Seismic Signals and Sensors

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Introduction

The fundamental observations used in seismology (the study of earthquakes) are seismograms which are a record of the ground motion at a specific location.

Seismograms come in many forms,

- "smoked" paper,
- photographic paper,
- common ink recordings on standard paper,
- digital format (on computers, tapes, CD ROMs).

Careful observation of ground vibrations during the last 80 years or so have lead to our understanding these vibrations, which are caused by seismic waves.

Waves

A wave is a disturbance that transfers energy through a medium.

The "disturbance" can be:
-an alternating electromagnetic field strength (light),
-a variation in water height (ocean waves),
-a variation in material density (sound waves),
-or a distortion of the shape of the ground (seismic waves).

Seismic waves travel outward in all directions from their source. Waves generated by large earthquakes can be detected throughout the world and are routinely recorded and analyzed by seismologists.

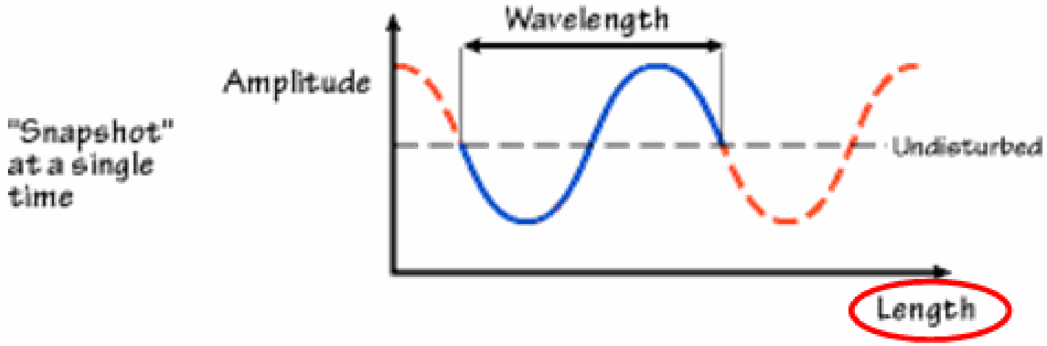
Seismic waves are generated by many different processes:

- Earthquakes
- Volcanoes
- Explosions (especially nuclear bombs)
- Wind
- Vehicles
- People

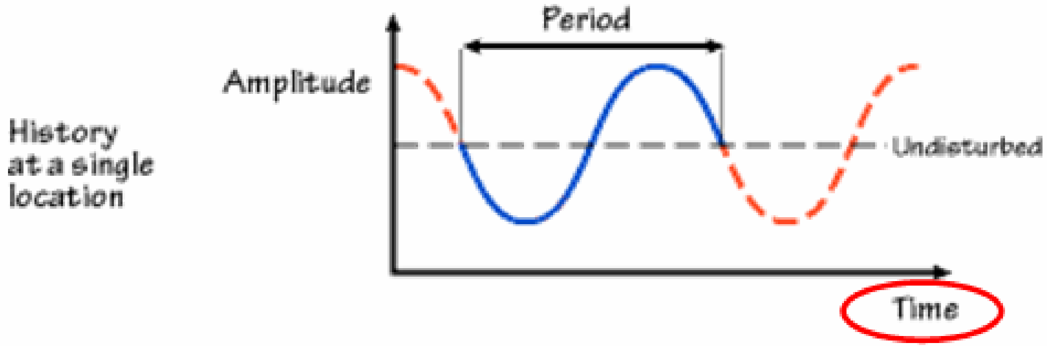
The range of ground motion amplitudes that are of interest in earthquake studies is very large and seismometers we use are very sensitive.

They can detect motions that are much smaller than the thickness of a sheet of paper or as tall as a room.

Wavelength and Period



Wavelength:
peak-to-peak distance on a wave measured at a single time



Period:
time between peaks in the motion

wavelength = period x speed	km = s x km/s
frequency = 1 / period	Hz = 1 / s

Seismic Signals

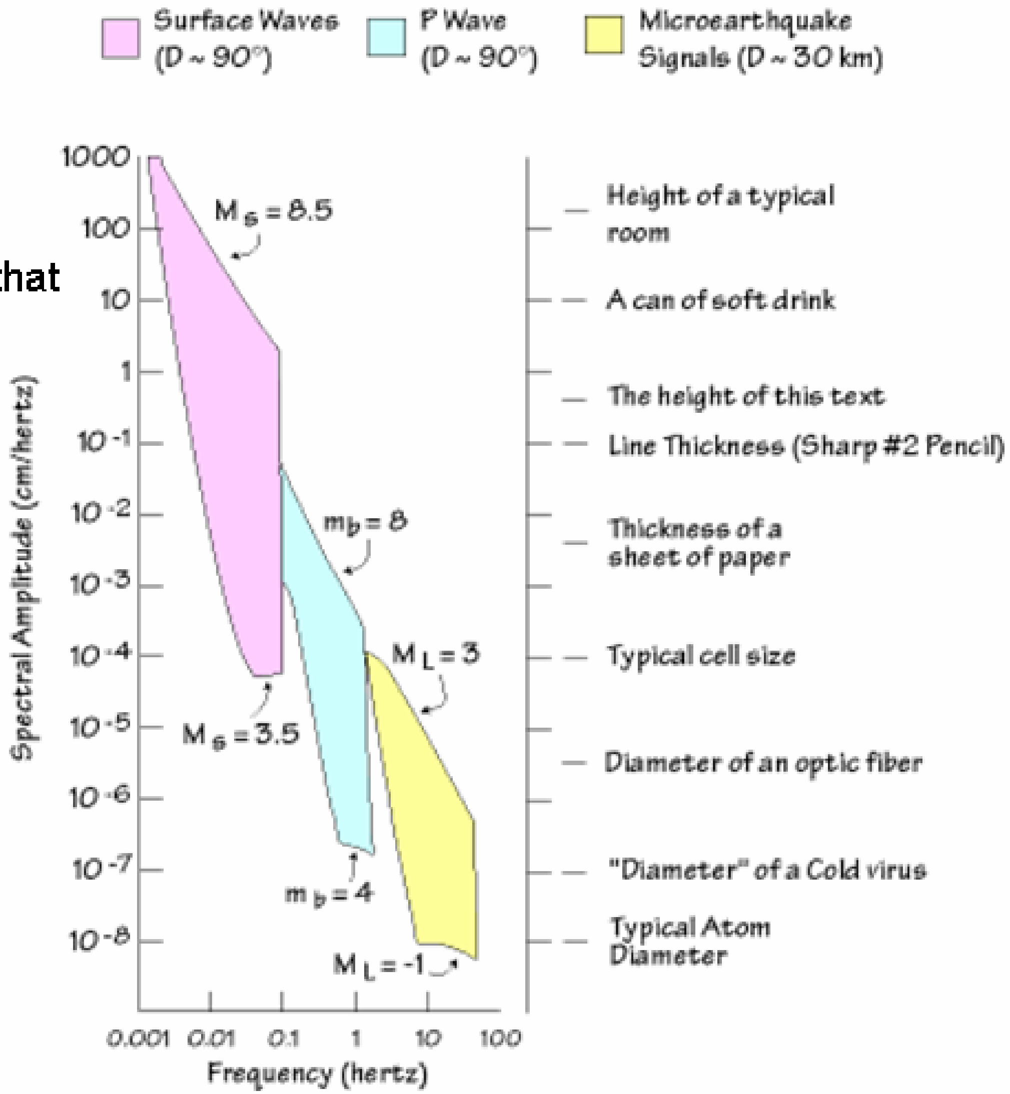
Seismic waves contain many different "frequencies" that we can record with specially "tuned" sensors.
The idea is completely analogous with light and sound:

Seismic	Light	Sound
Short-period	Blue	Treble
Long-period	Red	Bass

The range of ground motions or any other vibration that are interesting is very large because the process of earth deformation and or other sources of vibrations occur at many different rates and scales.

"D" represents the distance from the earthquake.

1 ° ~ 111.19 km



Seismic Scales

Strength			Ground Movement			Impact
Earthquake Classification	M [M_L]	Energy [Joule]	a [%g]	v [cm/s]	d [cm]	Epicentral – Intensity and maximum effect (EMS-98)
very minor	2	10^7	0,1	0,01		I not felt
minor	3	10^9		0,1	0,1	II scarcely felt III weak
light	4		1		1	IV largely observed V strong
moderate	5	10^{11}	10	1		VI slightly damaging
strong	6	10^{13}		10	10	VII damaging VIII heavily damaging
major	7	10^{15}	100	100		IX destructive X very destructive
great	8	10^{17}			100	XI devastating XII completely devastating

An approximation for the empirical link between the Magnitude and other physical quantities.

It is based on worldwide observed and averaged data.

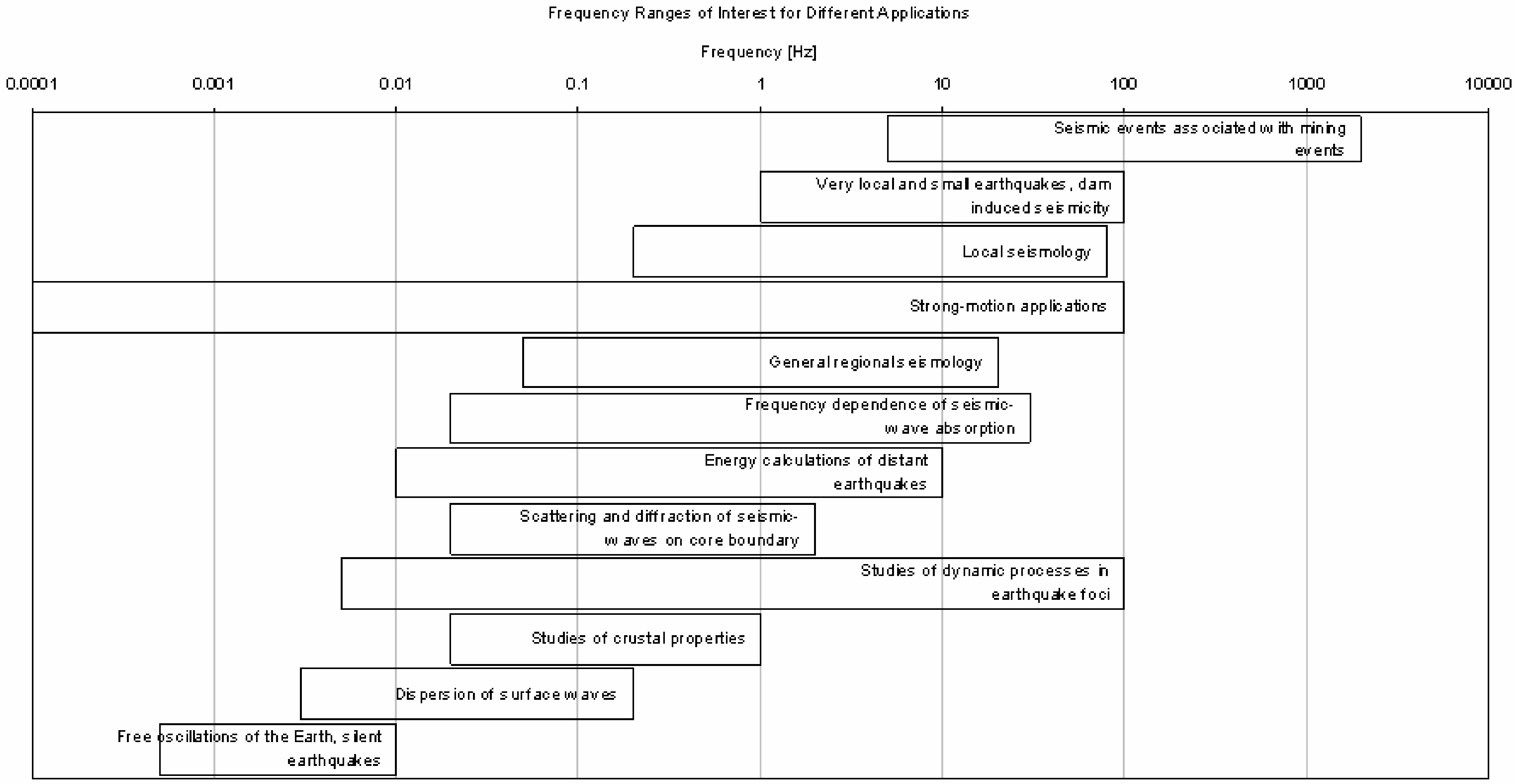
The parameters of the ground movement are the maximum values.

The table only approximately reflects the real relations.

The relationship between magnitude and the other quantities is estimated using a depth of 10-15 km.

Abbreviations:
M_L: Magnitude (Richter),
a: acceleration,
v: velocity,
d: displacement,
g: gravitational acceleration

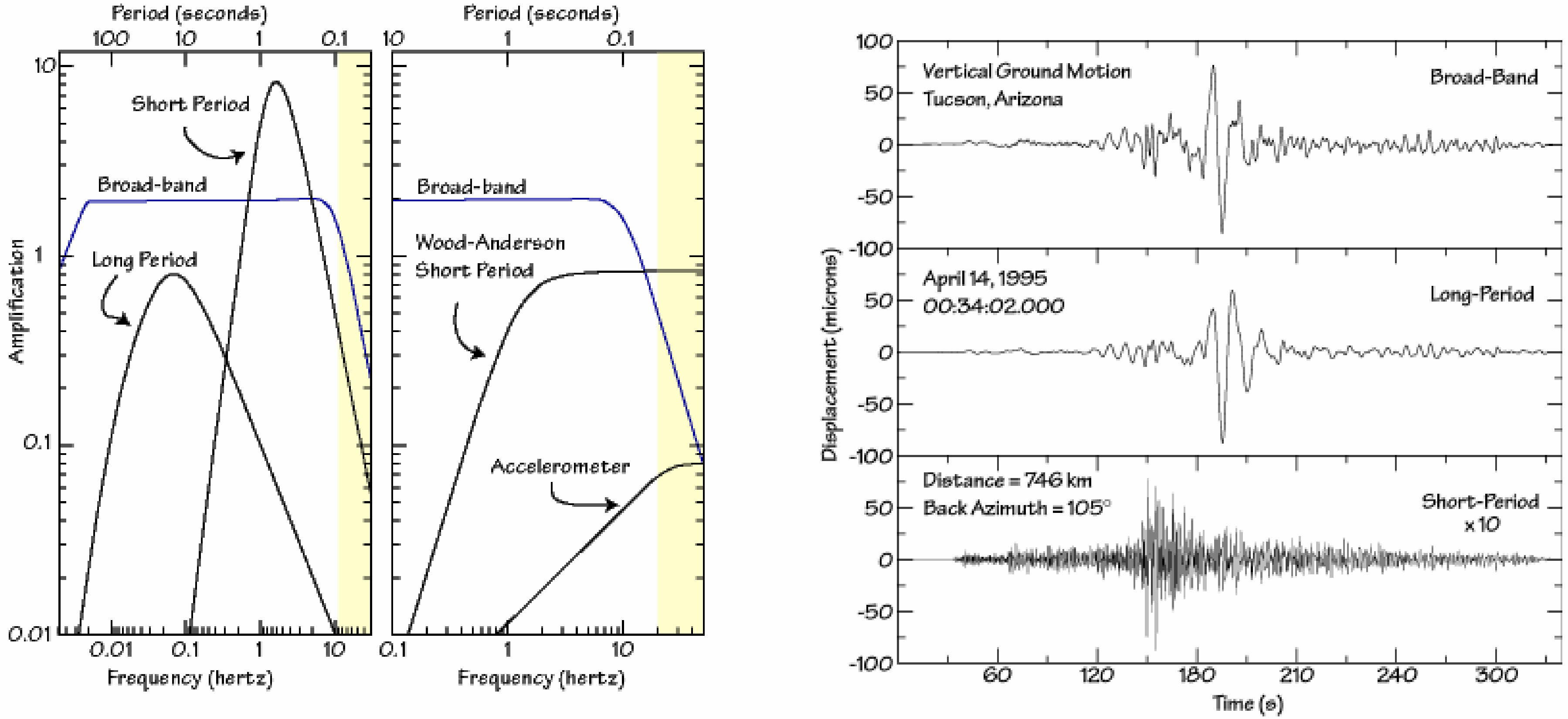
Application Frequency Ranges



Seismometers

Seismometers are usually designed to record signals over a specified range of frequencies so it is convenient to discuss instruments based on the range of vibration frequencies that they can detect.

Thus one way to characterize seismometers is to describe the range of vibration frequencies that they can detect. A plot of the amplification as a versus frequency is called an instrument response. An instrument is sensitive to vibrations at frequencies for which the "response" curve is relatively large.



To characterize an instrument, what's really important is the range of amplitudes, not the specific amplification, which is usually adjusted depending on the location of the seismometer.

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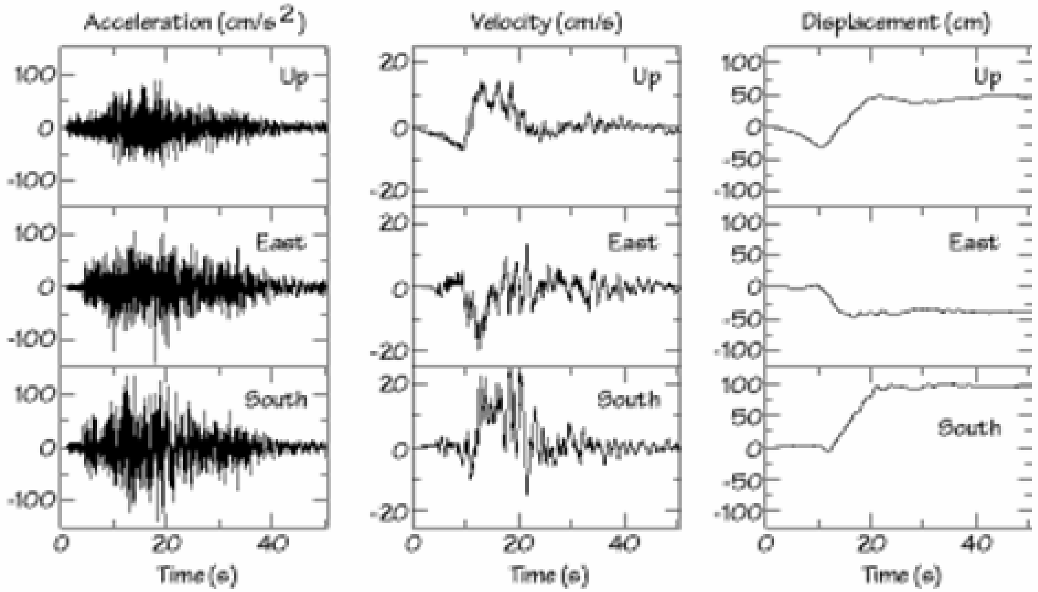
Accelerometers

Accelerometers are developed for recording large amplitude vibrations that are common within a few tens of kilometers of large earthquakes - these are called strong-motion seismometers. Strong-motion instruments were designed to record the high accelerations that are particularly important for designing buildings and other structures.



1985 Mw = 8.1, Michaocan, Mexico earthquake

The peak acceleration was about 150 cm/s^2 or about 0.15 g.

The acceleration in an elevator is about 2 m/s^2 or about 0.2 g. But smooth and comfortable.

During the earthquake the ground accelerations vary between -0.1g to +0.1g several times each second, for at least 10-15 seconds. That is not very gentle shaking.

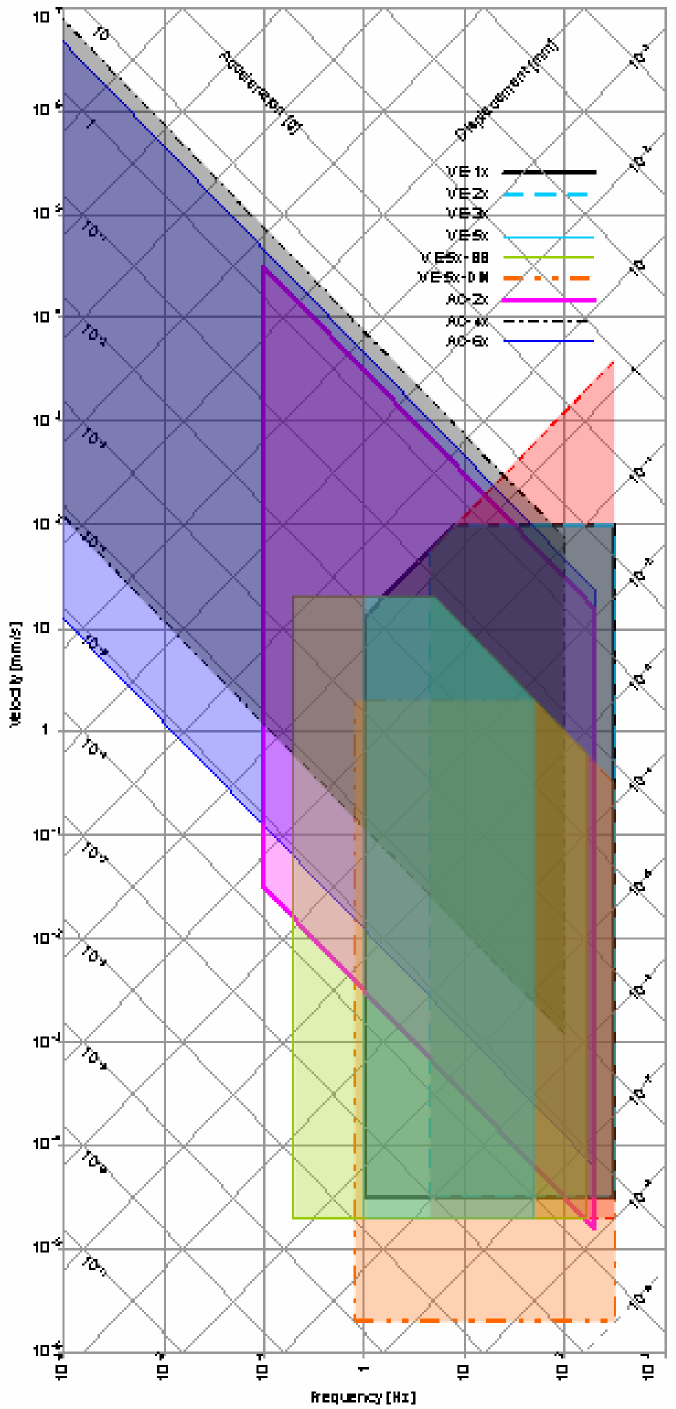
The peak velocity for this site during that earthquake was about 20-25 cm/s
The permanent offsets (displacements) near the seismometer were up, west, and south, for a total distance of about 125 cm (vector sum)

GeoSIG Sensor Matrix

Sensors	Full Scale Range	Bandwidth	Dynamic Range	Axes	Cross Axis Sensitivity	Downhole Version	Dimensions L x W x H	Weight
Accelerometers								
AC-2x	Jumper selectable: ± 0.2, ± 0.5, ± 1, or ± 2 g (± 0.1, ± 0.25, ± 0.5, or ± 1 g optional)	From : 0.1 Hz (1 pole, 0.2 Hz optional) To : 100 Hz (1 pole, 200 Hz optional)	> 125 dB	1,2,3	± 1 % typical ± 3 % maximum	AC-2x-DH	193 x 112 x 94 mm	2.5 kg
AC-4x	± 2g standard (± 0.625, ± 1, ± 4 or ± 5 g optional)	From : DC To : 100 Hz (200 Hz optional)	88.5 dB at ± 2 g FS 96.5 dB at ± 5 g FS	1,2,3	< 2 % typical	AC-4x-DH	193 x 112 x 94 mm	2 kg
AC-6x	± 2g standard (± 0.5 or ± 1 g optional)	From : DC To : 100 Hz (DC to 50 or 200 Hz opti.)	> 120 dB at ± 2 g FS	1,2,3	< 0.5 %	AC-6x-DH	193 x 112 x 94 mm	3 kg
GMG-5T (Güralp)	± 4, ± 2, ± 1, ± 0.5, ± 0.1 g at low gain ± 0.2, ± 0.2, ± 0.1, ± 0.05, ± 0.01 g at high gain	From : DC To : 100 Hz	> 145 dB, 0.005 to 0.05 Hz > 127 dB, 3 to 30 Hz	1,3	0.1%	CMG-5TB	max 152 mm diameter x 102 mm	max 2.5 kg
Seismometers								
VE-1x	± 100 mm/s (± 1, ± 10 mm/s optional)	From : 1Hz To : 315 Hz	> 96 dB	1,2,3	< 0.1 % of full scale	VE-1x-DH	193 x 112 x 94 mm	2.0 kg
VE-2x	± 100 mm/s (± 1, ± 10 mm/s optional)	From : 4.5 Hz To : 315 Hz	> 96 dB	1,2,3	< 0.1 % of full scale	VE-2x-DH	193 x 112 x 94 mm	2.0 kg
VE-3x	27.3 V/m/s	From : 4.5 Hz To : 315 Hz	> 96 dB	1,2,3	< 0.1 % of full scale		110 x 80 x 60 mm	1.0 kg
VE-5x	2 x 500 (1000) V/m/s (Optional DIN: 2 x 50 (100) V/m/s)	From : 1 Hz To : 50 Hz (-3 dB) DIN : 0.8 to 315 Hz	> 120 dB	1,2,3	± 1 % typical ± 3 % maximum	VE-5x-DH	193 x 112 x 94 mm	2.5 kg
VE-5x-BB	2 x 500 (1000) V/m/s	From : 0.2 Hz To : 160 Hz	> 120 dB	1,2,3	± 1 % typical ± 3 % maximum	Yes	193 x 112 x 94 mm	2.5 kg
CMG-3T (Güralp)	2 x 1'000 V/m/s (2 x 750 V/m/s to 2 x 10'000 V/m/s optional)	From : 0.01 Hz (0.0027, 0.0083, 0.0333 Hz optional) To : 50 Hz	> 140 dB	3	< 0.2 %	Yes	168 mm diameter x 362 mm	19 kg
CMG-40T (Güralp)	2 x 400 V/m/s standard (2 x 80 to 2 x 4000 V/m/s optional)	From : 0.033 Hz (0.05, 0.025, 0.0188, 0.008 Hz optional) To : 50 Hz	> 140 dB	3	< 0.2 %	Yes	168 mm diameter x 160 mm	7.5 kg
CMG-40T-1 (Güralp)	2 x 1000 V/m/s standard (2 x 400 to 2 x 10000 V/m/s optional)	From : 1 Hz To : 80 Hz	> 140 dB	3	< 0.2 %	Yes	168 mm diameter x 160 mm	7.5 kg
CMG-3ESP (Güralp)	2 x 750 V/m/s	From : 0.01 Hz (0.0083, 0.0333 Hz optional) To : 50 Hz	> 140 dB	3	< 0.2 %	Yes	168 mm diameter x 292 mm	16 kg
CMG-3ESPC (Güralp)	2 x 1000 V/m/s (2 x 400 to 2 x 4000 V/m/s optional)	From : 1 Hz (0.033, 0.016, 0.01, 0.0083 Hz optional) To : 100 Hz (50 Hz optional)	> 140 dB	3	< 0.2 %	Yes	168 mm diameter x 292 mm	16 kg

All specifications are subject to change without prior notice. Rev. 29.09.2009

GeoSIG Sensor Measuring Ranges



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Thank you

Thank you…