O2.4-656

New NMSOP chapter on analog seismogram processing

Josep Batlló [1], Raphael De Plaen [2]

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Rationale:

A manual for the use of old analog seismograms

- Present graduate student has never seen/use analog seismograms.
- "We" are the last generation of researchers/technicians that used regularly (and are acquainted with) analog seismograms.
- Documents/publications on the specific details for the proper management and understanding of the contents of analog seismograms have been published in old times and are not easy to identify/locate for young researchers.
- Each time a student goes into the topic has to receive "individual" training.
- A short manual, pointing to common topics when dealing with analog seismograms may facilitate the training of students and increase the use of such data.

The CoSOI recognized these facts (IUGG2023, Berlin) and decided to add a new chapter to the NMSOP on use of analog seismograms

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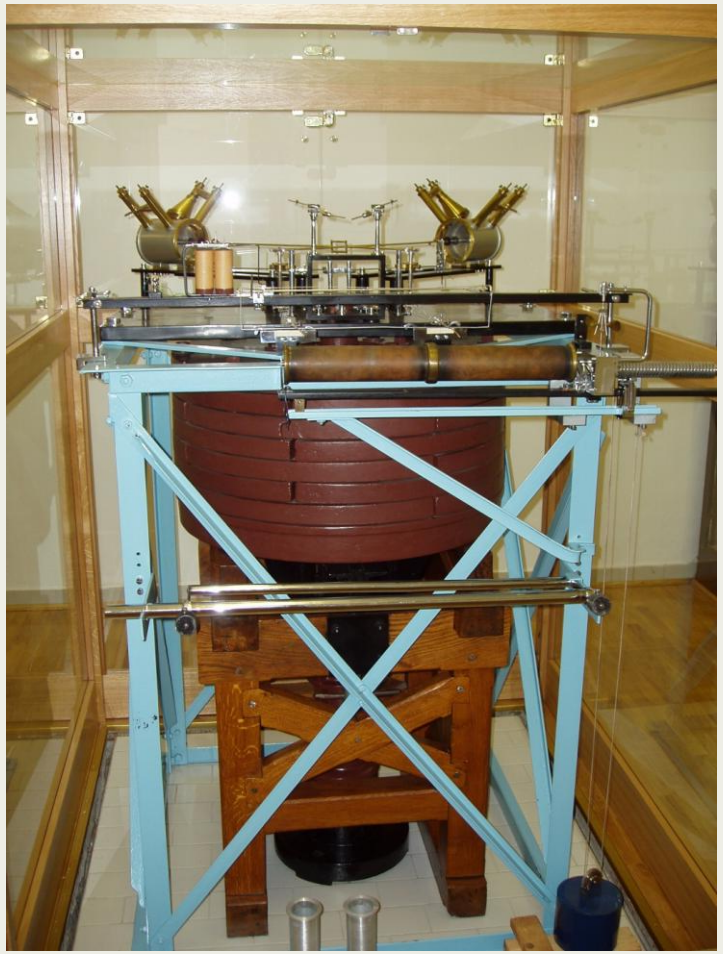
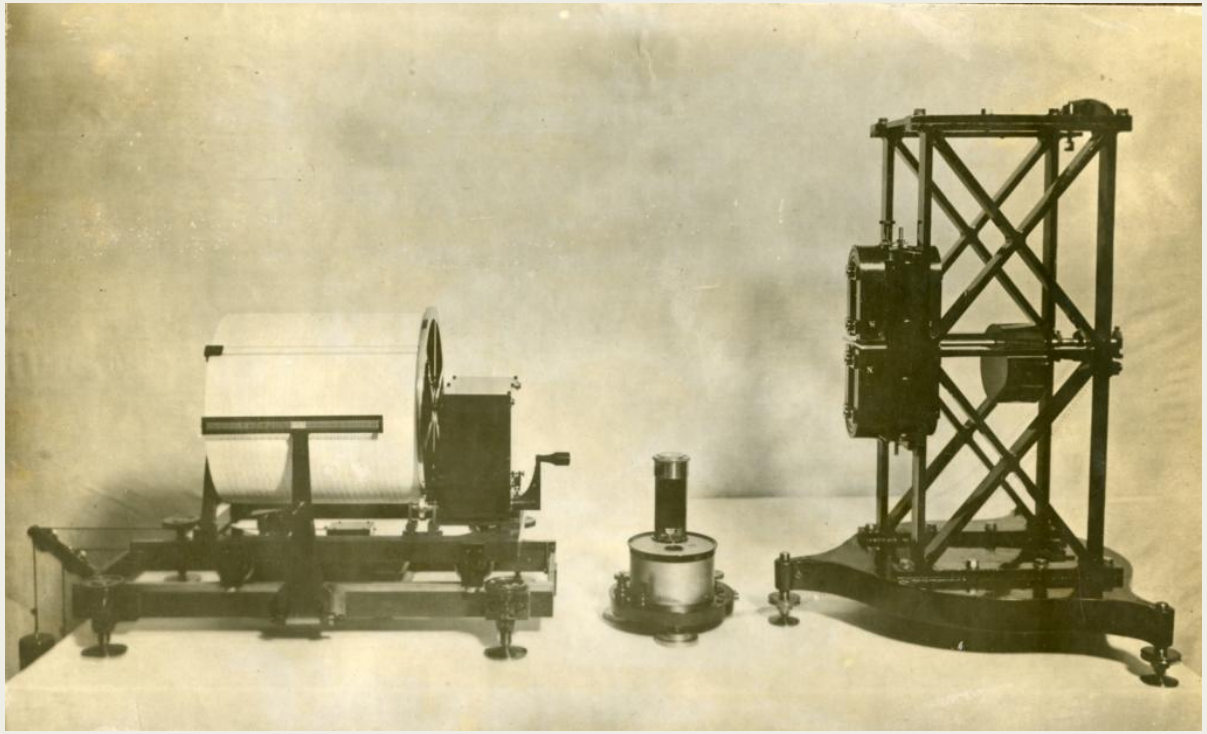
Our sources: Instruments



Wiechert, (http://www.gfz.hr/sobe-en/seismographs.htm)



Galitzin, (Rose, *Sci. Museum Group Journal,* 2021) ,

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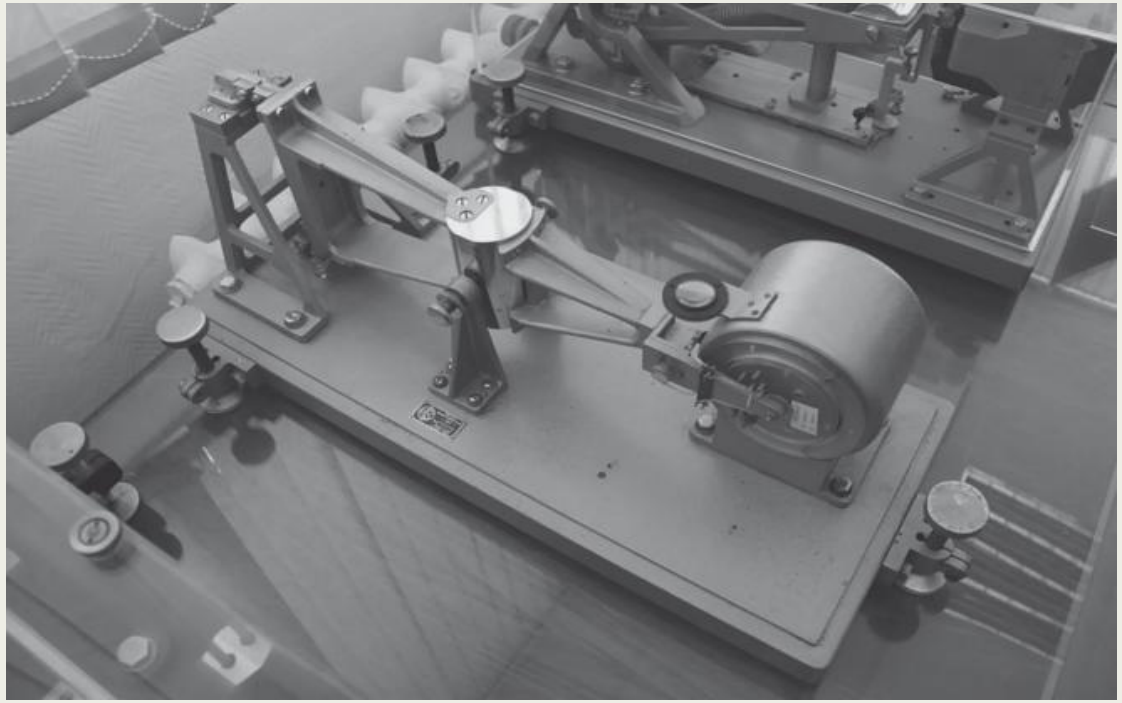
Our sources: Instruments

Benioff SP, (TOL)



Kirnos, (Rogozhin et al., *Izv. -Atmos. Ocean. Phys.*, 2019)

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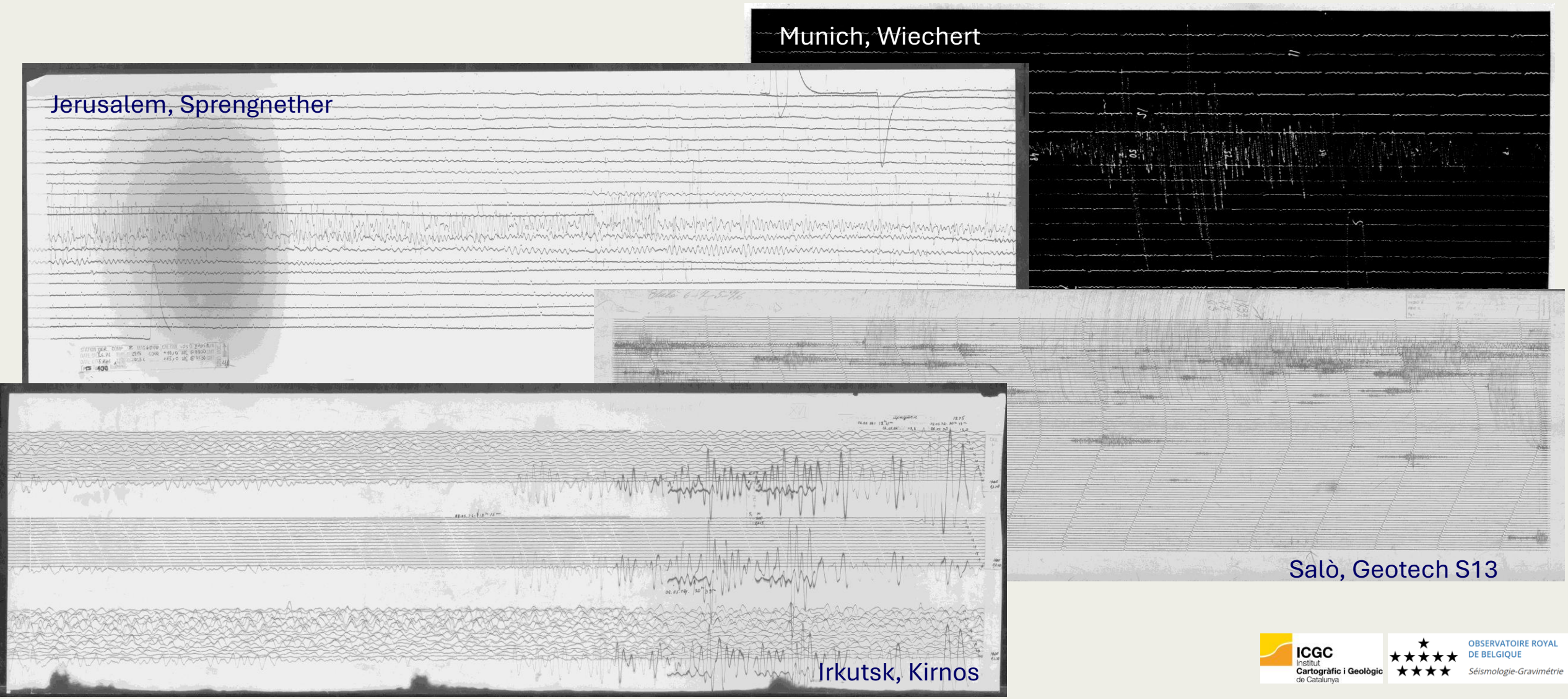
Our sources: Seismograms



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Our sources: Archives

Some where in Spain…
Barcelona, Fabra Observatory

IGN Geophysical Data Archive,
Toledo, Spain

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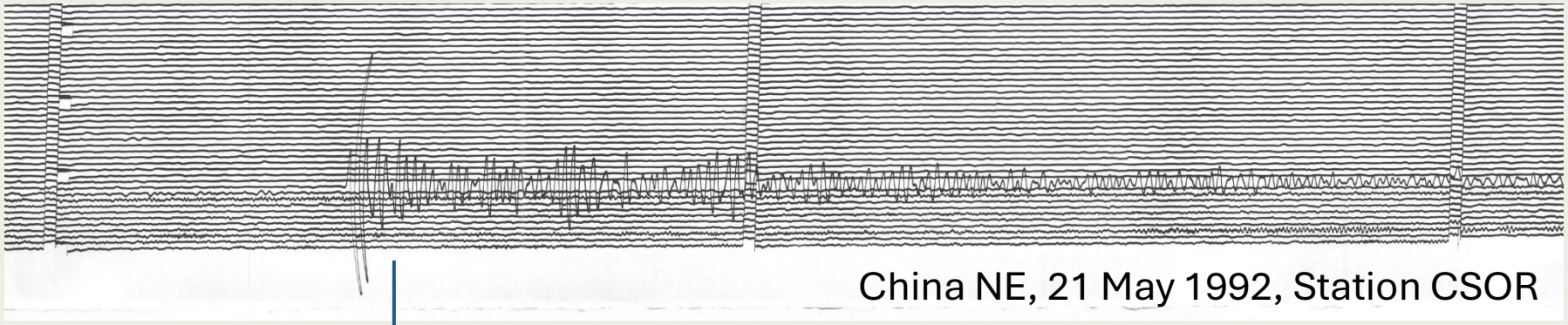
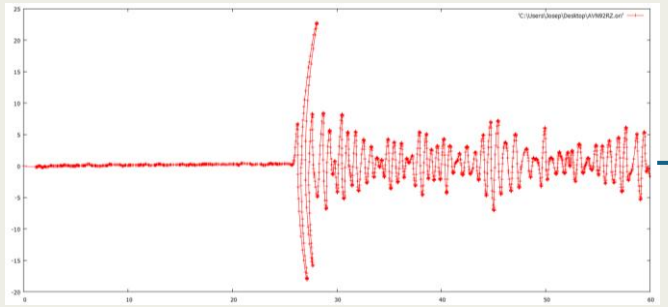
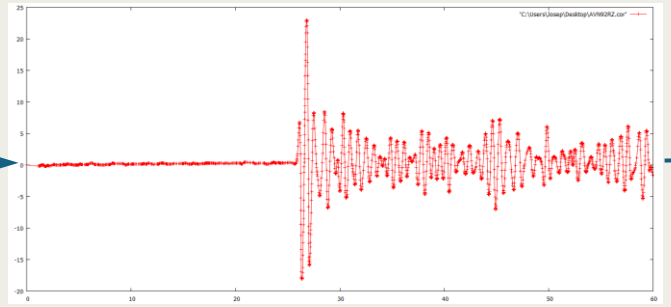
From materials to Results



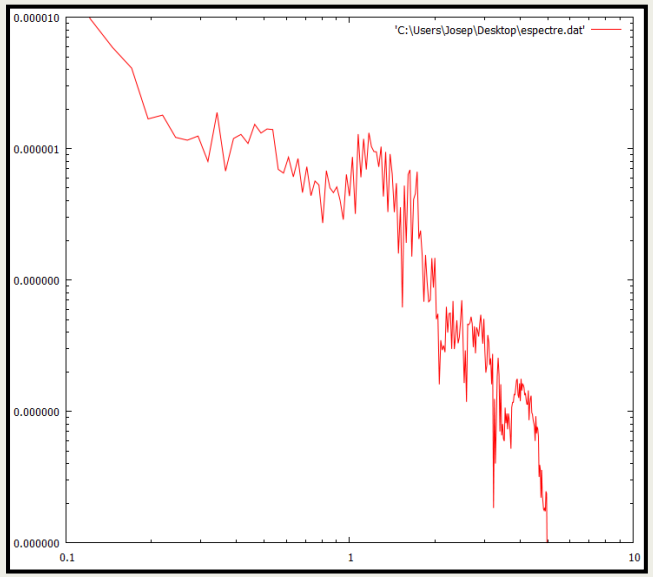
China NE, 21 May 1992, Station CSOR



Digitization



Corrected seismogram in useful (mSEED, SAC, etc.) format



Results

Covered by this manual

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Chapter Index:

NMSOP Chapter on analog seismograms use (tentative)

1. Introduction
2. Analog Seismogram morphology
3. Timing of seismograms
4. Record digitization – techniques/tips/programs
5. Seismograph transfer function
6. Working with digitized analog records

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More detailed Index:

NMSOP Chapter on analog seismograms use (tentative)

1.- Introduction.

- Ground motion recording. Early attempts.
- Mechanical and Electromagnetic Seismographs. (Seismograph history-evolution, mainly of transducers).

2.- Analog Seismogram morphology.

- Types: Smoked, Ink, Photographic and Thermal paper, Develocorder, Analog tapes.
- Record on seismograms: Lines, record speed, time marks, record sense/polarity, special cases.

3.- Timing of seismograms

- Absolute time acquisition.
- Seismogram time correction.
- Record speed variation.

4.- Record digitization – techniques/tips/programs

- Scanning/Preprocessing.
- Techniques/tips/programs.
- Analogue seismograms corrections: DC/Skew/finite arm length/irregular speed record/time marks.

5.- Seismograph transfer function.

- From Mag./Free period/Damping to Poles&Zeroes.

6.- Working with digitized analog records

- Phase reading: time and amplitude.
- Frequency contents.
- Waveform modelling. Body and Surface waves.
- Moment Tensor inversion.
- Pattern recognition.
- Other Applications.

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Present contents:

NMSOP Chapter on analog seismograms use

1. Introduction
2. Analog Seismogram overview and morphology
3. Record scanning and digitization
4. Seismogram corrections and timing
5. Seismograph transfer function
6. Bulletins and seismic phases
7. Applications of digitized analog records

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Example: Transfer function (mechanical instruments)

WIEN, K.K. Zentralanstalt f. Meteorologie und Geodynamik.

Seismische Aufzeichnungen.

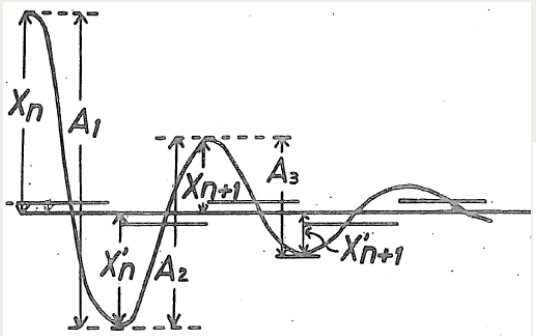
φ = 48°14.9' n. λ = 16°21.7' ö.v.Gr. Meereshöhe = 198 m Untergrund: Löß, darunter Lehm

Instrumente: Astat. Horizontal Pendel n. Wiechert, (Masse 1000 Kg), astat. Vertikal Pendel n. Wiechert (Masse 1300 Kg), Conrad-Pendel (Masse 24 Kg), Mikroseismograph n. Vicentini (ausser Betrieb).

		V	T_o	ε : 1	$\frac{r}{T_o^2}$
Wiechert	A_N:	150	7	4	0·002
	A_E:	175	8	4	0·004
	A_Z:	175	2·4	5	0·014

$$H_d(s) = A_m \frac{s^2}{(s^2 + 2s\omega_o h + \omega_o{}^2)}$$

$$(p_{1,2} = -\left(h \pm j\sqrt{1-h^2}\right)$$



$$h = \frac{\ln \varepsilon}{\sqrt{\pi^2 + \ln^2 \varepsilon}}$$

ε:1	h	ε:1	h	ε:1	h	ε:1	h
1.0	0.00	14.5	0.65	28.0	0.73	43.0	0.77
1.5	0.13	15.0	0.65	28.5	0.73	44.0	0.77
2.0	0.22	15.5	0.66	29.0	0.73	45.0	0.77
2.5	0.28	16.0	0.66	29.5	0.73	46.0	0.77
3.0	0.33	16.5	0.67	30.0	0.73	47.0	0.77
3.5	0.37	17.0	0.67	30.5	0.73	48.0	0.78
4.0	0.40	17.5	0.67	31.0	0.74	49.0	0.78
4.5	0.43	18.0	0.68	31.5	0.74	50.0	0.78
5.0	0.46	18.5	0.68	32.0	0.74	52.0	0.78
5.5	0.48	19.0	0.68	32.5	0.74	54.0	0.79
6.0	0.50	19.5	0.69	33.0	0.74	55.0	0.79
6.5	0.51	20.0	0.69	33.5	0.74	56.0	0.79
7.0	0.53	20.5	0.69	34.0	0.74	58.0	0.79
7.5	0.54	21.0	0.70	34.5	0.75	60.0	0.79
8.0	0.56	21.5	0.70	35.0	0.75	62.0	0.80
8.5	0.56	22.0	0.70	35.5	0.75	64.0	0.80
9.0	0.57	22.5	0.70	36.0	0.75	65.0	0.80
9.5	0.58	23.0	0.71	36.5	0.75	66.0	0.80
10.0	0.59	23.5	0.71	37.0	0.75	68.0	0.80
10.5	0.60	24.0	0.71	37.5	0.75	70.0	0.80
11.0	0.61	24.5	0.71	38.0	0.76	75.0	0.81
11.5	0.61	25.0	0.72	38.5	0.76	80.0	0.81
12.0	0.62	25.5	0.72	39.0	0.76	85.0	0.82
12.5	0.63	26.0	0.72	39.5	0.76	90.0	0.82
13.0	0.63	26.5	0.72	40.0	0.76	95.0	0.82
13.5	0.64	27.0	0.72	41.0	0.76	100.0	0.83
14.0	0.64	27.5	0.72	42.0	0.77		

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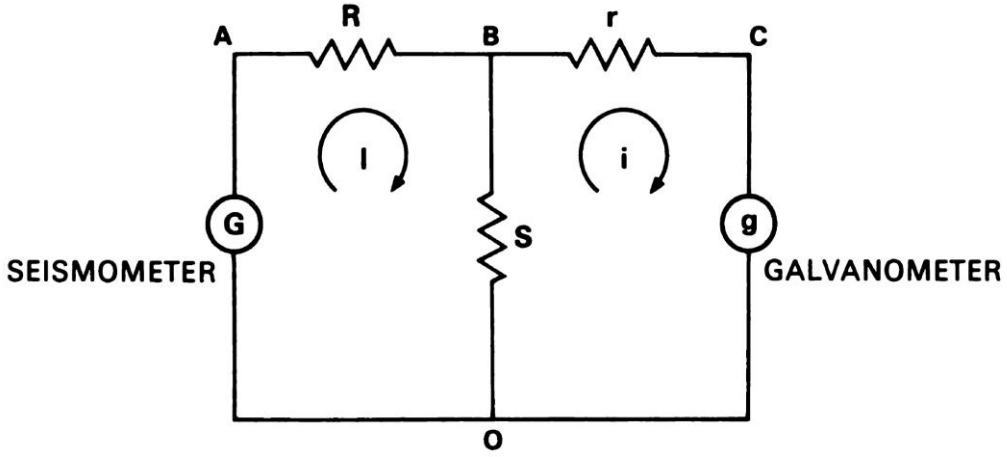
Example: Transfer function (electromagnetic instruments)

Instruments:

Galitzin pendulums with galvanometric registration.

Constants:

Component	l	T_1	A_1	μ^2	T	k
	cm	sec	cm		sec	
N	12.5	12.62	100	0.0	12.4	105
E	12.5	12.62	100	0.0	11.9	102
Z	14.4	11.56	100	−0.1	10	95



$$H_d(s) = A_m \frac{s^3}{(s^2 + 2s\omega_s h_s + \omega_s{}^2)(s^2 + 2s\omega_g h_g + \omega_g{}^2)}$$

$$p_{1,2} = -\left(h_s \pm j\sqrt{1 - h_s^2}\right)\omega_0$$

$$p_{3,4} = -\left(h_g \pm j\sqrt{1 - h_g^2}\right)\omega_0$$

$$A_m = \frac{2\,k\,A}{l}$$

- k - The transmission factor.
- A - The length of the beam of light from the galvanometer mirror to the recording drum.
- l - The length of the simple equivalent pendulum.

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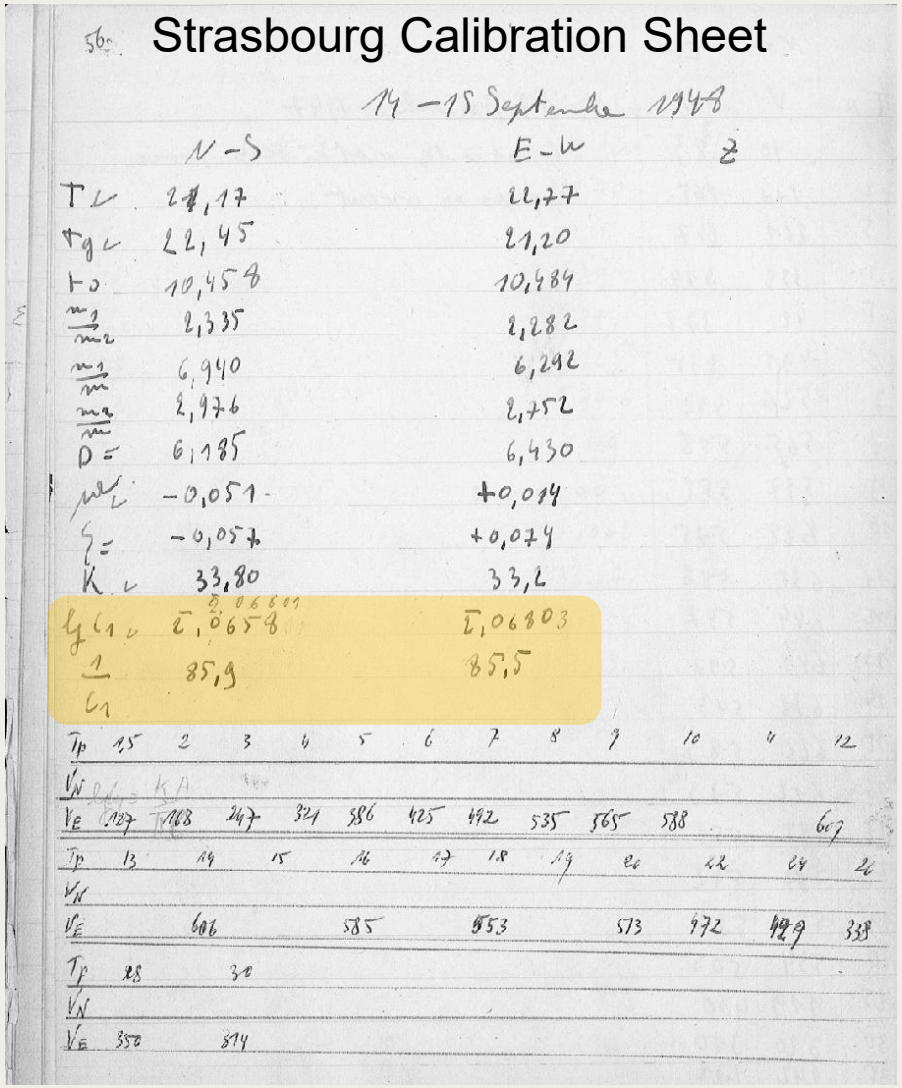
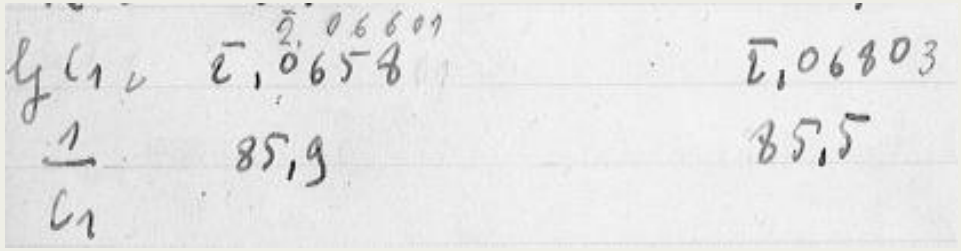
Transfer function (some tips)

Strasbourg Calibration Sheet



Meaning of C_1:



Maximum magnification for Galitzine is:

$$V_{max} = \frac{3\sqrt{3}}{16}\frac{kA}{\pi l}T$$

And we define C_1 as:

$$C = \frac{\pi l}{kA}$$

$log\ C_1 = \bar{2}.0658$

(in modern notation: $log\ C_1 = -1.9342$) $1/C_1 = 85.9$

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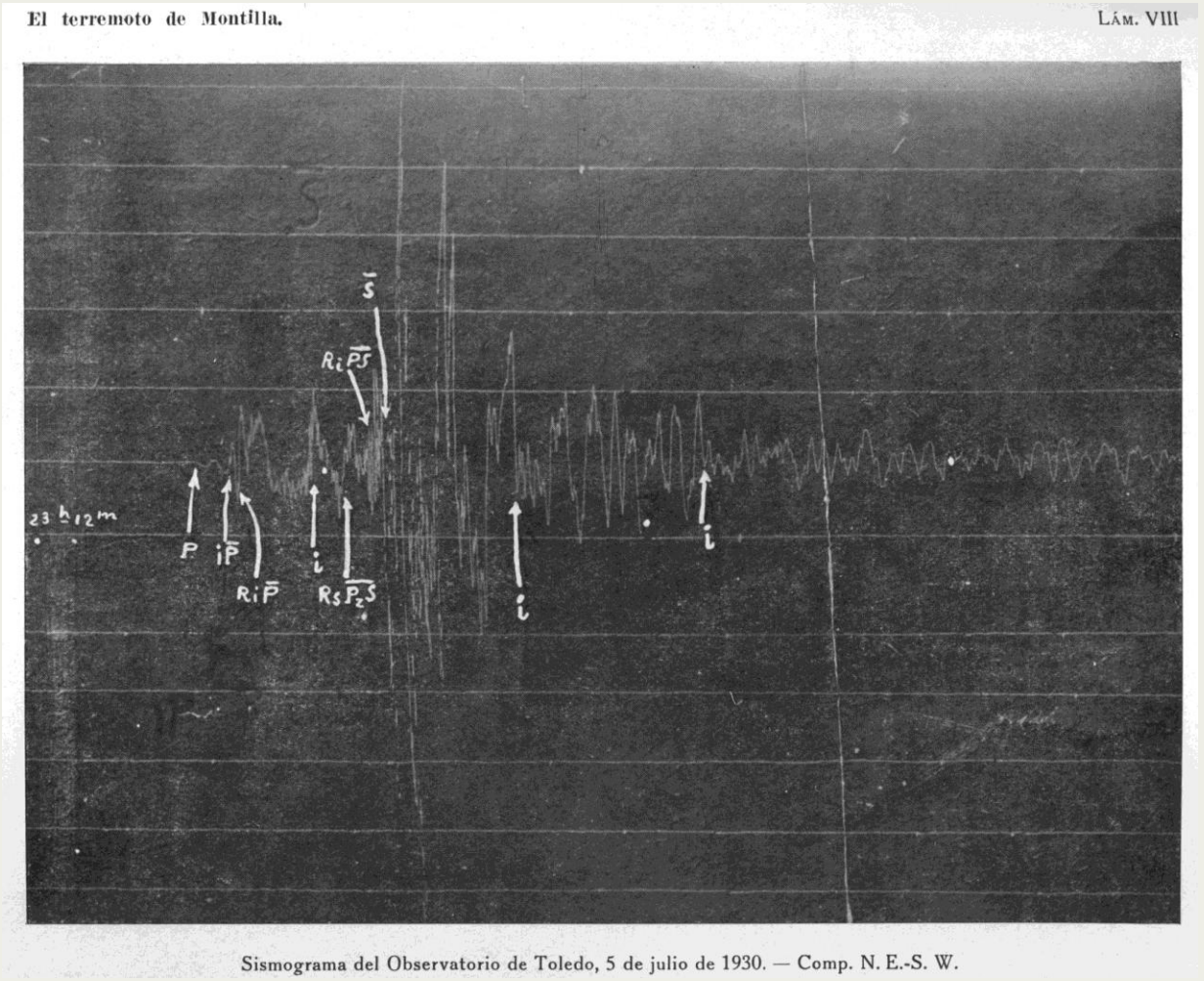
Bulletins (phase notation)

83	5	P	23	12	19,6	»	»	»	»	»	Epicentro: 37°, 35′ 42″ N. y 4°, 38′ 00″ W. Gr. Hora en el epicentro, 23 h. 11 m. 50 s. Profundidad hipocentral, 50 km. Hora en el hipocentro, 23 h. 11 m. 41 s. Sentido de Grado VIII (ruinoso) en Montilla: de Grado VIII-VII en Espejo (provincia de Córdoba, España.) La isosista VII pasa por el N., de Castro del Río, por Montemayor, S. de Aguilar y W. de Nueva Carteya, existiendo una zona secundaria de este mismo Grado alargada de NNE. a SSW., como la principal, y que comprende los pueblos de Cabra y Doña Mencía. La isosista VI se extiende por el N. hasta Cañete de las To-
		iP	23	12	21,9	»	»	»	»	»	
		$R_1\ \overline{P}$	23	12	24,8	0,7	»	»	»	»	
		$R_5\ \overline{P}$	23	12	30.4	»	»	»	»	»	
		$R_{12}\overline{P}$	23	12	33,7	»	»	»	»	»	
		$R_{s2}\overline{P}$	23	12	43,3	1,1	»	»	»	»	
		$R_{12}P_3S$	23	12	45,2	»	»	»	»	»	
		iS	23	12	48,4	2,5	»	»	»	»	
		$R_1\ \overline{S}$	23	12	51,5	»	»	»	»	»	
		$R_5\ \overline{S}$	23	13	1,6	»	»	»	»	»	
		M	23	13	4,5	2,2	»	67 E	»	»	
		$R_{12}\overline{PS}_1$	23	13	5,9	2,2	»	»	»	»	
		M	23	13	11,7	2,7	»	»	118 D	»	
		$R_{s_2}P_2\overline{S}_2$	23	13	12,0	»	»	»	»	»	

Phase notation evolved greatly in the first half of XX Century. Example of Mohorovicic phase notation for a Regional earthquake.



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Nex steps

- It will be available soon at the website of the ESC-WG.
- A second version will be rewritten and improved in the next months.
- The text, as chapter of the NMSOP-2 should be kept on proper dimensions (it is a tutorial, not a book).
- Exercises should complement this text.
- It is complemented by the “Seismic Patrimony Preservation Tutorial”.
- In the future, it will be a good complement to FOLDS (see poster P2.4-145).
- Any collaboration, help, remark, note will be welcome (contact us or the ESC-WG at https://www.legacy-seismograms.eu/contact-us/).

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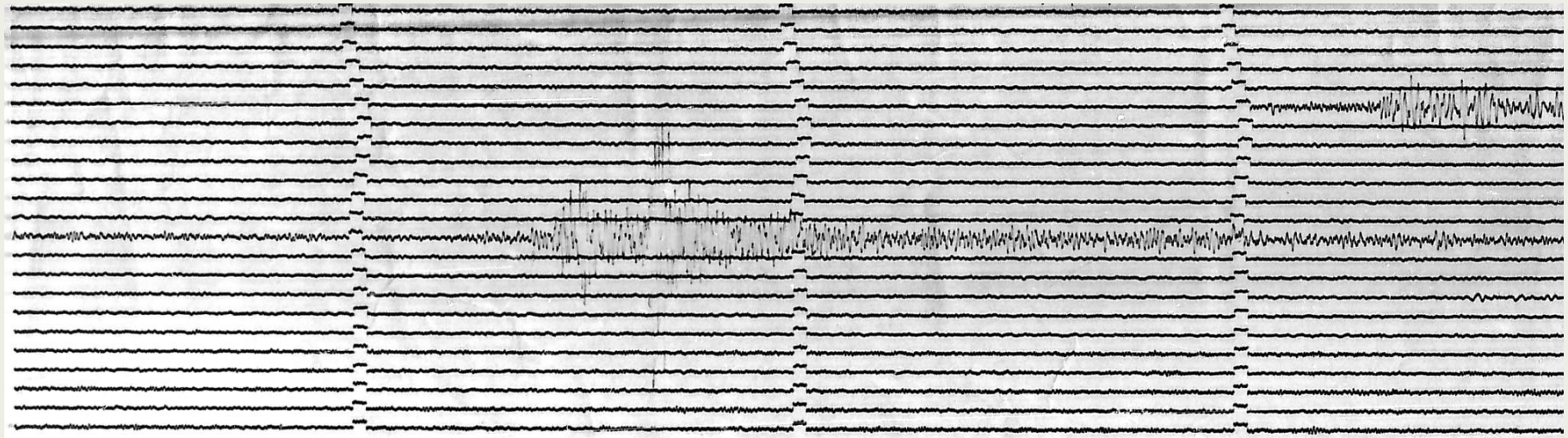
Thank you for your attention!



Trinity Nuclear Explosion recorded at Tucson (TUO), July 16, 1945, 11:29 GMT

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