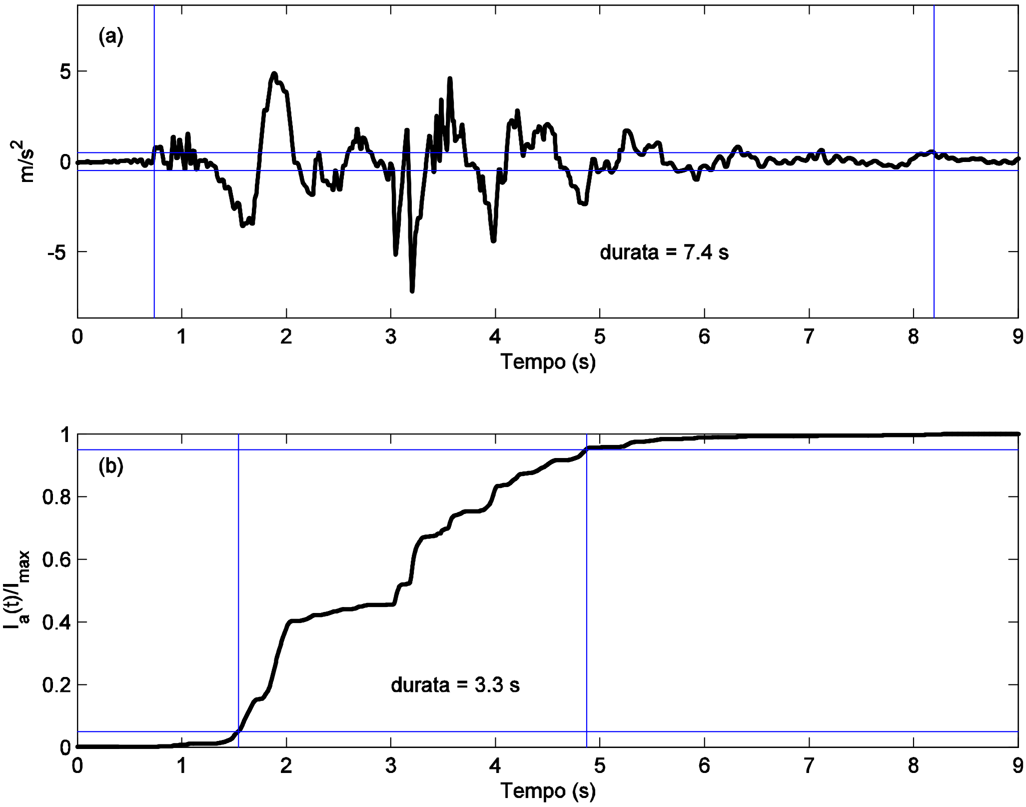
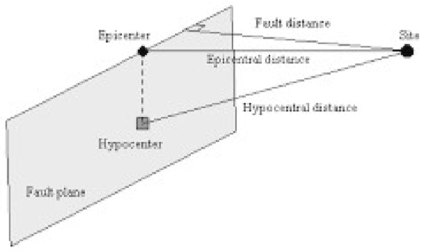
GLOSSARY[1]

Key Word	Meaning
Accelerometer (Analog or Digital)	Instrument to measure seismic acceleration. It can be of two types: *analog*: ground acceleration is reproduced by a mechanical instrument on a physical support, typically paper or photographic film, and it is digitized at a later stage. *digital*: it is typically based on either electro-magnetic or force-balance transducers. The electric signal is then properly conditioned, sampled and digitized. The digital instruments are operating from about the mid-80s. The picture of a digital accelerometer is illustrated in Fig. 1. The most representative parameters defining the characteristics of the recording instrument response are as follows: - sensor undamped natural vibration frequency (frequency); - sensor damping coefficient with respect to critical (damping); - frequency band for which the sensor gives a flat response (frequency band); - generator constant of the sensor (gain); - smallest signal that can be resolved by the sensor (sensitivity); - maximum signal that can be resolved by the sensor (full scale); - number of bits of the recorder (number of bits).  Figure 1– The digital accelerometer K2 with its main components.

1Part of text and figures are adapted from Faccioli E. e R. Paolucci: "Elementi di Sismologia applicata all'Ingegneria", Pitagora, 2005.

Arias Intensity	The Arias Intensity is an integral parameter of severity of ground motion. Introducing the function of motion intensity: $I(t) = \frac{\pi}{2g}\int_0^t a^2(\tau)d\tau$ where *a(t)* is the acceleration at time *t* and *g* the gravity acceleration, the Arias Intensity is the maximum value of this function, i.e.: $I_A = I(T_d)$ where T_d is the accelerogram total duration. Arias Intensity is dimensionally a velocity (cm/s). A sample of calculation of the Arias Intensity is shown in Fig. 2b (see *Duration*).
Baseline Correction	Baseline correction is a procedure to correct certain types of long period disturbances on accelerometric signals, both analog and digital. The simplest procedure is to subtract from the accelerogram its average value (which theoretically should be zero to ensure a zero velocity at the end of the seismic motion). Alternatively, in the case of digital accelerograms with pre-event, it is possible to remove from the entire signal the average value calculated only on the pre-event portion. Finally, in the case of more complex instrumental disturbances, more sophisticated baseline correction procedures can be used, for instance by first sub-dividing the velocity signal (obtained by integrating the initial accelerogram) into multiple ranges, by estimating subsequently the drifts relative to each range using least square regression, and finally by removing them. In processing the accelerometric data contained in ESM, the standard correction procedure has been used, i.e. the subtraction from the accelerogram of its average value. For further details about the adopted correction procedure see *Processed Record*.
Component	One of the three spatial components of the seismic motion. The two horizontal components, orthogonal to each other, are denoted by N (North-South) and E (East-West). The vertical component is denoted by Z.

Duration	Duration is defined as the time interval of the accelerometric signal in which the seismic motion is "significant". To this aim two definitions are often used: *a) duration based on the exceedance of a threshold value (bracketed duration)*: a threshold is fixed, typically 0.05g, above which it is deemed that the motion has relevance for engineering purposes; the duration is the time interval between the first and the last exceedance of this value (see Fig. 2a). *b) duration based on the motion intensity*: The Arias Intensity function *I(t)* is calculated (see *Arias Intensity*), and normalized with respect to its maximum value I_{max}; the duration corresponds to the time interval t_2-t_1, where $I(t_1) = 0.05$ and $I(t_2) = 0.95$ (see Fig. 2b). In ESM the seismic motion duration is calculated on the base of Arias Intensity.  Figure 2 – Example of calculation of the seismic motion duration, using the two definitions introduced in the text: (a) duration based on the exceedance of the 0.05g threshold value; (b) duration based on the Arias Intensity (see *Arias Intensity*).
Earthquake backazimuth	The backazimuth angle indicates the direction, measured clockwise from the North, from which the seismic waves arrive at the recording instrument (accelerometer).

EC8 site class	The seismic site classification is based on the stratigraphic and dynamic properties of the soil profile. Site classes are defined according to the Eurocode 8 as follows: - Class A: rock or other similar geologic formation, including 5 m (maximum) of surface weathered material. $V_{s,30}$ > 800 m/s (see $V_{s,30}$). - Class B: very dense sand or gravel, or very consistent clay, in soil deposits at least several tens of meters depth, characterized by a gradual increase of dynamic properties with depth. 360 m/s < $V_{s,30}$ < 800 m/s. - Class C: medium dense sand or gravel, or consistent clay, in deposits with depth between several tens to hundreds meters. 180 m/s < $V_{s,30}$ < 360 m/s. - Class D: loose to medium dense non-cohesive soil deposits (with or without cohesive soil layers), or medium consistence cohesive materials. $V_{s,30}$ < 180 m/s. - Class E: soil profile consisting of a shallow alluvial layer with V_s values typical of C or D class, and thickness between about 5 m and 20 m, lying on a material with $V_{s,30}$ > 800 m/s. - Class S_1: deposits consisting of – or containing one layer at least 10 m thick– high plasticity clays/silts (P1 > 40) with a high water content. - Class S_2: soil deposits susceptible to liquefaction, or sensitive clays, or any other profile which is not included in the A-E or S_1 classes.
Epicentral Distance	The epicentral distance is defined as the distance on the ground surface between the site and the earthquake epicenter. This latter is defined as the point on the earth surface placed exactly on the vertical passing from the hypocenter (or focus), where the rupture takes place. The distance between the site and the earthquake hypocenter is denoted as hypocentral distance.  Figure 3 – Definition of epicentral and ipocentral distance
Epicentral Intensity	The epicentral intensity I_0 is defined according to the MCS (Mercalli-Cancani-Sieberg) scale. The macro-seismic intensity scale classifies empirically the earthquake severity according to an ordinal scale of the effects produced by the ground shaking, in an area of limited spatial extension (the epicentral zone), on human beings, civil structures (damages to buildings) and environment (geologic and geomorphologic effects).
Event	The event is the considered earthquake. It is characterized by the geographical coordinates of the epicenter (latitude and longitude) and by the hypocentral depth (see *Hypocentral Depth*), and by the occurrence date (year, month and day). Other distinctive properties of the seismic event are the focal mechanism (see *Focal Mechanism*) and the epicentral intensity (see *Epicentral Intensity*).

<table>
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<td>Fault (Strike, Dip, Rake)</td>
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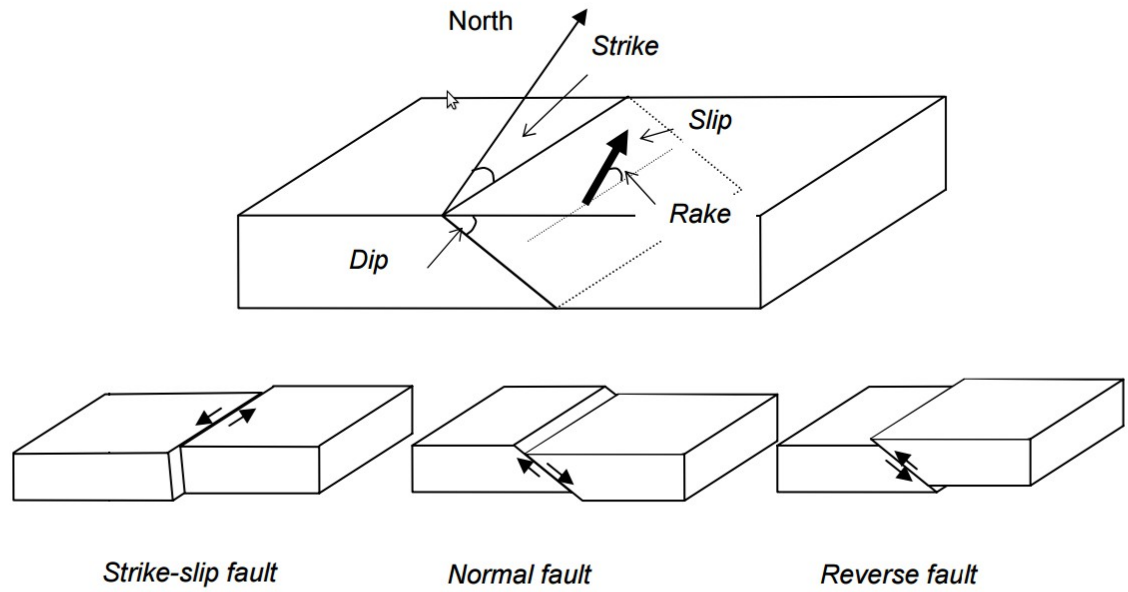
An earthquake occurs when a volume of rock, subject to deformation mechanisms of tectonic origin, ruptures along a weak surface, which is denoted as fault, resulting in a relative displacement between the two blocks of rock separated by the fault. To locate the fault plane position and the slip direction, the following definitions are usually considered (see Fig. 4):
- Strike: clockwise angle formed by the intersection of the fault plane with the ground surface and the North direction.
- Dip: angle formed by the fault plane and the horizontal direction.
- Rake: angle formed, with respect to the intersection of the fault plane with the surface, by the vector defining the relative displacement (slip) between the block above the fault plane (hanging wall) and the one below (foot wall). A simple classification (rakes angles within 30° of horizontal are strike-slip, angles from 30° to 50° are reverse, and angles from −30° to −150° are normal) is used to classify style of faulting.


Figure 4 – Definition of the fault plane and of the main fault types.
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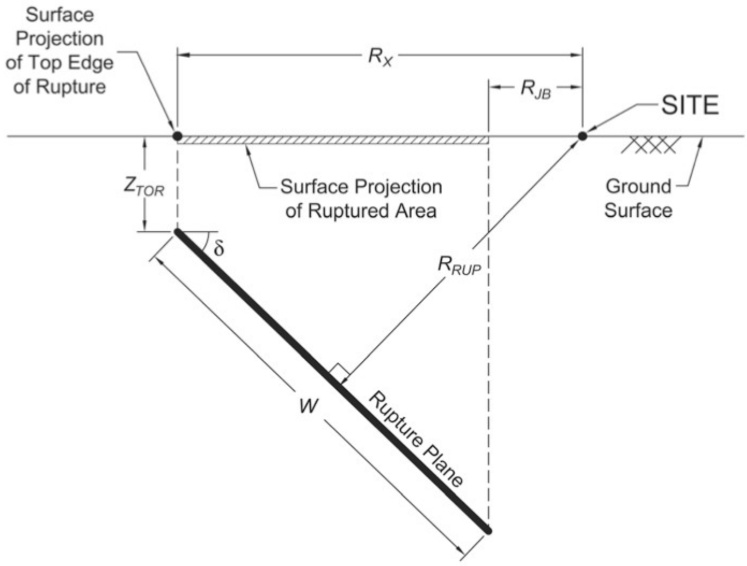
Fault Distance	Fig. 5 shows the different source-site distance measures, which are commonly used: - Hypocentral distance = distance from the earthquake hypocenter - Epicentral distance (R_X) = distance from the earthquake epicenter - Distance from the seismic source or distance from the fault (R_{RUP}) = minimum distance between the site and the earthquake fault plane. - Distance from the surface projection of the fault or Joyner-Boore distance (R_{JB}) = minimum distance between the site and the fault projection on the ground surface.  Figure 5 - Most commonly used source to site distance measures (from Kaklamanos, J., L. G. Baise, and D. M. Boore (2011), Estimating Unknown Input Parameters when Implementing the NGA Ground-Motion Prediction Equations in Engineering Practice, Earthq Spectra, 27(4), 1219, doi:10.1193/1.3650372.

Filter Correction

Raw data (see *Raw Record*) collected by the recording instrument are generally processed for the following purposes: a) correction with respect to the instrument characteristic curve; b) correction of the high and low frequency errors; c) filtering, in order to highlight or eliminate a particular frequency band. Such operations are often performed in the frequency domain, using filtering algorithms based on the Fast Fourier Transform (FFT), and schematized by the following procedure:

1. The FFT of the original accelerometric record is performed:

$$a(t) \leftrightarrow A(\omega)$$

2. The instrument characteristic curve $H(\omega)$ is removed. Recalling that $A(\omega) = H(\omega)\cdot U(\omega)$, the Fourier transform of the record is obtained, in which the instrument response is removed:

$$U(\omega) = \frac{A(\omega)}{H(\omega)}$$

3. The filter is applied in the frequency domain by multiplying the function $U(\omega)$ times the filter $B(\omega)$, either high-pass, or low-pass or band-pass, depending on the type of disturbance to eliminate or of the frequency band to highlight:

$$U_c(\omega) = U(\omega)\, B(\omega).$$

4. The inverse Fourier transform is computed, to obtain the corrected signal in the time domain:

$$u_c(t) \leftrightarrow U_c(f)$$

An acausal band-pass second order Butterworth filter has been used to filter the ESM accelerometric data. The frequency band was selected in each case based on visual inspection of the Fourier spectrum of the signal (see *Fourier Spectrum*). For the complete procedure of signal correction implemented in ESM see *Processed Record*.
An example of the effect of filter application on an accelerometric signal is shown in Fig. 6.

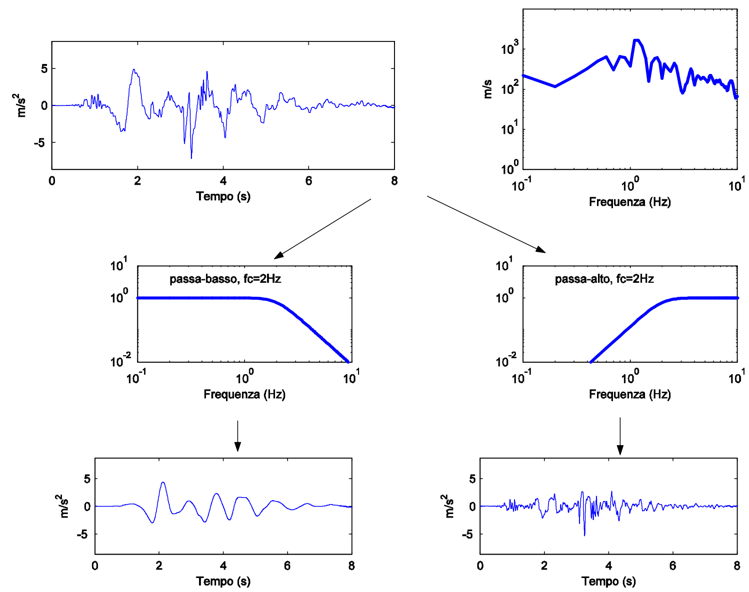
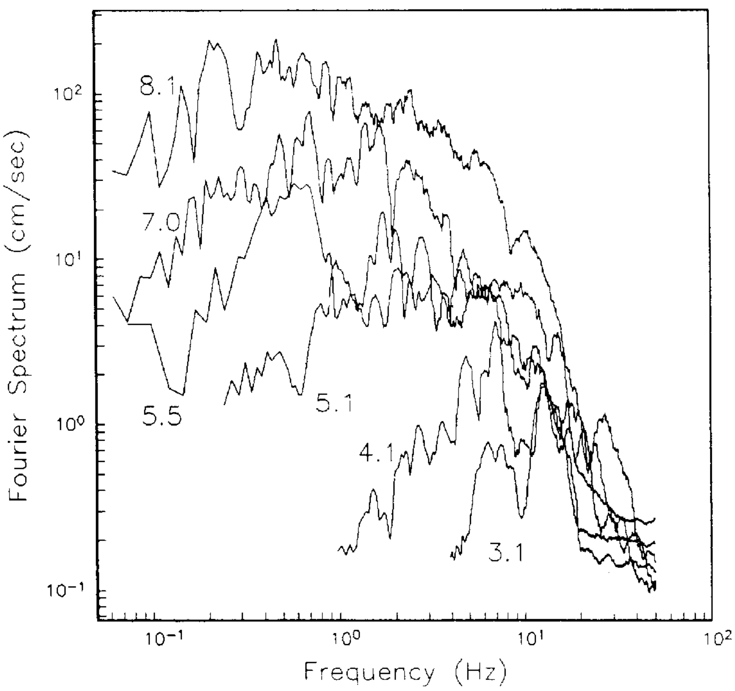


Figure 6 – Top: EW component of the accelerogram recorded in Gemona del Friuli (GMN) on September 15th 1976 03:16, and corresponding Fourier spectrum. Bottom: same accelerogram high-pass filtered (left) and low-pass filtered (right), where the corner frequency is f_c= 2Hz.

Focal Mechanism	The focal mechanism represents the geometry of fault rupture during an earthquake (see *Fault*). It is studied based on the polarity of the first arrivals of P and S waves recorded by a network of far field seismic stations. 3 basic types of focal mechanisms are distinguished (see Fig. 4 in *Fault*): - *strike-slip*: the blocks of rock on either side of the fault slide horizontally, parallel to the strike of the fault; - *reverse*: the Earth's crust is in compression along a dipping fault plane, where the hanging wall moves upwards relative to the footwall; - *normal*: the Earth's crust is in extension along a dipping fault plane, A geologic fault in which the hanging wall has moved downward relative to the footwall.
Fourier Spectrum	The Fourier transform of the signal *a(t)* is defined as follows: $A(f) = \int_{-\infty}^{+\infty} a(t) e^{-i2\pi ft} dt$ Generally *A(f)* is a complex function. The modulus of the Fourier transform is denoted as Fourier Spectrum of the signal *a(t)*: $\lvert A(f) \rvert = \sqrt{R^2 + I^2}$ where *R* and *I* are the real and imaginary part of *A(f)*, respectively.  Figure 7 – Fourier Spectra of increasing magnitude accelerograms, recorded in 1985-1986 by digital instruments located on the Pacific coast of Mexico (Guerrero network)
Free-field record	A free-field record is a record of seismic ground motion, obtained at a sufficient distance from near-by structures, so that its response is not altered significantly in a wide frequency range, indicatively between 0 and 20 Hz. The instrument location (see *Housing*) should minimize the interaction effect with the host structure or adjacent structures. ESM contains either free-field and structure related records.
Housing	*Housing* denotes the place where the recording instrument is located. In ESM: box, bridge, building, cave, dam, ENEL box, gallery, historical building, power plant, quarry, well.

Housner Intensity	Housner Intensity (or response spectrum intensity) is defined as follows: $$SI(\xi) = \int_{0.1}^{2.5} PSV(T,\xi) dT$$ where *PSV* is the pseudo-velocity response spectrum (see *Response Spectrum*), *T* and ξ are the structural natural period and damping, respectively. In the case of records contained in ESM, the Housner Intensity was calculated considering ξ = 5%. This parameter of seismic motion severity is related to the potential damage expected from the considered earthquake, since the majority of structures have a fundamental period of vibration in the range between 0.1 and 2.5 s. The Housner Intensity has the same units as displacement (cm).
Hypocentral Depth	The Hypocentral depth is the distance between the hypocenter and the epicenter of the earthquake (see Fig. 2 in *Epicentral Distance*).
Late/Normally triggered record	In a late triggered record, the recording instrument triggered after the arrival of the first seismic waves of significant amplitude. The recorded signal is then characterized by a high initial value, if compared to the peak value of the signal. In a *normally triggered record* the recording instrument triggered early enough to properly describe the first arrivals of the seismic waves.

Magnitude

The earthquake magnitude measures the intensity of the seismic event, based on an appropriate processing of the seismic signal. Two considered magnitude in ESM are: the local magnitude and the moment magnitude.
The local magnitude, or Richter magnitude, is defined as follows:

$$M_L = log\,A - log\,A_0$$

where:
A = peak amplitude, in mm, of the track recorded by a Wood-Anderson (WA) seismograph at a given distance;
A_0 = amplitude corresponding to the reference earthquake ("zero") at the same distance.
The Richter magnitude scale is logarithmic, so an increase of a unit of M_L implies an increase of 10 times in the motion amplitude. Therefore, in moving from M_L = 4 (low intensity earthquake) to M_L = 7 (strong intensity earthquake), there is an increase in amplitude of 1000 times.
One limitation of the magnitude scale M_L is the tendency to saturation for magnitude around 7.0-7.5 (see Fig. 8); this depends on the bandwidth limitations of the WA seismograph, which do not make it suitable for recording the long period oscillations generated by large earthquakes.
The moment magnitude is instead defined from the seismic moment, which is defined as:

$$M_0 = G\overline{\Delta u}A$$

where G is the shear modulus of the crustal material where the seismic rupture occurs, A the area of the rupture surface in the seismogenic fault, and $\overline{\Delta u}$ the average coseismic slip on the rupture surface. The seismic moment contains the most important physical parameters associated with the energy release during an earthquake.
The moment magnitude is calculated based on the seismic moment as follows:

$$M_W = \frac{2}{3} log\,M_0 - cost$$

where $cost$ = 10.7 if M_0 is measured in dyne·cm and $cost$ = 6.0 if M_0 is measured in N·m.
M_0 is a quantity that can increase indefinitely as the source and dislocation dimensions increase, so M_W does not saturate.
This concept is illustrated in Fig. 8 by the relationship between M_W and the other commonly used magnitude scales. This shows that, in practice, $M_W = M_L$ for $M_W \leq 6.2$ can be assumed.

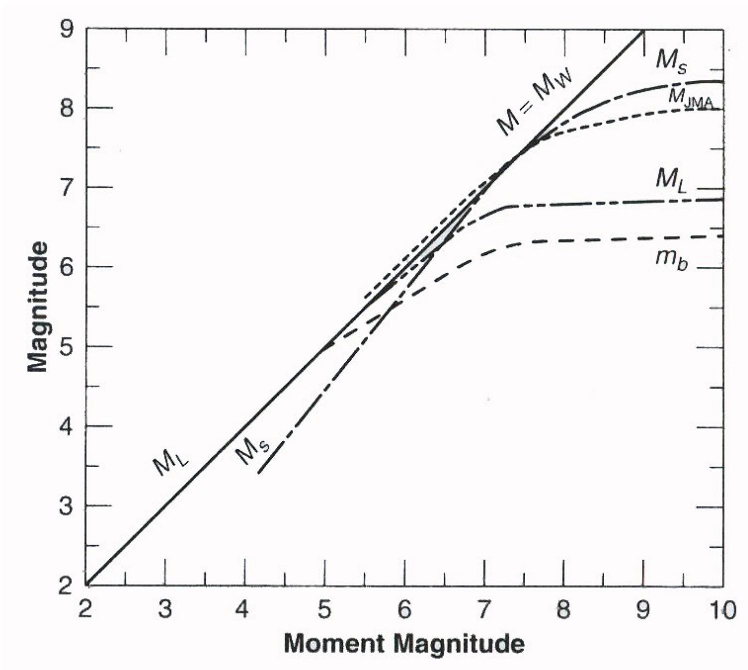
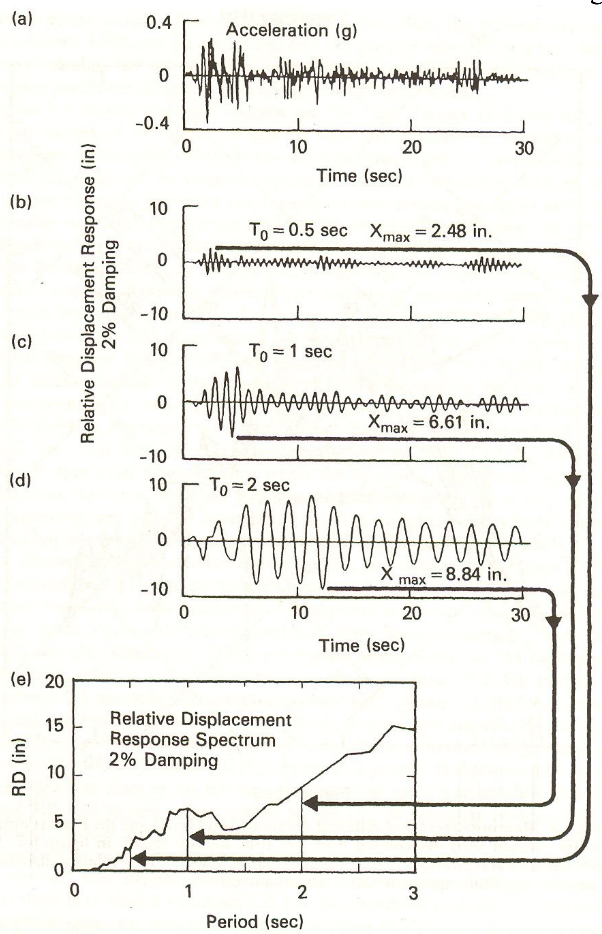


Figure 8 – Relationship between moment magnitude M_W and other magnitude scales, in particular the local magnitude M_L.

Morphology	This heading indicates the morphology of the site where the recording instrument is located. The following morphology types are distinguished: plain, valley centre, valley edge, alluvial fan, saddle, slope, edge of scarp and ridge.
Network	Network denotes the accelerometric network operating the recording instrument.
PGA	*PGA* (peak ground acceleration) denotes the maximum ground acceleration recorded during the seismic shaking.
PGD	*PGD* (peak ground displacement) denotes the maximum ground displacement recorded during the seismic shaking. It is the maximum value of the record obtained by integrating twice the acceleration time history.
PGV	*PGV* (peak ground velocity) denotes the maximum ground velocity recorded during the seismic shaking. It is the maximum value of the record obtaned by integrating once the acceleration time history.
Processed Record	In a Processed Record the disturbances present in the original signal at both high and low frequency have been removed or reduced (see *Raw/Unprocessed Record*). Two subsequent steps are employed in order to correct the low frequency disturbances: - the baseline is removed in the time domain (see *Baseline Correction*) - the accelerogram is high-pass filtered (see *Filter Correction*). In order to correct the errors at high frequencies, the accelerogram is low-pass filtered (see *Filter Correction*). The following procedure has been considered in the processing of ESM accelerometric data: - baseline correction (removal of the signal average value); - application of a cosine taper, with an extension based on a visual inspection of the record (typically between 2% and 5% of the signal total length); The taper is not applied to those records identified as late-triggered (see *Late triggered record*); - visual inspection of the Fourier spectrum (see *Fourier Spectrum*), to select the band-pass filter frequency range. When possible, the same frequency range is selected for the three components (see *Component*); - application of a acausal Butterworth filter of the second order, in the frequency range selected at the previous point; - double integration of the acceleration to obtain the displacement time history; - removal of the linear drift present in the displacement time history; - *double derivation to obtain the corrected acceleration, which is compatible with the corrected displacement.*

Response Spectrum	The response spectrum provides the maximum response (in terms of relative displacement, relative velocity or absolute acceleration) of a harmonic 1 degree-of-freedom (dof) oscillator, subject to an arbitrary accelerogram, as a function of the structural period T_n and of the damping ratio ξ (usually a standard value equal to 5% of the critical damping is used, generally applicable to all structures). The maximum amplitude of the response is obtained by integrating the equation of motion of the harmonic oscillator: $\ddot{x}(t) = -\omega_n^2 y(t) - 2\xi\omega_n^2 \dot{y}(t)$ where: *y(t)* is the relative displacement of the oscillator with respect to the ground $\ddot{x}(t)$ is the absolute acceleration of the oscillator ω_n is the oscillator natural circular frequency The following definitions are introduced: displacement spectrum (relative) $D(T_n,\xi) = \max_t \lvert y(t) \rvert$ velocity spectrum (relative) $V(T_n,\xi) = \max_t \lvert \dot{y}(t) \rvert$ acceleration spectrum (absolute) $A(T_n,\xi) = \max_t \lvert \ddot{x}(t) \rvert$ The pseudo-acceleration and pseudo-velocity spectra are also widely used in practice. They are defined as a function of the displacement spectrum as follows: pseudo-acceleration spectrum: $PSA\,(T_n,\xi) = \left(\frac{2\pi}{T_n}\right)^2 D(T_n,\xi)$ pseudo-velocity spectrum: $PSV\,(T_n,\xi) = \left(\frac{2\pi}{T_n}\right) D(T_n,\xi)$ The meaning of the acceleration response spectrum and the procedure for computing the spectral ordinates for selected periods on one of the ITACA records is illustrated in Fig. 9.  Figure 9 – Example of construction of the relative displacement response spectrum.

Unprocessed Record	The unprocessed record is the signal coming from the recording instrument after the analog-digital conversion and transformed by calibration factors to the proper measurement units. This signal typically contains instrumental errors in low and high frequency (noise or instrumental drifts), which are subsequently removed by the processing procedures (see *Processed Record*).
Sampling Interval - Time Step	The sampling interval corresponds to the time step between two consecutive points of the record, which is obtained either directly from a digital instrument or from the digitization of the analog signal.
Seismic Sequence	The seismic sequence is a series of earthquakes occurring in the same region at close intervals of time. Typically a seismic sequence consists of a strong and severe seismic event (*mainshock*), possibly anticipated by a series of minor earthquakes (*foreshocks*), and always followed by many events of lower intensity (*aftershocks*).
Station	Station denotes the recording instrument (accelerometer) and its physical location. Each recording station can be identified by its network (see *Network*), an alphanumeric code, a name and its geographical coordinates.
Time of first sample	The time of first sample of the record is given to synchronize the record with respect to the Greenwich Mean Time (GMT).
Topography	The following topographic categories are considered, according to the Italian Technical Norms for Civil Constructions (Norme Tecniche per le Costruzioni, 2008), close to those of the EC8 Part 5: T1: plains, slopes and isolated hills with an average inclination i < 15° T2: slopes with an average inclination i > 15° - T3: hills or mountains with a ridge width much smaller than the base width and average inclination 15° < i < 30° - T4: hills or mountains with a ridge width much smaller than the base width and average inclination i > 30°
V_s profile	The V_s profile contains the information on the propagation velocity of shear (*S*) waves in the soil underneath or in the vicinity of an accelerometric station, as a function of depth. Typically the stratigraphic profile is defined by layers of varying thickness, each of them characterized by the corresponding shear waves velocity, expressed in m/s. The knowledge of the S-wave velocity is one of the most important parameters for the mechanical characterization of the site of interest, and its classification (see *EC8 Site Class* and $V_{s,30}$)
$V_{s,30}$	$V_{s,30}$ is an average measure of the shear (*S*) wave velocity in the soil, within the first 30 meters of depth from the ground level. It is defined as follows: $$V_{s,30} = \frac{30}{\sum_{i=1,N} \frac{h_i}{V_i}}$$ where h_i and V_i are the thickness (in m) and the shear wave velocity V_s (in m/s) of the *Nth* soil layers present within the first 30 m.
Waveform	*Waveform* is the visual form of the recorded time history of wave motion. In ESM, under *Waveform plot previews*, the unprocessed acceleration time history (see *Unprocessed Record*), the processed acceleration, velocity and displacement (see *Processed Record*) are displayed, together with the acceleration and displacement response spectra plots (see *Response Spectrum*).