Special Lecture for SciUS schools What is a seismograph and How to use seismograms

Lecture by Yoshio Okamoto

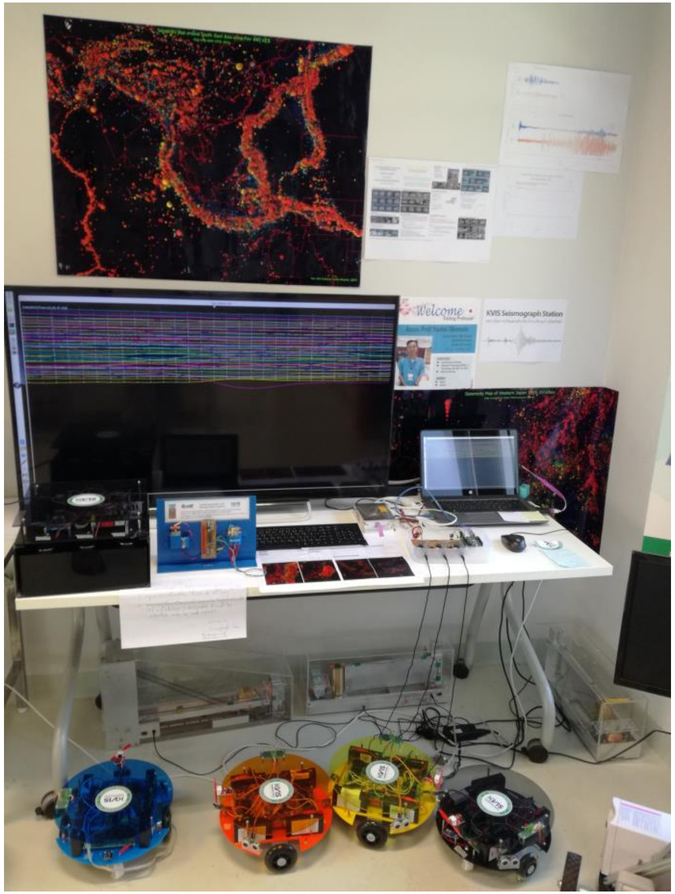
SciUS schools Aug. 2023

yossi.okamoto@gmail.com

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

Who am I?

- Earth science high school teacher at Osaka for 40 years
- Study at a teacher training center and a university
- Associate professor and part-time lecturer of Osaka-Kyoiku University since 2012 (this year retired)
- Earth Science visiting teacher at KVIS since 2017, at PCSHS Mukdahan in 2019, Loei and NST in 2022)
- Seismology and geology are my major
- Development of teaching tools is my life work
- School seismograph system (at KVIS and PCSHS Mukdahan, Loei, NST)
- 3D seismicity map, tsunami simulation, M5Stack gadgets etc.
- Polarized microscope unit, Thin-section making
- Linux programming (awk, C, Processing, Python, Arudino IDE etc.)



Principle of Seismometer

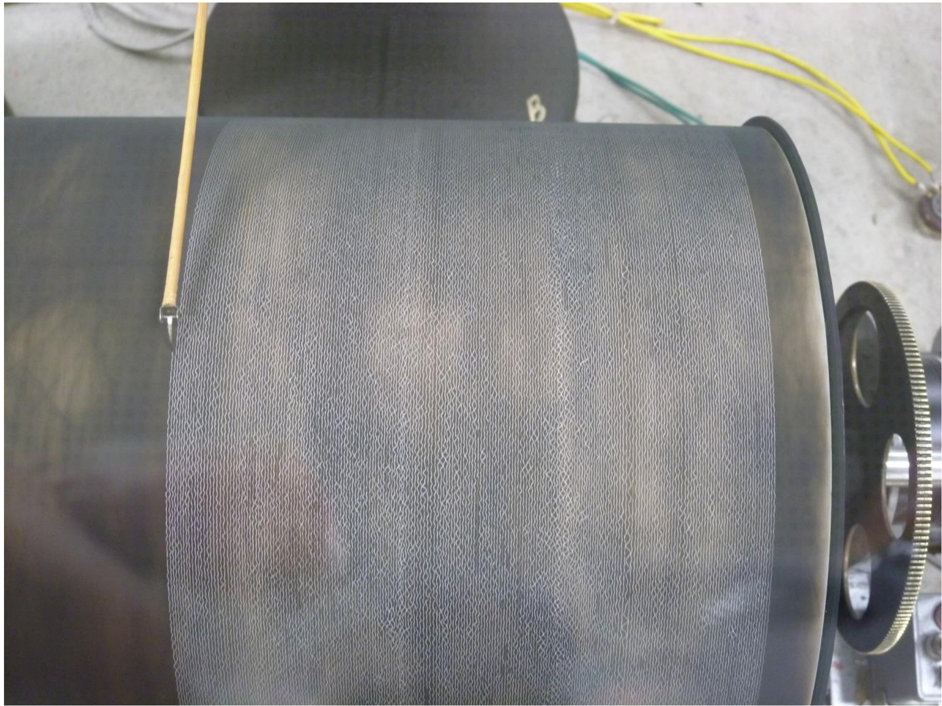
- Fixed mass in shaking
- Other movement in an earthquake shaking
- Pendulum (Vertical / Horizontal)
- Sensor + Amplifier
- →Mechanic (lever)

    →Electro-magnetic

    →Capacitance
- Recording system

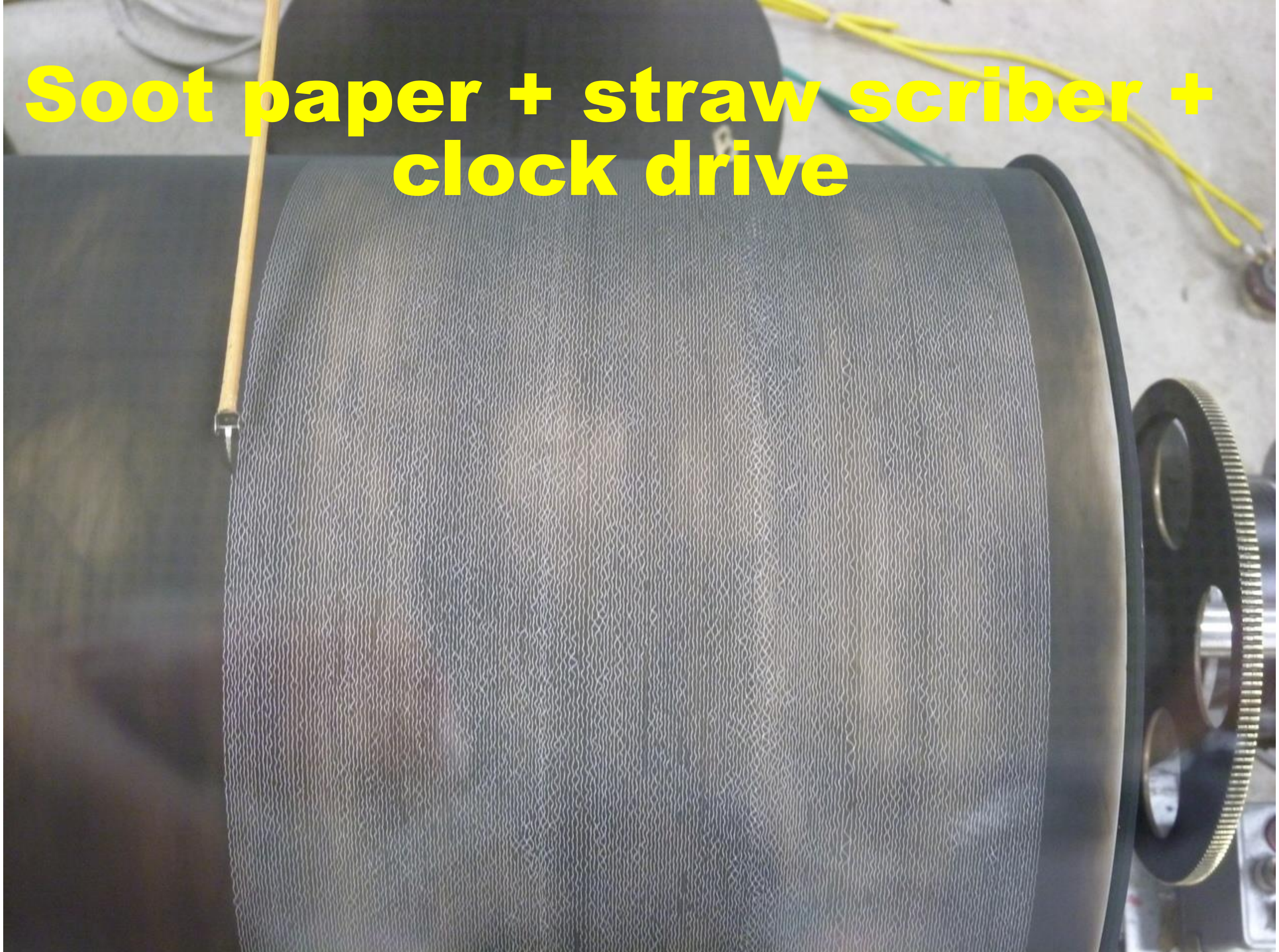
    →Old: straw and soot paper

    →New: PC



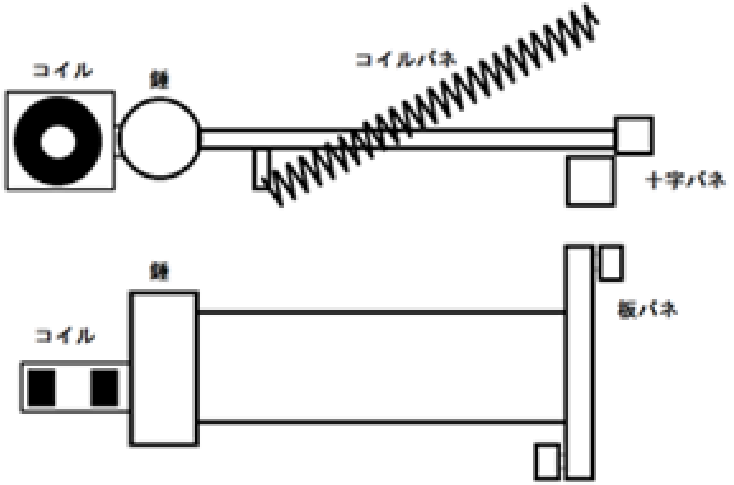
Omori type mechanical seismograph (1896) Seismograph museum at ERI (Tokyo Univ.)

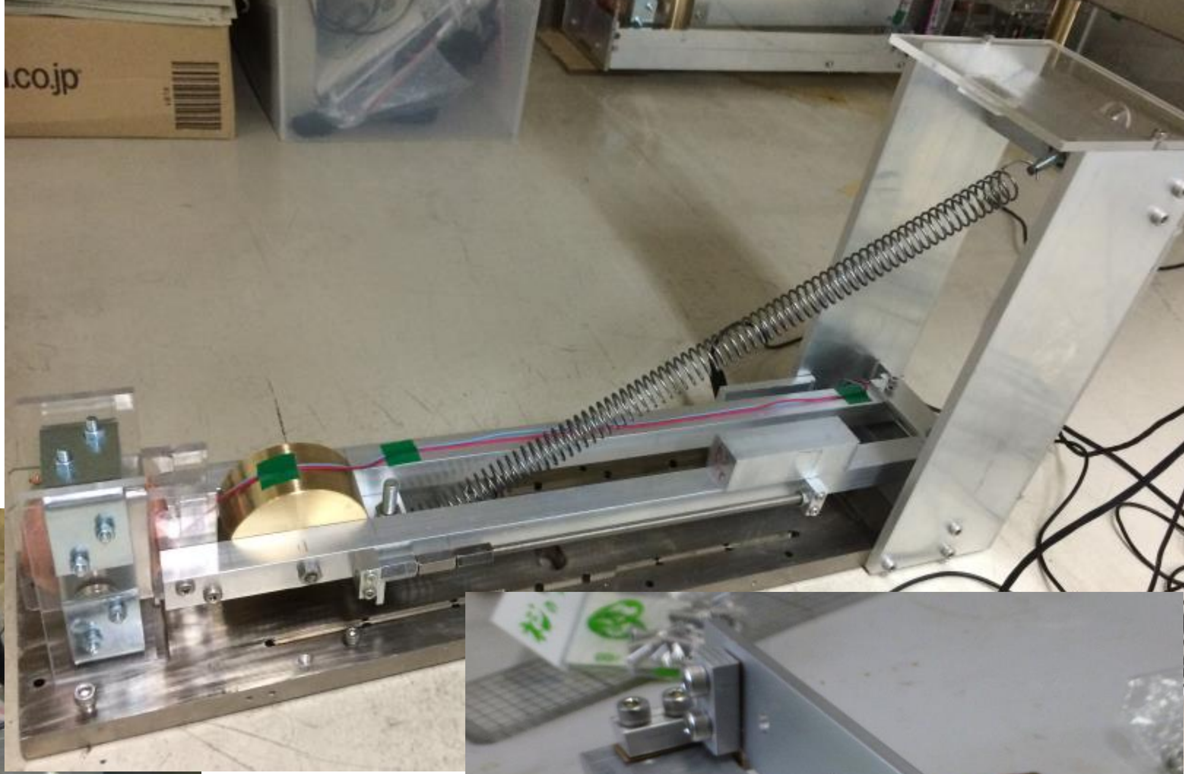
Soot paper + straw scriber + clock drive




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

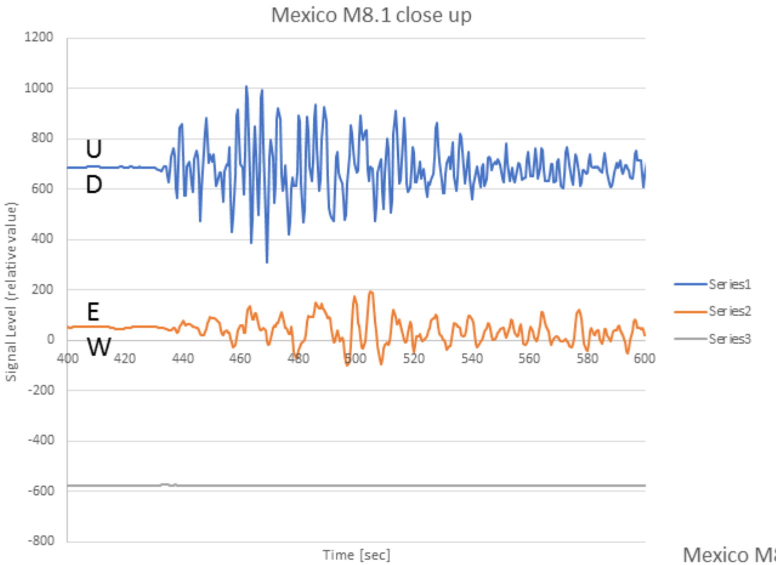
Modern seismograph systems at Matsushiro seismic observatory (Japan Meteorological Agency)

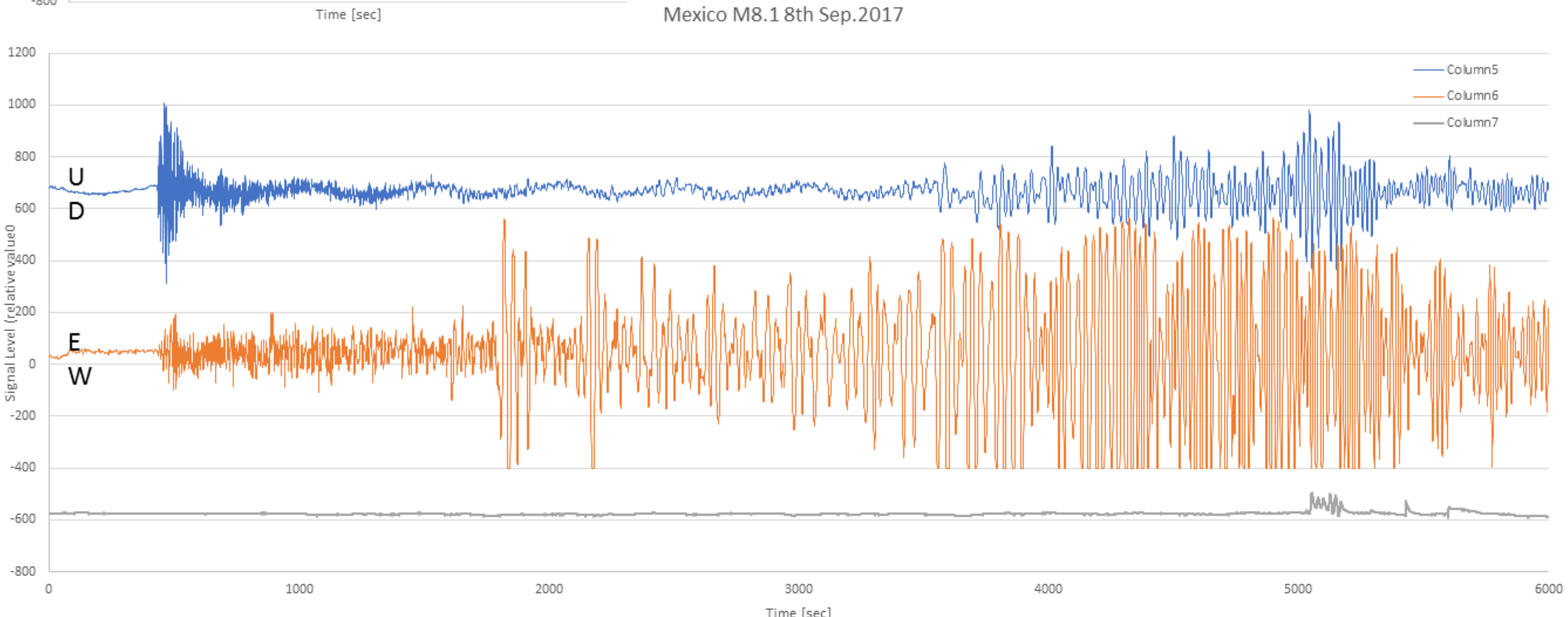

コイル
錘
コイルバネ
十字バネ
錘
板バネ
コイル

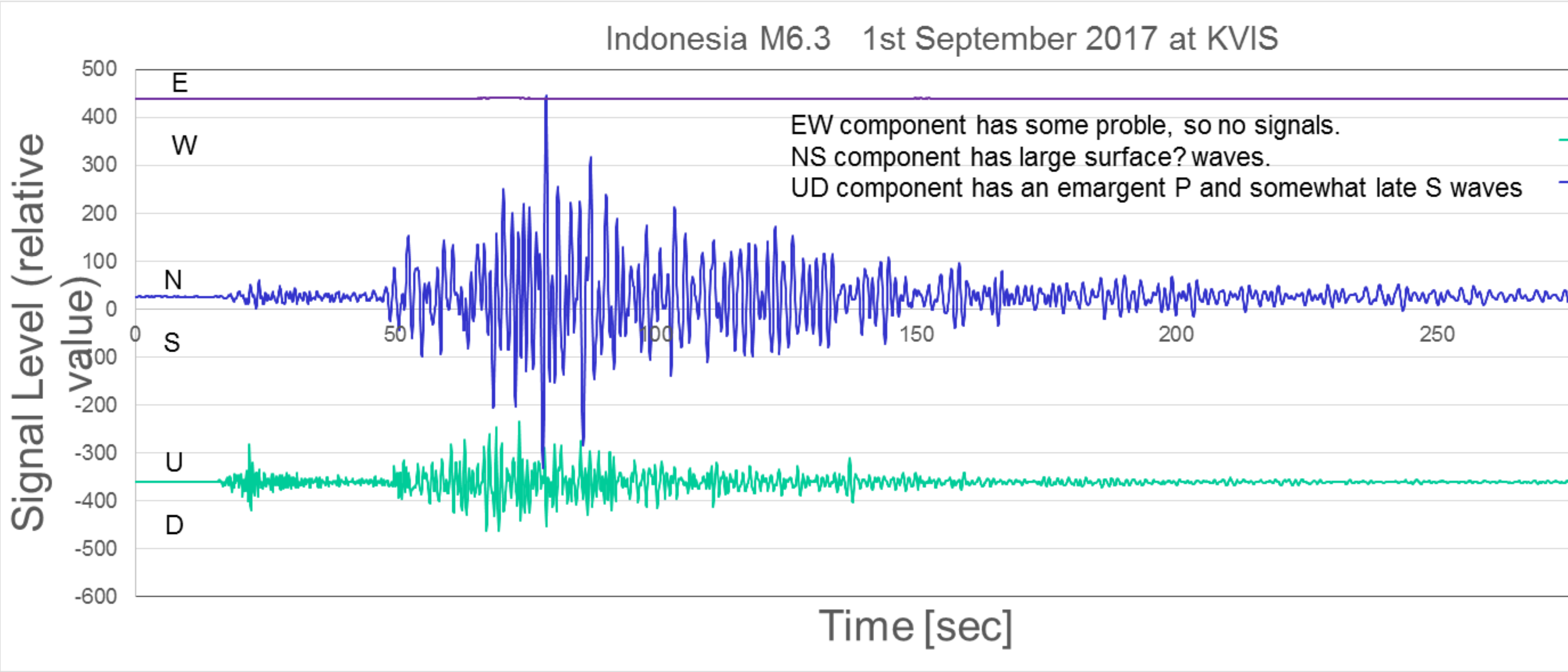


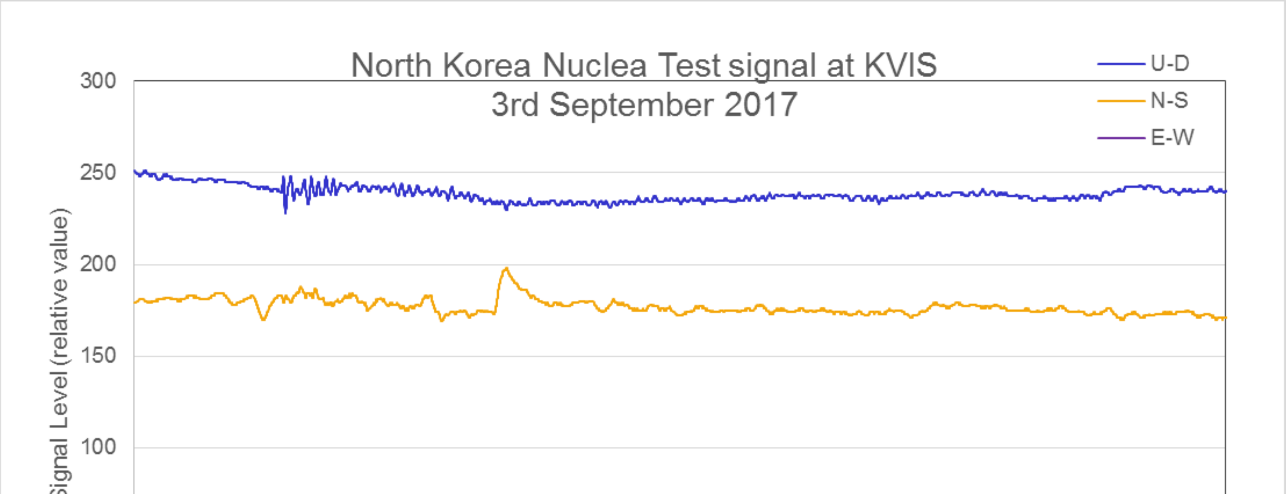

Aluminum plate
Free Period
= 5-6 [sec]

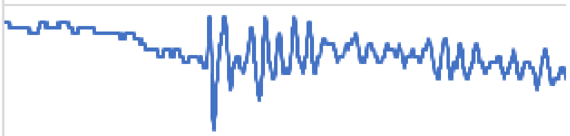

Cross bar spring

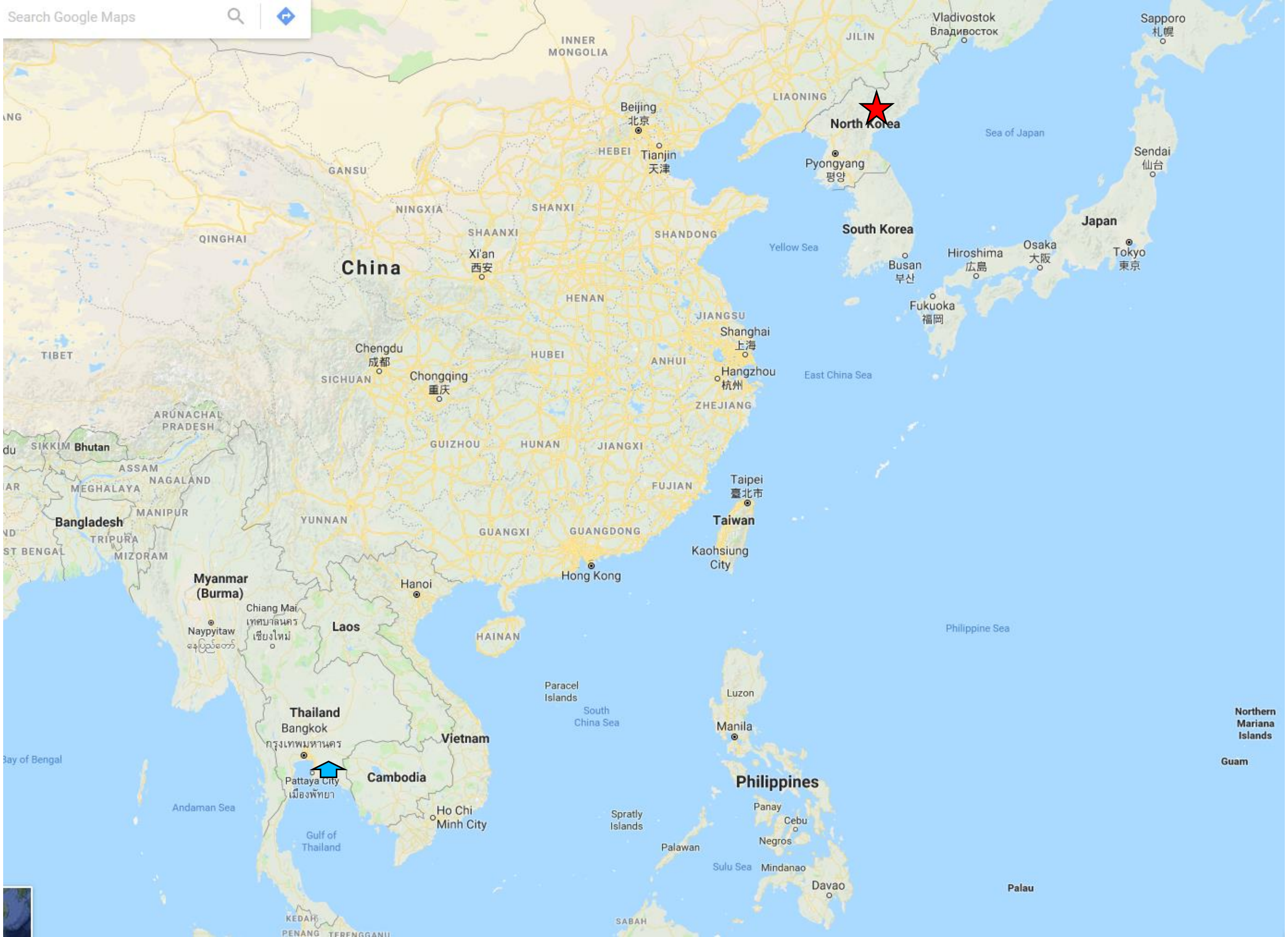

Mexico M8.1 close up
Signal Level (relative value)
Time [sec]
U
D
E
W
Series1
Series2
Series3
1200
1000
800
600
400
200
0
-200
-400
-600
-800
400
420
440
460
480
500
520
540
560
580
600


Mexico M8.1 8th Sep.2017
Signal Level (relative value0
Time [sec]
U
D
E
W
Column5
Column6
Column7
1200
1000
800
600
400
200
0
-200
-400
-600
-800
0
1000
2000
3000
4000
5000
6000


Indonesia M6.3 1st September 2017 at KVIS
Signal Level (relative value)
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
E
W
N
S
U
D
0
50
100
150
200
250
EW component has some proble, so no signals.
NS component has large surface? waves.
UD component has an emargent P and somewhat late S waves
Time [sec]


North Korea Nuclea Test signal at KVIS
3rd September 2017
U-D
N-S
E-W
300
250
200
150
100
Signal Level (relative value)




Search Google Maps
INNER MONGOLIA
Vladivostok
Владивосток
Sapporo
札幌
JILIN
LIAONING
North Korea
Sea of Japan
Beijing
北京
HEBEI
Tianjin
天津
Pyongyang
평양
GANSU
NINGXIA
SHANXI
Sendai
仙台
SHAANXI
SHANDONG
South Korea
Japan
QINGHAI
Xi'an
西安
China
Yellow Sea
Hiroshima
広島
Osaka
大阪
Tokyo
東京
Busan
부산
HENAN
Fukuoka
福岡
JIANGSU
Shanghai
上海
TIBET
Chengdu
成都
HUBEI
ANHUI
Chongqing
重庆
SICHUAN
Hangzhou
杭州
East China Sea
ZHEJIANG
ARUNACHAL PRADESH
GUIZHOU
HUNAN
JIANGXI
SIKKIM
Bhutan
ASSAM
NAGALAND
Taipei
臺北市
MEGHALAYA
FUJIAN
MANIPUR
Bangladesh
YUNNAN
Taiwan
TRIPURA
GUANGXI
GUANGDONG
MIZORAM
Kaohsiung City
Myanmar (Burma)
Hanoi
Hong Kong
Chiang Mai
Naypyitaw
Laos
HAINAN
Philippine Sea
Paracel Islands
Luzon
Thailand
Bangkok
South China Sea
Manila
Northern Mariana Islands
Vietnam
Bay of Bengal
Guam
Pattaya City
Cambodia
Philippines
Andaman Sea
Ho Chi Minh City
Spratly Islands
Panay
Cebu
Gulf of Thailand
Palawan
Negros
Sulu Sea
Mindanao
Davao
Palau
KEDAH
SABAH
PENANG
TERENGGANU

Film case Seismometer 1997

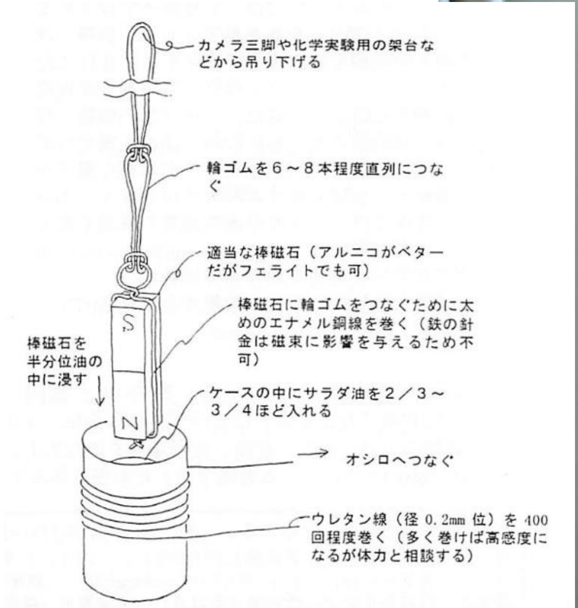


図2 フィルムケース地震計センサー部の組み立て

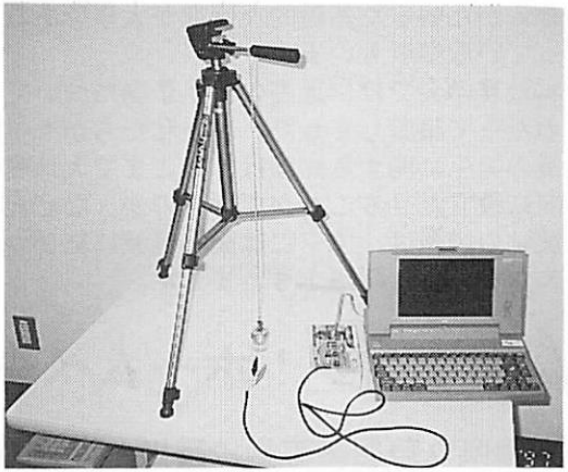
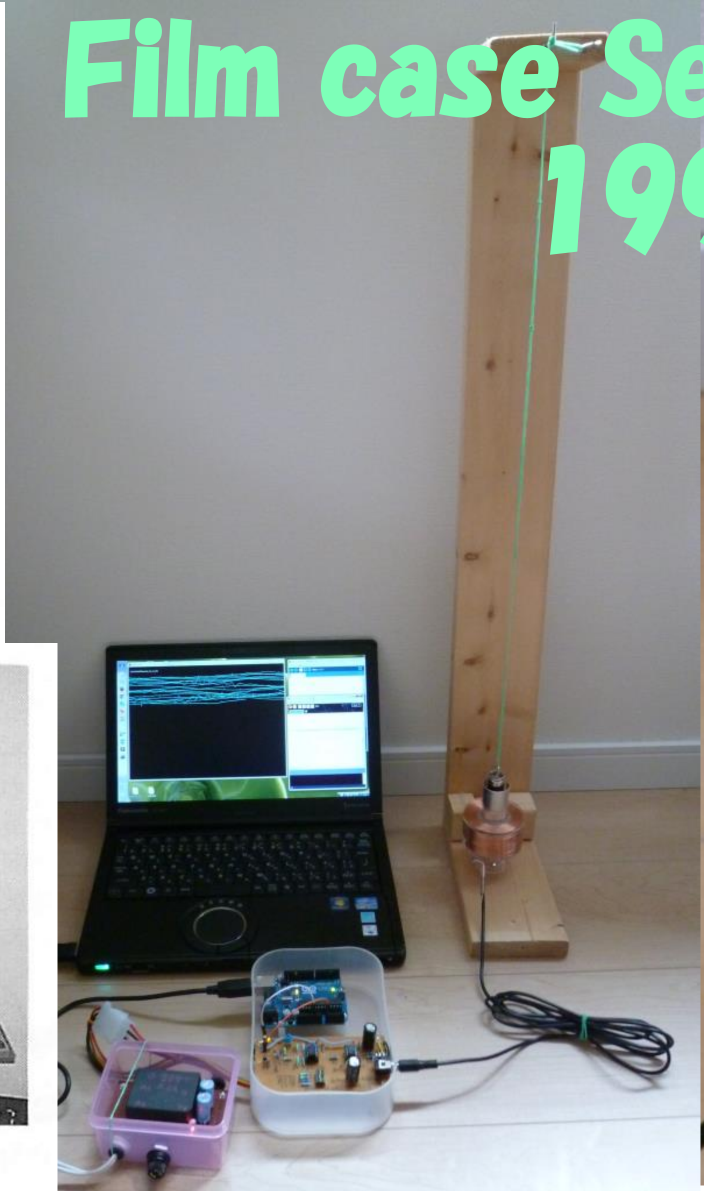
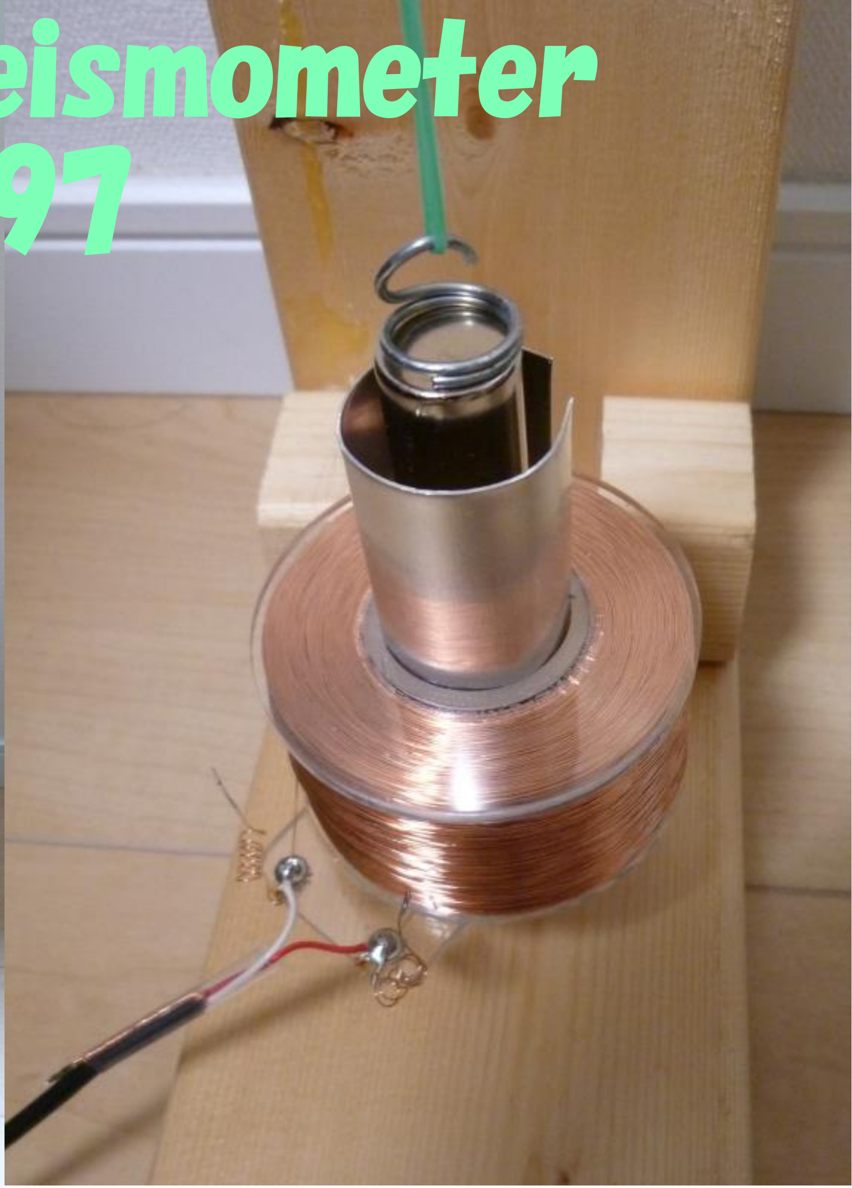


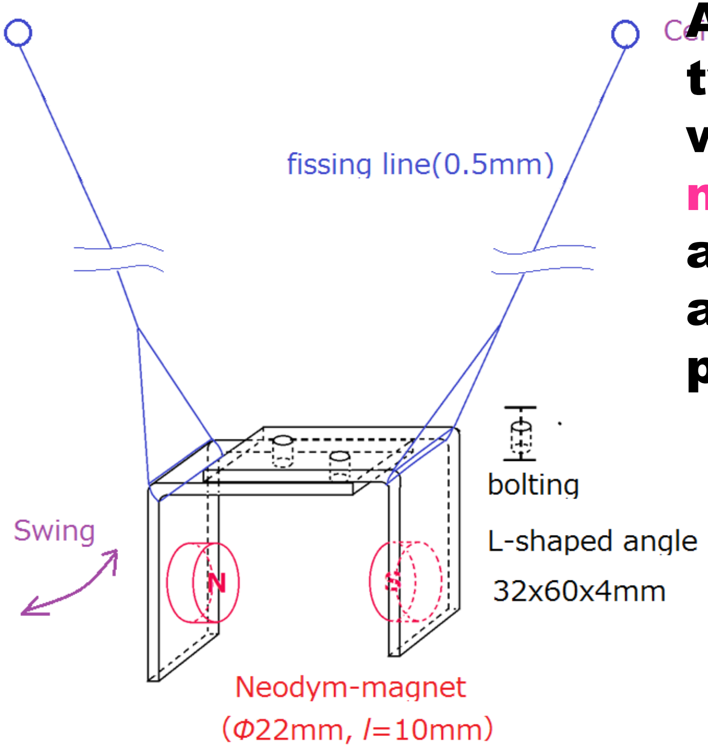
図1 フィルムケース地震計全景



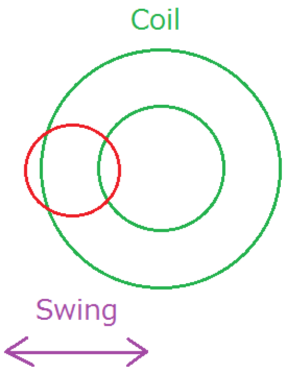


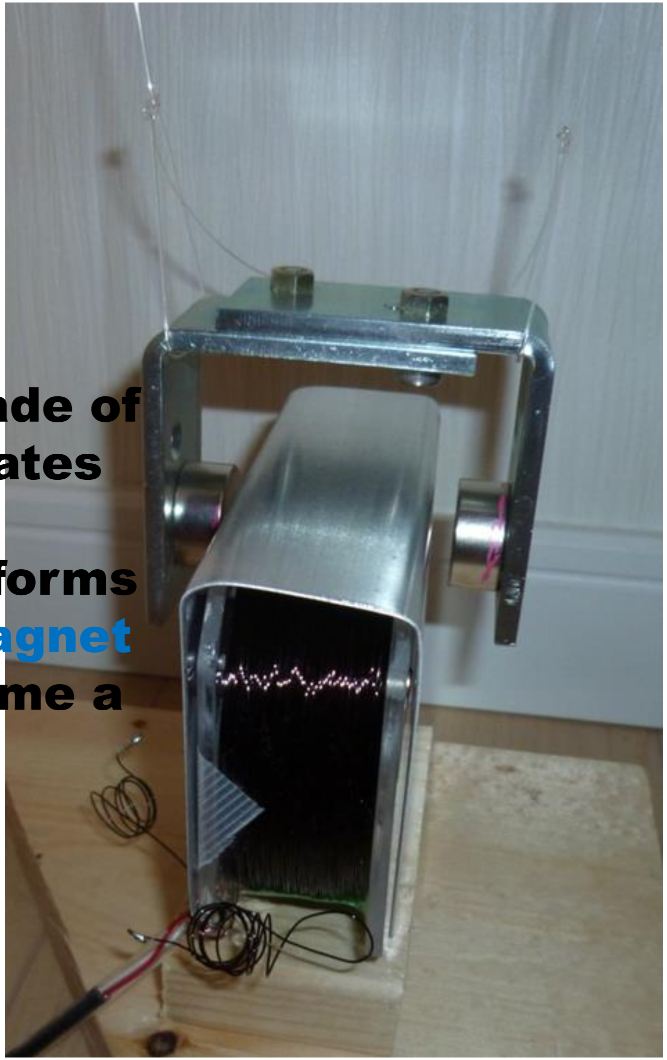
A simple bifilar suspension is used for the horizontal pendulum.

An aluminum plate covering coil is used as a "dumper"

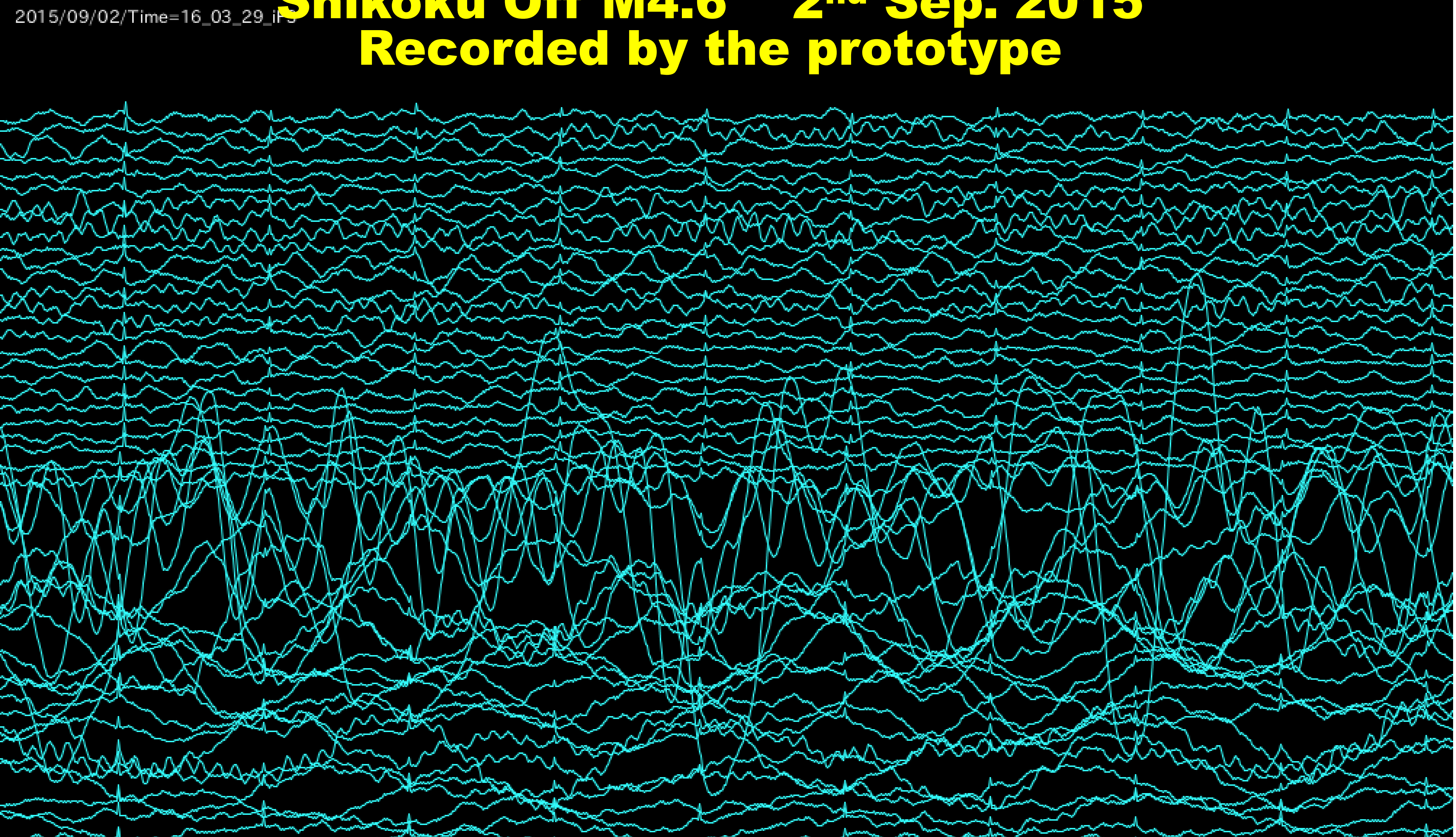


A magnetic circuit made of two L shaped steel plates with two columnar neodymium magnets forms a U-shaped bipolar magnet as a whole, also become a pendulum's weight.

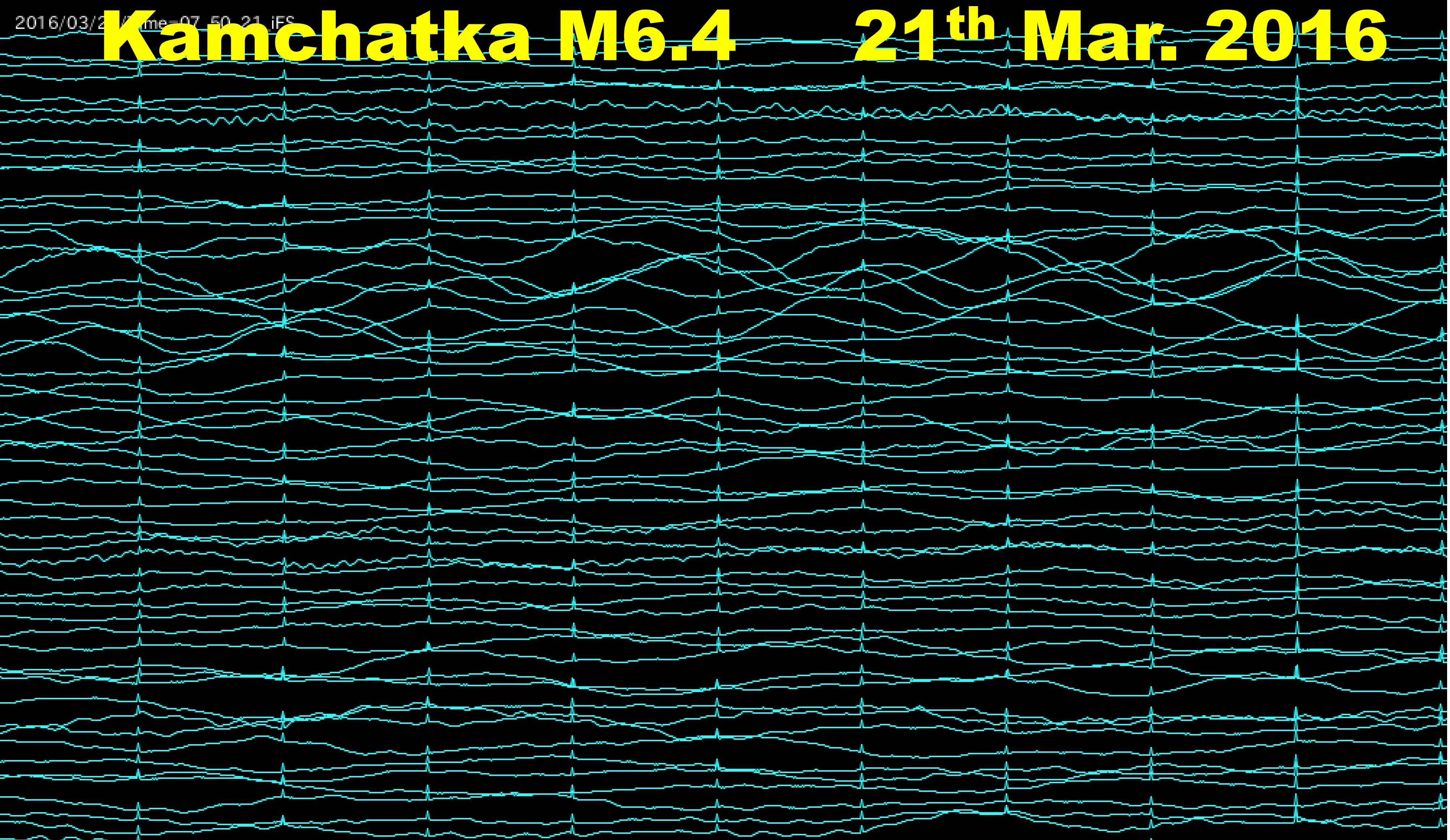




Shikoku Off M4.6 2nd Sep. 2015
Recorded by the prototype



Kamchatka M6.4 21th Mar. 2016



Hardware: Solder less Bread board

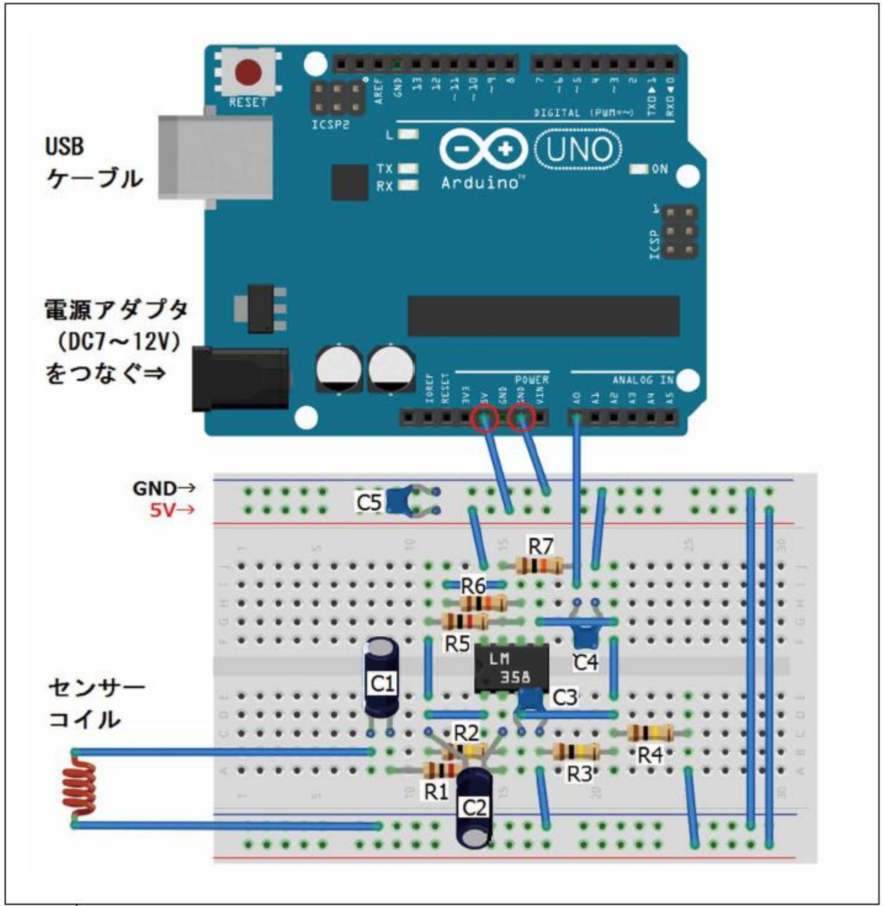


図 2　ブレッドボードの配線とArduinoとの接続

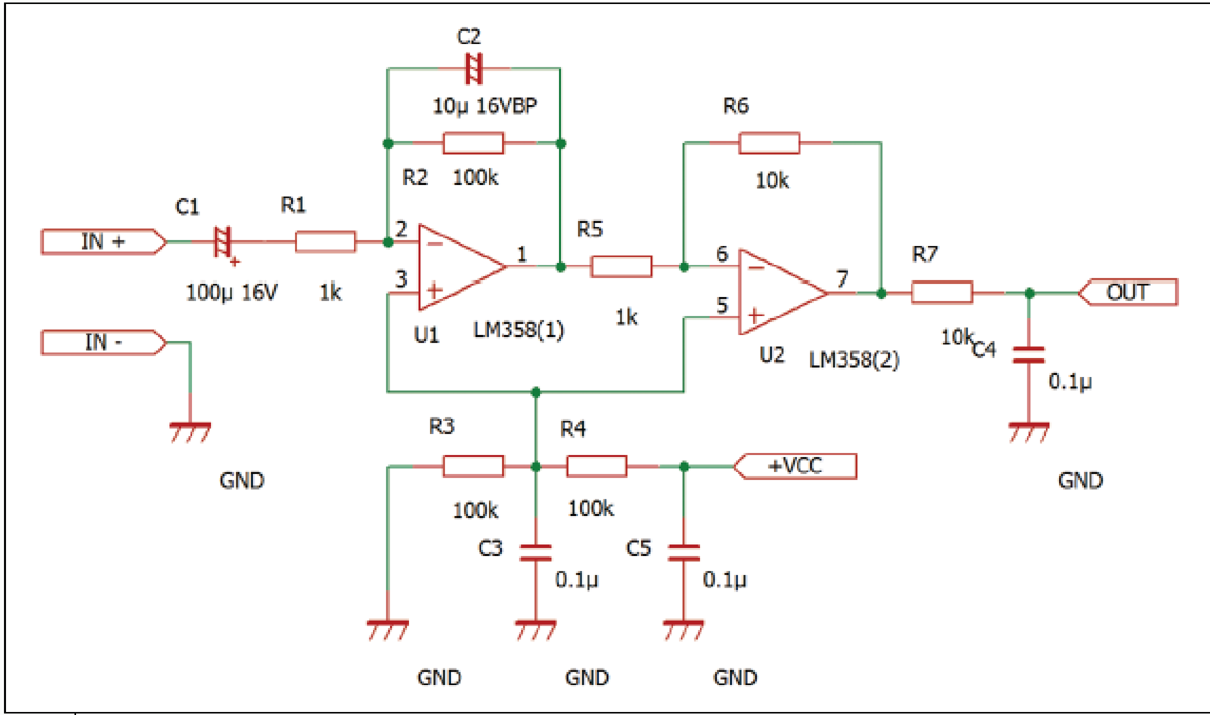
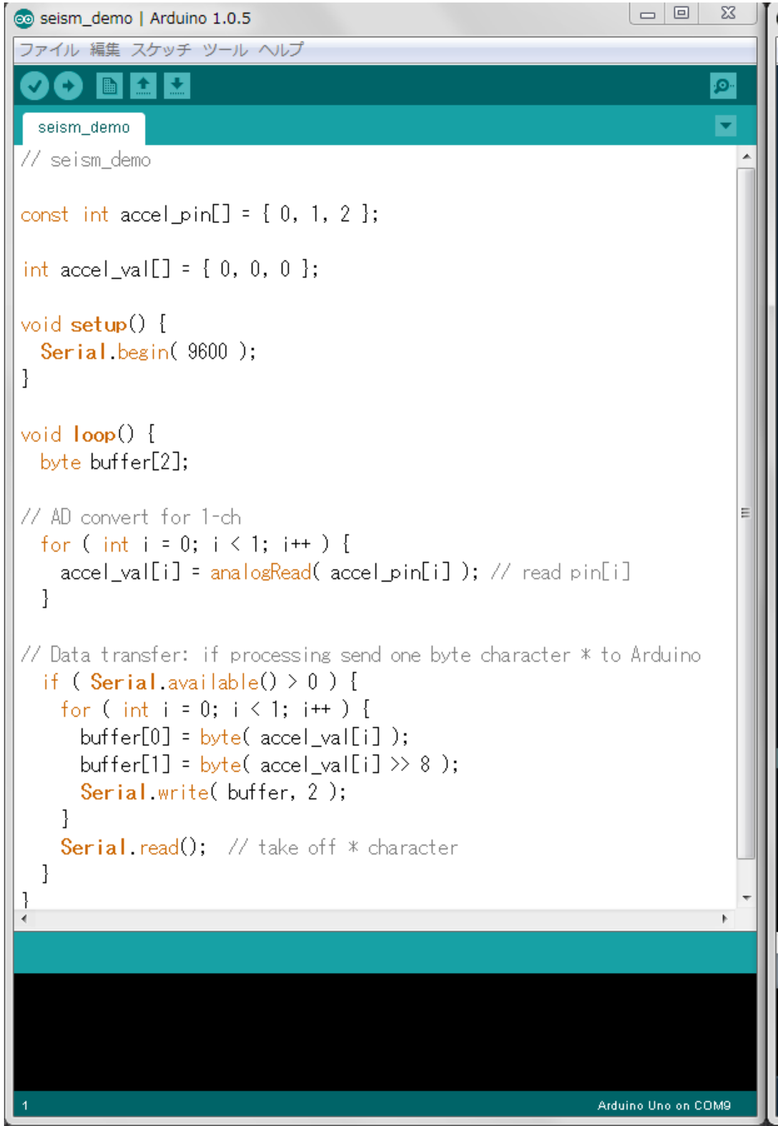
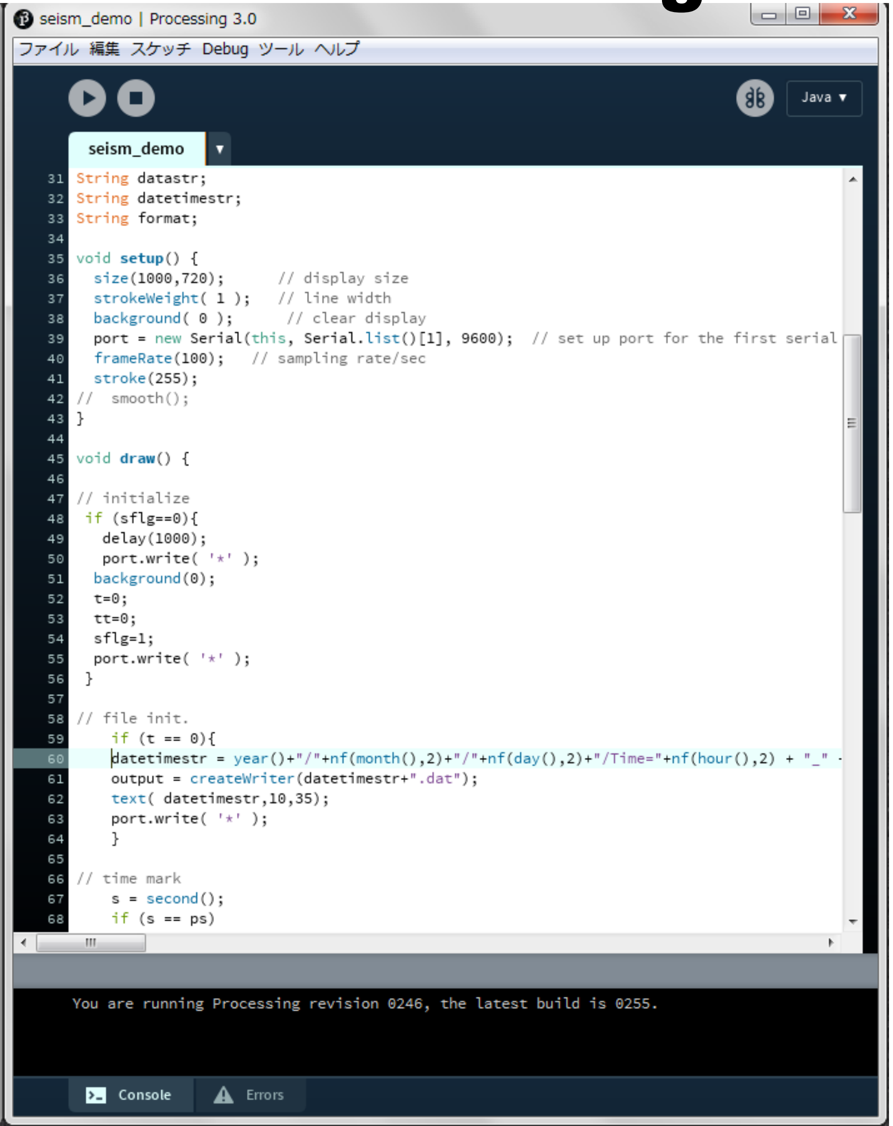


図 1　アンプの回路図（OPアンプの電源は省略、8番ピンに5V、4番ピンがグラウンド）

Software: Arduino IDE + Processing

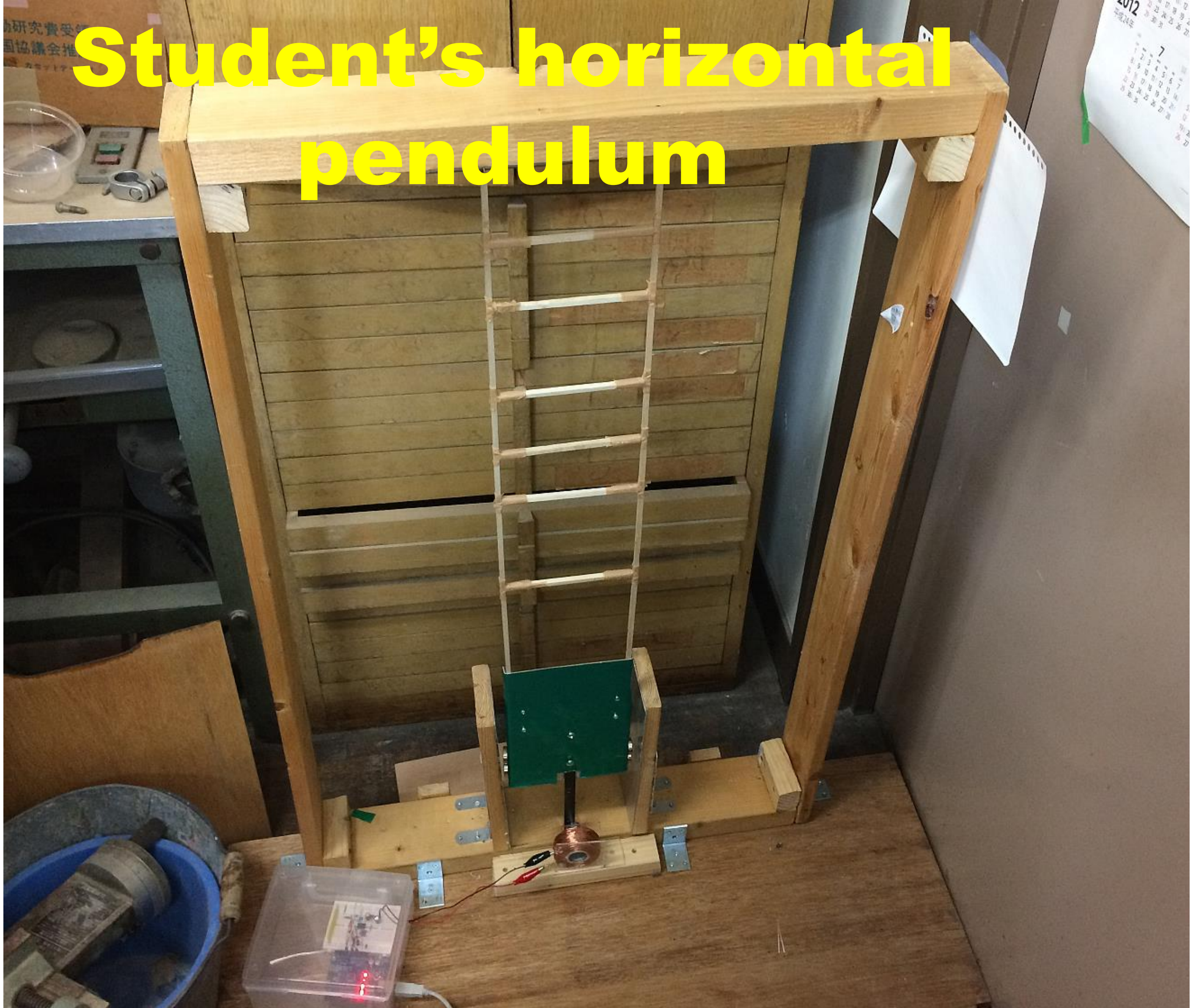




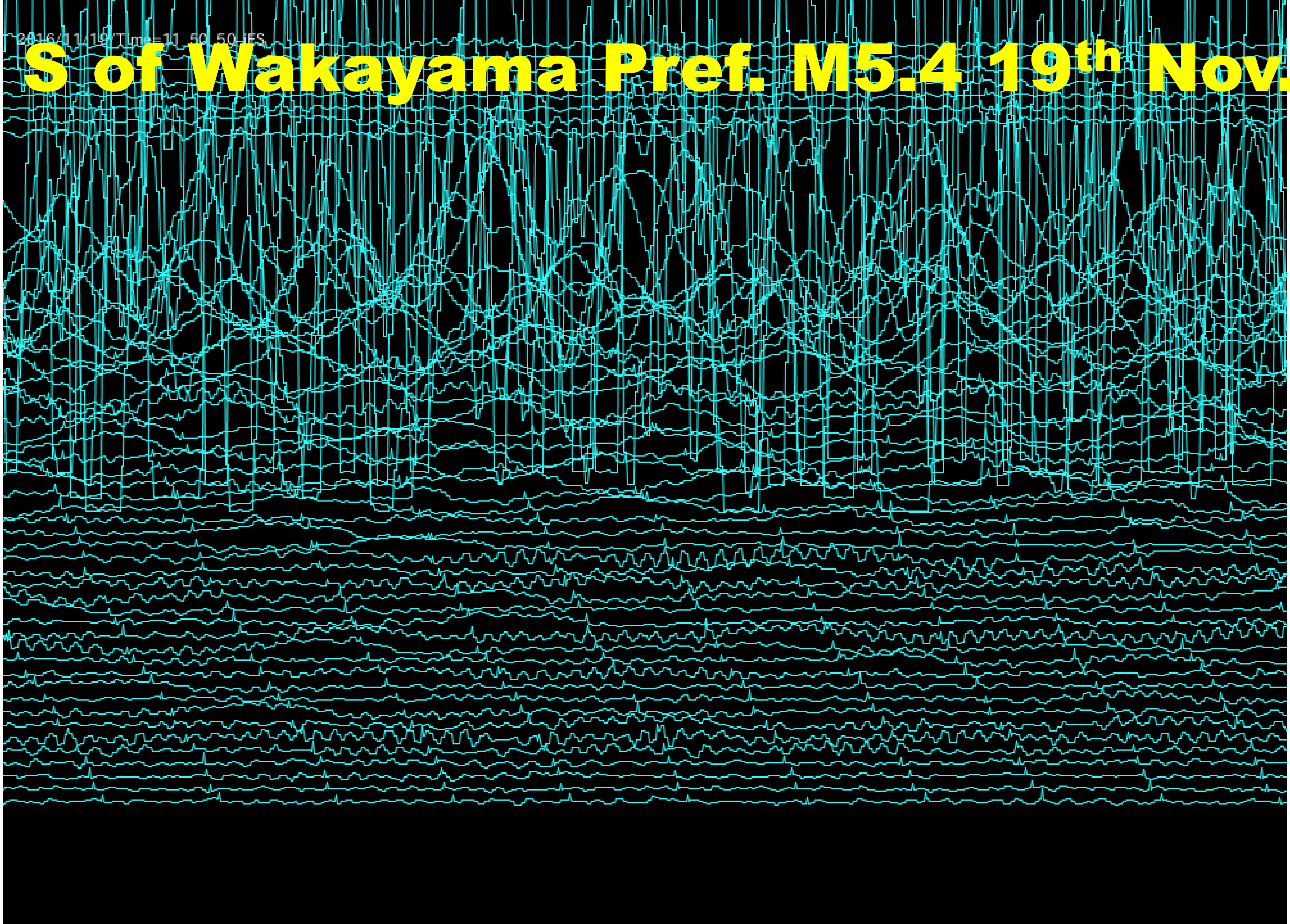
Make Your Own Seismograph!

- The recording system (hardware+software) is already developed.
- So, If you prepare your own made pendulum + sensor, you can make your own seismograph.
- Let us show you an example made by our student.

Student's horizontal pendulum

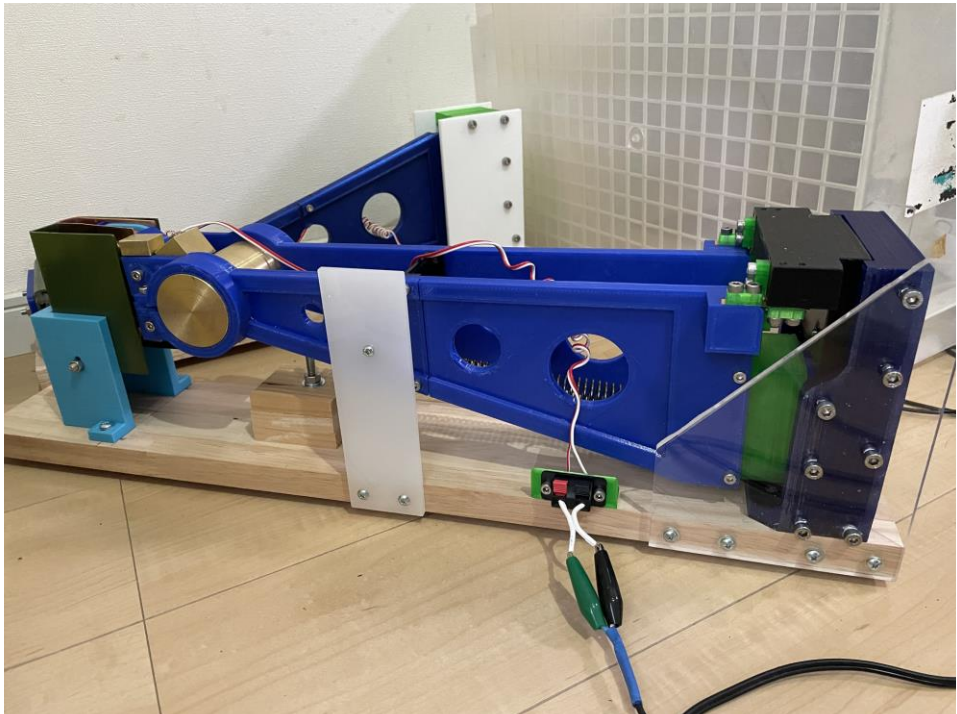


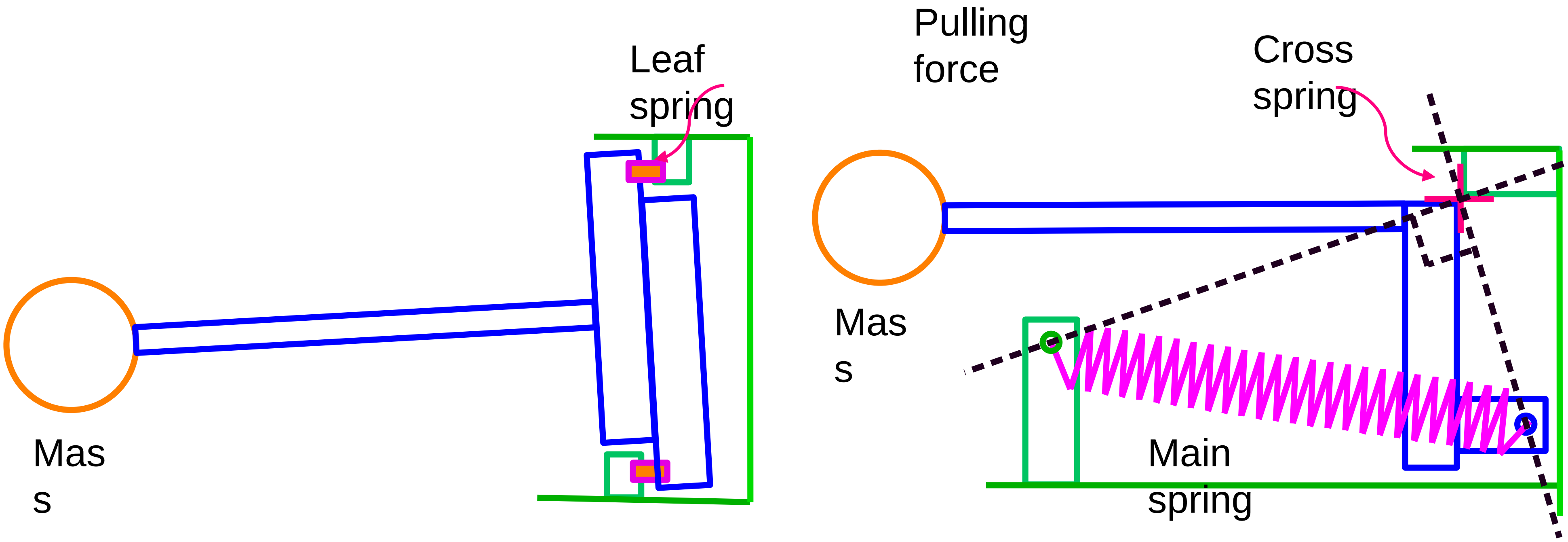
S of Wakayama Pref. M5.4 19th Nov.2015



My Seismograph

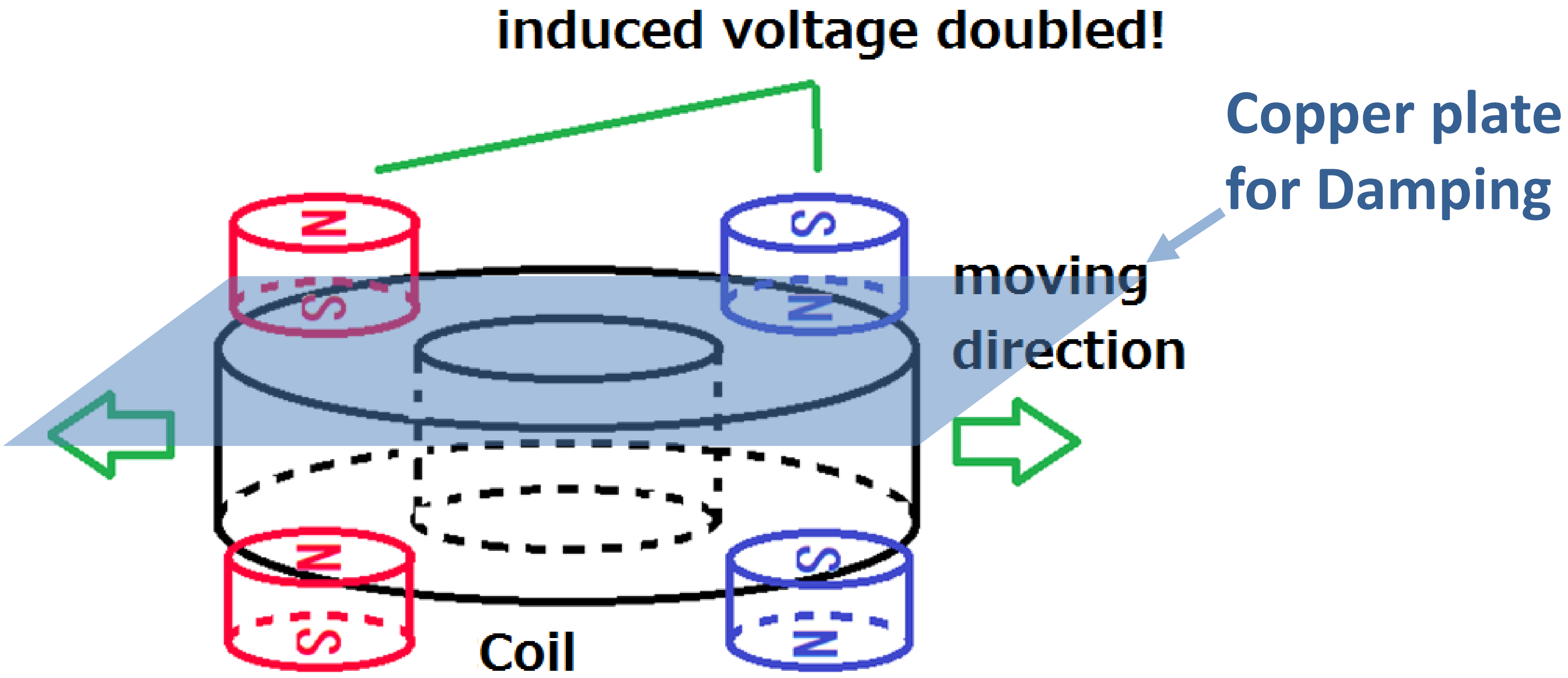
- Horizontal: Pascwitz type (Swing-gate type)
- Vertical: Kirnos type (modified Lacoste type)



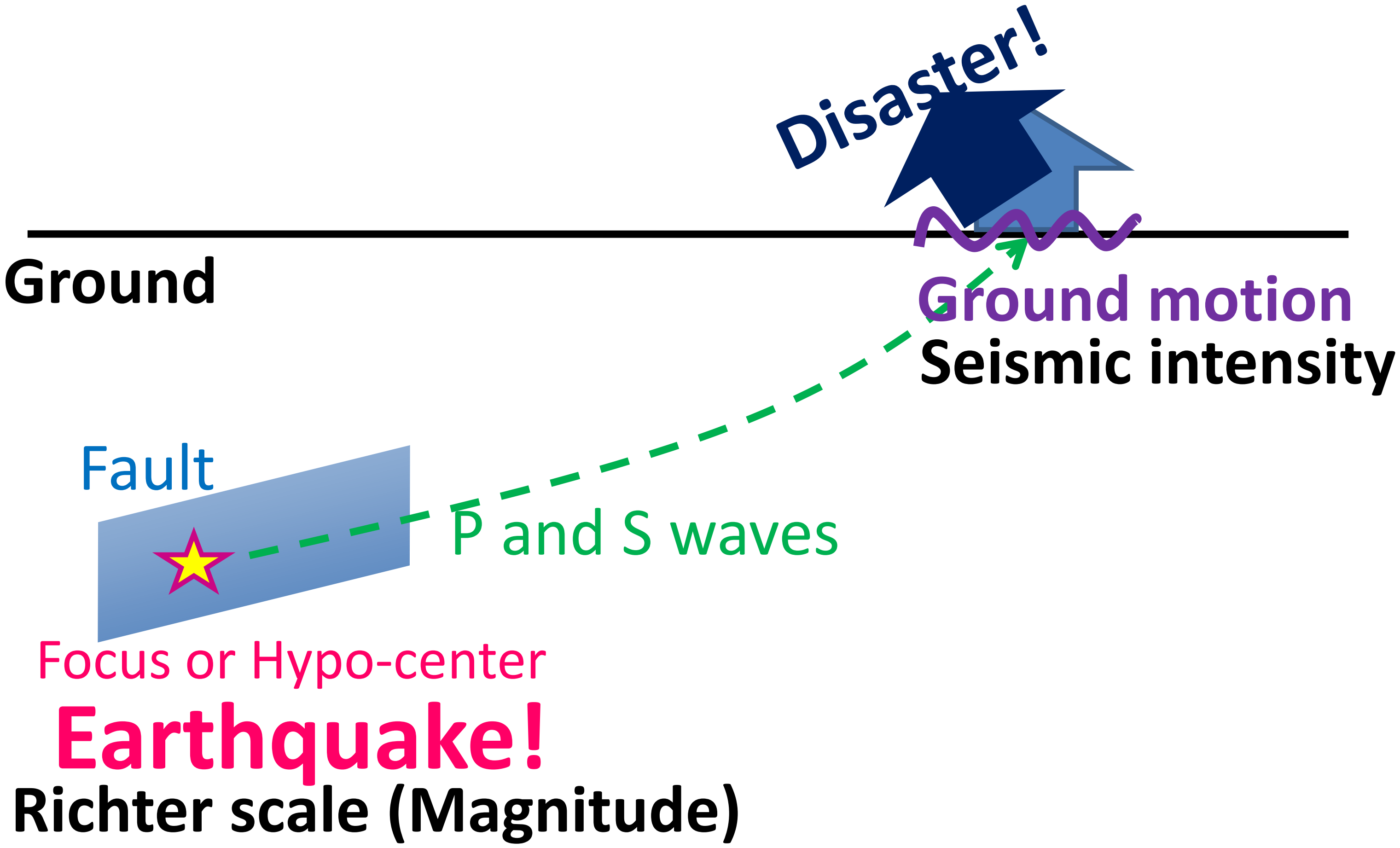


Leaf spring
Mas s
Pulling force
Cross spring
Mas s
Main spring

Structure of Electromagnetic sensor



Earthquake: cause and result



Hypo-Center Determination

- S-P time (old style)

  D = *k* x *t* *Omori's formula*

  D: distance of EQ [km]

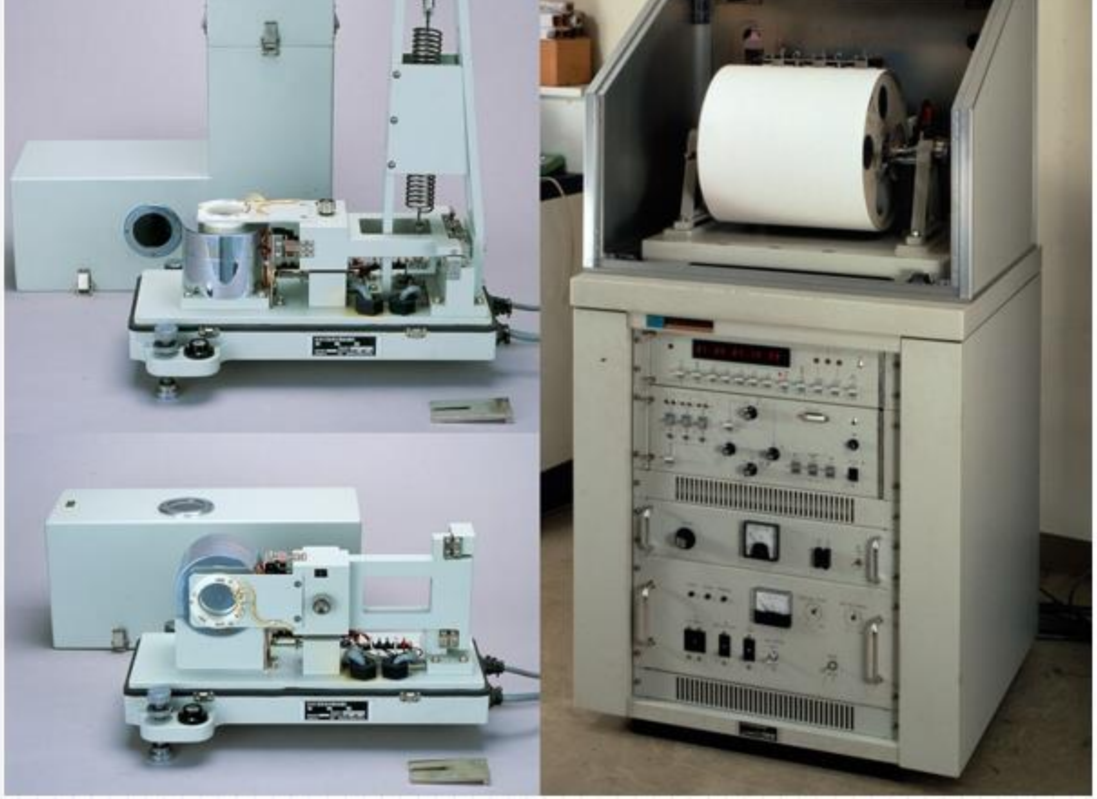
  k: Omori constant (8-9 [km/sec])

  t: S-P time [sec]

Fusakichi Omori

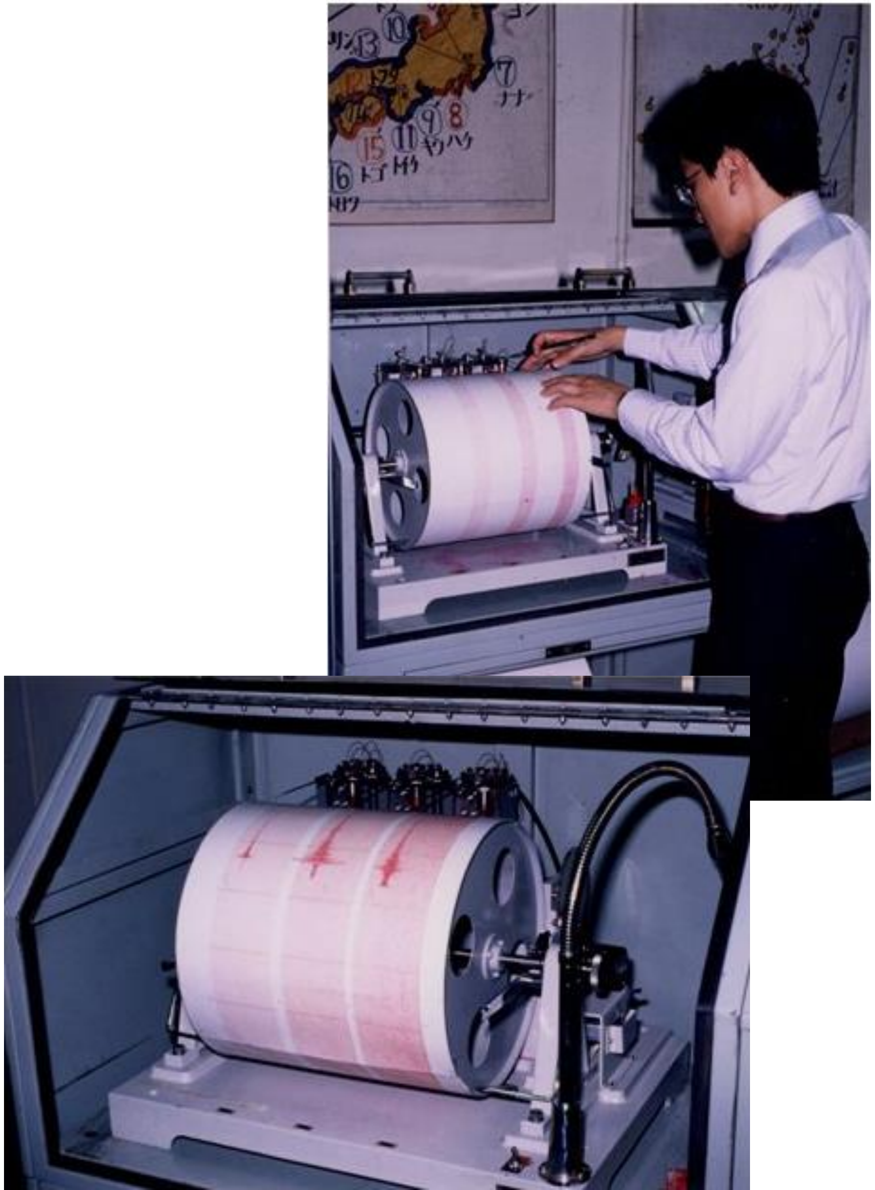
- P arrival times (modern style, development of crystal clock)
- Other methods (from seismic intensity, old documents etc.)

Left： Kahaku_Web
Right： Osaka kanku observatory



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.

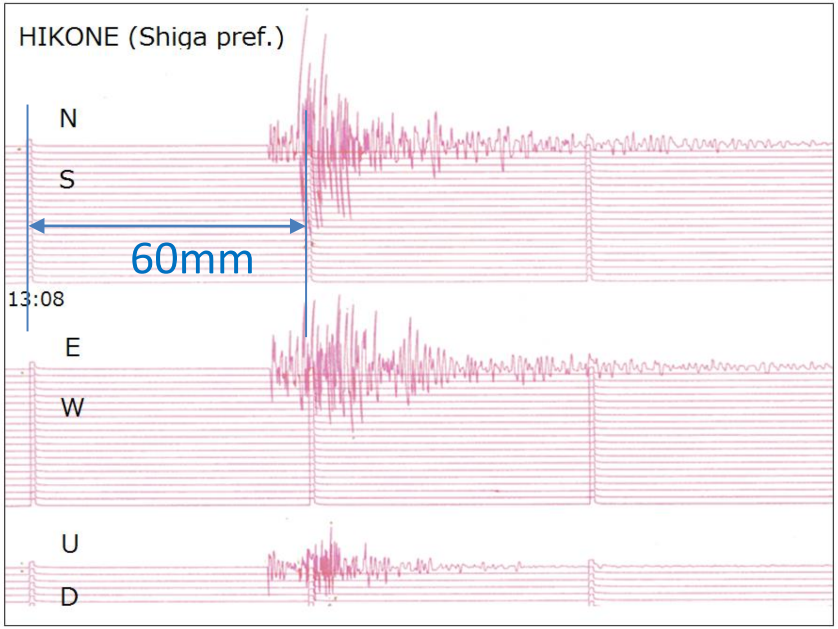
1) Compare the location of the epicenter determined in this exercise and the epicenter determined by JMA.
2) Let the value of the magnitude of the earthquake in this exercise be the average of the three magnitudes in Table 1. Write the value in the right (   ) and compare with the value determined by 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/

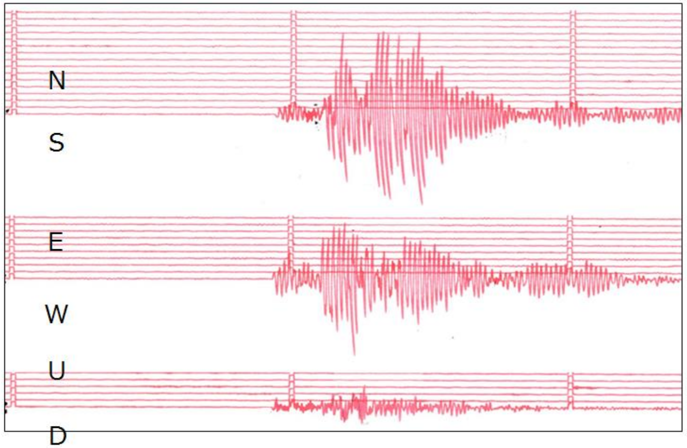
59type horizontal Seismographs in my house

Table 1 : Values to obtain in this exercise

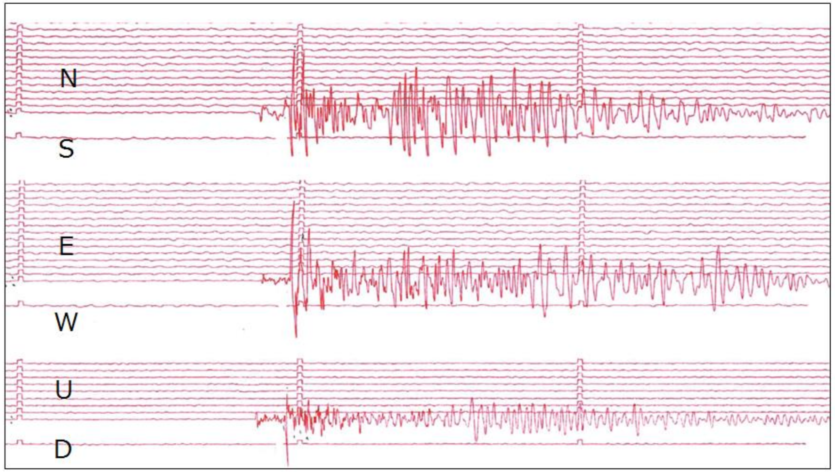
	HIKONE	OSAKA	TOYO-OKA
A arrival time of P-wave			
A arrival time of S-wave			
S-P time : T			
A hypocentral distance: $D = k \times T$ (k = 8.7)			
Maximum amplitude (NS)			
Maximum amplitude (EW)			
Maximum half-amplitude (NS)			
Maximum half-amplitude (EW)			
Amplitude : A			
Magnitude			

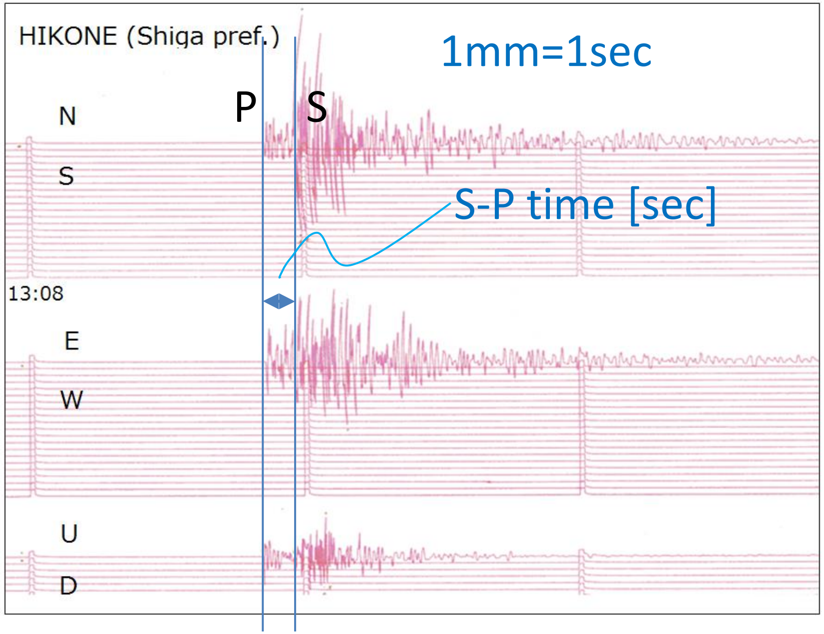


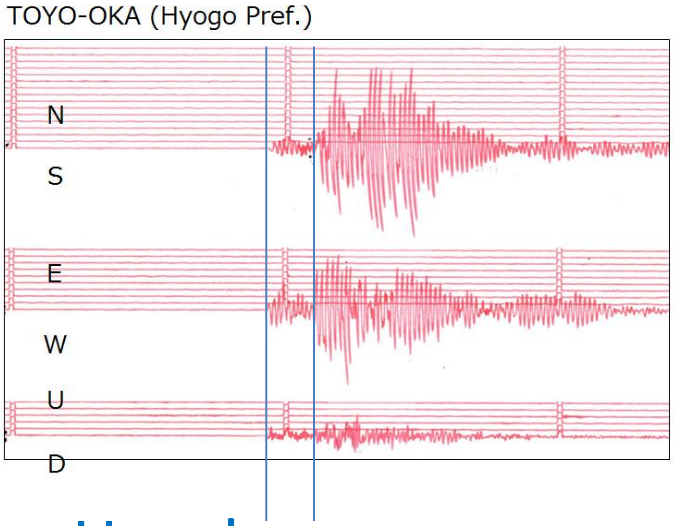
TOYO-OKA (Hyogo Pref.)



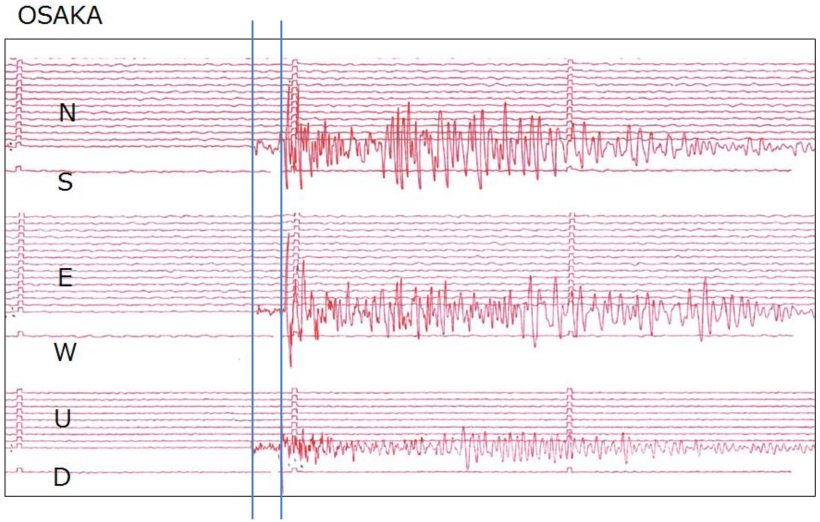
OSAKA







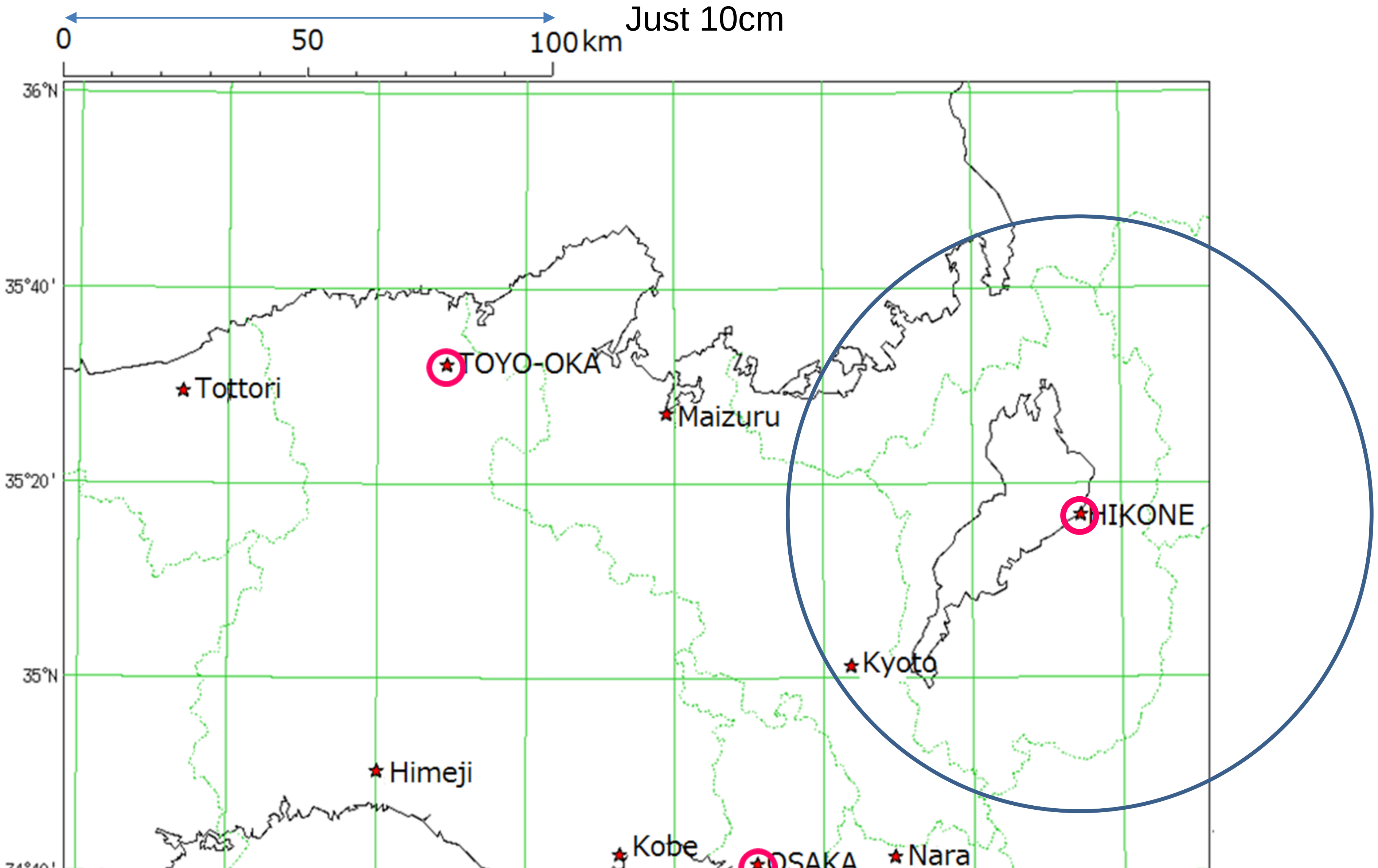
Here!



S-T time

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

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



Just 10cm
0
50
100km
36°N
35°40'
35°20'
35°N
TOYO-OKA
Tottori
Maizuru
HIKONE
Kyoto
Himeji
Kobe
OSAKA
Nara

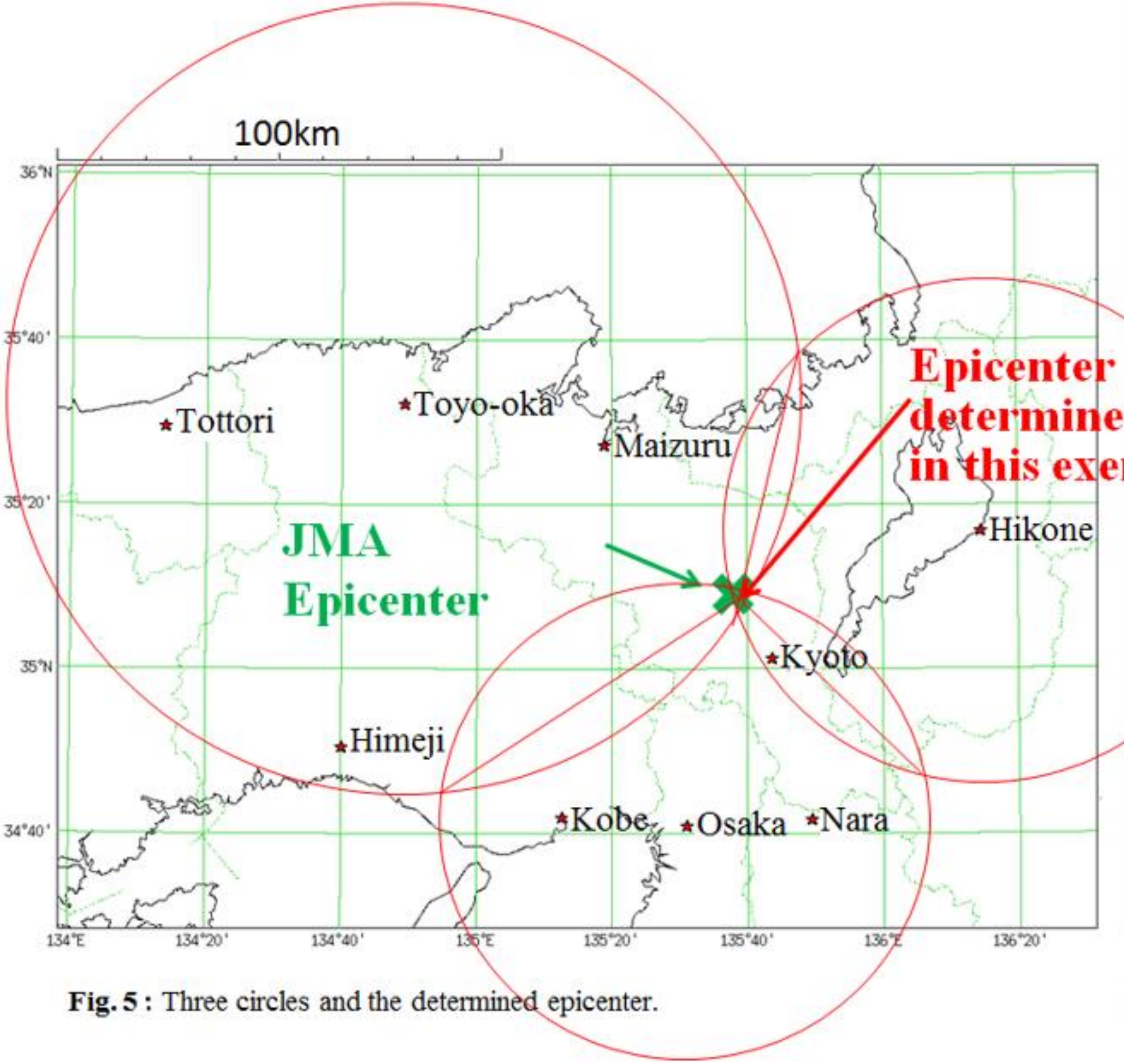


Fig. 5 : Three circles and the determined epicenter.

Fig. 6 : N

Magnitude

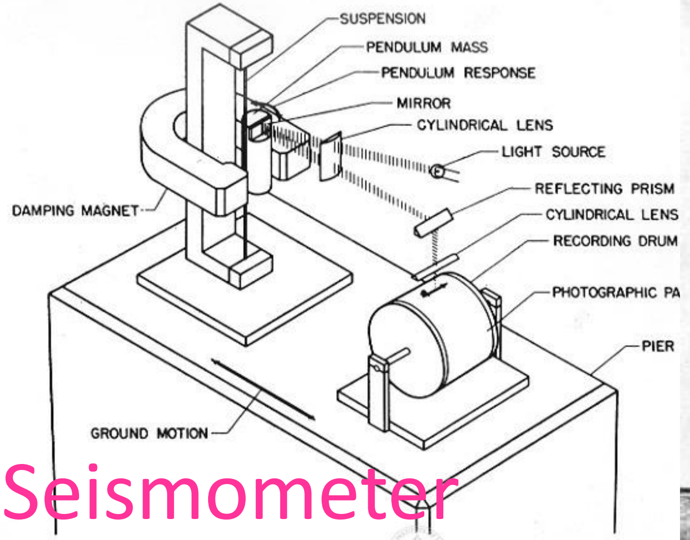
- Amplitude
- Distance

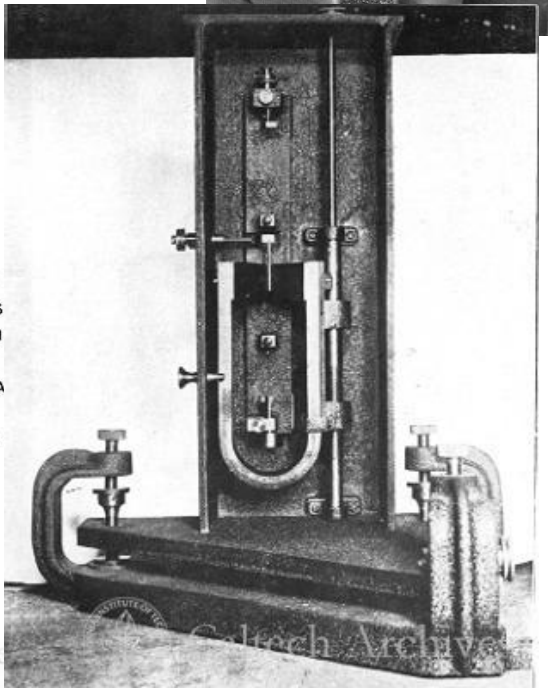
$M \sim \log A + \log D$

- Richter Scale (original definition)

C.F.Richter

Torsion Pendulum





Wood Anderson Seismometer

Bulletin of the
Seismological Society of America

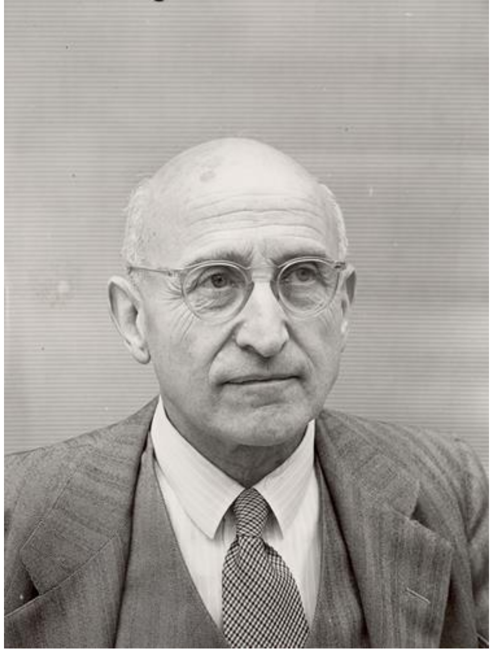
Vol. 32 JULY, 1942 No. 3

EARTHQUAKE MAGNITUDE, INTENSITY, ENERGY, AND ACCELERATION*

By B. Gutenberg and C. F. Richter

The magnitude of an earthquake was originally defined by the junior author (Richter, 1935), for shocks in southern California, as the logarithm of the maximum trace amplitude expressed in thousandths of a millimeter with which the standard short-period torsion seismometer (free period 0.8 sec., static magnification 2800, damping nearly critical) would register that earthquake at an epicentral distance of 100 kilometers. Gutenberg and Richter (1936) extended the scale to apply to earthquakes occurring elsewhere and recorded on other types of instruments.

Application of the scale involves tables of the logarithm of the maximum trace amplitude for a shock of magnitude zero as a function of epicentral distance. These tables, given in the papers referred to, are conveniently represented by a nomogram (fig. 1) designed by Mr. John M. Nordquist, who has drafted all the figures. The magnitude can then be found for shocks of "normal" depth (about 20 km.). For slightly different depths a correction can be



B.Gutenberg

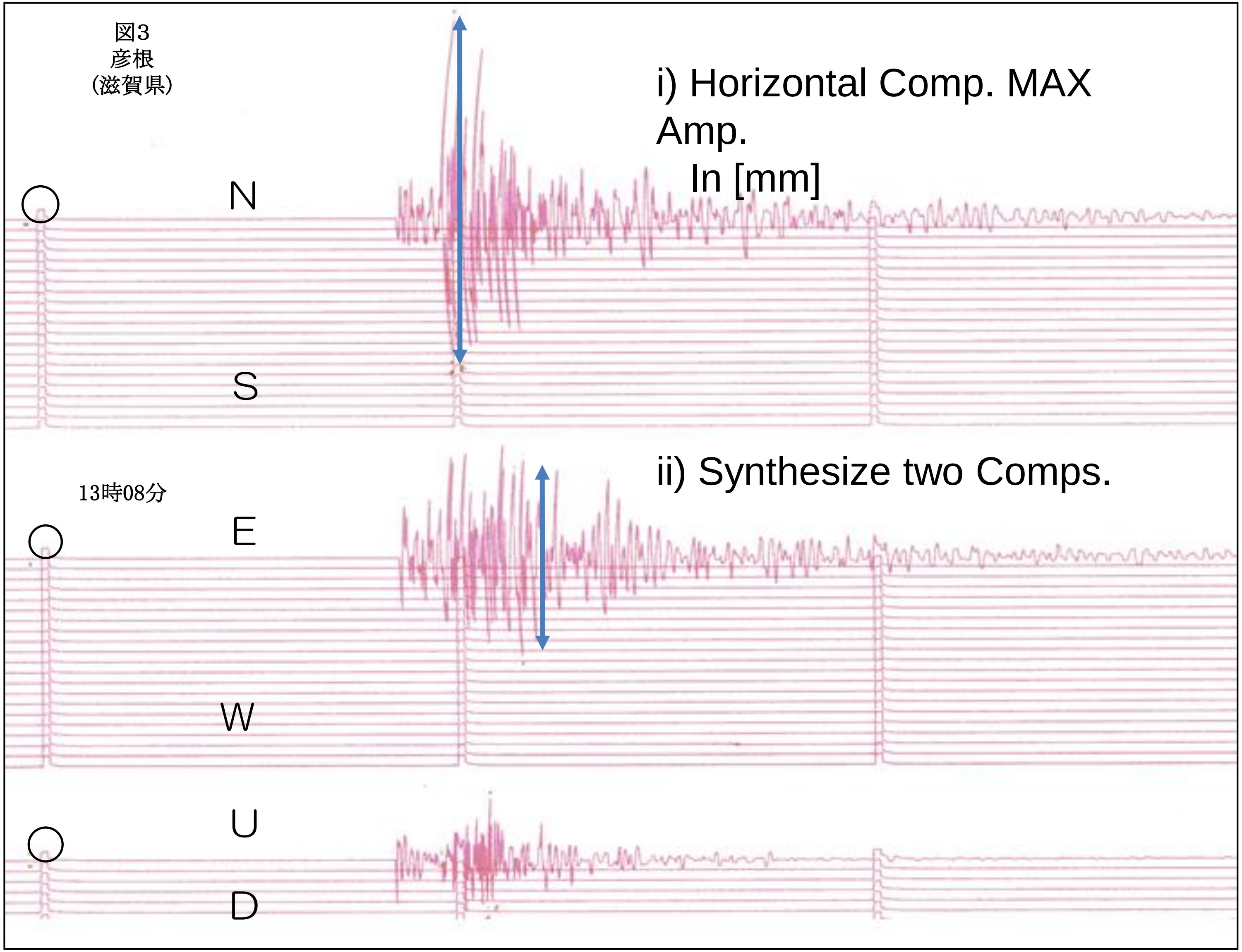
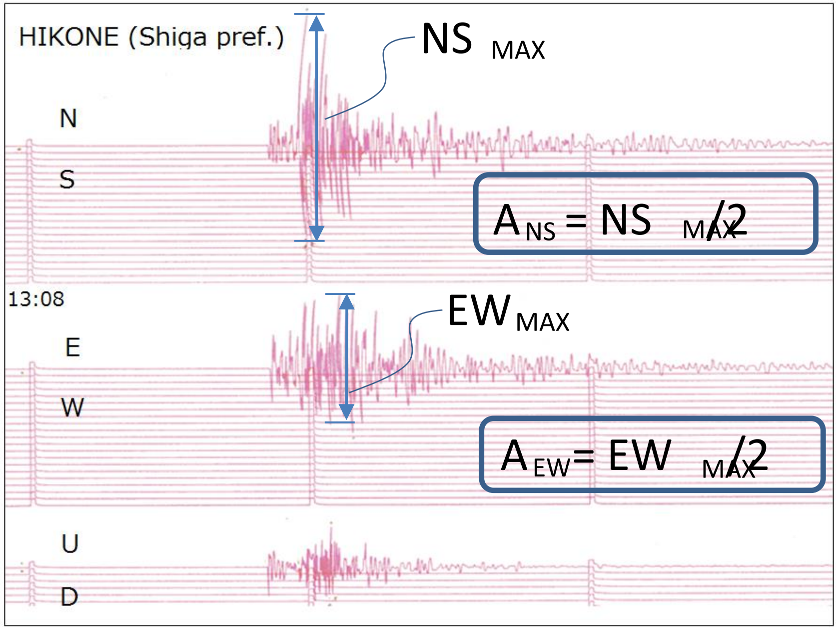
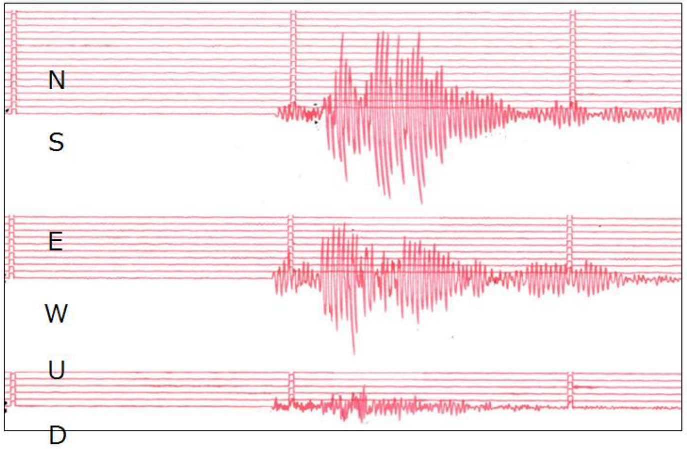


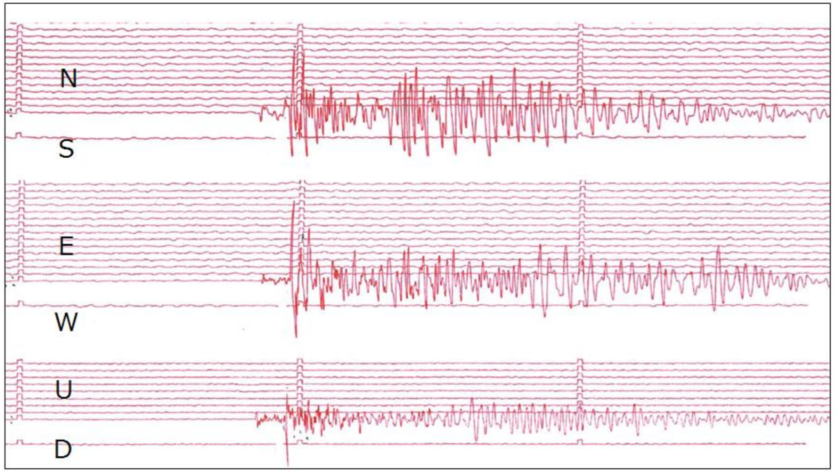
図3
彦根
(滋賀県)
N
S
i) Horizontal Comp. MAX Amp.
In [mm]
13時08分
E
W
ii) Synthesize two Comps.
U
D

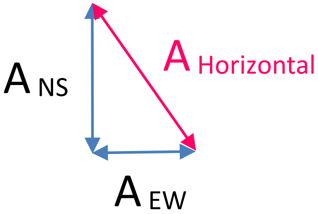


TOYO-OKA (Hyogo Pref.)



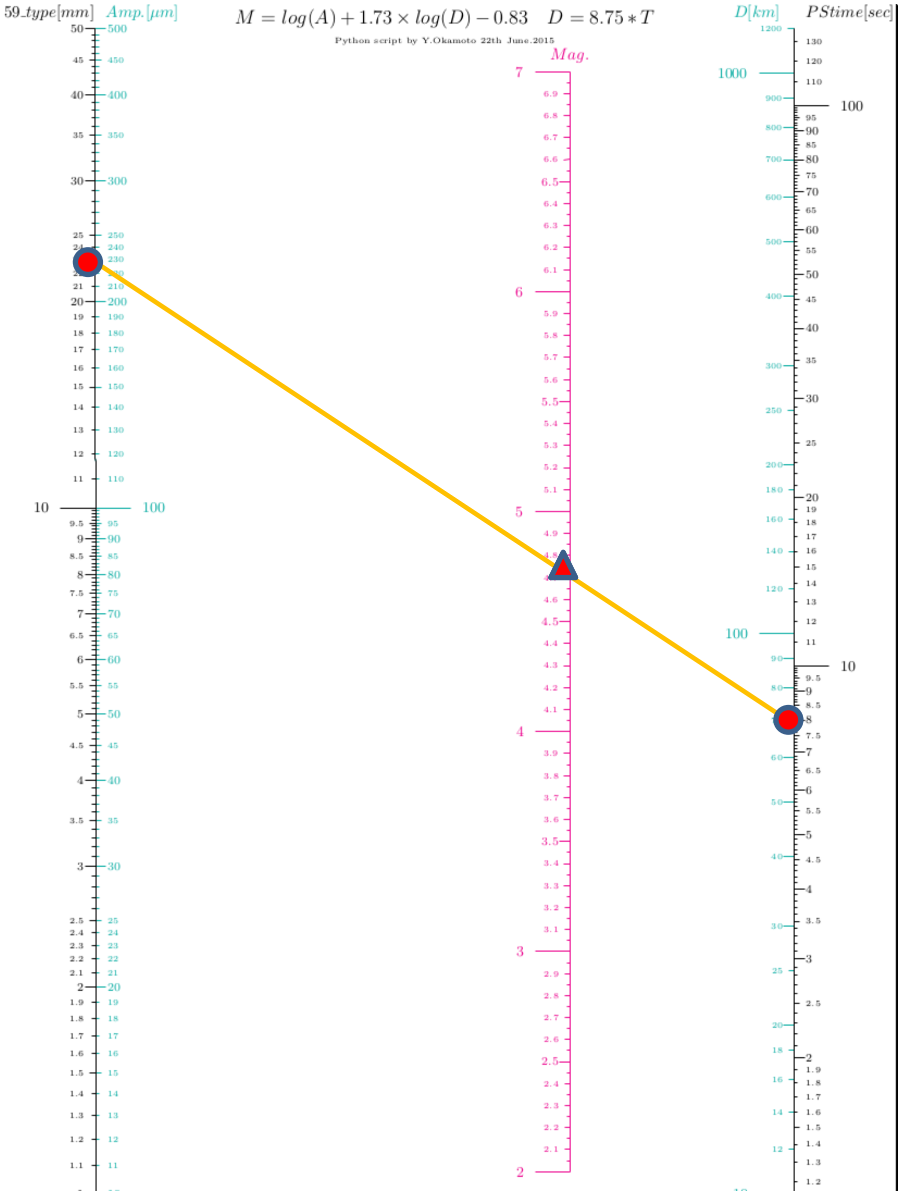
OSAKA





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

How to use Nomogram



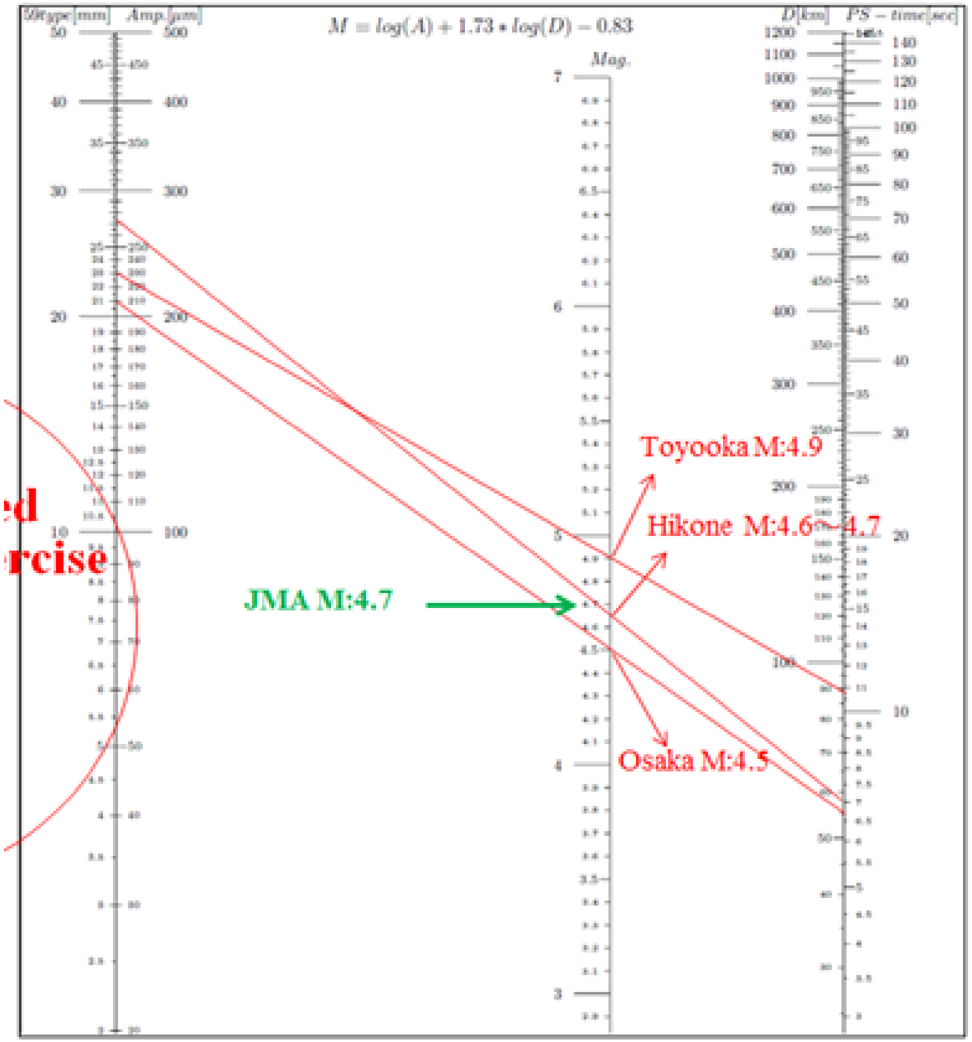
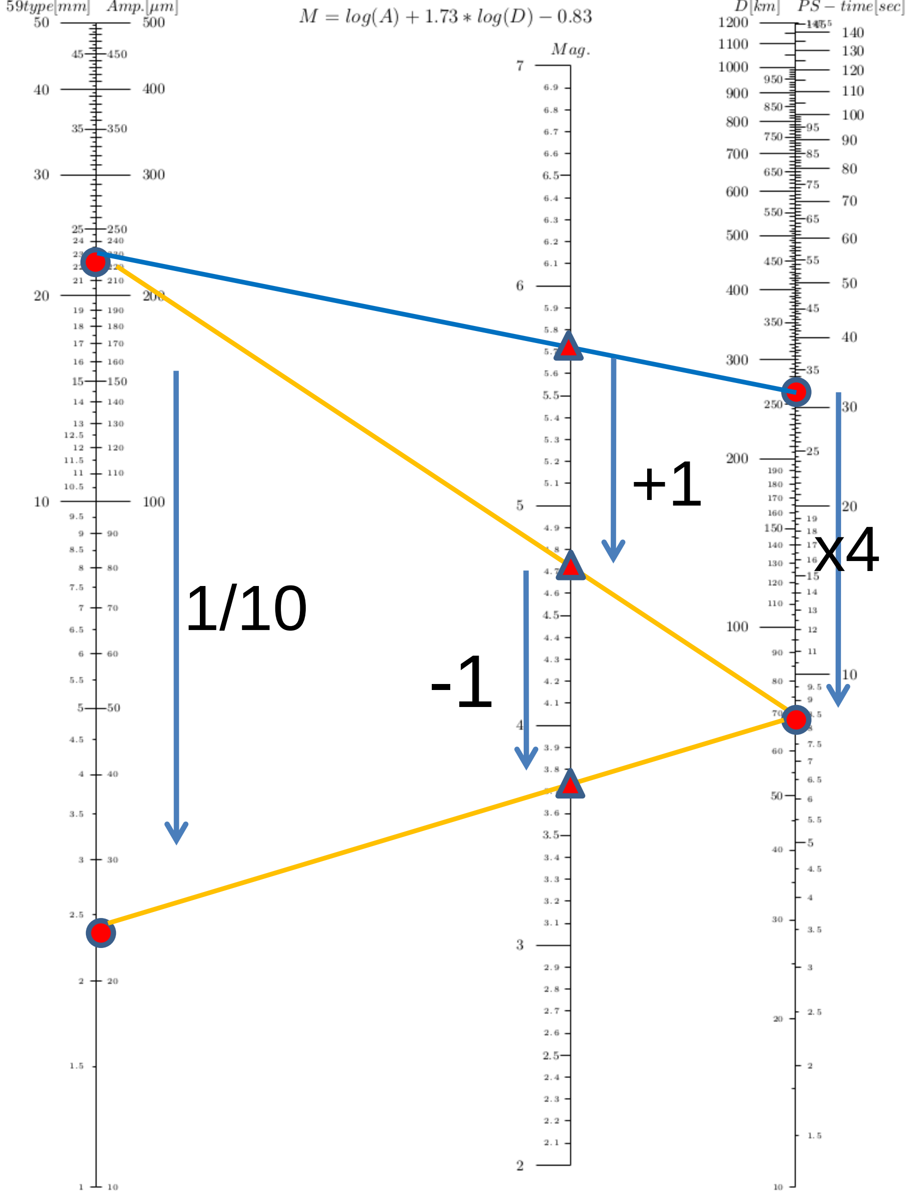


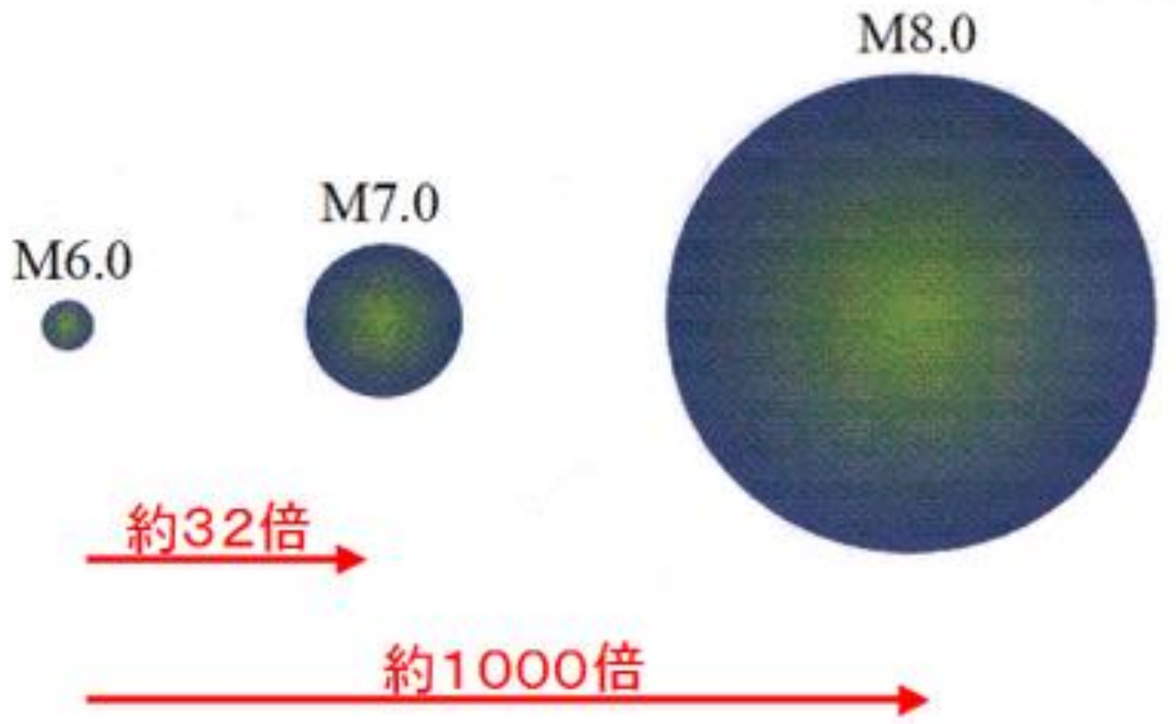
Fig. 6 : Nomogram

Application of Nomogram

- Quick look of logarithmic scaling

Multiple or divide
⇒add or subtract





マグニチュードと地震エネルギーの関係
（体積が地震エネルギーをあらわしている。）

Application of Nomogram

- Quick look of logarithmic scaling

Multiple or divide
⇒add or subtract