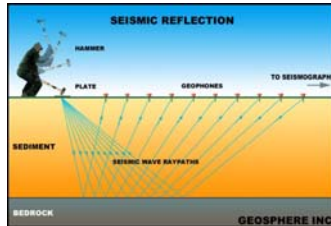


## Seismic methods: Seismic reflection - I



Reflection reading:  
Sharma p130-158; (Reynolds p343-379)

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## Reflection surveying

- Sensitive to impedance contrasts
- Use near-normal incidence i.e. P-waves

### Target scale:

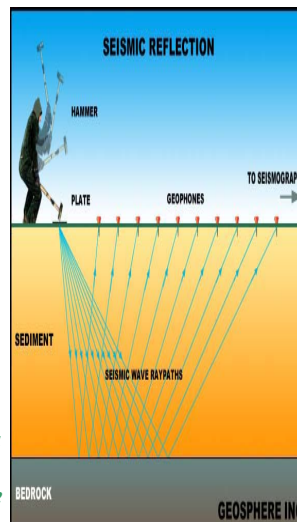
10's m: Ground water, engineering and environmental studies

km's: Oil exploration

10's km: Crustal structure

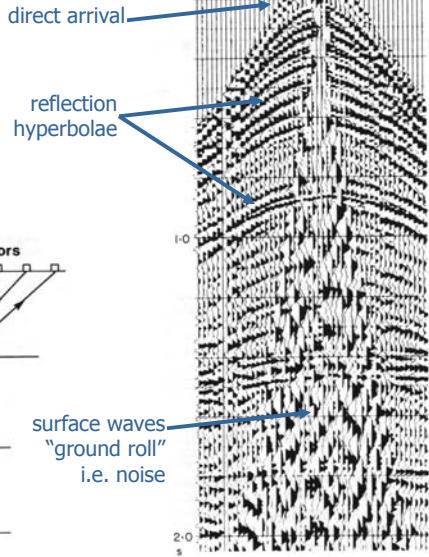
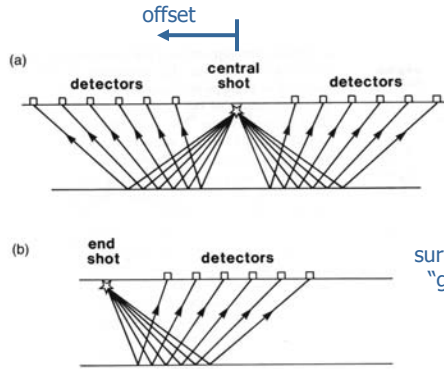
$$\rho_1 V_1$$

$$\rho_2 V_2$$



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# Shot gathers



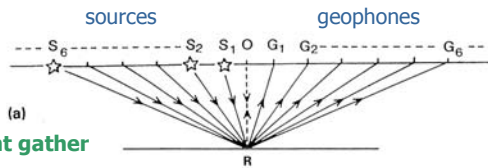
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# Common midpoint gathers

To enhance signal to noise we use more than one shot

Reflections from the same point are recorded by different source-station pairs

→ Common depth point gather



For dipping layers the reflection points are "smeared"

→ Common midpoint gather

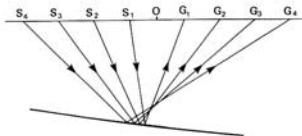


Fig. 4.16 (a) Ray paths of reflections belonging to the common-depth point (CDP) which is located below the shot-geophone common midpoint, O. The arrangement shown gives a six-fold coverage of the subsurface reflection point, R, on a horizontal reflector. (b) For a dipping reflector, the reflection point is not vertically below the shot-geophone midpoint, O.

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## Collecting Common midpoint gathers

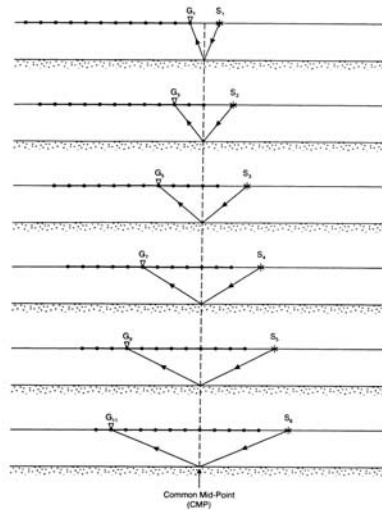
Sequentially move shot and receiver string across the surface

### Fold

- The number of times the same point on a reflector is sampled
- In this case: 6 fold (though 12 geophones)

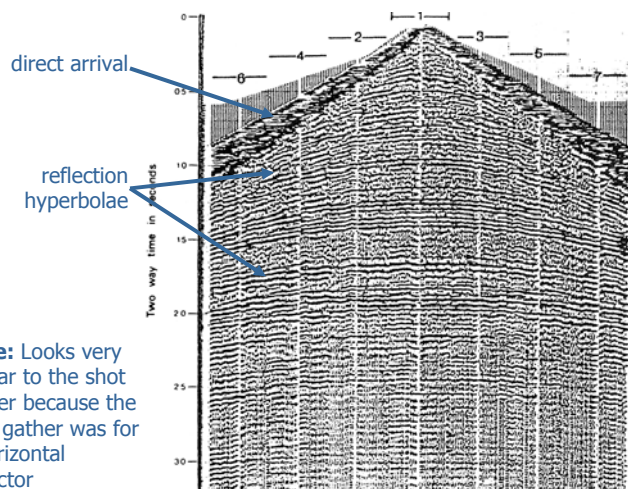
### Typical values

- 1-6 engineering studies
- 50, 100 or even 1000 in hydrocarbon exploration



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## Common midpoint gathers

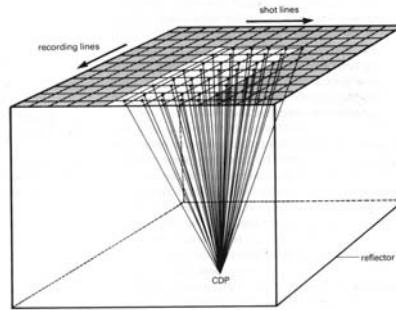
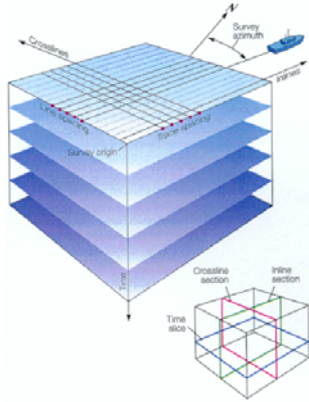


**Note:** Looks very similar to the shot gather because the shot gather was for a horizontal reflector

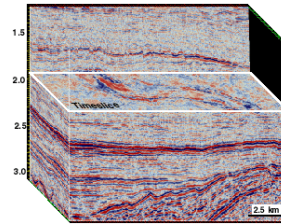
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## 3D surveys

Collect data on a grid rather than along a line



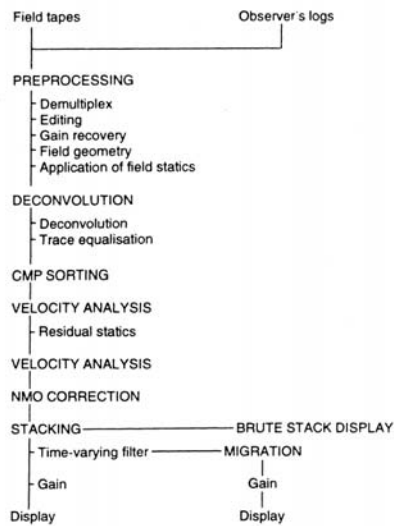
Produces a data cube rather than a line



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## Seismic reflection processing

### Flow overview



These are the main steps in processing

The order in which they are applied is variable

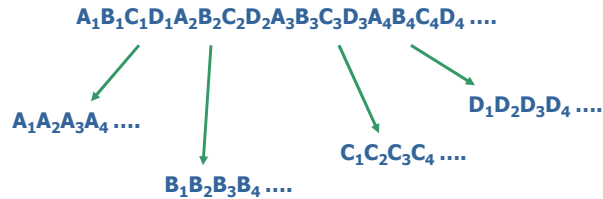
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## Preprocessing Demultiplexing

...bookkeeping!

Four geophones: A, B, C, D, recording samples 1, 2, 3, 4 ...

- The recording device stores samples in the order recorded
- Demultiplexing is separating all the samples to produce a time sequence for each geophone



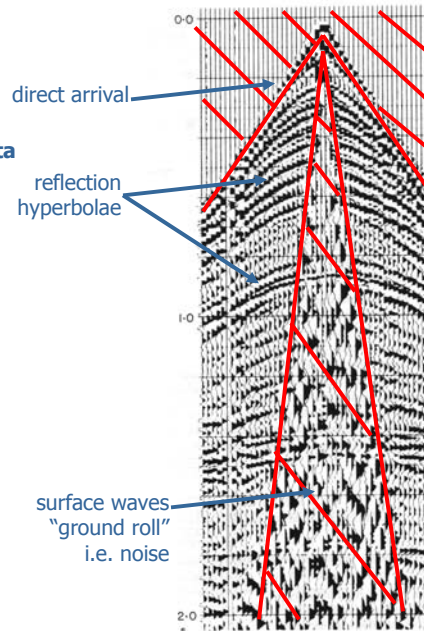
Industry standards (SEG) usually allows for painless translation of the data

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## Preprocessing Editing and muting

### Manually cleaning up the data

- Remove dead traces
- Remove noisy traces
- Switch polarity on reversed traces
- "Cut" out unwanted signal e.g. pre-arrival noise, direct arrival, ground roll

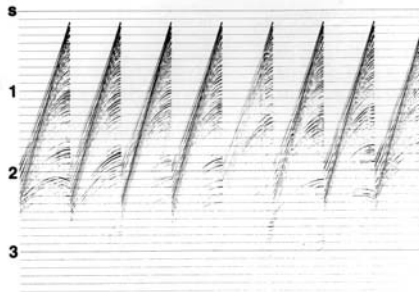


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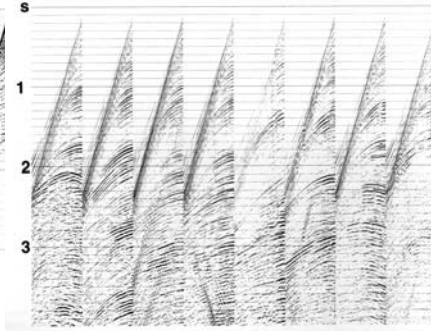
## Preprocessing Gain recovery

“Turn up the volume” to account for seismic attenuation

1. Could calculate the energy/amplitude loss using geometric spreading and apply a correction
2. **Automatic gain control (AGC)** apply a gain to equalize amplitude along the trace



Pre-AGC



Post-AGC

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## Static corrections

Correct for surface topography and the weathered surface layer

**Surface topography**

Time correction to each trace:

$$t_g = (E_g - E_d) / V$$

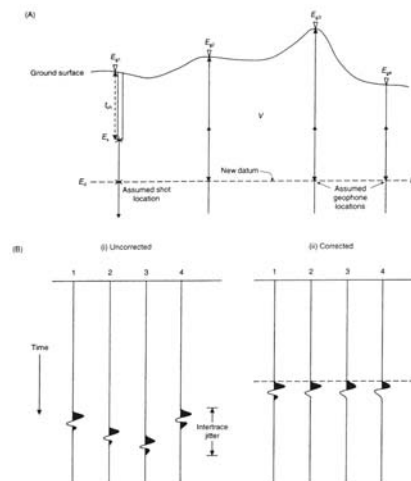
**Source depth**

$$t_s = (E_s - E_d) / V$$

total correction

$$t_e = t_s + t_g$$

Shift each trace by this amount to line up deeper reflectors



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## Static corrections

To make corrections we need to know the velocity of the surface weathered material

### Uphole traveltime

$$V = d / t_{uh}$$

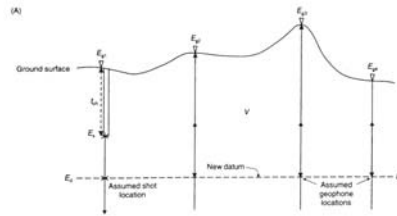
### Refraction studies

Used to determine near surface velocities and variations in the thickness of the weathered layer.

Finally,

### Data smoothing statics

- An automated process which lines up adjacent peaks
- Can only be applied when reflections are already within a wiggle

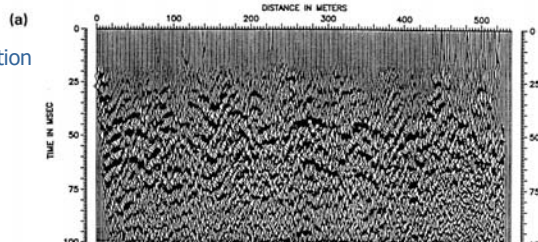


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## Static corrections

### An example

Pre-correction



Post-correction

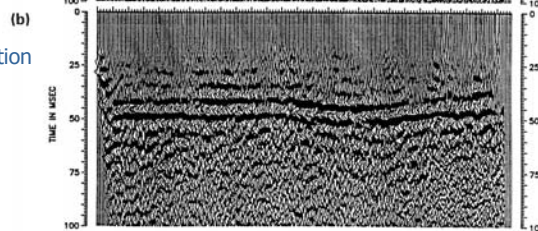


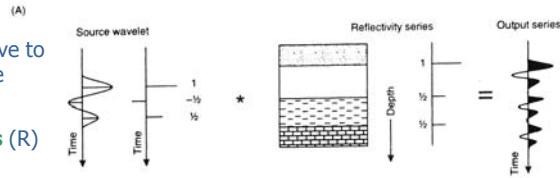
Fig. 4.17 Effect of applying residual static corrections on CDP reflection data recorded at a waste-dump site in Zealand, Denmark. Time section (a) before application of statics and (b) after application of statics. (After Ploug, 1991.)

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# Reflectivity and convolution

The seismic wave is sensitive to the sequence of impedance contrasts

→ The **reflectivity series** (R)



We input a source wavelet (W) which is reflected at each impedance contrast

The seismogram recorded at the surface (S) is the convolution of the two

$$S = W * R$$

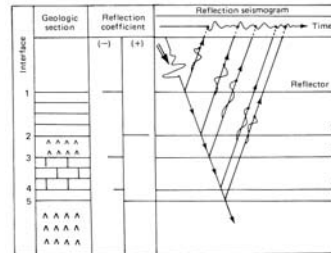


Fig. 4.18 Schematic of a model geological section, a reflectivity log, and a synthetic seismogram. The last is produced by convolving the input wavelet with the reflection effects at each interface derived from the reflectivity log. (Modified from Al-Saidi, 1982.)

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# Reflectivity and convolution

## Doing the convolution:

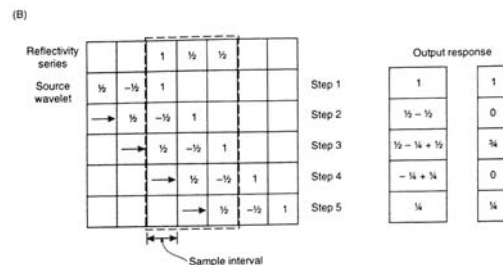
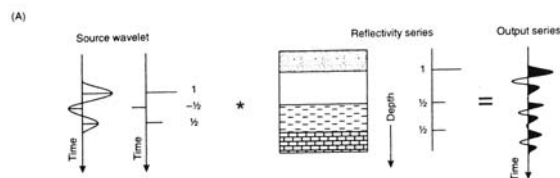
*Step 1:* Convolve source wavelet and reflectivity series by multiplying the first sample of the source wavelet (1) by the first component of the reflectivity series (1) to give the first constituent of the output response

*Step 2:* Move the source wavelet array on one sample and convolve; hence  $(1 \times \frac{1}{2}) + (1 \times (-\frac{1}{2})) = \frac{1}{2} - \frac{1}{2} = 0$

*Step 3:* Move the source wavelet array on one sample and convolve; hence  $(\frac{1}{2} \times 1) + (\frac{1}{2} \times (-\frac{1}{2})) + (1 \times \frac{1}{2}) = \frac{1}{2} + (-\frac{1}{4}) + \frac{1}{2} = \frac{3}{4}$

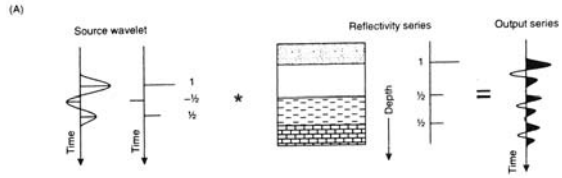
*Step 4:* Move the source wavelet array on one sample and convolve; hence  $(\frac{1}{2} \times (-\frac{1}{2})) + (\frac{1}{2} \times \frac{1}{2}) = -\frac{1}{4} + \frac{1}{4} = 0$

*Step 5:* Move the source wavelet array on the sample and convolve; hence  $(\frac{1}{2} \times \frac{1}{2}) = \frac{1}{4}$



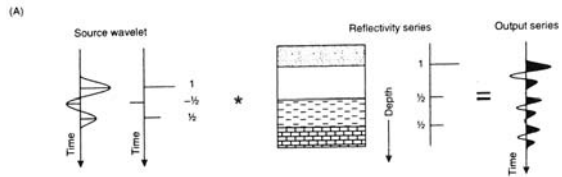
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# Convolution



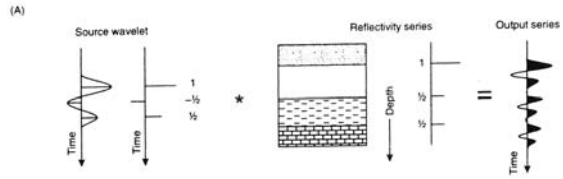
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# Convolution



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# Convolution



Reflectivity series

	1	1/2	1/2
--	---	-----	-----

Source wavelet

1/2	-1/2	1
-----	------	---

Output

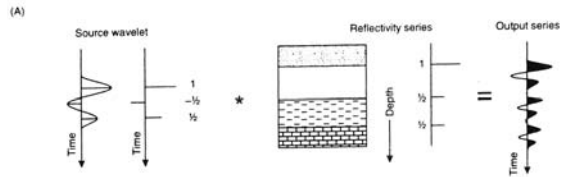
0	1	0
---	---	---

Recorded waveform



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# Convolution



Reflectivity series

1	1/2	1/2
---	-----	-----

Source wavelet

1/2	-1/2	1
-----	------	---

Output

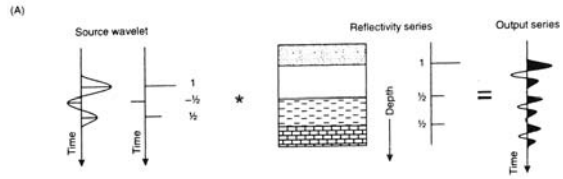
0	1	0	3/4
---	---	---	-----

Recorded waveform



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# Convolution



Reflectivity series



Source wavelet



Output

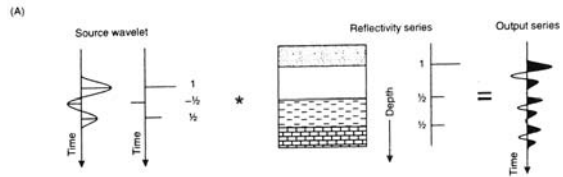


Recorded waveform



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# Convolution



Reflectivity series



Source wavelet



Output

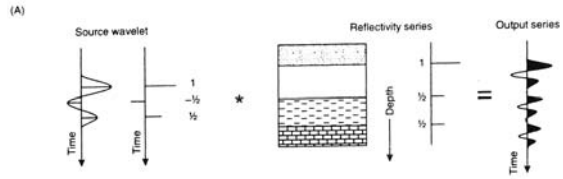


Recorded waveform



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# Convolution



Reflectivity series

1	1/2	1/2			
---	-----	-----	--	--	--

Source wavelet

1/2	-1/2	1
-----	------	---

Output

0	1	0	3/4	0	1/4	0
---	---	---	-----	---	-----	---

Recorded waveform

