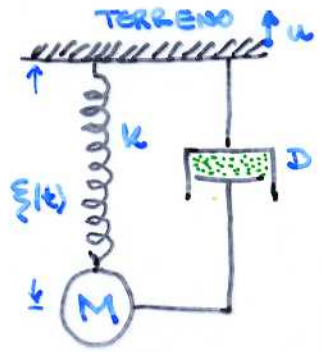
SISMOMETRI

Dicesi sismometro qualunque strumento che misura la dipendenza temporale dello spostamento del terreno. Per misurare lo spostamento del terreno su cui lo strumento poggia si usa l'inerzia: per un moto del terreno sufficientemente rapido una massa sospesa rimarrà immobile e ci darà un punto di riferimento contro il quale misurare il moto del terreno.



Il sismometro a pendolo consiste in una massa M appesa ad una molla con costante k e ad un ammortizzatore con costante D in parallelo.
La forza della molla è proporzionale allo spostamento, la forza dell'ammortizzatore invece alla velocità.

Indicando con u lo spostamento del terreno e con ξ lo spostamento della massa, l'equazione del moto sarà

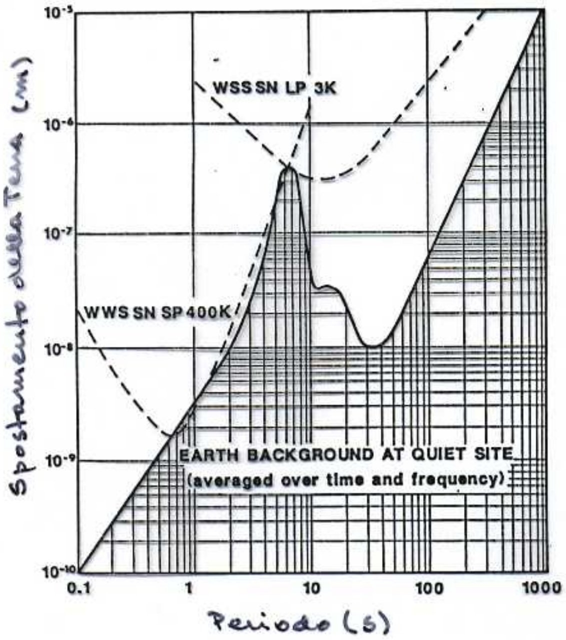
$$M(\ddot{\xi}+\ddot{u}) + D\dot{\xi} + k\xi = 0$$

Dividendo per M ed introducendo le quantità $\epsilon = \frac{D}{2M}$, $\omega_s^2 = \frac{k}{M}$ si trova

$$\ddot{\xi} + 2\epsilon\dot{\xi} + \omega_s^2\xi = -\ddot{u}$$

Da quest'equazione possiamo trovare il moto del terreno misurando ξ e le sue derivate temporali.
La risposta dello strumento al moto di una certa frequenza si può calcolare ricordando che la dipendenza temporale dello spostamento dovuto ad un'onda è

$$u \sim e^{-i\omega t}$$



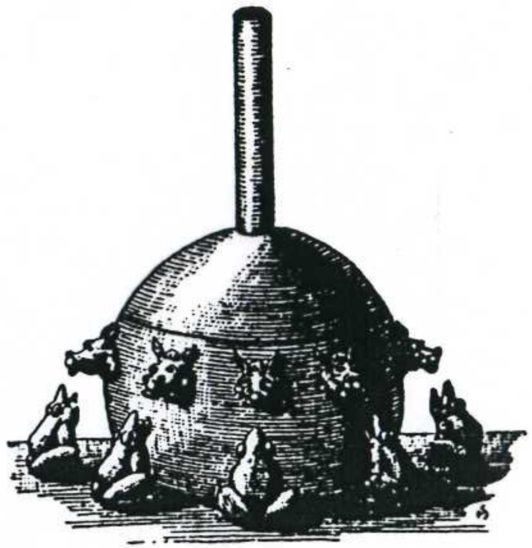
Le onde oceaniche producono grandi quantità d'energia a periodi attorno ai 6 s. Tali onde registrate con i sismometri vengono dette microsismi e dominano il moto del terreno a questi periodi (vedi grafico a sinistra).
Per rendere gli strumenti quanto più insensibili a questa banda, vennero introdotti due tipi di strumenti standard.

Il primo è detto a corto periodo, con periodi ($\frac{2\pi}{\omega_s}$) minori di 6 s (tipicamente $T_s \approx 1$ s) che registra quindi bene le alte frequenze. Di solito ha amplificazioni molto grandi.

Il secondo è detto a lungo periodo, con periodi maggiori di 6 s (tipicamente $T_s \sim 15$ s) che registra bene le basse frequenze.

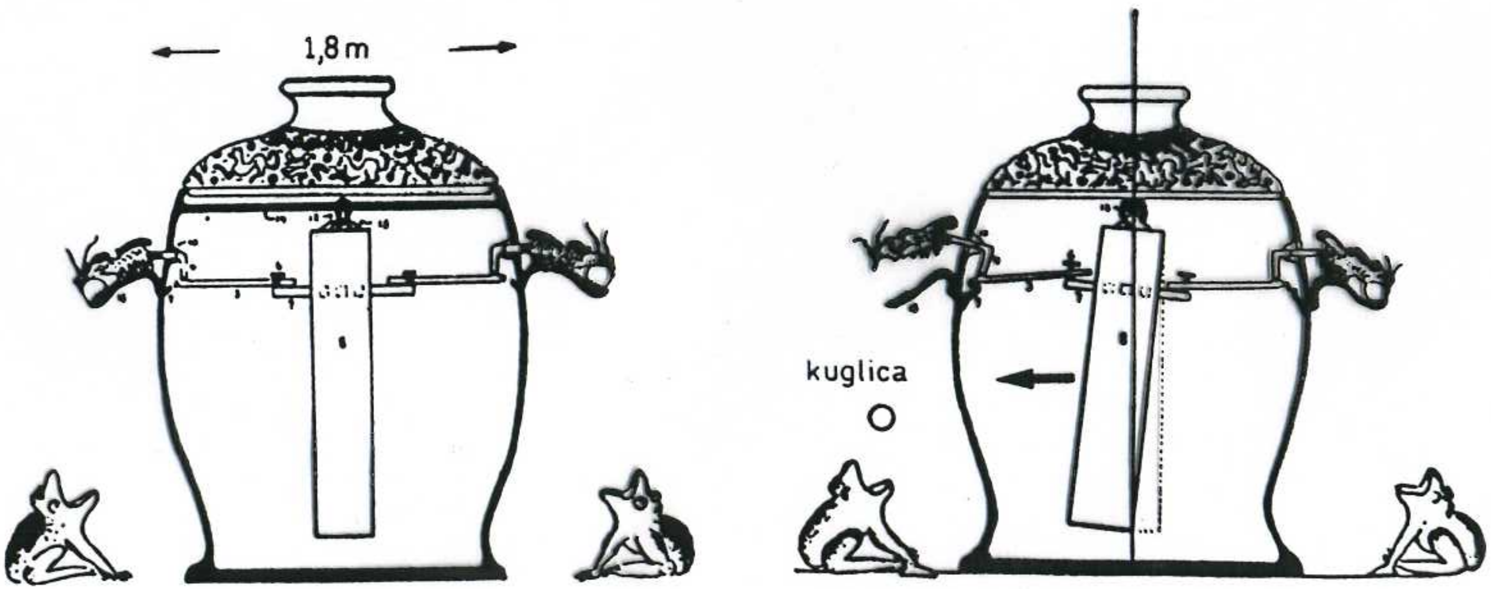
Poiché l'anelasticità della Terra attenua maggiormente le alte frequenze, gli strumenti a corto periodo (SP) sono usati per registrare terremoti locali, mentre i telesismi verranno registrati bene dagli strumenti a lungo periodo (LP).

Le moderne tecniche di filtraggio elettronico permettono di usare oggi un'unico sensore meccanico con un'alta risposta su una banda larga di frequenze, per cui tali strumenti vengono detti a larga banda. Le bande di frequenze indesiderate si possono eliminare o ridurre con filtraggi numerici. Inoltre l'acquisizione digitale permette una banda dinamica più elevata, che consente la registrazione sia di spostamenti piccoli che grandi su una stessa serie temporale.



Seizmoskop Chang Henga (132. g) služio je za određivanje smjera u kojem tlo najjače oscilira. Osnovni dio bila je posuda s njihalom koja je imala 8 otvora, a u svakom je bila glava zmaja s kuglicom u ustima. Za vrijeme potresa njihalo bi oslobodilo jednu kuglicu koja bi upala u usta žabe u smjeru u kojem tlo najjače oscilira.

The seismoscope of Chang Heng (132 A.D.) was used to determine the direction of major earth oscillation. Its main part was a vessel with a pendulum; the vessel had 8 openings, each with the head of a dragon holding a small ball in its mouth with a sitting frog figure below. During an earthquake the pendulum would release a ball, which would then fall into the mouth of the frog in the direction of the strongest earth oscillation.



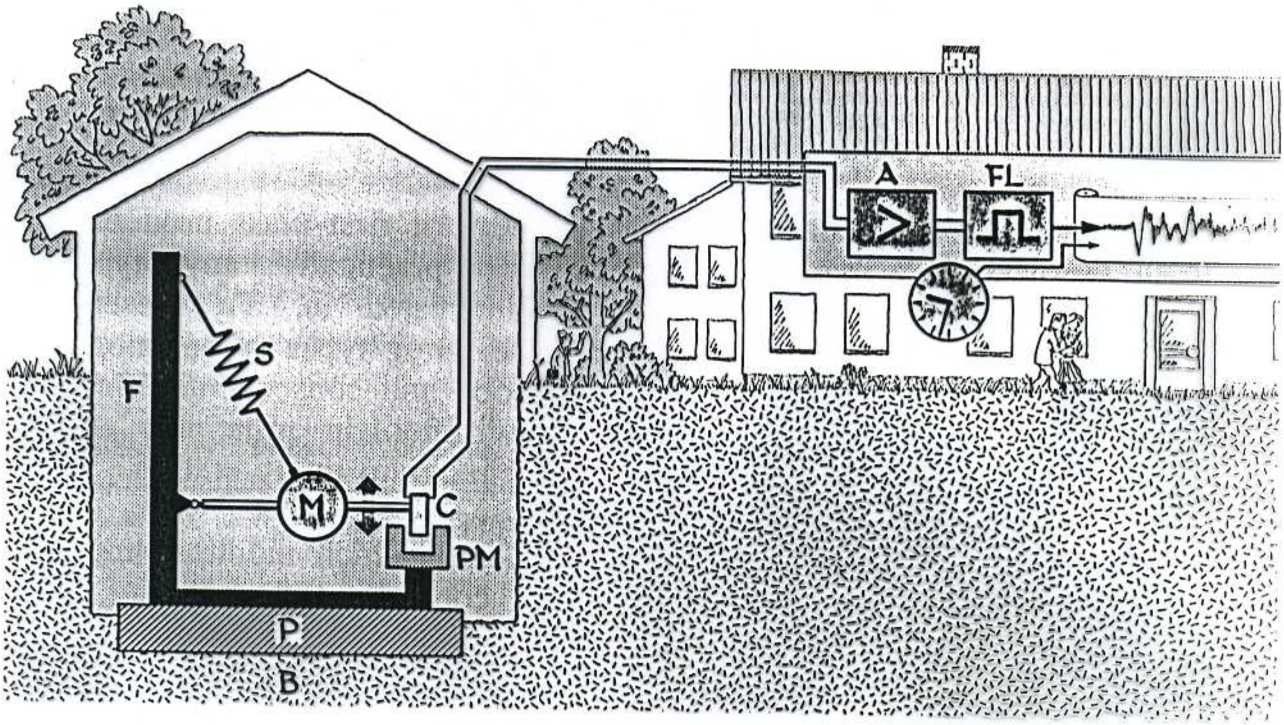
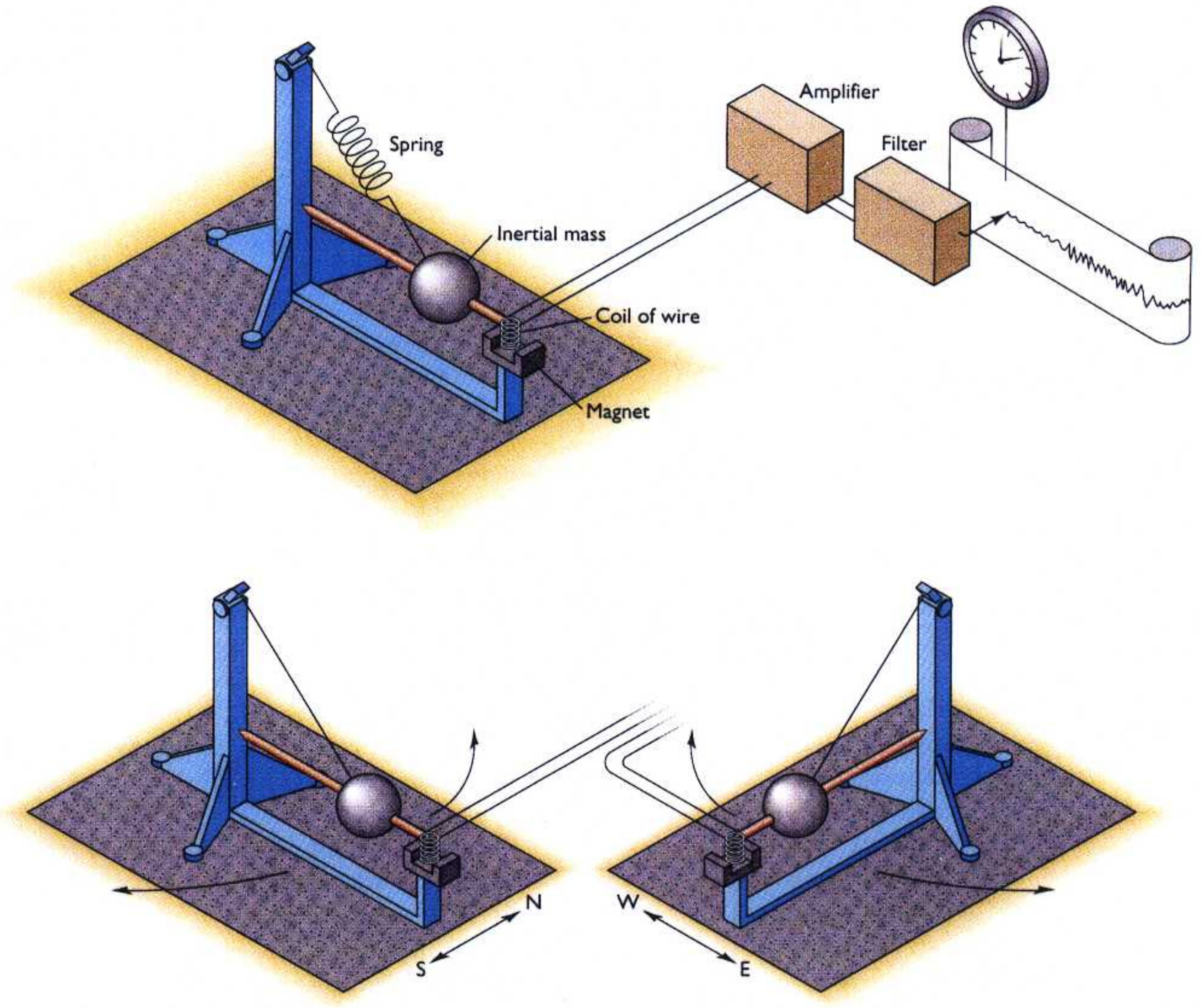


Fig. 27. The principle of a vertical-pendulum moving-coil seismometer. *B* is bedrock, *P* is concrete pier, *F* is frame, *M* is pendulum's mass, *PM* is permanent magnet, *C* is coil, *S* is helical spring, *A* is amplifier and *FL* is filter. Relative motion of the coil and the permanent magnet generates an electric signal that is electronically amplified, filtered and recorded, together with time information, by a proper plotting device. The arrows indicate that the instrument senses up-down, i.e. vertical, ground motion.

LE TRE COMPONENTI DI UN SISMOGRAFO



La componente verticale (in alto) e le due orizzontali (in basso)
[Bolt, 1993]

TABLE 2
Basic parameters of some more common instruments

Instrument type	Free period		Magnification
	Seismometer T_s (s)	Galvanometer T_g (s)	
Benioff, SP (WWSSN)[1]	1.0	0.7	
Grenet-Coulomb	1.4	0.7	$\sim 10^4$
SKM-3	1.6	0.4	2×10^4 flat for $T < 0.8$ s
Willmore	1.0	0.3	
S-13	0.75-1.1		
Wiechert, 1000 kg	10		~200 at 10 s
Milne-Shaw	10		~300 at 10 s
SK	10-25	~1.0	constant 1-10 s
Benioff, LP	1.0	90	
Press-Ewing (WWSSN)[1]	15	100	$\sim 10^3$
Galitzin	10-15	10-15	$\sim 10^3$
Kirnos	22	80	$\sim 10^3$

[1] WWSSN stands for World Wide Standardized Seismograph Network

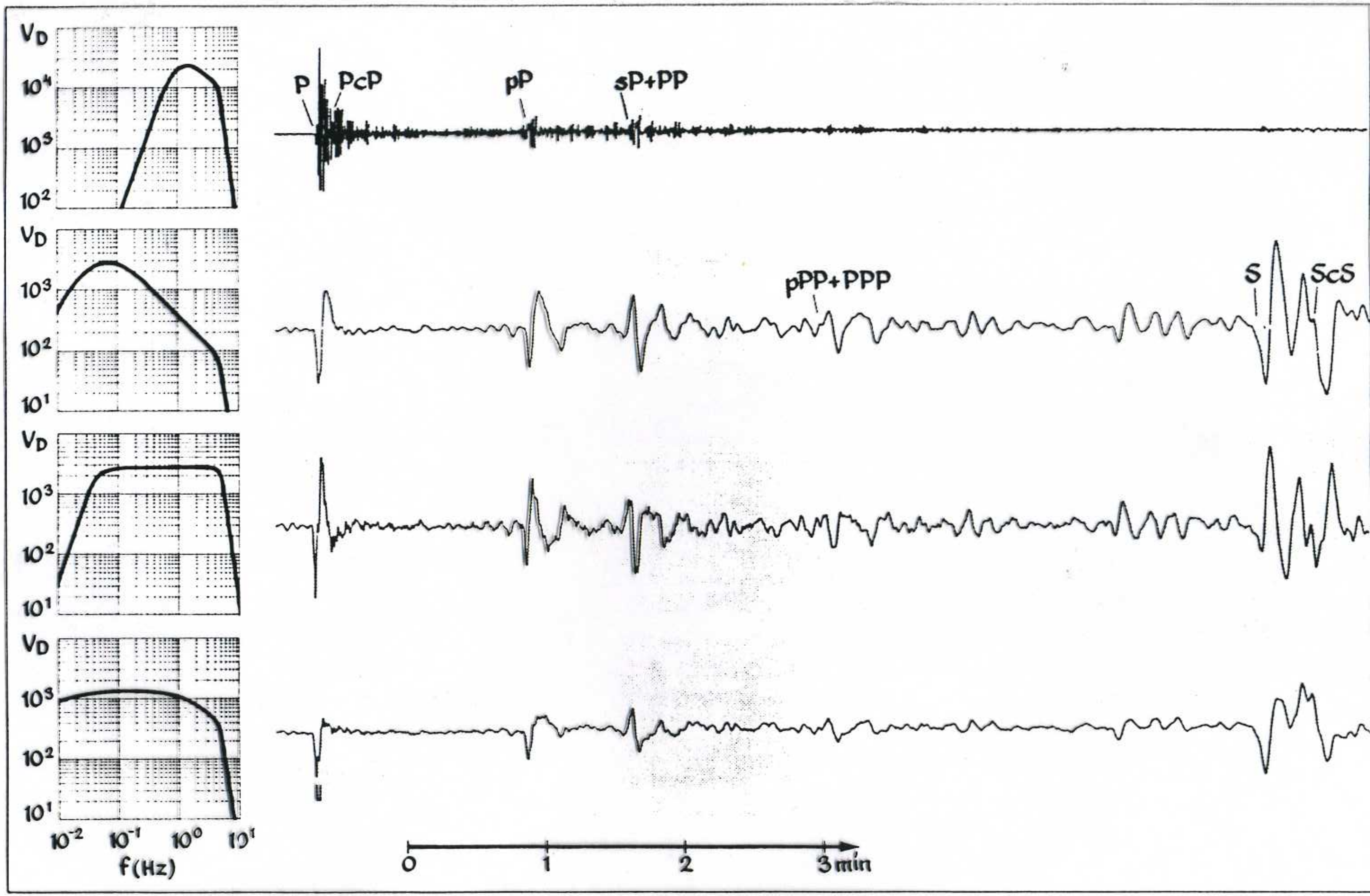
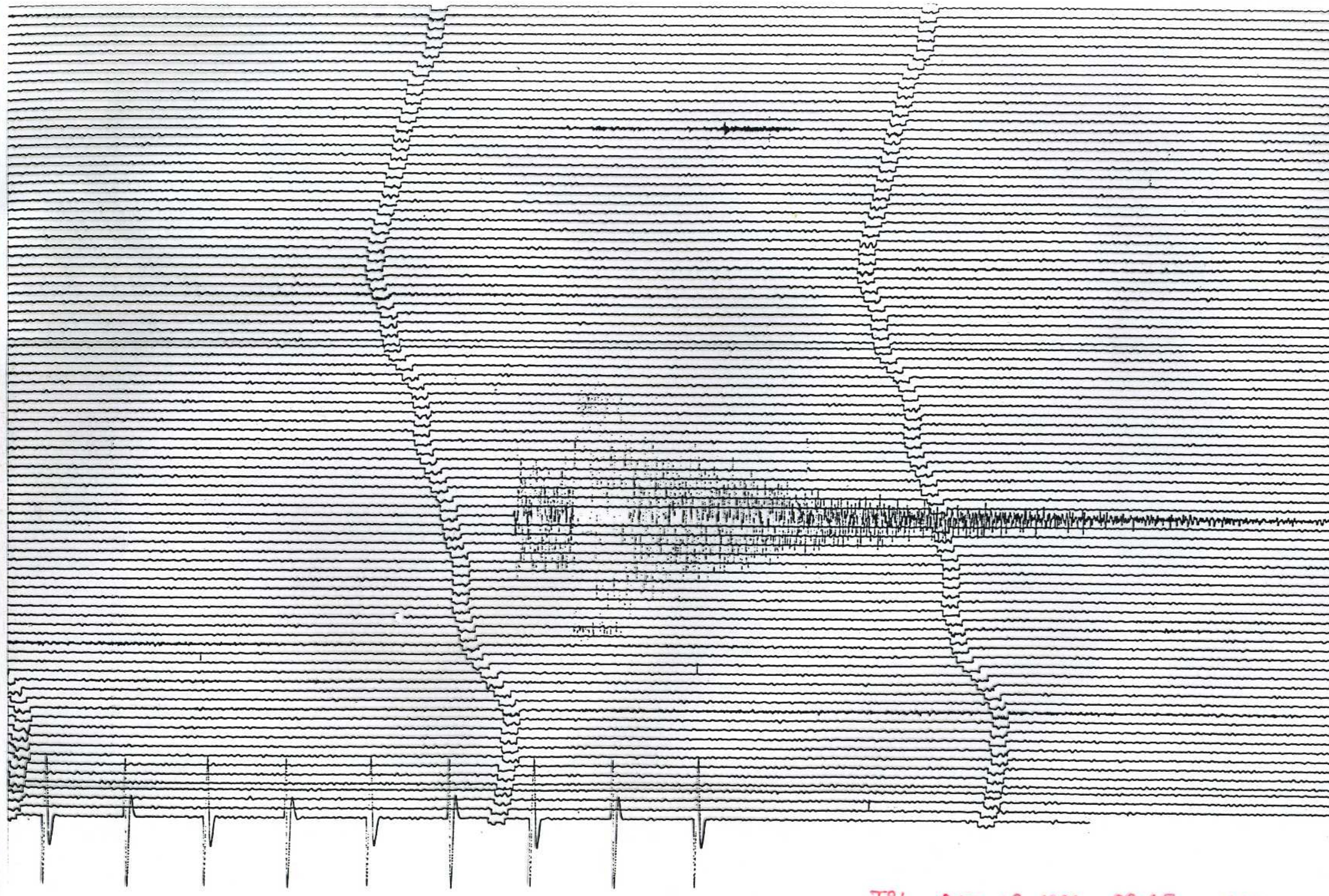


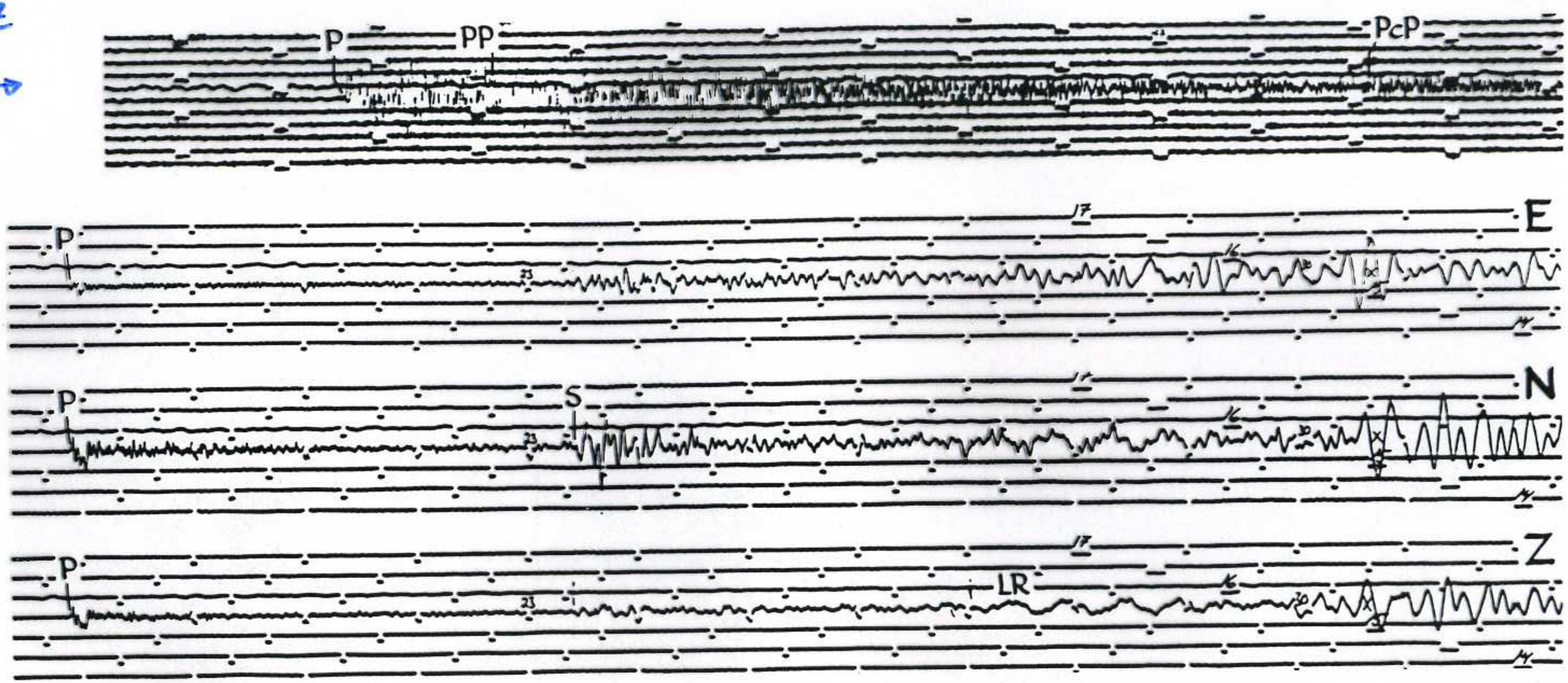
Fig. 30. Computer simulations of seismograms from four different seismograph systems. The deep-focus earthquake (h = 570 km) in Sea of Japan on March 9, 1977 (magnitude m = 5.9) is here used to demonstrate the influence of the pass-band width of a recording system upon the complexity of recorded waveforms. Displayed traces are vertical-component seismograms that would have been made at Erlangen, FRG, at an epicentral distance of 75° by (from top to bottom): 1) Short-period WWSSN seismograph; 2) Long-period WWSSN seismograph; 3) Kirnos seismograph; 4) Broad-band seismograph. Relevant response characteristics are given in the left-hand margin of the figure. After D. Seidl (personal communication), modified.



TRI OCT 15, 1986 00:45 N-S

SP-Z

MP



UPPSALA, SWEDEN JUNE 12, 1969

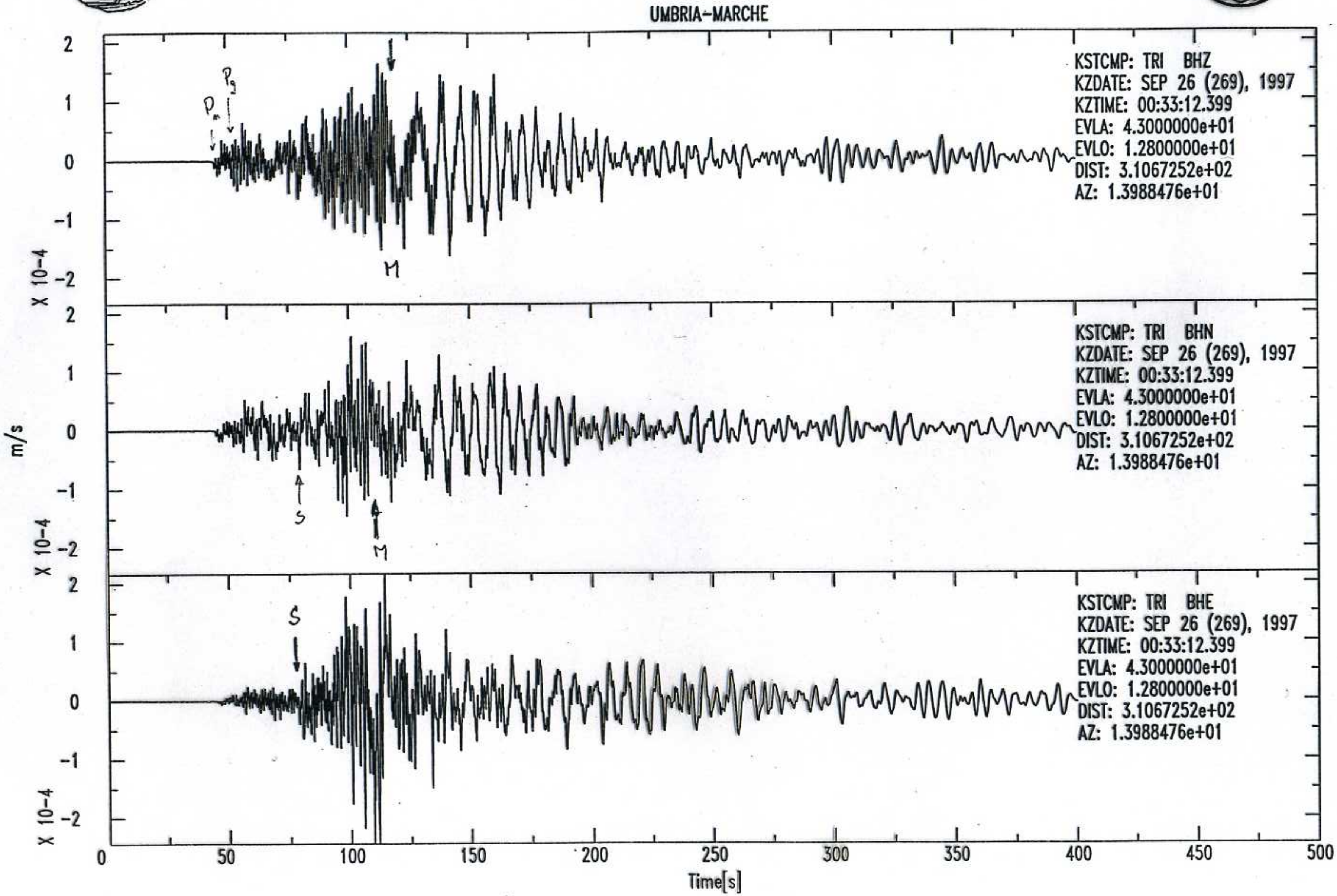
CRETE (GREECE) EVENT M 6.2 h 25 Δ=26°

DIPARTIMENTO DI SCIENZE DELLA TERRA, UNIVERSITA' DI TRIESTE

OSSERVATORIO GEOFISICO SPERIMENTALE, TRIESTE

VBB SEISMOGRAPHIC STATION OF TRIESTE - TRI

(Lat. 45° 42' 32" N Long. 13° 45' 51" E Alt. 161 m - *Network Affiliation: MedNet)*



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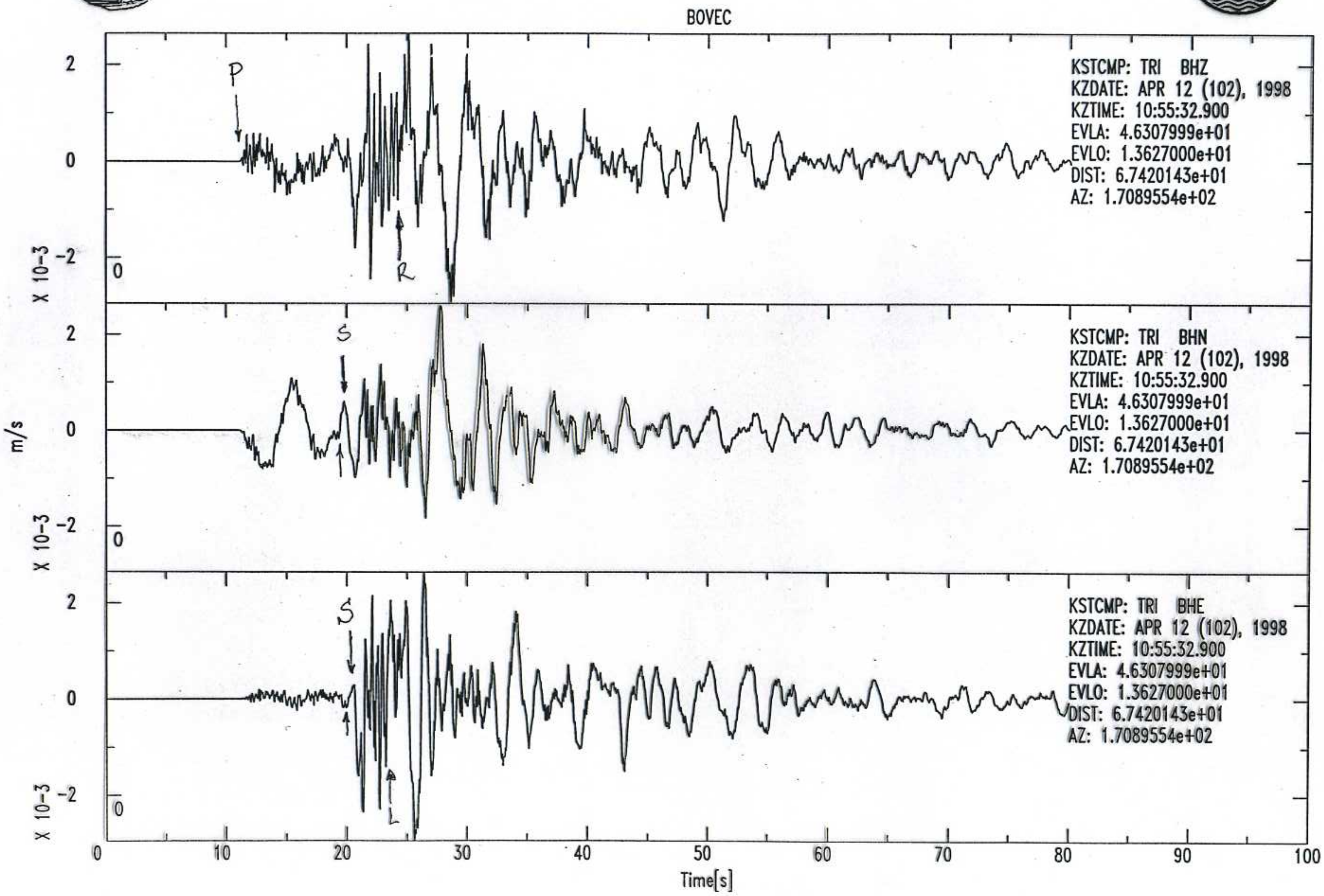


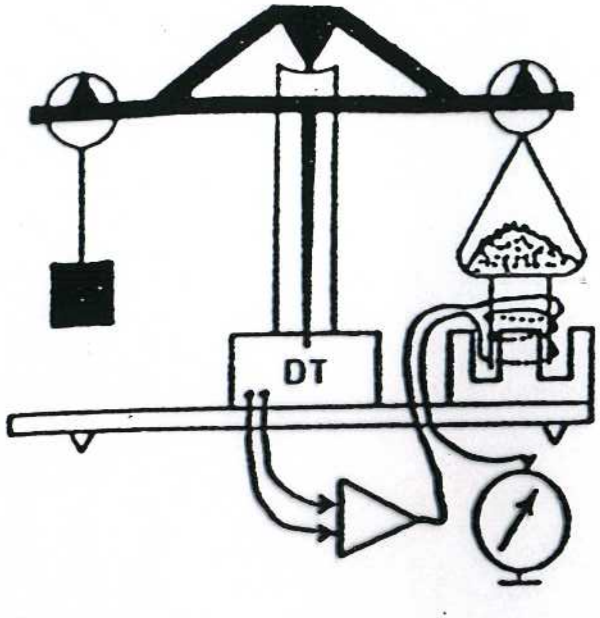


Fig. 12.

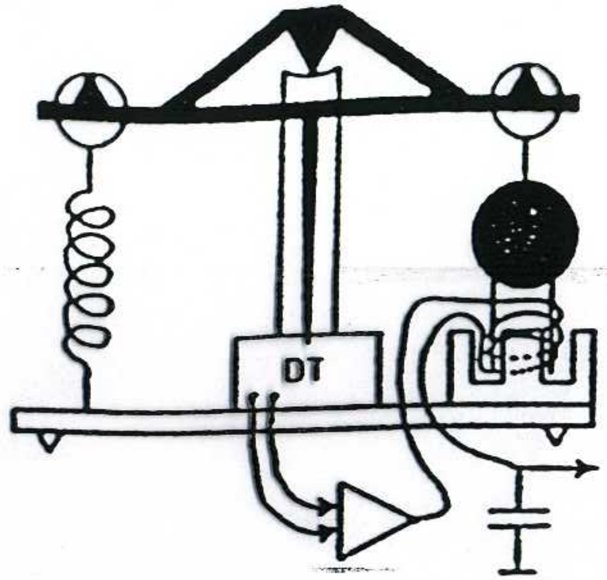


Fig. 13.

Fig. 12. – Balance with automatic weight substitution.

Fig. 13. – Force-balance seismometer.
Sismometro a controreazione.

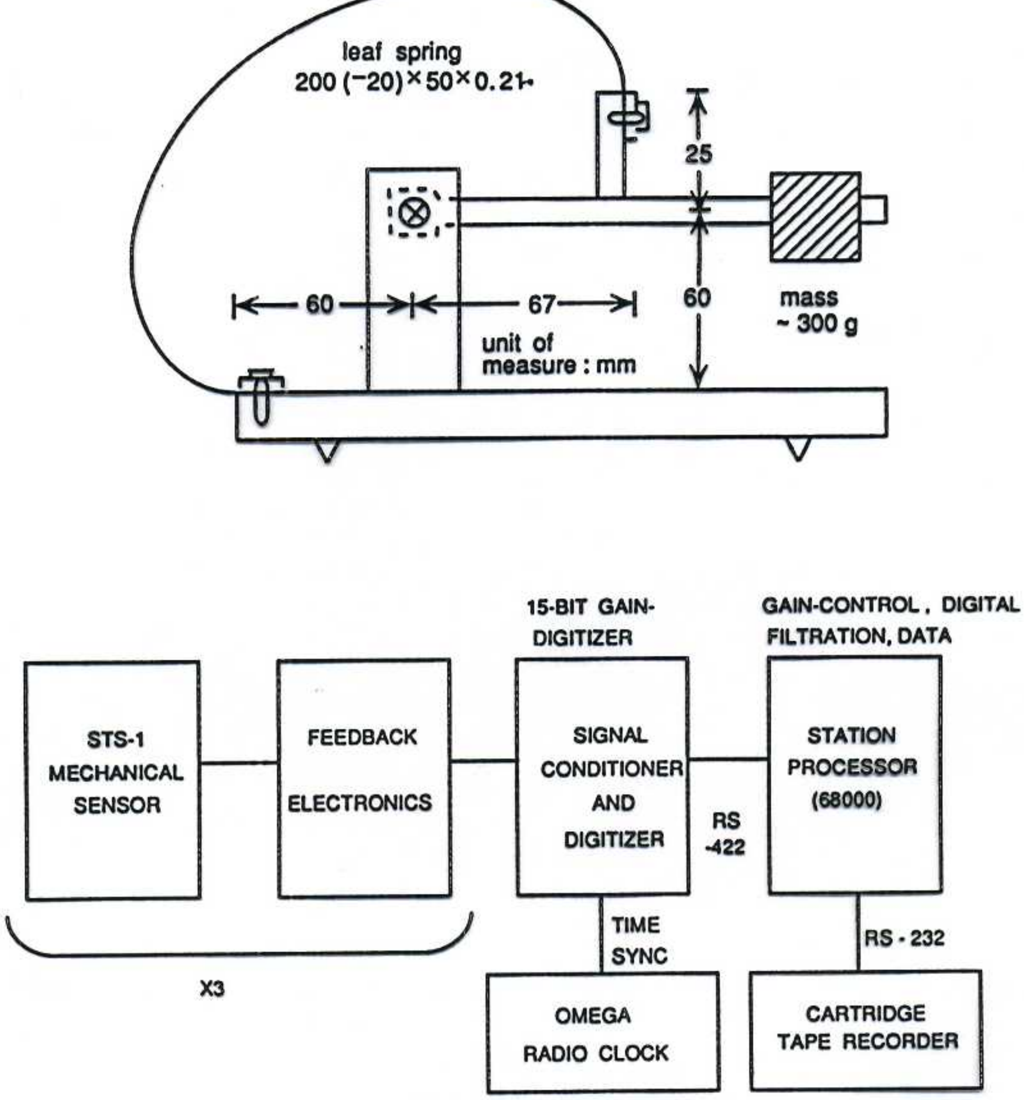


FIGURE 5.11 Schematic of the leaf-spring seismometer and system configuration involved in modern broadband digital seismographs. The Streckeisen STS-1 leaf-spring seismometers are attached to feedback electronics that adjust to minimize actual motions of the mass. The electric currents produced by the feedback are digitized, synchronized with time signals, and electronically filtered and recorded. These systems can reduce instrument noise by factors of 20–40 dB relative to GDSN-generation equipment.

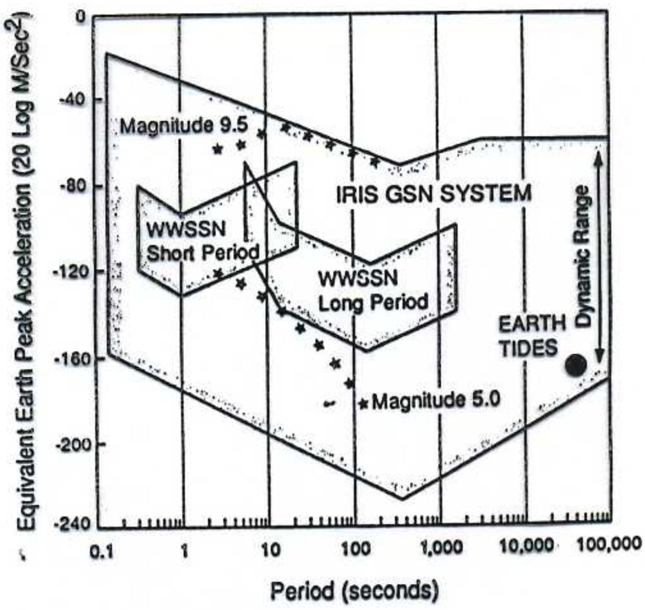


FIGURE 5.13 The range of ground acceleration (in dB) and perio of groun: motions spanned by the very broadband seismic system of IRIS Global Seismic N twork (GSN) compared with capabilities of the WWSSN instrumentation and expected gro''nd accelerations from magnitude 5.0 and 9.5 earthquakes at a distance of 30° (angular distance) and from Earth tide motions. GSN-type instruments have become dominant for lobal seismic reccrding since 1986. (From Incorporated Research Institutes for Seismology, 1991–1995.)

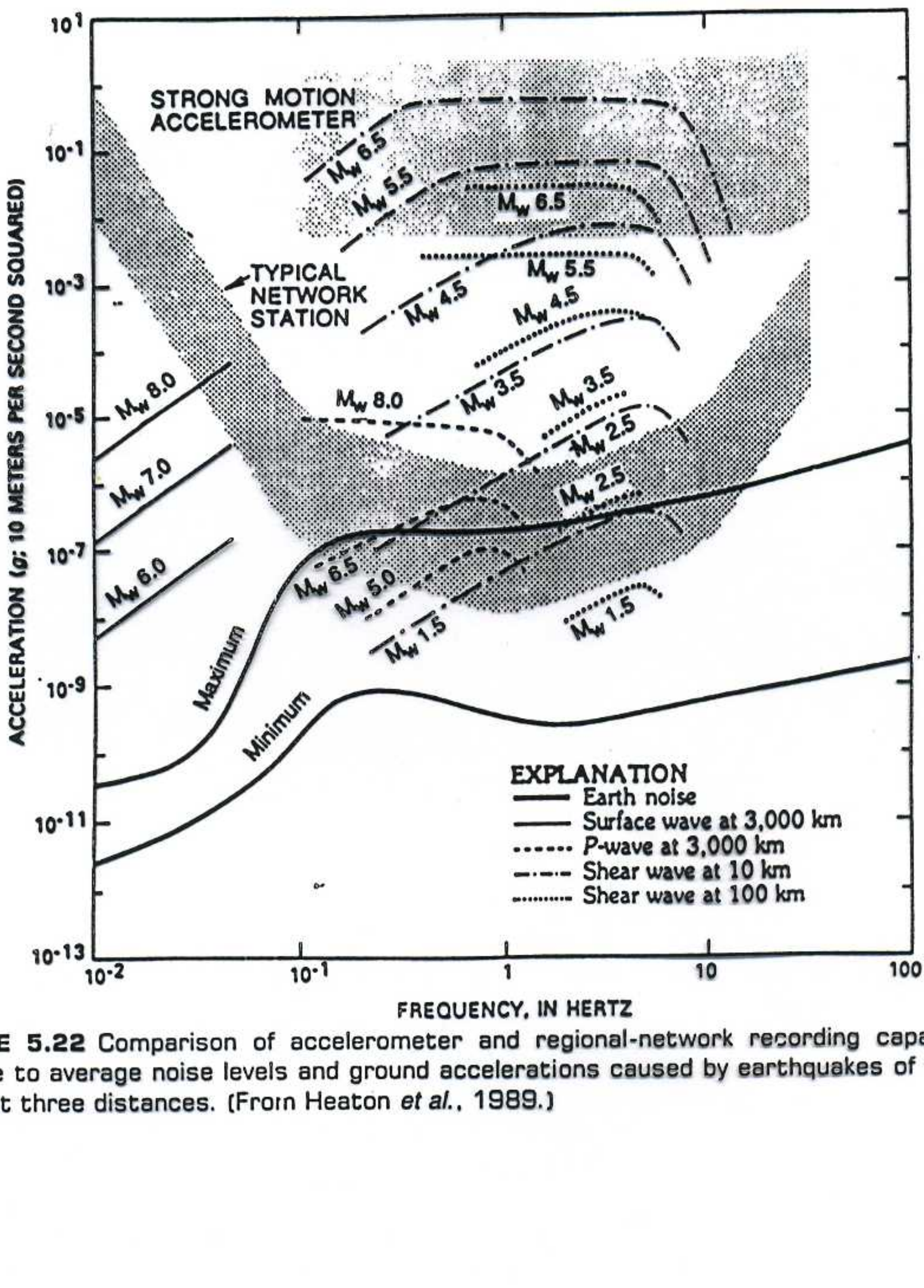


FIGURE 5.22 Comparison of accelerometer and regional-network recording capabilities relative to average noise levels and ground accelerations caused by earthquakes of various sizes at three distances. (From Heaton *et al.*, 1989.)

Box 5.2 Complete Ground Motion Recording

This chapter has focused on seismic instruments designed to record transient ground motions, but we must analyze other important ground motions to understand dynamic processes in the Earth. To address displacements caused by longer-term processes, specialized instruments like LaCoste accelerometers have been used to observe directly gravitational changes associated with mass redistribution, and strain and tilt meters have been developed to detect gradual displacements along faults and on or near volcanoes. Figure 5.B2.1 shows the types of ground motion and corresponding phenomena of interest that can be measured at different frequencies.

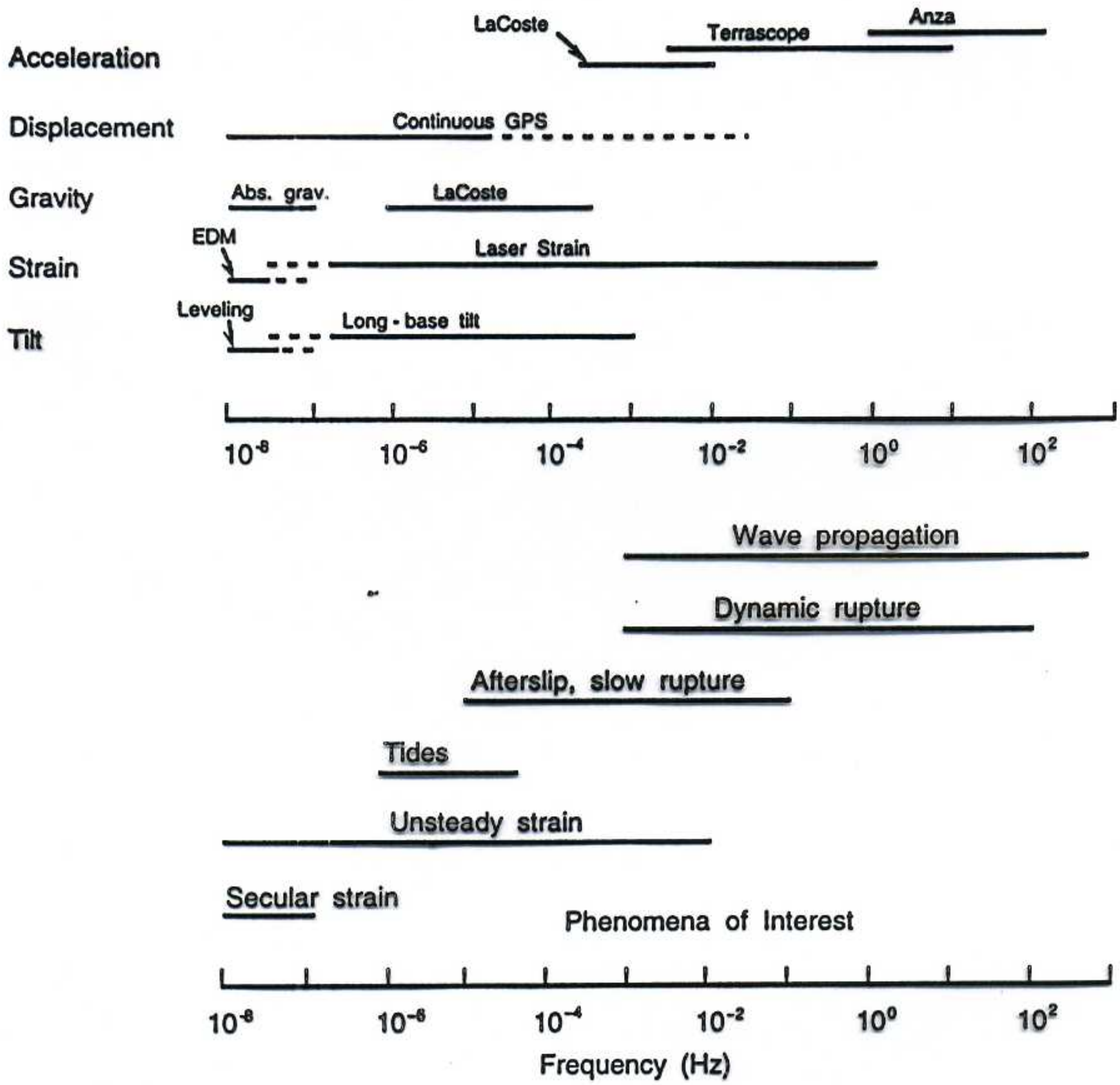
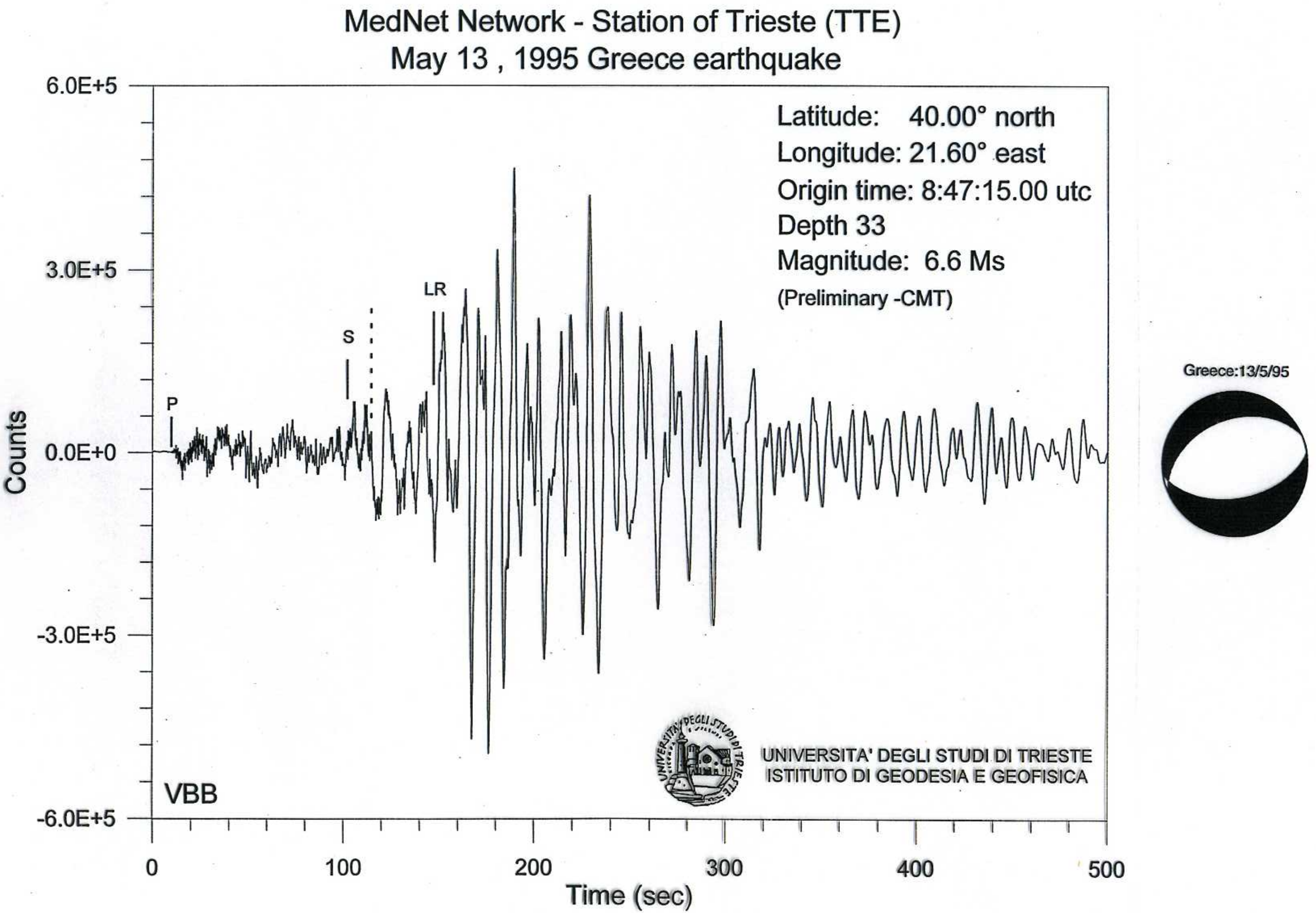
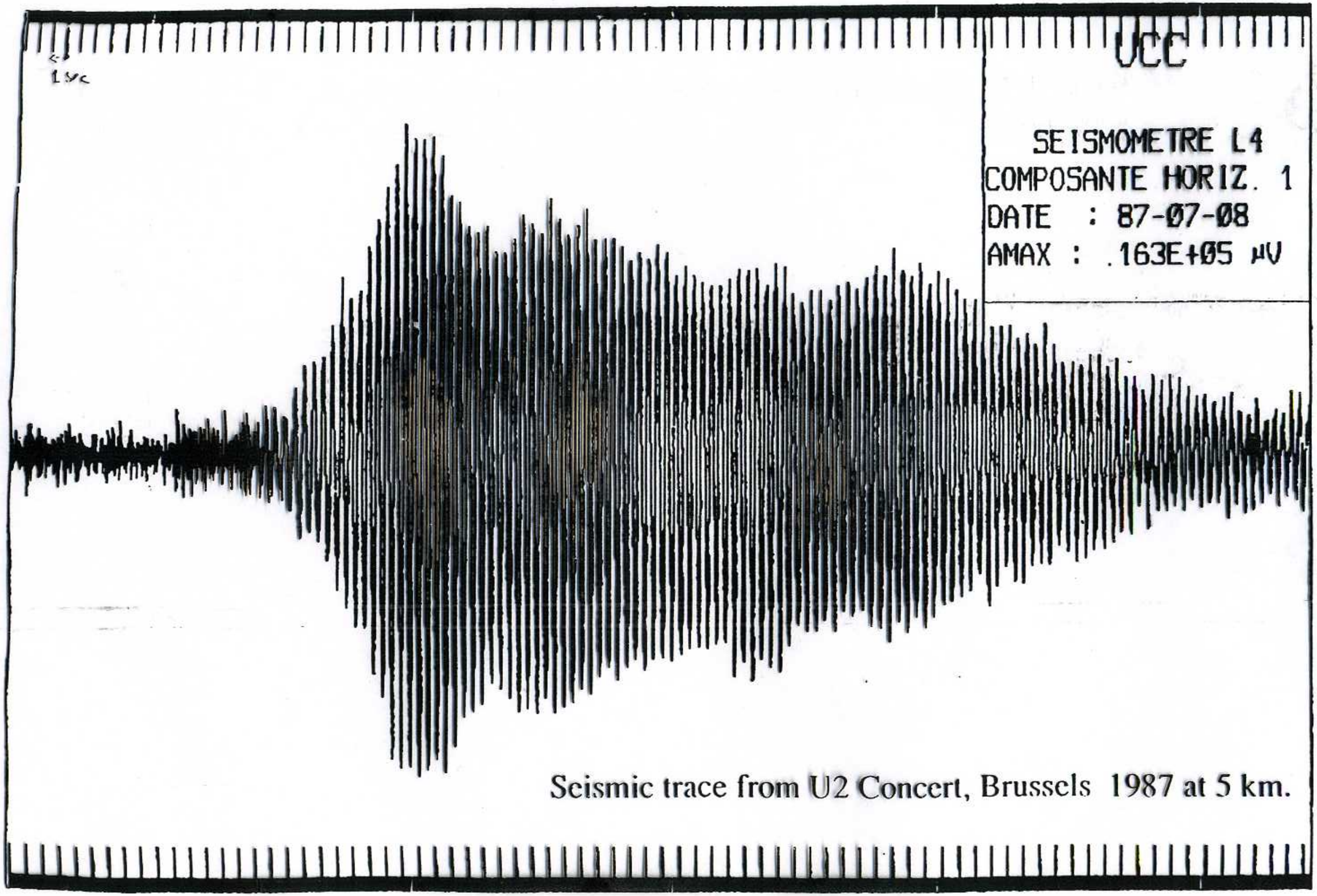
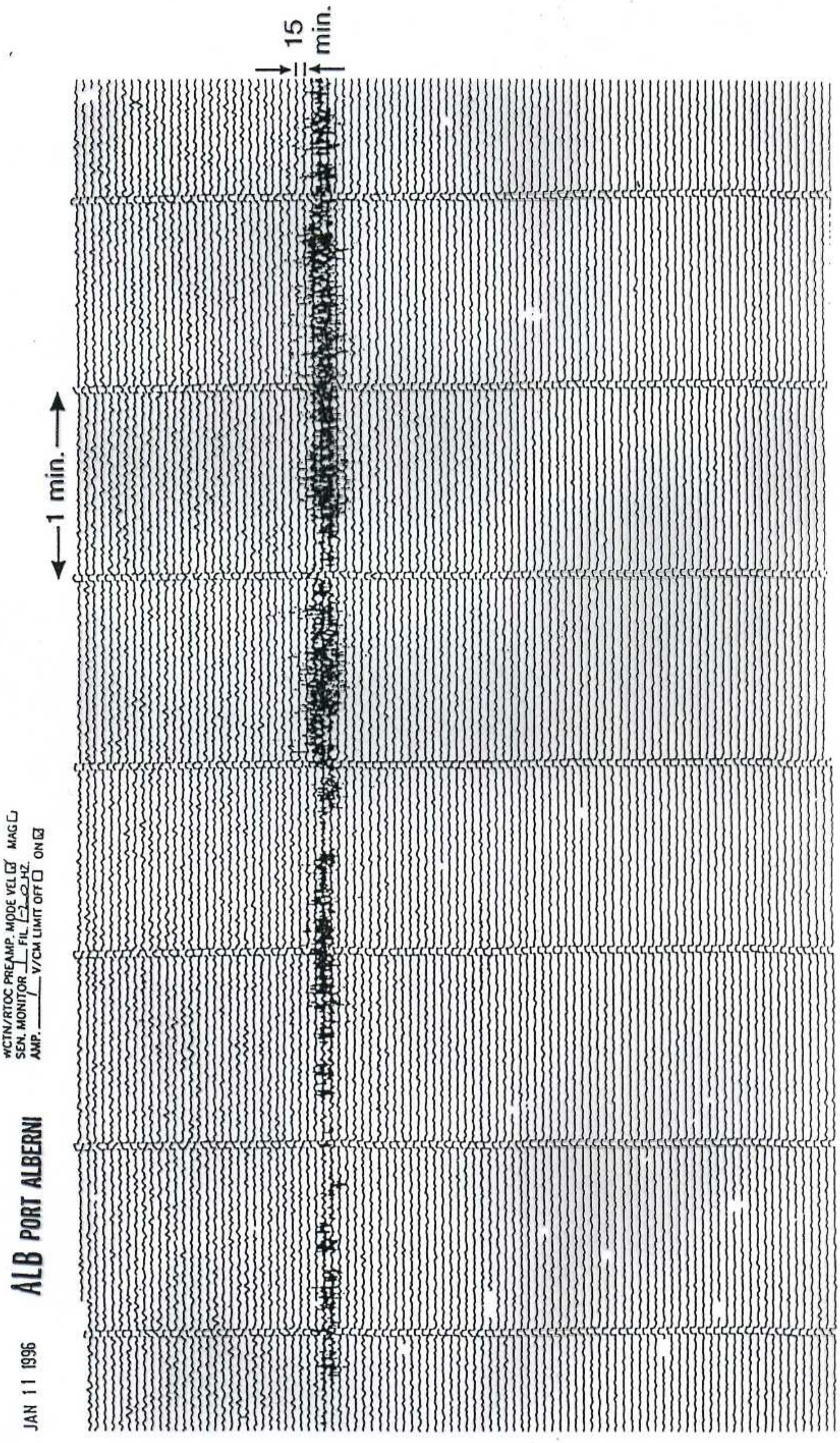


FIGURE 5.B2.1 Various ground-motion measurements and corresponding phenomena that can be studied using a variety of instrumentation. (Courtesy of D. Agnew.)


MedNet Network - Station of Trieste (TTE)
May 13 , 1995 Greece earthquake
Latitude: 40.00° north
Longitude: 21.60° east
Origin time: 8:47:15.00 utc
Depth 33
Magnitude: 6.6 Ms
(Preliminary -CMT)
P
S
LR
VBB
Counts
6.0E+5
3.0E+5
0.0E+0
-3.0E+5
-6.0E+5
0
100
200
300
400
500
Time (sec)
UNIVERSITA' DEGLI STUDI DI TRIESTE
ISTITUTO DI GEODESIA E GEOFISICA
Greece:13/5/95



Seismic trace from U2 Concert, Brussels 1987 at 5 km.



▲ **Figure 2.** Seismogram showing a very small segment of the unusual seismic disturbance. The lines are 15 minutes apart, and the small ticks are minute marks.

Unusual "Love Waves" Recorded Above the Cascadia Subduction Zone

John F. Cassidy
Art Whitford
Geological Survey of Canada

SHORT NOTE

On January 11, 1996 an extremely unusual recording was made by the Geological Survey of Canada's seismograph network. We have identified the source, and, to our knowledge, this is the first recording of its type. The purpose of this short note is to document this extremely rare seismogram.

On January 11, 1996 at approximately 3:45 PM local time (23:45 UT), the emergent onset of a significant seismic event was noticed at the station ALB of the Western Canadian Telemetered Network (WCTN). This seismic station, operated by the Geological Survey of Canada, is located on central Vancouver Island, above the Cascadia subduction zone. It consists of a short-period vertical seismometer buried in a concrete vault, in a quiet wooded setting (Figure 1a). The instrumentation is not far from a local school on the outskirts of Port Alberni, British Columbia. The digital seismic signals are telemetered to the Pacific Geoscience Centre (PGC) in Sidney, 125 km to the SE, where they are monitored continuously by scientists and technicians (Figure 1b) of the Geological Survey of Canada.

This seismograph station records approximately 150 local earthquakes, 100–200 teleseisms, and several dozen local blasts each year; however, it was obvious to the technical and scientific staff at PGC, that although the earth was moving in Port Alberni this was no ordinary earthquake. There were several enigmas. The large-amplitude signal was only present at ALB—not on any of the other seismograph stations of the WCTN, even those within 20 km of this station. Furthermore, after one-half hour the signal showed no sign of abating. Seismologists computed a coda magnitude in excess of $M_L = 6.8$, yet the amplitude of the signal indicated a body-wave magnitude of only 1.2, and the moment magnitude was only 0.2! Seismologists noted that the dominant frequency of the signal was nearly 1 Hz, and after correcting for the instrument response, computed a peak vertical acceleration of 10 cm/sec^2 (0.01 g) and a peak ground velocity of 1 cm/sec. Waveform modeling suggested a single-couple source. And still the signal showed no sign of abating.

At 4:15 PM the intensity of the disturbance increased significantly (Figure 2). The staff, recalling that the station at ALB had been vandalized a number of times over the years, became concerned that someone might be trying to break into the concrete vault that protected the seismometer. The decision was made to phone the local detachment of the Royal Canadian Mounted Police (RCMP). Officers were dispatched to the scene immediately. As the seismograph station was located very near to a public school, a phone call was also made to the school office. Fearing vandals, the school principal enlisted the help of the janitor and the secretary; all rushed to the scene. At the Pacific Geoscience Centre, an ever-increasing number of technicians, scientists, and even a few passers-by, watched in amazement as the signal increased in amplitude. At 4:28 PM, just when it looked like the seismograph needle might break, the signal suddenly stopped (in stark contrast to the very emergent onset of this event). Scientists later confirmed that 4:28 PM was the exact time that the RCMP officers and the school staff arrived at the site, where they found a young couple (oblivious to the fact that their every move was being monitored by the staff at PGC, some 125 km to the southeast) generating mad passionate "Love waves" on the flat surface of the seismic vault, in the quiet wooded setting located above the Cascadia subduction zone. ∎

Acknowledgements

Thanks to all of the people who have read this note and made helpful suggestions, in particular, Allison Bent, who recognized that this was a single-couple source. Geological Survey of Canada contribution number 1996199.

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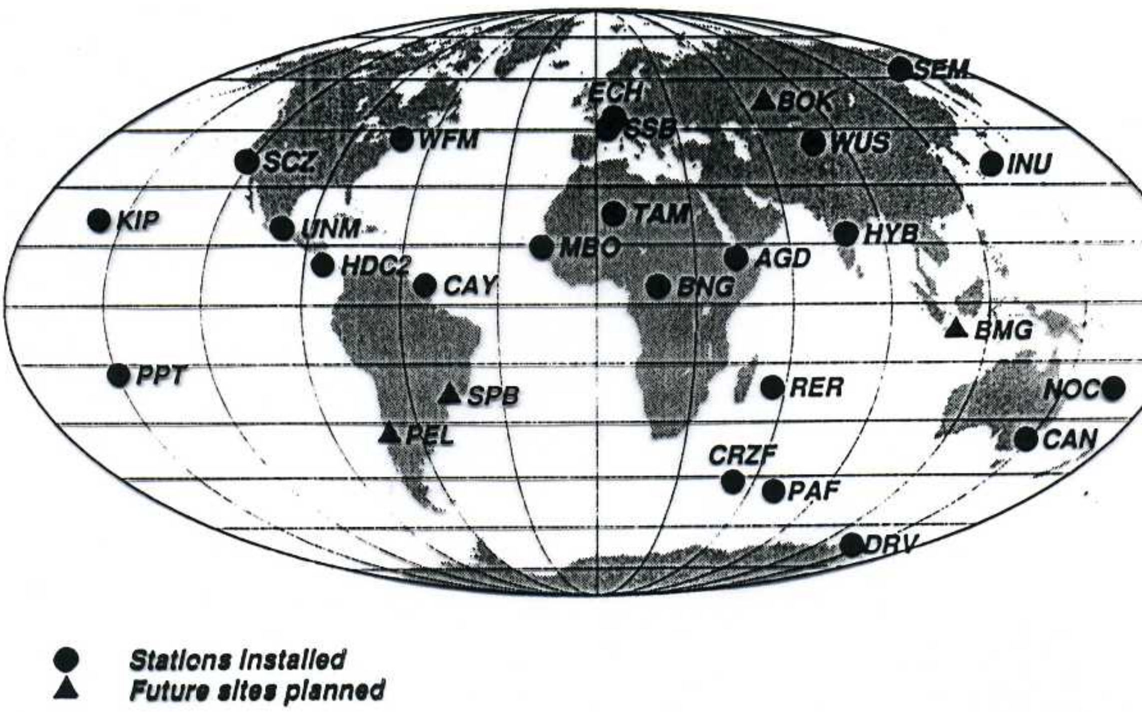
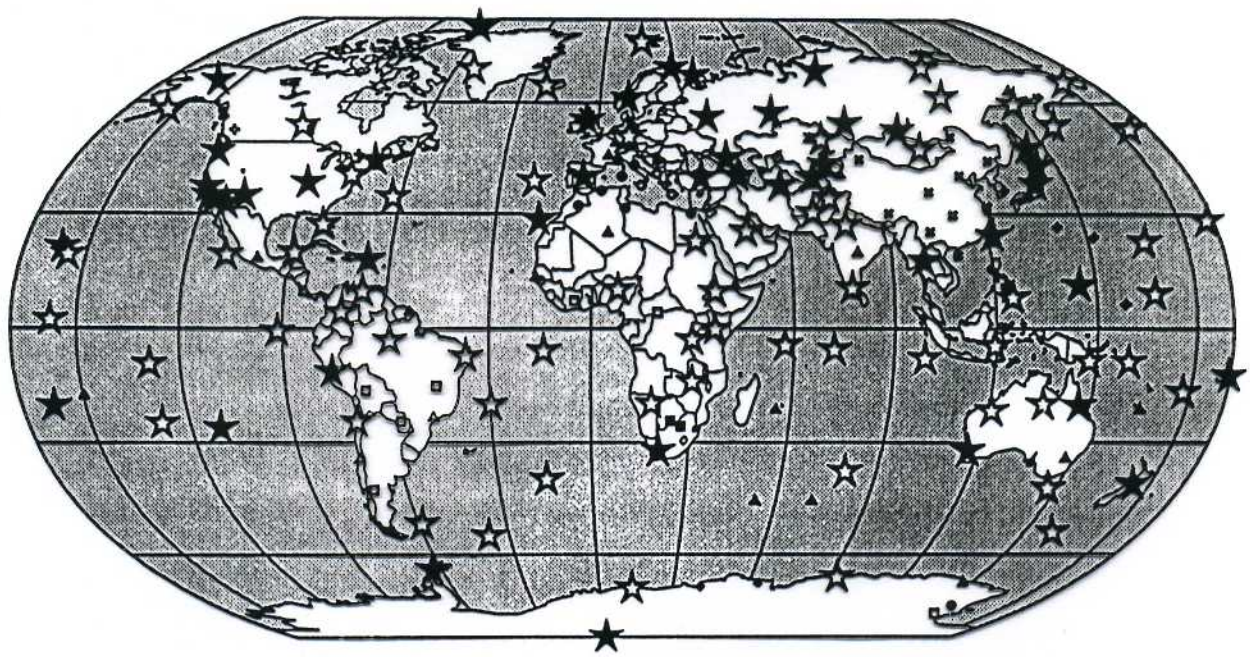


FIGURE 5.15 Global distribution of Project GEOSCOPE stations by the end of 1990. STS-1 seismometers are located at all stations, but slightly different recording characteristics are used at different sites. (Modified from Romanowicz *et al.*, 1991.)



Network	IRIS	Canada	China	France	Italy	Japan	Australia	USGS/AF	Germany
Current	★	✚	✖	▲	●	❖	✳	■	✦
Planned	☆	✧		△	○	◈		□	✧

FIGURE 5.16 Global network of very broadband seismometers planned for the end of the twentieth century, composed of various international network deployments. (Courtesy of R. Butler.)