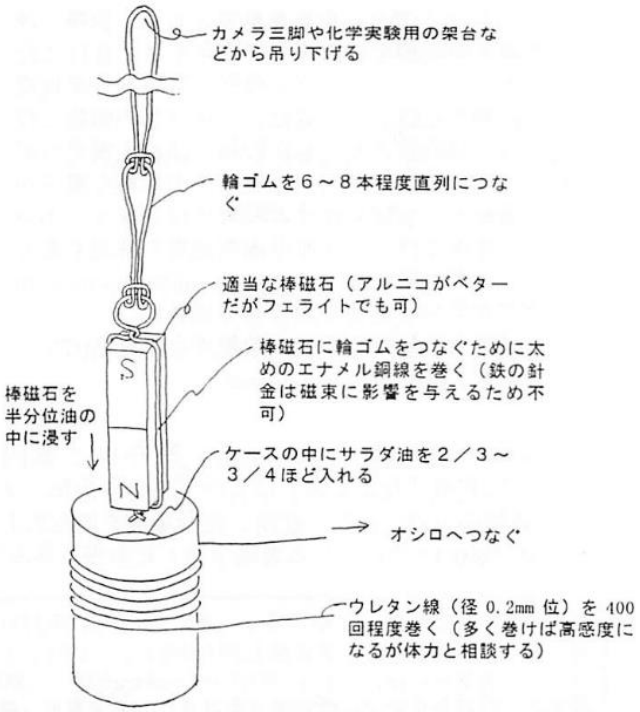


図２フィルムケース地震計センサー部の組み立て

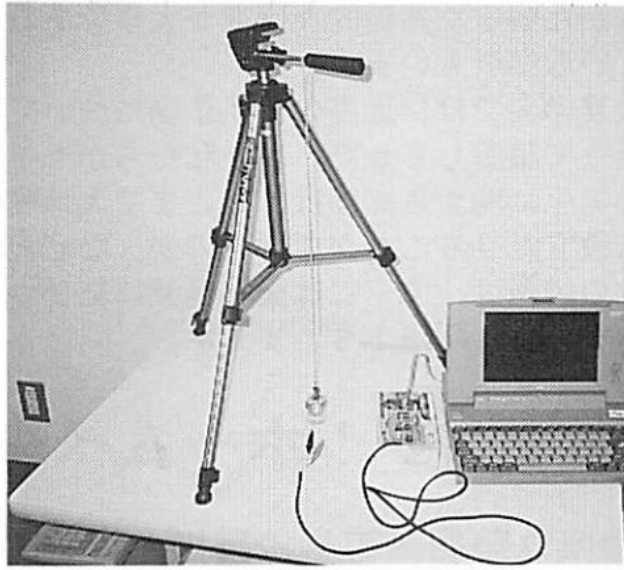


図１フィルムケース地震計全景

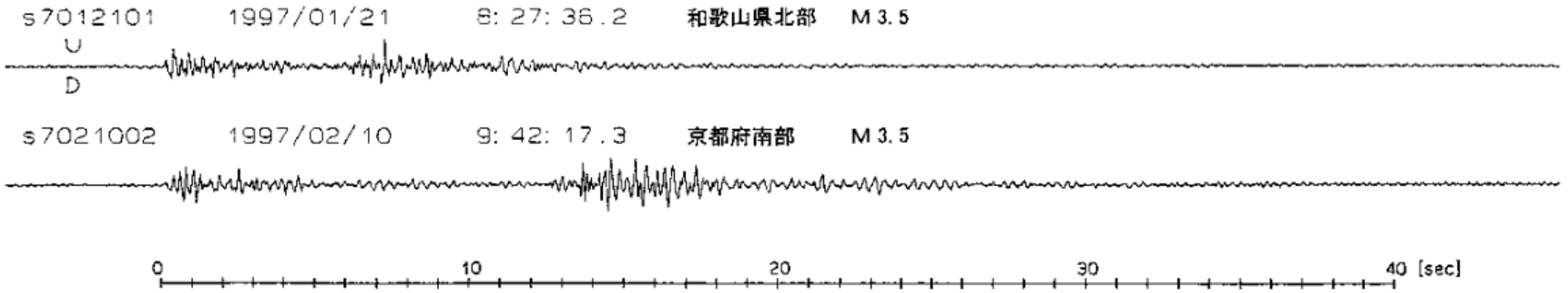


図１　フィルムケース地震計で記録した地震波形

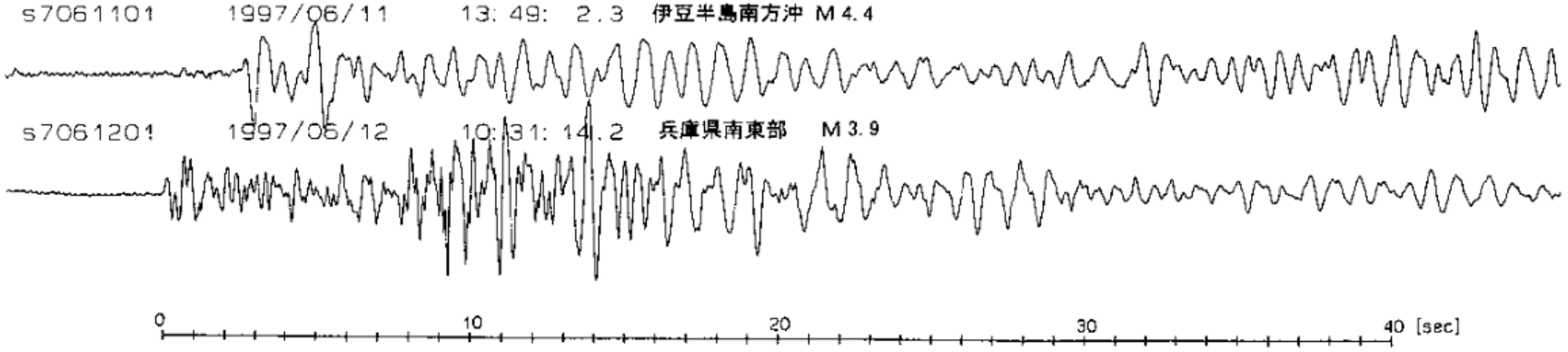


図３　図２の改良センサーによる記録波形（震源は気象庁速報値による。図はいずれも文献より引用）

My Film case Seismometer 1997

- Pendulum
- Sensor
- Damper
- Amplifier
- Recording unit
- Software

- Rubber band + magnet
- Magnet + coil
- Aluminum pipe
- OP amp. circuit
- Arduino + PC
- Arduino IDE + Processing

Principle of seismometer

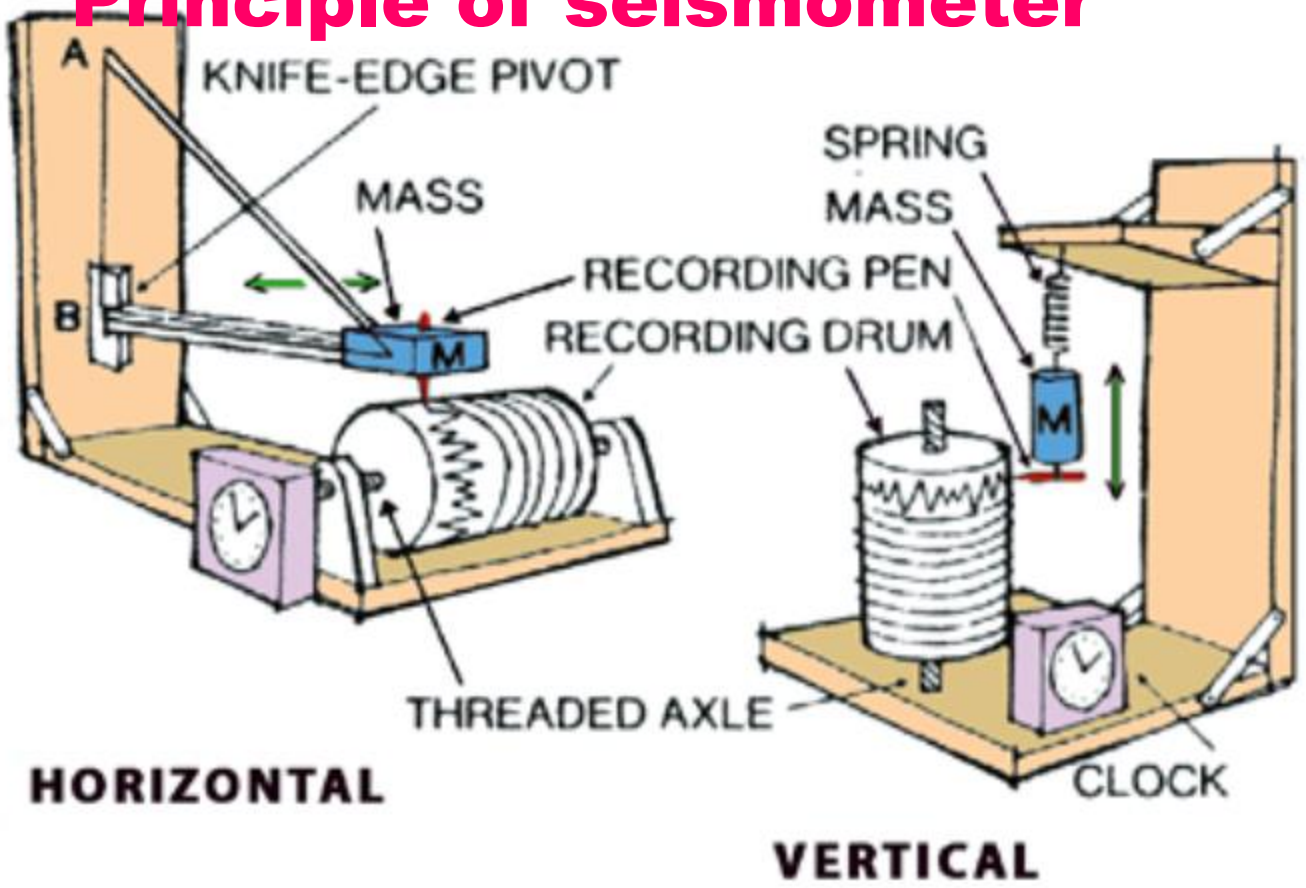
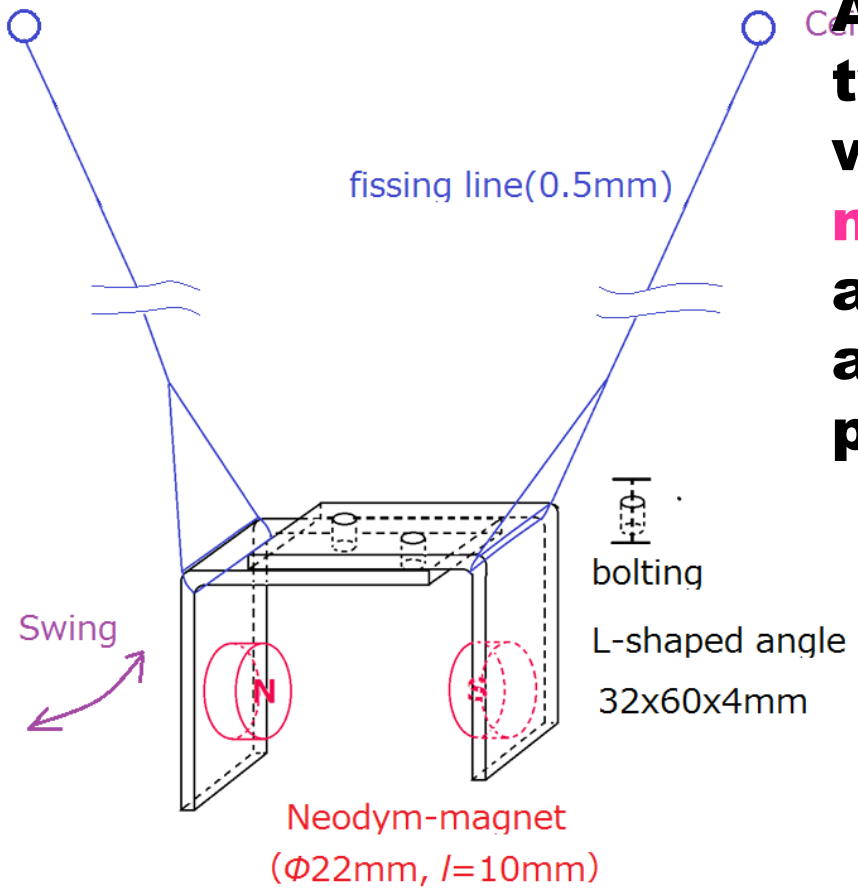


Figure 2—*The horizontal seismograph (above left moves only in the horizontal plane. Vertical seismographs ((Figure 1 and above right) use a "soft" link between the earth-anchored instrument and the suspended mass. In this design, the mass hangs from a spring, which absorbs some of the motion and causes the mass to lag behind actual motion. (From USGS.gov.)*

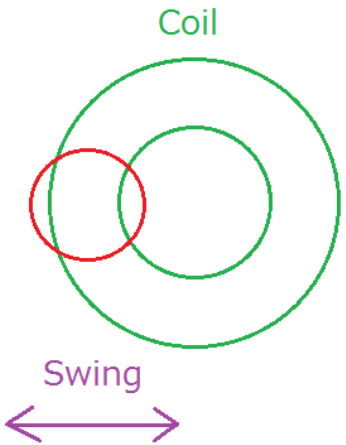
http://www.iris.edu/hq/files/programs/education_and_outreach/aotm/8/Seismograph_Background.pdf

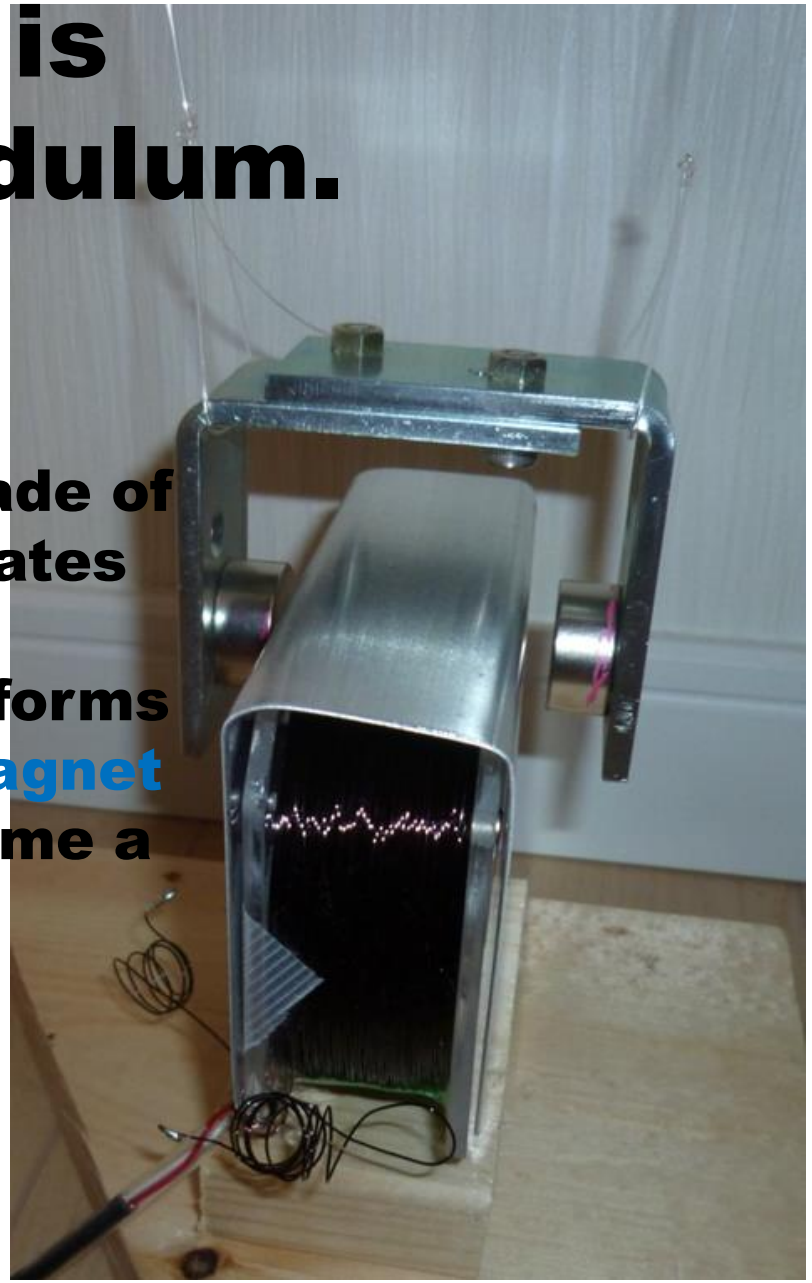
A simple bifilar suspension is used for the horizontal pendulum.

An aluminum plate covering coil is used as a “dumper”

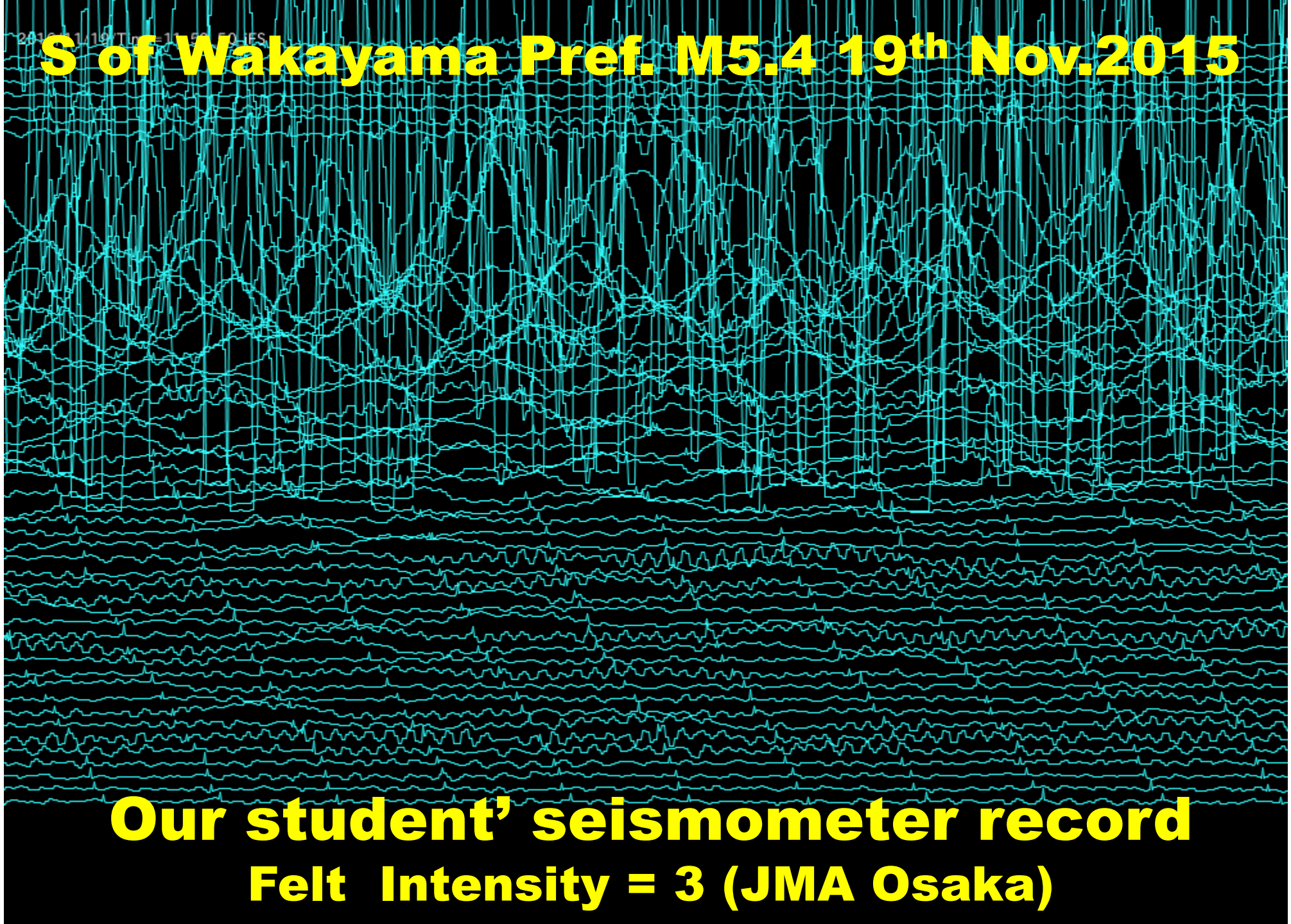


A magnetic circuit made of two L shaped steel plates with two columnar neodymium magnets forms a U-shaped bipolar magnet as a whole, also become a pendulum's weight.



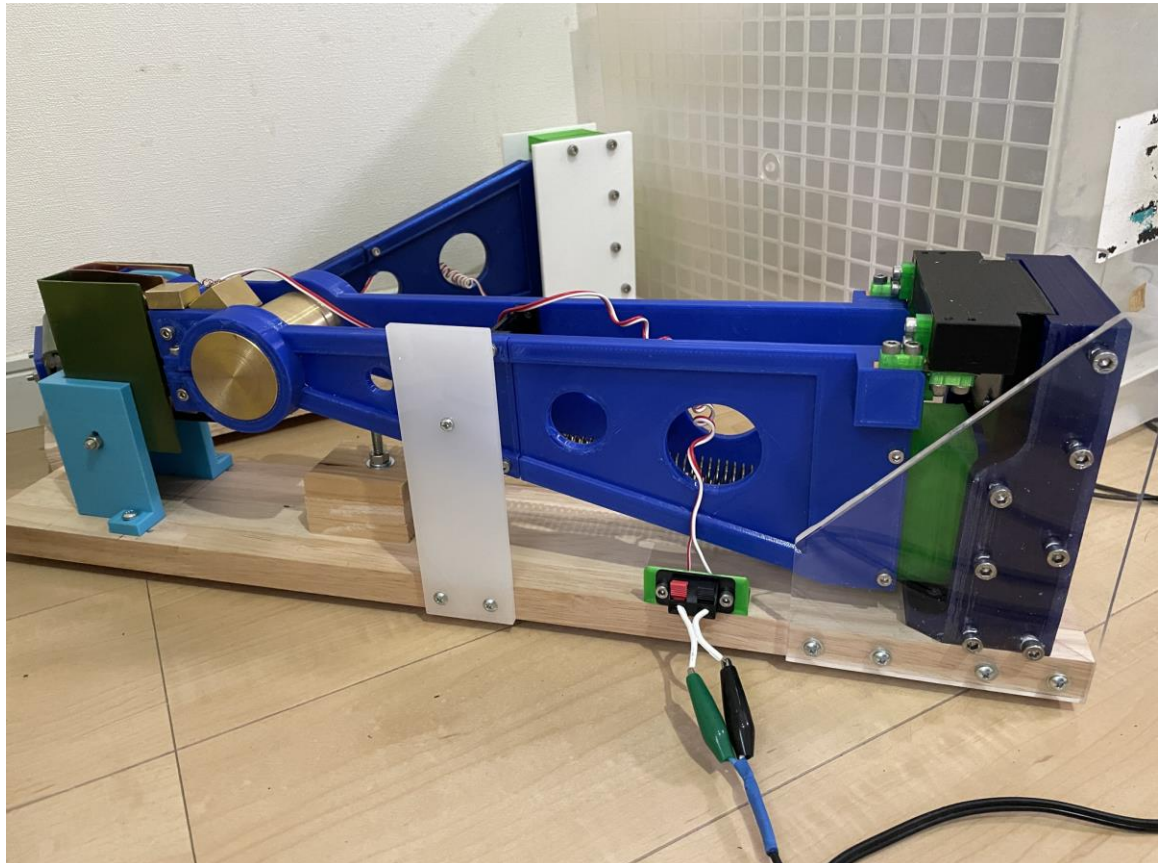


Student's horizontal pendulum


S of Wakayama Pref. M5.4 19th Nov.2015
Our student' seismometer record
Felt Intensity = 3 (JMA Osaka)

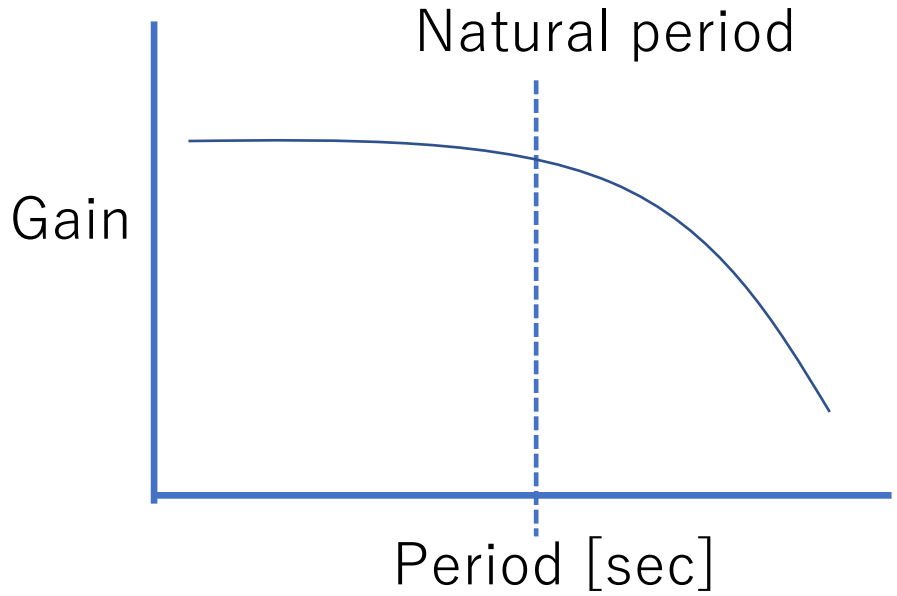
My New Seismograph

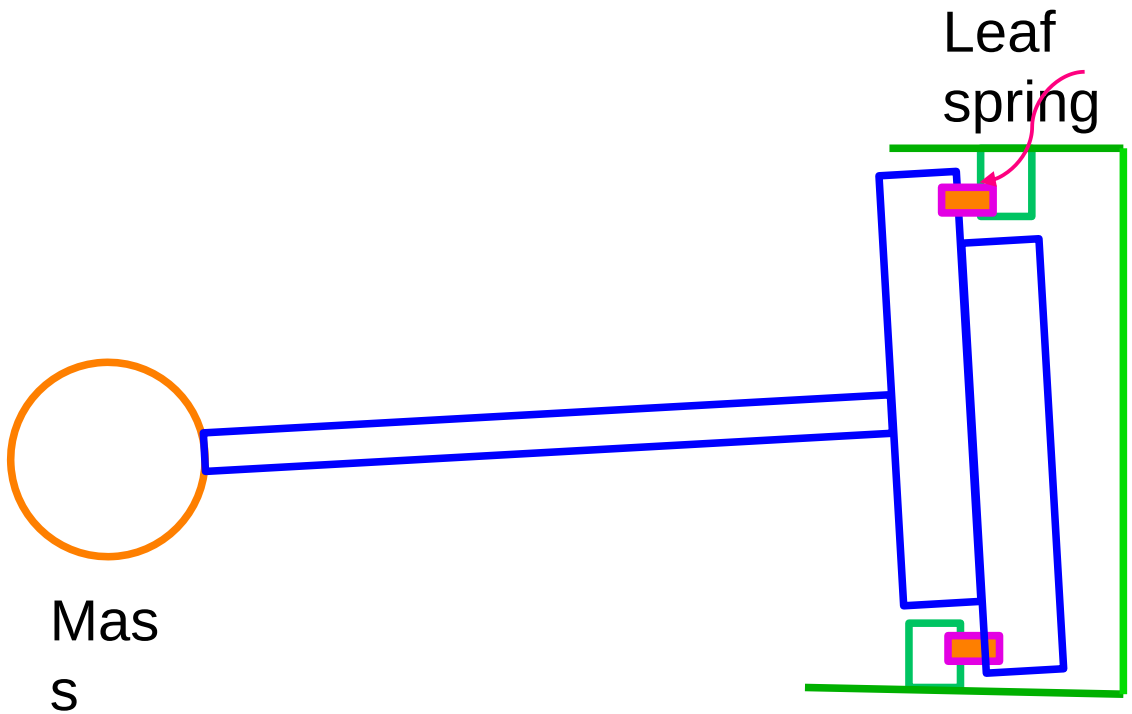
- Horizontal: Pascwitz type (Swing-gate pendulum)
- Vertical: Kirnos type (modified Lacoste pendulum)

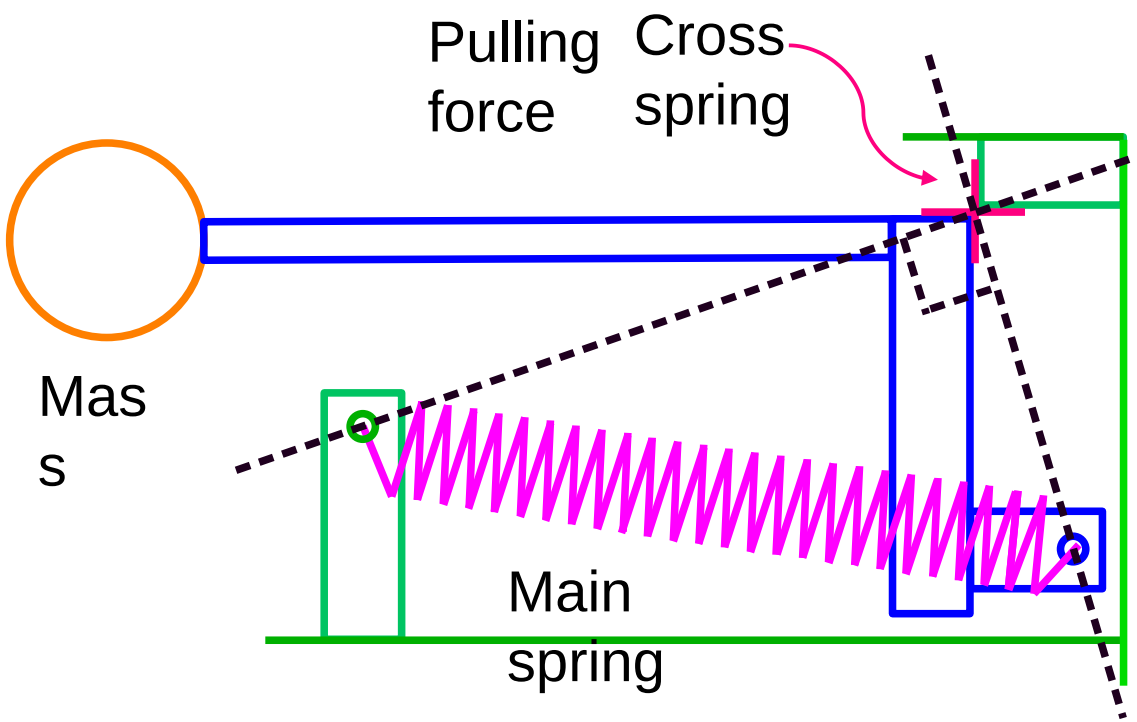


- Long-period pendulum
- Longer period ->

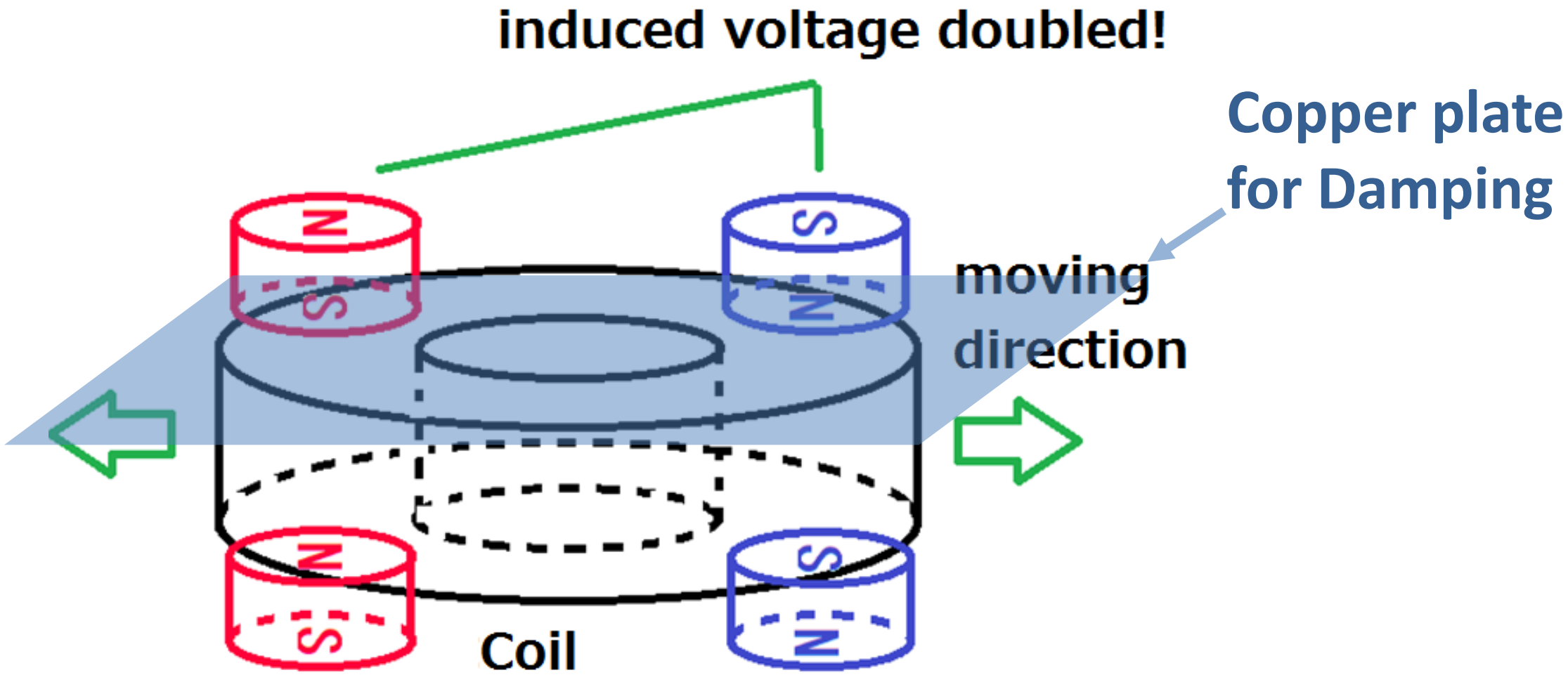
  more oversea earthquakes





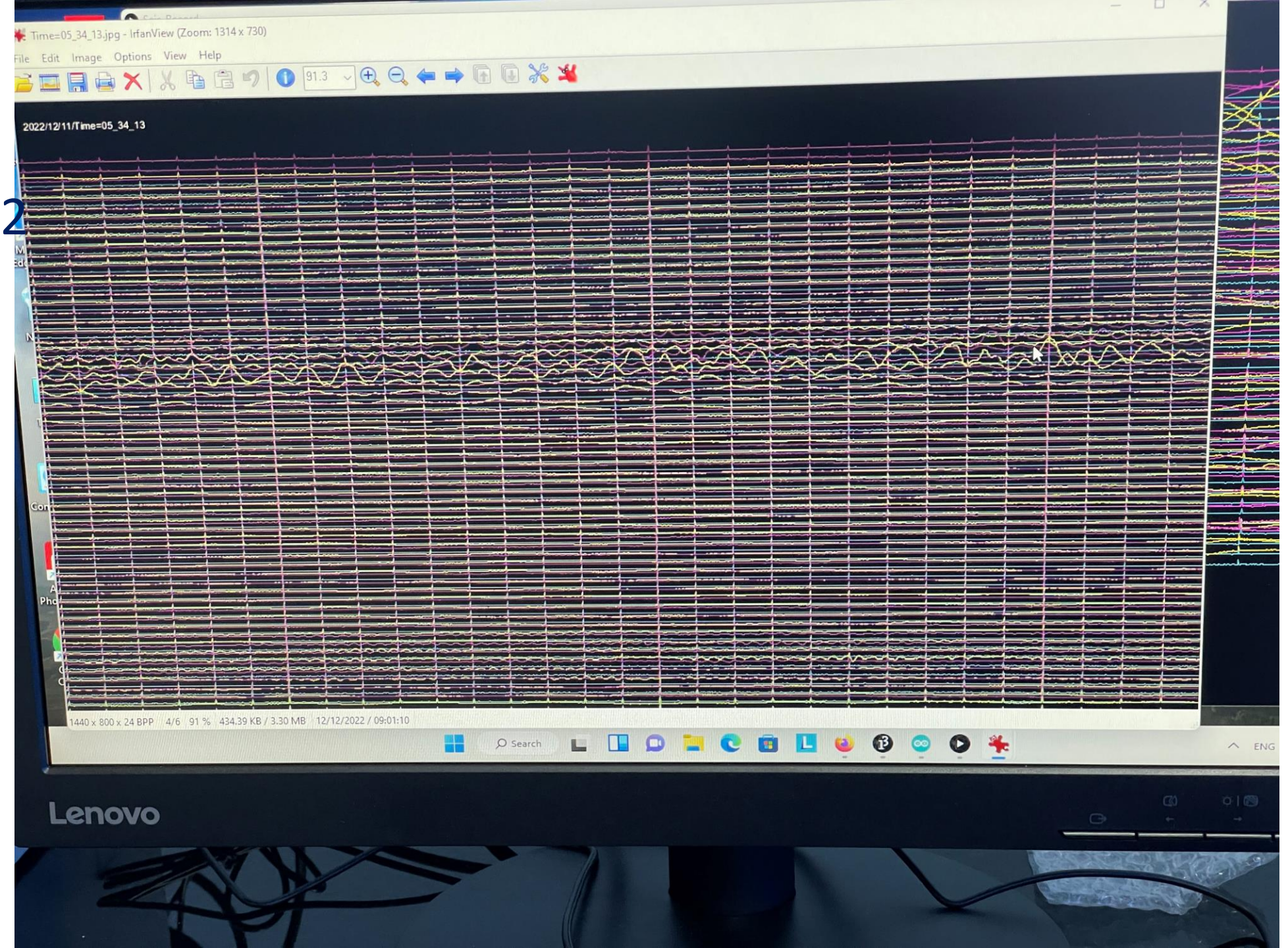


Structure of Electromagnetic sensor



Astronomy room

An unknown earthquake!
On 11th Dec. 2022 Morning



Why and How occur the 1995 Kobe earthquake? By SSJ 1996

Left： Kahaku_Web
Right： Osaka kanku observatory

Old JMA 59-type Seismographs until 1995

59型地震計

ヴィーヘルト式地震計にかわって全国の気象台・測候所で観測の主力として使われていた電磁式地震計のひとつで、この写真のものは正式には気象庁59C型直視式電磁地震計といいます。1959（昭和34）年に開発されたことから59型という名がついています。振り子の固有周期は５秒、倍率は100倍で、地震動の速度に比例した電圧を増幅回路で変位にして記録します。記録方式は初め煤書き、後にはこのようなペン書き式に変わりました。何回かの改変を経ながら４０年ものあいだ使われてきた地震計でしたが、今では計測震度計や新しい地震計にとってかえられ、その役割を終えています。

Epicenter and Magnitude (Righter scale)　(courtesy by Ms.Sayoko Furuta, JMA)　　30th Sep.2017

Yoshio Okamoto (visiting teacher of KVIS) yossi.okamoto@gmail.com

Purpose: Learn how to locate the epicenter and calculate magnitude!

Read arrival times of P- and S-waves and maximum amplitudes from the seismograms recorded by the JMA-59 type seismographs, and determine the epicenter and earthquake magnitude (Richter scale) from these values.

<Ref.1>. The JMA-59 type seismograph: standard seismograph for routine observations conducted by the Japanese Meteorological Agency (JMA) from the 1960s to 1990s using an analog recording system (see right figure).

Preparation:　Ruler, Compass

Overview of seismograms:

Fig.1, 2 and 3 are displacement seismograms of an earthquake that occurred on June 28, 1994 in the Kinki district Japan. The seismograms were recorded by pen recorders of seismographs installed in Hikone,　Osaka　and Toyo-oka observatories, respectively.

Each seismograph recorded three components (NS, EW and UD) of a ground motion: NS indicates north-south, EW indicates east-west and UD indicates up-down.

Seismograms were recorded from left to right in chronological order. And also continues to next line.

The right figure marls are stamped every minute. The time mark span is 60 mm and then 1 mm of the record corresponds to 1 second. Also the amplification of seismograms is just 100 times. So the 1mm amplitude on a seismogram corresponds to 0.01mm ground motion.

Procedure:

Step 1.

Read arrival times of P- and S-waves by 0.1 second in Fig.1, 2 and 3 and write them down in Table 1.
It will be easier to work using a ruler. The time with a mark (○) is for reference.
Pick P-wave arrival in the vertical (UD) component and pick S-wave in the horizontal (NS and EW) components.
The arrival time of the S-wave should be read the earlier pick between the two components.

Step 2.

Read maximum amplitudes of horizontal (NS and EW) components by 0.1 mm and write them down in Table 1.

Step 3.

Calculate each duration of preliminary trends of the earthquake (S-P time): T sec. and calculate each hypo-central distance: D km in Table 1. Round them off to a decimal place and write them down in Table 1. The Omori coefficient k is fixed to 8.75 here.

Step 4.

Obtain each amplitude of three seismograms: A mm from the maximum half-amplitudes of the two components (NS and EW) in order to determine magnitude: M. To be simple, obtain this value by drawing a figure: halve the maximum amplitudes read in Step 2 and draw a right triangle whose sides adjacent to the right angle are of lengths of the maximum half-amplitudes (see Fig.4).
Read the value of A using a ruler, and write them down to a decimal place in Table 1.

<Ref.2.>

The formula to calculate M in this exercise is $M = \log(A) + 1.73*\log(D) - 0.83$; this is used by JMA for earthquakes shallower than 61 km (Tsuboi, 1954).
The term A is the maximum horizontal amplitude obtained from the two components (NS and EW).

Step 5.

Draw three circles from each observation station at its center and with a radius of the hypo-central distance D and find the location of the epicenter, as shown in Fig.5.

<Ref.3>

Three or more common chords that link the points of intersection of the circles with a radius of the hypo-central distances always intersect at a point. This is the epicenter.

Step 6.

Fig.6 is a nomogram, which shows the logarithmic scale of amplitude A on the left, the logarithmic scale of hypocentral distance D on the right, and the scale of magnitude M between them. A value of M at an intersection of the scale of M and a line connecting points of A and D becomes a magnitude of an earthquake with the amplitude A at a location with the hypo-central distance D.
Draw a line for the earthquake and read the magnitude for each observation station. Write the values in Table 1.

Let's consider the following discussions.

1) Compare the location of the epicenter determined in this exercise and the epicenter determined by JMA.
2) Let the value of the magnitude of the earthquake in this exercise be the average of the three magnitudes in Table 1. Write the value in the right (　　) and compare with the value determined by JMA (　　).
3) Use the nomogram and see how the magnitude changes with 10 times of D while keeping A. Also, see how it changes with 1/10 of A keeping D fixed.

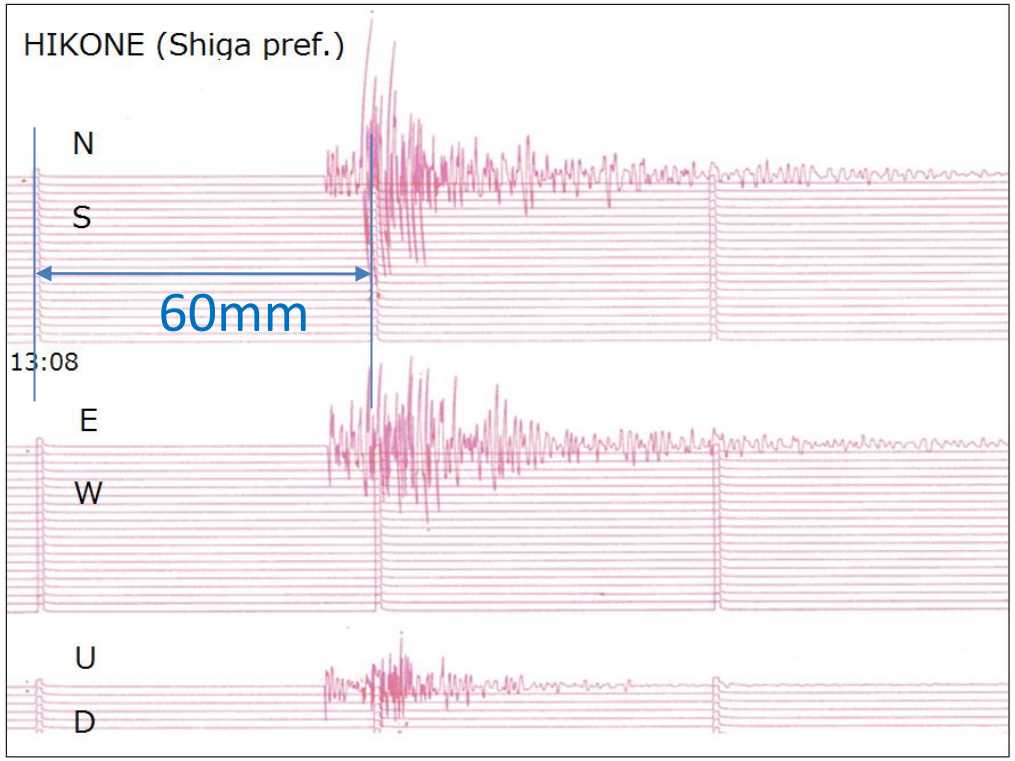
http://www.wikiwand.com/ja/

59type horizontal Seismographs in my house

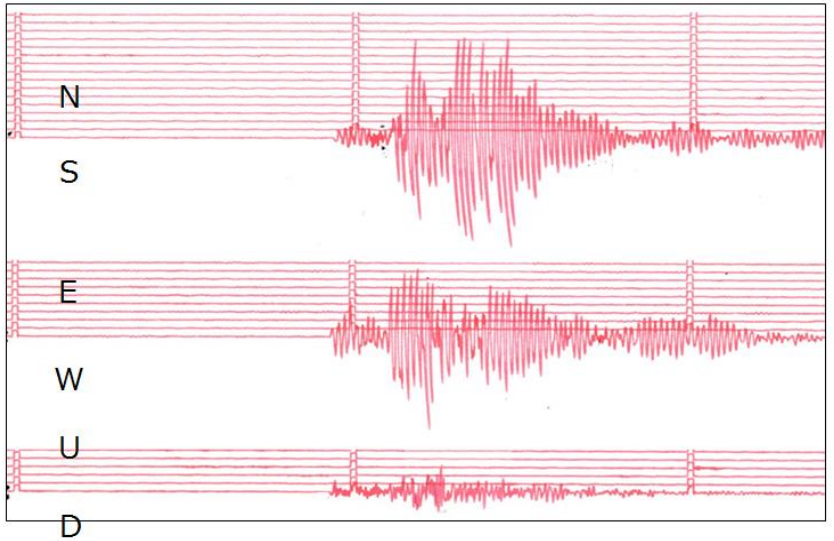
Table 1 : Values to obtain in this exercise

	HIKONE	OSAKA	TOYO-OKA
A arrival time of P-wave			
A arrival time of S-wave			
S-P time : T			
A hypocentral distance: $D = k \times T$ ($k = 8.7$)			
Maximum amplitude (NS)			
Maximum amplitude (EW)			
Maximum half-amplitude (NS)			
Maximum half-amplitude (EW)			
Amplitude : A			
Magnitude			

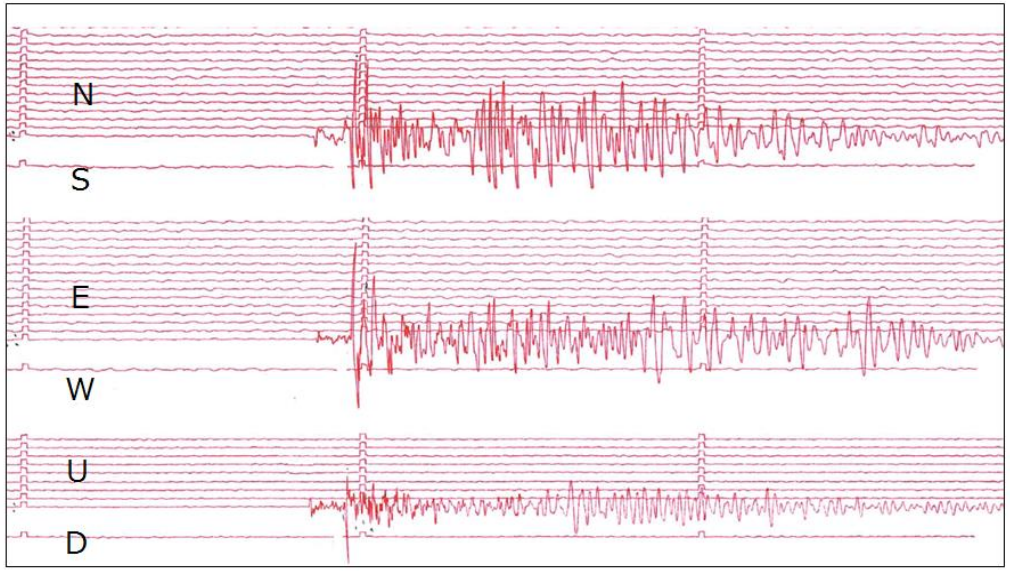
HIKONE (Shiga pref.)

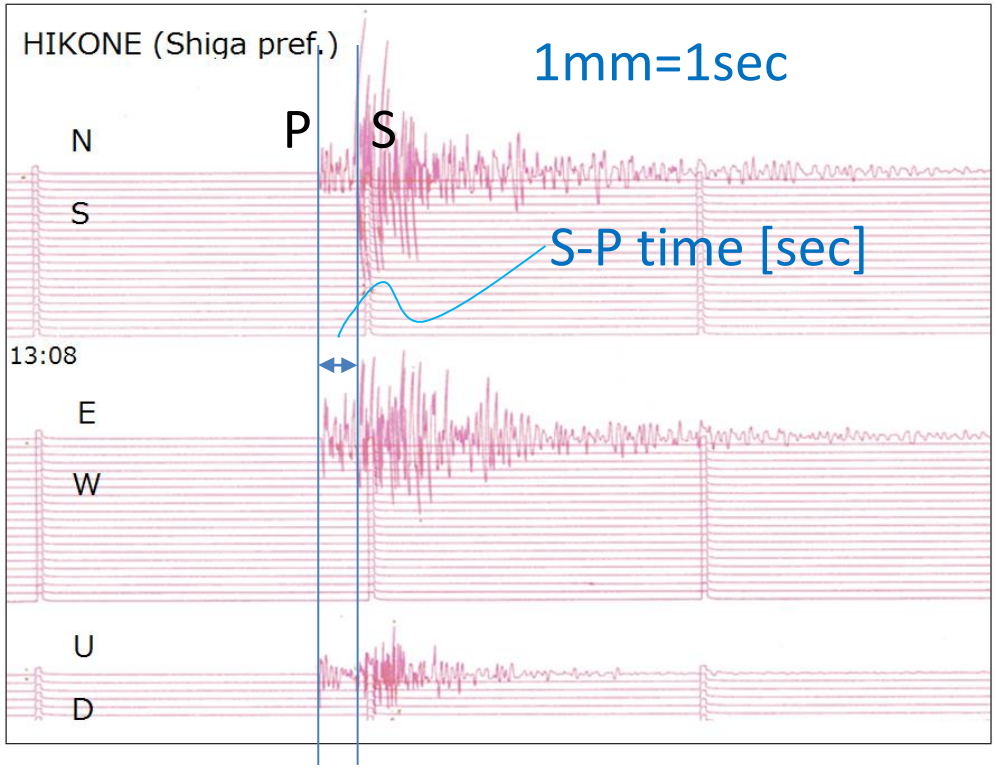


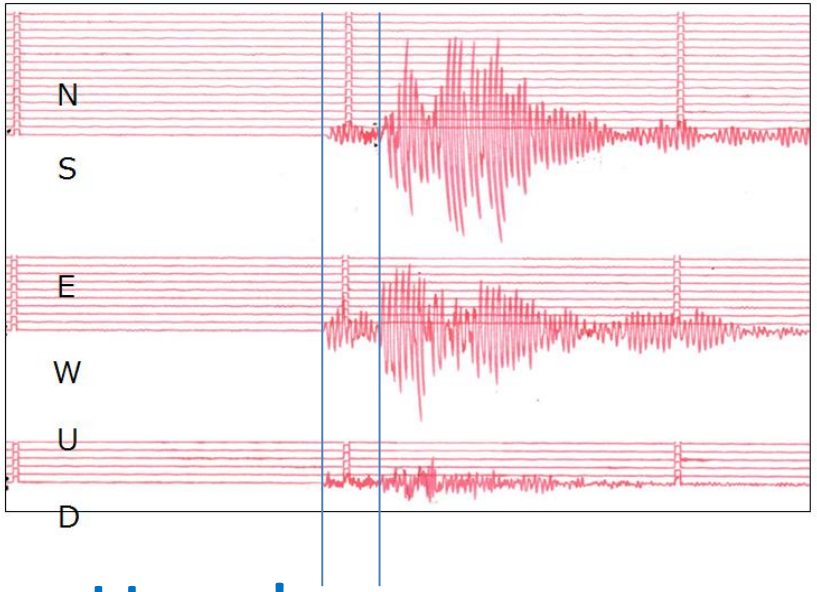
TOYO-OKA (Hyogo Pref.)



OSAKA

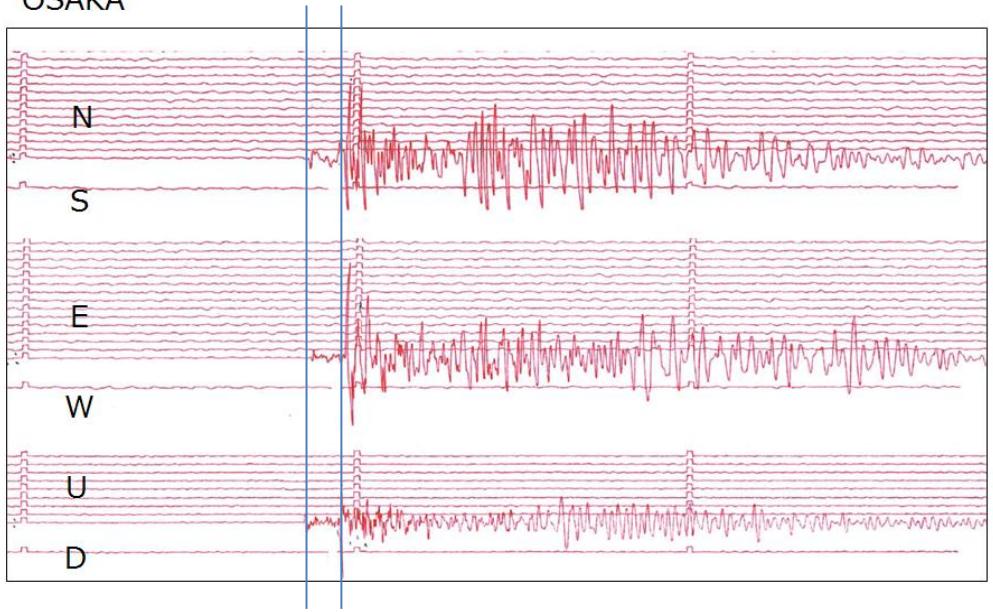






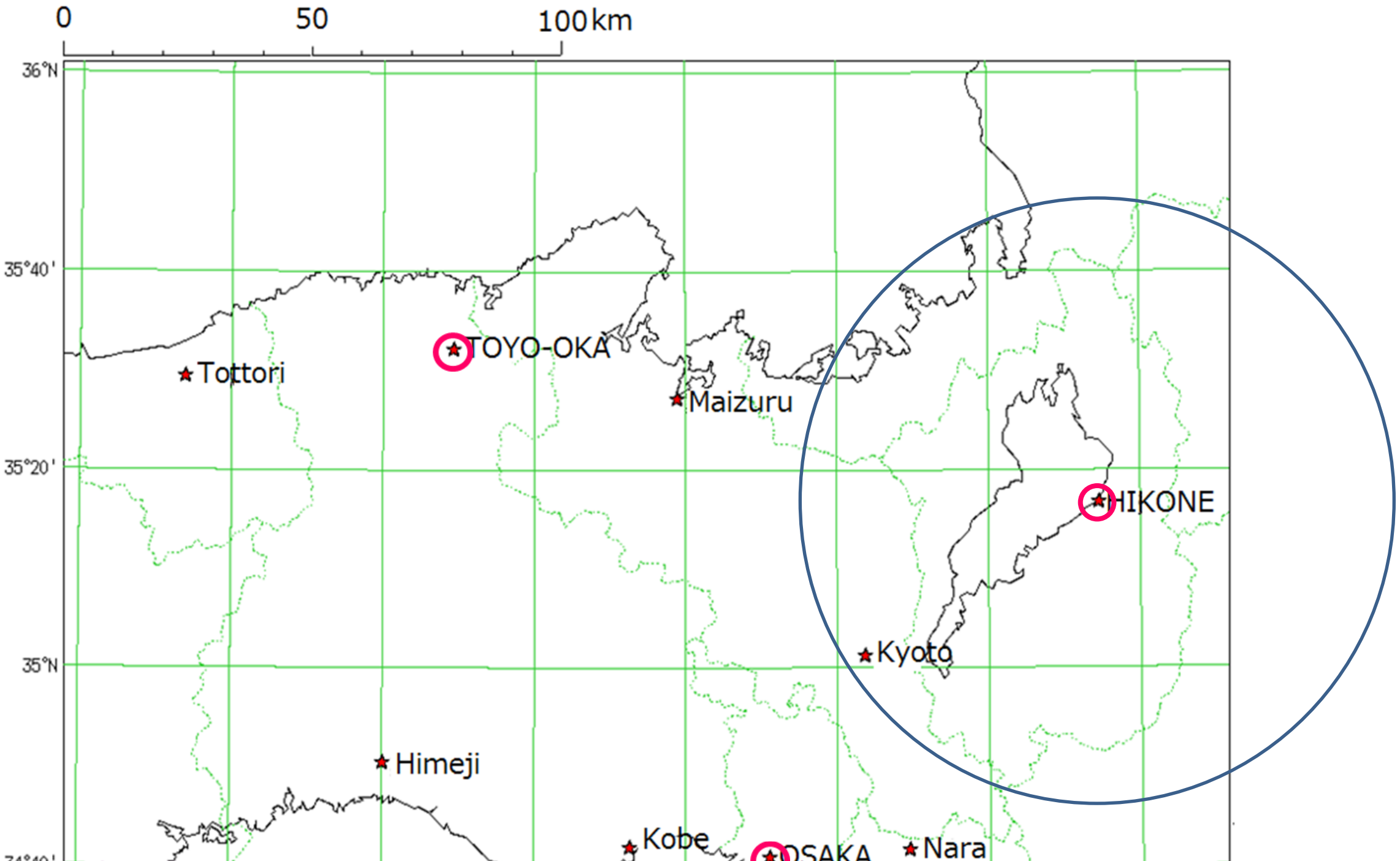
S-T time

Here!



$$D_{[km]} = k \times T_{[sec]}$$

$$K = 8.75 \ _{[km/sec]}$$


0
50
100 km
36°N
35°40'
35°20'
35°N
TOYO-OKA
Tottori
Maizuru
HIKONE
Kyoto
Himeji
Kobe
OSAKA
Nara

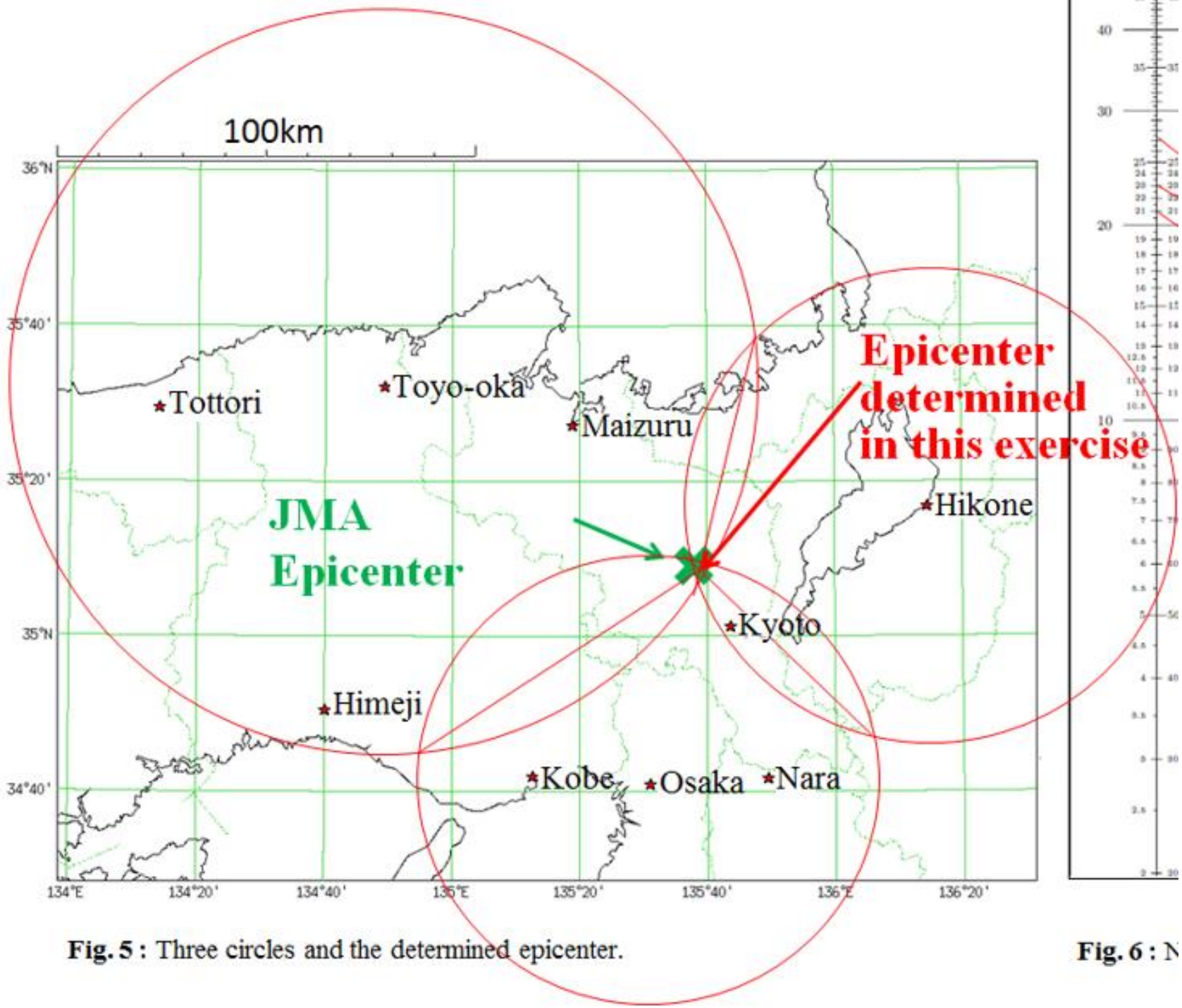


Fig. 5 : Three circles and the determined epicenter.

Fig. 6 : N

Magnitude

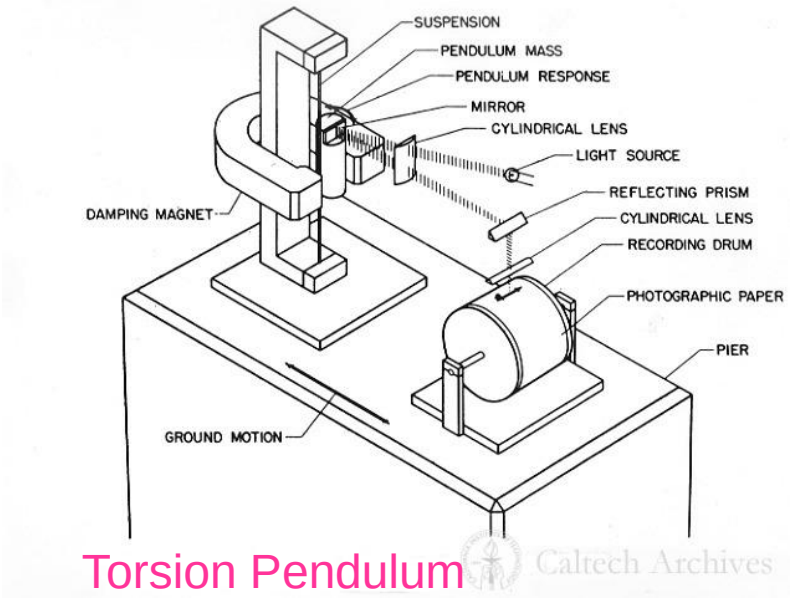
- Amplitude
- Distance

$$M \sim \log A + \log D$$

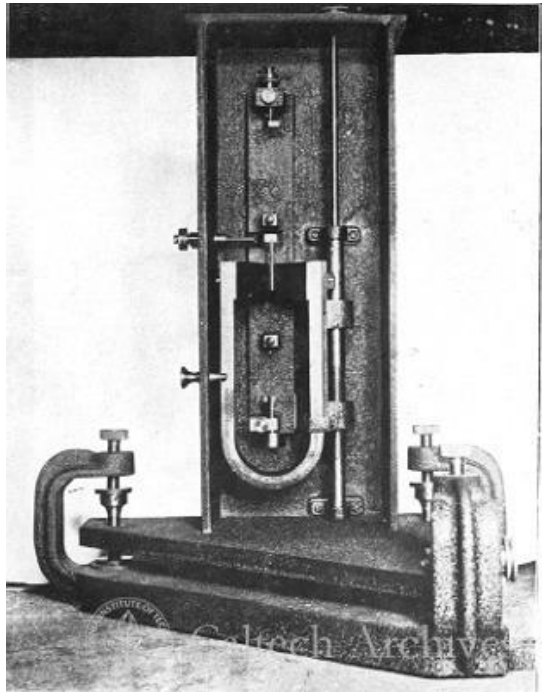
- Richter Scale (original definition)

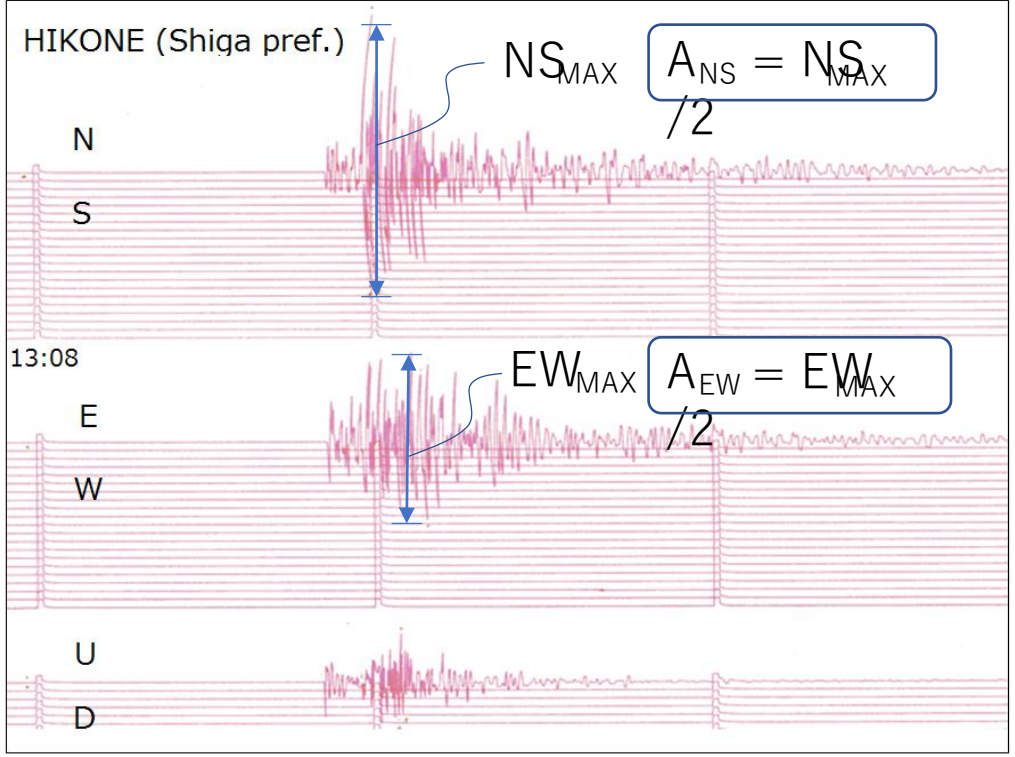
C.F.Richter

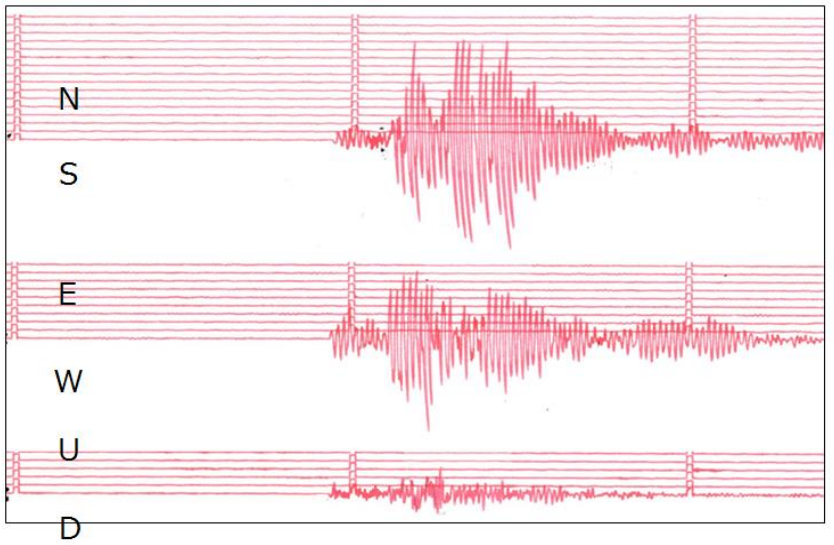
Wood Anderson Seismometer

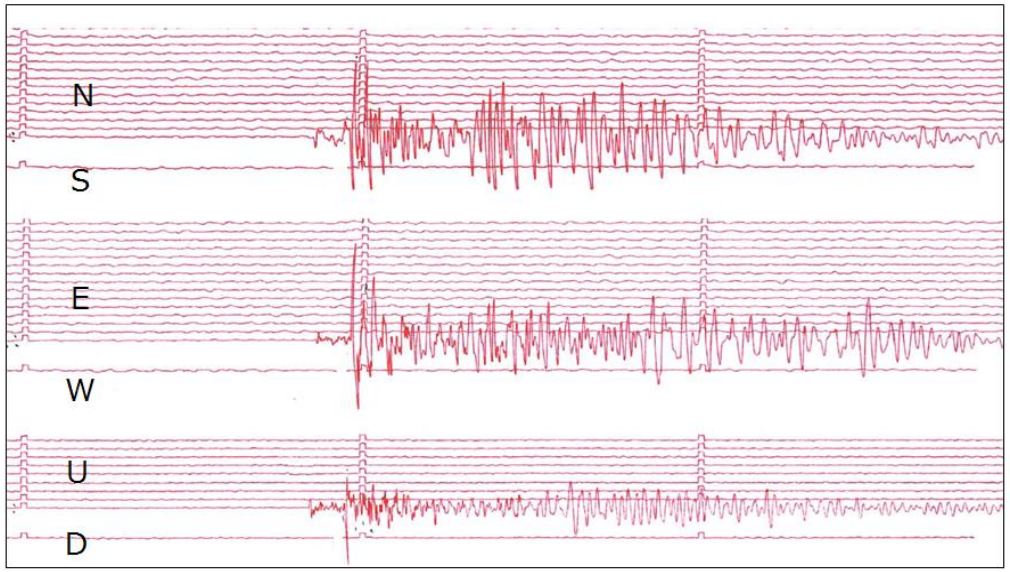


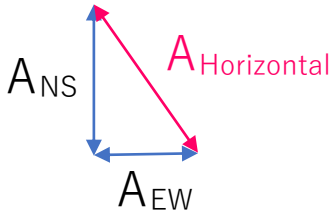
Torsion Pendulum











$$A = \sqrt{(A_{NS})^2 + (A_{Ew})^2}$$

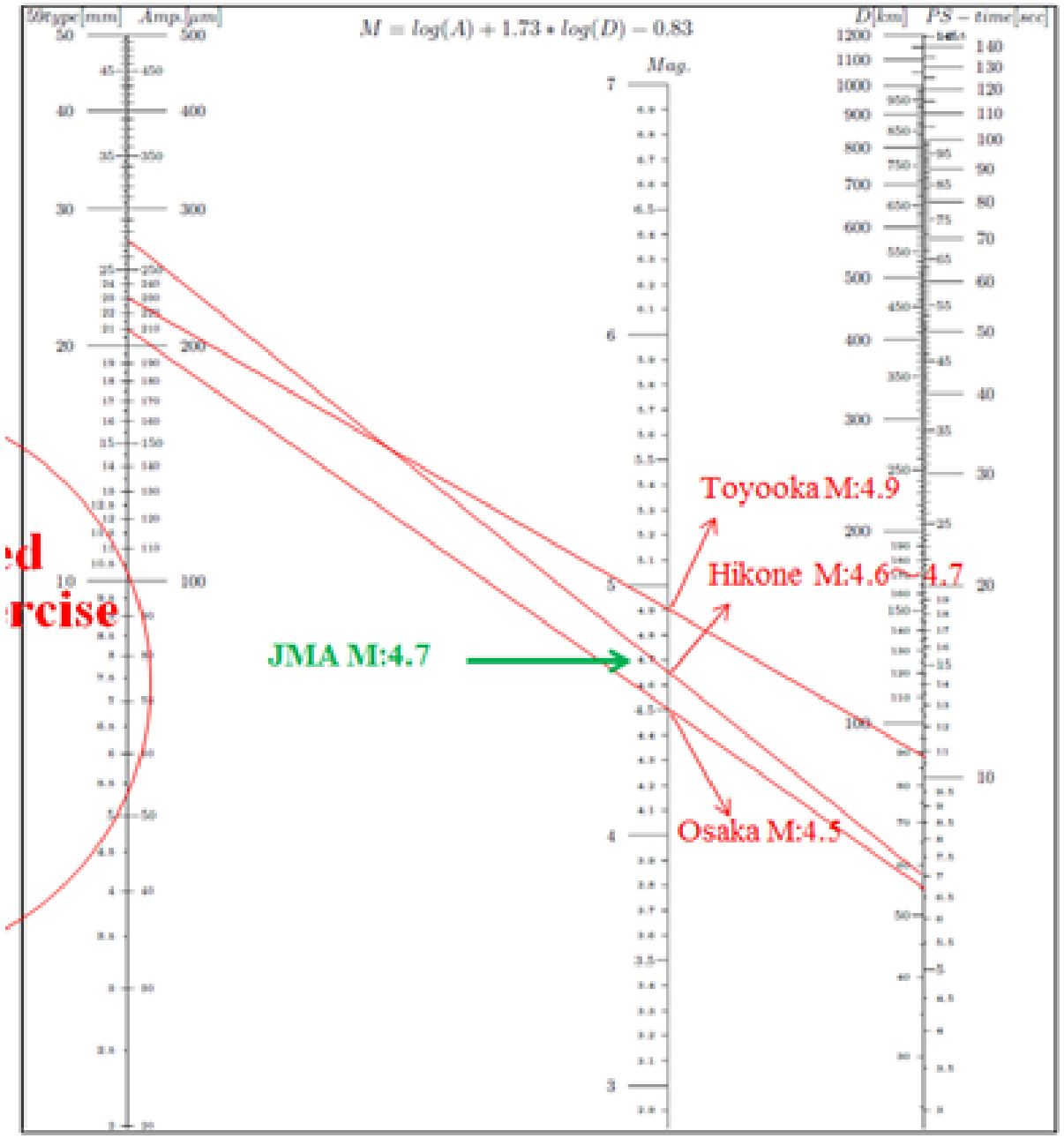
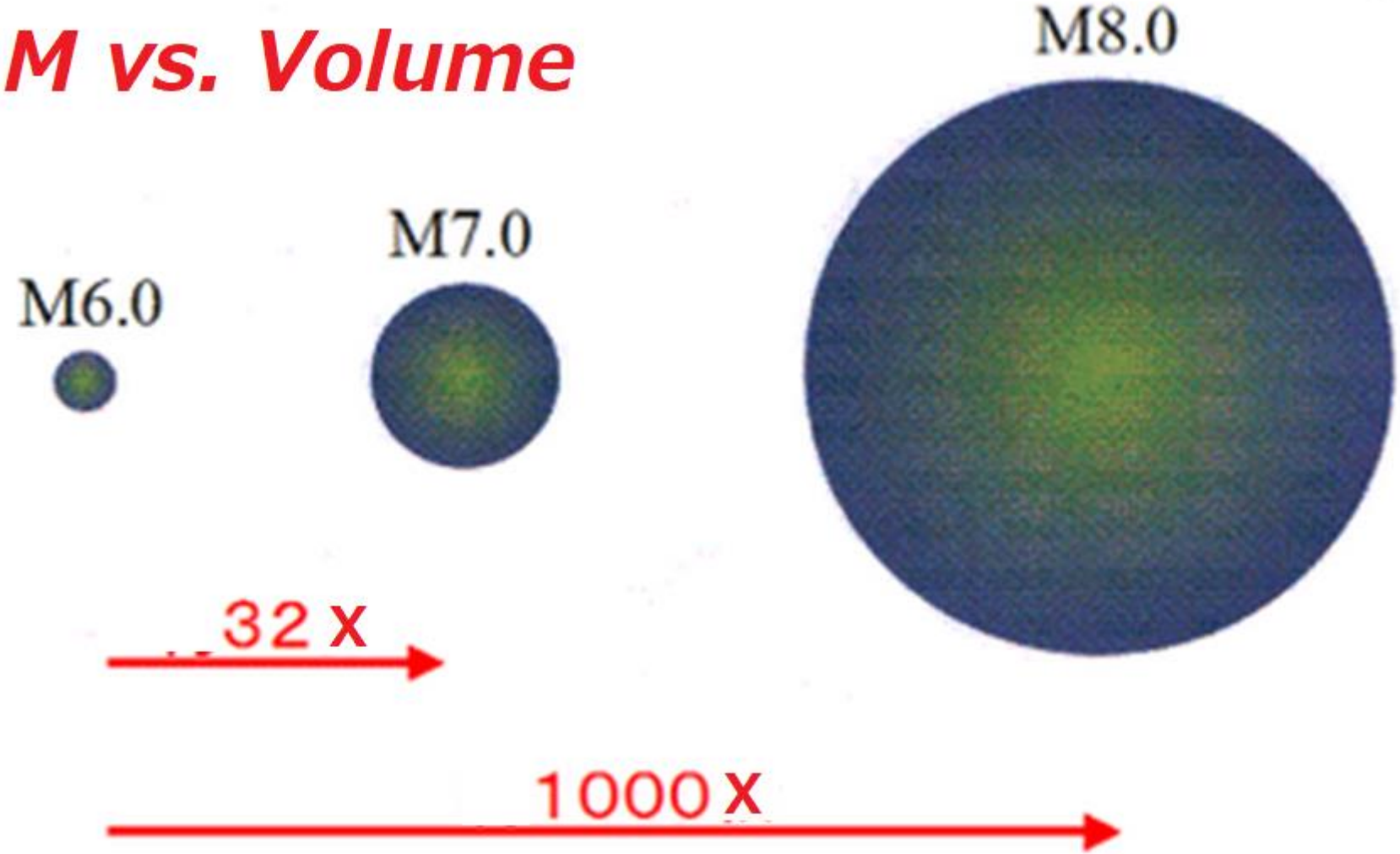


Fig. 6 : Nomogram

M vs. Volume

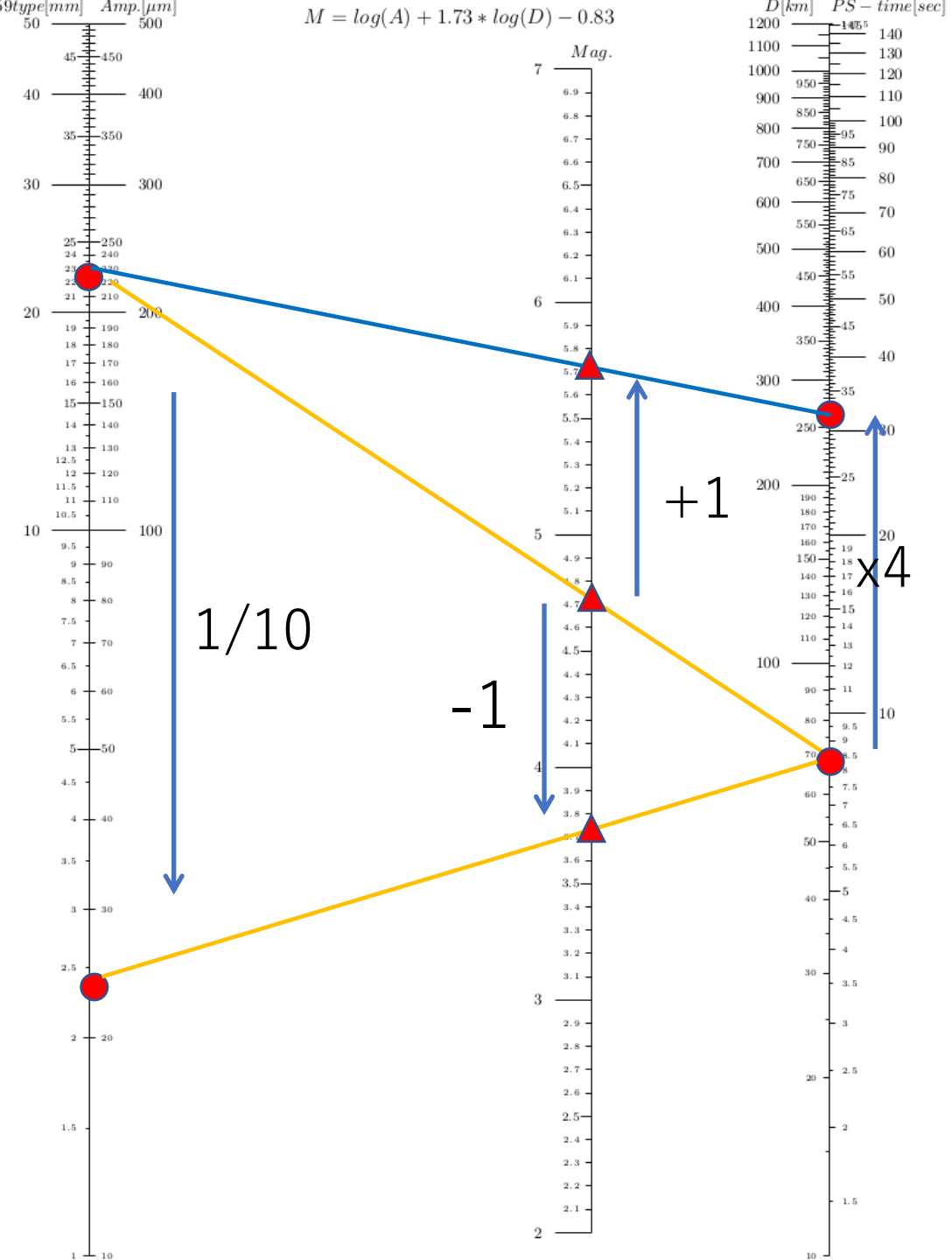


Application of Nomogram

- Quick look of logarithmic scaling

Multiple or divide

⇒add or subtract



Earthquake: cause and result