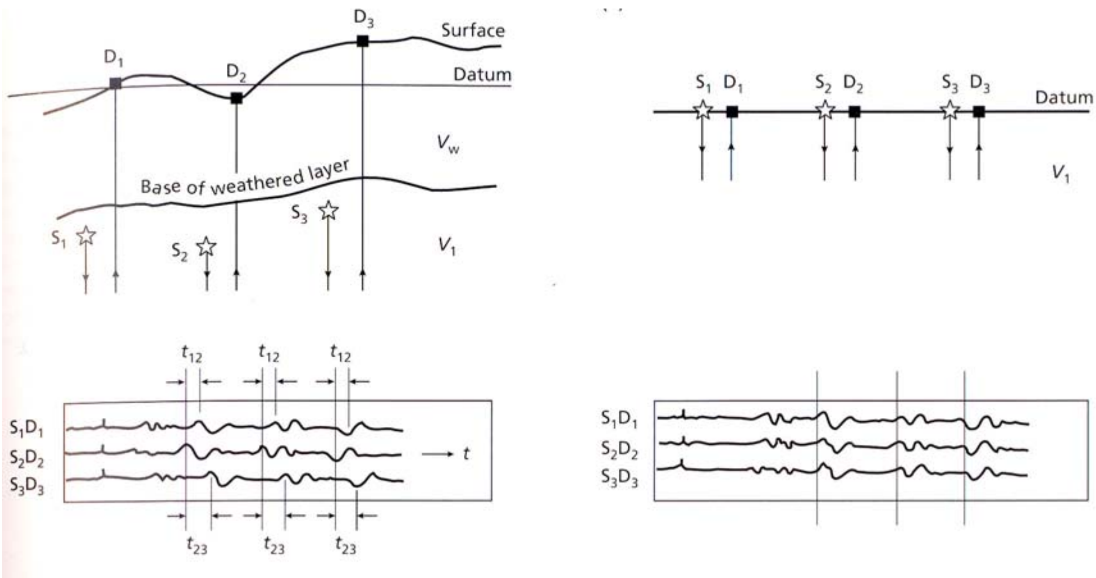
## C2.7 Statics, noise reduction and filtering of seismic reflection data

### C2.7.1 Statics and their removal

So far we have assumed that onshore seismic data is being collected on a flat surface with uniform near surface geology. However this assumption is not often valid, and two effects will cause a variation in arrival times between closely spaced traces. These time delays are called **statics** because they delay (or advance) all events in the seismic trace recorded by a particular shot-geophone combination.

***Elevation statics*****:** geophones at an elevation above a datum (or reference level) will detect the incoming signal later than a geophone on the datum.

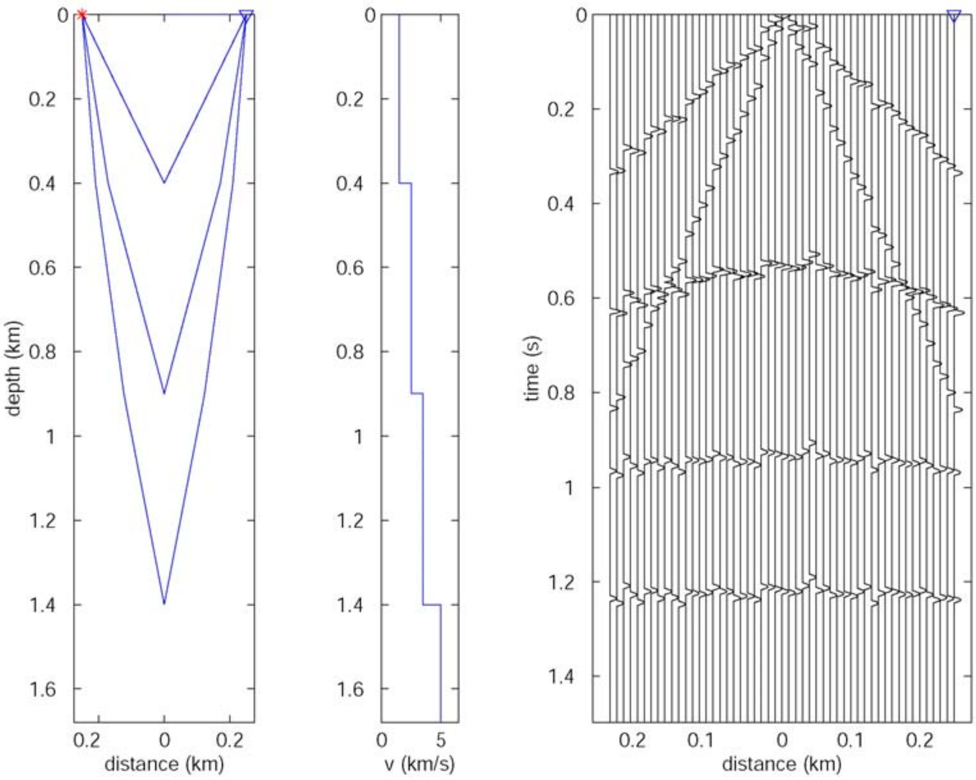
***Weathering statics*** : weathering of near surface rocks produces a zone of low velocities that is variable in thickness




*Kearey Figure 4.15*

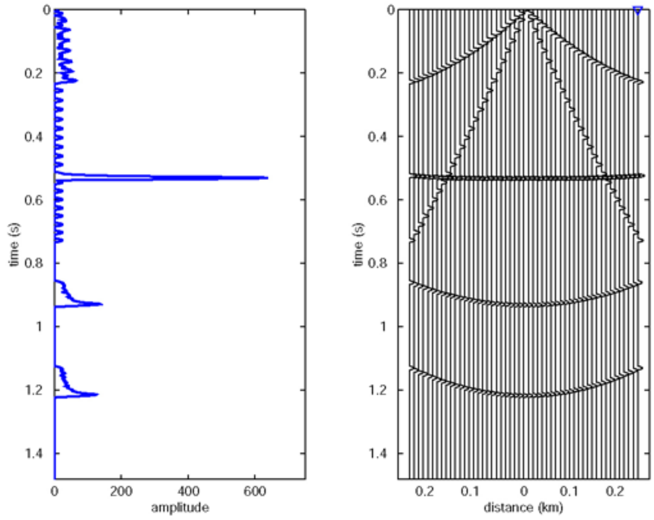
**Why are statics a problem in seismic reflection data?**

Statics produce a vertical offset in seismic traces, as shown in the CMP section generated by **cmp_v3.m.** Thus when the traces are stacked, they will not stack coherently.

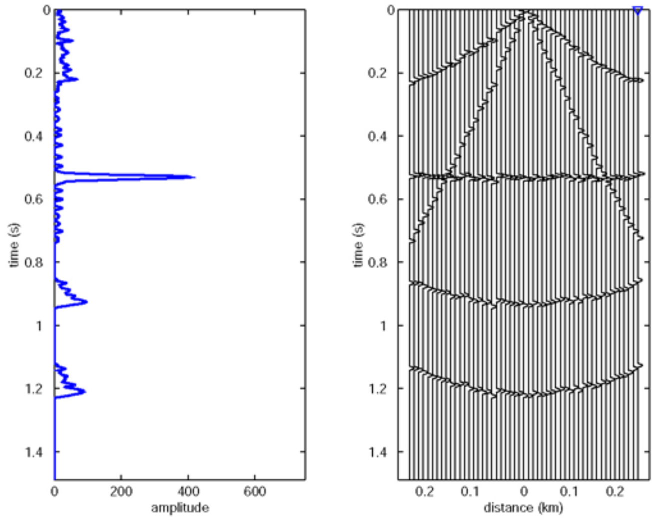


## C2.7 Effect of statics on a CMP stack

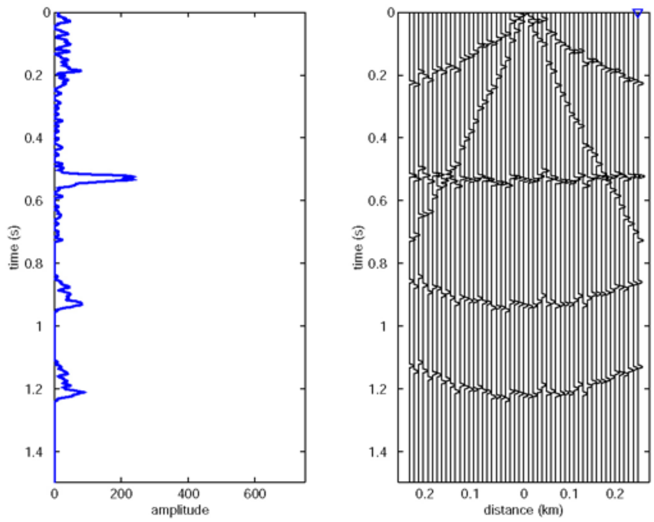
Reflection 1
No statics
Stacking velocity = 1500 m/s




Reflection 1
Statics ~ 5 ms
Stacking velocity = 1500 m/s




Reflection 1
Statics ~ 10 ms
Stacking velocity = 1500 m/s



***Example 1***

Statics are present in 50 Hz seismic reflection data. How large can the statics be and still permit coherent CMP stacking?

Signal period (T) = ___ ms

For reinforcement, maximum time delay for reinforcement = T/4 = ____ ms

***Example 2***

If there is no weathered layer, and the bedrock has v = 3000 m/s, what elevation change will produce a static of 5 ms?

***Example 3***

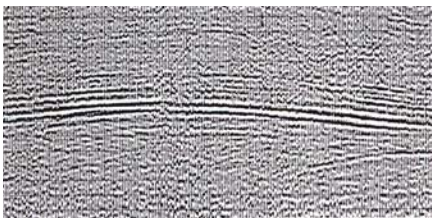
The weathered layer has v=1000 m/s and the bedrock has v = 2500 m/s. What change in the thickness of the weathered layer will produce a delay of 5 ms?

**Correction of statics**

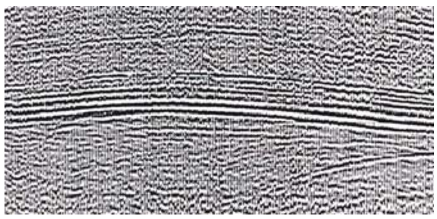
- Elevation statics can be removed by accurate surveying with GPS or differential GPS. A vertical accuracy of ±1 m is usually sufficient.

- Weathering statics can be estimated from a variety of techniques, including measuring the refracted arrival (head wave) that travels along the base of the weathered layer. Details in *Kearey, chapter 4, 58-59.*

- In residual static analysis, traces are automatically aligned to produce the most continuous seismic event. Example below is from *Kearey Figure 4.16*



Before



After residual static analysis

### C2.7.2 Frequency domain filtering

When seismic reflection data is recorded, the individual traces data are contaminated by signals other than seismic reflections. These signals include ground motion due to wind noise, vehicles etc. There are also other seismic phases that can obscure the reflections (ground roll). Electrical powerline noise (50 Hz and 60 Hz and harmonics) can also be picked up by the telemetry cables. In marine surveys, noise signals originate in the motion of the ship and streamer through the water.

Some of this noise has a frequency content that is quite distinct from the seismic signals being recorded. These can be removed by frequency domain filtering techniques.

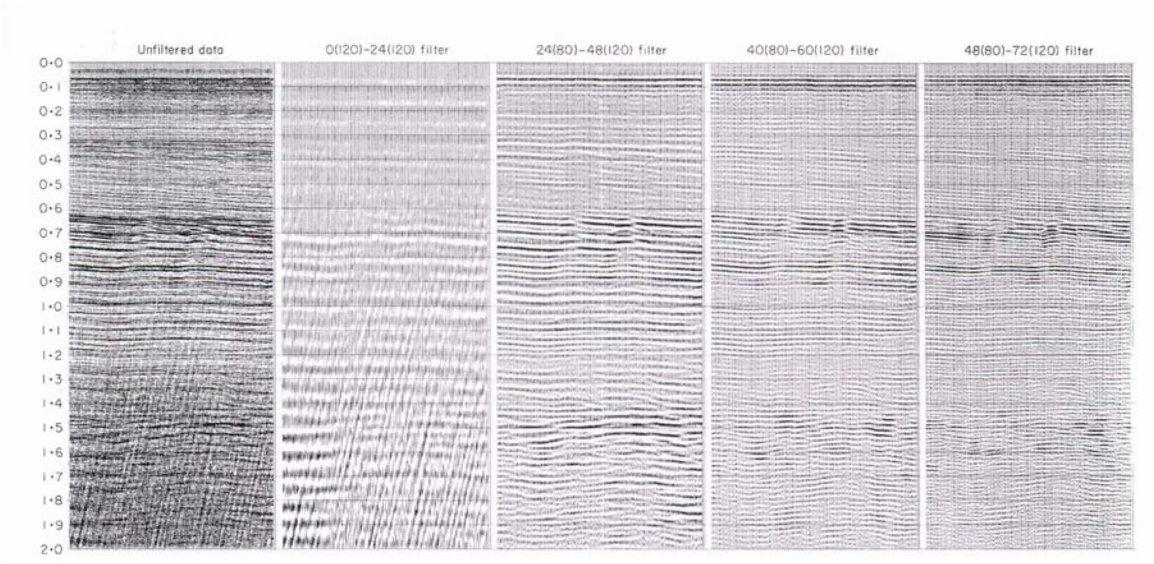
**Notch filter** : removes a very narrow band of signals (*e.g.* 60 Hz powerline noise)

**High pass filter**: All frequencies above the filter frequency are transmitted. This an remove ground roll and certain ship generated noise (also called a low-cut filter)

**Low pass filter**: all frequencies below the filter frequency are transmitted. Can be used to remove high frequency noise in some circumstances.

**Band pass filter** : transmits signals in a narrow frequency band.

***Example***: *Kearey figure 4.19*. Note that the frequency content in the seismic section changes with time. Low frequencies dominate at later times, as the high frequencies are more rapidly attenuated than lower frequencies.



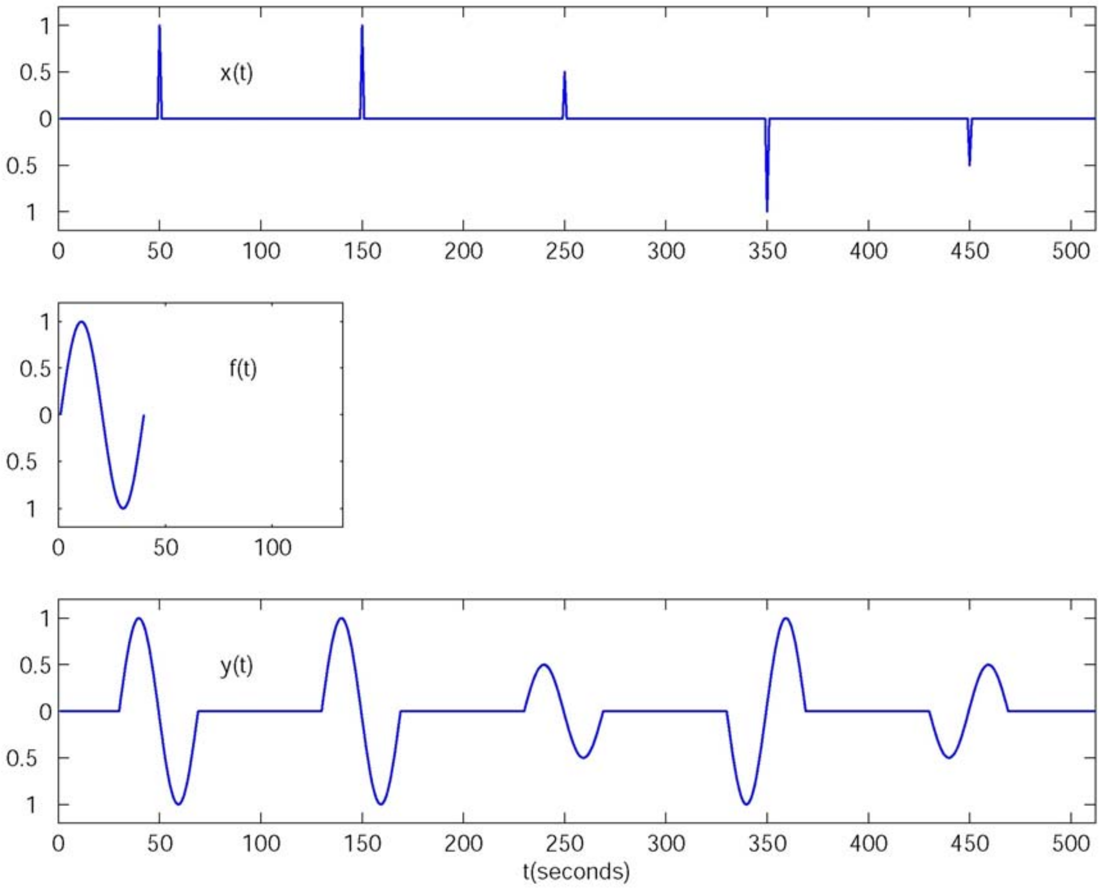

However, many artefacts in a seismic section have a frequency content that is very close to those present in the reflections. Thus they cannot be removed by conventional frequency domain filtering.

## C2.7.3 Convolution

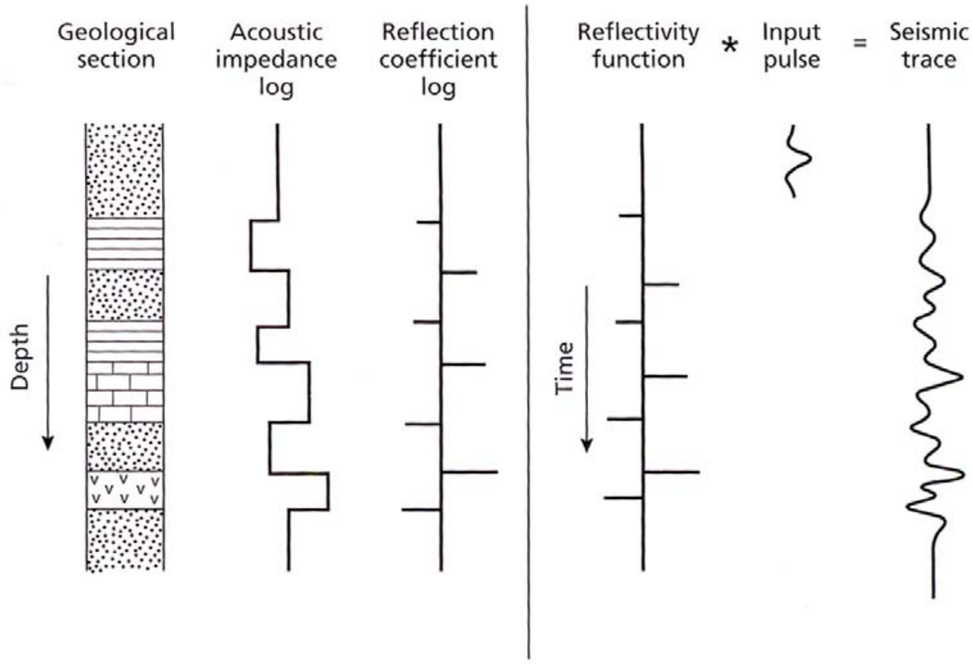
Convolution is a mathematical operation that can be defined as

$$y(t) = f(t)*x(t)$$
$$= \int f(\tau)x(\tau - t)d\tau$$

Graphically, convolution is illustrated in the attached figure, where the function *x(t)* is a series of spikes (delta functions) and *f(t)* is a sinusoidal wavelet (MATLAB script **convolution_C27.m**).




This mathematical procedure may seem quite abstract, but it occurs in reflection seismology, as illustrated in *Kearey Figure 4.6*.




The sharp changes in acoustic impedance (Z) in the geological section are called the **reflectivity function**. The locations where this function has **spikes** are the locations that reflect seismic energy back to the surface.

However, to measure the reflectivity function we need to send a seismic signal through the Earth. This seismic pulse has a finite length (in both space and time) and the seismic trace (measured by the geophone) can be shown to be the **convolution of the reflectivity function and the seismic pulse**.

This has the effect to spread out the sharp response in the reflectivity function associated with each interface. As a consequence, the measured seismic trace is lower in resolution and we cannot accurately locate the time at which a particular reflection arrives. This will limit resolution, since we showed in section C2.6 that layers can only be resolved if they are separated by more than $\lambda/4$.

Thus a sharper response will be obtained by making the seismic pulse as short as possible in time. However, this requires an increase in frequency, and this will have the side effect of increasing attenuation.

The mathematical process of **deconvolution** is used to reverse the process described above. The goal is to find the sharp reflectivity function from the measured seismic trace.

## C2.7.4 Deconvolution

The process of **deconvolution** can be used to undo the effect of other filtering operations. This includes the effect of a finite length seismic pulse, as illustrated above.

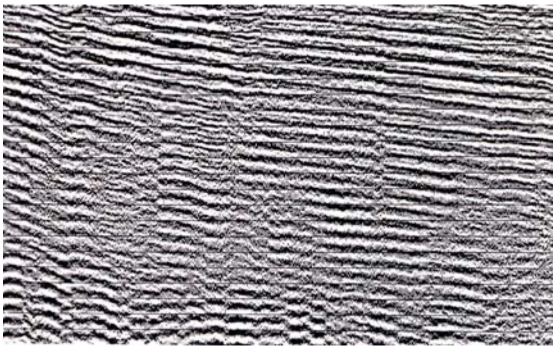
Often used to shorten the length of the seismic pulse. A seismic pulse can be lengthened by a number of processes:

**Reverberation** : multiple reflections in the water layer.

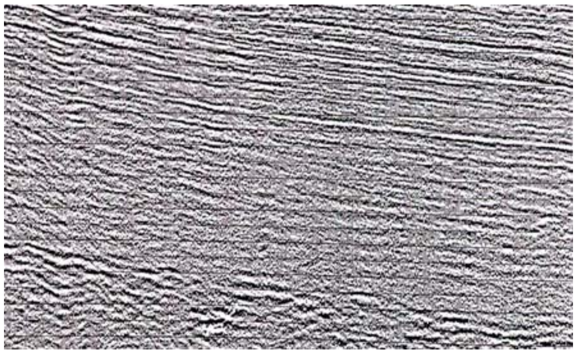
**Ghosting** : reverberation in the (low velocity) weathered layer at the surface.

To overcome these, and other effects, a range of deconvolution techniques may be used. More details and examples can be found in Kearey (p. 62-65).

*Kearey 4.22:* Reverberation removal with **predictive deconvolution**.



Before



After

- remember that in Vibroseis ® surveys, the seismic pulse is very long. However, the fact that the shape of the pulse is known allows us to correlate the seismic trace with the known waveform during processing. However, in surveys using explosives are airguns, the source function is generally not well enough known for this to be applied.