Automatic Magnitude Determination

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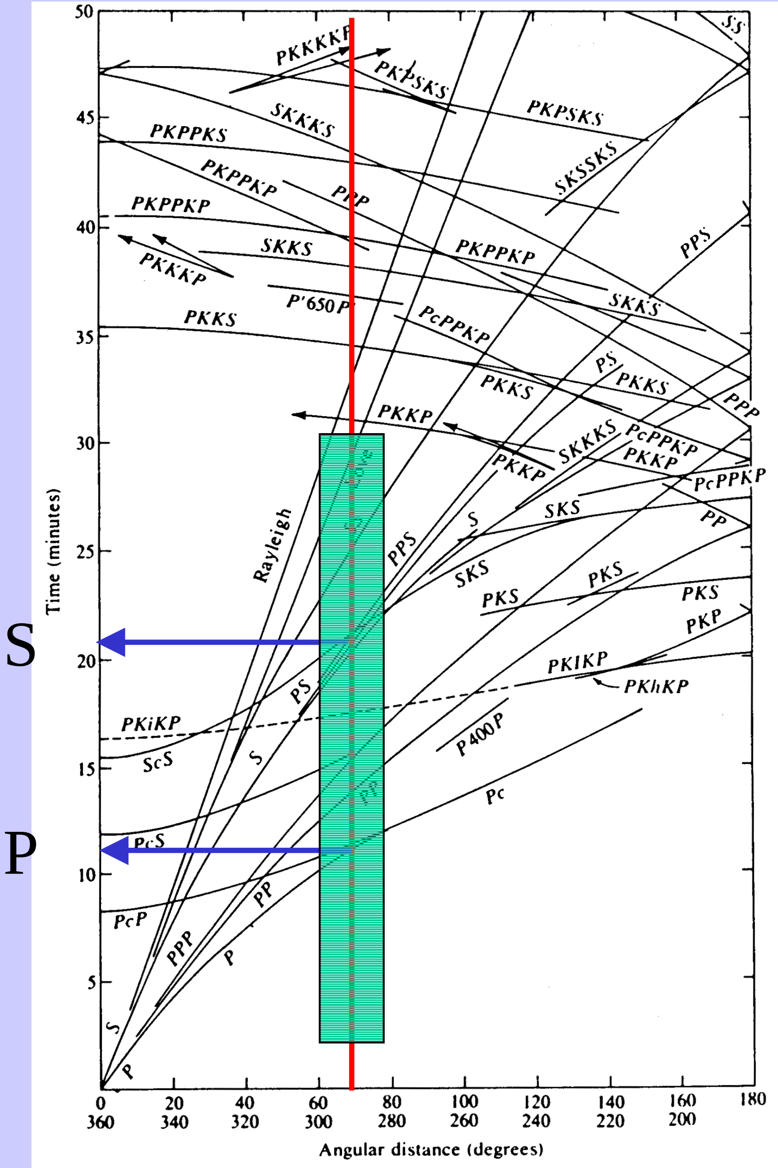
Moment Magnitude - Steps

1. The location of the earthquake must be known via gridassoc, dblocsat or genloc
2. Determine the theoretical P-wave arrival
3. Determine the theoretical S-wave arrival
4. Cut out a segment which starts at p-arrival minus s-p-arrival and ending at s-arrival + s-p-arrival.
5. Apply the "Transfer Function of the system". This transfer function must be either known or estimated (assured by comparative measurements).
6. Select filter
7. Estimate the average of the ground movements prior to the theoretical P-wave arrival from the noise
8. Select an appropriate S-wave time window (such as S-P-time*0,1) beginning at Stheo – (Stheo-Ptheo)*0.1 and ending at * (Stheo-Ptheo)*0.1
9. Apply a baseline correction to the recorded data stream (subtracting it) based on 5 seconds of data prior to the p-wave arrival (see point 4). Apply Cosine-taper.
10. Calculate the Fourier Spectrum
11. Determine the plateau of the spectrum, corner frequency, etc. and finally the moment magnitude

Time Window



Get theoretical P- and S-wave arrival based on hypocenter (epicentral distance and depth) from travel-time table.

Cut out trace according to large time window (green) ranging from “P minus S-P” until “S plus S-P”.

Apply transfer function to get the true velocity trace from the selected time-window (green).

The reason for the large time window is to minimize filter-effects when cutting out the noise- and S-wave time-series.

Choosing the Filter

Analyse **noise** by determining Nmin (Noise minimum), Nmax (Noise maximum), and average of the noise from a time-window prior to the theoretical p-wave arrival and determine average, E.g. from p-wave arrival minus (S_{theo}-P_{theo})*0.5 until p-wave arrival minus(S_{theo}-P_{theo})*0.1

Select an appropriate **S-wave** time window (such as S-P-time*0,1) beginning at S_{theo} – (S_{theo}-P_{theo})*0.1 and ending at * (S_{theo}-P_{theo})*0.1

Analyse S-wave (get min and max and determine Smax - Smin).)

If hypocentral distance < 300 km 1 – 10 Hz else 0.05 and 10 Hz

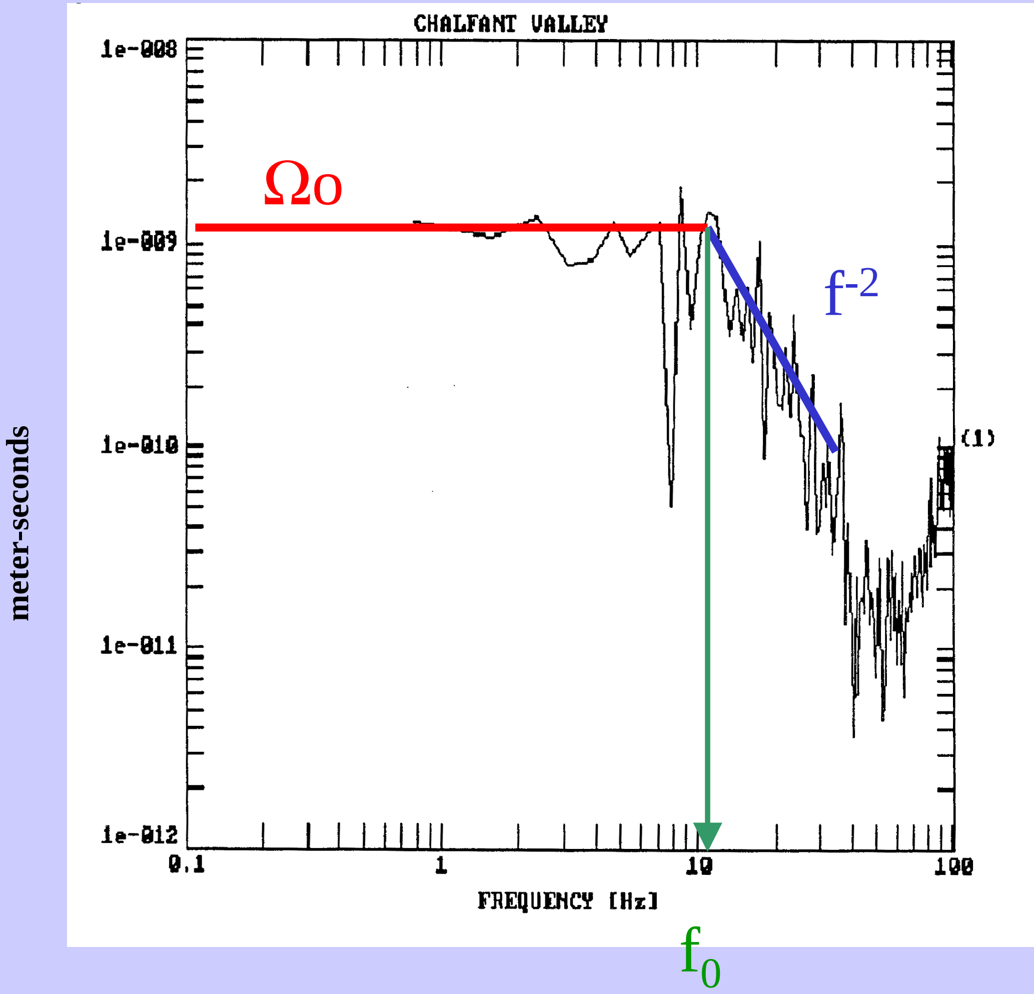
Determine again min, max and average of the **noise** and of the **S-wave**.

If Smax-Smin < 2*(Nmax – Nmin) then

Forget it, else

select the appropriate S-wave time window again (such as S-P-time*0,1) beginning at S_{theo} – (S_{theo}-P_{theo})*0.1 and ending at * (S_{theo}-P_{theo})*0.1

Spectra – Classical Approach



Corner frequency

1. **Subtract average noise from velocity trace**
2. **Integrate velocity trace giving the displacement or apply the Transfer Function and correct directly for displacement**
3. **Determine spectrum from displacement trace**

Seismic moment $M_0 = 4\pi\rho V_S^3 \Omega_0 R_c$

with a radiation factor

$R_c = 0.55$ *for P – waves and* $R_c = 0.63$ *for S – waves,*

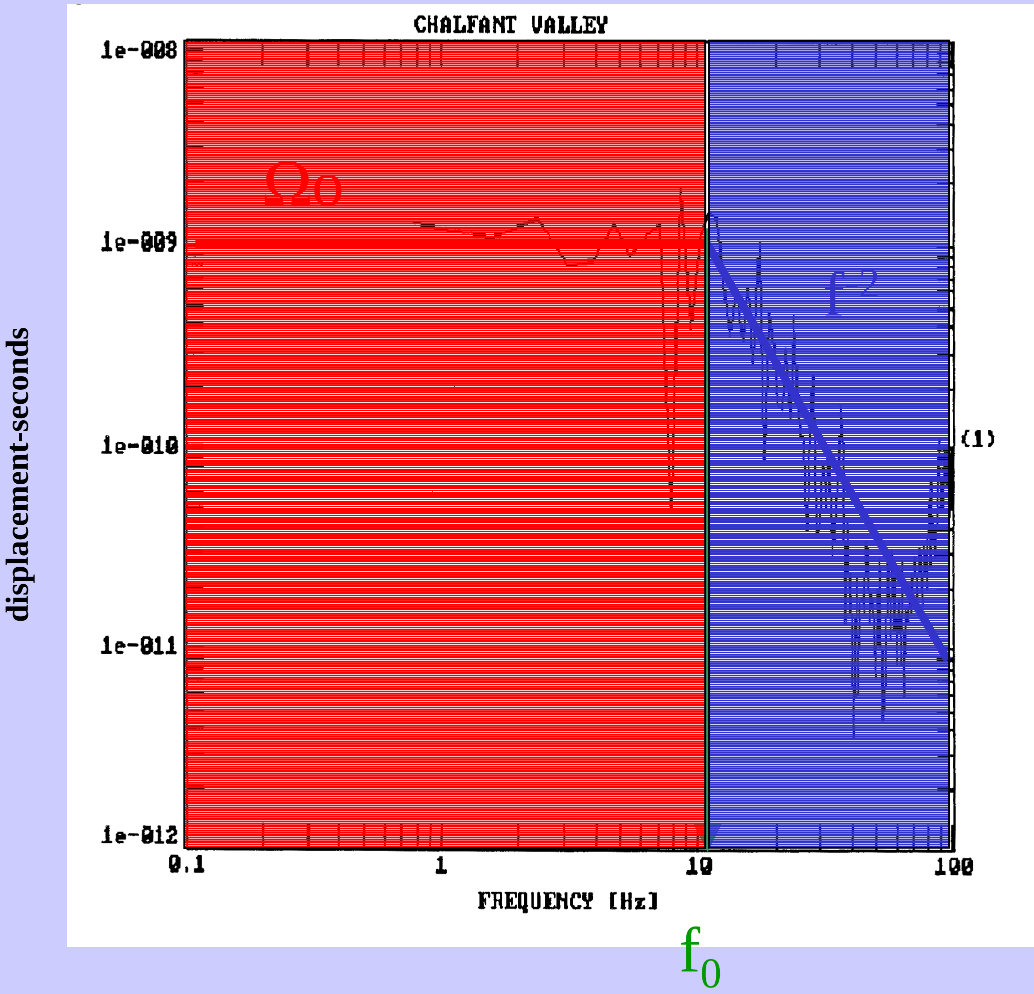
shear wave velocity $V_S = 3400 m/s$, *density* $= 2700 kg/m^3$

Source radius $r = \frac{kV_S}{2\pi f_0}$

with a source shape factor 'k' of = e.g. 2.34 (Brune)

Stress drop $\sigma = \frac{7M_0}{16r^3}$

Spectra – Trick



Corner frequency

I suggest the following ‚trick' when automatically calculating the corner frequency:

Smooth spectrum! Don't forget that we are dealing the double logarithmic scales.

Start an iteration from the Nyquist-frequency (2/sampling rate per second) down to the lowest frequency defined by the length of the selected time window (2/time window length) thus moving f_0.

1. Divide the spectra into a left (red) and a right (blue) part
2. Determine the variance of the left part with a fixed slope and determine the variance of the right part, while the slope must be –2 (Brune's model).
3. While moving f_0 determine the sum of both variances (left and right side) and find their minimum.

The smallest sum of variances indicates the desired corner frequency 'f_0'.

Note: Watch out for significance! Usually the left side has much less data than the right side…

Spectra – Alternative Approach

1. Subtract average noise from velocity trace
2. Determine spectrum from velocity trace V(f) velocity-trace
3. Integrate velocity trace giving the displacement
4. Determine spectrum from velocity trace D(f) displacement-trace

$$S_{V2} = 2\int_0^\infty V^2(f)df ;\longleftrightarrow S_{D2} = 2\int_0^\infty D^2(f)df$$

$$\Omega_0 = 2S_{V2}^{-1/4} S_{D2}^{3/4}$$

$$M_0 = 4\pi\rho V_S^3 \Omega_0 R_c$$ **Seismic moment**

$$with\ a\ radiation\ factor$$

$$R_c = 0.55\ for\ P-waves\ and\ R_c = 0.63\ for\ S-waves,$$

$$shear\ wave\ velocity\ V_S = 3400 m/s,\ density = 2700 kg/m^3$$

$$E_s = 4\pi\rho V_S S_{V2}$$ **Seismic energy**

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{S_{V2}}{S_{D2}}}$$ **Corner frequency**

$$r = \frac{kV_S}{2\pi f_0}$$ **Source radius**

$$with\ a\ source\ shape\ factor\ 'k'\ of = e.g.\ 2.34\ (Brune)$$

$$\sigma = \frac{7M_0}{16r^3}$$ **Stress drop**

See Di Bona, M. & Rovelli, A. 1988. Effects of the bandwidth limitation on stress drops estimated from integrals of the ground motion. Bull.Seism.Soc.Am., Vol.78, 1818 -1825

Comments

The final Moment Magnitude ‘M_w’ is defined by Hanks and Kanamori (1979) by (M_o in Newton-meters) assuming a constant stress drop of 1/10000 of the shear modulus)

$$M_w = 0.667*\log(M_o) - 6.1$$

The following options should be possible when determining the source parameters manually:

1. Time Window
2. Method (classic, alternative)
3. Filter
4. Type of wave (P or S, accordingly some constants would change)

As a control, the program could compare the theoretical peak velocity and/ or peak displacement of the shear wave, which should be of the order of (R = distance) with the observed ones:

$$v_{peak} = \frac{R_S}{4\pi\rho R V_S^3} 2\pi f_0^2 M_0 \longleftarrow R_S = 0.57; k = 2.34$$

$$v_{peak} = \frac{0.0686}{\rho R V_S} \sqrt[3]{\Delta\sigma^2 M_0} \longleftarrow M_0 = GD\pi r^2$$

$$D_{peak} = \frac{8.1 R v_{peak}}{V_S}$$

Other Magnitudes

Definition: Amplitude = (Peak to Peak) / 2

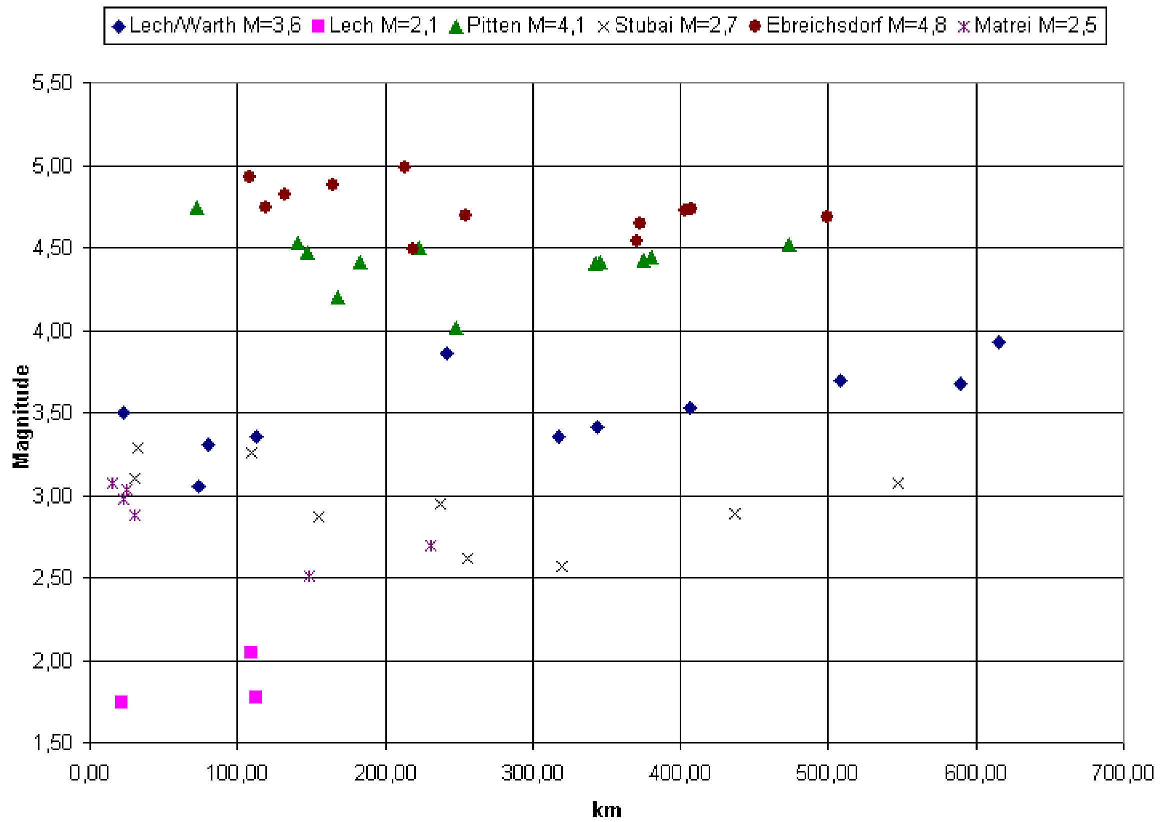
Advantage: Automatic determination possible

Same algorithm for velocity and acceleration traces

Velocity data are used for mb, Ml and Ms

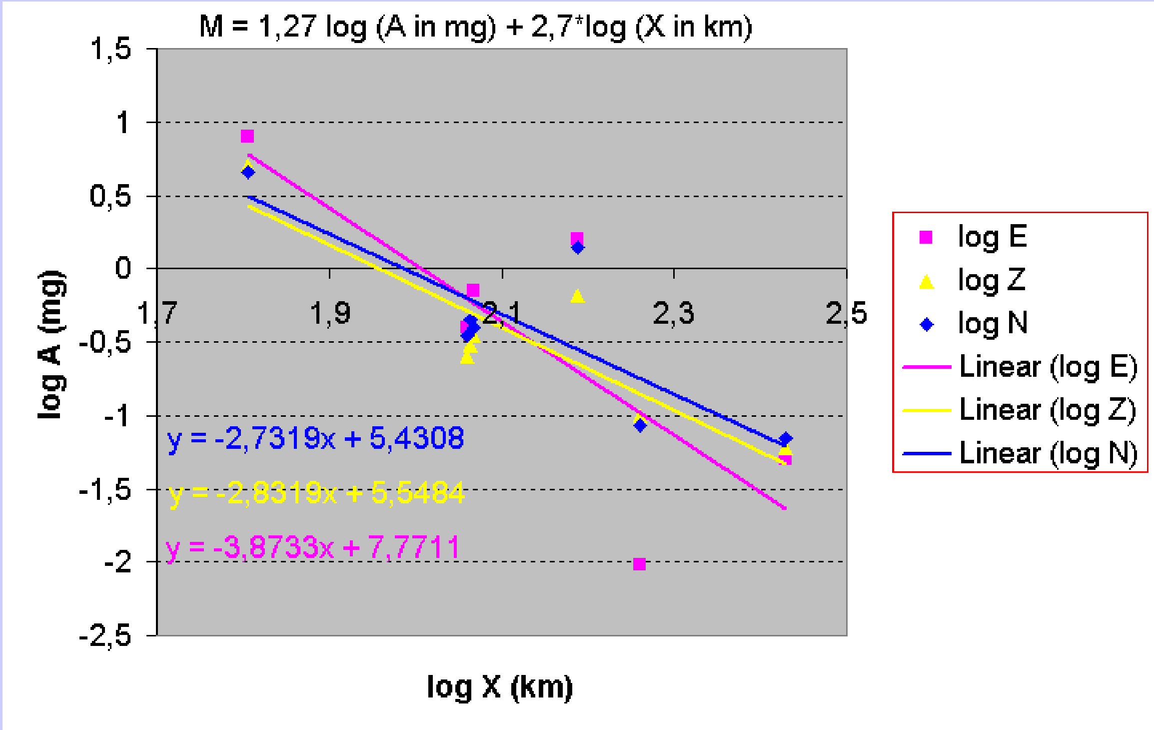
Acceleration data are correlated against Ml

Using Velocity Data



Ml= log(A in nm/s) + 1,66 log(X in km) - 3,7 ; mit Filter 0.01 HP

Using Acceleration Data



ZAMG

Summary

Ml very robust if the total time window (P & S) is considered
> circumventing focal pattern

Findings:
Ml (S13) = Ml (BB) – 0,3
mb = Ms – 0,3

Ms determined from surface waves require
the same constants as for Ml.

Interpretations based on Z-components
are more stable than those from
horizontal components.

Interpretations based on accelerations
require other constants than
those used for velocity traces >
attenuation effect

Single Station Location

User Command:
dbarrparams

Gives:
azimuth, incidence angle, rectilinearity
amplitude, period
first motion

Remark:
The incidence angle reflects the apparent angle of incidence.

It must be corrected via

$$i_{true} = \arcsin ((v_p/v_s) * \sin (i_{app}/2))$$

Hence, an assumption must be made for v_p/v_s for each station.
The"v_p/v_s"-ratio can be verified by using nearby blasts, where i_{true} should be ~ 90°.